the feedback to be driven to reduce this difference signal to a small value. The two differential amplifiers are made to match and have identical gains, G. As a result, the feedback signal that must be applied to the right-hand differential amplifier will precisely match the thermocouple input signal when the difference signal has been reduced to zero. The feedback network is trimmed so that the effective gain to the output, at pins 8 and 9, results in a voltage of 10mV/°C of thermocouple excitation.

In addition to the feedback signal, a cold junction compensation voltage is applied to the right-hand differential amplifier. The compensation is a differential voltage proportional to the Celsius temperature of the AD594/AD595. This signal disturbs the differential input so that the amplifier output must adjust to restore the input to equal the applied thermocouple voltage.

The compensation is applied through the gain scaling resistors so that its effect on the main output is also 10mV/°C. As a result, the compensation voltage adds to the effect of the thermocouple voltage a signal directly proportional to the difference between 0°C and the AD594/AD595 temperature. If the thermocouple reference junction is maintained at the AD594/AD595 temperature, the output of the AD594/AD595 will correspond to the reading that would have been obtained from amplification of a signal from a thermocouple referenced to an ice bath.

The AD594/AD595 also includes an input open circuit detector that switches on an alarm transistor. This transistor is actually a current-limited output buffer, but can be used up to the limit as a switch transistor for either pull-up or pull-down operation of external alarms.

The ice point compensation network has voltages available with positive and negative temperature coefficients. These voltages may be used with external resistors to modify the ice point compensation and recalibrate the AD594/AD595 as described in the next column.

The feedback resistor is separately pinned out so that its value can be padded with a series resistor, or replaced with an external resistor between pins 5 and 9. External availability of the feedback resistor allows gain to be adjusted, and also permits the AD594/AD595 to operate in a switching mode for set-point operation.

CAUTIONS:

The temperature compensation terminals (+C and −C) at pins 2 and 6 are provided to supply small calibration currents only. The AD594/AD595 may be permanently damaged if they are grounded or connected to a low impedance.

The AD594/AD595 is internally frequency compensated for feedback ratios (corresponding to normal signal gain) of 75 or more. If a lower gain is desired, additional frequency compensation should be added in the form of a 300pF capacitor from pin 10 to the output at pin 9. As shown in Figure 5 an additional 0.01μF capacitor between pins 10 and 11 is recommended.

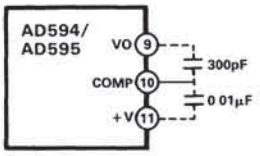


Figure 5. Low Gain Frequency Compensation

RECALIBRATION PRINCIPLES AND LIMITATIONS

The ice point compensation network of the AD594/AD595 produces a differential signal which is zero at 0°C and corresponds to the output of an ice referenced thermocouple at the temperature of the chip. The positive TC output of the circuit is proportional to Kelvin temperature and appears as a voltage at +T. It is possible to decrease this signal by loading it with a resistor from +T to COM, or increase it with a pull-up resistor from +T to the larger positive TC voltage at +C. Note that adjustments to +T should be made by measuring the voltage which tracks it at −T. To avoid destabilizing the feedback amplifier the measuring instrument should be isolated by a few thousand ohms in series with the lead connected to −T.

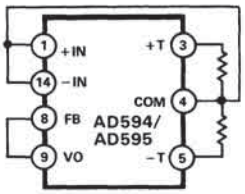


Figure 6. Decreased Sensitivity Adjustment

Changing the positive TC half of the differential output of the compensation scheme shifts the zero point away from 0°C. The zero can be restored by adjusting the current flow into the negative input of the feedback amplifier, the −T pin. A current into this terminal can be produced with a resistor between −C and −T to balance an increase in +T, or a resistor from −T to COM to offset a decrease in +T.

If the compensation is adjusted substantially to accommodate a different thermocouple type, its effect on the final output voltage will increase or decrease in proportion. To restore the nominal output to 10mV/°C the gain may be adjusted to match the new compensation and thermocouple input characteristics. When reducing the compensation the resistance between −T and COM automatically increases the gain to within 0.5% of the correct value. If a smaller gain is required, however, the nominal 47kΩ internal feedback resistor can be paralleled or replaced with an external resistor.

Fine calibration adjustments will require temperature response measurements of individual devices to assure accuracy. Major reconfigurations for other thermocouple types can be achieved without seriously compromising initial calibration accuracy, so long as the procedure is done at a fixed temperature using the factory calibration as a reference. It should be noted that intermediate recalibration conditions may require the use of a negative supply. An example using a type E thermocouple and an AD594 is given on the next page.

EXAMPLE: TYPE E RECALIBRATION – AD594/AD595

Both the AD594 and AD595 can be configured to condition the output of a type E (chromel-constantan) thermocouple. Temperature characteristics of type E thermocouples differ less from type J, than from type K, therefore the AD594 is preferred for recalibration.

While maintaining the device at a constant temperature follow the recalibration steps given here. First, measure the device temperature by tying both inputs to common (or a selected common mode potential) and connecting FB to V_O. The AD594 is now in the stand alone Celsius thermometer mode. For this example assume the ambient is 24°C and the initial output V_O is 240mV. Check the output at V_O to verify that it corresponds to the temperature of the device.

Next, measure the voltage $-T$ at pin 5 with a high impedance DVM (capacitance should be isolated by a few thousand ohms of resistance at the measured terminals). At 24°C the $-T$ voltage will be about 8.3mV. To adjust the compensation of an AD594 to a type E thermocouple a resistor, R1, should be connected between $+T$ and $+C$, pins 2 and 3, to raise the voltage at $-T$ by the ratio of thermocouple sensitivities. The ratio for converting a type J device to a type E characteristic is:

$$r\ (AD594) = (60.9\mu V/°C)/(51.7\mu V/°C) = 1.18$$

Thus, multiply the initial voltage measured at $-T$ by r and experimentally determine the R1 value required to raise $-T$ to that level. For the example the new $-T$ voltage should be about 9.8mV. The resistance value should be approximately 1.8kΩ.

The zero differential point must now be shifted back to 0°C. This is accomplished by multiplying the original output voltage V_O by r and adjusting the measured output voltage to this value by experimentally adding a resistor, R2, between $-C$ and $-T$, pins 5 and 6. The target output value in this case should be about 283mV. The resistance value of R2 should be approximately 240kΩ.

Finally, the gain must be recalibrated such that the output V_O indicates the device's temperature once again. Do this by adding a third resistor, R3, between FB and $-T$, pins 8 and 5. V_O should now be back to the initial 240mV reading. The resistance value of R3 should be approximately 280kΩ. The final connection diagram is shown in Figure 7. An approximate verification of the effectiveness of recalibration is to measure the differential gain to the output. For type E it should be 164.2.

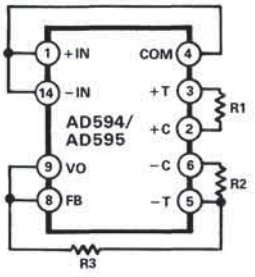


Figure 7. Type E Recalibration

When implementing a similar recalibration procedure for the AD595 the values for R1, R2, R3 and r will be approximately 650Ω, 84kΩ, 93kΩ and 1.51, respectively. Power consumption will increase by about 50% when using the AD595 with type E inputs.

Note that during this procedure it is crucial to maintain the AD594/AD595 at a stable temperature because it is used as the temperature reference. Contact with fingers or any tools not at ambient temperature will quickly produce errors. Radiational heating from a change in lighting or approach of a soldering iron must also be guarded against.

USING TYPE T THERMOCOUPLES WITH THE AD595

Because of the similarity of thermal EMFs in the 0 to 50°C range between type K and type T thermocouples, the AD595 can be directly used with both types of inputs. Within this ambient temperature range the AD595 should exhibit no more than an additional 0.2°C output calibration error when used with type T inputs. The error arises because the ice point compensator is trimmed to type K characteristics at 25°C. To calculate the AD595 output values over the recommended -200 to 350°C range for type T thermocouples, simply use the ANSI thermocouple voltages referred to 0°C and the output equation given on page 3 for the AD595. Because of the relatively large nonlinearities associated with type T thermocouples the output will deviate widely from the nominal 10mV/°C. However, cold junction compensation over the rated 0 to 50°C ambient will remain accurate.

STABILITY OVER TEMPERATURE

Each AD594/AD595 is tested for error over temperature with the measuring thermocouple at 0°C. The combined effects of cold junction compensation error, amplifier offset drift and gain error determine the stability of the AD594/AD595 output over the rated ambient temperature range. Figure 8 shows an AD594/AD595 drift error envelope. The slope of this figure has units of °C/°C.

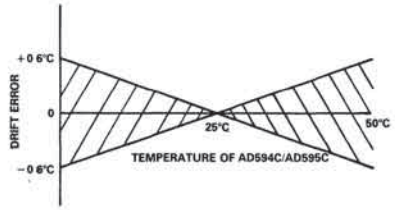


Figure 8. Drift Error vs. Temperature

THERMAL ENVIRONMENT EFFECTS

The inherent low power dissipation of the AD594/AD595 and the low thermal resistance of the package make self-heating errors almost negligible. For example, in still air the chip to ambient thermal resistance is about 80°C/watt (for the D package). At the nominal dissipation of 800μW the self-heating in free air is less than 0.065°C. Submerged in fluorinert liquid (unstirred) the thermal resistance is about 40°C/watt, resulting in a self-heating error of about 0.032°C.

SET-POINT CONTROLLER

The AD594/AD595 can readily be connected as a set-point controller as shown in Figure 9.

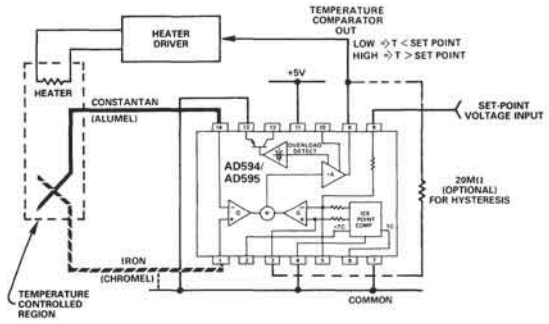


Figure 9. Set-Point Controller

The thermocouple is used to sense the unknown temperature and provide a thermal EMF to the input of the AD594/AD595. The signal is cold junction compensated, amplified to 10mV/°C and compared to an external set-point voltage applied by the user to the feedback at pin 8. Table I lists the correspondence between set-point voltage and temperature, accounting for the nonlinearity of the measurement thermocouple. If the set-point temperature range is within the operating range (−55°C to +125°C) of the AD594/AD595, the chip can be used as the transducer for the circuit by shorting the inputs together and utilizing the nominal calibration of 10mV/°C. This is the centigrade thermometer configuration as shown in Figure 13.

In operation if the set-point voltage is above the voltage corresponding to the temperature being measured the output swings low to approximately zero volts. Conversely, when the temperature rises above the set-point voltage the output switches to the positive limit of about 4 volts with a +5V supply. Figure 9 shows the set-point comparator configuration complete with a heater element driver circuit being controlled by the AD594/AD595 toggled output. Hysteresis can be introduced by injecting a current into the positive input of the feedback amplifier when the output is toggled high. With an AD594 about 200nA into the +T terminal provides 1°C of hysteresis. When using a single 5V supply with an AD594, a 20MΩ resistor from V_O to +T will supply the 200nA of current when the output is forced high (about 4V). To widen the hysteresis band decrease the resistance connected from V_O to +T.

ALARM CIRCUIT

In all applications of the AD594/AD595 the −ALM connection, pin 13, should be constrained so that it is not more positive than (V+) − 4V. This can be most easily achieved by connecting pin 13 to either common at pin 4 or V− at pin 7. For most applications that use the alarm signal, pin 13 will be grounded and the signal will be taken from +ALM on pin 12. A typical application is shown in Figure 10.

In this configuration the alarm transistor will be off in normal operation and the 20k pull up will cause the +ALM output on pin 12 to go high. If one or both of the thermocouple leads are interrupted, the +ALM pin will be driven low. As shown in Figure 10 this signal is compatible with the input of a TTL gate which can be used as a buffer and/or inverter.

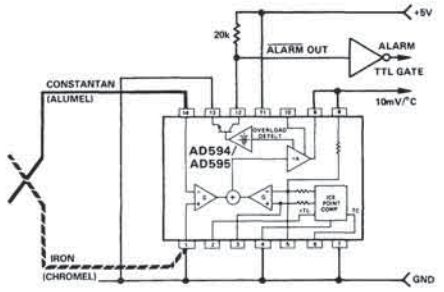


Figure 10. Using the Alarm to Drive a TTL Gate ("Grounded" Emitter Configuration)

Since the alarm is a high level output it may be used to directly drive an LED or other indicator as shown in Figure 11.

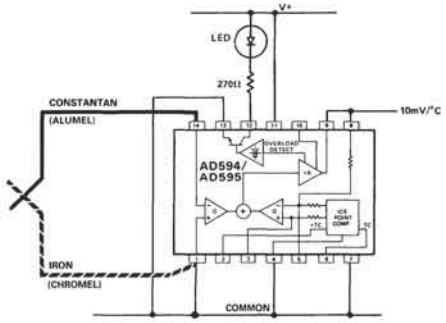


Figure 11. Alarm Directly Drives LED

A 270Ω series resistor will limit current in the LED to 10mA, but may be omitted since the alarm output transistor is current limited at about 20mA. The transistor, however, will operate in a high dissipation mode and the temperature of the circuit will rise well above ambient. Note that the cold junction compensation will be affected whenever the alarm circuit is activated. The time required for the chip to return to ambient temperature will depend on the power dissipation of the alarm circuit, the nature of the thermal path to the environment and the alarm duration.

The alarm can be used with both single and dual supplies. It can be operated above or below ground. The collector and emitter of the output transistor can be used in any normal switch configuration. As an example a negative referenced load can be driven from −ALM as shown in Figure 12.

The collector (+ALM) should not be allowed to become more positive than (V−) +36V, however, it may be permitted to be more positive than V+. The emitter voltage (−ALM) should be constrained so that it does not become more positive than 4 volts below the V+ applied to the circuit.

Additionally, the AD594/AD595 can be configured to produce an extreme upscale or downscale output in applications where an extra signal line for an alarm is inappropriate. By tying either of the thermocouple inputs to common most runaway control conditions can be automatically avoided. A +IN to common connection creates a downscale output if the thermocouple opens, while connecting −IN to common provides an upscale output.

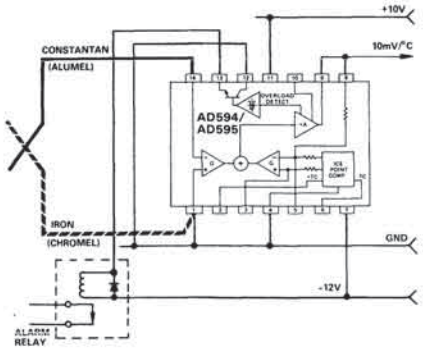


Figure 12. –ALM Driving A Negative Referenced Load

CELSIUS THERMOMETER

The AD594/AD595 may be configured as a stand-alone celsius thermometer as shown in Figure 13.

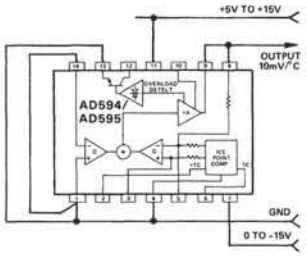


Figure 13. AD594/AD595 as a Stand-Alone Celsius Thermometer

Simply omit the thermocouple and connect the inputs (pins 1 and 14) to common. The output now will reflect the compensation voltage and hence will indicate the AD594/AD595 temperature with a scale factor of 10mV/°C. In this three terminal, voltage output, temperature sensing mode, the AD594/AD595 will operate over the full military −55°C to +125°C temperature range.

THERMOCOUPLE BASICS

Thermocouples are economical and rugged; they have reasonably good long-term stability. Because of their small size, they respond quickly and are good choices where fast response is important. They function over temperature ranges from cryogenics to jet-engine exhaust and have reasonable linearity and accuracy.

Because the number of free electrons in a piece of metal depends on both temperature and composition of the metal, two pieces of dissimilar metal in isothermal contact will exhibit a potential difference that is a repeatable function of temperature, as shown in Figure 14. The resulting voltage depends on the temperatures, T1 and T2, in a repeatable way.

Since the thermocouple is basically a differential rather than absolute measuring device, a known reference temperature is required for one of the junctions if the temperature of the other is to be inferred from the output voltage. Thermocouples made of specially selected materials have been exhaustively characterized in terms of voltage versus temperature compared to primary temperature standards. Most notably the water-ice point of 0°C is used for tables of standard thermocouple performance.

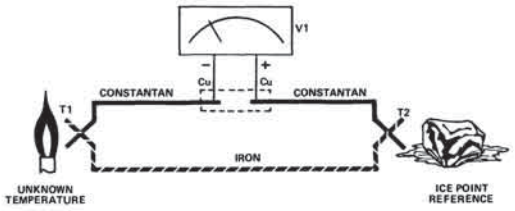


Figure 14. Thermocouple Voltage with 0°C Reference

An alternative measurement technique, illustrated in Figure 15, is used in most practical applications where accuracy requirements do not warrant maintenance of primary standards. The reference junction temperature is allowed to change with the environment

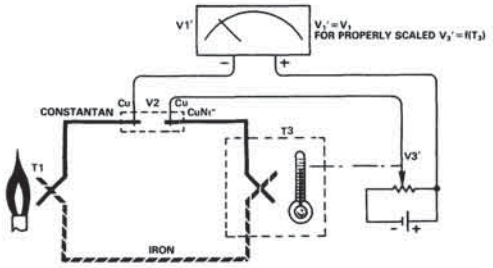


Figure 15. Substitution of Measured Reference Temperature for Ice Point Reference

of the measurement system, but it is carefully measured by some type of absolute thermometer. A measurement of the thermocouple voltage combined with a knowledge of the reference temperature can be used to calculate the measurement junction temperature. Usual practice, however, is to use a convenient thermoelectric method to measure the reference temperature and to arrange its output voltage so that it corresponds to a thermocouple referred to 0°C. This voltage is simply added to the thermocouple voltage and the sum then corresponds to the standard voltage tabulated for an ice-point referenced thermocouple.

The temperature sensitivity of silicon integrated circuit transistors is quite predictable and repeatable. This sensitivity is exploited in the AD594/AD595 to produce a temperature related voltage to compensate the reference or "cold" junction of a thermocouple as shown in Figure 16.

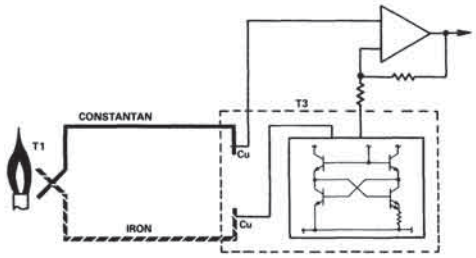


Figure 16. Connecting Isothermal Junctions

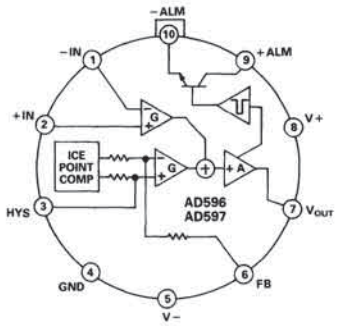
Since the compensation is at the reference junction temperature, it is often convenient to form the reference "junction" by connecting directly to the circuit wiring. So long as these connections and the compensation are at the same temperature no error will result.

Thermocouple Conditioners and Set-Point Controllers

AD596*/AD597*

FEATURES
- **Low Cost**
- **Operates with Type J (AD596) or Type K (AD597) Thermocouples**
- **Built-In Ice Point Compensation**
- **Temperature Proportional Operation – 10mV/°C**
- **Temperature Set-Point Operation – ON/OFF**
- **Programmable Switching Hysteresis**
- **High Impedance Differential Input**

AD596/AD597 FUNCTIONAL BLOCK DIAGRAM



PRODUCT DESCRIPTION

The AD596/AD597 is a monolithic temperature set-point controller which has been optimized for use at elevated temperatures such as those found in oven control applications. The device cold junction compensates and amplifies a type J or K thermocouple input to derive an internal signal proportional to temperature. The internal signal is then compared with an externally applied set-point voltage to yield a low impedance switched output voltage. Dead-Band or switching hysteresis can be programmed using a single external resistor. Alternately, the AD596/AD597 can be configured to provide a voltage output (10mV/°C) directly from a type J or K thermocouple signal. It can also be used as a stand-alone voltage output temperature sensor.

The AD596/AD597 can be powered with a single supply from +5V to +30V, or dual supplies up to a total span of 36V. Typical quiescent supply current is 160μA which minimizes self-heating errors.

The AD596/AD597 includes a thermocouple failure alarm that indicates an open thermocouple lead when operated in the temperature proportional measurement mode. The alarm output has a flexible format which can be used to drive relays, LEDs or TTL logic.

The device is packaged in a reliability qualified, cost effective 10-pin metal can and is trimmed to operate over an ambient temperature range from +25°C to +100°C. Operation over an extended ambient temperature range is possible with slightly reduced accuracy. The AD596 will amplify thermocouple signals covering the entire −200°C to +760°C temperature range recommended for type J thermocouples while the AD597 can accommodate −200°C to +1250°C type K inputs.

The AD596/AD597 has a calibration accuracy of ±4°C at an ambient temperature of 60°C and an ambient temperature stability specification of 0.05°C/°C from +25°C to +100°C. If higher accuracy, or a lower ambient operating temperature is required, either the AD594 (J thermocouple) or AD595 (K thermocouple) should be considered.

PRODUCT HIGHLIGHTS

1. The AD596/AD597 provides cold junction compensation and a high gain amplifier which can be used as a set-point comparator.
2. The input stage of the AD596/AD597 is a high quality instrumentation amplifier that allows the thermocouple to float over most of the supply voltage range.
3. Linearization not required for thermocouple temperatures close to 175°C (+100°C to +540°C for AD596).
4. Cold junction compensation is optimized for ambient temperatures ranging from +25°C to +100°C.
5. In the stand-alone mode, the AD596/AD597 produces an output voltage that indicates its own temperature.

11

***Protected by U.S. Patent No. 4,029,974.**

SPECIFICATIONS (@ +60°C and V_S = 10V, Type J (AD596), Type K (AD597) Thermocouple, unless otherwise noted)

Model	AD596AH			AD597AH			Units
	Min	Typ	Max	Min	Typ	Max	
ABSOLUTE MAXIMUM RATINGS							
$+V_S$ to $-V_S$			36			36	Volts
Common-Mode Input Voltage	$(-V_S - 0.15)$		$+V_S$	$(-V_S - 0.15)$		$+V_S$	Volts
Differential Input Voltage	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Alarm Voltages							
+ALM	$-V_S$		$(-V_S + 36)$	$-V_S$		$(-V_S + 36)$	Volts
−ALM	$-V_S$		$+V_S$	$-V_S$		$+V_S$	Volts
Operating Temperature Range	−55		+125	−55		+125	°C
Output Short Circuit to Common	Indefinite			Indefinite			
TEMPERATURE MEASUREMENT							
(Specified Temperature Range +25°C to +100°C)							
Calibration Error[1]	**−4**		**+4**	**−4**		**+4**	°C
Stability vs. Temperature[2]		±0.02	±0.05		±0.02	±0.05	°C/°C
Gain Error	**−1.5**		**+1.5**	**−1.5**		**+1.5**	%
Nominal Transfer Function		10			10		mV/°C
AMPLIFIER CHARACTERISTICS							
Closed Loop Gain[3]		180.6			245.5		V/V
Input Offset Voltage		°C × 53.21 + 235			°C × 41.27 − 37		µV
Input Bias Current		0.1			0.1		µA
Differential Input Range	−10		+50	−10		+50	mV
Common-Mode Range	$(-V_S - 0.15)$		$(+V_S - 4)$	$(-V_S - 0.15)$		$(+V_S - 4)$	Volts
Common-Mode Sensitivity – RTO			**10**			**10**	mV/V
Power Supply Sensitivity – RTO		1	**10**		1	**10**	mV/V
Output Voltage Range							
Dual Supplies	$(-V_S + 2.5)$		$(+V_S - 2)$	$(-V_S + 2.5)$		$(+V_S - 2)$	Volts
Single Supply	**0**		$(+V_S - 2)$	**0**		$(+V_S - 2)$	Volts
Usable Output Current[4]	±5			±5			mA
3dB Bandwidth		15			15		kHz
ALARM CHARACTERISTICS							
$V_{CE(SAT)}$ at 2mA		0.3			0.3		Volts
Leakage Current			**±1**			**±1**	µA
Operating Voltage at −ALM			$(+V_S - 4)$			$(+V_S - 4)$	Volts
Short Circuit Current		20			20		mA
POWER REQUIREMENTS							
Operating[5]		$(+V_S$ to $-V_S) \leq 30$			$(+V_S$ to $-V_S) \leq 30$		Volts
Quiescent Current							
$+V_S$		160	**300**		160	**300**	µA
$-V_S$		100	**200**		100	**200**	µA
PACKAGE OPTION[6]							
TO-100 (H-10A)	AD596AH			AD597AH			

NOTES

[1]This is a measure of the deviation from ideal with a measuring thermocouple junction of 175°C and a chip temperature of 60°C. The ideal transfer function is given by:
AD596. $V_{OUT} = 180.57 \times (V_M - V_A +$ (ambient in °C) $\times 53.21\mu V/°C + 235\mu V)$
AD597. $V_{OUT} = 245.46 \times (V_M - V_A +$ (ambient in °C) $\times 41.27\mu V/°C - 37\mu V)$.
Where V_M and V_A represent the measuring and ambient temperatures and are taken from the appropriate J or K thermocouple table. The ideal transfer function minimizes the error over the ambient temperature range of 25°C to 100°C with a thermocouple temperature of approximately 175°C.

[2]Defined as the slope of the line connecting the AD596/AD597 CJC errors measured at 25°C and 100°C ambient temperature.

[3]Pin 6 shorted to Pin 7.

[4]Current Sink Capability in single supply configuration is limited to current drawn to ground through a 50kΩ resistor at output voltages below 2.5V.

[5]$-V_S$ must not exceed −16.5V.

[6]See Section 16 for package outline informatin.

Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

Thermocouple Temperature °C	Type J Voltage mV	AD596 Output mV	Type K Voltage mV	AD597 Output mV	Thermocouple Temperature °C	Type J Voltage mV	AD596 Output mV	Type K Voltage mV	AD597 Output mV
− 200	− 7.890	−1370	− 5.891	−1446	500	27.388	5000	20.640	5066
− 180	− 7.402	−1282	− 5.550	−1362	520	28.511	5203	21.493	5276
− 160	− 6.821	−1177	− 5.141	−1262	540	29.642	5407	22.346	5485
− 140	− 6.159	−1058	− 4.669	−1146	560	30.782	5613	23.198	5694
− 120	− 5.426	− 925	− 4.138	−1016	580	31.933	5821	24.050	5903
− 100	− 4.632	− 782	− 3.553	− 872	600	33.096	6031	24.902	6112
− 80	− 3.785	− 629	− 2.920	− 717	620	34.273	6243	25.751	6321
− 60	− 2.892	− 468	− 2.243	− 551	640	35.464	6458	26.599	6529
− 40	− 1.960	− 299	− 1.527	− 375	660	36.671	6676	27.445	6737
− 20	− .995	− 125	− .777	− 191	680	37.893	6897	28.288	6944
− 10	− .501	− 36	− .392	− 96	700	39.130	7120	29.128	7150
0	0	54	0	0	720	40.382	7346	29.965	7355
10	.507	146	.397	97	740	41.647	7575	30.799	7560
20	1.019	238	.798	196	750	42.283	7689	31.214	7662
25	1.277	285	1.000	245	760	–	–	31.629	7764
30	1.536	332	1.203	295	780	–	–	32.455	7966
40	2.058	426	1.611	395	800	–	–	33.277	8168
50	2.585	521	2.022	496	820	–	–	34.095	8369
60	3.115	617	2.436	598	840	–	–	34.909	8569
80	4.186	810	3.266	802	860	–	–	35.718	8767
100	5.268	1006	4.095	1005	880	–	–	36.524	8965
120	6.359	1203	4.919	1207	900	–	–	37.325	9162
140	7.457	1401	5.733	1407	920	–	–	38.122	9357
160	8.560	1600	6.539	1605	940	–	–	38.915	9552
180	9.667	1800	7.338	1801	960	–	–	39.703	9745
200	10.777	2000	8.137	1997	980	–	–	40.488	9938
220	11.887	2201	8.938	2194	1000	–	–	41.269	10130
240	12.998	2401	9.745	2392	1020	–	–	42.045	10320
260	14.108	2602	10.560	2592	1040	–	–	42.817	10510
280	15.217	2802	11.381	2794	1060	–	–	43.585	10698
300	16.325	3002	12.207	2996	1080	–	–	44.439	10908
320	17.432	3202	13.039	3201	1100	–	–	45.108	11072
340	18.537	3402	13.874	3406	1120	–	–	45.863	11258
360	19.640	3601	14.712	3611	1140	–	–	46.612	11441
380	20.743	3800	15.552	3817	1160	–	–	47.356	11624
400	21.846	3999	16.395	4024	1180	–	–	48.095	11805
420	22.949	4198	17.241	4232	1200	–	–	48.828	11985
440	24.054	4398	18.088	4440	1220	–	–	49.555	12164
460	25.161	4598	18.938	4649	1240	–	–	50.276	12341
480	26.272	4798	19.788	4857	1250	–	–	50.633	12428

Table I. Output Voltage vs. Thermocouple Temperature (Ambient +60°C, V_S = −5V, +15V)

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TEMPERATURE PROPORTIONAL OUTPUT MODE

The AD596/AD597 can be used to generate a temperature proportional output of 10mV/°C when operated with J and K type thermocouples as shown in Figure 1. Thermocouples produce low level output voltages which are a function of both the temperature being measured and the reference or cold junction temperature. The AD596/AD597 compensates for the cold junction temperature and amplifies the thermocouple signal to produce a high level 10mV/°C voltage output which is a function only of the temperature being measured. The temperature stability of the part indicates the sensitivity of the output voltage to changes in ambient or device temperatures. This is typically 0.02°C/°C over the +25°C to +100°C recommended ambient temperature range. The parts will operate over the extended ambient temperature ranges from −55°C to +125°C, but thermocouple nonlinearity at the reference junction will degrade the temperature stability over this extended range. Table I is a list of ideal AD596/AD597 output voltages as a function of Celsius temperature for type J and K ANSI standard thermocouples with package and reference junction at 60°C. As is normally the case, these outputs

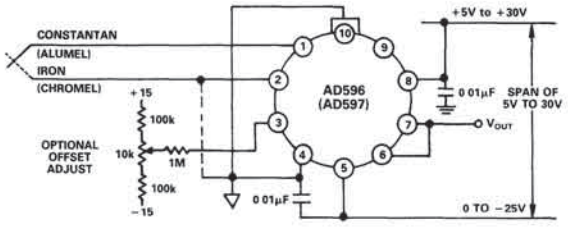


Figure 1. Temperature Proportional Output Connection

are subject to calibration and temperature sensitivity errors. These tables are derived using the ideal transfer functions:

AD596 output = (Type J voltage +301.5µV) × 180.57
AD597 output = (Type K voltage) × 245.46

The offsets and gains of these devices have been laser trimmed to closely approximate thermocouple characteristics over measurement temperature ranges centered around 175°C with the

AD596/AD597 at an ambient temperature between 25°C and 100°C. This eliminates the need for additional gain or offset adjustments to make the output voltage read:

$$V_{OUT} = 10mV/°C \times (\text{thermocouple temperature in °C})$$
(within specified tolerances).

Excluding calibration errors, the above transfer function is accurate to within 1°C from +80°C to +550°C for the AD596 and −20°C to +350°C for the AD597. The different temperature ranges are due to the differences in J and K type thermocouple curves.

European DIN FE-CuNi thermocouple vary slightly from ANSI type J thermocouples. Table I does not apply when these types of thermocouples are used. The transfer functions given previously and a thermocouple table should be used instead.

Figure 1 also shows an optional trimming network which can be used to change the device's offset voltage. Injecting or sinking 200nA from Pin 3 will offset the output aproximately 10mV (1°C).

The AD596/AD597 can operate from a single supply from 5V to 36V or from split supplies totalling 36V or less as shown. Since the output can only swing to within 2V of the positive supply, the usable measurement temperature range will be restricted when positive supplies less than 15V for the AD597 and 10V for the AD596 are used. If the AD596/AD597 is to be used to indicate negative Celsius temperatures, then a negative supply is required.

Common-mode voltages on the thermocouple inputs must remain within the common-mode voltage range of the AD596/AD597, with a return path provided for the bias currents. If the thermocouple is not remotely grounded, then the dotted line connection shown in Figure 1 must be made to one of the thermocouple inputs. If there is no return path for the bias currents, the input stage will saturate, causing erroneous output voltages.

In this configuration, the AD596/AD597 has circuitry which detects the presence of an open thermocouple. If the thermocouple loop becomes open, one or both of the inputs to the device will be deprived of bias current causing the output to saturate. It is this saturation which is detected internally and used to activate the alarm circuitry. The output of this feature has a flexible format which can be used to source or sink up to 20mA of current. The collector (+ALM) should not be allowed to become more positive than ($-V_S$ +36V), however, it may be permitted to be more positive than $+V_S$. The emitter voltage (−ALM) should be constrained such that it does not become more positive than 4V below $+V_S$. If the alarm feature is not used, this pin should be connected to Pins 4 or 5 as shown in Figure 1.

SET-POINT CONTROL MODE

The AD596/AD597 can be connected as a set-point controller as shown in Figure 2. The thermocouple voltage is cold junction compensated, amplified, and compared to an external set-point voltage. The relationship between set-point voltage and temperature is given in Table I. If the temperature to be controlled is within the operating range (−55°C to +125°C) of the device, it can monitor its own temperature by shorting the inputs to ground. The set-point voltage with the thermocouple inputs grounded is given by the expressions:

AD596 Set-Point Voltage = °C × 9.6mV/°C +42mV
AD597 Set-Point Voltage = °C × 10.1mV/°C −9.1mV

The input impedance of the set-point pin of the AD596/AD597 is approximately 50kΩ. The temperature coefficient of this resistance is ±15ppm/°C. Therefore, the 100ppm/°C 5kΩ pot

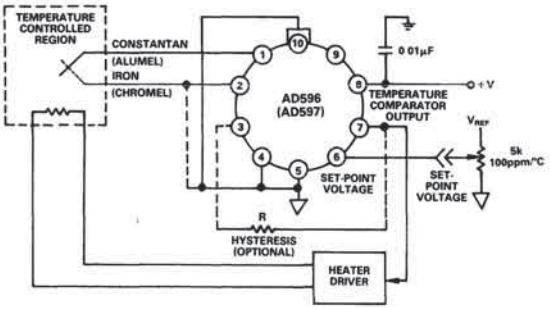


Figure 2. Set-Point Control Mode

shown in Figure 2 will only introduce an additional ±1°C degradation of temperature stability over the +25°C to +100°C ambient temperature range.

Switching hysteresis is often used in set-point systems of this type to provide noise immunity and increase system reliability. By reducing the frequency of on-off cycling, mechanical component wear is reduced leading to enhanced system reliability. This can easily be implemented with a single external resistor between Pins 7 and 3 of the AD596/AD597. Each 200nA of current injected into Pin 3 when the output switches will cause about 1°C of hysteresis; that is: $R_{HYST}\,(\Omega) = \frac{V_{OUT}}{200nA} \times \frac{1}{°C_{HYST}}$.

In the set-point configuration, the AD596/AD597 output is saturated at all times, so the alarm transistor will be ON regardless of whether there is an open circuit or not. However, −ALM must be tied to a voltage below ($+V_S$ −4V) for proper operation of the rest of the circuit.

STAND-ALONE TEMPERATURE TRANSDUCER

The AD596/AD597 may be configured as a stand-alone Celsius thermometer as shown in Figure 3.

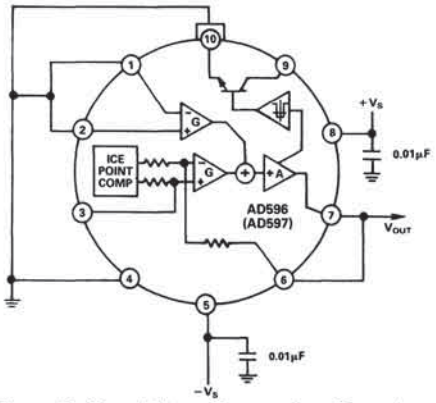


Figure 3. Stand-Alone Temperature Transducer Temperature Proportional Output Connection

Simply omit the thermocouple and connect the inputs (Pins 1 and 2) to common. The output will now reflect the compensation voltage and hence will indicate the AD596/AD597 temperature. In this three terminal, voltage output, temperature sensing mode, the AD596/AD597 will operate over the full extended −55°C to +125°C temperature range. The output scaling will be 9.6mV per °C with the AD596 and 10.1mV per °C with the AD597. Additionally there will be a 42mV offset with the AD596 causing it to read slightly high when used in this mode.

THERMOCOUPLE CONNECTIONS

The connection of the thermocouple wire and the normal wire or printed circuit board traces going to the AD596/AD597 forms an effective reference junction as shown in Figure 4. This junction must be kept at the same temperature as the AD596/AD597 for the internal cold junction compensation to work properly. Unless the AD596/AD597 is in a thermally stable enclosure, the thermocouple leads should be brought in directly to Pins 1 and 2.

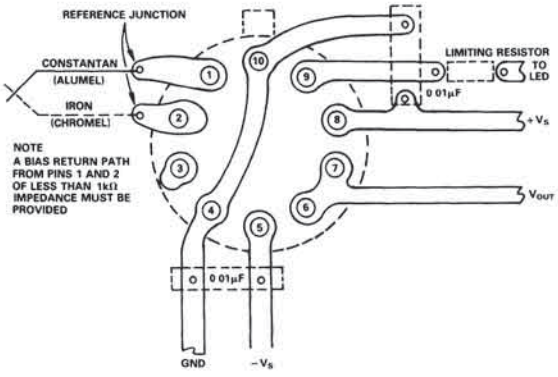


Figure 4. PCB Connections

To ensure secure bonding, the thermocouple wire should be cleaned to remove oxidization prior to soldering. Noncorrosive resin flux is effective with iron, constantan, chromel, and alumel, and the following solders: 95% tin–5% silver, or 90% tin–10% lead.

SINGLE AND DUAL SUPPLY CONNECTIONS

In the single supply configuration as used in the set-point controller of Figure 2, any convenient voltage from +5V to +36V may be used, with self-heating errors being minimized at lower supply levels. In this configuration, the $-V_S$ connection at Pin 5 is tied to ground. Temperatures below zero can be accommodated in the single supply set-point mode, but not in the single supply temperature measuring mode (Figure 1 reconnected for single supply). Temperatures below zero can only be indicated by a negative output voltage, which is impossible in the single supply mode.

Common-mode voltages on the thermocouple inputs must remain below the positive supply, and not more than 0.15V more negative than the minus supply. In addition, a return path for the input bias currents must be provided. If the thermocouple is not remotely grounded, then the dotted line connections in Figures 1 and 2 are mandatory.

STABILITY OVER TEMPERATURE

The AD596/AD597 is specified for a maximum error of ±4°C at an ambient temperature of 60°C and a measuring junction temperature at 175°C. The ambient temperature stability is specified to be a maximum of 0.05°C/°C. In other words, for every degree change in the ambient temperature, the output will change no more than 0.05 degrees. So, at 25°C the maximum deviation from the temperature-voltage characteristic of Table I is ±5.75°C, and at 100°C it is ±6°C maximum (see Figure 5). If the offset error of ±4°C is removed with a single offset adjustment, these errors will be be reduced to ±1.75°C and ±2°C max. The optional trim circuit shown in Figure 1 demonstrates how the ambient offset error can be adjusted to zero.

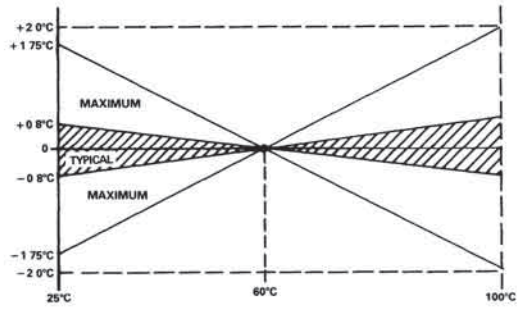


Figure 5. Drift Error vs. Temperature

THERMAL ENVIRONMENTAL EFFECTS

The inherent low power dissipation of the AD596/AD597 keeps self-heating errors to a minimum. However, device output is capable of delivering ±5mA to an external load and the alarm circuitry can supply up to 20mA. Since the typical junction to ambient thermal resistance in free air is 150°C/W, significant temperature difference between the package pins (where the reference junction is located) and the chip (where the cold junction temperature is measured and then compensated) can exist when the device is operated in a high dissipation mode. These temperature differences will result in a direct error at the output. In the temperature proportional mode, the alarm feature will only activate in the event of an open thermocouple or system transient which causes the device output to saturate. Self-Heating errors will not effect the operation of the alarm but two cases do need to be considered. First, after a fault is corrected and the alarm is reset, the AD596/AD597 must be allowed to cool before readings can again be accurate. This can take 5 minutes or more depending upon the thermal environment seen by the device. Second, the junction temperature of the part should not be allowed to exceed 150°C. If the alarm circuit of the AD596/AD597 is made to source or sink 20mA with 30V across it, the junction temperature will be 90°C above ambient causing the die temperature to exceed 150°C when ambient is above 60°C. In this case, either the load must be reduced, or a heat sink used to lower the thermal resistance.

TEMPERATURE READOUT AND CONTROL

Figure 6 shows a complete temperature indication and control system based on the AD596/AD597. Here the AD596/AD597 is being used as a closed-loop thermocouple signal conditioner and an external op-amp is used to implement set point. This has two important advantages. It provides a high level (10mV/°C) output for the A/D panel meter and also preserves the alarm function for open thermocouples.

The A/D panel meter can easily be offset and scaled as shown to read directly in degrees Fahrenheit. If a two temperature calibration scheme is used, the dominant residual errors will arise from two sources; the ambient temperature rejection (typically ±2°C over a 25°C to 100°C range) and thermocouple nonlinearity typical +1°C from 80°C to 550°C for type J and +1°C from −20°C to 350°C for type K.

An external voltage reference is used both to increase the stability of the A/D converter and supply a stable reference for the set-point voltage.

A traditional requirement for the design of set-point control thermocouple systems has been to configure the system such that the appropriate action is taken in the event of an open thermocouple. The open thermocouple alarm pin with its flexible current-limited output format supports this function when the part operates in the temperature proportional mode. In addition, if the thermocouple is not remotely grounded, it is possible to program the device for either a positive or negative full scale output in the event of an open thermocouple. This is done by connecting the bias return resistor directly to Pin 1 if a high output voltage is desired to indicate a fault condition. Alternately, if the bias return is provided on the thermocouple lead connected to Pin 2, an open circuit will result in an output low reading. Figure 6 shows the ground return connected to Pin 1 so that if the thermocouple fails, the heater will remain off. At the same time, the alarm circuit lights the LED signalling the need to service the thermocouple. Grounding Pin 2 would lead to low output voltage saturation, and in this circuit would result in a potentially dangerous thermal runaway under fault conditions.

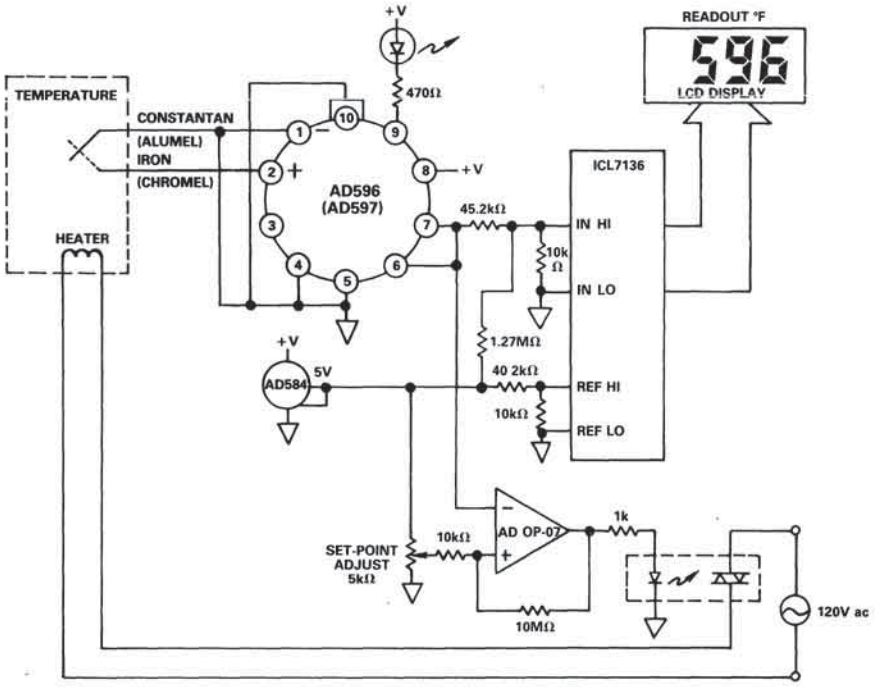


Figure 6. Temperature Measurement and Control

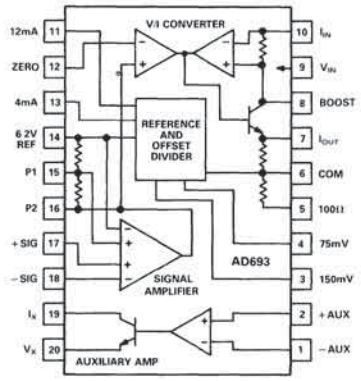
Loop-Powered 4-20mA Sensor Transmitter

AD693

FEATURES

- **Instrumentation Amplifier Front End**
- **Loop-Powered Operation**
- **Precalibrated 30mV or 60mV Input Spans**
- **Independently Adjustable Output Span and Zero**
- **Precalibrated Output Spans: 4-20mA Unipolar**
  0-20mA Unipolar
  12 ± 8mA Bipolar
- **Precalibrated 100Ω RTD Interface**
- **6.2V Reference with Up to 3.5mA of Current Available**
- **Uncommitted Auxiliary Amp for Extra Flexibility**
- **Optional External Pass Transistor to Reduce Self-Heating Errors**

AD693 PIN CONFIGURATION



PRODUCT DESCRIPTION

The AD693 is a monolithic signal conditioning circuit which accepts low-level inputs from a variety of transducers to control a standard 4-20mA, two-wire current loop. An on-chip voltage reference and auxiliary amplifier are provided for transducer excitation; up to 3.5mA of excitation current is available when the device is operated in the loop-powered mode. Alternatively, the device may be locally powered for three-wire applications when 0-20mA operation is desired.

Precalibrated 30mV and 60mV input spans may be set by simple pin strapping. Other spans from 1mV to 100mV may be realized with the addition of external resistors. The auxiliary amplifier may be used in combination with on-chip voltages to provide six precalibrated ranges for 100Ω RTDs. Output span and zero are also determined by pin strapping to obtain the standard ranges: 4-20mA, 12 ± 8mA and 0-20mA.

Active laser trimming of the AD693's thin-film resistors result in high levels of accuracy without the need for additional adjustments and calibration. Total unadjusted error is tested on every device to be less than 0.5% of full scale at +25°C, and less than 0.75% over the industrial temperature range. Residual nonlinearity is under 0.05%. The AD693 also allows for the use of an external pass transistor to further reduce errors caused by self-heating.

For transmission of low-level signals from RTDs, bridges and pressure transducers, the AD693 offers a cost-effective signal conditioning solution. It is recommended as a replacement for discrete designs in a variety of applications in process control, factory automation and system monitoring.

The AD693 is packaged in an 20-pin ceramic side-brazed DIP and is specified over the −40°C to +85°C industrial temperature range.

PRODUCT HIGHLIGHTS

1. The AD693 is a complete monolithic low-level voltage-to-current loop signal conditioner.
2. Precalibrated output zero and span options include 4-20mA, 0-20mA, and 12 ± 8mA in two- and three-wire configurations.
3. Simple resistor programming adds a continuum of ranges to the basic 30mV and 60mV input spans.
4. The common-mode range of the signal amplifier input extends from ground to near the device's operating voltage.
5. Provision for transducer excitation includes a 6.2V reference output and an auxiliary amplifier which may be configured for voltage or current output and signal amplification.
6. The circuit configuration permits simple linearization of bridge, RTD, and other transducer signals.
7. A monitored output is provided to drive an external pass transistor. This feature off-loads power dissipation to extend the temperature range of operation, enhance reliability, and minimize self-heating errors.
8. Laser-wafer trimming results in low unadjusted errors and affords precalibrated input and output spans.
9. Zero and span are independently adjustable and noninteractive to accommodate transducers or user defined ranges.
10. Six precalibrated temperature ranges are available with a 100Ω RTD via pin strapping.

SPECIFICATIONS (@ +25°C and V_S = +24V, Input Span = 30mV or 60mV, Output Span = 4-20mA, R_L = 250Ω, V_{CM} = 3.1V, with external pass transistor unless otherwise specified)

Model	Conditions	AD693AD Min	Typ	Max	Units
LOOP POWERED OPERATION					
TOTAL UNADJUSTED ERROR[1,2]			±0.25	**±0.5**	% Full Scale
T_{min} to T_{max}			±0.4	**±0.75**	% Full Scale
100Ω RTD CALIBRATION ERROR[3]	(See Fig. 17)		±0.5	±2.0	°C
LOOP POWERED OPERATION[2]					
Zero Current Error[4]	Zero = 4mA		±25	**±80**	µA
	Zero = 12mA		±40	**±120**	µA
	Zero = 0mA[5]	+7	+35	**+100**	µA
vs. Temp.	Zero = 4mA		±0.5	±1.5	µA/°C
Power Supply Rejection (RTI)	12V≤V_{OP}≤36V[6]		±3.0	**±5.6**	µV/V
	0V≤V_{CM}≤6.2V				
Common-Mode Input Range	(See Fig. 3)	0		+V_{OP} − 4V[6]	V
Common-Mode Rejection (RTI)	0V≤V_{CM}≤6.2V		±10	**±30**	µV/V
Input Bias Current[7]			+5	**+20**	nA
T_{min} to T_{max}			+7	**+25**	nA
Input Offset Current[7]	V_{SIG} = 0		±0.5	**±3.0**	nA
Transconductance					
Nominal	30mV Input Span		0.5333		A/V
	60mV Input Span		0.2666		A/V
Unadjusted Error			±0.05	**±0.2**	%
vs. Common-Mode	0V≤V_{CM}≤6.2V				
	30mV Input Span		±0.03	±0.04	%/V
	60mV Input Span		±0.05	±0.06	%/V
Error vs. Temp.			±20	±50	ppm/°C
Nonlinearity[8]	30mV Input Span		±0.01	**±0.05**	% of Span
	60mV Input Span		±0.02	**±0.07**	% of Span
OPERATIONAL VOLTAGE RANGE					
Operational Voltage, V_{OP}[6]		**+12**		**+36**	V
Quiescent Current	Into Pin 9		+500	**+700**	µA
OUTPUT CURRENT LIMIT		**+21**	+25	**+32**	mA
COMPONENTS OF ERROR					
SIGNAL AMPLIFIER[9]					
Input Voltage Offset			±40	**±200**	µV
vs. Temp			±1.0	±2.5	µV/°C
Power Supply Rejection	12V≤V_{OP}≤36V[6]		±3.0	**±5.6**	µV/V
	0V≤V_{CM}≤6.2V				
V/I CONVERTER[9,10]					
Zero Current Error	Output Span = 4-20mA		±30	±80	µA
Power Supply Rejection	12V≤V_{OP}≤36V[6]		±1.0	±3.0	µA/V
Transconductance					
Nominal			0.2666		A/V
Unadjusted Error			±0.05	±0.2	%
6.200V REFERENCE[9,12]					
Output Voltage Tolerance			±3	**±12**	mV
vs. Temp.			±20	±50	ppm/°C
Line Regulation	12V≤V_{OP}≤36V[6]		±200	**±300**	µV/V
Load Regulation[11]	0mA≤I_{REF}≤3mA		±0.3	**±0.75**	mV/mA
Output Current[13]	Loop Powered, (Fig. 10)	**+3.0**	+3.5		mA
	3-Wire Mode, (Fig. 15)		+5.0		mA
AUXILIARY AMPLIFIER					
Common-Mode Range		0		+V_{OP} − 4V[6]	V
Input Offset Voltage			±50	±200	µV
Input Bias Current			+5	+20	nA
Input Offset Current			+0.5	±3.0	nA
Common-Mode Rejection			90		dB
Power Supply Rejection			105		dB

Model	Conditions	AD693AD Min	Typ	Max	Units
Output Current Range	Pin I_X OUT	+0.01		+5	mA
Output Current Error	Pin V_X – Pin I_X		±0.005		%
TEMPERATURE RANGE					
Case Operating[14]	T_{min} to T_{max}	–40		+85	°C
Storage		–65		+150	°C
PACKAGE OPTION[15]			D-20		

NOTES

[1]Total error can be significantly reduced (typically less than 0.1%) by trimming the zero current. The remaining unadjusted error sources are transconductance and nonlinearity.

[2]The AD693 is tested as a loop powered device with the signal amp, V/I converter, voltage reference, and application voltages operating together. Specifications are valid for preset spans and spans between 30mV and 60mV.

[3]Error from ideal output assuming a perfect 100Ω RTD at 0 and +100°C.

[4]Refer to the Error Analysis to calculate zero current error for input spans less than 30mV.

[5]By forcing the differential signal amplifier input sufficiently negative the 7μA zero current can always be achieved.

[6]The operational voltage (V_{OP}) is the voltage directly across the AD693 (Pin 10 to 6 in two-wire mode, Pin 9 to 6 in local power mode). For example, $V_{OP} = V_S - (I_{LOOP} \times R_L)$ in two-wire mode (refer to Figure 10).

[7]Bias currents are not symmetrical with input signal level and flow out of the input pins. The input bias current of the inverting input increases with input signal voltage, see Figure 2.

[8]Nonlinearity is defined as the deviation of the output from a straight line connecting the endpoints as the input is swept over a 30mV and 60mV input span.

[9]Specifications for the individual functional blocks are components of error that contribute to, and that are included in, the Loop Powered Operation specifications.

[10]Includes error contributions of V/I converter and Application Voltages.

[11]Changes in the reference output voltage due to load will affect the Zero Current. A 1% change in the voltage reference output will result in an error of 1% in the value of the Zero Current.

[12]If not used for external excitation, the reference should be loaded by approximately 1mA (6.2kΩ to common).

[13]In the loop powered mode up to 5mA can be drawn from the reference, however, the lower limit of the output span will be increased accordingly. 3.5mA is the maximum current the reference can source while still maintaining a 4mA zero.

[14]The AD693 is tested with a pass transistor so $T_A \cong T_C$.

[15]See Section 16 for package outline information.

Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	+36V
Reverse Loop Current	200mA
Signal Amp Input Range	–0.3V to V_{OP}
Reference Short Circuit to Common	Indefinite
Auxiliary Amp Input Voltage Range	–0.3V to V_{OP}
Auxiliary Amp Current Output	10mA
Storage Temperature	–65°C to 150°C
Lead Temperature, 10sec Soldering	+300°C
Max Junction Temperature	+150°C

Typical Characteristics

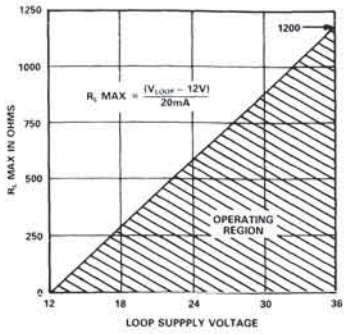


Figure 1. Maximum Load Resistance vs. Power Supply

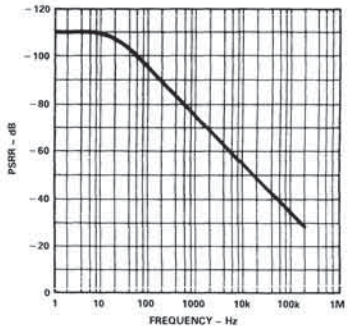


Figure 5. Signal Amplifier PSRR vs. Frequency

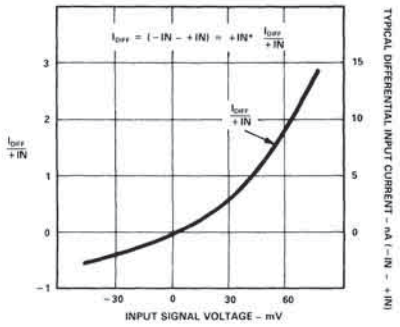


Figure 2. Differential Input Current vs. Input Signal Voltage Normalized to +IN

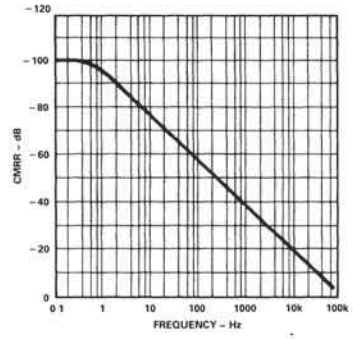


Figure 6. CMRR (RTI) vs. Frequency

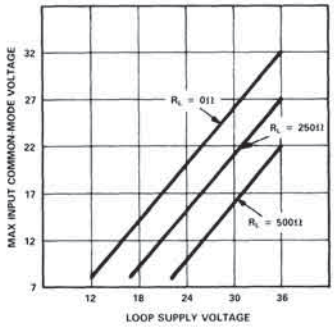


Figure 3. Maximum Common-Mode Voltage vs. Supply

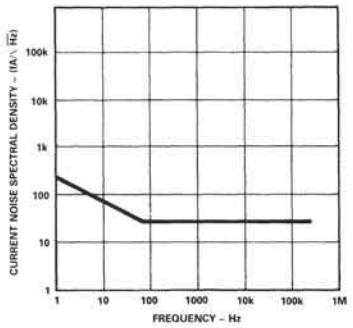


Figure 7. Input Current Noise vs. Frequency

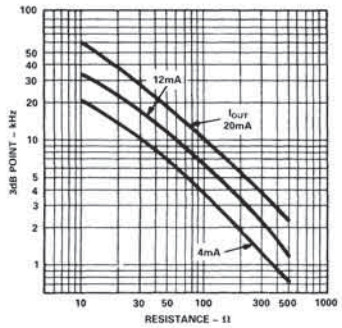


Figure 4. Bandwidth vs. Series Load Resistance

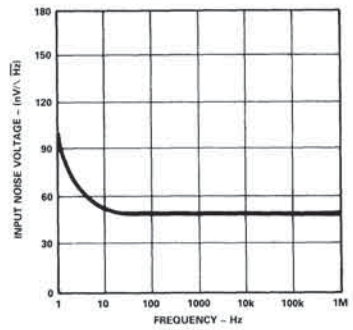


Figure 8. Input Voltage Noise vs. Frequency

FUNCTIONAL DESCRIPTION

The operation of the AD693 can be understood by dividing the circuit into three functional parts (see Figure 9). First, an instrumentation amplifier front-end buffers and scales the low-level input signal. This amplifier drives the second section, a V/I converter, which provides the 4-to-20mA loop current. The third section, a voltage reference and resistance divider, provides application voltages for setting the various "live zero" currents. In addition to these three main sections, there is an on-chip auxiliary amplifier which can be used for transducer excitation.

VOLTAGE-TO-CURRENT (V/I) CONVERTER

The output NPN transistor for the V/I section sinks loop current when driven on by a high gain amplifier at its base. The input for this amplifier is derived from the difference in the outputs of the matched preamplifiers having gains, G2. This difference is caused to be small by the large gain, +A, and the negative feedback through the NPN transistor and the loop current sampling resistor between I_{IN} and Boost. The signal across this resistor is compared to the input of the left preamp and servos the loop current until both signals are equal. Accurate voltage-to-current transformation is thereby assured. The preamplifiers employ a special design which allows the active feedback amplifier to operate from the most positive point in the circuit, I_{IN}.

The V/I stage is designed to have a nominal transconductance of 0.2666 A/V. Thus, a 75mV signal applied to the inputs of the V/I (Pin 16, noninverting; Pin 12, inverting) results in a full-scale output current of 20mA.

The current limiter operates as follows: the output of the feedback preamp is an accurate indication of the loop current. This output is compared to an internal setpoint which backs off the drive to the NPN transistor when the loop current approaches 25mA. As a result, the loop and the AD693 are protected from the consequences of voltage overdrive at the V/I input.

VOLTAGE REFERENCE AND DIVIDER

A stabilized bandgap voltage reference and laser-trimmed resistor divider provide for both transducer excitation as well as precalibrated offsets for the V/I converter. When not used for external excitation, the reference should be loaded by approximately 1mA (6.2kΩ to common).

The 4mA and 12mA taps on the resistor divider correspond to −15mV and −45mV, respectively, and result in a live zero of 4mA or 12mA of loop current when connected to the V/I converter's inverting input (Pin 12). Arranging the zero offset in this way makes the zero signal output current independent of input span. When the input to the signal amp is zero, the noninverting input of the V/I is at 6.2V.

Since the standard offsets are laser trimmed at the factory, adjustment is seldom necessary except to accommodate the zero offset of the actual source. (See "Adjusting Zero".)

SIGNAL AMPLIFIER

The Signal Amplifier is an instrumentation amplifier used to buffer and scale the input to match the desired span. Inputs applied to the Signal Amplifier (at Pins 17 and 18) are amplified and referred to the 6.2V reference output in much the same way as the level translation occurs in the V/I converter. Signals from the two preamplifiers are subtracted, the difference is amplified, and the result is fed back to the upper preamp to minimize the difference. Since the two preamps are identical, this minimum will occur when the voltage at the upper preamp just matches the differential input applied to the Signal Amplifier at the left.

Since the signal which is applied to the V/I is attenuated across the two 800Ω resistors before driving the upper preamp, it will necessarily be an amplified version of the signal applied between Pins 17 and 18. By changing this attenuation, you can control the span referred to the Signal Amplifier. To illustrate: a 75mV signal applied to the V/I results in a 20mA loop current. Nominally, 15mV is applied to offset the zero to 4mA leaving a 60mV range to correspond to the span. And, since the nominal attenuation of the resistors connected to Pins 16, 15 and 14 is 2.00, a 30mV input signal will be doubled to result in 20mA of loop current. Shorting Pins 15 and 16 results in unity gain and permits a 60mV input span. Other choices of span may be implemented with user supplied resistors to modify the attenuation. (See section "Adjusting Input Span".)

The Signal Amplifier is specially designed to accommodate a large common-mode range. Common-mode signals anywhere up to and beyond the 6.2V reference are easily handled as long as V_{IN} is sufficiently positive. The Signal Amplifier is biased with respect to V_{IN} and requires about 3.5 volts of headroom. The extended range will be useful when measuring sensors driven, for example, by the auxiliary amplifier which may go above the 6.2V potential. In addition, the PNP input stage will continue to operate normally with common-mode voltages of several hundred mV, negative, with respect to common. This feature accommodates self-generating sensors, such as thermocouples,

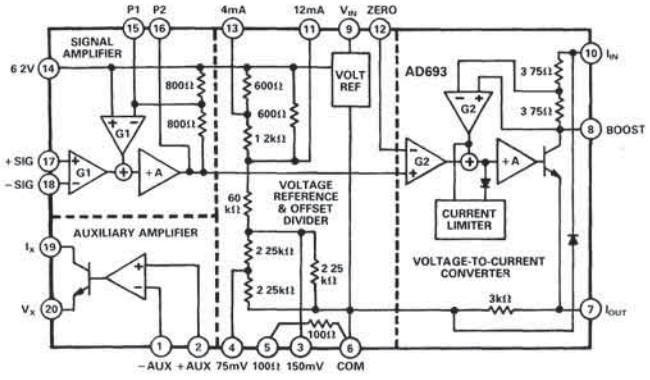


Figure 9. Functional Block Diagram

which may produce small negative normal-mode signals as well as common-mode noise on "grounded" signal sources.

AUXILIARY AMPLIFIER

The Auxiliary Amplifier is included in the AD693 as a signal conditioning aid. It can be used as an op amp in noninverting applications and has special provisions to provide a controlled current output. Designed with a differential input stage and an unbiased Class A output stage, the amplifier can be resistively loaded to common with the self-contained 100Ω resistor or with a user supplied resistor.

As a functional element, the Auxiliary Amplifier can be used in dynamic bridges and arrangements such as the RTD signal conditioner shown in Figure 17. It can be used to buffer, amplify and combine other signals with the main Signal Amplifier. The Auxiliary Amplifier can also provide other voltages for excitation if the 6.2V of the reference is unsuitable. Configured as a simple follower, it can be driven from a user supplied voltage divider or the precalibrated outputs of the AD693 divider (Pins 3 and 4) to provide a stiff voltage output at less than the 6.2 level, or by incorporating a voltage divider as feedback around the amplifier, one can gain-up the reference to levels higher than 6.2V. If large positive outputs are desired, I_X, the Auxiliary Amplifier output current supply, should be strapped to either V_{IN} or Boost. Like the Signal Amplifier, the Auxiliary requires about 3.5V of headroom with respect to V_{IN} at its input and about 2V of difference between I_X and the voltage to which V_X is required to swing.

The output stage of the Auxiliary Amplifier is actually a high gain Darlington transistor where I_X is the collector and V_X is the emitter. Thus, the Auxiliary Amplifier can be used as a V/I converter when configured as a follower and resistively loaded. I_X functions as a high-impedance current source whose current is equal to the voltage at V_X divided by the load resistance. For example, using the onboard 100Ω resistor and the 75mV or 150mV application voltages, either a 750μA or 1.5mA current source can be set up for transducer excitation.

The I_X terminal has voltage compliance within 2V of V_X. If the Auxiliary Amplifier is not to be used, then Pin 2, the noninverting input, should be grounded.

REVERSE VOLTAGE PROTECTION FEATURE

In the event of a reverse voltage being applied to the AD693 through a current-limited loop (limited to 200mA), an internal shunt diode protects the device from damage. This protection mode avoids the compliance voltage penalty which results from a series diode that must be added if reversal protection is required in high-current loops.

Applying the AD693

CONNECTIONS FOR BASIC OPERATION

Figure 10 shows the minimal connections for basic operation: 0-30mV input span, 4-20mA output span in the two-wire, loop-powered mode. If not used for external excitation, the 6.2V reference should be loaded by approximately 1mA (6.2kΩ to common).

USING AN EXTERNAL PASS TRANSISTOR

The emitter of the NPN output section, I_{OUT}, of the AD693 is usually connected to common and the negative loop connection (Pins 7 to 6). Provision has been made to reconnect I_{OUT} to the base of a user supplied NPN transistor as shown in Figure 11. This permits the majority of the power dissipation to be moved off chip to enhance performance, improve reliability, and extend the operating temperature range. An internal hold-down resistor of about 3k is connected across the base emitter of the external transistor.

The external pass transistor selected should have a BV_{CEO} greater than the intended supply voltage with a sufficient power rating for continuous operation with 25mA current at the supply voltage. Ft should be in the 10MHz to 100MHz range and β should be greater than 10 at a 20mA emitter current. Some transistors that meet this criteria are the 2N1711 and 2N2219A. Heat sinking the external pass transistor is suggested.

The pass transistor option may also be employed for other applications as well. For example, I_{OUT} can be used to drive an LED connected to Common, thus providing a local monitor of loop fault conditions without reducing the minimum compliance voltage.

ADJUSTING ZERO

In general, the desired zero offset value is obtained by connecting an appropriate tap of the precision reference/voltage divider network to the inverting terminal of the V/I converter. As shown in Figure 9, precalibrated taps at Pins 14, 13 and 11 result in zero offsets of 0mA, 4mA and 12mA, respectively, when connected to Pin 12. The voltages which set the 4mA and 12mA zero operating points are 15mV and 45mV negative with respect to

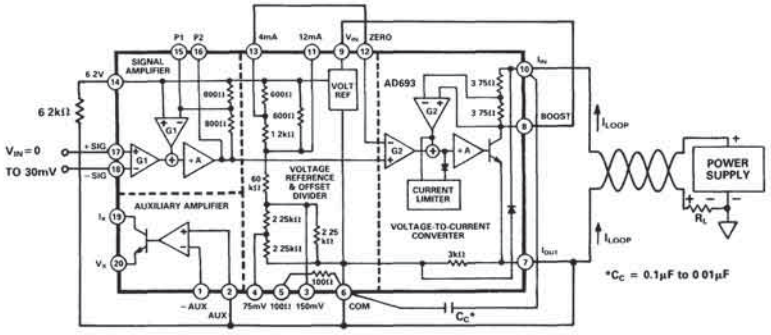


Figure 10. Minimal Connection for 0-30mV Unipolar Input, 4-20mA Output

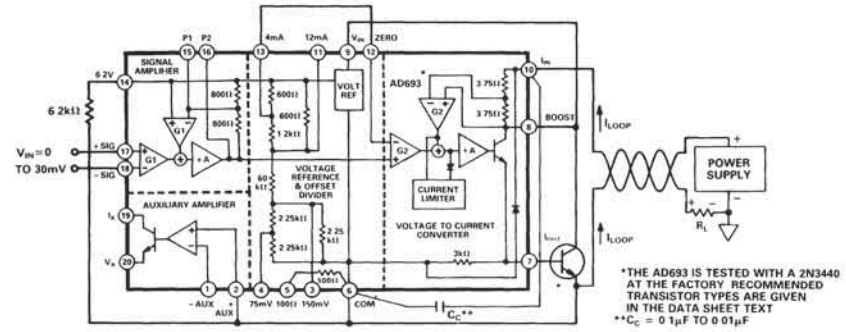


Figure 11. Using an External Pass Transistor to Minimize Self-Heating Errors

6.2V, and they each have a nominal source resistance of 450Ω. While these voltages are laser trimmed to high accuracy, they may require some adjustment to accommodate variability between sensors or to provide additional ranges. You can adjust zero by pulling up or down on the selected zero tap, or by making a separate voltage divider to drive the zero pin.

The arrangement of Figure 12 will give an approximately linear adjustment of the precalibrated options with fixed limits. To find the proper resistor values, first select I_A, the desired range of adjustment of the output current from nominal. Substitute this value in the appropriate formula below for adjustment at the 4mA tap.

$R_{Z1} = (1.6V/I_A) - 400\Omega$ and

$R_{Z2} = R_{Z1} \times 3.1V/(15mV + I_A \times 3.75\Omega)$

Use a similar connection with the following resistances for adjustments at the 12mA tap.

$R_{Z1} = (4.8V/I_A) - 400\Omega$ and

$R_{Z2} = R_{Z1} \times 3.1V/(45mV + I_A \times 3.75\Omega)$

These formulae take into account the ±10% tolerance of tap resistance and insure a minimum adjustment range of I_A. For example, choosing $I_A = 200\mu A$ will give a zero adjustment range of ±1% of the 20mA full-scale output. At the 4mA tap the maximum value of:

$R_{Z1} = 1.6V/200\mu A - 400\Omega = 7.6k\Omega$ and

$R_{Z2} = 7.6k\Omega \times 3.1V/(15mV + 200\mu A \times 3.75\Omega) = 1.49M\Omega$

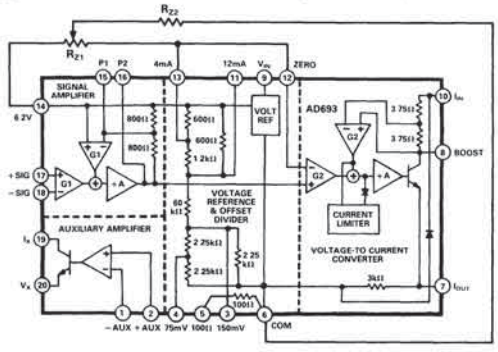


Figure 12. Optional 4mA Zero Adjustment (12mA Trim Available Also)

These can be rounded down to more convenient values of 7.5kΩ and 1.3MΩ, which will result in an adjustment range comfortably greater than ±200μA.

ADJUSTING INPUT SPAN

Input Span is adjusted by changing the gain of the Signal Amplifier. This amplifier provides a 0-to-60mV signal to the V/I section to produce the 4-to-20mA output span (or a 0-to-75mV signal in the 0-to-20mA mode). The gain of this amplifier is trimmed to 2.00 so that an input signal ranging from 0-to-30mV will drive the V/I section to produce 4-to-20mA. Joining P1 and P2 (Pins 15 and 16) will reduce the Signal Amplifier gain to one, thereby requiring a 60mV signal to drive the V/I to a full 20mA span.

To produce spans less than 30mV, an external resistor, R_{S1}, can be connected between P1 and 6.2V. The nominal value is given by:

$$R_{S1} = \frac{400\Omega}{\frac{30mV}{S} - 1}$$

where S is the desired span. For example, to change the span to 6mV a value of:

$$R_{S1} = \frac{400\Omega}{\frac{30mV}{6mV} - 1} = 100\Omega$$

is required. Since the internal, 800Ω gain setting resistors exhibit an absolute tolerance of 10%, R_{S1} should be provided with up to ±10% range of adjustment if the span must be well controlled.

For spans between 30mV and 60mV a resistor R_{S2} should be connected between P1 and P2. The nominal value is given by:

$$R_{S2} = \frac{400\Omega\,(1 - \frac{60mV}{S})}{\frac{30mV}{S} - 1}$$

For example, to change the span to 40mV, a value of:

$$R_{S2} = \frac{400\Omega\,(1 - \frac{60mV}{40mV})}{\frac{30mV}{40mV} - 1} = 800\Omega$$

is required. Remember that this is a nominal value and may require adjustment up to ±10%. In many applications the span must be adjusted to accommodate *individual* variations in the sensor as well as the AD693. The span changing resistor should, therefore, include enough adjustment range to handle both the

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sensor uncertainty and the absolute resistance tolerance of P1 and P2. Note that the temperature coefficient of the internal resistors is nominally −17ppm/°C, and that the external resistors should be comparably stable to insure good temperature performance.

An alternative arrangement, allowing wide range span adjustment between two set ranges, is shown in Figure 13. R_{S1} and R_{S2} are calculated to be 90% of the values determined from the previous formulae. The smallest value is then placed in series with the wiper of the 1.5kΩ potentiometer shown in the figure. For example, to adjust the span between 25mV and 40mV, R_{S1} and R_{S2} are calculated to be 2000Ω and 800Ω, respectively. The smaller value, 800Ω, is then reduced by 10% to cover the possible ranges of resistance in the AD693 and that value is put in place.

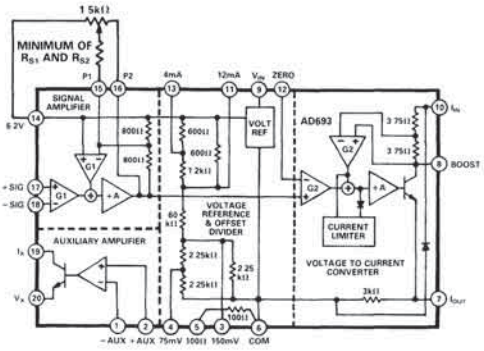


Figure 13. Wide Range Span Adjustment

A number of other arrangements can be used to set the span as long as they are compatible with the pretrimmed noninverting gain of two. The span adjustment can even include thermistors or other sensitive elements to compensate the span of a sensor.

In devising your own adjustment scheme, remember that you should adjust the gain such that the desired span voltage at the Signal Amplifier input translates to 60mV at the output. Note also that the full differential voltage applied to the V/I converter is 75mV; in the 4-20mA mode, −15mV is applied to the inverting input (zero pin) by the Divider Network and +60mV is applied to the noninverting input by the Signal Amplifier. In the 0-to-20mA mode, the total 75mV must be applied by the Signal Amplifier. As a result, the total span voltage will be 25% larger than that calculated for a 4-20mA output.

Finally, the external resistance from P2 to 6.2V should not be made less than 1kΩ unless the voltage reference is loaded to at least 1.0mA. (A simple load resistor can be used to meet this requirement if a low value potentiometer is desired.) In no case should the resistance from P2 to 6.2V be less than 200Ω.

Input Spans Between 60 and 100mV

Input spans of up to 100mV can be obtained by adding an offset proportional to the output signal into the zero pin of the V/I converter. This can be accomplished with two resistors and adjusted via the optional trim scheme shown in Figure 14. The resistor divider formed by R_{E1} and R_{E2} from the output of the Signal Amplifier modifies the differential input voltage range applied to the V/I converter.

In order to determine the fixed resistor values, R_{E1} and R_{E2}, first measure the source resistance (R_D) of the internal divider network. This can be accomplished (power supply disconnected) by measuring the resistance between the 4mA of offset (Pin 13) and common (Pin 6) with the 6.2V reference (Pin 14) connected to common. The measured value, R_D, is then used to calculate R_{E1} and R_{E2} via the following formula:

$$R_{E2} = R_D\left(\frac{S}{S - 60mV} - 1.0024\right)$$

and $R_{E1} = 412R_{E2}$

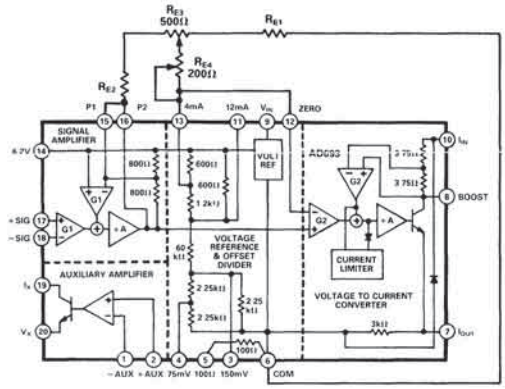


Figure 14. Adjusting for Spans between 60mV and 100mV (R_{E1} and R_{E2}) with Fine-Scale Adjust (R_{E3} and R_{E4})

Figure 14 shows a scheme for adjusting the modified span and 4mA offset via R_{E3} and R_{E4}. The trim procedure is to first connect both signal inputs to the 6.2V Reference, set R_{E4} to zero and then adjust R_{E3} so that 4mA flows in the current loop. This in effect, creates a divider with the same ratio as the internal divider that sets the 4mA zero level (−15mV with respect to 6.2V). As long as the input signal remains zero the voltage at Pin 12, the zero adjust, will remain at −15mV with respect to 6.2V.

After adjusting R_{E3} place the desired full scale (S) across the signal inputs and adjust R_{E4} so that 20mA flows in the current loop. An attenuated portion of the input signal is now added into the V/I zero to maintain the 75mV maximum differential. If there is some small offset at the input to the Signal Amplifier, it may be necessary to repeat the two adjustments.

LOCAL-POWERED OPERATION FOR 0-20mA OUTPUT

The AD693 is designed for local-powered, three-wire systems as well as two-wire loops. All its usual ranges are available in three-wire operation, and in addition, the 0-to-20mA range can be used. The 0-20mA convention offers slightly more resolution and may simplify the loop receiver, two reasons why it is sometimes preferred.

The arrangement, illustrated in Figure 15, results in a 0-20mA transmitter where the precalibrated span is 37.5mV. Connecting P1 to P2 will double the span to 75mV. Sensor input and excitation is unchanged from the two-wire mode except for the 25% increase in span. Many sensors are ratiometric so that an increase in excitation can be used instead of a span adjustment.

In the local-powered mode, increases in excitation are made easier. Voltage compliance at the I_{IN} terminal is also improved; the loop voltage may be permitted to fall to 6 volts at the AD693, easing the trade-off between loop voltage and loop resistance. Note that the load resistor, R_L, should meter the current into Pin 10, I_{IN}, so as not to confuse the loop current with the local power supply current.

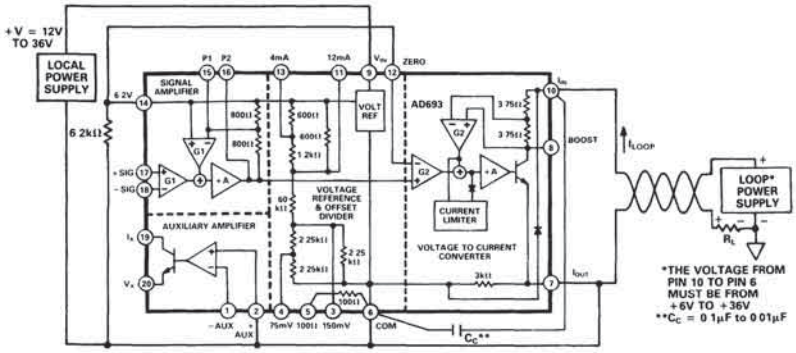


Figure 15. Local Powered Operation with 0-20mA Output

OPTIONAL INPUT FILTERING

Input filtering is recommended for all applications of the AD693 due to its low input signal range. An RC filter network at each input of the signal amplifier is sufficient, as shown in Figure 16. In the case of a resistive signal source it may be necessary only to add the capacitors, as shown in Figure 18. The capacitors should be placed as close to the AD693 as possible. The value of the filter resistors should be kept low to minimize errors due to input bias current. Choose the 3dB point of the filter high enough so as not to compromise the bandwidth of the desired signal. The RC time constant of the filter should be matched to preserve the ac common-mode rejection.

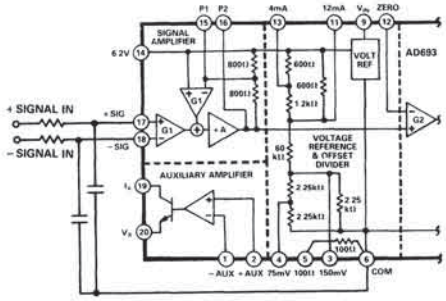


Figure 16. Optional Input Filtering

INTERFACING PLATINUM RTDs

The AD693 has been specially configured to accept inputs from 100Ω Platinum RTDs (Resistance Temperature Detectors). Referring to Figure 17, the RTD and the temperature stable 100Ω resistor form a feedback network around the Auxiliary Amplifier resulting in a noninverting gain of $(1+R_T/100\Omega)$, where R_T is the temperature dependent resistance of the RTD. The noninverting input of the Auxiliary Amplifier (Pin 2) is then driven by the 75mV signal from the Voltage Divider (Pin 4). When the RTD is at 0, its 100Ω resistance results in an amplifier gain of +2 causing V_X to be 150mV. The Signal Amplifier compares this voltage to the 150mV output (Pin 3) so that zero differential signal results. As the temperature (and therefore, the resistance) of the RTD increases, V_X will likewise increase according to the gain relationship. The difference between this voltage and the zero degree value of 150mV drives the Signal Amp to modulate the loop current. The AD693 is precalibrated such that the full 4-20mA output span corresponds to a 0 to 104°C range in the RTD. (This assumes the European Standard of $\alpha = 0.00385$.) A total of 6 precalibrated ranges for three-wire (or two-wire) RTDs are available using only the pin strapping options as shown in Table I.

A variety of other temperature ranges can be realized by using different application voltages. For example, loading the Voltage Divider with a 1.5kΩ resistor from Pin 3 to Pin 6 (common) will approximately halve the original application voltages and

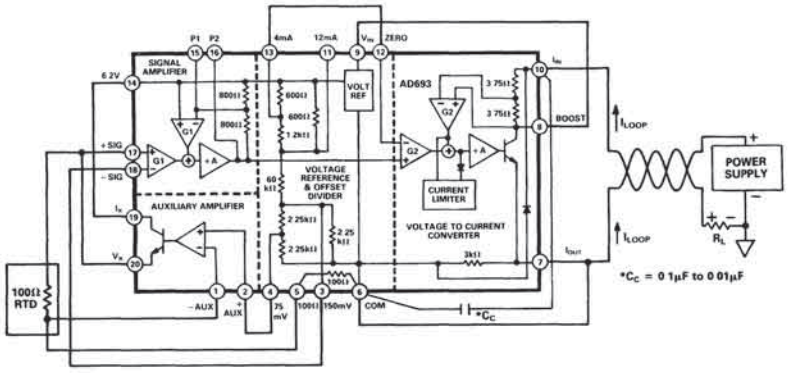


Figure 17. 0-to-104°C Direct Three-Wire 100Ω RTD Interface, 4-20ma Output

Temperature Range	Pin Connections
0 to +104°C	12 to 13
0 to +211°C	12 to 13, and 15 to 16
+25°C to +130°C	12 to 14
+51°C to +266°C	12 to 14, and 15 to 16
−50°C to +51°C	12 to 11
−100°C to +104°C	12 to 11 and 15 to 16

Table I. Precalibrated Temperature Range Options Using a European Standard 100Ω RTD and the AD693.

allow for a doubling of the range of resistance (and therefore, temperature) required to fill the two standard spans. Likewise, increasing the application voltages by adding resistance between Pins 14 and 3 will decrease the temperature span.

An external voltage divider may also be used in conjunction with the circuit shown to produce any range of temperature spans as well as providing zero output (4mA) for a non 0 temperature input. For example, measuring V_X with respect to a voltage 2.385 times the excitation (rather than 2 times) will result in zero input to the Signal Amplifier when the RTD is at 100°C (or 138.5Ω).

As suggested in Table I, the temperature span may also be adjusted by changing the voltage span of the Signal Amplifier. Changing the gain from 2 to 4, for example, will halve the temperature span to about 52°C on the 4-20mA output configuration. (See section "Adjusting Input Span".)

The configuration for a three-wire RTD shown in Figure 17 can accommodate two-wire sensors by simply joining Pins 1 and 5 of the AD693.

INTERFACING LOAD CELLS AND METAL FOIL STRAIN GAGES

The availability of the on-chip Voltage Reference, Auxiliary Amplifier and 3mA of excitation current make it easy to adapt the AD693 to a variety of load cells and strain gages.

The circuit shown in Figure 18 illustrates a generalized approach in which the full flexibility of the AD693 is required to interface to a low resistance bridge. For a high impedance transducer the bridge can be directly powered from the 6.2V Reference.

Component values in this example have been selected to match the popular standard of 2mV/V sensitivity and 350Ω bridge resistance. Load cells are generally made for either tension and compression, or compression only; use of the 12mA zero tap allows for operation in the tension and compression mode. An optional zero adjustment is provided with values selected for ±2% FS adjustment range.

Because of the low resistance of most foil bridges, the excitation voltage must be low so as not to exceed the available 4mA zero current. About 1V is derived from the 6.2V Reference and an external voltage divider; the Aux-Amp is then used as a follower to make a stiff drive for the bridge. Similar applications with higher resistance sensors can use proportionally higher voltage.

Finally, to accommodate the 2mV/V sensitivity of the bridge, the full-scale span of the Signal Amplifier must be reduced. Using the load cell in both tension and compression with 1V of excitation, therefore, dictates that the span be adjusted to 4mV. By substituting in the expression, $R_{S1} = 400\Omega/[(30mV/S) - 1]$, the nominal resistance required to achieve this span is found to be 61.54Ω. Calculate the minimum resistance required by subtracting 10% from 61.54Ω to allow for the internal resistor tolerance of the AD693, leaving 55.38Ω (See "Adjusting Input Span".) The standard value of 54.9Ω is used with a 20Ω potentiometer for full-scale adjustment.

If a load cell with a precalibrated sensitivity constant is to be used, the resultant full-scale span applied to the Signal Amplifier is found by multiplying that sensitivity by the excitation voltage. (In Figure 18, the excitation voltage is actually (10kΩ/62.3kΩ) (6.2V) = 0.995V).

THERMOCOUPLE MEASUREMENTS

The AD693 can be used with several types of thermocouple inputs to provide a 4-20mA current loop output corresponding to a variety of measurement temperature ranges. Cold junction compensation (CJC) can be implemented using an AD592 or AD590 and a few external resistors as shown in Figure 19.

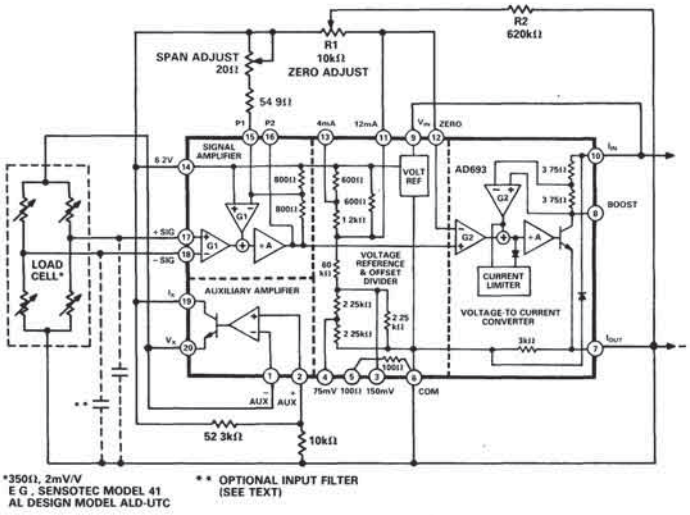


Figure 18. Utilizing the Auxiliary Amplifier to Drive A Load Cell, 12mA ±8mA Output

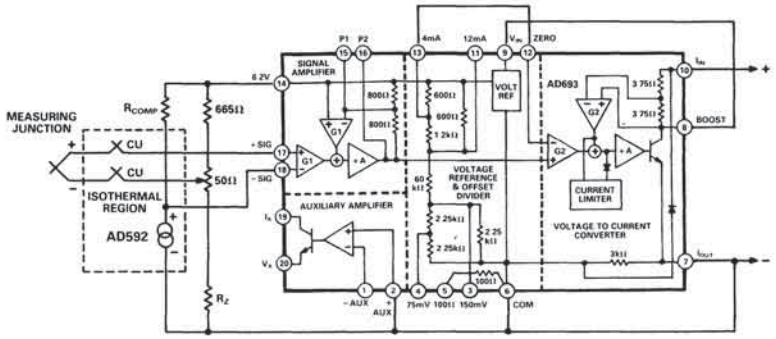


Figure 19. Thermocouple Inputs with Cold Junction Compensation

POLARITY	MATERIAL	TYPE	AMBIENT TEMP	RCOMP	RZ	30mV TEMP RANGE	60mV TEMP RANGE
+	IRON	J	25°	51.7Ω	301K	546°C	1035°C
–	CONSTANTAN		75°	53.6Ω	294K		
+	NICKEL-CHROME	K	25°	40.2Ω	392K	721°C	—
–	NICKEL-ALUMINUM		75°	42.2Ω	374K		
+	NICKEL-CHROME	E	25°	60.4Ω	261K	413°C	787°C
–	COPPER-NICKEL		75°	64.9Ω	243K		
+	COPPER	T	25°	40.2Ω	392K	USE WITH GAIN>2	
–	COPPER-NICKEL		75°	45.3Ω	340K		

Table II. Thermocouple Application – Cold Junction Compensation Table

From Table II simply choose the type of thermocouple and the appropriate average reference junction temperature to select values for R_{COMP} and R_Z. The CJC voltage is developed across R_{COMP} as a result of the AD592 1μA/K output and is added to the thermocouple loop voltage. The 50Ω potentiometer is biased by R_Z to provide the correct zero adjustment range appropriate for the divider and also translates the Kelvin scale of the AD592 to °Celsius. To calibrate the circuit, put the thermocouple in an ice bath (or use a thermocouple simulator set to 0) and adjust the potentiometer for a 4mA loop current.

The span of the circuit in °C is determined by matching the signal amplifier input voltage range to it's temperature equivalent via a set of thermocouple tables referenced to °C. For example, the output of a properly referenced type J thermocouple is 60mV when the hot junction is at 1035°C. Table II lists the maximum measurement temperature for several thermocouple types using the preadjusted 30mV and 60mV input ranges.

More convenient temperature ranges can be selected by determining the full-scale input voltages via standard thermocouple tables and adjusting the AD693 span. For example, suppose only a 300°C span is to be measured with a type K thermocouple. From a standard table, the thermocouple output is 12.207mV; since 60mV at the signal amplifier corresponds to a 16mA span at the output a gain of 5, or more precisely 60mV/12.207mV = 4.915 will be needed. Using a 12.207mV span in the gain resistor formula given in "Adjusting Input Span" yields a value of about 270Ω as the minimum from P1 to 6.2V. Adding a 50Ω potentiometer will allow ample adjustment range.

With the connection illustrated, the AD693 will give a full-scale indication with an open thermocouple.

ERROR BUDGET ANALYSIS

Loop-Powered Operation specifications refer to parameters tested with the AD693 operating as a loop-powered transmitter. The specifications are valid for the preset spans of 30mV, 60mV and those spans in between. The section, "Components of Error", refers to parameters tested on the individual functional blocks, (Signal Amplifier, V/I Converter, Voltage Reference, and Auxiliary Amplifier). These can be used to get an indication of device performance when the AD693 is used in local power mode or when it is adjusted to spans of less than 30mV.

Table III lists the expressions required to calculate the total error. The AD693 is tested with a 250Ω load, a 24V loop supply and an input common-mode voltage of 3.1V. The expressions below calculate errors due to deviations from these nominal conditions.

The total error at zero consists only of offset errors. The total error at full scale consists of the offset errors plus the span errors. Adding the above errors in this manner may result in an error as large as 0.8% of full scale, however, as a rule, the AD693 performs better as the span and offset errors do not tend to add worst case. The specification "Total Unadjusted Error", (TUE), reflects this and gives the maximum error as a % of full scale for any point in the transfer function when the device is operated in one of its preset spans, with no external trims. The TUE is less than the error you would get by adding the span and offset errors worst case.

Thus, an alternative way of calculating the total error is to start with the TUE and add to it those errors that result from operation of the AD693 with a load resistance, loop supply voltage, or common-mode input voltage different than specified. (See Example 1 below.)

ERROR BUDGET FOR SPANS LESS THAN 30mV

An accommodation must be made to include the input voltage offset of the signal amplifier when the span is adjusted to less than 30mV. The TUE and the Zero Current Error include the input offset voltage contribution of the signal amplifier in a gain of 2. As the input offset voltage is multiplied by the gain of the signal amplifier, one must include the additional error when the signal amplifier is set to gains greater than 2.

For example, the 300 °K span thermocouple application discussed previously requires a 12.207mV input span; the signal amplifier must be adjusted to a gain of approximately 5. The loop transconductance is now 1.333 A/V, (5 × 0.2666 A/V). Calculate the total error by substituting the new values for the transconductance and span into the equations in Table III as was done in Example I. The error contribution due to V_{OS} is $5 \times V_{OS}$, however, since $2 \times V_{OS}$ is already included in the TUE and the Zero Current Error it is necessary to add an error of only $(5-2) \times V_{OS}$ to the error budget. Note that span error may be reduced to zero with the span trim, leaving only the offset and nonlinearity of the AD693.

RTI Contributions to Offset Error

	Error Source	Expression for RTI Error at Zero
I_{ZE}	Zero Current Error	I_{ZE}/X_S
PSRR	Power Supply Rejection Ratio	$(\lvert V_{LOOP} - 24V\rvert + [\lvert R_L - 250\Omega\rvert \times I_Z]) \times PSRR$
CMRR	Common-Mode Rejection Ratio	$\lvert V_{CM} - 3.1V\rvert \times CMRR$
IOS	Input Offset Current	$R_S \times IOS$

RTI Contributions to Span Error

	Error Source	Expression for RTI Error at Full Scale
X_{SE}	Transconductance Error	$V_{SPAN} \times X_{SE}$
X_{PSRR}	Transconductance PSRR[1]	$\lvert R_L - 250\Omega\rvert \times I_S \times PSRR$
X_{CMRR}	Transconductance CMRR	$\lvert V_{CM} - 3.1V\rvert \times V_{SPAN} \times X_{CMRR}$
X_{NL}	Nonlinearity	$V_{SPAN} \times X_{NL}$
I_{DIFF}	Differential Input Current[2]	$R_S \times I_{DIFF}$

Abbreviations

I_Z	Zero Current (usually 4mA)
I_S	Output span (usually 16mA)
R_S	Input source impedance
R_L	Load resistance
V_{LOOP}	Loop supply voltage
V_{CM}	Input common-mode voltage
V_{SPAN}	Input span
X_S	Nominal transconductance in A/V

[1]The 4-20mA signal, flowing through the metering resistor, modulates the power supply voltage seen by the AD693. The change in voltage causes a power supply rejection error that varies with the output current, thus it appears as a span error.

[2]The input bias current of the inverting input increases with input signal voltage. The differential input current, I_{DIFF}, equals the inverting input current minus the noninverting input current; see Figure 2. I_{DIFF}, flowing into an input source impedance, will cause an input voltage error that varies with signal. If the change in differential input current with input signal is approximated as a linear function, then any error due to source impedance may be approximated as a span error. To calculate I_{DIFF}, refer to Figure 2 and find the value for $I_{DIFF}/+In$ corresponding to the full-scale input voltage for your application. Multiply by +In max to get I_{DIFF}. Multiply I_{DIFF} by the source impedance to get the input voltage error at full scale.

Table III. RTI Contributions to Span and Offset Error

EXAMPLE I

The AD693 is configured as a 4-20mA loop powered transmitter with a 60mV FS input. The inputs are driven by a differential voltage at 2V common mode with a 300Ω balanced source resistance. A 24V loop supply is used with a 500Ω metering resistance. (See Table IV below.)

Trimming the offset and span for your application will remove all span and offset errors except the nonlinearity of the AD693.

OFFSET ERRORS			
I_Z	Already included in the TUE spec.	0.0μV	
PSRR	PSRR = 5.6μV/V; (|24V − 24V| + [|500Ω − 250Ω| × 4mA]) × 5.6μV/V = V_{LOOP} = 24V, R_L = 500Ω I_Z = 4mA	5.6μV	
CMRR	CMRR = 30μV/V; |2V − 3.1V| × 30μV/V = V_{CM} = 2V	33.0μV	
IOS	IOS = 3nA, R_S = 300Ω; 300Ω × 3nA =	0.9μV	
Total Additional Error at 4mA			**39.5μV**
As % of full scale; (39.5μV × 0.2666 A/V)/20mA × 100% =		0.053% of FS	
SPAN ERRORS			
X_{SE}	Already included in the TUE spec.	0.0μV	
X_{PSRR}	PSRR = 5.6μV/V; (|500Ω − 250Ω| × 16mA) × 5.6μV/V = R_L = 500Ω, I_S = 16mA	22.4μV	
X_{CMRR}	X_{CMRR} = 0.06%/V; |2V − 3.1V| × 60mV × 0.06%/V = V_{CM} = 2V, V_{SPAN} = 60mV	39.6μV	
I_{DIFF}	V_{SPAN} = +60mV; 300Ω × 2 × 20nA $I_{DIFF}/+In$ = 2 from Figure 2)	12.0μV	
X_{NL}	Already included in the TUE	0.0μV	
Total Additional Span Error at Full Scale			**74.0μV**
Total Additional Error at Full Scale; $\epsilon_{OFFSET} + \epsilon_{SPAN}$ = 39.5μV + 74.0μV =		113.5μV	
As % of Full Scale; (113.5μV × 0.2666 A/V)/20mA × 100% =		0.151% of FS	
New Total Unadjusted Error @ FS; $\epsilon_{TUE} + \epsilon_{ADDITIONAL}$ = 0.5% + 0.151% =			**0.651% of FS**

Table IV. Example 1

Isolated, Loop-Powered Voltage-to-Current Converter

1B21

FEATURES
- **Wide Input Range: 0-1V to 0-10V**
- **High CMV Isolation: 1500V rms**
- **Programmable Output Ranges: 4mA to 20mA**
  0 to 20mA
- **Load Resistance Range: 0 to 1.35kΩ max**
- **High Accuracy**
  - **Low Offset Tempco: ±300nA/°C**
  - **Low Gain Tempco: ±50ppm/°C**
  - **Low Nonlinearity: ±0.02%**
  - **High CMR: 90dB min**
- **Small Package: 0.7″ × 2.1″ × 0.35″**
- **Meets IEEE Std. 472: Transient Protection (SWC)**

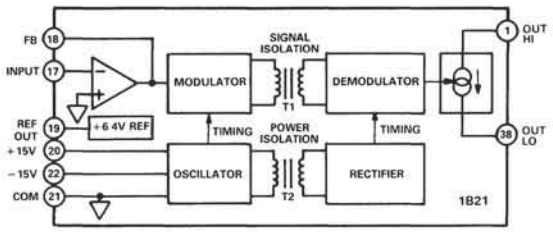
APPLICATIONS
- **Multichannel Process Control**
- **D/A Converter – Current Loop Interface**
- **Analog Transmitters and Controllers**
- **Remote Data Acquisition Systems**

GENERAL DESCRIPTION

The 1B21 is an isolated voltage-to-current converter that incorporates a unique circuit design utilizing transformer based isolation and automated surface mount manufacturing technology. It provides an unbeatable combination of versatility and performance in a compact plastic package. Designed for industrial applications, it is especially suited for harsh environments with extremely high common-mode interference.

Functionally, the V/I converter consists of four basic sections: input conditioning, modulator, demodulator and current source (1B21 Functional Block Diagram). The input is a resistor programmable gain stage that accepts a 0-1V to 0-10V voltage input. This maps into a 0 to 20mA output or can be offset by 20% using the internal reference for 4mA to 20mA operation. The high level signal is modulated and passed across the barrier which provides complete input to output galvanic isolation of 1500V rms continuous by the use of transformer coupling techniques. Nonlinearity is an excellent ±0.05% max.

1B21 FUNCTIONAL BLOCK DIAGRAM



Designed for multichannel applications, the 1B21 requires an external loop supply and can accept up to 30V max. This would provide a loop compliance of 27V, which is sufficient to drive a 1.35kΩ load resistance.

The 1B21 is fully specified over −25°C to +85°C and operates over the industrial (−40°C to +85°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

High CMV Isolation: The 1B21 features high input to output galvanic isolation to eliminate ground loops and offer protection against damage from transients and fault voltages. The isolation barrier will withstand continuous CMV of 1500V rms and meets the IEEE Standard for Transient Voltage Protection (Std. 472-SWC).

Small Size: The 1B21 package size (0.7″ × 2.1″ DIP) makes it an excellent choice in multichannel systems for maximum channel density. The 0.35″ height also facilitates applications with limited board clearance.

Ease of Use: Complete isolated voltage-to-current conversion with minimum external parts required to get a conditioned current signal. No external buffers or drivers are required.

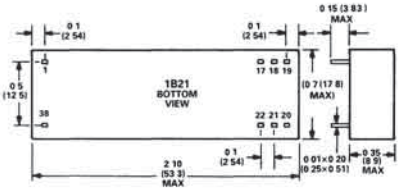
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SPECIFICATIONS (typical at +25°C and V_S = ±15V unless otherwise noted)

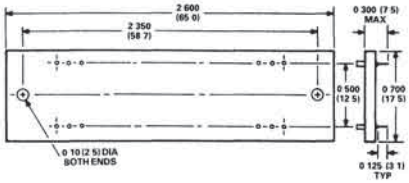
Model	1B21AN
INPUT SPECIFICATIONS	
Input Range	0 to +10V
Full-Scale Input	+1V min to +10V max
Input Bias Current	±30pA (±400pA max)
OUTPUT SPECIFICATIONS	
Current Output Range	4mA to20mA, 0 to 20mA
Load Compliance at V_{LOOP} = 30V	27V min
Max Output Current @ Input Overload	25mA
Output Noise, 100Hz Bandwidth	1μA p-p
NONLINEARITY (% of Span)	±0.02% (±0.05% max)
ISOLATION	
CMV, Input to Output Continuous	1500V rms
CMR, @ 60Hz	90dB min
Transient Protection	IEEE-STD 472 (SWC)
ACCURACY	
Warm-Up Time to Rated Performance	5 min
Total Output Error @ +25°C (Untrimmed)	
Offset (V_{IN} = 0V)[1]	±100μA
Span (V_{IN} = +10V)	±0.6% FSR
vs. Temperature (−25°C to +85°C)	
Offset[2]	±300nA/°C
Span	±50ppm/°C
REFERENCE OUTPUT	
Voltage	+6.4V dc
Output Error	±1.5% max
Temperature Coefficient	±20ppm/°C max
DYNAMIC RESPONSE	
Settling Time to 0.1% of F.S. for 10V Step	9ms
Small Signal Bandwidth	100Hz
POWER SUPPLY	
Input Side	
Operating Voltage	±15V ±5%
Quiescent Current	
+15V Supply	10mA
−15V Supply	5mA
Power Supply Rejection	±0.01%/V
Loop Side	
Operating Voltage	+15V to +30V
Maximum Current	25mA
ENVIRONMENTAL	
Temperature Range	
Rated Performance	−25°C to +85°C
Operating	−40°C to +85°C
Storage	−40°C to +85°C
Relative Humidity, Noncondensing	0 to 95% @ +60°C
CASE SIZE	0.7" × 2.1" × 0.35" (17.8 × 53.3 × 8.9)mm

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



AC1060 MATING SOCKET



PIN DESIGNATIONS

PIN	FUNCTION
1	OUT HI
17	IN
18	FB
19	REF
20	+15V
21	COM
22	−15V
38	OUT LOW

NOTES

[1]For 0-20mA mode. For 4-20mA mode an additional 60μA is contributed by the ±1.5% reference error on the 4mA output.

2For a complete discussion of the temperature effects of the offset resistor and reference refer to "Using the 1B21" section.

Specifications subject to change without notice.

INSIDE THE 1B21

Referring to the functional block diagram, the ±15V power inputs provide power to both the input side circuitry and the power oscillator. The 25kHz power oscillator provides both the timing information for the signal modulator and drives transformer T2 for the output side power supplies. The secondary winding of T2 is full wave rectified and filtered to create the output side power.

The input stage is configured as an inverting amplifier with three user supplied resistors for gain, offset and feedback. The conditioned signal is modulated to generate a square wave with a peak-to-peak amplitude proportional to V_{IN}. This signal drives the signal transformer T1. An internal reference with a nominal output voltage of +6.4V and tempco of ±20ppm/°C is provided to develop a 4mA offset for 4mA to 20mA current loop applications.

After passing through signal transformer T1, the amplitude modulated signal is demodulated and filtered by a single pole filter. Timing information for the output side is derived from the power transformer T2. The filtered output provides the control signal for the voltage-to-current converter stage. An external power supply is required in series with the load to complete the current loop.

USING THE 1B21

Input Configurations: The 1B21 has been designed with a flexible input stage for a variety of input and output ranges. The basic interconnection for setting gain and offset is shown in Figure 1. The output of the internal amplifier is constrained to 0 to −5V, which maps into 0 to 20mA across the isolation barrier. Thus to create a 4mA offset at the output, the input amplifier has to be offset by 1V.

For example, for 0 to 20mA operation the transfer function for the input stage is:

$$5/V_{IN} = R_F/R_I$$

and no offset resistor is needed. For 4mA to 20mA operation we get:

$$4/V_{IN} = R_F/R_I$$

which maps the input voltage into a 4V span. To create a 1V offset at the output of the internal amplifier (4mA at the output of the 1B21) a current derived from the reference can be fed into the summing node. The offset resistor (for a 1V output offset) will be given by the equation: $R_O = 6.4R_F$. For most applications it is recommended that R_F be in the 25kΩ ±20% range. Resistor values for typical input and output ranges are shown in Table I.

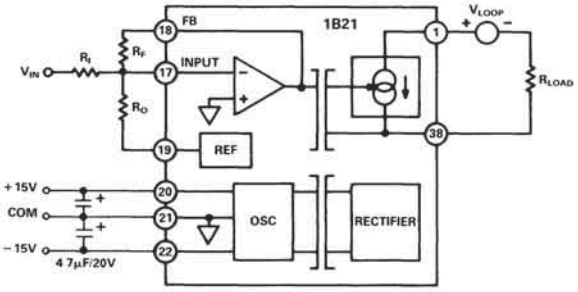


Figure 1. Basic Interconnections

Input Volts	Output mA	R_I kΩ	R_F kΩ	R_O kΩ
0-5	0-20	25	25	Open
0-10	0-20	50	25	Open
0-5	4-20	25	20	128
0-10	4-20	50	20	128
1-5	4-20	25	25	Open

Table I. Resistor Values for Typical Ranges

Adjustments: Figure 2 is an example of using potentiometers for trimming gain and offset for a 0-5V input and 0 to 20mA output. The network for offset adjustment keeps the resistors relatively small to minimize noise effects while giving a sensitivity of ±1% of span. For more adjustment range, resistors smaller than 274k can be used. Resistor values from Table I can be substituted for other input and output ranges.

In general, any bipolar voltage can be input to the 1B21 as long as it is offset to meet the 0 to −5V constraint of the modulator and the input signal range is 1V minimum.

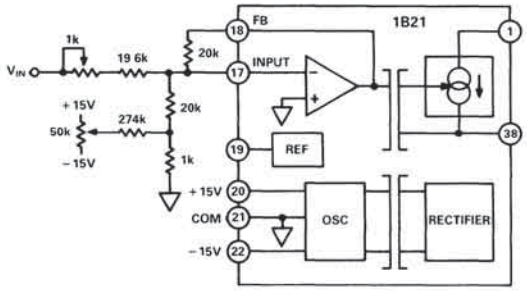


Figure 2. Offset and Span Adjustment

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TC Considerations of External Resistors: The specifications for gain and offset temperature coefficient (TC) for the 1B21 exclude the effects of external components. The total gain TC for the circuit in Figure 1 is:

Gain TC = 1B21 Gain TC + (Tracking TC of R_F and R_I)

The offset TC is also affected by the thermal stability of the internal voltage reference and its contribution is:

Ref TC = $(V_{REF})(R_F/R_O)(4mA/V)$(TC of V_{REF} + Tracking TC of R_F and R_O)$/1\times10^6$

Total Offset TC = 1B21 Offset TC + Ref TC

Specifically using R_F, R_I and R_O from Case 3 in Table I, with absolute TCs of ±25ppm/°C we get:

Gain TC = 50 + (25+25) = 100ppm/°C

Offset TC = $300+(6.4V)(20k/128k)(4mA/V)(20+25+25)/1\times10^6$

= ±580nA/°C

Similarly, when using a resistor network with a tracking spec of ±5ppm/°C, the total gain TC would be ±55ppm/°C and the total offset TC would be ±400nA/°C.

APPLICATIONS

Output Protection: In many industrial applications it may be necessary to protect the current output from accidental shorts to ac line voltages in addition to high common-mode voltages and short circuits to ground. The circuit shown in Figure 3 can be used for this purpose. The maximum permissible load resistance will be lowered by the fuse resistance (typically 8Ω) when protection circuitry is utilized.

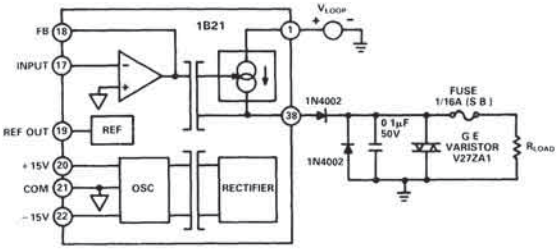


Figure 3. Output Protection Circuitry

Low Drift Input Network: Figure 4 shows a configuration suitable for applications where errors have to be minimized over a wide temperature range. A temperature tracking network such as a 50k Beckman (PN 698-3R50KD) can be used to implement both offset and gain for either 0 to 20mA or 4mA to 20mA current loops. For 0-10V signals either IN1 or IN2 can be used for input. For 0-5V signals, jumper IN1 to IN2. Similarly, for 4mA to 20mA operation the 4mA node should be jumpered to OFFSET, while for 0 to 20mA it should be tied to COM.

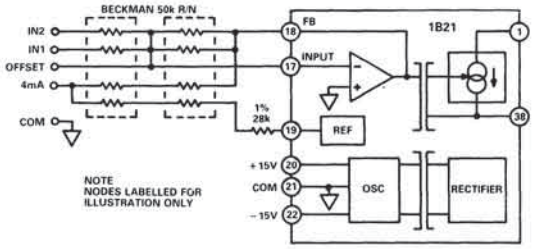


Figure 4. Low Tempco Resistor Network Configuration

Multiloop Isolation: Multiple 1B21s can be connected to a single loop supply in parallel as shown in Figure 5. The amperage of the loop supply should be sufficient to drive all the loops at full-scale output.

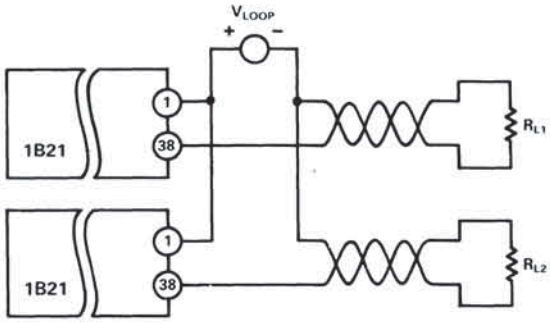


Figure 5. Multiple IB21s with Single Loop Supply

Programmable, Isolated Voltage-to-Current Converter

1B22

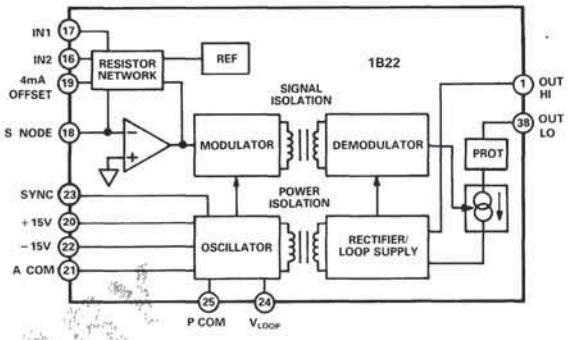
FEATURES

- Internal Isolated Loop Supply Drives 1000Ω Load
- Pin Programmable Inputs: 0-5V or 0-10V
- Pin Programmable Outputs: 4-20mA or 0-20mA
- High CMV Isolation: 1500V rms
- Normal-Mode Output Protection: 240V rms
- Wide Input Range: 0-1V to 0-10V
- High Accuracy
  - Low Input Offset Tempco: ±300nA/°C
  - Low Gain Tempco: ±50ppm/°C
  - Low Nonlinearity: ±0.02%
  - High CMR: 90dB min
- Small Package: 1.0″ × 2.1″ × 0.35″
- Meets IEEE Std 472: Transient Protection (SWC)

APPLICATIONS

- Multichannel Process Control
- D/A Converter – Current Loop Interface
- Analog Transmitters and Controllers
- Remote Data Acquisition Systems

1B22 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The 1B22 is an isolated voltage-to-current converter that incorporates transformer isolation to achieve high performance and automated surface mount manufacturing for lower cost and increased reliability. Designed for industrial applications, it is especially suited for harsh environments with extremely high common-mode interference. With programmable inputs and outputs, the 1B22 provides an unbeatable combination of versatility and performance in a compact plastic package.

Functionally, the V/I converter consists of four basic sections: input conditioning, modulator/demodulator, isolated loop supply and current source (Figure 1). The input is pin programmable for 0-5V or 0-10V inputs and 0-20mA or 4-20mA outputs using an internal resistor network. It can also be set by an external resistor to accept 0-1V to 0-10V voltage inputs. Transformer coupling provides 1500V rms galvanic isolation between the inputs and the current loop. Nonlinearity is an excellent ±0.05% max.

Loop power is generated internally through a dc/dc converter and is also isolated from the input side (1500V rms). Loop compliance voltage is dependent on the voltage supplied to the 1B22, and with V_{LOOP} = 28V, it is sufficient to drive a 1000Ω load.

The 1B22 is fully specified over −25°C to +85°C and operates over the industrial (−40°C to +85°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

Isolated Loop Power: Internal loop supply completely isolates the loop from the input terminals (1500V rms) and provides the capability to drive 0 to 1000Ω loads. This eliminates the need for an external dc/dc converter.

Ease of Use: The 1B22 offers complete isolated voltage-to-current conversion with minimum external parts required to get a conditioned current signal. No external buffers or drivers are required.

High CMV Isolation: The 1B22 features high input to output galvanic isolation to eliminate ground loops and offer protection against damage from transients and fault voltages. The isolation barrier will withstand continuous CMV of 1500V rms and meets the IEEE Standard for Transient Voltage Protection (Std. 472-SWC).

Small Size: The 1B22 package size (1.0″ × 2.1″ DIP) makes it an excellent choice in multichannel systems for maximum channel density. The 0.35″ height also facilitates applications with limited board clearance.

SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwise noted)

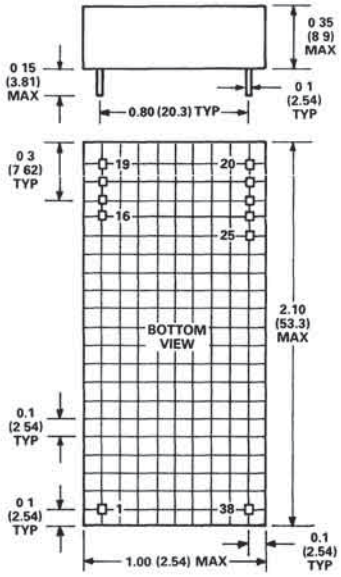
Model	1B22AN
INPUT SPECIFICATIONS	
Factory Calibrated, User Selectable	0 to +5V, 0 to +10V
Input Impedance	
0-10V input range	50kΩ
0-5V input range	25kΩ
OUTPUT SPECIFICATIONS	
Current Output Range, User Selectable	4 to 20mA, 0 to 20mA
Load Compliance Range, V_{LOOP} = +15V	8V min
V_{LOOP} = +28V	22V min
Maximum Output Current @ Input Overload	25mA
Output Noise, 100Hz Bandwidth	1μA p-p
NONLINEARITY (% OF SPAN)	±0.02% (0.05% max)
ISOLATION	
CMV, Input to Output Continuous	1500V rms
CMR, @ 60Hz	90dB min
Normal-Mode Output Protection	240V rms continuous
Transient Protection	IEEE - STD 472 (SWC)
ACCURACY	
Warm-Up Time to Rated Performance	5 min
Total Output Error @ +25°C	
Offset (V_{IN} = 0V)	±100μA
Span (V_{IN} = +10V)	±0.6% Full Scale max
vs. Temperature (−25°C to +85°C)	
Offset	±300nA/°C
Span	±50ppm/°C
DYNAMIC RESPONSE	
Settling Time to 0.1% of F.S. for 10V Step	TBD
Small Signal Bandwidth	400Hz
POWER SUPPLY	
Bipolar Input Supplies	
Operating Voltage	±15V ±5%
Quiescent Current	±7.5mA
Power Supply Rejection	±0.001%/V
Loop Supply	
Operating Voltage	+14V to +30V
Operating Current, at Full-Scale Output	30mA
ENVIRONMENTAL	
Temperature Range	
Rated Performance	−25°C to +85°C
Operating	−40°C to +85°C
Storage	−40°C to +85°C
Relative Humidity, Noncondensing	0 to 95% @ 60°C
CASE SIZE	1.0" × 2.1" × 0.35"

NOTE
Specifications subject to change without notice.

PRELIMINARY TECHNICAL DATA

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



PIN DESIGNATIONS

PIN	FUNCTION
1	OUT HI
16	IN2
17	IN1
18	S. NODE
19	4mA OFFSET
20	+15V
21	ANA COM
22	−15V
23	SYNC
24	V_{LOOP}
25	POWER COM
38	OUT LOW

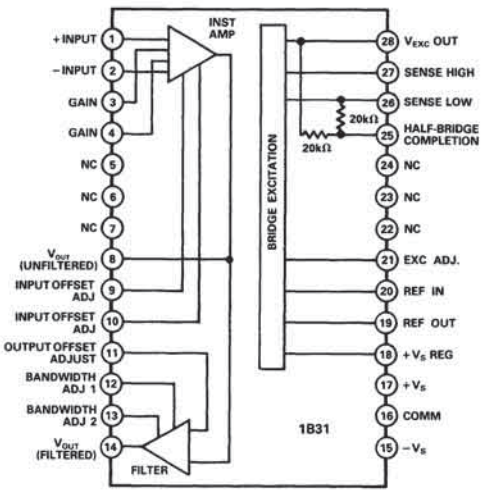
Wide Bandwidth Strain Gage Signal Conditioner

1B31

FEATURES
- **Low Cost**
- **Complete Signal-Conditioning Solution**
- **Small Package: 28-Pin Double DIP**
- **Internal Half-Bridge Completion Resistors**
- **Remote Sensing**
- **High Accuracy**
  - **Low Drift: ±0.25μV/°C**
  - **Low Noise: 0.3μV p-p**
  - **Low Nonlinearity: ±0.005% max**
  - **High CMR: 140dB min (60Hz, G = 1000V/V)**
- **Programmable Bridge Excitation: +4V to +15V**
- **Adjustable Low Pass Filter: f_C = 10Hz to 20kHz**

APPLICATIONS
- **Measurement of: Strain, Torque, Force, Pressure**
- **Instrumentation: Indicators, Recorders, Controllers**
- **Data Acquisition Systems**
- **Microcomputer Analog I/O**

1B31 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Model 1B31 is a high performance strain gage signal-conditioning component that offers the industry's best price/performance solution for applications involving high-accuracy interface to strain gage transducers and load cells. Packaged in a 28-pin double DIP using hybrid technology, the 1B31 is a compact and highly reliable product. Functionally, the signal conditioner consists of three sections: a precision instrumentation amplifier, a two-pole low pass filter, and an adjustable transducer excitation.

The instrumentation amplifier (IA) section features low input offset drift of ±0.25μV/°C (RTI, G = 1000V/V) and excellent nonlinearity of ±0.005% max. In addition, the IA exhibits low noise of 0.3μV p-p typ (0.1Hz-10Hz), and outstanding 140dB min common-mode rejection (G = 1000V/V, 60Hz). The gain is programmable from 2V/V up to 5000V/V by one external resistor.

The two-pole low pass filter offers a 40dB/decade roll-off from 1kHz to reduce high frequency noise and improve system signal-to-noise ratio. The corner frequency is adjustable downwards by external capacitors and upwards to 20kHz by three resistors. The output voltage can also be offset by ±10V with an external potentiometer to null out dead weight.

The 1B31's regulated transducer excitation stage features low output drift (±0.004%/°C typ) and can drive 120Ω or higher resistance load cells. The excitation is preset at +10V and is adjustable from +4V and +15V. This section also has remote sensing capability to allow for lead-wire compensation in 6-wire bridge configurations. For half-bridge strain gages, a matched pair of thin-film 20kΩ resistors is connected across the excitation outputs. This assures temperature tracking of ±5ppm/°C max and reduces part count.

The 1B31 is available in a plastic package specified over the industrial (–40°C to +85°C) temperature range and will be available soon in a bottom-brazed ceramic package specified over the military (–55°C to +125°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

Ease of Use: Direct transducer interface with minimum external parts required, convenient offset and span adjustment capability.

Half-Bridge Completion: Matched resistor pair tracking to ±5ppm/°C max for half-bridge strain gage applications.

Remote Sensing: Voltage drops across the excitation lead-wires are compensated by the regulated supply, making 6-wire load-cell interfacing straightforward.

Programmable Transducer Excitation: Excitation source preset for +10V dc operation without external components. User-programmable from a +4V to +15V dc to optimize transducer performance.

Adjustable Low Pass Filter: The two-pole active filter (f_C = 1kHz) reduces noise bandwidth and aliasing errors with provisions for external adjustment of cutoff frequency (10Hz to 20kHz).

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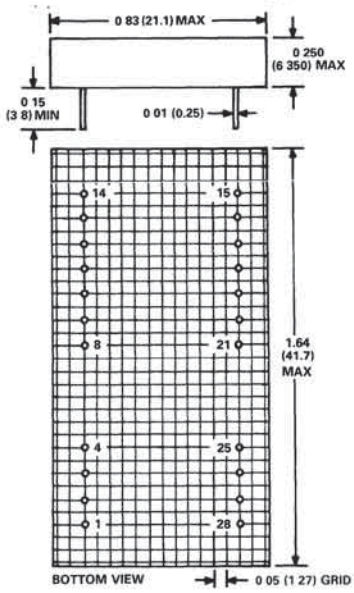
SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwise noted)

Model	1B31AN	1B31SD†
GAIN[1]		
Gain Range	2 to 5000V/V	*
Gain Equation	$R_G = \frac{80k\Omega}{G-2}$	*
Gain Equation Accuracy, G≤1000V/V	±3%	*
Gain Temperature Coefficient[2]	±15ppm/°C (±25ppm/°C max)	*
Nonlinearity	±0.005% max	*
OFFSET VOLTAGES[1]		
Total Offset Voltage, Referred to Input		
Initial, @ +25°C (Adjustable to Zero)		
G = 2V/V	±2mV (±10mV max)	*
G = 1000V/V	±50µV (±200µV max)	*
Warm-Up Drift, 5 min, G = 1000V/V	Within ±1µV of final value	*
vs. Temperature		
G = 2V/V	±25µV/°C (±50µV/°C max)	*
G = 1000V/V	±0.25µV/°C (±2µV/°C max)	*
At Other Gains	$\left(\pm 2 \pm \frac{100}{G}\right)\mu V/°C$	*
vs. Supply		
G = 2V/V	±50µV/V	*
G = 1000V/V	±0.5µV/V	*
Output Offset Adjust Range	±10V min	*
INPUT BIAS CURRENT		
Initial @25°C	±10nA (±50nA max)	*
vs. Temperature	±25pA/°C	*
INPUT DIFFERENCE CURRENT		
Initial @ +25°C	±5nA (±20nA max)	*
vs. Temperature	±10pA/°C	*
INPUT IMPEDANCE		
Differential	1GΩ‖4pF	*
Common Mode	1GΩ‖4pF	*
INPUT VOLTAGE RANGE		
Linear Differential Input (V_D)	±5V	*
Maximum CMV Input	$\pm\left(12 - \frac{G \times V_D}{4}\right)$ V max	*
CMR, 1kΩ Source Imbalance		
G = 2V/V, dc to 60Hz	86dB	*
G = 100V/V to 5000V/V		
1kHz Bandwidth[3]		
@ dc to 60Hz	110dB min	*
10Hz Bandwidth[4]		
@ dc	110dB min	*
@ 60Hz	140dB min	*
INPUT NOISE		
Voltage, G = 1000V/V		
0.1Hz to 10Hz	0.3µV p-p	*
10Hz to 100Hz	1µV p-p	*
Current, G = 1000V/V		
0.1Hz to 10Hz	60pA p-p	*
10Hz to 100Hz	100pA p-p	*
RATED OUTPUT[1]		
Voltage, 2kΩ Load, min	±10V	*
Current	±5mA	*
Impedance, dc to 2Hz, G = 2V/V to 1000V/V	0.5Ω	*
Load Capacitance	1000pF	*
Output Short-Circuit Duration	Indefinite	*
DYNAMIC RESPONSE[1]		
Small Signal Bandwidth −3dB, G = 2V/V to 1000V/V	1kHz	*
Slew Rate	0.05V/µs	*
Full Power	350Hz	*
Settling Time, G = 2V/V to 1000V/V, ±10V Output, Step to ±0.1%	2ms	*
LOW PASS FILTER		
Number of Poles	2	*
Gain (Pass Band)	−2V/V	*
Cutoff Frequency (−3dB Point)	1kHz	*
Roll-Off	40dB/decade	*

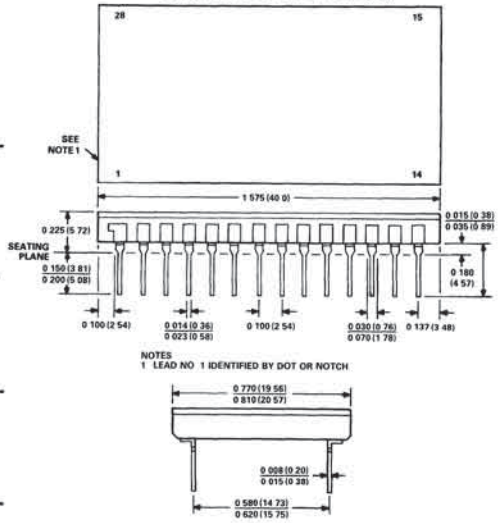
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

PLASTIC PACKAGE (N)



CERAMIC PACKAGE (D)



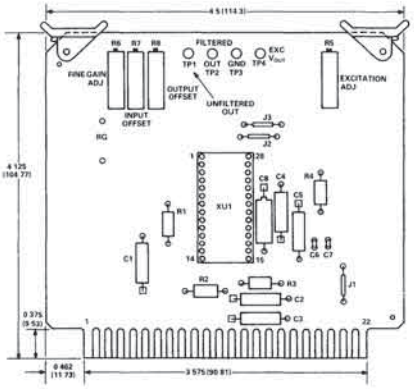
PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	+INPUT	15	$-V_S$
2	−INPUT	16	COMMON
3	GAIN	17	$+V_S$
4	GAIN	18	$+V_S$ REGULATOR
8	V_{OUT} (UNFILTERED)	19	REF OUT
9	INPUT OFFSET ADJ.	20	REF IN
10	INPUT OFFSET ADJ	21	EXCITATION ADJ.
11	OUTPUT OFFSET ADJ.	25	HALF-BRIDGE COMP.
12	BANDWIDTH ADJ 1	26	SENSE LOW
13	BANDWIDTH ADJ. 2	27	SENSE HIGH
14	V_{OUT} (FILTERED)	28	V_{EXC} OUT

Model	1B31AN	1B31SD†
BRIDGE EXCITATION		
Regulator Input Voltage Range	+9.5V to +28V	*
Output Voltage Range	+4V to +15V	*
Regulator Input/Output Voltage Differential	+3V to +24V	*
Output Current[5]	100mA max	*
Regulation, Output Voltage vs. Supply	±0.05%/V	*
Load Regulation, I_L = 1mA to 50mA	±0.1%	*
Output Voltage vs. Temperature	±0.004%/°C	*
Output Noise, 10Hz to 1kHz[6]	200µV p-p	*
Reference Voltage (Internal)	+6.8V ±5%	*
Internal Half-Bridge Completion		
Nominal Resistor Value	20kΩ ±1%	*
Temperature Tracking	±5ppm/°C max	*
POWER SUPPLY		
Voltage, Rated Performance	±15V dc	*
Voltage, Operating	±12V to ±18V dc	*
Current, Quiescent[7]	+10mA	*
ENVIRONMENTAL		
Temperature Range		
Rated Performance	−40°C to +85°C	−55°C to +125°C
Operating	−40°C to +85°C	−55°C to +125°C
Storage	−40°C to +100°C	−65°C to +150°C
Relative Humidity	0 to 95% @ +60°C	*
CASE SIZE	0.83" × 1.64" × 0.25" (21.1 × 41.7 × 6.350mm) max	0.81" × 1.57" × 0.23" (20.6 × 40.0 × 5.72mm)

NOTES
*Specifications same as 1B31AN
†SD grade available in Spring 1988
[1]Specifications referred to the filtered output at Pin 14
[2]Exclusive of external gain setting resistor
[3]Unadjusted filter setting
[4]Filter cutoff frequency set with external capacitors
[5]Derate from +50°C as shown in Figure 14
[6]4.7µF capacitor from $V_{REF\ IN}$ (Pin 20) to COMM
[7]Excluding bridge excitation's current, and with no loading on the output
Specifications subject to change without notice

AC1222 MOUNTING CARD



AC1222 CONNECTOR DESIGNATION

PIN	FUNCTION	PIN	FUNCTION
1	+INPUT	S	V_{EXC} OUT
2	−INPUT	T	SENSE HIGH
3	N/C	U	SENSE LOW
4	GAIN (3)	V	HALF-BRIDGE COMP
5	GAIN (4)	X	REF OUT
6	V_{OUT} (UNFILTERED)	Y	REF IN
7	INPUT OFFSET ADJ (9)	Z	EXC ADJ
8	INPUT OFFSET ADJ (10)		
9	OUTPUT OFFSET ADJ		
10	BANDWIDTH ADJ 1		
11	BANDWIDTH ADJ 2		
12	V_{OUT} (FILTERED)		
19	$-V_S$		
20	COMMON		
21	$+V_S$		
22	$+V_S$ REG		

The AC1222 mounting card is available for the 1B31. The AC1222 is an edge connector card with a 28-pin socket for plugging in the 1B31. In addition, it has provisions for installing the gain resistor and adjusting the bridge excitation voltage and cutoff frequency. Adjustment potentiometers for offset, fine gain and excitation are also provided. The AC1222 comes with a Cinch 251-22-30-160 (or equivalent) edge connector

APPLICATIONS

The 1B31 can be interfaced easily and directly to a wide variety of transducers for precise measurement of strain, torque, force and pressure. For applications in harsh industrial environments, such characteristics as high CMR, low noise and excellent temperature stability make the 1B31 unsurpassed for use in indicators, recorders and controllers.

The combination of low cost, small size and high performance of the 1B31 allows the system designer to use one conditioner per channel. The advantages include significantly lower system noise and high resolution, and elimination of crosstalk and aliasing errors.

FUNCTIONAL DESCRIPTION

Model 1B31 is based on a two-stage amplifier design and an adjustable voltage regulator section, as shown in Figure 1. The front end is a low noise, low drift, instrumentation amplifier (IA) that is optimized to amplify low level transducer signals (from 2mV full scale) riding on high common-mode voltage (±9.5V). The gain of the IA is programmed by a single resistor (1V/V to 2500V/V) and the input offset nulled out by an external potentiometer across the offset adjust Pins 9 and 10. The inverted signal ($V_{-INPUT} - V_{+INPUT}$) is brought out to Pin 8 for applications such as vibration and torque testing where the unfiltered output is required.

The signal is also fed to an inverting Butterworth filter with a fixed gain of −2V/V. This two-pole filter is preset with a 1kHz

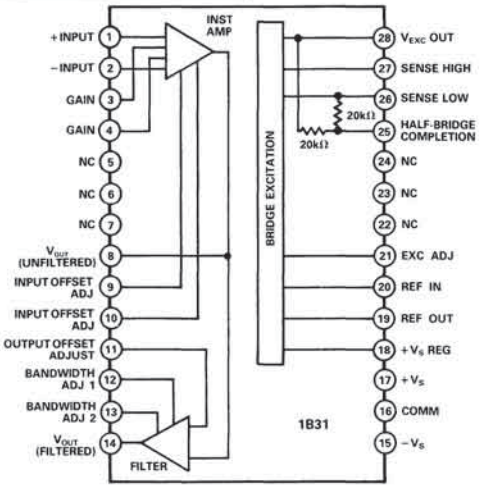


Figure 1. Block Diagram and Pinout

corner frequency which can be adjusted downwards to 10Hz by using two external capacitors or upwards to 20kHz by three resistors. This stage also provides a convenient means of adjusting output offset voltage (±10V) by connecting a 50kΩ potentiometer to Pin 11.

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The bridge excitation section is an adjustable output, regulated supply with an internally provided reference voltage (+6.8V). It is configured as a gain stage with the output preset at +10V. The excitation voltage is increased by connecting a resistor between Pins 21 and 26, and decreased by connecting a resistor between Pins 19 and 20. Sense lines are provided to compensate for lead-wire resistance by effectively bringing the leads into the feedback loop.

For half-bridge applications, two tracking thin-film resistors (20kΩ), ±5ppm/°C max) are connected from V_{EXC} OUT (Pin 28) to SENSE LOW (Pin 26).

OPERATING INSTRUCTIONS

Gain Setting: The differential gain, G, is determined by the equation:

$$G = 2 + \frac{80k\Omega}{R_G}$$

where R_G is connected between the GAIN terminals (Pins 3 and 4) of the IB31, as shown in Figure 2. For best performance, a low temperature coefficient (5ppm/°C) R_G is recommended. For fine span adjustment, a 50Ω potentiometer may be connected in series with R_G.

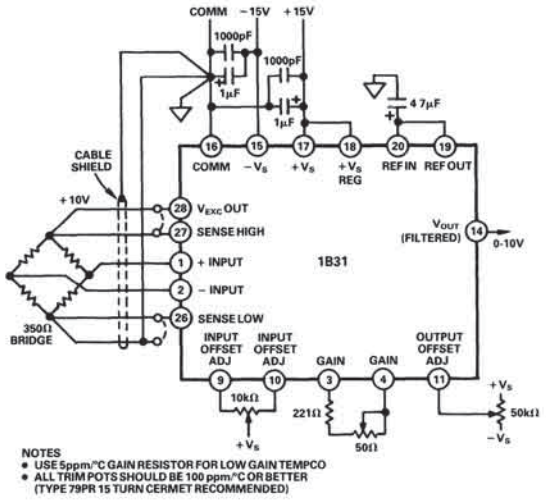


Figure 2. Typical Application

Input Offset Adjustment: To null input offset voltage, an optional 10kΩ potentiometer may be connected across the INPUT OFFSET ADJ. terminals (Pins 9 and 10 in Figure 2). With gain set at the desired value, connect both inputs (Pins 1 and 2) to COMMON (Pin 16), and adjust the 10kΩ potentiometer for zero volts at Pin 14. For applications using software nulling, Pins 9 and 10 should be left unconnected.

Output Offset Adjustment: The output can be offset over the ±10V range to compensate for dead load or bridge imbalance by using a 50kΩ potentiometer connected to Pin 11 as shown in Figure 2. Pin 11 is normally grounded if output offsetting is not desired.

Filter Cutoff Frequency Programming: The low pass filter cutoff frequency is internally set at 1kHz. It may be decreased from 1kHz by the addition of two external capacitors connected as shown in Figure 3 (from Pin 12 to common and between Pins 13 and 14). The values of capacitors required for a desired cutoff frequency, f_C, below 1kHz are obtained by the equations below:

$$C_{SEL1} = 0.015\mu F \left[\frac{1kHz}{f_C} - 1\right]$$

$$C_{SEL2} = 0.0022\mu F \left[\frac{1kHz}{f_C} - 1\right]$$

C_{SEL1} can be polarized for large values.

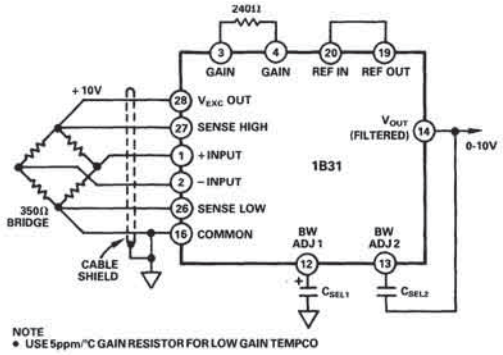


Figure 3. Narrow Bandwidth Application

The cutoff frequency may also be increased from 1kHz to 20kHz by the addition of three external resistors, connected as shown in Figure 4. The equations for determining the resistor values are:

$$R_{SEL1} = 20k\Omega / \left[\frac{f_C}{1kHz} - 1\right]$$

$$R_{SEL2} = 16k\Omega / \left[\frac{f_C}{1kHz} - 1\right]$$

$$R_{SEL3} = 40k\Omega / \left[\frac{f_C}{1kHz} - 1\right]$$

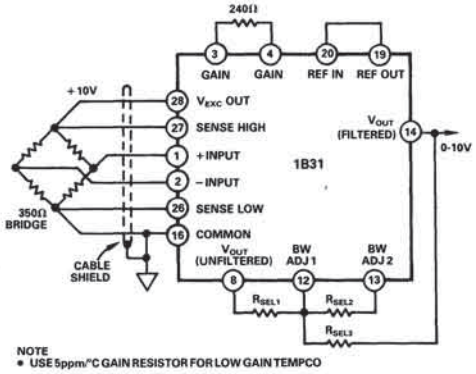


Figure 4. Wide Bandwidth Application

Table I gives the nearest resistor and capacitor values for several common filter cutoff frequencies.

f_C(Hz)	C_{SEL1}(μF)	C_{SEL2}(μF)	
10	1.5	0.2	
50	0.27	0.039	
100	0.15	0.02	
200	0.056	0.0082	
500	0.015	0.0022	
	R_{SEL1}(kΩ)	R_{SEL2}(kΩ)	R_{SEL3}(kΩ)
2000	20	16.2	40.2
5000	4.99	4.12	10.0
10000	2.21	1.78	4.42
20000	1.05	0.866	2.21

Table I. Filter Cutoff Frequency vs. R_{SEL} and C_{SEL}

Note: The 25MHz gain bandwidth product of the IA should be considered in high-gain, wide bandwidth configurations.

Voltage Excitation Programming: The excitation voltage is preset to +10V. To increase V_{EXC} up to +15V a resistor must be connected between EXC. ADJ. and SENSE LOW (Pins 21 and 26) as shown in Figure 5. For a desired V_{EXC} the resistor value, R_{EXT}, is determined by the following equations:

$$R_T = \frac{10k\Omega \times V_{REF\ OUT}}{V_{EXC} - V_{REF\ OUT}} \quad ; \quad V_{REF\ OUT} = +6.8V$$

$$R_{EXT} = \frac{20k\Omega \times R_T}{20k\Omega - R_T}$$

The +10V to +15V range can be covered by a 20kΩ potentiometer between the reference terminals.

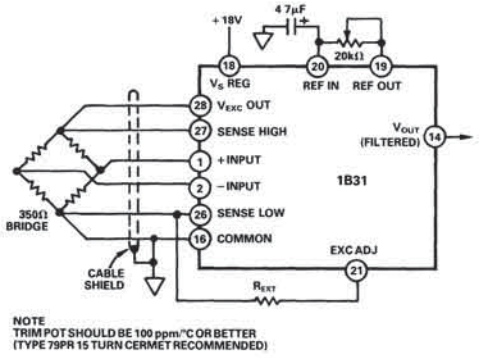


Figure 5. Constant Voltage Excitation: +10V to +15V Range

To decrease V_{EXC} down to +4V, a resistor has to be connected between REF IN and REF OUT (Pins 19 and 20) as shown in Figure 6. The equations to determine the value of R_{EXT} are:

$$V_{REF\ IN} = 0.68V_{EXC}$$

$$R_{EXT} = 10k\Omega \left[\frac{V_{REF\ OUT}}{V_{REF\ IN}} - 1 \right] ; \quad V_{REF\ OUT} = +6.8V$$

A 20kΩ potentiometer between the REF IN and REF OUT pins will span the +4V to +10V excitation range. A 4.7μF tantalum capacitor from REF IN (Pin 20) to COMMON (Pin 16) is recommended in all cases to lower the voltage noise at the reference input.

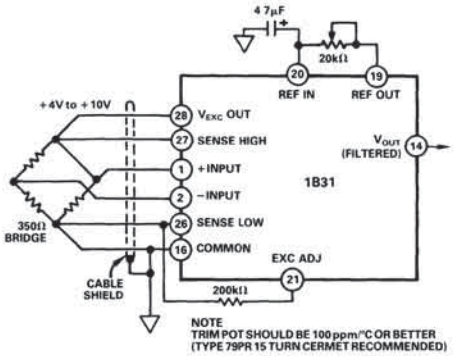


Figure 6. Constant Voltage Excitation: +4V to +10V Range

The remote sensing inputs should be connected to the transducer separately from the excitation leads or jumpered as shown in Figure 2.

Power Supply Decoupling: The power supplies should be decoupled with 1μF tantalum and 1000pF ceramic capacitors as close to the 1B31 as possible (Figure 2).

Input Protection: The differential inputs of the 1B31 can be protected from accidental shorts to power line voltages (115V rms) by the circuit shown in Figure 7. The back-to-back diodes clamp the inputs to a maximum of ±12.5V and were selected for low leakage current. The 15kΩ resistors in series with the inputs will degrade the noise performance of the 1B31 to 4.2μV p-p in a bandwidth of 0.1Hz to 1kHz. For six-wire load cells in harsh environments the additional protection for the sense inputs shown in Figure 7 is recommended.

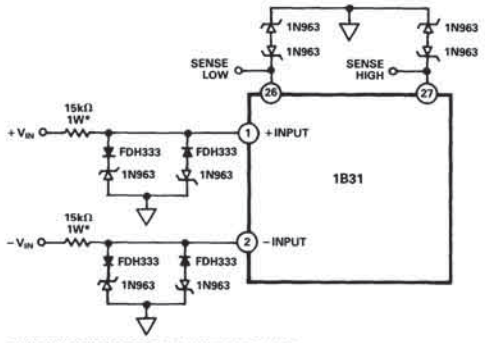


Figure 7. 115V Input Protection for 1B31

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PERFORMANCE CHARACTERISTICS

Input Offset Voltage Drift: Total offset voltage drift is composed of input and output drifts and is a function of gain. The 1B31 typically exhibits ±0.25μV/°C RTI drift at a gain of 1000V/V over the full temperature range. The RTI voltage offset drift vs. gain is graphed in Figure 8.

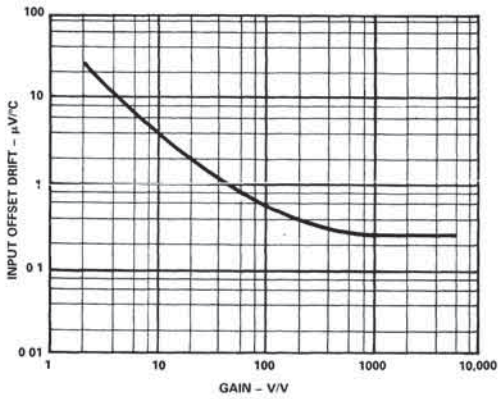


Figure 8. Total Input Offset Drift vs. Gain

Low Pass Filter: The two pole Butterworth filter is a multiple feedback design with a gain of −2V/V. It is preset at a cutoff frequency of 1kHz (−3dB) with a 40dB/decade roll-off. The step response at 1kHz is 1.5ms settling time to 0.1% of final value with less than 5% overshoot. The frequency response of the filter is shown graphically in Figure 9.

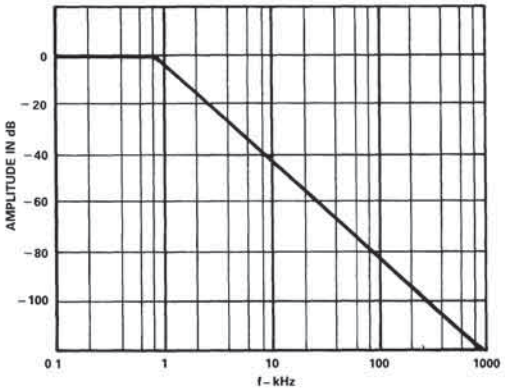
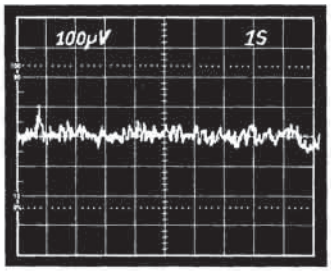
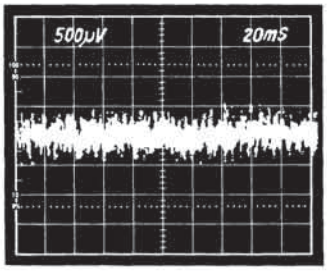


Figure 9. Filter Amplitude Response vs. Frequency

Gain Nonlinearity and Noise: Gain Nonlinearity is specified as a percent of full-scale output, and for the 1B31 it is ±0.005% maximum over the full-gain range. The IA design also offers exceptionally quiet performance with typical input noise of 0.3μV p-p for a 10Hz bandwidth (Figure 10a) and 1μV p-p for a 1kHz bandwidth (Figure 10b).



a. Bandwidth = 0.1Hz to 10Hz



b. Bandwidth = 0.1Hz to 1kHz

Figure 10. Voltage Noise, RTO @ G = 1000V/V

Common-Mode Rejection: CMR as a function of gain and frequency is shown in Figure 11. The best results (140dB @ 60Hz) are obtained by programming the low pass filter with a 10Hz cutoff frequency, which contributes an additional 30dB to the 1kHz specification where 60Hz noise is not attenuated by the filter.

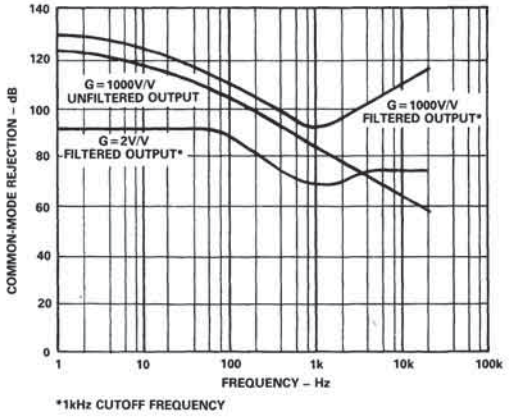


Figure 11. Common-Mode Rejection vs. Frequency and Gain

Turn On Drift: The input offset of the 1B31 stabilizes to within 1μV of final value in 5 minutes (Figure 12). The test conditions are: 350Ω bridge with +10V excitation and ambient temperature of +25°C.

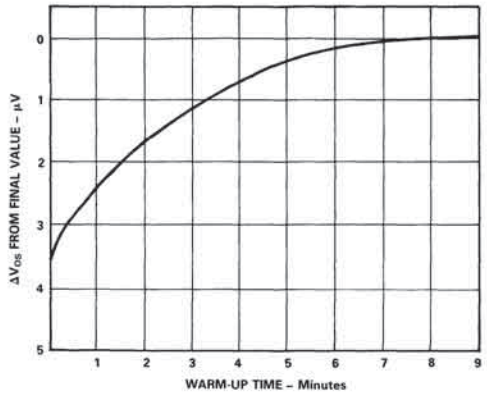


Figure 12. Offset Voltage, RTI, Turn-On Drift

Bridge Excitation: The adjustable bridge excitation is specified over a wide regulator input voltage range (+9.5V to +28V). Maximum load current I_L as a function of regulator input-output differential voltage is shown in Figure 13. The maximum output current also depends on ambient temperature and above 50°C a derating factor should be derived from Figure 14.

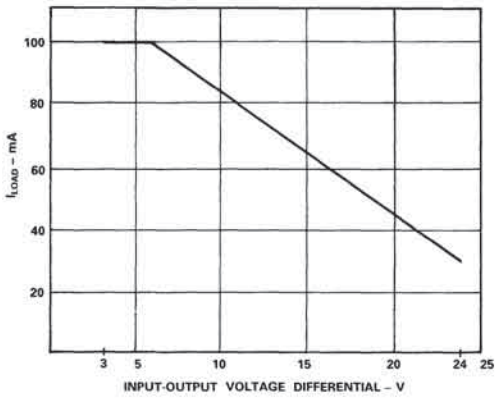


Figure 13. Excitation Source Input – Output Voltage Differential vs. Load Current; Ambient Temperature ≤25°C.

APPLYING THE 1B31

Strain Measurement: The 1B31 is shown in a strain measurement system in Figure 15. A single active gage (120Ω, Gage Factor = 2) is used in a bridge configuration to detect fractional changes in gage resistance caused by strain. An equivalent resistance

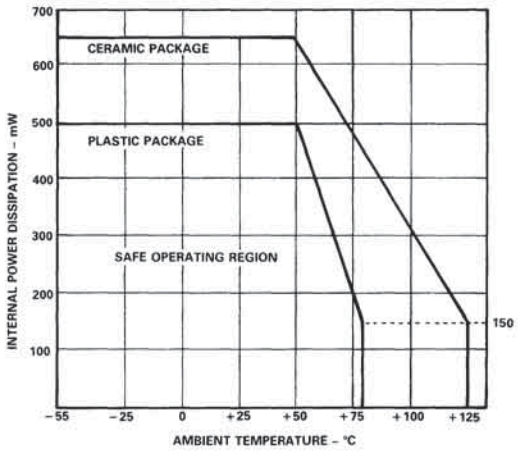


Figure 14. Excitation Source Internal Power Dissipation vs. Temperature

dummy gage mounted adjacent to the active gage provides temperature compensation. The rest of the bridge is completed by the 1B31 internal half-bridge network which consists of two 20kΩ, 1% thin-film resistors tracking to within ±5ppm/°C max. Bridge excitation is set at +4V to avoid self-heating errors from the strain gage. System calibration produces a +1V output for an input of 1000 microstrains. The filter cutoff frequency is set at approximately 100Hz.

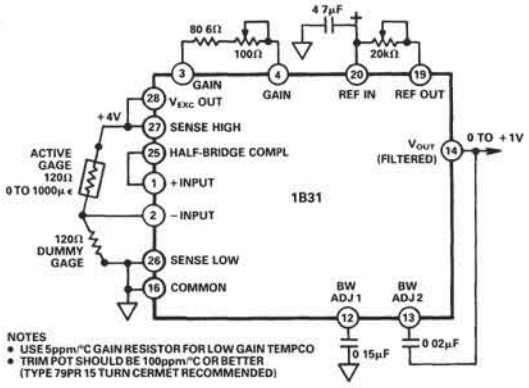


Figure 15. Strain Gage Application Using Internal Half-Bridge

Pressure Transducer Inferface: A strain gage type pressure transducer (Dynisco 800 series) is interfaced to a 1B31 in Figure 16. Regulated excitation of +10V dc is provided for a 30mV full-scale output. The gain is sett at 333.3 to achieve a 0-10V output for a 0-10,000 psi range of the transducer. A shunt calibration resistor is built into the transducer for easy verification of the 80% point of its full-scale output. A typical shielding scheme to preserve the excellent performance characteristics of the 1B31 is also shown. To avoid ground loops, signal return or cable shield should be grounded only at one point.

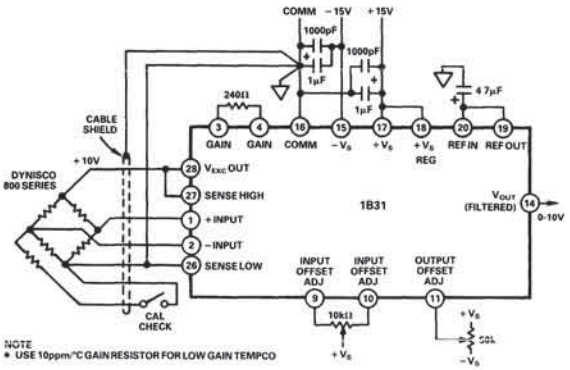


Figure 16. Pressure Transducer Application

Multiple Load-Cells: For transducer configurations where the maximum load current of 100mA of the 1B31 is not sufficient, a buffer and a power transistor such as a TIP31 can be used as shown in Figure 17. This design can supply 300mA at +10V excitation over the full industrial temperature range (−25°C to +85°C). In a multiple 1B31 system an added advantage is that ratiometric operation can be preserved by using one excitation source which also serves as the reference voltage for the system A/D converter.

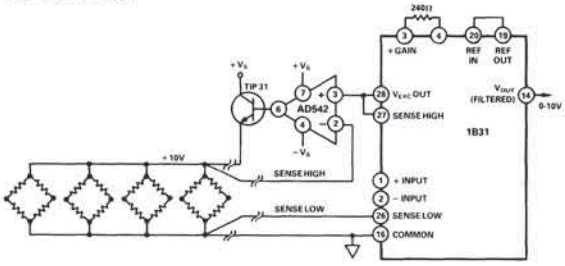


Figure 17. Multiple Load-Cell Application

Mobile Transducer Application: The small size and reliability of the 1B31 make it an ideal choice for mobile applications. Since the 1B31 requires a negative supply, one possible solution for its generation is shown in Figure 18. The positive voltage of a +12V battery is used to drive a CMOS TLC555 oscillator with a typical supply current of 360µA. The output is a square wave that is rectified by the diodes and filtered to provide a −9V supply. Excitation voltage should be equal to or less than +9V for adequate headroom for the 1B31 voltage regulator.

Pressure Transducer Data Acquisition System: Figure 19 shows a two module solution for microcomputer based data acquisition using a 1B31 and an AD1170 18-bit A/D converter. A 3mV/V pressure transducer (e.g. Dynisco 800 series) is interfaced to a 1B31 set up with a gain of 333.3 to give a 0 – 5V output. The regulated excitation is +5V, and for ratiometric operation it is also used as the voltage reference input for the AD1170. An initial ECAL command establishes the voltage excitation as the full-scale input of the AD1170 and periodic calibration cycles keep the converter tracking the reference input. This configuration yields very high CMR (168dB @ 60Hz) enhanced by the 1B31 low pass filter and the integrating conversion scheme of the

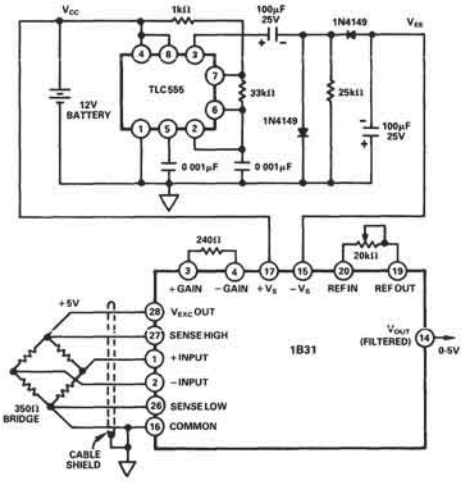


Figure 18. Negative Supply Generation for 1B31

AD1170. In addition, fixed offsets caused by bridge imbalance can be nulled out by the AD1170 with a power-up initialization command from the microcomputer. This eliminates a potentiometer or software overhead which might otherwise be needed.

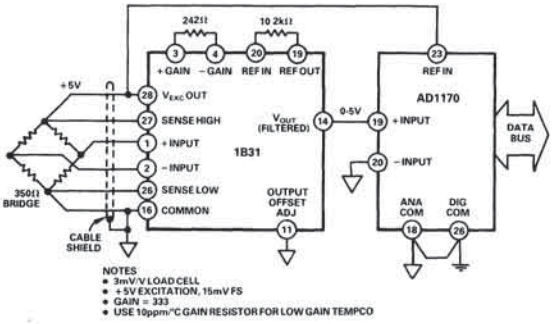


Figure 19. Pressure Transducer Data Acquisition Using 1B31 and AD1170

Isolated Current Loop Interface: The output of the 1B31 can be interfaced to a process loop as shown in Figure 20. The 2B23 module produces an isolated 4-to-20mA output current which is proportional to the input voltage and independent of the output load resistance. Common-mode input/output isolation is ±1500V pk continuous.

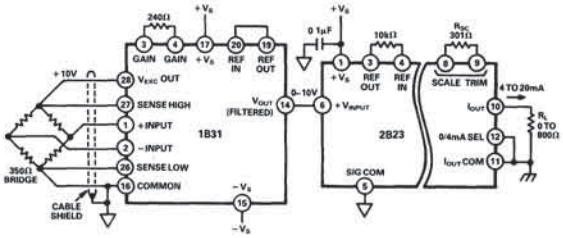


Figure 20. Isolated 4-20mA Transmitter

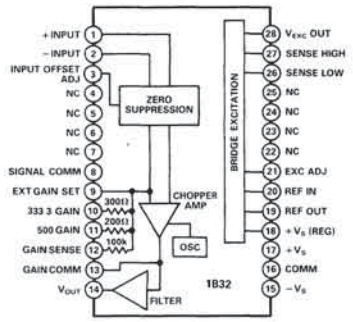
Bridge Transducer Signal Conditioner

1B32

FEATURES
- **Low Cost**
- **Complete Signal-Conditioning Solution**
- **Small Package: 28-Pin Double DIP**
- **Internal Thin-Film Gain Network**
- **High Accuracy**
  - **Low Input Offset Tempco: ±0.07μV/°C**
  - **Low Gain Tempco: ±2ppm/°C**
  - **Low Nonlinearity: ±0.005% max**
  - **High CMR: 140dB min (60Hz, G=1000V/V)**
- **Programmable Bridge Excitation: +4V to +15V**
- **Remote Sensing**
- **Low Pass Filter (f_C=4Hz)**

APPLICATIONS
- **Weigh Scales**
- **Instrumentation: Indicators, Recorders, Controllers**
- **Data Acquisition Systems**
- **Microcomputer Analog I/O**

1B32 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Model 1B32 is a precision, chopper-based, signal-conditioning component ideally suited for high-accuracy applications of load cells and bridge transducers. Packaged in a compact 28-pin plastic double DIP, the 1B32 takes advantage of hybrid technology for high reliability as well as higher channel density. Functionally, the signal conditioner consists of three basic parts: a high performance chopper-based amplifier, a low-pass filter and an adjustable transducer excitation source.

The chopper-based amplifier features extremely low input offset tempco of ±0.07μV/°C (RTI, G=500V/V) and excellent nonlinearity of ±0.005% max over its full gain range of 100 to 5000V/V. The 1B32 has a thin-film resistor network for pin-strapping the gain to 500V/V or 333.3V/V (for 2mV/V and 3mV/V load cells). The gain tempco for these fixed gains is a highly stable ±2ppm/°C. Additionally, the gain can be set to any value in the gain range with two external resistors. The amplifier also has a wide-range input referred zero suppression capability (±10V), which can easily be interfaced to a D/A converter. The bandwidth of the chopper is 4Hz at G=100V/V.

The integral three-pole, low-pass filter offers a 60dB/decade roll-off from 4Hz to reduce common-mode noise and improve system signal-to-noise ratio.

The 1B32's regulated transducer excitation stage features low output drift (±40ppm/°C typ) and can drive 120Ω or higher resistance load cells. The excitation is preset at +10V with other voltages between +4V and +15V programmable with external resistors. This section also has remote sensing capability to allow for lead-wire compensation in 6-wire load cells and other bridge configurations.

The 1B32 is fully specified over the industrial (–25°C to +85°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

Pin-Strappable Gain: The internal resistor network can be pin-strapped for gains of 500V/V and 333.3V/V for 2mV/V and 3mV/V load cells. The tracking network guarantees a gain tempco of ±6ppm/°C max.

Custom Trimmable Network: For volume applications, the 1B32 can be supplied with a custom laser trimmed gain network. Contact factory for further information.

Wide Range Zero Suppression: The output can be offset by ±10V for nulling out a dead load or to do a tare adjustment.

Remote Sensing: Voltage drops across the excitation lead-wires are compensated by the regulated supply, making 6-wire load-cell interfacing straightforward.

Programmable Transducer Excitation: The excitation source is preset for +10V dc operation without external components. It is user-programmable for a +4V to +15V dc range (@ 100mA) to optimize transducer performance.

Low-Pass Filter: The three-pole active filter (f_C=4Hz) reduces 60Hz line noise and improves system signal-to-noise ratio.

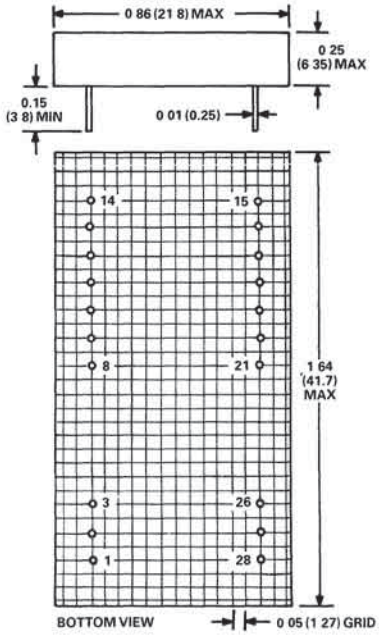
SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwise noted)

Model	1B32AN
GAIN	
Gain Range	100V/V to 5000V/V
Internal Gain Setting	333.3V/V and 500V/V
Gain Equation	$1 + \frac{R_F}{R_I}$
Gain Equation Accuracy[1]	±0.1%
Gain Temperature Coefficient[2]	±2ppm/°C (±6ppm/°C max)
Gain Nonlinearity	±0.005% max
OFFSET VOLTAGES	
Total Offset Voltage, RTI	
Initial, @ +25°C, G = 1000V/V	±40µV
Warm-Up Drift, G = 1000V/V, 10 min	Within ±1µV
vs. Temperature (−25°C to +85°C)	
G = 1000V/V	±0.07µV/°C (±0.2µV/°C max)
At Other Gains	$\pm\left(0.06 + \frac{15}{G}\right)$µV/°C
Output Offset Adjust Range	±10V
INPUT BIAS CURRENT	
Initial @25°C	±3nA
vs. Temperature (−25°C to +85°C)	±50pA/°C
INPUT DIFFERENCE CURRENT	
Initial @ +25°C	±3nA
vs. Temperature (−25°C to +85°C)	±10pA/°C
INPUT RESISTANCE	
Differential	100MΩ
Common Mode	100MΩ
INPUT VOLTAGE RANGE	
Linear Differential Input	±0.1V
Maximum Differential Input	+5V
CMV Input Range	0 to +7.5V
CMR, 1kΩ Source Imbalance[3]	
G = 100V/V to 5000V/V @ dc	86dB
G = 100V/V, @ 60Hz	120dB
G = 1000V/V, @ 60Hz	140dB min
INPUT NOISE	
Voltage, G = 1000V/V	
0.1Hz to 10Hz	1µV p-p
Current, G = 1000V/V	
0.1Hz to 10Hz	3pA p-p
RATED OUTPUT	
Voltage, 2kΩLoad, min	±10V
Current	±5mA
Impedance, dc to 2Hz, G = 100V/V	0.6Ω
Load Capacitance	500pF
Output Short Circuit Duration (to Ground)	Indefinite
DYNAMIC RESPONSE	
Small Signal Bandwidth	
−3dB Gain Accuracy, G = 100V/V	4Hz
G = 1000V/V	3.5Hz
Slew Rate	20V/sec
Full Power	0.5Hz
Settling Time, G = 100V/V, ±10V Output Step to ±0.1%	2sec
LOW PASS FILTER	
Number of Poles	3
Cutoff Frequency (−3dB Point)	4Hz
Roll-Off	60dB/decade

(Continued on next page)

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



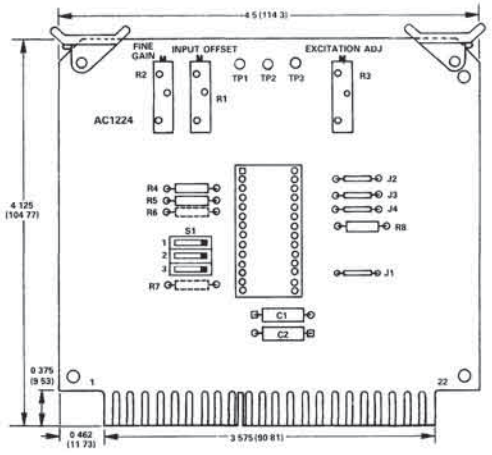
PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	+INPUT	15	$-V_S$
2	−INPUT	16	COMM
3	INPUT OFFSET ADJ	17	$+V_S$
4	NC	18	$+V_S$ REG
5	NC	19	REF OUT
6	NC	20	REF IN
7	NC	21	EXC ADJ
8	SIGNAL COMM	22	NC
9	EXT GAIN SET	23	NC
10	333.3 GAIN	24	NC
11	500 GAIN	25	NC
12	GAIN SENSE	26	SENSE LOW
13	GAIN COMM	27	SENSE HIGH
14	V_{OUT}	28	V_{EXC} OUT

Model	1B32AN
BRIDGE EXCITATION	
Regulator Input Voltage Range	+9.5V to +28V
Output Voltage Range	+4V to +15V
Regulator Input/Output Voltage Differential	+3V to +24V
Output Current[4]	100mA max
Regulation, Output Voltage vs. Supply	±0.05%/V
Load Regulation, I_L = 1mA to 50mA	±0.1%
Output Voltage vs. Temperature (−25°C to +85°C)	±40ppm/°C
Output Noise, 0.1Hz to 10Hz[5]	300μV p-p
Reference Voltage (Internal)	+6.8V ±5%
Sense & Excitation Lead Resistance	10Ω max
POWER SUPPLY	
Voltage, Rated Performance	±15V dc
Voltage, Operating	±12V to ±18V dc
Current, Quiescent[6]	+4mA, −1mA
ENVIRONMENTAL	
Temperature Range	
Rated Performance	−25°C to +85°C
Operating	−40°C to +85°C
Storage	−40°C to +100°C
Relative Humidity	0 to 95%, Noncondensing, @ +60°C
CASE SIZE	0.83" × 1.64" × 0.25" (21.1 × 41.7 × 6.35mm) max

NOTES
[1]Using internal network for gain.
[2]For pin-strapped gain. The tempco of the individual thin-film resistors is ±50ppm/°C max.
[3]3V p-p 60Hz common-mode signal used in test setup.
[4]Derate 2mA/°C from +50°C.
[5]4.7μF capacitor from REF IN (Pin 20) to COMM.
[6]Excluding bridge excitation current and with no loading on the output.
Specifications subject to change without notice.

AC1224 Mounting Card



AC1224 Connector Designation

PIN	FUNCTION	PIN	FUNCTION
T	V_{EXC} OUT	1	+INPUT
U	SENSE HIGH	2	−INPUT
V	SENSE LOW	12	V_{OUT}
X	REF OUT	19	$-V_S$
Y	REF IN	20	COMM
Z	EXC ADJ	21	$+V_S$
		22	$+V_S$ REG

The AC1224 mounting card is available for the 1B32. The AC1224 is an edge connector card with a socket for plugging in the 1B32. In addition it has provisions for switch selecting internal gains as well as installing gain resistors. Adjustment pots for offset, fine gain and excitation are also provided. The AC1224 comes with a Cinch 251-22-30-160 (or equivalent) edge connector.

11

FUNCTIONAL DESCRIPTION

Model 1B32 is based on a switched capacitor, chopper stabilized amplifier followed by an active filter and an adjustable voltage regulator section for excitation. The ultralow drift chopper samples the difference between the +INPUT and −INPUT at 190Hz. The signal is modulated, amplified and then demodulated. This stage introduces a pole with a 20dB/decade rolloff from 4Hz. The high-level signal is then filtered by a two-pole active filter with a 4Hz cutoff frequency to give a ±10V output. The clock signal for the chopper is generated by an on-board oscillator.

As shown in Figure 1, the gain can be pin-strapped by an internal resistor network. Standard gains of 333.3 and 500 can be achieved by this method with gain tempco of ±6ppm/°C max. Finally, the offset adjust of the amplifier is input referred, and requires a voltage input similar to the differential input voltage to implement wide range suppression.

The bridge excitation section is an adjustable ouput, regulated supply with an internally provided reference voltage (+6.8V). It is configured as a gain stage with the output preset at +10V. The excitation voltage is increased by connecting a resistor between Pins 19 and 20. Sense lines are provided to compensate for lead-wire resistance by bringing the leads into the feedback loop.

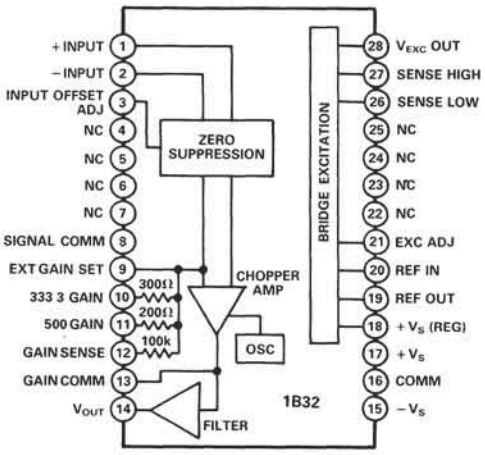


Figure 1. 1B32 Block Diagram and Pinout

OPERATING INSTRUCTIONS

Gain Setting: The differential gain of the 1B32 can be either pin-strapped or programmed externally with two resistors. The internal thin-film gain network (Figure 1) provides gains of 500 and 333.3 for standard load-cell sensitivities of 2mV/V and 3mV/V. This is achieved by connecting GAIN SENSE (Pin 12) to GAIN COMM (Pin 13) and grounding Pin 10 or Pin 11 (Figure 2). The gain tempco using the internal network is an excellent ±2ppm/°C typ (±6ppm/°C max).

To program the gain externally, two resistors are connected as shown in Figure 3. The gain equation is:

$$G = 1 + \frac{R_F}{R_I}$$

The gain-strapping Pins (11 and 12) and GAIN SENSE (Pin 12) are left unconnected, effectively floating the internal network.

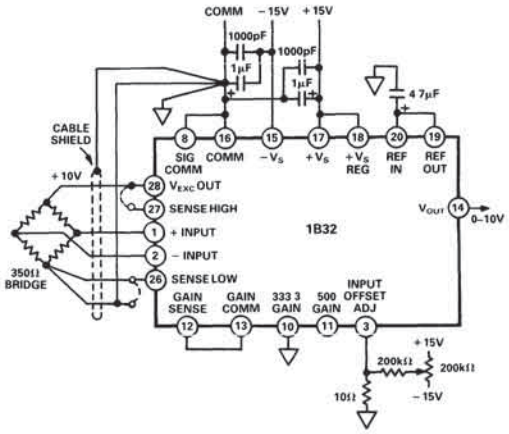


Figure 2. Internal Gain Strapping

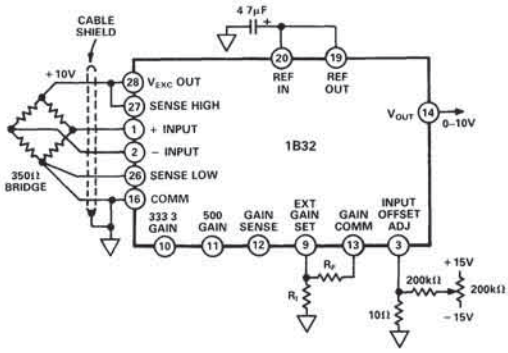


Figure 3. External Gain Setting

Offset Adjustment: The input-referred offset adjust has the same sensitivity as the inputs of the 1B32. The voltage level at INPUT OFFSET ADJ (Pin 3) is gained by the same factor as the input signal to provide a ±10V output adjust. Figure 2 shows an external network and potentiometer set up for a ±7.5mV span at the input, which gives a ±2.5V (7.5mV × 333.3) output adjust capability. Wider ranges can be chosen with the appropriate resistor and potentiometer values.

Note: If offset adjustment is not required, Pin 3 must be grounded.

Voltage Excitation Programming: The excitation voltage is preset to +10V. To increase V_{EXC} up to +15V a resistor must be connected between EXC ADJ and SENSE LOW (Pins 21 and 26) as shown in Figure 4.

The V_S (REG) input (Pin 18) must be raised to +18V to satisfy the +3V min input-output voltage differential of the regulator. Consult the Performance Characteristics section for safe operating conditions of the regulator. For a desired V_{EXC} the resistor value, R_{EXT}, is determined by the following equations:

$$R_T = \frac{10k\Omega \times V_{REF\,OUT}}{V_{EXC} - V_{REF\,OUT}} \quad ; \quad V_{REF\,OUT} = +6.8V$$

$$R_{EXT} = \frac{20k\Omega \times R_T}{20k\Omega - R_T}$$

The +10V to +15V range can be covered by a 20kΩ potentiometer between REF IN (Pin 20) and REF OUT (Pin 19). R_{EXT} of

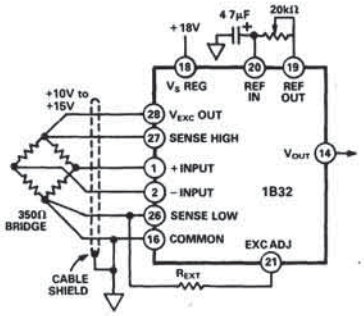


Figure 4. Constant Voltage Excitation: +10V to +15V Range.

200kΩ is recommended for fine adjustment at +10V excitation voltage.

Similarly to decrease V_{EXC} down to +4V, connect a 200kΩ resistor and a 20kΩ potentiometer between Pins 19 and 20, between SENSE LOW and EXC ADJ (Pins 26 and 21), as shown in Figure 5.

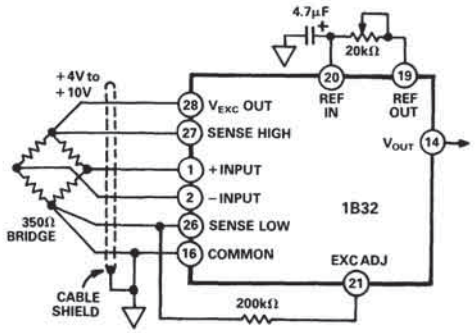


Figure 5. Constant Voltage Excitation: +4 to +10V Range

A 4.7μF tantalum capacitor from REF IN (Pin 20) to COMMON (16) is recommended in all cases to lower the voltage noise at the reference input.

The remote sensing inputs should be connected to the transducer separately from the excitation leads or jumpered as shown in Figure 2. The resistance of the excitation and sense lines should not exceed 10Ω.

Power Supply: The V_S REG input (Pin 18) should be connected to $+V_S$ (Pin 17) even if the bridge excitation section is not used. Also the power supplies should be decoupled with 1μF tantalum and 1000pF ceramic capacitors as close to the 1B32 as possible (Figure 2).

Input Protection: The 1B32 differential inputs can be protected from accidental shorts to power line voltages (115V rms) by the circuit shown in Figure 6. The back-to-back diodes clamp the inputs to a maximum of ±12.5V and were selected for low leakage current. The 15kΩ resistors in series with the inputs will degrade the noise performance of the 1B32 to 4μV p-p (0.1Hz to 10Hz). When interfacing with six-wire load cells in harsh environments, input protection for the sense inputs is also recommended (Figure 6).

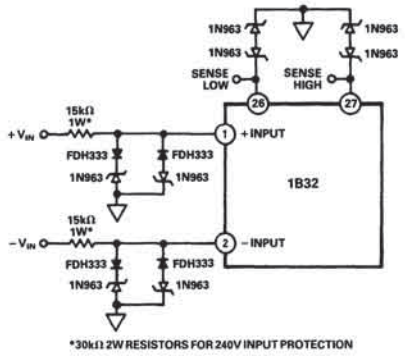


Figure 6. 115V Input Protection

PERFORMANCE CHARACTERISTICS

Input Offset Voltage Drift: The chopper front end of the 1B32 gives it excellent input offset stability. As shown in Figure 7, it typically exhibits drift of ±0.07μV/°C RTI at a gain of 1000V/V (±75μV/°C RTO). The measurement is two-point, and is taken at −25°C and +85°C, which covers the specified temperature range of the 1B32.

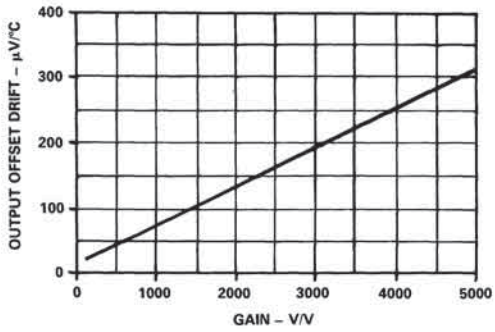


Figure 7. Total Output Offset Drift vs. Gain

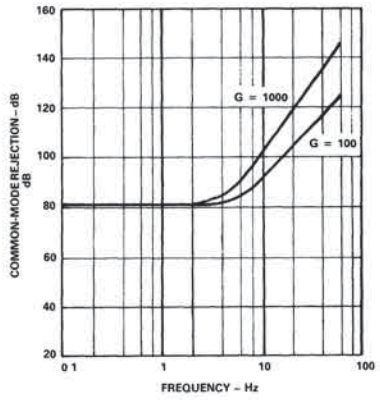


Figure 8. Common-Mode Rejection vs. Frequency

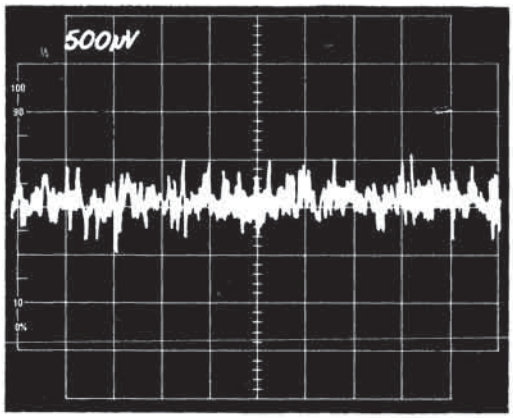


Figure 9. Voltage Noise, 0.1Hz to 10Hz, G = 1000

Common-Mode Rejection: CMR as a function of frequency is shown in Figure 8. Test conditions are a 3V p-p common-mode signal and 1kΩ source imbalance. The CMR improves with increasing gain. Note that the 4Hz filter enhances the CMR performance above the corner frequency by attenuating the normal-mode signal at 60dB/decade.

Gain Nonlinearity and Noise: Gain Nonlinearity is specified as a percent of full-scale output, and for the 1B32 it is ±0.005% max over the full span. The chopper design also offers exceptional low-noise performance, with typical input noise of 1μV p-p in the 0.1Hz to 10Hz bandwidth (Figure 9).

Low-Pass Filter: The 1B32 has three poles at 4Hz in its design. One is introduced in the amplifier, while the other two are provided by an active Butterworth filter following the amplifier. Total roll-off is 60dB/decade from 4Hz. The frequency response of the filter is shown in Figure 10.

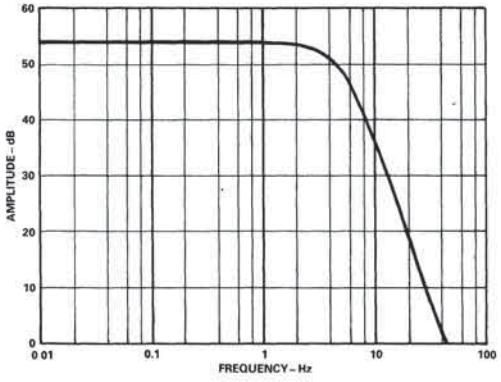


Figure 10. Filter Amplitude Response vs. Frequency, G = 500

Turn-On Drift: The 1B32 offset voltage stabilizes to within 1μV of its final value in 10 minutes (Figure 11). The test conditions are: 350Ω bridge with a +10V excitation and ambient temperature of +25°C.

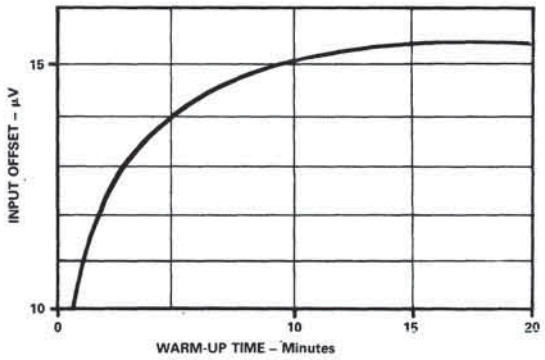


Figure 11. Offset voltage RTI, Turn-On Drift

Bridge Excitation: The adjustable bridge excitation is specified over a wide regulator input voltage range (+9.5V to +28V). Maximum load current I_L as a function of regulator input-output differential voltage is shown in Figure 12. The maximum output current also depends on ambient temperature, and above +50°C a derating factor of 2mA/°C must be applied. The safe operating region for internal power dissipation vs. temperature is graphed in Figure 13.

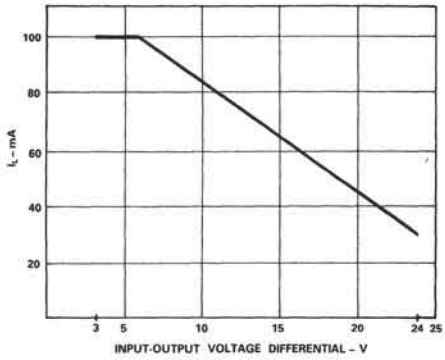


Figure 12. Excitation Source Load Current vs. Input-Output Voltage Differential, ≤25°C

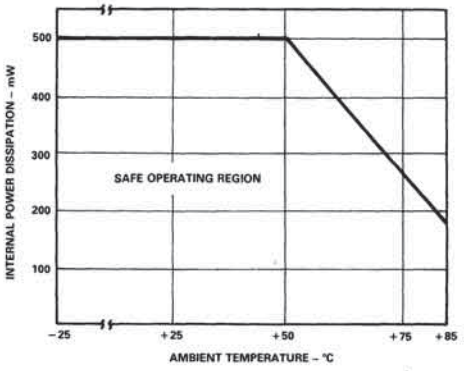


Figure 13. Excitation Source Internal Power Dissipation vs. Temperature

APPLYING THE 1B32

Pressure Transducer Interface: A strain gage type pressure transducer (Dynisco 800 series) is interfaced to a 1B32 in Figure 14. Regulated excitation of +10V dc is provided for a 30mV full-scale output for a 0-10,000 psi range of the transducer. A shunt calibration resistor is built into the transducer for easy verification of the 80% point of its full-scale output. A typical shielding scheme to preserve the excellent performance characteristics of the 1B32 is also shown. To avoid ground loops, signal return and cable shield should be grounded only at one point.

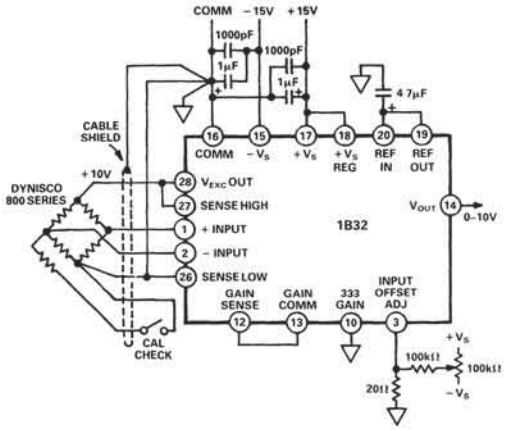


Figure 14. Pressure Transducer Interface

Pressure Transducer Data Acquisition System: A two module solution for microcomputer based data acquisition using a 1B32 and an AD1170 18-bit A/D converter is shown in Figure 15. A 3mV/V pressure transducer (e.g. Dynisco 800 series) is interfaced to a 1B32 configured with a gain of 333.3, to provide a 0 to 5V output. The regulated excitation is +5V, and is used as the reference input for the AD1170 to produce ratiometric operation. This configuration yields very high CMR enhanced by the 1B32 low pass filter and the integrating conversion scheme of the AD1170.

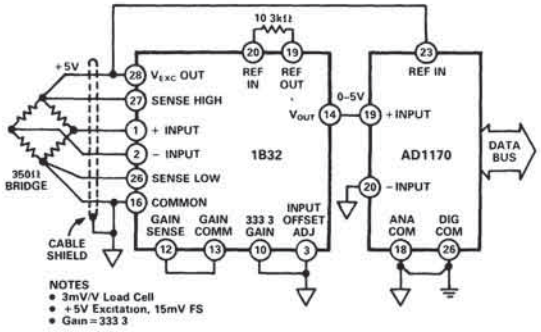


Figure 15. Auto-Calibrating Data Acquisition Using 1B32 and AD1170

In addition, fixed offsets caused by bridge imbalance can be nulled out by the AD1170 with a power-up initialization command from the microcomputer. The full-scale output of the 1B32 and transducer can be normalized to the AD1170 full scale through the electronic calibration command ECAL. Both the offset and full-scale correction data will then be stored in nonvolatile memory to eliminate the need for the trim process after each power-up. The AD1170 eliminates a potentiometer or software overhead which might otherwise be needed for these functions.

Multiple Load-Cells: For transducer configurations where the maximum load current of the 1B32 is not sufficient, a buffer and a power transistor such as a TIP31 can be used as shown in Figure 16. This approach will supply 300mA at +10V excitation over −25°C to +85°C temperature range. In a multiple 1B32 system an added advantage is that ratiometric operation can be preserved by using the excitation voltage as the reference for the system A/D converter.

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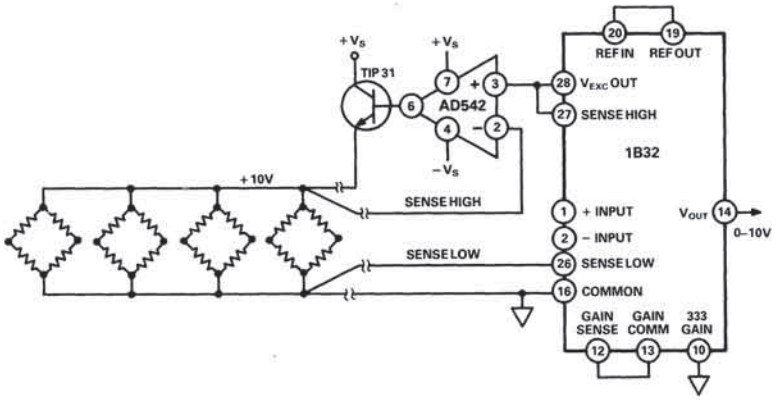


Figure 16. Multiple Load-Cell Application

Mobile Transducer Applications: The small size and reliability of the 1B32 make it an excellent choice for mobile applications. Since the 1B32 requires bipolar supplies, a possible circuit to provide the negative voltage is shown in Figure 17. The CMOS TLC555 is powered by a +12V battery, and typically draws 360μA. The output is a square wave that is rectified by the diodes and filtered to provide a −9V supply. Excitation voltage should be equal to or less than +9V for adequate headroom for the 1B32 voltage regulator. Note that the 1B32 will operate with ±9V supplies as long as the excitation voltage and the output range are less than 5V.

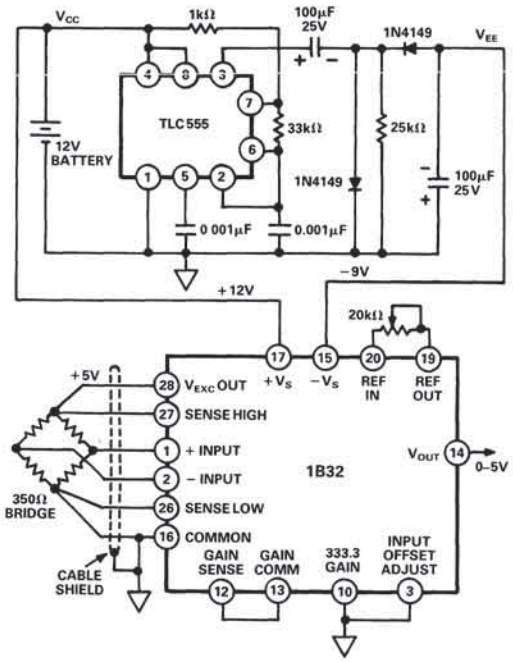


Figure 17. Negative Supply Generation for 1B32

Digital Output Offset Adjust: A 10-bit multiplying DAC such as the AD7533 can be used to control the output offset of the 1B32 as shown in Figure 18. The DAC is configured for unipolar operation with an AD OP-07 generating a voltage output. This 0-10V output is attenuated by R_1 and R_{SEL} and superposed on another fixed voltage derived from V_{EXC}. Thus the voltage at Pin 3 (INPUT OFFSET ADJUST) is insensitive to the tempco of the excitation voltage since it is also used as the reference of the DAC. For best performance R_1 and R_2 should track to ±5ppm/°C. As an example, a ±5V output adjustment can be obtained by using R_{SEL} = 200Ω for G = 500 and V_{EXC} = 10V.

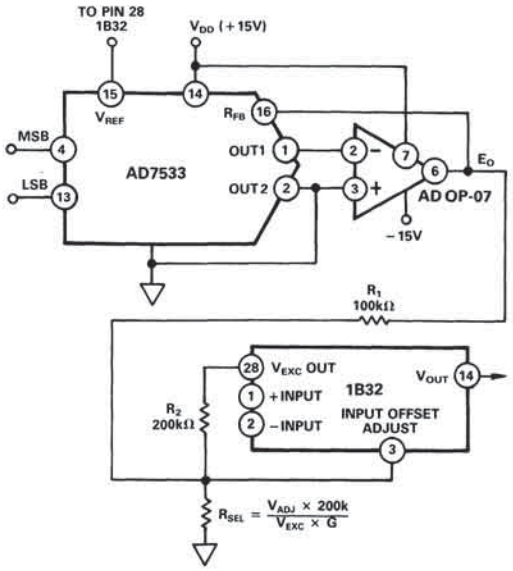


Figure 18. Output Offset Adjust Using a 10-Bit DAC

DIGITAL INPUT MSB LSB	ANALOG OUTPUT (E_O as shown in Figure 18)
1111111111	$-V_{REF}\left(\frac{1023}{1024}\right)$
1000000001	$-V_{REF}\left(\frac{513}{1024}\right)$
1000000000	$-V_{REF}\left(\frac{512}{1024}\right)=\frac{V_{REF}}{2}$
0111111111	$-V_{REF}\left(\frac{511}{1024}\right)$
0000000001	$-V_{REF}\left(\frac{1}{1024}\right)$
0000000000	$-V_{REF}\left(\frac{0}{1024}\right)=0$

Table I. Unipolar Binary Code Table

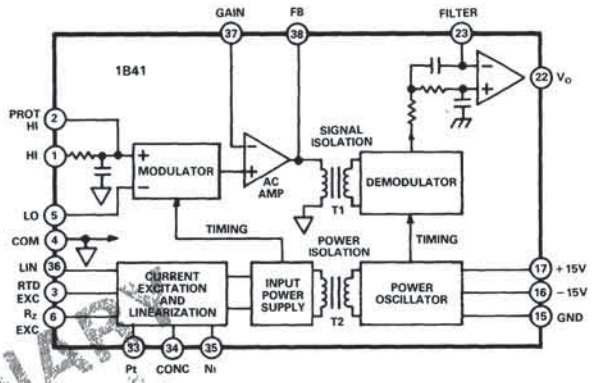
Isolated RTD Signal Conditioner

1B41

FEATURES
- Complete RTD Signal Conditioning Solution
- Resistor Programmable Linearization
- High CMV Isolation: 1500V rms Continuous
- High Accuracy
  - Low Input Offset Tempco: ±1V/C
  - Low Gain Tempco: ±50ppm/°C
  - Low Nonlinearity: ±0.01%
- High CMR: 160dB (60Hz, G=1000V/V)
- Small Package: 1.0″×2.1″×0.35″ DIP
- Low Pass Filter (f_C=3Hz)
- Pin Compatible with 1B51 Isolated mV/Thermocouple Conditioner

APPLICATIONS
- Multichannel RTD Temperature Measurement
- Industrial Measurement and Control Systems
- Data Acquisition Systems

1B41 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The 1B41 is a precision, isolated, RTD signal conditioner that incorporates a circuit design utilizing transformer based isolation and automated surface mount manufacturing technology. It provides an unbeatable combination of versatility and performance in a compact plastic package. Designed for measurement and control applications, it is especially suited for harsh environments with extremely high common-mode interference. Unlike expensive solutions that require separate dc/dc converters, each 1B41 generates its own floating current excitation, providing true low-cost channel-to-channel isolation.

Functionally, the signal conditioner consists of five basic sections: chopper stabilized amplifier, dc/dc converter, signal isolation, RTD current excitation and output filter. The amplifier section features user selectable gains from 10 to 1000 with a gain tempco of ±50ppm/°C. Wide-range zero suppression and low input offset drift of 1μV/°C are accomplished by chopper stabilization.

The isolation section has complete input to output galvanic isolation of 1500V rms continuous by the use of transformer coupling techniques. Nonlinearity is an excellent ±0.01% which meets the demands of 12-bit systems.

A stable sensor excitation provides 0.25mA for most RTD applications. For nickel and platinum RTDs the excitation is compensated to provide an output that is linear with temperature. The linearizing curvature can be set positive or negative by pin-strapping the 1B41. Filtering at 3Hz is implemented by a passive anti-aliasing filter at the input and a two-pole active filter at the output. Overall NMR is 60dB and CMR is 160dB min @ 60Hz.

The 1B41 is fully specified over −25°C to +85°C and operates over the industrial (−40°C to +85°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

Ease of Use: The IB41 has direct RTD interface with minimum external parts required to get a high-level, conditioned signal.

High Noise Rejection: The combination of a chopper stabilized front end with a low pass filter provides high system accuracy in harsh industrial environments as well as good rejection of 50/60Hz noise.

Small Size: The 1B41 package size (1.0″×2.1″× 0.35″) and functional completeness makes it an excellent choice in systems with limited board space and clearance.

Wide Range Zero Suppression: This input referred function is a convenient way to null large input offsets.

Low Pass Filter: The three-pole active filter (f_C=3Hz) reduces 50/60Hz noise and aliasing errors.

PRELIMINARY DATA

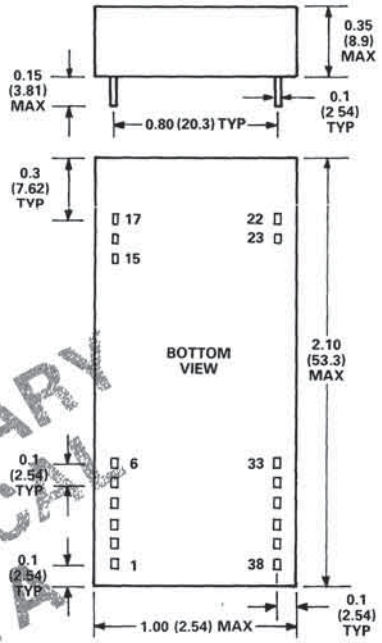
SPECIFICATIONS (typical @ +25°C and V_S = +15V unless otherwise noted)

Model	1B41AN
GAIN	
Gain Equation	$\left(1+\frac{R_{FB}}{R_G}\right)\times 4$
Gain Error	±1%
Gain Temperature Coefficient	±50ppm/°C
Gain Nonlinearity	±0.01% max
OFFSET VOLTAGES	
Total Offset Voltage, Referred to Input	
Initial, @ +25°C (Adjustable to Zero)	±500μV max
vs. Temperature	±1μV/°C
vs. Time, Noncumulative	±1μV/month max
Output Offset vs. Temperature	±20μV/°C
INPUT IMPEDANCE	
Power On	5MΩ
Power Off	39kΩ
INPUT VOLTAGE RANGE	
Linear Differential Input	±5mV to ±0.5V
Max CMV, Input to Output	
ac, 60Hz, Continuous	1500V rms
Continuous, dc	±2000V peak
CMR, @ 60Hz, 1kΩ Source Imbalance	160dB min
NMR @ 60Hz	60dB min
Transient Protection	IEEE-STD 472 (SWC)
INPUT NOISE	
Voltage, 0.1Hz to 10Hz, 1kΩ Source Imbalance	1μV p-p
INPUT BIAS CURRENT	
Initial @ +25°C	5pA
vs. Temperature	25pA/°C
RATED OUTPUT	
Voltage, 2kΩ Load, min[1]	±5V
Current	±5mA
Output Noise, dc to 100kHz	TBD
Impedance, dc	0.1Ω
DYNAMIC RESPONSE	
Bandwidth, −3dB	dc to 3Hz
LINEARIZATION	
Temperature Measurement Range	User Programmable
Linearizing Accuracy	
0 to 100°C, Pt 100Ω, a α = 0.00385	±0.05°C max
CURRENT EXCITATION	
Excitation Level	0.25mA
vs. Temperature	±70ppm/°C
POWER SUPPLY	
Voltage, Rated Performance	±15V dc
Voltage, Operating	+12V to +18V
Current, Quiescent	10mA
ENVIRONMENTAL	
Temperature Range	
Rated Performance	−25°C to +85°C
Operating	−40°C to +85°C
Storage	−40°C to +85°C
Relative Humidity	0 to 95% @ +60°C
CASE SIZE	1.0" × 2.1" × 0.35" (25.4 × 53.3 × 8.9)mm

NOTES
[1] ±10V output can be obtained by doubling the gain of the output stage.
Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



PIN DESIGNATIONS

PIN	DESIGNATION
1	HI
2	PROT HI
3	RTD EXC
4	COM
5	LO
6	R_Z EXC
15	GND
16	−15V
17	+15V
22	V_O
23	FILTER
33	PT
34	CONC
35	NI
36	LIN
37	G
38	FB

PRELIMINARY TECHNICAL DATA

Isolated mV/Thermocouple Signal Conditioner

1B51

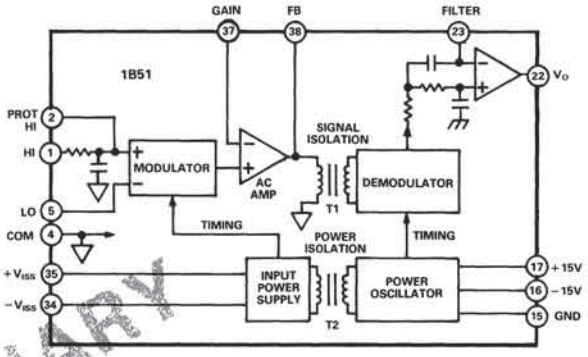
FEATURES

- **Functionally Complete Precision Conditioner**
- **High Accuracy**
  - **Low Input Offset Tempco: ±1μV/°C**
  - **Low Gain Tempco: ±50ppm/°C**
  - **Low Nonlinearity: ±0.01%**
  - **High CMR: 160dB (60Hz, G=1000V/V)**
- **High CMV Isolation: 1500V rms Continuous**
- **Small Package: 1.0″×2.1″×0.35″ DIP**
- **Isolated Power**
- **Low Pass Filter (f_C=3Hz)**
- **Pin Compatible with 1B41 Isolated RTD Conditioner**

APPLICATIONS

- **Multichannel Thermocouple Temperature Measurement**
- **Low Level Data Acquisition Systems**
- **Industrial Measurement & Control Systems**

1B51 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The 1B51 is a precision, mV/thermocouple signal conditioner that incorporates a circuit design utilizing transformer based isolation and automated surface mount manufacturing technology. It provides an unbeatable combination of versatility and performance in a compact plastic package. Designed for measurement and control applications, it is especially suited for harsh environments with extremely high common-mode interference. Unlike costlier solutions that require separate dc/dc converters, each 1B51 generates its own input side power, providing true low-cost channel-to-channel isolation.

Functionally, the signal conditioner consists of three basic sections: chopper stabilized amplifier, isolation and output filter. The chopper amplifier features a highly stable offset tempco of ±1μV/°C and resistor programmable gains from 10 to 1000. Wide range zero suppression can be implemented at this stage.

The isolation section has complete input to output galvanic isolation of 1500V rms continuous using transformer coupling techniques. Nonlinearity is an excellent ±0.01% which meets the demands of 12-bit systems. Isolated power of 2mA at ±4.5V is provided for ancillary circuits such as zero suppression and open-input alarm. Filtering at 3Hz is implemented by a passive anti-aliasing filter at the front end and a two pole active filter at the output. Overall NMR is 60dB and CMR is 160dB min @ 60Hz.

The 1B51 is specified over −25°C to +85°C and operates over the industrial (−40°C to +85°C) temperature range.

DESIGN FEATURES AND USER BENEFITS

High Noise Rejection: The combination of a chopper stabilized front end with a low pass filter provides high system accuracy in harsh industrial environments as well as good rejection of 50/60Hz noise.

Low Cost: The 1B51 offers a very low cost per channel for high performance, isolated, low-level signal conditioners.

Small Size: The 1B51 package size (1.0″×2.1″×0.35″) and functional completeness makes it an excellent choice in systems with limited board space and clearance.

Wide Range Zero Suppression: This input referred function is a convenient way to null large input offsets.

Low Pass Filter: The three pole active filter (f_C=3Hz) reduces 60Hz noise and aliasing errors.

PRELIMINARY INFORMATION

11

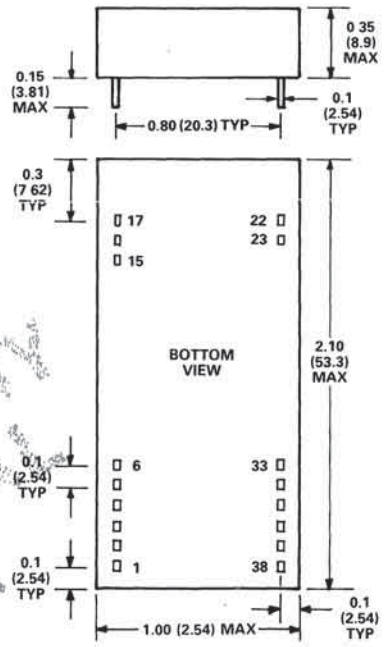
SPECIFICATIONS (typical @ +25°C and $V_S = \pm 15V$ unless otherwise noted)

Model	1B51AN
GAIN	
Gain Equation	$\left[1 + \frac{R_{FB}}{R_G}\right] \times 4$
Gain Error	1%
Gain Temperature Coefficient	±50ppm/°C
Gain Nonlinearity	±0.01% max
OFFSET VOLTAGES	
Total Offset Voltage, Referred to Input	
Initial, @ +25°C (Adjustable to Zero)	200μV max
vs. Temperature	±1μV/°C
vs. Time, Noncumulative	±1μV/month max
Output Offset	
vs. Temperature	±20μV/°C
INPUT IMPEDANCE	
Power On	5MΩ
Power Off	39kΩ
INPUT VOLTAGE RANGE	
Linear Differential Input	±5mV to ±0.5V
Max CMV, Input to Output	
ac, 60Hz, Continuous	1500V rms
Continuous, dc	±2000V peak
CMR @ 60Hz, 1kΩ Source Imbalance	160dB min
NMR @ 60Hz	60dB min
Transient Protection	IEEE-STD 472 (SWC)
INPUT NOISE	
Voltage, 0.1Hz to 10Hz, 1kΩ Source Imbalance	1μV p-p
INPUT BIAS CURRENT	
Initial @ +25°C	5nA
vs. Temperature	25pA/°C
RATED OUTPUT	
Voltage, 2kΩ Load, min[1]	±5V
Current	±5mA
Output Noise, dc to 100kHz	TBD
Impedance, dc	0.1Ω
FREQUENCY RESPONSE	
Bandwidth, −3dB	dc to 3Hz
ISOLATED POWER	
Voltage, No Load	±4.5V
Current	2mA
Regulation, No Load to Full Load	5%
Ripple	100mV p-p
POWER SUPPLY	
Voltage, Rated Performance	±15V dc
Voltage, Operating	±12V to ±18V
Current, Quiescent	10mA
ENVIRONMENTAL	
Temperature Range	
Rated Performance	−25°C to +85°C
Operating	−40°C to +85°C
Storage	−40°C to +85°C
Relative Humidity	0 to 95% @ +60°C
CASE SIZE	1.00" × 2.10" × 0.35" (25.4 × 53.3 × 8.9)mm

NOTES
[1] ±10V output can be obtained by doubling the gain of the output stage.
Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



PIN DESIGNATIONS

PIN	DESIGNATION
1	HI
2	PROT HI
4	COM
5	LO
15	GND
16	−15V
17	+15V
22	V_O
23	FILTER
34	$-V_{ISS}$
35	$+V_{ISS}$
37	GAIN
38	FB

RELEASED FOR PRODUCTION

INSIDE THE 1B51

Referring to the functional block diagram, the ±15V power inputs provide power to both the output side circuitry and the power oscillator. The 10kHz power oscillator provides both the timing information for the signal demodulator and drives transformer T2 for the input side power supplies. The secondary winding of T2 is full wave rectified and filtered to create the input side power.

The signal input (HI) is single pole filtered for noise rejection and anti-aliasing. PROT HI is the output node of the filter, and is used only for special input applications, as described in the applications section of this data sheet. Timing information derived from transformer T2 controls a precision input switch which alternates between HI and LO input pins. The output of the switch is a square wave with a peak-to-peak amplitude equal to the difference between the HI and LO input voltages. A wide bandwidth ac amplifier, whose gain is set by an external feedback/gain resistor pair, amplifies the signal and drives the signal transformer T1.

The amplitude modulated signal is demodulated after passing through signal transformer T1. The demodulator output is then passed through an active two pole filter, completing a three pole 3Hz low pass filter with the input anti-aliasing filter stage. The output of the filter (V_O) is brought out separately from the filter node (FILTER) to facilitate output side gain.

USING THE 1B51

Gain Setting: The gain of the 1B51 is controlled on the input side by a pair of user provided resistors (see Figure 1). A feedback resistor of 20kΩ ±20% is required between the feedback pin (FB) and the gain pin. The gain setting resistor is connected between the gain pin and input side common (COM). The gain equation is

$$G = \left[1 + \frac{R_{FG}}{R_G}\right] \times 4$$

Gains of 10-1000 can be achieved by adjusting this ratio.

The accuracy of the resistor values must be taken into account when calculating the initial gain accuracy of an application. The initial accuracy of the 1B51 must then be added to the resistor errors to predict the total accuracy. Likewise, the ratiometric temperature coefficient of the gain and feedback resistors must be added to the temperature coefficient of the 1B51 to predict the total resulting thermal drift.

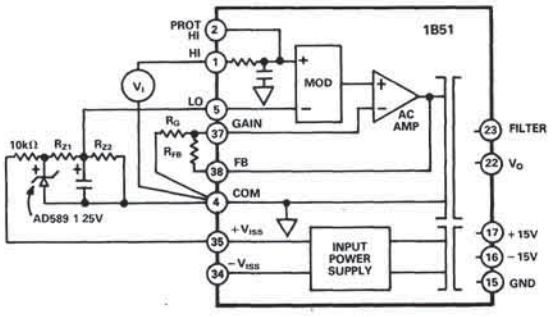


Figure 1. Input Gain Setting and Zero Suppression

It is possible to use a trimpot to correct for initial gain and system gain errors. The feedback resistor can be comprised of a resistor in series with a trimpot, as long as the total resistance remains within ±20% of 20kΩ. Alternatively, the gain resistor can also be an adjustable resistor.

Output Gain Setting: On the output side, FILTER is normally connected to V_O for ±5V. These pins can be used to provide a ±10V output swing, or to increase the maximum gain of the unit. This is described in the applications examples below.

Zero Suppression: Since the 1B51 is a differential input device, true input referred zero suppression can be accomplished (see Figure 1). A voltage reference powered by the input side power supplies is applied to the LO terminal. Since the transfer function is

$$V_O = (V(HI) - V(LO)) \times GAIN$$

the input voltage for which the desired output is zero should be applied to the LO pin. The equation is

$$V_Z = 1.25(R_{Z1}/(R_{Z1} + R_{Z2}))$$

Any drift of this input zero suppression voltage appears as offset drift, so a temperature stable reference should be used. If the source impedance seen by the LO input exceeds 100Ω, a 1μF bypass capacitor should be connected between LO and COM.

APPLICATION EXAMPLES

Input Protection: Although the 1B51 provides ±1500V of common-mode protection, it is sometimes desirable to have some level of normal-mode protection as well. The signal input of the 1B51 is normally less than ±500mV (5V out at a gain of 10) but could be very large under a fault condition.

The circuit shown in Figure 2 illustrates how to use the PROT HI pin to protect the 1B51 against accidental application of up to 220V ac. Under normal operation, one of the diode connected transistors is forward biased, while the other is reverse biased.

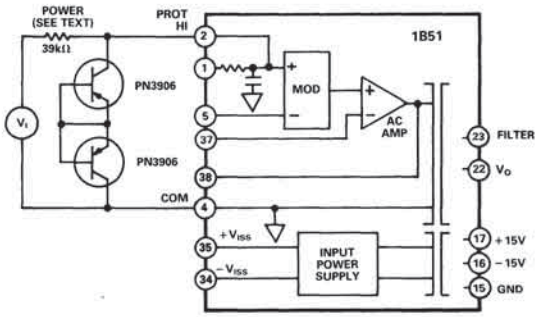


Figure 2. Input Protection

When the input voltage exceeds the reverse base-emitter breakdown voltage plus the forward bias voltage drop of the other transistor (totaling about 8 volts for the PN3906), current flows through the input resistor and transistor pair to input side common. The PN3906 also exhibits a very low base-emitter reverse leakage current, so as not to affect normal operation of the device.

PRELIMINARY DATA

The fault voltage appears mostly across the input resistor, which must be 39kΩ ±10% because it is part of the input filter. This resistor must be capable of dissipating the power supplied by the fault source. For 130V ac, this is 0.43W, and for 220V ac, it must be able to dissipate 1.24W.

Output Gain: The 1B51 can be configured to provide gain at the output to produce an output range of ±10V or to increase its maximum gain capability to 10,000. By connecting two resistors as shown in Figure 3, the output gain is (R1+R2)/R1. This ratio can be as high as 10. The gain of the 1B51 is multiplied by this output gain to get the overall gain. The thermal drift of the resistor ratio is added to the thermal drift of the 1B51 and input side gain resistors.

Open Input Detection: This can be accomplished by putting a resistor from the HI input terminal to $+V_{ISS}$ or $-V_{ISS}$ when a low impedance input such as a thermocouple is used. For example, a 1MΩ resistor from $-V_{ISS}$ to HI will cause the output voltage to go below the minus full-scale output if the input is opened, like a broken thermocouple.

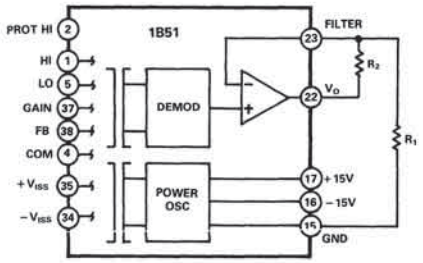


Figure 3. Increasing Output Range

PRELIMINARY TECHNICAL DATA

High Performance, 4-20mA Output Voltage-to-Current Converter

2B20

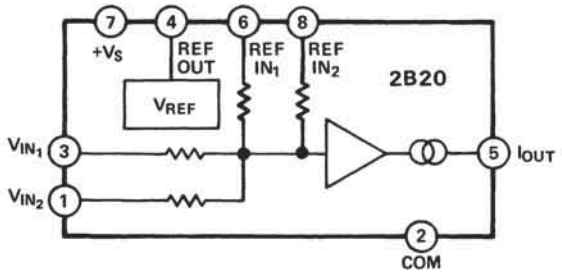
FEATURES

- Complete, No External Components Needed
- Small Size: 1.1" x 1.1" x 0.4" Module
- Input: 0 to +10V; Output: 4 to 20mA
- Low Drift: 0.005%/°C max; Nonlinearity: 0.005% max (2B20B)
- Wide Temperature Range: -25°C to +85°C
- Single Supply: +10V to +32V
- Meets ISA Std 50.1 for Type 3, Class L and U, Nonisolated Current Loop Transmitters
- Economical

APPLICATIONS

- Industrial Instrumentation and Control Systems
- D/A Converter – Current Loop Interface
- Analog Transmitters and Controllers
- Remote Data Acquisition Systems

2B20 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Model 2B20 is a complete, modular voltage-to-current converter providing the user with a convenient way to produce a current output signal which is proportional to the voltage input. The nominal input voltage range is 0 to +10V. The output current range is 4 to 20mA into a grounded load.

Featuring low drift (0.005%/°C max, 2B20B) over the -25°C to +85°C temperature range and single supply operation (+10V to +32V), model 2B20 is available in two accuracy grades. The 2B20B offers precision performance with nonlinearity error of 0.005% (max) and guaranteed low offset error of ±0.1% max and span error of ±0.2% max, without external trims. The 2B20A is an economical solution for applications with lesser accuracy requirements, featuring nonlinearity error of 0.025% (max), offset error of ±0.4% (max), span error of ±0.6% (max), and span stability of 0.01%/°C max.

The 2B20 is contained in a small (1.1" x 1.1" x 0.4"), rugged, epoxy encapsulated package. For maximum versatility, two signal input (V_{IN1} and V_{IN2}) and two reference input (REF_{IN1} and REF_{IN2}) terminals are provided. Utilizing terminals V_{IN1} and REF_{IN1} eliminates the need for any external components, since offset and span are internally calibrated. If higher accuracy (up to ±0.01%) is required, inputs V_{IN2} and REF_{IN2} with series trim potentiometers may be utilized.

APPLICATIONS

Model 2B20 has been designed for applications in process control and monitoring systems to transmit information between subsystems or separated system elements. The 2B20 can serve as a transmission link between such elements of process control system as transmitters, indicators, controllers, recorders, computers, actuators and signal conditioners.

In a typical application, model 2B20 may act as an interface between the D/A converter output of a microcomputer based system and a process control device such as a variable position valve. Another typical application of the 2B20 may be as a current output stage of a proportional controller to interface devices such as current-to-position converters and current-to-pneumatic transducers.

DESIGN FEATURES AND USER BENEFITS

Process Signal Compatibility: To provide output signal compatibility, the 2B20 meets the requirements of the Instrument Society of America Standard S50.1, "Compatibility of Analog Signals for Electronic Industrial Process Instruments" for Type 3, Class L and U, nonisolated current loop transmitters.

External Reference Use: For increased flexibility, when ratiometric operation is desired, the 2B20 offers a capability of connecting an external reference (i.e., from multiplying D/A converter) to the REF_{IN2} terminal.

Wide Power Supply Range: A wide power supply range (+10V to +32V dc) allows for operation with either a +12V battery, a +15V powered data acquisition system, or a +24V powered process control instrumentation.

SPECIFICATIONS (typical @ +25°C and V_S = +15V unless otherwise noted)

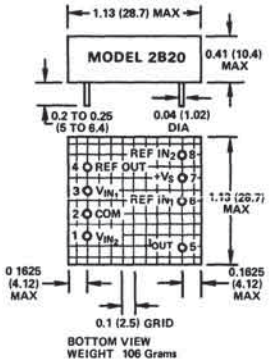
Model	2B20A	2B20B
INPUT SPECIFICATIONS		
Voltage Signal Range	0 to +10V	*
Input Impedance	10kΩ	*
OUTPUT SPECIFICATIONS		
Current Output Range[1]	4 to 20mA	*
Load Resistance Range[2]		
V_S = +12V	0 to 350Ω max	*
V_S = +15V	0 to 500Ω max	*
V_S = +24V	0 to 950Ω max	*
NONLINEARITY (% of Span)	±0.025% max	±0.005% max
ACCURACY[3]		
Warm-Up Time to Rated Specs	1 minute	*
Total Output Error @ +25°C[3,4]		
Offset (V_{IN} = 0 volts)	±0.4% max	±0.1% max
Span (V_{IN} = +10 volts)	±0.6% max	±0.2% max
vs. Temperature (-25°C to +85°C)		
Offset (V_{IN} = 0 volts)	±0.01%/°C max	±0.005%/°C max
Span (V_{IN} = +10 volts)	±0.01%/°C max	±0.005%/°C max
DYNAMIC RESPONSE		
Settling Time – to 0.1% of F.S. for 10V Step	25μs	*
Slew Rate	2.5mA/μs	*
REFERENCE INPUT[5]		
Voltage	+2.5V dc	*
Input Impedance	10kΩ	*
POWER SUPPLY		
Voltage, Rated Performance	+15V dc	*
Voltage, Operating	+10V to +32V dc max	*
Supply Change Effect (% of Span)[6]		
on Offset	±0.005%/V	*
on Span	±0.005%/V	*
Supply Current	6mA + I_{LOAD}	*
TEMPERATURE RANGE		
Rated Performance	-25°C to +85°C	*
Storage	-55°C to +125°C	*
CASE SIZE	1.125" X 1.125" X 0.4"	*

NOTES
*Specifications same as 2B20A.
[1] Current output sourced into a grounded load over a supply voltage range of +10V to +32V.
[2] See Figure 1 for the maximum load resistance value over the power supply range.
[3] Accuracy is guaranteed with no external trim adjustments when REF_{IN} is connected to REF_{OUT}.
[4] All accuracy is specified as % of output span where output span is 16mA (±0.1% = ±0.016mA output error).
[5] Reference input is normally connected to the reference output (+2.5V dc).
[6] Optional trim pots may be used for calibration at each supply voltage.

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



MATING SOCKET: AC1016

LOAD RESISTANCE RANGE

The load resistance is the sum of the resistances of all connected receivers and the connection lines. The 2B20 operating load resistance is power supply dependent and will decrease by 50 ohms for each 1 volt reduction in the power supply. Similarly, it will increase by 50 ohms per volt increase in the power supply, but must not exceed the safe voltage capability of the unit.

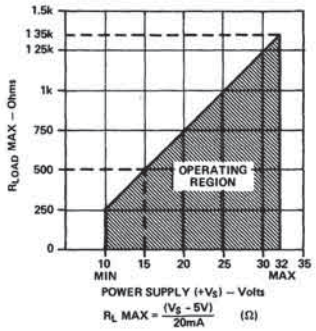


Figure 1. Maximum Load Resistance vs. Power Supply

PRINCIPLE OF OPERATION

The design of the 2B20 is comprised of high performance op amps, precision resistors and a high stability voltage reference to develop biasing and output drive capability. The 2B20 is designed to operate from a single positive power supply over a wide range of +10V to +32V dc and accepts a single ended, 0 to +10V voltage input. The internal reference has nominal output voltage of +2.5V (REF_{OUT}) and is used to develop 4mA output current for a zero volts input when REF_{IN} is connected to REF_{OUT}.

The output stage of the 2B20 utilizes a sensing resistor in the feedback loop, so the output current is linearly related to the voltage input and independent of the load resistance. There is no minimum resistance for the loads driven by the 2B20; it can drive even a short circuit with no damage to the unit. The maximum resistance of the load as seen by the unit (resistance of the load plus the resistance of the connecting wire) is limited. The maximum external loop resistance, R_L, is given by:

$$R_L\ (\Omega)\ \text{max} = \left(\frac{+V_S - 5V}{20mA}\right)$$

Figure 1 shows the operating region of the 2B20. The load must be returned to power supply common. The voltage appearing between I_{OUT} (pin 5) and COM (pin 2) should not exceed $V_{max} = +V_S - 5V$. Exceeding this value (up to +32V dc) will not damage the unit, but it will result in a loss of linearity.

The basic connections of the 2B20 are shown in Figure 2.

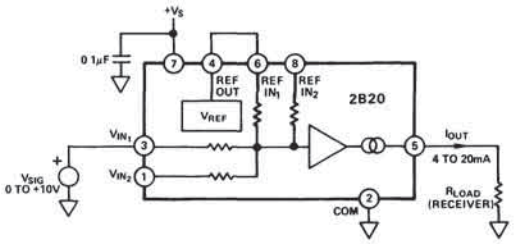


Figure 2. Basic Connections Diagram

OPTIONAL CALIBRATION AND TRIM PROCEDURE

Model 2B20's factory trimmed offset error is ±0.1% max and span error is ±0.2% max (2B20B). In most applications, further trimming will not be required. If it is necessary to obtain calibrated accuracy of up to ±0.01%, or, if a high signal source resistance (with respect to 10kΩ) introduces calibration error, inputs V_{IN2} and REF_{IN2} and optional trim pots should be used with V_{IN1} and REF_{IN1} open. To perform external trims, connect 500Ω potentiometers in series with V_{IN2} (span trim) and REF_{IN2} (offset trim) as shown in Figure 3. Adjust span pot, monitoring voltage drop across R_{LOAD}, to obtain an output voltage of 5.000V (I_{OUT}=20mA) for a +10V input. Next, with 0 volts input, adjust offset pot to obtain 1.000V output (I_{OUT}=4mA). Check both offset and span and retrim if necessary after each adjustment.

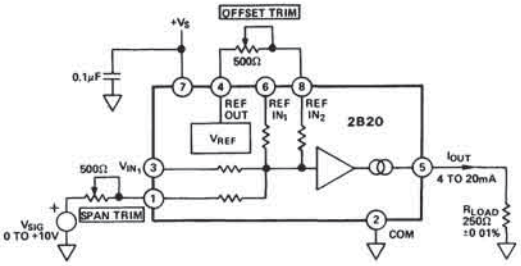


Figure 3. Model 2B20 Connections Using Optional Offset and Span Trims

CONNECTING THE 2B20 FOR 0 TO 10mA OUTPUT

The 2B20 may be utilized in applications requiring 0 to 10mA current output for a 0 to +10V input voltage range as shown in Figure 4a. To obtain 0mA output for 0V input, adjust the offset potentiometer until there is no current flowing in the output. The 2B20 span calibration may be adjusted by a 2kΩ gain potentiometer in series with the V_{SIG} input.

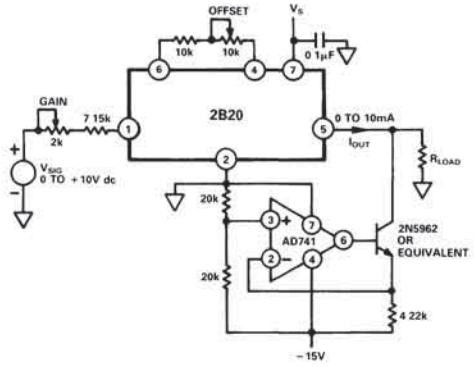


Figure 4a. 2B20 Configuration for 0 to 10mA Operation

CONNECTING THE 2B20 FOR 0 TO 20mA OUTPUT

The 2B20 may also be configured for use in applications requiring 0 to 20mA output for a 0 to +10V input range as shown in Figure 4b. To obtain 0mA output for 0V input, adjust the offset potentiometer. The 2B20 span calibration may be adjusted by a 2kΩ gain potentiometer in series with the V_{SIG} input.

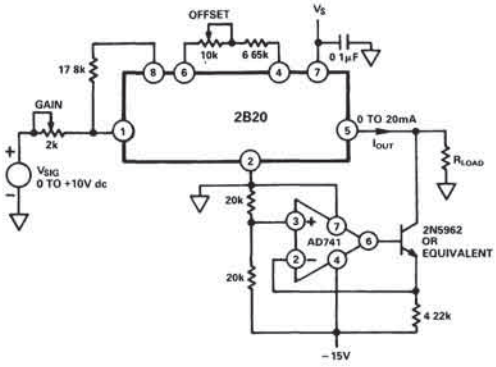


Figure 4b. 2B20 Configuration for 0-to-20mA Operation

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OUTPUT PROTECTION

In many industrial applications, it may be necessary to protect the 4 to 20mA output from accidental shorts to ac line voltages. The circuit shown in Figure 5 can be used for this purpose. The maximum permissible load resistance will be lowered by a fuse resistance value when protection circuitry is utilized.

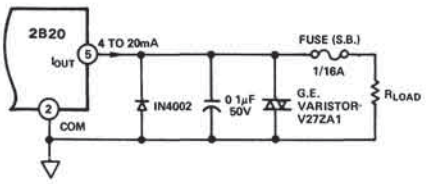


Figure 5. Output Protection Circuitry Connections

APPLICATIONS

Interfacing Voltage Output D/A Converters: The 2B20 is well suited in applications requiring 4 to 20mA output from D/A converters. The voltage necessary to power the current loop can be derived from the same +15V supply that is used to power the converter. The D/A converter, such as the 12-bit AD DAC80, should be connected for operation on the unipolar 0 to +10V output range. This is shown in Figure 6. After the load resistor connection has been made, the current loop can be calibrated using the offset and span adjustment potentiometers associated with the 2B20 (or the AD DAC80). First, a digital input code of all ones is loaded into the D/A, and the offset adjustment potentiometer is adjusted for a current output of exactly 4mA. Then, a digital code of all 0s is loaded into the D/A, and the span adjustment potentiometer is adjusted for a voltage across the load that corresponds to a current of 20mA −1LSB = 19.9961mA.

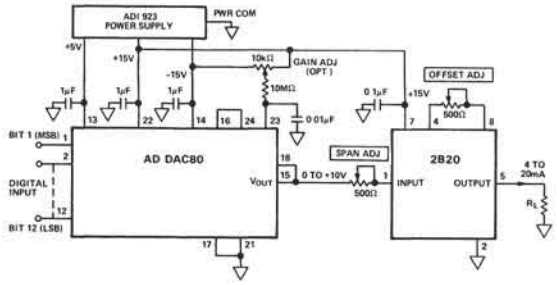


Figure 6. AD DAC80 – 4 to 20mA Current Loop Interface

Interfacing Current Output D/A Converters: To interface current output D/A converters, such as the AD562, a circuit configuration illustrated in Figure 7 should be used. Since the AD562 is designed to operate with an external +10V reference, the same external reference may be utilized by the 2B20 for ratiometric operation. The output of the AD562 is used to drive the summing junction of an operational amplifier to produce an output voltage. Using the internal feedback resistor of the AD562 provides a 0 to +10V output voltage range suitable to drive the 2B20.

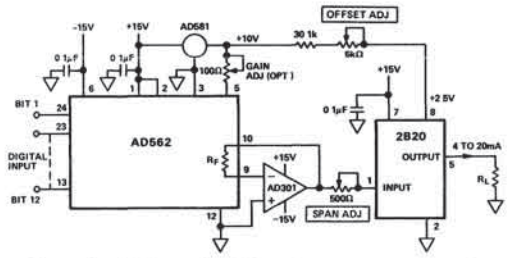


Figure 7. 12-Bit – 4 to 20mA Current Loop Interface

Microcomputer – Current Loop Interface: Figure 8 shows a typical application of the 2B20 in a multichannel microcomputer analog output system. When a microcomputer is to control a final control element, such as a valve positioner, servomechanism or motor, an analog output board with 4 to 20mA outputs is often necessary. The output boards typically have from one to eight channels, each with its own D/A converter. The 2B20, in a compact package, allows for an easy installation without any additional components and offers a 12-bit system compatible performance.

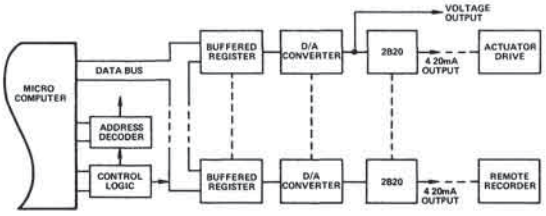


Figure 8. Microcomputer Analog Output Subsystem

Pressure Control System: In Figure 9, model 2B20 is used in a proportional pressure control system. The 3-15psi working pressure of a system is monitored with a pressure transducer interfaced by the model 2B31 signal conditioner. The high level voltage output of the 2B31 is converted to a 4 to 20mA to provide signal to the limit alarm and proportional control circuitry. A current-to-position converter controlling a motorized valve completes the pressure-control loop.

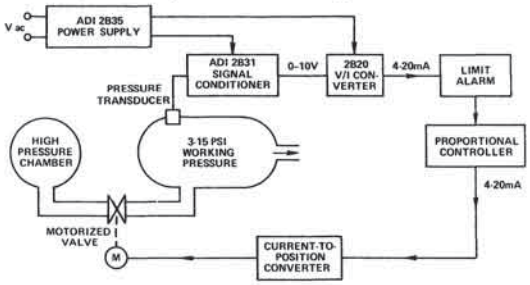


Figure 9. Proportional Pressure Control System

Isolated 4 to 20mA Output: For applications requiring up to ±1500V dc input to output isolation, consider using Analog Devices' model 2B22 isolated voltage-to-current converter.

High Performance, Isolated Voltage-to-Current Converter

2B22

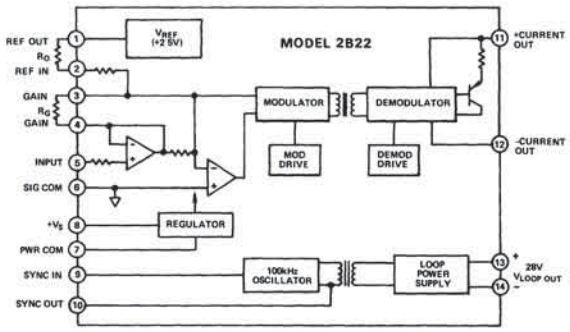
FEATURES

Wide Input Range: 0 to +1V to 0 to +10V
Standard Output Range: 4 to 20mA
High CMV Input/Output Isolation: 1500V dc Continuous
Low Nonlinearity: 0.05% max, 2B22L
Low Span Drift: 0.005%/°C max, 2B22L
Single Supply: +14V to +32V
Meets IEEE Std 472: Transient Protection (SWC)
Meets ISA Std 50.1: Isolated Current Loop Transmitters

APPLICATIONS

Industrial Instrumentation and Process Control
Ground Loop Elimination
High Voltage Transient Protection
D/A Converter – Current Loop Interface
Analog Transmitters and Controllers
Remote Data Acquisition Systems

2B22 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Model 2B22 is a high performance, compact voltage-to-current converter offering 1500V dc input to output isolation in interfacing standard process signals. The input stage of the model 2B22 is single resistor programmable to accept voltage ranges from 0 to +1V to 0 to +10V. The isolated output current range is 4 to 20mA, and the 2B22 can be operated with 0 to 1000Ω grounded or floating loads.

Using modulation techniques with transformer isolation for reliable performance, the 2B22 is available in three accuracy selections offering guaranteed nonlinearity error (2B22L: ±0.05% max, 2B22K: ±0.1% max, and 2B22J: ±0.2% max) and guaranteed low span drift: ±0.005%/°C max, ±0.01%/°C max, and ±0.015%/°C max, respectively. The internally trimmed span and offset errors are ±0.1% max for the 2B22L and ±0.25% max for the 2B22J/2B22K. Both span and offset are adjustable by the optional external potentiometers.

Featuring a wide range, single supply operation (+14V to +32V), the 2B22 provides isolated +28V loop power and is capable of delivering rated current into an external 0 to 1000Ω load resistance. The unique output stage configuration also allows the user to utilize an optional external loop power supply to interface systems designed for a two-wire operation.

APPLICATIONS

Model 2B22 has been specifically designed for high accuracy applications in process control and monitoring systems to offer complete galvanic isolation and protection against damage from transients and fault voltages in transmitting information between subsystems or separated system elements. The 2B22 meets the requirements of the Instrument Society of America Std. 50.1 "Compatibility of Analog Signals for Electronic Industrial Process Instruments" for Type 4, Class U isolated current loop transmitters.

In the industrial environment, model 2B22 can serve as a transmission link between such system elements as transmitters, indicators, controllers, recorders, computers, actuators and signal conditioners. In data acquisition and control systems, the 2B22 may act as an isolated interface between the D/A converter output of a microcomputer and standard 4 to 20mA analog loops.

DESIGN FEATURES AND USER BENEFITS

High Reliability: Model 2B22 is a conservatively designed, compact module capable of reliable operation in harsh environments. To assure high reliability, the 2B22 has a calculated MTBF of over 270,000 hours and has been designed to meet the IEEE Standard for Transient Voltage Protection (472-1974: Surge Withstand Capability).

Process Signal Compatibility: The versatile input stage design with a single resistor gain adjustment enables the 2B22 to accept any one of the standard inputs—0-1V, 0-10V, 1-5V; or 1-5mA, 4-20mA, 10-50mA; and provide standard, isolated 4-20mA output.

Isolated Loop Power: Internal 28V dc loop supply, completely isolated from the input power terminals (±1500V dc isolation), provides the capability to drive 0 to 1000Ω loads and eliminates the need for an external dc/dc converter.

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SPECIFICATIONS (typical @ +25°C and V_S = +15V unless otherwise noted)

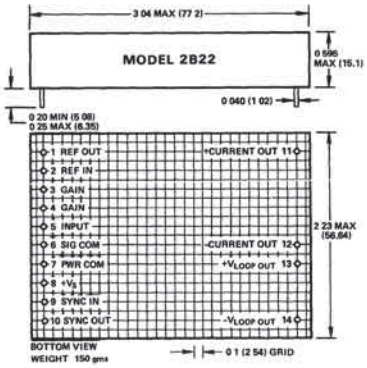
Model	2B22J	2B22K	2B22L
INPUT SPECIFICATIONS			
Voltage Signal Range, G = 1.6mA/V	0 to +10V	•	•
G = 16mA/V	0 to +1V	•	•
Gain Range	1.6 to 16mA/V	•	•
Maximum Safe Input	+15V	•	•
Input Impedance	10MΩ	•	•
OUTPUT SPECIFICATIONS			
Current Output Range	4 to 20mA	•	•
Load Resistance Range, V_S = +14V to +32V, Internal Loop Power	0 to 1000Ω max	•	•
Maximum Output Current, @ Input Overload	25mA	•	•
Output Ripple, 100Hz Bandwidth G = 1.6mA/V	60μA pk-pk	•	•
NONLINEARITY (% of Span)	±0.2% max	±0.1% max	±0.05% max
CMV, INPUT TO OUTPUT			
ac, 60Hz, 1 Minute Duration	1500V rms	•	•
Continuous, ac or dc	±1500V pk max	•	•
CMR, INPUT TO OUTPUT			
60Hz, 1kΩ Source Imbalance	90dB	•	•
ACCURACY[1]			
Warm Up Time to Rated Performance 5 Minutes			
Total Output Error @ +25°C[1,2]			
Offset (V_{IN} = 0V)	±0.25% max	±0.25% max	±0 1% max
Span (V_{IN} = +10V)	±0.25% max	±0 25% max	±0.1% max
vs. Temperature (0 to +70°C, G = 1.6mA/V)			
Offset (V_{IN} = 0V)	±0.01%/°C max	±0.005%/°C max	±0 0025%/°C max
Span (V_{IN} = +10V)	±0.015%/°C max	±0.01%/°C max	±0.005%/°C max
vs. Temperature (0 to +70°C)			
Offset (V_{IN} = 0V, G = 1.6mA/V to 16mA/V)	±0.01%/°C	±0 005%/°C	±0.0025%/°C
Span (G = 1.6mA/V to 16mA/V)[3]	±0.015%/°C	±0 01%/°C	±0 005%/°C
DYNAMIC RESPONSE			
Settling Time — to 0.1% of F.S. for 10V Step	300μs	•	•
Slew Rate	0.06mA/μs	•	•
REFERENCE INPUT			
Voltage	+2.5V dc	•	•
Input Impedance	6kΩ	•	•
OSCILLATOR			
Frequency, Internal Oscillator	100kHz ± 10%	•	•
External Sync Input			
Frequency	100kHz ± 10% max	•	•
Waveform	Square wave, 50% duty cycle	•	•
Voltage	20V p-p	•	•
POWER SUPPLY			
Voltage, Rated Performance	+15V dc	•	•
Voltage, Operating	+14V to +32V dc	•	•
Supply Current (at Full Scale Output)			
Using Internal Loop Power	100mA	•	•
Using External Loop Power	50mA	•	•
Supply Change Effect (% of Span)			
on Offset (V_{IN} = 0V)	±0.0005%/V	•	•
on Span (V_{IN} = +10V)	±0.0005%/V	•	•
TEMPERATURE RANGE			
Rated Performance	0 to +70°C	•	•
Operating	-25°C to +75°C	•	•
Storage	-55°C to +85°C	•	•
CASE SIZE	2.2" X 3" X 0.6"	•	•

NOTES
[1] Accuracy is guaranteed at G = 1 6mA/V with no external trim adjustments when connected as shown in Figure 1.
[2] All accuracy is % of span where span is 16mA (±0.1% = ±0.016mA error).
[3] Span T.C. for gains higher than 1.6mA/V is R_G dependent — a low T.C. (±10ppm/°C) R_G is recommended for best performance
*Specifications same as 2B22J

Specifications subject to change without notice.

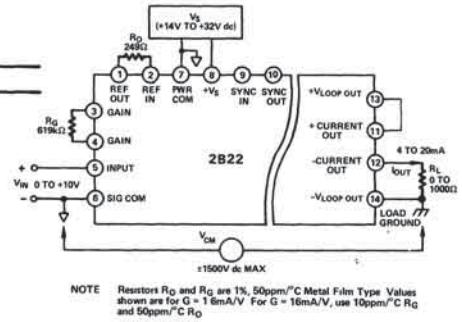
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



INTERCONNECTION DIAGRAM

Model 2B22 can be applied directly to achieve rated performance as shown in Figure 1 below. The input stage gain of 1.6mA/V, to convert a 0 to +10V signal into a 4 to 20mA output current, is obtained with the values shown. A single polarity power supply (+14V to +32V dc) should be connected to pin 8. To eliminate ground loops, the user should ensure that the signal return (common) lead does not carry the power supply current. Power common (pin 7) and signal common (pin 6) should be tied at the power supply common terminal. The voltage difference between pins 6 and 7 should not exceed 0.2V. An internal dc-dc converter provides isolated output loop power (pins 13 and 14), which is connected externally to the current output terminals (pins 11 and 12) and a load resistance. The standard 4 to 20mA current output signal is delivered into any external load between zero and 1000Ω.



NOTE Resistors R_O and R_G are 1%, 50ppm/°C Metal Film Type Values shown are for G = 1 6mA/V For G = 16mA/V, use 10ppm/°C R_G and 50ppm/°C R_O

Figure 1. Basic Connections

Applying the Isolated Voltage-to-Current Converter

FUNCTIONAL DESCRIPTION

The high performance of model 2B22 is derived from the carrier isolation technique which is used to transfer both signal and power between the V/I converter's input circuitry and the output stage. High CMV isolation is achieved by the transformer coupling between the input amplifier, modulator section and the current output circuitry. The block diagram for model 2B22 is shown in Figure 2 below.

The 2B22 produces an isolated 4 to 20mA output current which is proportional to the voltage input and independent of the load resistance. The input amplifier operates single-ended and accepts a positive voltage within 0 to +10V range. Gain can be set from 1.6mA/V to 16mA/V by changing the gain resistor R_G to accommodate input ranges from 0 to +1V (G = 16mA/V) to 0 to +10V (G = 1.6mA/V). The transfer function is $I_{OUT} = (4mA + G \times V_{IN})$.

An internal, high stability reference has nominal output voltage of +2.5V (REF OUT) and is used to develop a 4mA output current for a 0 volts input. The terminals REF OUT (pin 1) and REF IN (pin 2) should be connected via the offset setting resistor R_O. For ratiometric operation, an external reference voltage can be connected to the REF IN terminal.

The 2B22 is designed to operate from a single positive power supply over a wide range of +14V to +32V dc. An internal dc-dc converter provides isolated +28V loop power which is independent of $+V_S$. The maximum resistance of the load R_L (resistance of the receivers plus the resistance of the connecting wire) is 1000Ω. Since the loop power is derived from the input side, the current capability of the power supply ($+V_S$) must be 100mA min to supply full output signal current.

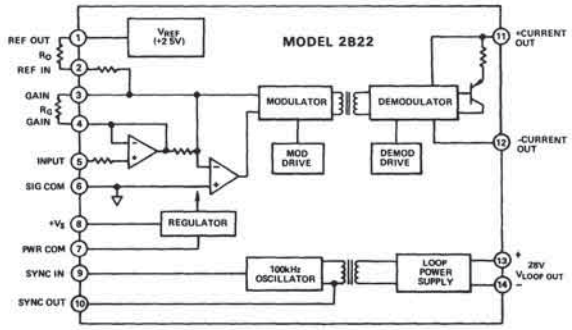


Figure 2. Block Diagram — Model 2B22

OPTIONAL TRIM ADJUSTMENTS

Model 2B22 is factory calibrated for a 0 to +10V input range (G = 1.6mA/V). As shipped, the 2B22 meets its listed specifications without use of any external trim potentiometers. Additional trim adjustment capability, to reduce span and offset errors to ±0.05% max, is easily provided as shown in Figure 3. The span and offset trim pots are adjusted while monitoring the voltage drop across a precision (or known) load resistor. The following trim procedure is recommended:

1. Connect model 2B22 as shown in Figure 3.
2. Apply V_{IN} = 0 volts and adjust R_O (Offset Adjust) for V_{OUT} = +2V ± 4mV.
3. Apply V_{IN} = +10.00V and adjust R_G (Span Adjust) for V_{OUT} = +10V ± 4mV.

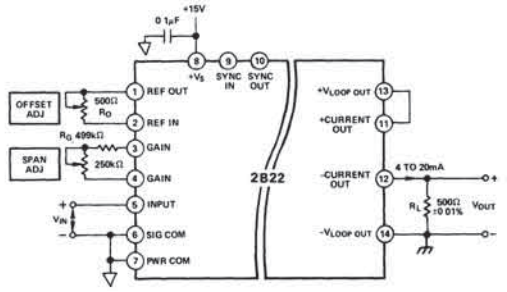


Figure 3. Optional Span and Offset Adjustment

GAIN AND OFFSET SETTING

The gain of the 2B22 is a scale factor setting that establishes the nominal conversion relationship to accommodate +1V to +10V full scale inputs (V_{IN}). The value of the gain setting resistor R_G is determined by: $R_G(k\Omega) = 6.314SF/(10.1 - SF)$ where SF is a scale factor equal to the value of V_{IN} F.S. Example: to convert a 0 to +1V input to the 4 to 20mA output, SF = 1 and R_G = 693Ω. Due to device tolerances, allowance should be made to vary R_G by ±5% using the potentiometer.

The value of the offset resistor R_O is independent from the gain setting and given by the relationship: $R_O(k\Omega) = 2.5(V_{REF} - 2.4)$ where V_{REF} is the reference voltage applied. For example, the reference provided by the 2B22 is +2.5V and therefore R_O = 250Ω. The accuracy of the R_O calculation from from the above formula is ±5%. When an external reference operation is desired (i.e. for ratiometric operation), connect the reference voltage via R_O to pin 2 and leave pin 1 open.

EXTERNAL LOOP POWER OPERATION

For maximum versatility, the 2B22's output stage is designed to operate from the optional, isolated external loop power supply. This feature allows the user to interface systems wired for a two-wire operation. As shown in Figure 4, the same wiring is used for loop power and output. The load resistance is connected in series with an external dc power supply (+6V to +32V), and the current drawn from the supply is the 4 to 20mA output signal. The input stage of the 2B22 still requires $+V_S$ power, but the current drain from $+V_S$ is limited to 50mA. Use of an external loop power may require gain and offset trimming to obtain specified accuracy. The maximum series load resistance depends on the loop supply voltage as shown in Figure 4.

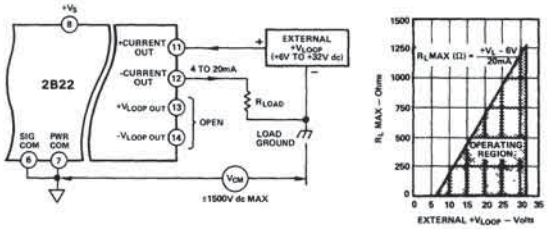


Figure 4. Optional External Loop Power Operation

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SYNCHRONIZING MULTIPLE 2B22'S

In applications where multiple 2B22's are used in close proximity, radiated individual oscillator frequencies may cause "beat frequency" related output errors. These errors can be eliminated by synchronizing multiple units by connecting the SYNC OUT (pin 10) terminal to the SYNC IN (pin 9) terminal of the adjacent 2B22. The SYNC OUT terminal of this "slaved" unit can be used to drive another adjacent 2B22 (Figure 5). For best accuracy, each 2B22 should be retrimmed when synchronizing connections are used.

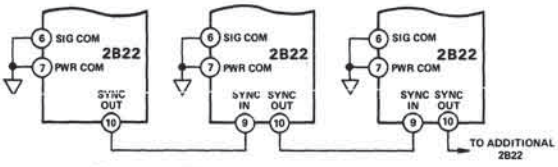


Figure 5. Multiple 2B22's Synchronization

OUTPUT PROTECTION

The current output terminals (pins 11 and 12) are protected from shorts up to +32V dc but in many industrial applications, it may be necessary to protect the 4 to 20mA output from accidental shorts to ac line voltages in addition to back EMF induced from long output connections. The circuit shown in Figure 6 can be used for this purpose. The maximum permissible load resistance will be lowered by a fuse resistance value when protection circuitry is utilized.

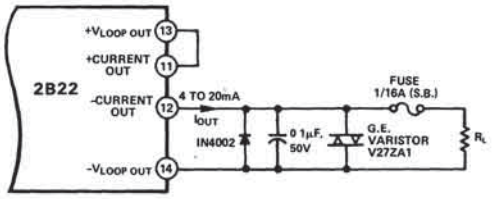


Figure 6. Output Protection Circuitry Connections

APPLICATIONS IN INDUSTRIAL MEASUREMENT AND CONTROL SYSTEMS

Process Signal Isolator: In process control applications, model 2B22 can be applied to interface standard process signals (e.g. 1 to 5mA, 4 to 20mA, 10 to 50mA, 1 to 5V) and convert them to isolated 4 to 20mA output. A typical hook-up of model 2B22 is illustrated in Figure 7, showing input resistor R_C converting the current from a remote loop to a voltage input, and a span adjustment resistor R_G. A value of R_C should be selected to develop a minimum of +1V signal with full scale input current applied. For example, a 50Ω resistor converts the 4 to 20mA current input to a 200mV to 1V voltage input, which the 2B22 isolates and converts to a 4 to 20mA output. The reference input (pin 2) is not connected since the process signal provides a desired offset.

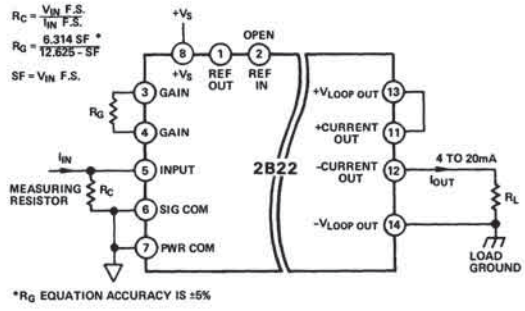


Figure 7. Process Signal Current Isolator

Isolated D/A Converter: Model 2B22 offers total ground isolation and protection from high voltage transients in interfacing D/A converters to standard 4 to 20mA current loops. This requirement is common in a microcomputer-based control system. The voltage necessary to power the current loop can be derived from the same +15V supply that is used to power the D/A converter. The D/A converter, such as the 12-bit AD DAC80, should be connected for operation on the unipolar 0 to +10V output range. This is shown in Figure 8. After the load resistor connection has been made, the current loop can be calibrated using the offset and span adjustment potentiometers associated with the 2B22. First, a digital input code of all one's is loaded into the D/A, and the offset adjustment potentiometer is adjusted for a current output of exactly 4mA. Then, a digital code of all zero's is loaded into the D/A, and the span adjustment potentiometer is adjusted for a voltage across the load that corresponds to a current of 20mA less 1LSB (19.9961mA).

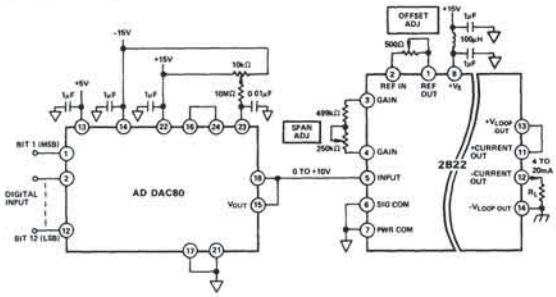


Figure 8. D/A Converter – Isolated 4 to 20mA Interface

Pressure Transmitter: In Figure 9, model 2B22 is used in a pressure transmitter application to provide complete input-output isolation and avoid signal errors due to ground loop currents. The process pressure is monitored with a strain gage type pressure transducer interfaced by the Analog Devices' model 2B30 transducer conditioner. The bridge excitation and system power is provided by the model 2B35 triple output power supply. The high level voltage output of the 2B30 is converted to the isolated 4 to 20mA current for transmission to a remote recorder or indicator.

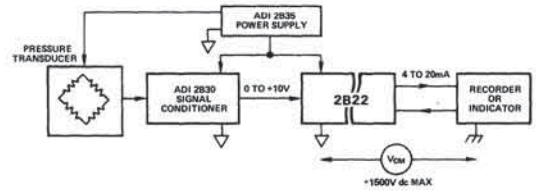


Figure 9. Isolated Pressure Transmitter

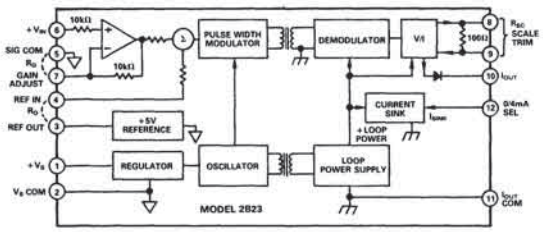
Programmable Output, Isolated Voltage-to-Current Converter

2B23

FEATURES
- **Wide Input Range, Resistor Programmable**
- **Pin Programmable Output: 4 to 20mA or 0 to 20mA**
- **High CMV Input/Output Isolation: ±1500V pk Continuous**
- **Low Nonlinearity: ±0.05% max (2B23K)**
- **Low Span Drift: ±0.005%/°C max (2B23K)**
- **Single Supply Operation: +14V to +28V**
- **Small Size: 1.8″ × 2.4″ × 0.6″**
- **Meets IEEE Std. 472: Transient Protection (SWC)**
- **Meets ISA Std. 50.1: Isolated Current Loop Transmitters**

APPLICATIONS
- **Industrial Instrumentation and Process Control**
  - **Ground Loop Elimination**
  - **Transient Voltage Protection**
- **Analog Transmitters and Controllers**
- **Remote Data Acquisition Systems**

2B23 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The model 2B23 is a high performance, low cost voltage to current converter featuring ±1500V pk input to output isolation for interfacing with standard process signals. The input stage of the 2B23 may be single resistor programmed to accept voltages within a 0 to +10V range (+0.1V to +10V full scale). The isolated output is pin programmable to provide current in the range of 4 to 20mA or 0 to 20mA and can be operated with 0 to 800Ω grounded or floating loads.

The 2B23 uses reliable transformer isolation techniques and is available in two accuracy selections offering guaranteed nonlinearity error (2B23K: ±0.05% max, 2B23J: ±0.1% max) and guaranteed low span drift (2B23K: ±0.005%/°C max, 2B23J: ±0.01%/°C max). The internally trimmed span and offset errors are ±0.1% for the 2B23K and ±0.25% for the 2B23J. Both span and offset may be adjusted using optional external potentiometers.

Featuring wide range, single supply operation (+14V to +28V dc), the 2B23 provides isolated loop power, thus eliminating the need for an external dc/dc converter.

APPLICATIONS

Model 2B23 has been designed to provide high accuracy, versatility and low cost in industrial and laboratory system applications requiring isolated current transmission. The 2B23 meets the requirements of the Instrument Society of America Std. 50.1 "Compatibility of Analog Signals for Electronic Industrial Process Instruments" and may serve as a transmission link between such system elements as computers, controllers, actuators, recorders and indicators.

In data acquisition and control systems, the 2B23 may act as an isolated interface between the D/A converter output of a microcomputer analog I/O and standard 4 to 20mA or 0 to 20mA analog loops. In process control systems, the 2B23 may be used as a current output stage of a proportional controller to interface devices such as current-to-position converters and current-to-pneumatic transducers.

DESIGN FEATURES AND USER BENEFITS

High CMV Isolation: The 2B23 features high input to output galvanic isolation to eliminate ground loops and offer protection against damage from transients and fault voltages. Its isolation barrier will withstand continuous CMV of ±1500V pk and 1500V rms @ 60Hz for 60 seconds.

High Reliability: To assure high reliability in harsh industrial environments, reliable magnetic isolation is used. The 2B23 meets the IEEE Standard for Transient Voltage Protection (472–1974: Surge Withstand Capability) and offers reliable operation over −25°C to +85°C temperature range.

Versatility: The 2B23 can be easily tailored to the user's application, accommodating a wide range of input voltages, providing pin programmable, standard current outputs and offering wide range, single supply operation.

Small Size: To conserve board space, the 2B23 is packaged in a compact, 1.8″ × 2.4″ × 0.6″ module.

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SPECIFICATIONS (typical @ +25°C and V_S = +15V unless otherwise noted)

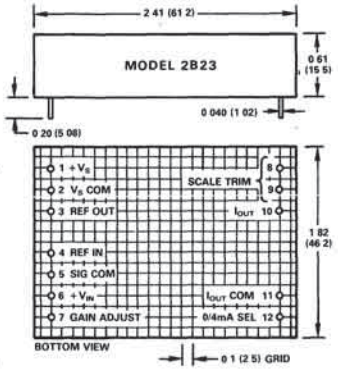
Model	2B23J	2B23K
INPUT SPECIFICATIONS		
Input Voltage Range		
Factory Calibrated	0 to +10V	*
Full Scale Input	+0.1V min to +10V max	*
Transfer Function (TF)		
Factory Calibrated	1.6mA/V	*
User Programmable	1.6mA/V to 200mA/V	*
Maximum Safe Input	±15V	*
Input Impedance	10MΩ	*
OUTPUT SPECIFICATIONS		
Current Output Range		
User Selectable	4 to 20mA, 0 to 20mA	*
Load Resistance Range		
Internal Loop Power	0 to 800Ω max	*
Maximum Output Current		
@ Input Overload	22mA typ	*
Output Noise		
100Hz Bandwidth	1.5μA pk-pk	*
NONLINEARITY	±0.1% max	±0.05% max (±0.02% typ)
ISOLATION		
CMV, Input to Output		
ac, 60Hz, 1 min	1500V rms	*
Continuous, ac or dc	±1500V pk	*
Transient Protection	IEEE Std. 472 (SWC)	*
CMR		
@ 60Hz, 1kΩ Source Imbalance	86dB	*
ACCURACY[1]		
Warm Up Time to Rated Performance	5 Minutes	*
Total Output Error @ +25°C[2,3]		
Offset (V_{IN} = 0V)	±0.25% max	±0.1% max
Span (V_{IN} = +10V)	±0.25% max	±0.1% max
vs. Temperature (0 to +70°C)		
Offset, 4-20mA Mode	±0.01%/°C max	±0.005%/°C max
0-20mA Mode	±0.01%/°C typ	±0.005%/°C typ
Span, Both Modes	±0.01%/°C max	±0.005%/°C max
DYNAMIC RESPONSE		
Settling Time to 0.1% of FS for 10V Step	5ms	*
Small Signal Bandwidth	400Hz	*
POWER SUPPLY		
Voltage, Rated Performance (+V_S)	+15V dc	*
Voltage, Operating	+14V min to +28V max	*
Supply Current (@ 20mA Output)	75mA	*
Supply Change Effect		
on Offset and Span	±0.0015%/V	*
ENVIRONMENTAL		
Temperature Range		
Rated Performance	0 to +70°C	*
Operating	−25°C to +85°C	*
Relative Humidity		
per MIL-STD 202, Method 103B	±0.2% Error	*
RFI Immunity		
27MHz @ 5W @ 3ft	±0.1% Error	*
CASE SIZE	1.8" × 2.4" × 0.6"	*

NOTES
[1]Accuracy is guaranteed @ TF = 1.6mA/V with no external trim adjustments when connected in the basic configuration.
[2]All accuracy is % of span where span is 16mA (i.e., ±0.1% = 0.016mA error).
[3]Span T.C. for transfer functions higher than 1.6mA/V is R_G dependent – low T.C. (±10ppm/°C)
R_G recommended for best performance

*Specifications same as 2B23J.
Specifications subject to change without notice.

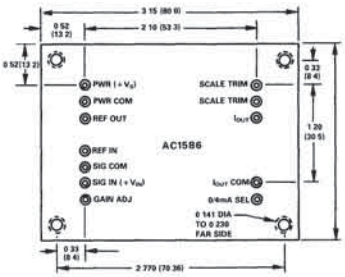
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



MATING SOCKET: AC1586

Dimensions shown in inches and (mm).



FUNCTIONAL DESCRIPTION

The high performance of model 2B23 is derived from the carrier isolation technique which is used to transfer both signal and power between the V/I converter's input circuitry and the output stage. High CMV isolation is achieved by the transformer coupling between the input amplifier stage, modulator, and current output circuitry. A block diagram of the 2B23 is shown in Figure 1.

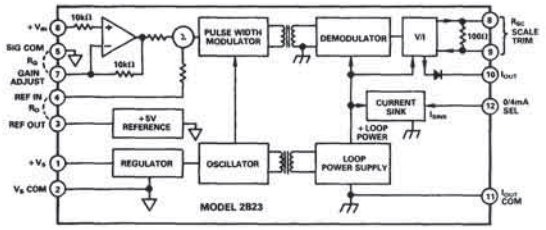


Figure 1. 2B23 Functional Block Diagram

The model 2B23 produces an isolated 4 to 20mA or 0 to 20mA output current which is proportional to the input voltage and independent of the output load resistance. The input amplifier accepts a positive voltage within the range of 0 to +10V. The transfer function of the input stage may be set from 1.6mA/V to 200mA/V (dependent upon the output current range desired) by changing the gain resistor R_G connected between pins 5 and 7.

An internal, high stability reference having a nominal output voltage of +5V (REF OUT) is used to develop a 4mA output current for a 0 volts input. REF OUT (Pin 3) and REF IN (Pin 4) should be connected via the offset scaling resistor R_O. An output current bypass section allows scaling of the nominal 4 to 20mA output current to a range of 0 to 20mA. This is accomplished by connecting the output range select pin (Pin 12) to the I_{OUT} pin (Pin 10) thereby providing a bypass for the 4mA. For 4-20mA operation, the bypass pin is connected to I_{OUT} COMMON (Pin 11).

The 2B23 is designed to operate from a single positive power supply ($+V_S$) over a range of +14V to +28V dc. The power supply section consists of an input voltage regulator, a dc/dc converter, plus associated rectifying and filtering circuitry. The dc/dc converter generates isolated loop power which is independent of V_S and capable of driving the maximum load resistance (resistance of receivers plus the resistance of connecting wire) of 800Ω. The current capability of the power supply ($+V_S$) must be 75mA minimum to supply full output signal current.

BASIC INTERCONNECTIONS

The 2B23 may be applied to achieve rated performance as shown in Figure 2. The transfer function of 1.6mA/V, for conversion of the 0 to +10V input signal into a 4 to 20mA output current, is obtained using the values shown (R_O = 10kΩ, R_{SC} = 301Ω, R_G open). For best performance, R_{SC} should be a metal film, ±0.1% tolerance, 25ppm/°C resistor and R_O should be ±1%, 100ppm/°C.

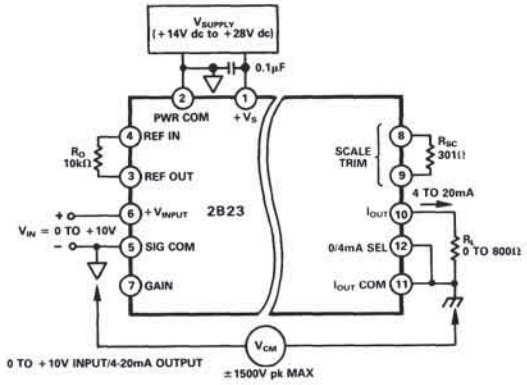


Figure 2. Basic Interconnections

A power supply ($+V_S$) is connected to Pin 1. To avoid ground loops, the user should ensure that the input signal return (SIG COM) does not carry the power supply return current. Power common (Pin 2) and signal common (Pin 5) should be tied at the power supply common terminal.

OPTIONAL TRIM ADJUSTMENTS

Model 2B23 is factory calibrated for a 0 to +10V input range and an output of 4 to 20mA, meeting its listed specifications without use of any external trim potentiometers. If desired, optional span and zero trim adjustments may be easily accomplished as described in the following sections.

Input Gain Adjustment: The input gain of the 2B23 is a scale factor setting that establishes the nominal conversion relationship to accommodate +1V to +10V full scale inputs (V_{IN}). In addition, full scale inputs as low as 100mV may be accommodated.

The value of the gain setting resistor R_G is determined by: R_G (kΩ) = 10kΩ/(G−1) where G represents a ratio of $10V/V_{IN}$(V) F.S. For example, to convert a 0 to +1V input to 4 to 20mA output, V_{IN} F.S. = +1V and G = 10V/1V = 10, therefore R_G = 10kΩ/9 = 1.1kΩ. Due to resistor tolerances, allowance should be made to vary R_G by using a series cermet type potentiometer (Figure 3). For best performance, R_G should be a metal film, 1% tolerance, 25ppm/°C resistor.

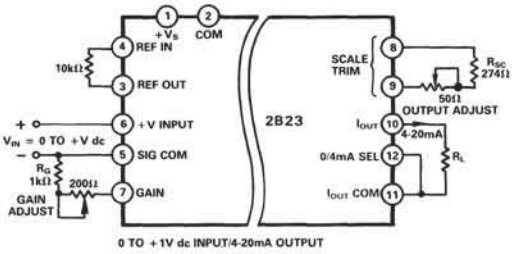
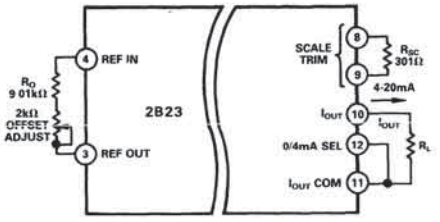


Figure 3. Input Gain Adjustment

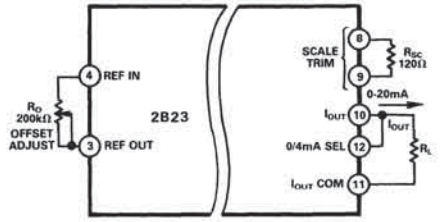
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Offset and Output Scaling Adjustments: After selecting the required input stage gain, the 2B23 must then be configured for either 4 to 20mA or 0 to 20mA output current range. Figures 4a and 4b illustrate the respective methods for each. The value of the offset resistor R_O is independent from the gain setting and may be adjusted by a series cermet pot.

For fine adjustment of the output current, R_{SC} value should be trimmed as shown in Figure 3.



4a. 4-20mA Output Connections



4b. 0-20mA Output Connections

Figure 4. 4-20mA/0-20mA Scaling Connections

USING MULTIPLE 2B23s

Unlike other transformer-based isolators, the 2B23 does not require any synchronizing circuits to eliminate beat frequency related output errors in multichannel applications. This is due to the use of pulse-width modulation technique in the 2B23. Radiated individual oscillator frequencies will have no effect upon performance, even in situations requiring multiple 2B23s to be located in close proximity to one another. For this reason, no provisions for external synchronization are necessary.

OUTPUT PROTECTION

The current output terminals (Pins 10 and 11) are protected for reverse voltage and shorts up to +32V dc but in many industrial applications it may be necessary to protect the 4 to 20mA from accidental shorts to ac line voltages. The circuit shown in Figure 5 may be employed for this purpose. The maximum permissible load resistance will be lowered by a fuse resistance value when protection circuitry is utilized.

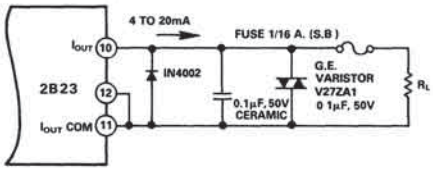


Figure 5. Output Protection Circuitry

APPLICATIONS

In Figure 6, model 2B23 is used in multiloop application of the data acquisition and control system to provide isolated current interface to a recorder, indicator and a valve positioner.

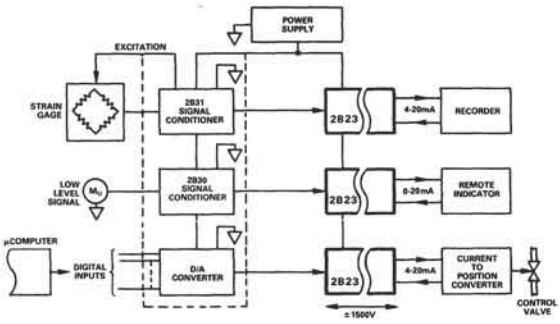


Figure 6. Multiloop Isolation

In applications requiring current to voltage conversion, the 2B23 may be used as shown in Figure 7. An external −10V reference is used to provide necessary input offset. This circuit will provide ±1500V isolation in converting 4-20mA into a 0 to +10V output. The output measurement device must have a high input impedance to avoid loading errors.

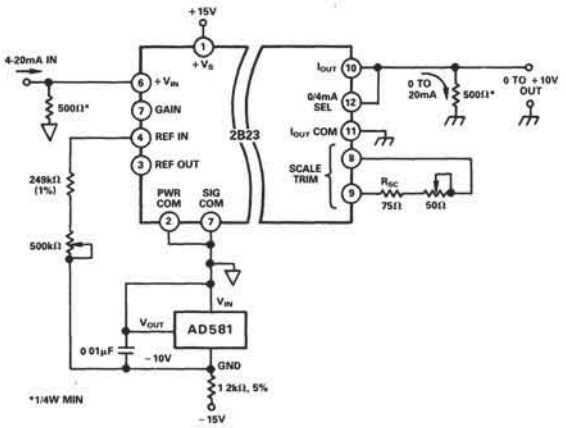


Figure 7. 4-20mA to 0 to +10V Isolated Converter

ANALOG DEVICES

High Performance, Economy Strain Gage/RTD Conditioners

2B30/2B31

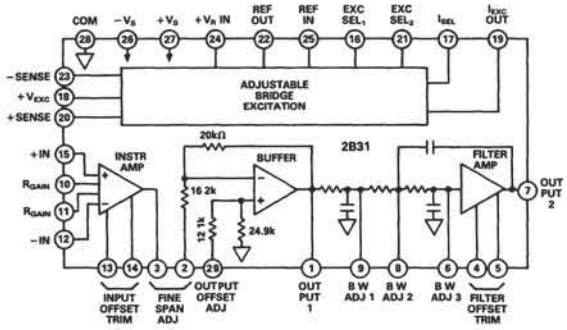
FEATURES

- Low Cost
- Complete Signal Conditioning Function
- Low Drift: 0.5μV/°C max ("L"); Low Noise: 1μV p-p max
- Wide Gain Range: 1 to 2000V/V
- Low Nonlinearity: 0.0025% max ("L")
- High CMR: 140dB min (60Hz, G = 1000V/V)
- Input Protected to 130V rms
- Adjustable Low Pass Filter: 60dB/Decade Roll-Off (from 2Hz)
- Programmable Transducer Excitation: Voltage (4V to 15V @ 100mA) or Current (100μA to 10mA)

APPLICATIONS

- Measurement and Control of:
  - Pressure, Temperature, Strain/Stress, Force, Torque
- Instrumentation: Indicators, Recorders, Controllers
- Data Acquisition Systems
- Microcomputer Analog I/O

2B31 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Models 2B30 and 2B31 are high performance, low cost, compact signal conditioning modules designed specifically for high accuracy interface to strain gage-type transducers and RTD's (resistance temperature detectors). The 2B31 consists of three basic sections: a high quality instrumentation amplifier; a three-pole low pass filter, and an adjustable transducer excitation. The 2B30 has the same amplifier and filter as the 2B31, but no excitation capability.

Available with low offset drift of 0.5μV/°C max (RTI, G = 1000V/V) and excellent linearity of 0.0025% max, both models feature guaranteed low noise performance (1μV p-p max) and outstanding 140dB common mode rejection (60Hz, CMV = ±10V, G = 1000V/V) enabling the 2B30/2B31 to maintain total amplifier errors below 0.1% over a 20°C temperature range. The low pass filter offers 60dB/decade roll-off from 2Hz to reduce normal-mode noise bandwidth and improve system signal-to-noise ratio. The 2B31's regulated transducer excitation stage features a low output drift (0.015%/°C max) and a capability of either constant voltage or constant current operation.

Gain, filter cutoff frequency, output offset level and bridge excitation (2B31) are all adjustable, making the 2B30/2B31 the industry's most versatile high-accuracy transducer-interface modules. Both models are offered in three accuracy selections, J/K/L, differing only in maximum nonlinearity and offset drift specifications.

APPLICATIONS

The 2B30/2B31 may be easily and directly interfaced to a wide variety of transducers for precise measurement and control of pressure, temperature, stress, force and torque. For applications in harsh industrial environments, such characteristics as high CMR, input protection, low noise, and excellent temperature stability make 2B30/2B31 ideally suited for use in indicators, recorders, and controllers.

The combination of low cost, small size and high performance of the 2B30/2B31 offers also exceptional quality and value to the data acquisition system designer, allowing him to assign a conditioner to each transducer channel. The advantages of this approach over low level multiplexers include significant improvements in system noise and resolution, and elimination of crosstalk and aliasing errors.

DESIGN FEATURES AND USER BENEFITS

High Noise Rejection: The true differential input circuitry with high CMR (140dB) eliminating common-mode noise pickup errors, input filtering minimizing RFI/EMI effects, output low pass filtering (f_c=2Hz) rejecting 50/60Hz line frequency pickup and series-mode noise.

Input and Output Protection: Input protected for shorts to power lines (130V rms), output protected for shorts to ground and either supply.

Ease of Use: Direct transducer interface with minimum external parts required, convenient offset and span adjustment capability.

Programmable Transducer Excitation: User-programmable adjustable excitation source-constant voltage (4V to 15V @ 100mA) or constant current (100μA to 10mA) to optimize transducer performance.

Adjustable Low Pass Filter: The three-pole active filter (f_c=2Hz) reducing noise bandwidth and aliasing errors with provisions for external adjustment of cutoff frequency.

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SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwise noted)

MODEL	2B30J 2B31J	2B30K 2B31K	2B30L 2B31L
GAIN[1]			
Gain Range	1 to 2000V/V	*	*
Gain Equation	G = (1 + 94kΩ/R_G) [20kΩ/(R_F + 16 2kΩ)]	*	*
Gain Equation Accuracy	±2%	*	*
Fine Gain (Span) Adjust Range	±20%	*	*
Gain Temperature Coefficient	±25ppm/°C max (±10ppm/°C typ)	*	*
Gain Nonlinearity,	±0 01% max	±0.005% max	±0 0025% max
OFFSET VOLTAGES[1]			
Total Offset Voltage, Referred to Input			
Initial, @ +25°C	Adjustable to Zero (±0 5mV typ)	*	*
Warm-Up Drift, 10 Min , G = 1000	Within ±5μV (RTI) of Final Value	*	*
vs Temperature			
G = 1V/V	±150μV/°C max	±75μV/°C max	±50μV/°C max
G = 1000V/V	±3μV/°C max	±1μV/°C max	±0 5μV/°C max
At Other Gains	±(3 ± 150/G)μV/°C max	±(1 ± 75/G)μV/°C max	±(0 5 ± 50/G)μV/°C max
vs. Supply, G = 1000V/V[5]	±25μV/V	*	*
vs. Time, G = 1000V/V	±5μV/month	*	*
Output Offset Adjust Range	±10V	*	*
INPUT BIAS CURRENT			
Initial @ +25°C	+200nA max (100nA typ)	*	*
vs Temperature (0 to +70°C)	-0 6nA/°C	*	*
INPUT DIFFERENCE CURRENT			
Initial @ +25°C	±5nA	*	*
vs Temperature (0 to +70°C)	±40pA/°C	*	*
INPUT IMPEDANCE			
Differential	100MΩ‖47pF	*	*
Common Mode	100MΩ‖47pF	*	*
INPUT VOLTAGE RANGE			
Linear Differential Input	±10V	*	*
Maximum Differential or CMV Input			
Without Damage	130V rms	*	*
Common Mode Voltage	±10V	*	*
CMR, 1kΩ Source Imbalance			
G = 1V/V, dc to 60Hz[1]	90dB	*	*
G = 100V/V to 2000V/V, 60Hz[1]	140dB min	*	*
dc[2]	90dB min (112 typ)	*	*
INPUT NOISE			
Voltage, G = 1000V/V			
0 01Hz to 2Hz	1μV p-p max	*	*
10Hz to 100Hz[2]	1μV p-p	*	*
Current, G = 1000			
0 01Hz to 2Hz	70pA p-p	*	*
10Hz to 100Hz[2]	30pA rms	*	*
RATED OUTPUT[1]			
Voltage, 2kΩ Load[3]	±10V min	*	*
Current	±5mA min	*	*
Impedance, dc to 2Hz, G = 100V/V	0 1Ω	*	*
Load Capacitance	0 01μF max	*	*
DYNAMIC RESPONSE (Unfiltered)[2]			
Small Signal Bandwidth			
-3dB Gain Accuracy, G = 100V/V	30kHz	*	*
G = 1000V/V	5kHz	*	*
Slew Rate	1V/μs	*	*
Full Power	15kHz	*	*
Settling Time, G = 100, ±10V Output			
Step to ±0 1%	30μs	*	*
LOW PASS FILTER (Bessel)			
Number of Poles	3	*	*
Gain (Pass Band)	+1	*	*
Cutoff Frequency (-3dB Point)	2Hz	*	*
Roll-Off	60dB/decade	*	*
Offset (at 25°C)	±5mV	*	*
Settling Time, G = 100V/V, ±10V			
Output Step to ±0 1%	600ms	*	*
BRIDGE EXCITATION (See Table 1)			
POWER SUPPLY[4]			
Voltage, Rated Performance	±15V dc	*	*
Voltage, Operating	±(12 to 18)V dc	*	*
Current, Quiescent[6]	±15mA	*	*
TEMPERATURE RANGE			
Rated Performance	0 to +70°C	*	*
Operating	-25°C to +85°C	*	*
Storage	-55°C to +125°C	*	*
CASE SIZE	2" x 2" x 0 4" (51 x 51 x 10 2mm)	*	*

NOTES

*Specifications same as 2B30J/2B31J

[1] Specifications referred to output at pin 7 with 3 75k, 1%, 25ppm/°C fine span resistor installed and internally set 2Hz filter cutoff frequency

[2] Specifications referred to the unfiltered output at pin 1

[3] Protected for shorts to ground and/or either supply voltage

[4] Recommended power supply ADI model 902-2 or model 2B35

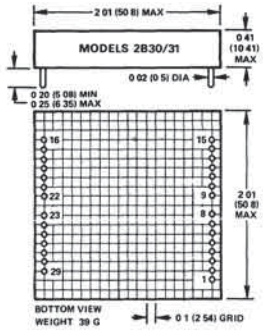
[5] Tracking power supplies

[6] Does not include bridge excitation and load currents

Specifications subject to change without notice

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

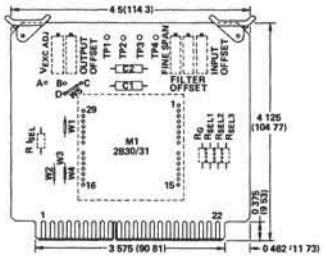


PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	OUTPUT 1 (UNFILTERED)	16	EXC SEL 1
2	FINE GAIN (SPAN) ADJ	17	I SEL
3	FINE GAIN (SPAN) ADJ.	18	$V_{EXC\ OUT}$
4	FILTER OFFSET TRIM	19	$I_{EXC\ OUT}$
5	FILTER OFFSET TRIM	20	SENSE HIGH (+)
6	BANDWIDTH ADJ 3	21	EXC SEL 2
7	OUTPUT 2 (FILTERED)	22	REF OUT
8	BANDWIDTH ADJ. 2	23	SENSE LOW (-)
9	BANDWIDTH ADJ 1	24	REGULATOR $+V_{R\ IN}$
10	R_{GAIN}	25	REF IN
11	R_{GAIN}	26	$-V_S$
12	-INPUT	27	$+V_S$
13	INPUT OFFSET TRIM	28	COMMON
14	INPUT OFFSET TRIM	29	OUTPUT OFFSET TRIM
15	+ INPUT		

Note Pins 16 thru 25 are not connected in Model 2B30

AC1211/AC1213 MOUNTING CARDS



AC1211/AC1213 CONNECTOR DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
A	REGULATOR $+V_{R\ IN}$	1	EXC SEL 1
B	SENSE LOW (-)	2	I SEL
C	REF OUT	3	$V_{EXC\ OUT}$
D	REF IN	4	$I_{EXC\ OUT}$
E		5	SENSE HIGH (+)
F		6	EXC SEL 2
H		7	OUTPUT OFFSET TRIM
J		8	
K	$-V_S$	9	$-V_S$
L	$+V_S$	10	$+V_S$
M		11	
N	COMMON	12	COMMON
P		13	
R	FINE GAIN ADJ	14	
S	FINE GAIN ADJ.	15	
T	FILTER OFFSET TRIM	16	
U	FILTER OFFSET TRIM	17	R_{GAIN}
V	OUTPUT 2 (FILTERED)	18	R_{GAIN}
W	- INPUT	19	OUTPUT 1 (UNFILTERED)
X	INPUT OFFSET TRIM	20	BANDWIDTH ADJ 1
Y	INPUT OFFSET TRIM	21	BANDWIDTH ADJ 3
Z	+ INPUT	22	BANDWIDTH ADJ 2

The AC1211/AC1213 mounting card is available for the 2B30/2B31. The AC1211/AC1213 is an edge connector card with pin receptacles for plugging in the 2B30/2B31 In addition, it has provisions for installing the gain resistors and the bridge excitation, offset adjustment and filter cutoff programming components. The AC1211/AC1213 is provided with a Cinch 251-22-30-160 (or equivalent) edge connector. The AC1213 includes the adjustment pots; no pots are provided with the AC1211.

FUNCTIONAL DESCRIPTION

Models 2B30 and 2B31 accept inputs from a variety of full bridge strain gage-type transducers or RTD sensors and convert the inputs to conditioned high level analog outputs. The primary transducers providing direct inputs may be 60Ω to 1000Ω strain gage bridges, four-wire RTD's or two- or three-wire RTD's in the bridge configuration.

The 2B30 and 2B31 employ a multi-stage design, shown in Figure 1, to provide excellent performance and maximum versatility. The input stage is a high input impedance (10^8 Ω), low offset and drift, low noise differential instrumentation amplifier. The design is optimized to accurately amplify low level (mV) transducer signals riding on high common mode voltages (±10V), with wide (1-2000V/V), single resistor (R_G), programmable gain to accommodate 0.5mV/V to 36mV/V transducer spans and 5Ω to 2000Ω RTD spans. The input stage contains protection circuitry for accidental shorts to power line voltage (130V rms) and RFI filtering circuitry.

The inverting buffer amplifier stage provides a convenient means of fine gain trim (0.8 to 1.2) by using a 10kΩ potentiometer (R_F); the buffer also allows the output to be offset by up to ±10V by applying a voltage to the noninverting input (pin 29). For dynamic, high bandwidth measurements—the buffer output (pin 1) should be used.

The three-pole active filter uses a unity-gain configuration and provides low-pass Bessel-type characteristics-minimum overshoot response to step inputs and a fast rise time. The cutoff frequency (–3dB) is factory set at 2Hz, but may be increased up to 5kHz by addition of three external resistors (R_{SEL_1} – R_{SEL_3}).

INTERCONNECTION DIAGRAM AND SHIELDING TECHNIQUES

Figure 1 illustrates the 2B31 wiring configuration when used in a typical bridge transducer signal conditioning application. A recommended shielding and grounding technique for preserving the excellent performance characteristics of the 2B30/2B31 is shown.

Because models 2B30/2B31 are direct coupled, a ground return path for amplifier bias currents must be provided either by direct connection (as shown) or by an implicit ground path having up to 1MΩ resistance between signal ground and conditioner common (pin 28). The sensitive input and gain setting terminals should be shielded from noise sources for best performance, especially at high gains. To avoid ground loops, signal return or cable shield should never be grounded at more than one point.

The power supplies should be decoupled with 1μF tantalum and 1000pF ceramic capacitors as close to the amplifier as possible.

TYPICAL APPLICATION AND ERROR BUDGET ANALYSIS

Models 2B30/2B31 have been conservatively specified using min-max values as well as typicals to allow the designer to develop accurate error budgets for predictable performance. The error calculations for a typical transducer application, shown in Figure 1 (350Ω bridge, 1mV/V F.S., 10V excitation), are illustrated below.

Assumptions: 2B31L is used, G = 1000, ΔT = ±10°C, source imbalance is 100Ω, common mode noise is 0.25V (60Hz) on the ground return.

Absolute gain and offset errors can be trimmed to zero. The remaining error sources and their effect on system accuracy (worst case) as a % of Full Scale (10V) are listed:

Error Source	Effect on Absolute Accuracy % of F.S.	Effect on Resolution % of F.S.
Gain Nonlinearity	±0 0025	±0.0025
Gain Drift	±0.025	
Voltage Offset Drift	±0 05	
Offset Current Drift	±0.004	
CMR	±0.00025	±0.00025
Noise (0 01 to 2Hz)	±0 01	±0.01
Total Amplifier Error	±0 09175 max	±0.01275 max
Excitation Drift	±0.15 (±0.03 typ)	
Total Output Error (Worst Case)	±0.24175 max (±0.1 typ)	±0.0127 max

The total worst case effect on absolute accuracy over ±10°C is less than ±0.25% and the 2B31 is capable of 1/2 LSB resolution in a 12 bit, low input level system. Since the 2B31 is conservatively specified, a typical overall accuracy error would be lower than ±0.1% of F.S.

In a computer or microprocessor based system, automatic recalibration can nullify gain and offset drifts leaving noise, nonlinearity and CMR as the only error sources. A transducer excitation drift error is frequently eliminated by a ratiometric operation with the system's A/D converter.

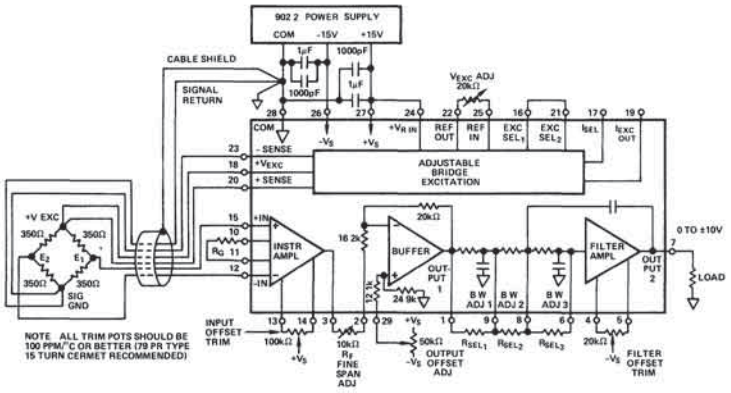


Figure 1. Typical Bridge Transducer Application Using 2B31

BRIDGE EXCITATION (2B31)

The bridge excitation stage of the model 2B31 is an adjustable output, short circuit protected, regulated supply with internally provided reference voltage (+7.15V). The remote sensing inputs are used in the voltage output mode to compensate for the voltage drop variations in long leads to the transducer. The regulator circuitry input (pin 24) may be connected to $+V_S$ or some other positive dc voltage (pin 28 referenced) within specified voltage level and load current range. User-programmable constant voltage or constant current excitation mode may be used. Specifications are listed below in Table I.

MODEL	2B31J	2B31K	2B31L
Constant Voltage Output Mode			
Regulator Input Voltage Range	+9.5V to +28V	*	*
Output Voltage Range	+4V to +15V	*	*
Regulator Input/Output Voltage Differential	3V to 24V	*	*
Output Current[1]	0 to 100mA max	*	*
Regulation, Output Voltage vs Supply	0 05%/V	*	*
Load Regulation, I_L = 1mA to I_L = 50mA	0 1%	*	
Output Voltage vs Temperature (0 to +70°C)	0 015%/°C max 0 003%/°C typ	* *	* *
Output Noise	1mV rms	*	*
Reference Voltage (Internal)	7 15V ±3%	*	*
Constant Current Output Mode			
Regulator Input Voltage Range	+9 5V to +28V	*	*
Output Current Range	100µA to 10mA	*	*
Compliance Voltage	0 to 10V	*	*
Load Regulation	0 1%	*	*
Temperature Coefficient (0 to +70°C)	0 003%/°C	*	*
Output Noise	1µA rms	*	*

[1] Output Current derated to 33mA max for 24V regulator input/output voltage differential

Table I. Bridge Excitation Specifications

OPERATING INSTRUCTIONS

Gain Setting: The differential gain, G, is determined according to the equation:

$$G = (1 + 94k\Omega/R_G)\ [20k\Omega/(R_F + 16.2k\Omega)]$$

where R_G is the input stage resistor shown in Figure 1 and R_F is the variable 10kΩ resistor in the output stage. For best performance, the input stage gain should be made as large as possible, using a low temperature coefficient (10ppm/°C) R_G, and the output stage gain can then be used to make a ±20% linear gain adjustment by varying R_F.

Input Offset Adjustment: To null input offset voltage, an optional 100kΩ potentiometer connected between pins 13 and 14 (Figure 1) can be used. With gain set at the desired value, connect both inputs (pins 12 and 15) to the system common (pin 28), and adjust the 100kΩ potentiometer for zero volts at pin 3. The purpose of this adjustment is to null the internal amplifier offset and it is not intended to compensate for the transducer bridge unbalance.

Output Offset Adjustment: The output of the 2B30/2B31 can be intentionally offset from zero over the ±10V range by applying a voltage to pin 29, e.g., by using an external potentiometer or a fixed resistor. Pin 29 is normally grounded if output offsetting is not desired. The optional filter amplifier offset null capability is also provided as illustrated in Figure 1.

Filter Cutoff Frequency Programming: The low pass filter cutoff frequency may be increased from the internally set 2Hz by the addition of three external resistors connected as shown in Figure 1. The values of resistors required for a desired cutoff frequency, f_c, above 5Hz are obtained by the equation below:

$$R_{SEL_1} = 11.6 \times 10^6/(2.67f_c - 4.34);$$

$$R_{SEL_2} = 27.6 \times 10^6/(4.12f_c - 7)$$

$$R_{SEL_3} = 1.05 \times 10^6/(0.806f_c - 1.3)$$

where R_{SEL} is in ohms and f_c in Hz. Table II gives the nearest 1% R_{SEL} for several common filter cutoff (-3dB) frequencies.

f_c (Hz)	R_{SEL1} (kΩ) (Pin 1 to 9)	R_{SEL2} (kΩ) (Pin 9 to 8)	R_{SEL3} (kΩ) (Pin 8 to 6)
2	Open	Open	Open
5	1270.000	2050 00	383 000
10	523 000	806 00	154.000
50	90 000	137.00	26.700
100	44.200	68.10	13 300
500	8 660	13 30	2.610
1000	4.320	6 65	1.300
5000	0.866	1 33	0.261

Table II. Filter Cutoff Frequency vs. R_{SEL}

Voltage Excitation Programming: Pin connections for a constant voltage output operation are shown in Figure 2. The bridge excitation voltage, V_{EXC}, is adjusted between +4V to +15V by the 20kΩ (50ppm/°C) R_{VSEL} potentiometer. For ratiometric operation, the bridge excitation can be adjusted by applying an external positive reference to pin 25 of the 2B31. The output voltage is given by: $V_{EXC\ OUT} = 3.265V_{REF\ IN}$. The remote sensing leads should be externally connected to the excitation leads at the transducer or jumpered as shown in Figure 2 if sensing is not required.

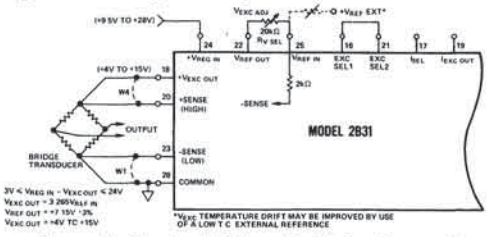


Figure 2. Constant Voltage Excitation Connections

Current Excitation Programming: The constant current excitation output can be adjusted between 100µA to 10mA by two methods with the 2B31. Figure 3 shows circuit configuration for a current output with the maximum voltage developed across the sensor (compliance voltage) constrained to +5V. The value of programming resistor R_{ISEL} may be calculated from the relationship: $R_{ISEL} = (V_{REG\ IN} - V_{REF\ IN})/I_{EXC\ OUT}$. This application requires a stable power supply because any variation of the input supply voltage will result in a change in the excitation current output.

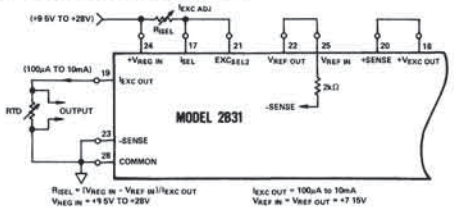


Figure 3. Constant Current Excitation Connections (V_{COMPL} = 0 to +5V)

A compliance voltage range of 0 to +10V can be obtained by connecting the 2B31 as shown in Figure 4. The 2kΩ potentiometer R_{ISEL} is adjusted for desired constant current excitation output.

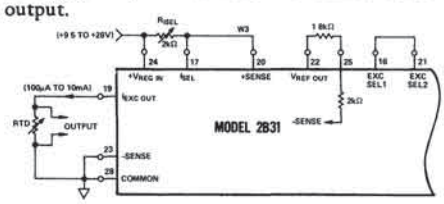


Figure 4. Constant Current Excitation Connections (V_{COMPL} = 0 to +10V)

APPLICATIONS

Strain Measurement: The 2B30 is shown in Figure 5 in a strain measurement system. A single active gage (120Ω, GF = 2) is used in a bridge configuration to detect small changes in gage resistance caused by strain. The temperature compensation is provided by an equivalent dummy gage and two high precision 120Ω resistors complete the bridge. The 2B35 adjustable power supply is set to a low +3V excitation voltage to avoid the self-heating error effects of the gage and bridge elements. System calibration produces a 1V output for an input of 1000 microstrains. The filter cutoff frequency is set at 100Hz.

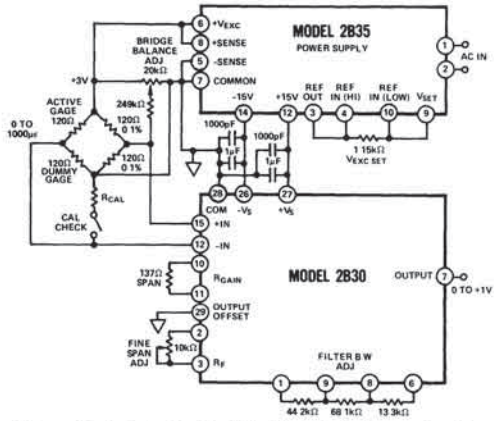


Figure 5. Interfacing Half-Bridge Strain Gage Circuit

Pressure Transducer Interface: A strain gage type pressure transducer (BLH Electronics, DHF Series) is interfaced by the 2B31 in Figure 6. The 2B31 supplies regulated excitation (+10V) to the transducer and operates at a gain of 333.3 to achieve 0-10V output for 0-10,000 p.s.i. at the pressure transducer. Bridge Balance potentiometer is used to cancel out any offset which may be present and the Fine Span potentiometer adjustment accurately sets the full scale output. Depressing the calibration check pushbutton switch shunts a system calibration resistor (R_{CAL}) across the transducer bridge to give an instant check on system calibration.

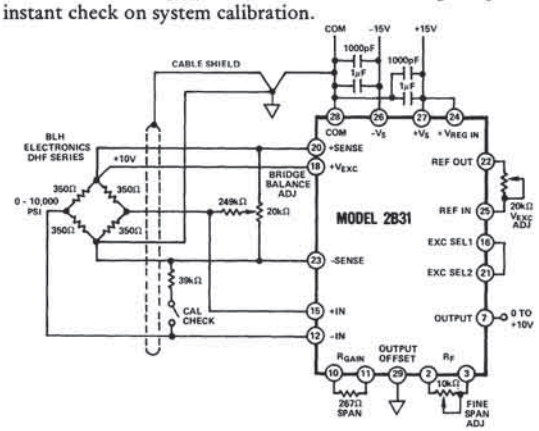


Figure 6. Pressure Transducer Interface Application

Platinum RTD Temperature Measurement: In Figure 7 model 2B31 provides complete convenient signal conditioning in a wide range (−100°C to +600°C) RTD temperature measurement system. YSI - Sostman four-wire, 100Ω platinum RTD (PT139AX) is used. The four wire sensor configuration, combined with a constant current excitation and a high input impedance offered by the 2B31, eliminates measurement errors resulting from voltage drops in the lead wires. Offsetting may be provided via the 2B31's offset terminal. The gain is set by the gain resistor for a +10V output at +600°C. This application requires a stable power supply.

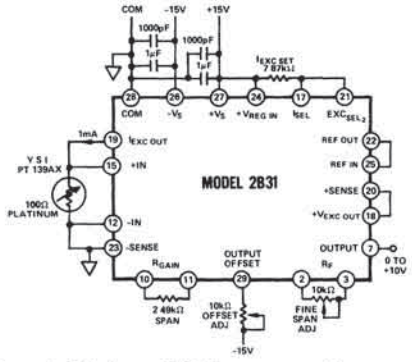


Figure 7. Platinum RTD Temperature Measurement

Interfacing Three-Wire Sensors: A bridge configuration is particularly useful to provide offset in interfacing to a platinum RTD and to detect small, fractional sensor resistance changes. Lead compensation is employed, as shown in Figure 8, to maintain high measurement accuracy when the lead lengths are so long that thermal gradients along the RTD leg may cause changes in line resistance. The two completion resistors (R1, R2) in the bridge should have a good ratio tracking (±5ppm/°C) to eliminate bridge error due to drift. The single resistor (R3) in series with the platinum sensor must, however, be of very high absolute stability. The adjustable excitation in the 2B31 controls the power dissipated by the RTD itself to avoid self-heating errors.

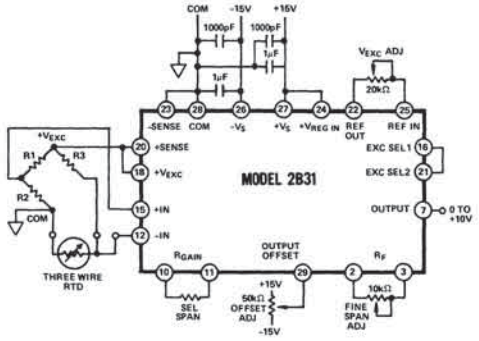


Figure 8. Three-Wire RTD Interface

Linearizing Transducer Output: To maximize overall system linearity and accuracy, some strain gage-type and RTD transducer analog outputs may require linearization. A simple circuit may be used with the 2B31 to correct for the curvature in the input signal as shown in Figure 9. The addition of feedback in the excitation stage will allow for the correction of

nonlinearity by the addition of two components. The sense of the feedback is determined by whether the nonlinearity is concave upward or concave downward (jumper A to pin 21, or to pin 25). The magnitude of the correction is determined by the resistor, R_{SEL}, and the *linearity adjust* pot provides a fine trim.

If an RTD is to be used, the adjustment can be made efficiently, without actually changing the temperature, by simulating the RTD with a precision resistance decade. The offset is adjusted at the low end of the resistance range, the fine span is adjusted at about one third of the range, and the linearity is adjusted at a resistance corresponding to full-scale temperature. One or two iterations of the adjustments will probably be found necessary because of the interaction of linearity error and scale-factor error. This circuit's applications are not restricted to RTD's; it will work in most cases where bridges are used – e.g., load cells and pressure transducers.

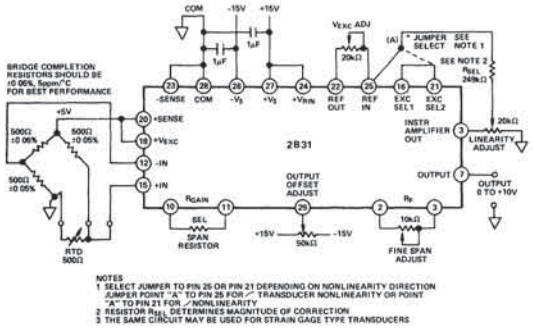


Figure 9. Transducer Nonlinearity Correction

PERFORMANCE CHARACTERISTICS

Input Offset Voltage Drift: Models 2B30/2B31 are available in three drift selections: ±0.5, ±1 and ±3μV/°C (max, RTI, G = 1000V/V). Total input drift is composed of two sources (input and output stage drifts) and is gain dependent. Figure 10 is a graph of the worst case total voltage offset drift vs. gain for all versions.

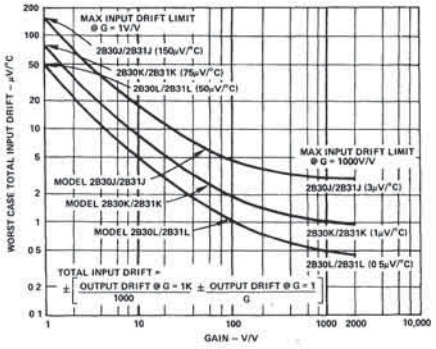


Figure 10. Total Input Offset Drift (Worst Case) vs. Gain

Gain Nonlinearity and Noise: Nonlinearity is specified as a percent of full scale (10V), e.g. 0.25mV RTO for 0.0025%. Three maximum nonlinearity selections offered are: ±0.0025%, ±0.005% and ±0.01% (G = 1 to 2000V/V). Models 2B30/2B31 offer also an excellent voltage noise performance by guaranteeing maximum RTI noise of 1μV p-p (G = 1000V/V, $R_S \leq 5k\Omega$) with noise bandwidth reduced to 2Hz by the LPF.

Common Mode Rejection: CMR is rated at ±10V CMV and 1kΩ source imbalance. The CMR improves with increasing gain. As a function of frequency, the CMR performance is enhanced by the incorporation of low pass filtering, adding to the 90dB minimum rejection ratio of the instrumentation amplifier. The effective CMR at 60Hz at the output of the filter (f_c = 2Hz) is 140dB min. Figure 11 illustrates a typical CMR vs. Frequency and Gain.

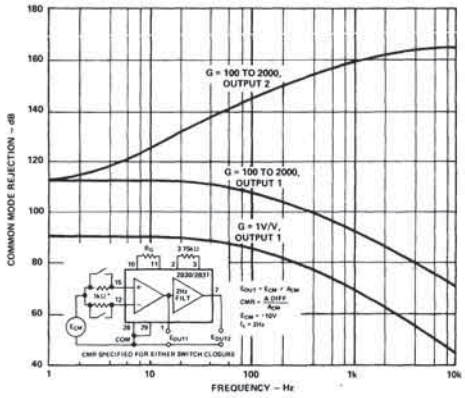


Figure 11. Common-Mode Rejection vs. Frequency and Gain

Low Pass Filter: The three pole Bessel-type active filter attenuates unwanted high-frequency components of the input signal above its cutoff frequency (–3dB) with 60dB/decade rolloff. With a 2Hz filter, attenuation of 70dB at 60Hz is obtained, settling time is 600ms to 0.1% of final value with less than 1% overshoot response to step inputs. Figure 12 shows the filter response.

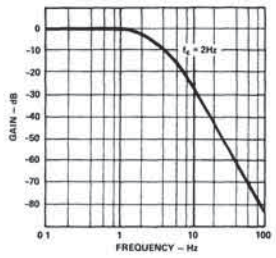


Figure 12. Filter Amplitude Response vs. Frequency

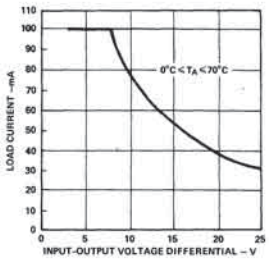


Figure 13. Maximum Load Current vs. Regulator Input-Output Voltage Differential

Bridge Excitation (2B31): The adjustable bridge excitation is specified to operate over a wide regulator input voltage range (+9.5V to +28V). However, the maximum load current is a function of the regulator circuit input-output differential voltage, as shown in Figure 13. Voltage output is short circuit protected and its temperature coefficient is ±0.015% V_{OUT}/°C max (±0.003%/°C typ). Output temperature stability is directly dependent on a temperature coefficient of a reference and for higher stability requirements, a precision external reference may be used.

Isolated, Thermocouple Signal Conditioner

2B50

FEATURES

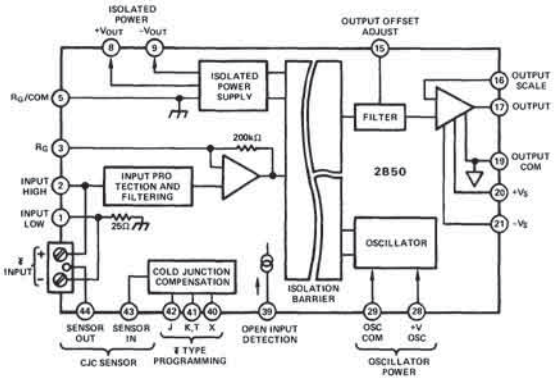
- Accepts J, K, T, E, R, S or B Thermocouple Types
- Internally Provided Cold Junction Compensation
- High CMV Isolation: ±1500V pk
- High CMR: 160dB min @ 60Hz
- Low Drift: ±1μV/°C max (2B50B)
- High Linearity: ±0.01% max (2B50B)
- Input Protection and Filtering
- Screw Terminal Input Connections

APPLICATIONS

Precision Thermocouple Signal Conditioning For:

- Process Control and Monitoring
- Industrial Automation
- Energy Management
- Data Acquisition Systems

2B50 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The model 2B50 is a high performance thermocouple signal conditioner providing input protection, isolation and common mode rejection, amplification, filtering and integral cold junction compensation in a single, compact package.

The 2B50 has been designed to condition low level analog signals, such as those produced by thermocouples, in the presence of high common mode voltages. Featuring direct thermocouple connection via screw terminals and internally provided reference junction temperature sensor, the 2B50 may be jumper programmed to provide cold junction compensation for thermocouple types J, K, T, and B, or resistor programmed for types E, R, and S.

The high performance of the 2B50 is accomplished by the use of reliable transformer isolation techniques. This assures complete input to output galvanic isolation (±1500V pk) and excellent common mode rejection (160dB @ 60Hz).

Other key features include: input protection (220V rms), filtering (NMR of 70dB @ 60Hz), low drift amplification (±1μV/°C max – 2B50B), and high linearity (±0.01% max – 2B50B).

APPLICATIONS

The 2B50 has been designed to provide thermocouple signal conditioning in data acquisition systems, computer interface systems, and temperature measurement and control instrumentation.

In thermocouple temperature measurement applications, outstanding features such as low drift, high noise rejection, and 1500V isolation make the 2B50 an ideal choice for systems used in harsh industrial environments.

DESIGN FEATURES AND USER BENEFITS

High Reliability: To assure high reliability and provide isolation protection to electronic instrumentation, the 2B50 has been conservatively designed to meet the IEEE Standard for transient voltage protection (472-1974: SWC) and provide 220V rms differential input protection.

High Noise Rejection: The 2B50 features internal filtering circuitry for elimination of errors caused by RFI/EMI, series mode noise, and 50Hz/60Hz pickup.

Ease of Use: Internal compensation enables the 2B50 to be used with seven different thermocouple types. Unique circuitry offers a choice of internal or remote reference junction temperature sensing. Thermocouple connections may be made either by screw terminals or, in applications requiring PC Board connections, by terminal pins.

Small Package: 1.5″ X 2.5″ X 0.6″ size conserves board space.

11

SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwise noted)

MODEL	2B50A	2B50B
INPUT SPECIFICATIONS		
Thermocouple Types		
Jumper Configurable Compensation	J, K, T, or B	*
Resistor Configurable Compensation	R, S, or E	*
Input Span Range	±5mV to ±100mV	*
Gain Range	50V/V to 1000V/V	*
Gain Equation	$1 + (200k\Omega/R_G)$	*
Gain Error	±0.25%	*
Gain Temperature Coefficient	±35ppm/°C max	±25ppm/°C max
Gain Nonlinearity[1]	±0.025% max	±0.01% max
Offset Voltage		
Input Offset (Adjustable to Zero)	±50μV	*
vs. Temperature	±2.5μV/°C max	±1μV/°C max
vs. Time	±1.5μV/month	*
Output Offset (Adjustable to Zero)	±10mV	*
vs. Temperature	±30μV/°C	*
Total Offset Drift	$\pm\left(2.5 + \frac{30}{G}\right)$ μV/°C	$\pm\left(1 + \frac{30}{G}\right)$ μV/°C
Input Noise Voltage		
0.01Hz to 100Hz, R_S = 1kΩ	1μV p-p	*
Maximum Safe Differential Input Voltage	220V rms, Continuous	*
CMV, Input to Output		
Continuous, ac or dc	±1500V pk max	*
Common Mode Rejection		
@ 60Hz, 1kΩ Source Unbalance	160dB min	*
Normal Mode Rejection @ 60Hz	70dB min	*
Bandwidth	dc to 2.5Hz (–3dB)	*
Input Impedance	100MΩ	*
Input Bias Current[2]	±5nA	*
Open Input Detection	Downscale	*
Response Time[3], G = 250	1.4sec	*
Cold Junction Compensation		
Initial Accuracy[4]	±0.5°C	*
vs. Temperature[5] (+5°C to +45°C)	±0.01°C/°C	*
OUTPUT SPECIFICATIONS		
Output Voltage Range[6]	±5V @ ±2mA	*
Output Resistance	0.1Ω	*
Output Protection	Continuous Short to Ground	*
POWER SUPPLY		
Voltage		
Output ±V_S (Rated Performance)	±15V dc ±10% @ ±0.5mA	*
(Operating)	±12V to ±18V dc max	*
Oscillator +V_{OSC} (Rated Performance)	+13V to +18V @ 15mA	*
ENVIRONMENTAL		
Temperature Range, Rated Performance	0 to +70°C	*
Operating	–25°C to +85°C	*
Storage Temperature Range	–55°C to +85°C	*
RFI Effect (5W @ 470MHz @ 3ft)		
Error	±0.5% of Span	*
PHYSICAL		
Case Size	1.5" X 2.5" X 0.6"	*

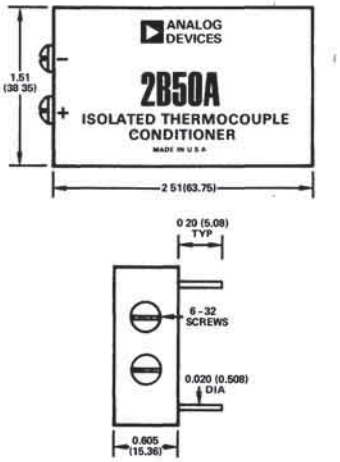
NOTES

*Specifications same as 2B50A.
[1] Gain nonlinearity is specified as a percentage of output signal span representing peak deviation from the best straight line; e.g., nonlinearity at an output span of 10V pk-pk (±5V) is ±0.01% or ±1mV.
[2] Does not include open circuit detection current of 20nA (optional by jumper connection).
[3] Open input response time is dependent upon gain.
[4] When used with internally provided CJC sensor.
[5] Compensation error contributed by ambient temperature changes at the module.
[6] Output swing of ±10V may be obtained through output scaling (Figure 5).

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	INPUT LO	23	
2	INPUT HI	24	
3	R_G	25	
4		26	
5	R_G/COM	27	
6		28	+V OSC
7		29	OSC COM
8	+V ISO OUT	30	
9	-V ISO OUT	31	
10		32	
11		33	
12		34	
13		35	
14		36	
15	OUTPUT OFFSET ADJUST	37	
		38	
16	OUTPUT SCALE	39	OPEN INPUT DET
17	OUTPUT	40	X
18		41	K, T } Σ TYPE PROGRAMMING
19	OUTPUT COM	42	J
20	+V_S	43	CJC SENSOR IN
21	-V_S	44	CJC SENSOR OUT
22			

MATING SOCKET: AC1218

FUNCTIONAL DESCRIPTION

The internal structure of the 2B50 is shown in Figure 1. An input filtering and protection network precedes a low drift, high performance amplifier whose gain is set by a user supplied resistor (R_G) for gains of 50 to 1000V/V. Isolated power is brought out to permit convenient adjustment of the input offset voltage, if desired.

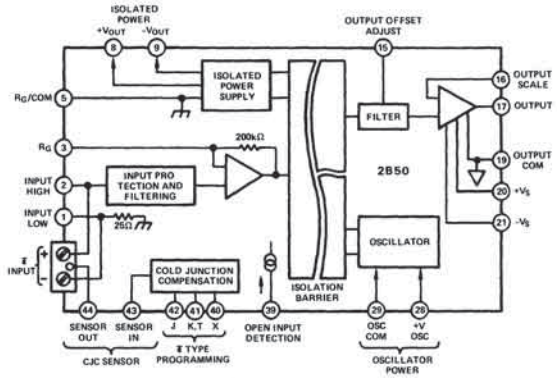


Figure 1. 2B50 Functional Block Diagram

Internal circuitry provides reference junction compensation. An integral reference junction sensor is provided for direct thermocouple connections, or an external reference sensor (2N2222 transistor) may be used in applications having remote thermocouple termination. Compensating networks for thermocouple types J, K, and T are built into the 2B50. A fourth compensation (X) may be programmed with a single resistor for any other thermocouple type. The 2B50 can be programmed for uncompensated output when used with inputs other than thermocouples.

Transformer coupling is used to achieve stable, reliable input to output galvanic isolation, as well as elimination of ground loop error effects.

Normally, the full scale output of the 2B50 is ±5V. However, with the addition of an external resistive divider, the output buffer amplifier may be scaled for a gain of up to 2, providing a full scale output swing of ±10V.

OPERATING INSTRUCTIONS

The connections shown in Figure 2 are common to most applications using the 2B50, and, in many cases, will be all that is required.

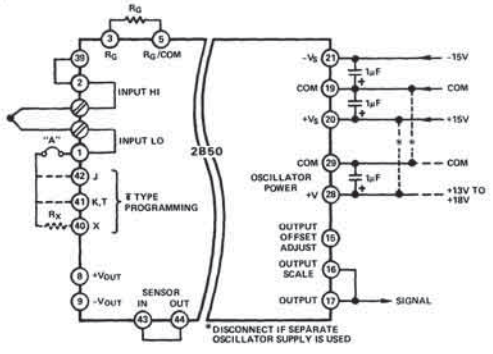


Figure 2. Basic 2B50 Application

Two sets of parallel thermocouple input connections are provided. The thermocouple input may be connected by screw terminals (input +, Input −) or to terminal Pins 1 (−) and 2 (+) in cases where thermocouples are to be remotely terminated. The following sections describe a basic thermocouple application, as well as detail some optional connections to enhance performance in more demanding applications. Jumper A (Figure 2) is used to disconnect cold junction compensation circuitry during offset adjustments.

INTERCONNECTION GUIDELINES

All power supply inputs should be decoupled with 1μF capacitors as close to the unit as possible. Any jumpers installed for programming purposes should also be installed as close as possible to minimize noise pickup effects.

Since the oscillator section of the 2B50 accounts for most of the power consumption but can accept a wide range of voltages (+13V to +18V), it may be desirable to power this section from a convenient source of unregulated power.

If the same supply is to be used for both amplifier and oscillator circuitry, the power supply returns should be brought out separately so that oscillator power supply currents do not flow in the low lead of the signal output. In either case, a 1μF capacitor must be connected from $+V_{OSC}$ (Pin 28) to Oscillator COM (Pin 29).

The oscillator and amplifier sections are completely isolated; therefore, a dc power return path is not required between the two power supply commons.

GAIN SETTING

The gain of the 2B50 is set by a user-supplied resistor (R_G) connected as shown in Figure 2. Gain will normally be selected so that the maximum output of the signal source will result in a plus full scale output swing. The resistor value required is determined by the equation: $R_G = 200k\Omega/(G-1)$.

A series trim on the gain setting resistor can be used to trim out the resistor tolerance and module gain error (Figure 3). Since addition of a series resistance will always decrease gain, the value of the gain-setting resistor should be selected to provide a gain somewhat higher than the desired trimmed gain. A good quality (e.g., 10ppm/°C), metal-film resistor should be used for R_G, since drift of R_G will add to the overall gain drift of the 2B50. A cermet pot is suitable for the trim. Note that a minimum gain of 50 is required for guaranteed operation.

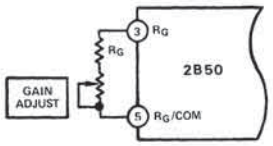


Figure 3. Gain Adjustment

INPUT AND OUTPUT OFFSET ADJUSTMENTS

The 2B50 has provisions for adjusting input and output offset errors of the module. None of the offset adjustments will affect drift performance, and adjustments need not be used unless the particular application calls for lower offsets than those specified.

Connections for offset adjustments are shown in Figure 4. Isolated supply voltages are brought out for input trimming convenience only and are not for use as a power supply for external components.

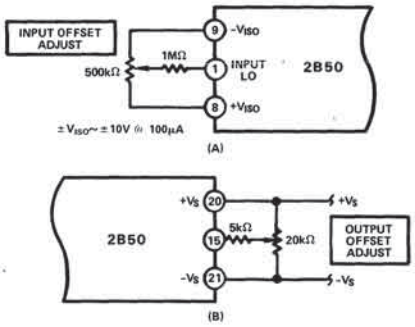


Figure 4. (A) Input and (B) Output Offset Adjustment

OFFSET CALIBRATION

1. Short Input + and Input – together.
2. Disconnect cold junction compensation circuitry by removing Jumper "A" (Figure 2).
3. Adjust input offset trim pot (±250μV range, RTI) to zero output while operating at the desired gain. In most applications, adjustment of the input offset alone will be sufficient. Output offset adjustment (±30mV range) may be performed if it is desired to adjust output offset on the nonisolated side.

OPEN INPUT DETECTION

Connecting the open input detection pin (Pin 39) to Input High (Pin 2) creates a 20nA bias current which will provide a negative overscale response if the input is opened, or in case of thermocouple "burn out". The speed at which this occurs is dependent on gain, with a typical response time of 1.4sec @ G = 250. For positive upscale response, connect a 500MΩ resistor between $+V_{ISO}$ (Pin 8) and Input Hi (Pin 2).

OUTPUT SCALING

With the output scale (Pin 16) connected to the output (Pin 17), the full scale output range is ±5V and the total gain is equal to the gain set by R_G. For applications requiring a full scale output of ±10V, a resistive divider may be connected to provide a gain of 2 at the output amplifier (see Figure 5). In this configuration, total gain will be twice the gain set by R_G. Output gains greater than 2 cannot be used.

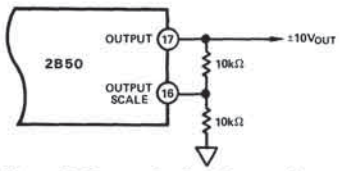


Figure 5. Output Scaling Connections

COLD JUNCTION COMPENSATION

The 2B50 may be programmed to provide cold junction compensation for types J, K and T thermocouples by connecting a jumper from Input Low (Pin 1) to the appropriate programming points (Pin 42 for J, Pin 41 for K or T). To compensate other themocouple types, a resistor (R_X) is connected from the "X" programming point (Pin 40) to Input Low (Pin 1). Table I shows the appropriate R_X values for types E, R, and S. R_X should be a 50ppm/°C, 1% tolerance resistor.

Type B thermocouples are unique, in that they have almost no output in the +5°C to +45°C range, and, therefore, do not require cold junction compensation at all. To accommodate a type B thermocouple, resistor R_X must be left open. Error due to cold junction temperature will be less than ±1°C for any measurement above 260°C. In the measurement range above 1000°C (where type B thermocouples are normally used) the error will be less than ±0.3°C.

T Type	R_X (kΩ)
E	1.87
R,S	19.6
B	Open

Table I. Compensation Values for Thermocouple Types E, R, S and B

REMOTE REFERENCE SENSING

In applications requiring termination of thermocouple leads at a point located remotely from the 2B50, with connections brought to the 2B50 (Pins 1, 2) by copper wires, reference temperature sensing at the remote location will be necessary. The 2B50 has provisions for connection of a 2N2222 transistor (metal can version) for use as a reference junction sensor. The connections are shown in Figure 6. The remote sensing transistor is calibrated by adjusting R_{CAL} to obtain the value of V_{CAL} as specified in Table II.

(Example: V_{CAL} = 570.0mV @ 25°C)

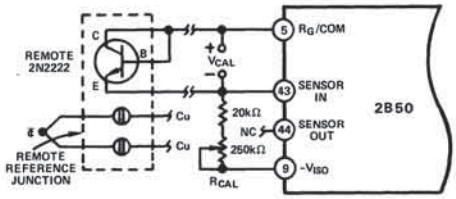


Figure 6. Remote Reference Junction Sensing

Sensor Temp (°C)	V_{CAL} (mV)
5	616.5
10	604.9
15	593.3
20	581.6
25	570.0
30	558.4
35	546.8
40	535.1
45	523.5

(Values may be interpolated)

Table II. Calibration Voltages vs. Sensor Temperature

Proper sensor placement is important. Close thermal contact of the sensor and thermocouple termination point (reference junction) is essential for accurate operation of the 2B50. The sensor may be placed any distance from the 2B50. When the sensor leads are more than ten feet long, or in the presence of strong noise signal sources, shielded cable should be used.

Four-Channel, Isolated Thermocouple/mV Conditioners

2B54/2B55

FEATURES

Low Cost Per Channel
Wide Input Span Range: ±5mV to ±100mV (2B54)
±50mV to ±5V (2B55)
Pin Compatible with 2B34 RTD Conditioner
High CMV Isolation: ±1000V dc; CMR = 156dB min @ 60Hz
Low Input Offset Voltage Drift: ±1μV/°C max (2B54B)
Low Gain Drift: ±25ppm/°C max (2B54B)
Low Nonlinearity: ±0.02% max (±0.012% typ)
Normal Mode Input Protection (130V rms) and Filtering
Channel Multiplexing: 400 chan/sec Scanning Speed
Solid State Reliability

APPLICATIONS

Multichannel Thermocouple Temperature Measurements
Low and High Level Data Acquisition Systems
Industrial Measurement and Control Systems

GENERAL DESCRIPTION

Models 2B54 and 2B55 are low cost, high performance, four-channel signal conditioners. Both models are functionally complete, providing input protection, isolation and common mode rejection, multiplexing, filtering and amplification.

The 2B54 has been designed to condition low level signals (±5mV to ±100mV), like those generated by thermocouples or strain gages, in the presence of high common mode voltages. The 2B55 is optimized to condition ±50mV to ±5V or 4 to 20mA transmitter signals as inputs. The four-channel structure of both models results in significant cost and size reduction.

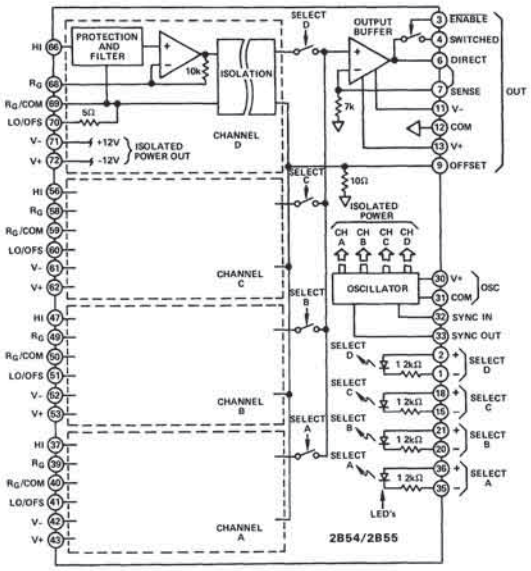
The high performance of the 2B54 and 2B55 is accomplished by the use of reliable transformer isolation techniques and an amplifier-per-channel architecture. Each of the input channels is galvanically isolated (±1000V dc) from the other input channels and from output ground. The amplifier-per-channel structure is used to obtain low input drift (±1μV/°C max, 2B54B), high common mode rejection (156dB @ 60Hz), and very stable gain (±25ppm/°C max). Other key features include low input noise (1μV p-p), low nonlinearity (±0.02% max) and open-thermocouple detection (2B54).

APPLICATIONS

Models 2B54 and 2B55 were designed to serve as a superior alternative to the relay multiplexing circuits used in multichannel data acquisition systems, computer interface systems, process signal isolators, and temperature measurement and control instrumentation. Advantages over relay circuits include functional versatility, superior performance, and solid state reliability. Both models are also pin compatible with the 2B34, four-channel RTD/strain gage conditioner.

In thermocouple temperature measurement applications, outstanding low drift, high noise rejection, high throughput and 1000V isolation make the 2B54 a natural choice over flying capacitor multiplexers in conditioning any thermocouple type. When cold junction compensation is required in measurement of temperature with thermocouples, the 2B54 may be used directly with the model 2B56 Universal Cold Junction Compensator.

2B54/2B55 FUNCTIONAL BLOCK DIAGRAM



DESIGN FEATURES AND USER BENEFITS

High Reliability: To assure high reliability and provide isolation protection to electronic instrumentation, reliable transformer isolation and solid state switching are used. Both models have been conservatively designed to meet the IEEE standard for Transient Voltage Protection (472-1974:SWC) and offer 130V rms normal mode input protection.

High Noise Rejection: To preserve high system accuracy in electrically noisy industrial environments, the 2B54 and 2B55 provide excellent common mode noise rejection, RFI/EMI immunity, and low pass filtering for rejection of series mode noise and 50Hz/60Hz pickup.

Ease of Use: The multichannel, functionally complete design in a compact (2″ × 4″ × 0.4″) module, assures ease of use, conserves board space and eliminates the need for a number of discrete components necessary in relay multiplexing circuits.

Low Cost: The 2B54 and 2B55 offer the lowest cost per channel for isolated, solid state, low level signal conditioners.

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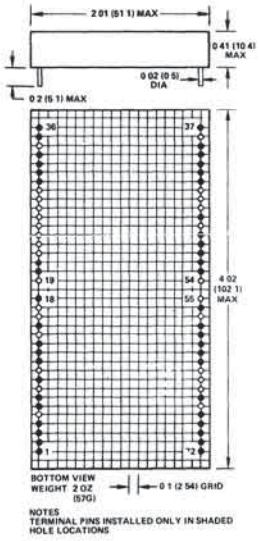
SPECIFICATIONS (typical @ +25°C and V_S = ±15V and V_{OSC} = +15V, unless otherwise noted)

Model	2B54A	2B54B	2B55A
ANALOG INPUTS			
Number of Channels	4	*	*
Input Span Range	±5mV to ±100mV	*	±50mV to ±5V
Gain Equation	$G = 1 + 10k\Omega/R_G$	*	*
Gain Error	±0.2% max (G = 50 to 300)	*	±0.2% max (G = 1 to 100)
	±1% max (G = 1000)	*	NA
Gain Temperature Coefficient	±35ppm/°C max	±25ppm/°C max	±25ppm/°C max
Gain Nonlinearity[1]	±0.03% max (G = 50 to 300)	±0.02% max(±0.012% typ)	±0.02% max (G = 1 to 100)
	±0.03% (G = 1000)	*	NA
Offset Voltage			
Input Offset, Initial (Adj. to Zero)	±20µV max	*	±50µV max
vs Temperature	±2.5µV/°C max	±1µV/°C max(±0.5µV/°C typ)	±5µV/°C max
vs Time	±1.5µV/month	*	*
Output Offset (Adjustable to Zero)	±12mV max	*	*
vs. Temperature	±50µV/°C max	*	*
Total Offset Drift (RTI), max	$\pm\left(2.5+\frac{50}{G}\right)\mu V/^\circ C$	$\pm\left(1+\frac{50}{G}\right)\mu V/^\circ C$	$\pm\left(5\mu V+\frac{50}{G}\right)\mu V/^\circ C$
Input Noise Voltage			
0.01Hz–100Hz, R_S = 1kΩ	1µV p-p	*	*
CMV, Channel-to-Channel or Channel-to-Ground			
Continuous, ac, 60Hz	750V rms	*	*
Continuous, ac or dc	±1000V pk max	*	*
Common Mode Rejection			
$R_S \leq 100\Omega$, $f \geq 50Hz$	156dB min (G = 1000)	*	145dB min (G = 100)
$R_S \leq 100\Omega$, $f \geq 50Hz$	128dB min (G = 50)	*	110dB min (G = 1)
Normal Mode Input, Without Damage	130V rms, 60Hz	*	*
Normal Mode Rejection, @ 60Hz	55dB min (G = 1000)	*	55dB min (G = 100)
Input Resistance, Power On	100MΩ	*	*
Power Off	35kΩ min	*	74kΩ min
Input Bias Current	±8nA max	*	*
ANALOG OUPUT			
Output Voltage Swing[2]	±5V @ ±5mA	*	*
Output Noise, dc – 100kHz	0.8mV p-p	*	*
Output Resistance			
Direct Output	0.1Ω	*	*
Switched Output	35Ω	*	*
CHANNEL SELECTION			
Channel Selection Time to ±0.01% FS	2.5ms max	*	*
Channel Scanning Speed	400 chan/sec min	*	*
Channel Select Input Reverse Voltage Rating	3V max	*	*
POWER SUPPLY			
Voltage			
Output ±V_S (Rated Performance)	±15V dc ±10%	*	*
(Operating)	±12V to ±18V dc max	*	*
Oscillator +V_{OSC} (Rated Performance)	+13.5V to +24V	*	*
Absolute max +V_{OSC}	+26V	*	*
Current			
Output ±V_S = ±15V	±4mA max	*	*
Oscillator +V_{OSC} = +15V	40mA max	*	*
Supply Effect on Offset			
Output ±V_S	100µV/V RTO	*	*
Oscillator +V_{OSC}	1µV/V RTI	*	*
ENVIRONMENTAL			
Temperature			
Rated Performance	0 to +70°C	*	*
Operating	–25°C to +85°C	*	*
Storage	–55°C to +85°C	*	*
Relative Humidity			
Non-Condensing to +40°C	0 to 85%	*	*
CASE SIZE	2" X 4" X 0.4"	*	*

NOTES
*Specifications same as 2B54A.
[1] Gain nonlinearity is specified as a percentage of output signal span representing peak deviation from the best straight line, e.g. nonlinearity at an output span of 10V pk-pk (±5V) is ±0.02% or ±2mV
[2] Protected for shorts to ground and/or either supply voltage.
Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

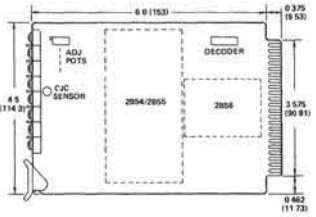


2B54/2B55 PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	– SELECT CH D	37	HI
2	+ SELECT CH D	38	
3	SW'D OUTPUT ENABLE	39	R_G
4	SWITCHED OUTPUT	40	R_G/COM CHANNEL A
5	SWITCHED OUTPUT	41	LO/OFS CHANNEL A
6	DIRECT OUTPUT	42	V– OUT CHANNEL A
7	SENSE OUTPUT	43	V+ OUT CHANNEL A
8		44	
9	OFS ADJ	45	
10		46	
11	–V_S	47	HI
12	COM	48	
13	+V_S	49	R_G
14		50	R_G/COM CHANNEL B
15	– SELECT CH C	51	LO/OFS CHANNEL B
16	SELECT CH C	52	V– OUT CHANNEL B
17	SELECT CH C	53	V+ OUT CHANNEL B
18	+ SELECT CH C	54	
19		55	
20	– SELECT CH B	56	HI
21	+ SELECT CH B	57	
22		58	R_G
23		59	R_G/COM CHANNEL C
24		60	LO/OFS CHANNEL C
25		61	V– OUT CHANNEL C
26		62	V+ OUT CHANNEL C
27		63	
28		64	
29		65	
30	+V_{OSC} OSC POWER	66	HI
31	COM OSC POWER	67	
32	IN SYNC	68	R_G
33	OUT SYNC	69	R_G/COM CHANNEL D
34		70	LO/OFS CHANNEL D
35	– SELECT CH A	71	V– OUT CHANNEL D
36	+ SELECT CH A	72	V+ OUT CHANNEL D

AC1215 OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



Mating Connector:
Cinch 251-22-30-160 or equivalent.

MOUNTING CARDS AC1215, AC1216

The AC1215 and AC1216 mounting cards are available to assist in evaluation of the 2B54 and 2B55. These 4 1/2" X 6" printed circuit edge connector cards have sockets that allow a 2B54/2B55 and 2B56 to be plugged directly onto them, as well as offset adjustment pots, and address decoding circuitry. The AC1215 and AC1216 differ only in input signal connections: the AC1215 includes a screw terminal block and AC1216 has an edge connector.

FUNCTIONAL DESCRIPTION

The internal structure of the 2B54/2B55 is shown in Figure 1. Four individually isolated input channels are multiplexed into a single output buffer, with the desired channel selected by control inputs SELECT A through SELECT D. Isolated power and timing signals for the input channels are provided by an internal oscillator.

Each channel contains an input protection and filtering network and a low-drift amplifier whose gain is set by a user-supplied resistor (R_G). Additional filtering is provided in the amplifier circuit. This structure preserves signal integrity by taking all signal gain ahead of the isolation and multiplexing circuits. The isolated power supply for each channel is brought out to permit convenient fine adjustment of the input offset voltage if desired.

Transformer coupling is used to achieve stable, reliable galvanic isolation of each channel from all other channels and from output ground. Although the bandwidth of the input channels is small (<2Hz at high gains) to provide immunity to normal-mode noise, the multiplexing technique allows the channels to be scanned at a high rate (400 channels/sec). Thus a high revisitation rate is maintained even in systems with a large number of input channels.

The output buffer amplifier operates at unity gain with feedback provided by an external connection from the DIRECT output to the SENSE input. The DIRECT output provides a ±5V swing with low source resistance to permit error-free operation with heavy loads. In addition, a separate series-switched output with an active-low enable control is provided so that multiple modules may be combined without the use of external analog multiplexers. An offset trim point which does not affect drift is also provided on the output channel.

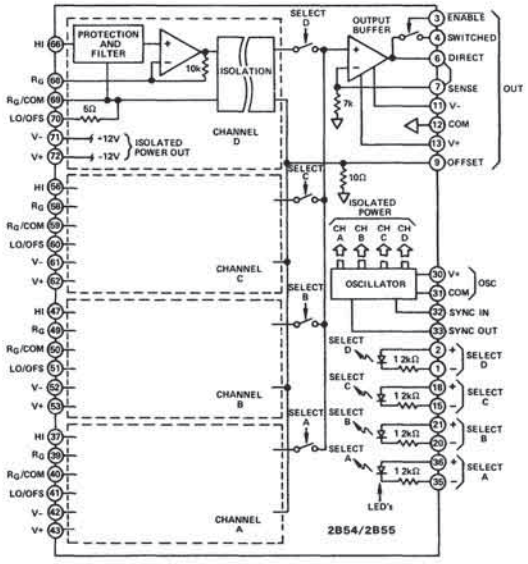


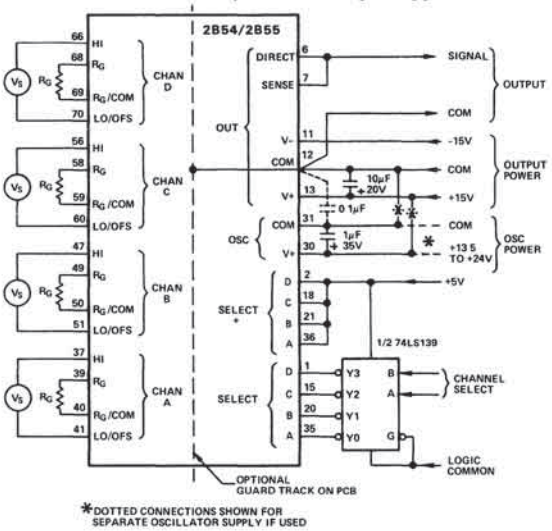
Figure 1. 2B54/2B55 Functional Diagram

The internal oscillator has its own power supply pins for enhanced application flexibility, and a sync mechanism is provided to eliminate beat-frequency errors when multiple 2B54/2B55's are used or when a system clock is present.

The 2B54 and 2B55 share the same design, differing only in input specifications and filter characteristics.

OPERATING INSTRUCTIONS

The connections shown in Figure 2 are common to most applications of the 2B54/2B55, and in many cases will be all that is required. The following sections describe this basic application and also detail some optional connections which enhance the module's utility in more complex applications.



*DOTTED CONNECTIONS SHOWN FOR SEPARATE OSCILLATOR SUPPLY IF USED

Figure 2. Basic 2B54/2B55 Application

Interconnection Guidelines

In any high accuracy isolator application it is important to minimize coupling between input and output, and the 2B54/2B55 pinout has been designed to make this easy to do. For best results, keep all leads associated with signals on the input edge as far as possible from signals on the output edge. This will minimize the effects of board leakage and capacitance. The use of a guard track on both sides of the board (Figure 2) can also be helpful.

The power supplies should be decoupled with tantalum capacitors as close to the unit as possible. For lowest noise, the output grounding scheme should be as shown in Figure 2. The output signal common is connected directly to pin 12, with power supply returns brought separately to that pin so that power supply currents do not flow in the low lead of the signal output.

Since most of the power taken by the 2B54/2B55 is supplied to the internal oscillator which requires only a positive supply and can accommodate a wide range of supply voltages, it is sometimes desirable to power the oscillator from a convenient source of unregulated power (such as +24V — Figure 2). A 0.1μF capacitor should be then connected directly from pin 12 to pin 31. Since the output and oscillator circuits are not fully isolated, a dc path must exist between the two power supply commons. A small (one or two volts) potential difference between OUT COM and OSC COM will not affect operation.

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Gain Setting

The gain of each channel is independently set by a user-supplied resistor (R_G) connected as shown in Figure 2. Channel gain will normally be selected so that the maximum output of the signal source will result in a plus or minus full scale (±5V) output swing. The resistor value required is $R_G = 10k\Omega/(G-1)$. Thus if $R_G = 101\Omega$, the gain will be 100, and an input signal swing of ±50mV will yield an output span of ±5V.

A parallel trim on the gain-setting resistor can be used to trim out the resistor's tolerance and the module's gain error (Figure 3). Since a parallel trim will always increase the gain, the value of the gain-setting resistor should be chosen to give an untrimmed gain somewhat lower than the desired trimmed gain. Good quality metal-film resistors should be used for R_G since gain accuracy and drift are a direct function of R_G's characteristics. Cermet pots are suitable for the trim.

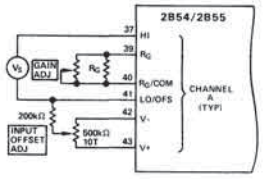


Figure 3. Input Offset and Gain Adjustments

Optional Offset Adjustment

The 2B54/2B55 has provision for fine adjustment of the input offset of each channel and the output offset of the entire module. None of the offset adjustments affect offset drift, and there is no need to make any adjustment unless the application calls for tighter offsets than those specified for the module type.

Connections for input offset adjustment are shown in Figure 3. This is a fine trim with a limited range (±250μV – 2B54 and ±1mV – 2B55, RTI), used to adjust each channel for zero offset while operating at the desired gain. Since the range of the input offset trim is small, it will usually be necessary to adjust output offset first. This can be conveniently done by operating one channel with zero input at unity gain (by disconnecting the gain resistor) and adjusting the output offset control for zero output. Connections for output offset adjustment are shown in Figure 4.

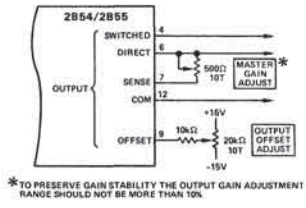


Figure 4. Output Offset and Master Gain Adjustments

An alternative offset adjustment procedure is appropriate in applications where the channel gains are field-selected by switching the gain-setting resistor. Here it is desirable to set the input offset so that there is no zero shift at the output when the gain is changed. To make the adjustment, switch back and forth from low to high gain with zero input and adjust the input offset control until no shift occurs at the output when changing gains. Then adjust the output offset control for zero output at the lower gain.

Stable components (a metal film resistor and a cermet pot) should be used for the input offset adjustment to avoid compromising drift. Output offset adjustment components are not critical and may be omitted altogether when a single 2B54/2B55 is followed by an A to D Converter that has a zero adjustment.

Channel Selection

Each channel in the 2B54/2B55 is turned on and off by a SELECT input. As indicated in Figure 1, each SELECT input consists of an LED in series with a resistor, and is not connected to any other circuits in the module. Turning the LED on ($I \geq 2.5mA$) turns the channel on, and turning the LED off ($I \leq 50\mu A$) turns the channel off. This allows considerable flexibility of connection, but the easiest way to use the SELECT inputs is to tie all four SELECT + pins to +5V and drive the SELECT–inputs from TTL logic (either open-collector or totem-pole outputs can be used), as shown in Figure 2.

It is also possible to use CMOS logic to drive the SELECT inputs (Figure 5). With a +15V logic supply a standard CMOS decoder or gate can supply enough current to drive the SELECT inputs directly, but at lower supply voltages it is advisable to use a buffer such as that shown in Figure 5b. The power taken by the SELECT inputs is small, since only one is on at a time, but at the higher CMOS supply voltages more current than the required 2.5mA will flow. This does not affect operation, but if desired the current can be brought back to the minimum value with series resistors as shown in Figure 5. Use 2kΩ for 10V operation, and 3.9kΩ at 15V.

The maximum reverse voltage applied to any SELECT input must be limited to 3V to avoid damage to the LED. Maximum forward current should be kept below 25mA. Each SELECT input is isolated from all other circuits in the module and may be operated up to ±50V away from output and power ground.

Channels may be selected in any order, and there are no restrictions on rate or duty cycle except the 2.5ms settling time for access to a channel. It should be noted, however, that selecting two or more channels simultaneously for more than a few microseconds will result in a very long settling time when the conflict is resolved. Timing overlaps should therefore be avoided.

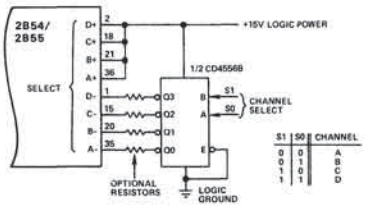


Figure 5a.

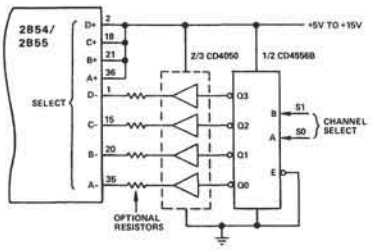


Figure 5b.

Figure 5. CMOS Channel Selection

Channel Expansion

The 2B54/2B55 has provision for directly interconnecting several modules when more than four channels are needed. The series-switched outputs of a group of modules are connected together, the SELECT inputs are driven in parallel, and the output of the desired module is selected using the Output Enable pin. This is shown in Figure 6. A single 74LS139 decoder is used to drive the SELECT inputs of up to four modules, and also provides address expansion so that the binary coded channel address word selects the appropriate module output via the Output Enable pins. The overall operation of the series-switched outputs is analogous to three-state logic, and the output rail is thus an analog bus.

It is possible to operate up to sixteen modules in parallel, for a total of 64 input channels. Note that it will be necessary to break up the SELECT inputs into several groups to avoid overloading the decoder when many modules are used. The settling time of the output switches is <50μs to ±0.01% and is thus negligible in comparison to the channel selection times.

The Output Enable signal is active low, and is compatible with both TTL and CMOS logic. The switching threshold is +1.8V; input current at 0V is typically -0.4mA.

The output resistance of the Switched Output (typically 35Ω +0.5%/°C) is low enough to provide fast switching times but will cause gain errors when driving a heavy load. A single buffet isolating the Switched Outputs from the load will solve this problem in an "analog bus" application (Figure 6). In single-module applications the DIRECT (low impedance) output should be used. Note that in all cases the SENSE pin *must* be connected to the DIRECT output to provide feedback for the output amplifier.

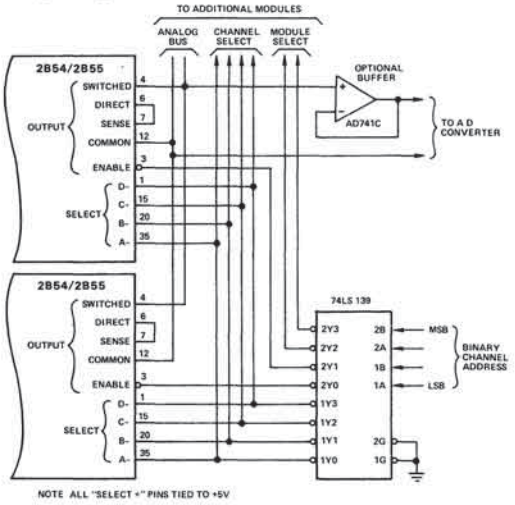


Figure 6. Expansion to More than Four Channels

Synchronization

In applications where multiple 2B54/2B55's are used in close proximity or when system clock signals are present near the isolator, differences in individual oscillator frequencies may cause "beat frequency" related output errors. To eliminate these errors, multiple units may be synchronized by connecting the SYNC OUT (pin 33) terminal to the SYNC IN (pin 32) terminal of the adjacent 2B54/2B55 (Figure 7). The first of a group of modules may be synchronized to an external source via the SYNC IN pin. To minimize noise pickup, sync wiring should be separated from analog signal runs.

The frequency of the external sync source, when used, will have a small effect on the gain and output offset of the 2B54/2B55. Thus any adjustments should be made with the module synchronized.

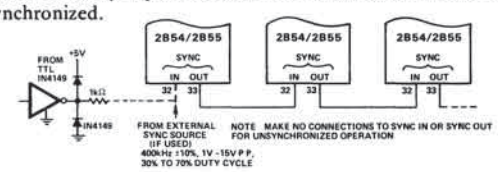


Figure 7. Synchronization

Open Input Detection

The 2B54 can be programmed to respond to an open-circuit condition on a channel input with either an upscale or downscale response when the affected channel is selected. The response time to detect an open input can be in the tens of seconds, since only a few nA of input bias current are available to charge the input filter. The circuits in Figure 8 indicate the selection of either downscale or upscale response and can be used to provide shorter open-circuit response times. Either circuit will produce a bias current of approximately 20nA which can be used to aid or oppose the 3nA typically supplied by the module, as shown. The circuit of Figure 8A has the advantage of simplicity, but the high-value resistor may not be readily available. Figure 8B shows how to solve the problem at the expense of complexity. The values shown may be modified to give an optimum trade of bias current for response time in a given application. A 2 to 5 second response is typical for the values shown.

If a downscale response is desired, a resistor divider circuit like Figure 8B may be desired to prevent a negative overscale. If a negative overscale condition occurs (typically -7V), the output will saturate on all channels.

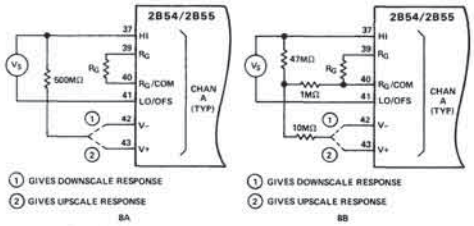


Figure 8. High Speed or Reversed Open Input Detection

Output Filtering

In most applications, no output filtering will be required since the effect of the small carrier-related noise spikes on the output (<1mV p-p, 100kHz B.W.) drops off rapidly as bandwidth decreases and in many cases will be negligible. In some applications (e.g., when driving a successive-approximation A to D) the effective system bandwidth may be large enough to pass the noise. To eliminate the carrier noise (without any effect on switching times), a simple R-C filter may be used at the output (Figure 9A). Only one filter is needed even when multiple modules are used, as shown in Figure 9B. If the load to be driven has an input resistance of less than 10MΩ, a buffer will be needed.

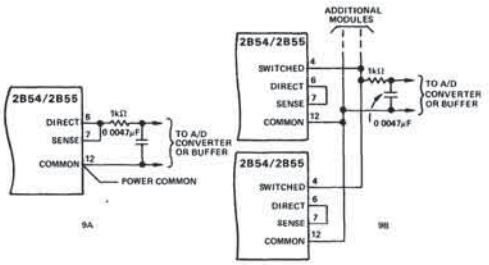


Figure 9. Output Filtering

CMR AND NMR PERFORMANCE

Common mode rejection is a result of both isolation and filtering and indicates ability to reject common mode inputs while amplifying differential signal inputs. CMR is dependent on source impedance imbalance, signal frequency and conditioner gain.

Normal mode rejection is also a function of the 2B54/2B55 gain. Figures 10 and 11 illustrate typical CMR and NMR performance. Note that any additional low pass filtering (e.g., an integrating A to D converter) at the output of the 2B54/2B55 will further improve both CMR and NMR performance.

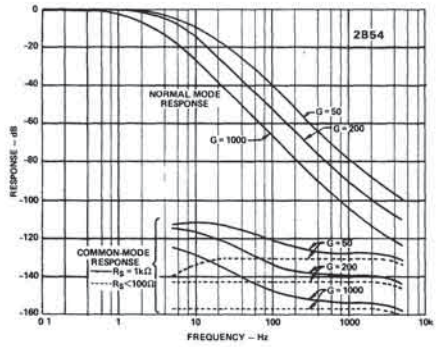


Figure 10. Common Mode and Normal Mode Response — Model 2B54

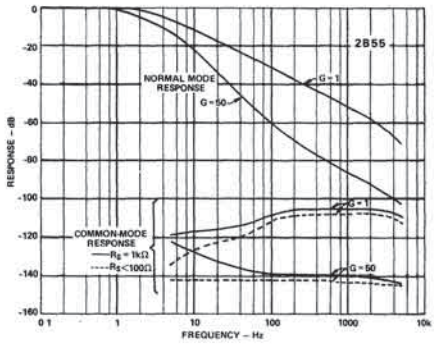


Figure 11. Common Mode and Normal Mode Response — Model 2B55

APPLICATIONS

Thermocouple Temperature Measurement: Figure 12 shows a four-channel thermocouple input system with isolation, amplification, and multiplexing provided by the 2B54. Several different thermocouple types are used, and the gain-setting resistors on each channel have been chosen to take the standard ANSI range for each type to a 5V output span. Since thermocouples must be compensated for the temperature of the reference junction which is formed where the thermocouple leads are terminated, the 2B56 Universal Cold Junction Compensator is used. The 2B56 monitors the temperature of the reference junction (terminal block) via an external sensor and corrects the signal at the output of the 2B54 for reference temperature. Compensation for several thermocouple types is selectable via digital control inputs. Thermocouple linearization, if needed, would be typically performed in system's software.

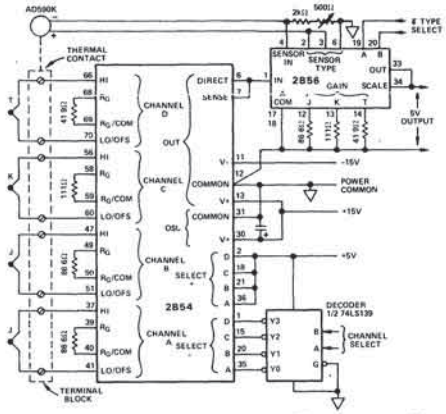


Figure 12. Four-Channel Thermocouple Temperature Measurement with Cold Junction Compensation

Process Signals Interface: In Figure 13, the 2B55 is used to provide floating inputs for four 4-20mA process signal loops. The use of floating inputs in this type of application gives protection from common-mode voltages and greatly simplifies system configuration, since additional loads in series with the loop can be connected on either side of the isolator input.

Each current input is converted into a 1 to 5 volt signal by a 250Ω resistor. The 2B55 is operated at unity gain (no gain-setting resistors) so that a 1 to 5 volt signal appears at the output. Since no gain-setting resistors are used, gain adjustment, if required, is done by connecting trims directly across the input resistors. Other current ranges can be accommodated by changing the value of the input resistors.

When there are several loads on the loop, compliance voltage at the transmitter may be at a premium. In this case it will be advantageous to reduce the voltage swing at the isolator inputs by using smaller resistors (perhaps 25Ω) and scaling the output back to a 5V span by taking an appropriate gain in the isolator.

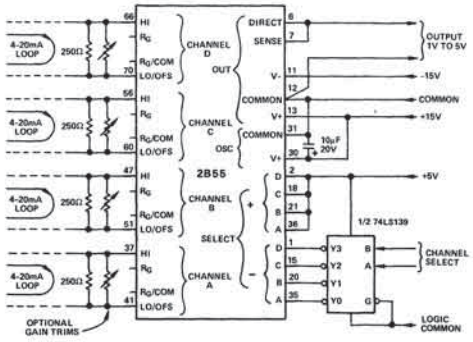


Figure 13. Isolated 4-20mA Loop Signals Interface

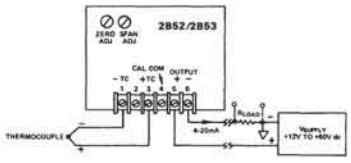
ANALOG DEVICES

Low-Cost, Two-Wire Transmitters

2B Series

The 2B Series two-wire transmitters are versatile, rugged and accurate (±0.1%) instruments designed to operate in harsh environments. All units feature RFI/EMI immunity and an operating temperature range of −30°C to +85°C. The 2B Series transmitters accept input from thermocouples (both isolated and nonisolated), RTDs, AD590 sensors and dc current or voltage sources. The thermocouple and RTD models are FM approved for intrinsically safe operation. A loop-powered isolator is also available.

2B52 and 2B53: Thermocouple Input



- Accuracy: ±0.1%
- Isolation: ±800V pk (2B52 only)
- Supply voltage range: +12V to +60V
- Load resistance range: 0 to 600Ω (at V_S = +24V)
- FM approved (2B52)

Ordering Information

Example: **Model 2B52A-1-J-03**

Enter Model
- 2B52A (Isolated)
- 2B53A (Nonisolated)

Enter Housing
- 1-standard enclosure

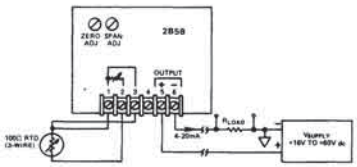
Enter Thermocouple Type
- J, K or T

Enter Temperature Range
- 01 through 06

Range in °C (°F)	TC Type	No.
−100 to +300 (−148 to +572)	J, K, T	01
0 to +200 (+32 to +392)	T	02
0 to +500 (+32 to +932)	J	03
0 to +600 (+32 to +1112)	K	04
0 to +750 (+32 to +1382)	J	05
0 to +1000 (+32 to +1832)	K	06

Custom ranging is also available.

2B58: RTD Input



- Accuracy ±0.1%
- Linearized output
- Sensor excitation: 0.5mA
- Supply voltage range: +16V to +60V
- Load resistance range: 0 to 400Ω (at V_S = +24V)
- FM approved

Ordering Information

Example: **Model 2B58A-1-1-01**

Enter Model
- 2B58A

Enter Housing
- 1-standard enclosure

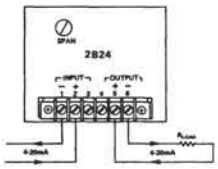
Enter RTD Type
- 1-100Ω Pt, α = 0.00385

Enter Temperature Range
- 01 through 04

Range in °C (°F)	No.
−100 to +100 (−148 to +212)	01
0 to +100 (+32 to +212)	02
0 to +200 (+32 to +392)	03
0 to +400 (+32 to +752)	04

Custom ranging is also available.

2B24: Loop-Powered Isolator



- Accuracy: ±0.1%
- Input current: 1-30mA (2B24A), 1-50mA (2B24B)
- Input voltage requirement: 3.5V plus voltage drop across output load
- Isolation: ±1500V pk

Ordering Information

Example: **Model 2B24A**

Enter Model
- 2B24A (1-30mA)
- 2B24B (1-50mA)

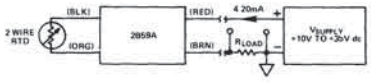
11

This two-page data summary contains key specifications to speed your selection of the proper solution for your application. Additional information on this product can be obtained from your local sales office.

TRANSMITTERS FOR ENERGY MANAGEMENT APPLICATIONS

The 2B57 in a modular form and 2B59 two-wire transmitters were specifically designed to provide low cost, small size and ease of installation in multipoint temperature monitoring applications. These transmitters can be mounted in a standard 2″ × 4″ utility box with a probe for duct temperature sensing or in wall thermostat boxes. The 2B57 is also available in a standard metal enclosure.

2B59: RTD Input



- Accuracy ±0.1%
- Supply voltage range. +10V to +35V
- Load resistance range 0 to 700Ω (at V_S = +24V)

Ordering Information

Example: **Model 2B59A-0-1-01**

Enter Model
2B59A

Enter Housing
0-Module

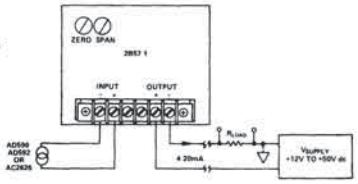
Enter Sensor Type
1-100Ω Pt, α = 0.00385
2-1000Ω NiFe, α = 0.00527
3-2000Ω NiFe, α = 0.00527

Enter Temperature Range
01 through 06

Available Temperature Ranges

Range in °C (°F)	Sensor Type	No.
−18 to +38 (0 to +100)	1, 2	01
−7 to +49 (+20 to +120)	1, 2, 3	02
+10 to +66 (+50 to +150)	1, 2	03
0 to +100 (+32 to +212)	1, 2, 3	04
−34 to +54 (−30 to +130)	3	05
+93 to +204 (+200 to +400)	3	06

2B57: Solid State Temperature Transducer Input



- AD590 or AC2626 probe input
- Accuracy ±0.1%
- Supply voltage range: +12V to +50V
- Load resistance range: 0 to 600Ω (at V_S = +24V)

Ordering Information

Example: **Model 2B57A-1**

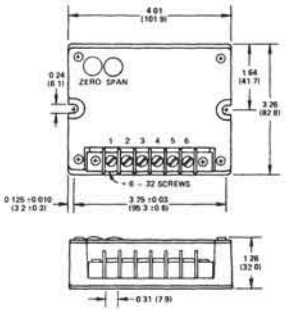
Enter Model
2B57A

Enter Housing
1-standard enclosure

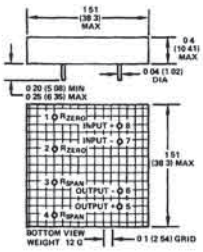
Outline Dimensions

Dimensions shown in inches and (mm)).

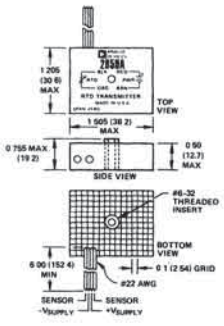
2B24, 2B52, 2B53, 2B57, 2B57A-1, 2B58



2B57



2B59



The Complete Signal Conditioning I/O Subsystem

3B Series

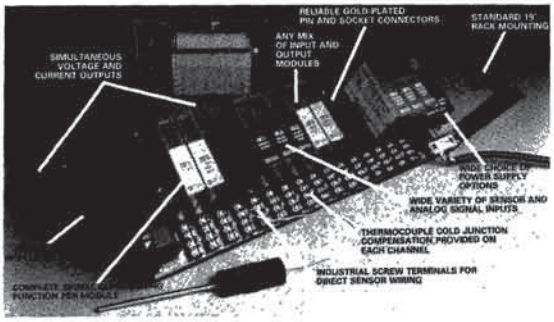
FEATURES/BENEFITS

Low Cost, Completely Integrated 16-Channel Modular Signal Conditioning Subsystem
- **Wide Selection of Functionally Complete Input and Output Plug-In Modules**
- **Rugged Industrial Chassis, Rack or Surface Mounted**
- **On-Board Power Supplies Available**

Analog Input Modules Available for Direct Interface to a Wide Variety of Signal Sources
- **Thermocouples, RTDs, Strain Gages, LVDTs**
- **Millivolt, Voltage and Frequency Sources,**
- **4-20mA/0-20mA Process Current Inputs**

Current Output Modules
- **4-20mA/0-20mA Outputs**

Complete Signal Conditioning Function
- **Input Protection, Filtering, Amplification,**
- **Galvanic Isolation to ±1500V,**
- **Wide-Range Zero Suppression,**
- **High Noise Rejection and RFI/EMI Immunity,**
- **Simultaneous Voltage and Current Outputs**



GENERAL DESCRIPTION

The 3B Series Signal Conditioning I/O Subsystem provides a low cost, versatile method of interconnecting real-world analog signals to a data acquisition, monitoring or control system. It is designed to interface directly to analog signals such as thermocouple, RTD, Strain Gage, or AD590/AC2626 solid state temperature sensor outputs or millivolt or process current signals and convert the inputs to standardized analog outputs compatible with high level analog I/O subsystems.

The 3B Series Subsystem consists of a 19" relay rack compatible universal mounting backplane and a family of plug in (up to 16 per rack) input and output signal conditioning modules. Eight and four channel backplanes are also available. Each backplane incorporates screw terminals for sensor inputs and current outputs and a connector for high level single ended outputs to the user's equipment.

The input and output modules are offered in both isolated (±1500V peak) and nonisolated versions. The input modules feature complete signal conditioning circuitry optimized for specific sensors or analog signals and provide high level analog outputs. Each input module provides two simultaneous outputs: 0 to 10V (or ±10V) and 4-20mA (or 0-20mA). Output modules accept high level single ended signals and provide an isolated or nonisolated 4-20mA (or 0-20mA) process signal. All modules feature a universal pin-out and may be readily "mixed and matched" and interchanged without disrupting field wiring.

Each backplane contains the provision for a subsystem power supply. The 3B Series Subsystem can operate from a dc/dc converter or ac power supply mounted on each backplane or from externally provided dc power. Two LEDs are used to indicate that power is being applied.

APPLICATIONS

The Analog Devices 3B Series Signal Conditioning Subsystem is designed to provide an easy and convenient solution to signal conditioning problems in measurement and control applications. Some typical uses are in mini- and microcomputer based systems, standard data acquisition systems, programmable controllers, analog recorders, dedicated control systems, and any other applications where monitoring and control of temperature, pressure, flow, and analog signals are required. Since each input module features two simultaneous outputs, the voltage output can be used to provide an input to a microprocessor based data acquisition or control system while the current output can be used for analog transmission, operator interface, or an analog backup system.

DESIGN FEATURES AND USER BENEFITS

Ease of Use: Direct sensor interface via screw terminals, standardized high level outputs, factory precalibration of each unit and the modular design make the 3B Series Subsystem extremely easy to use. The subsystem features rugged packaging for the industrial environment and can be easily installed and maintained.

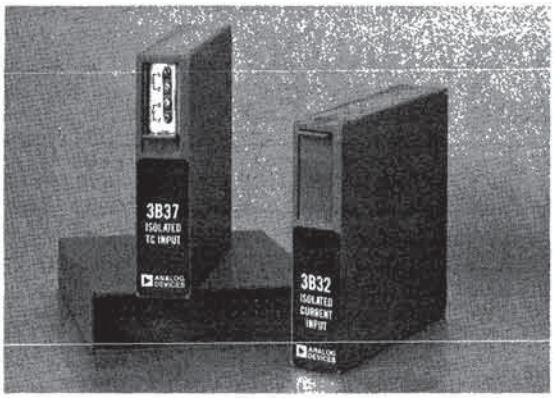
High Protection and Reliability: All field wired terminations offer 130V or 220V rms normal-mode protection. To assure connection reliability, gold plated pin and socket connections are used throughout the system. The isolated modules offer protection against high common-mode voltages and are designed to meet the IEEE Standard for Transient Voltage Protection (472–1974: SWC).

High Performance: The high quality signal conditioning features ±0.1% calibration accuracy and chopper-based amplification which assures low drift (±1μV/°C) and excellent long-term stability. For thermocouple applications, high accuracy cold junction sensing is provided in the backplane on each channel. Low drift sensor excitation is provided for RTD and strain gage models. For RTD models, the input signal is linearized to provide an output which is linear with temperature.

This four-page data summary contains key specifications to speed your selection of the proper solution for your application. Additional information on this product can be obtained from your local sales office.

FEATURES

Wide Variety of Sensor Inputs
Thermocouples, RTDs, Strain Gages, LVDTs, AD590/AC2626
Dual High Level Outputs
Voltage: 0 to +10V or ±10V
Current: 4-20mA/0-20mA
Mix and Match Input Capability
Sensor Signals, mV, V, 4-20mA, 0-20mA
High Accuracy: ±0.1%
Low Drift: ±1μV/°C
Reliable Transformer Isolation:
±1500V CMV, CMR =160dB
Meets IEEE-STD 472: Transient Protection (SWC)
Input Protection: 130V or 220V rms Continuous
Low Cost Per Channel



GENERAL DESCRIPTION

Each input module is a single channel signal conditioner that plugs into sockets on the backplane and accepts its signal from the input screw terminals. All input modules provide input protection, amplification and filtering of the input signal, accuracy of ±0.1%, low drift of 1μV/°C (low level input modules), and feature two high level analog outputs that are compatible with most process instrumentation. The isolated input modules also provide ±1500V isolation.

The choice of specific 3B module depends on the type of input signal and also whether an isolated or nonisolated interface is required. Input modules are available to accept millivolt, volt, process current, thermocouple, RTD, strain gage, and AD590 inputs. The voltage output of each module is available from the voltage I/O connector while the current output is available on the output screw terminals.

THERMOCOUPLE INPUT MODELS 3B37, 3B47

The isolated thermocouple models incorporate cold junction compensation circuitry which provides an accuracy of ±0.5°C over the +5°C to +45°C ambient temperature range. Open thermocouple detection (upscale) is also provided. Standard models are available for thermocouple types J, K, T, E, R, S and B. Factory configured custom ranges are also available. The 3B37-X-00 can be user configured with the AC1310 ranging card. The 3B47 internally linearizes the thermocouple signal. All screw terminals have a 220V rms protection.

RTD INPUT MODELS 3B14, 3B15, 3B34

Each RTD model provides a sensor excitation current and produces an output signal that is linear with temperature with a conformity error of ±0.05% of span and accuracy of ±0.1% span. The lead resistance effect for the three models is ±0.02°C/Ω for the 3B14 and the 3B34, and ±.00001°C/Ω for the 3B15. All excitation input and output screw terminal connections have at least 130V rms protection.

STRAIN GAGE INPUT MODEL 3B16

Models 3B16 accepts inputs from full four arm bridge strain gage-type transducers. It provides a constant +10V bridge excitation and can be used with a bridge resistance of 300Ω or greater. All excitation input and output screw terminal connections have 130V rms protection.

WIDEBAND STRAIN GAGE MODEL 3B18

Model 3B18 accepts inputs from full four arm bridge strain gage-type transducers. It provies a switch selectable excitation of +3.3V or +10.0V and can be used with 100Ω to 1000Ω strain gage bridges. The module has a 20kHz bandwidth to interface to dynamic signals.

MILLIVOLT AND VOLTAGE INPUT MODELS 3B10, 3B11, 3B30, 3B31

Models 3B10 and 3B11 are nonisolated modules that accept mV and V signals respectively. Models 3B30 and 3B31 are isolated modules that accept mV and V signals respectively. All screw terminal connections have at least 130V rms protection.

WIDEBAND MILLIVOLT AND VOLT INPUT MODELS 3B40, 3B41

Models 3B40 and 3B41 are isolated modules that accept mV and V signals respectively. The modules have a 10kHz bandwidth to interface to dynamic signals. All screw terminal connections have at least 130V rms protection.

CURRENT INPUT MODELS 3B12, 3B32

Models 3B12 (nonisolated) and 3B32 (isolated) accept process current signals. Both models use a 100Ω sensing resistor that is mounted on backplane terminals 2 and 3. All screw terminal connections have at least 130V rms protection.

AD590 INPUT MODEL 3B13

Model 3B13 accepts an AD590 as its input signal. Sensor excitation is provided and a 2kΩ sensing resistor is mounted on backplane terminals 2 and 3. All excitation input and output screw terminal connections have 130V rms protection.

LVDT OR RVDT INPUT MODEL 3B17

Model 3B17 accepts signals from 4, 5 and 6 wire LVDT or RVDT transducers. It provides an ac excitation of 1-5V rms at frequencies ranging from 1kHz to 10kHz and has a 100Hz bandwidth. All screw terminal connections have 130V rms protection.

AC INPUT MODELS 3B42, 3B43 AND 3B44

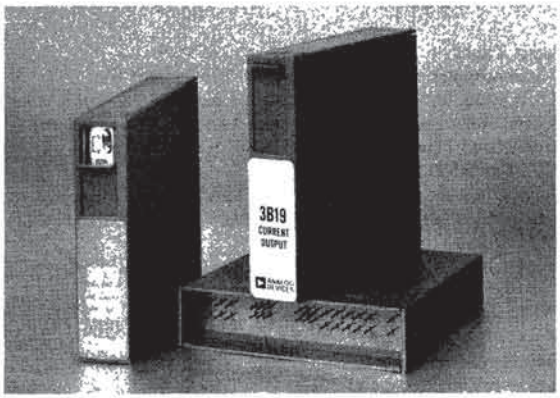
Models 3B42, 3B43, and 3B44 accept ac signals from 20mV to 450V rms. The modules are rms calibrated for sinusoidal inputs, such as ac power lines. All screw terminal connections have at least 130V rms protection.

FREQUENCY INPUT MODELS 3B45, 3B46

Models 3B45 and 3B46 accept frequency input signals from 25Hz to 25kHz. User selectable thresholds of 1.6V and 0V (for zero crossing) are available. All screw terminal connections have at least 130V rms protection.

Output Modules

FEATURES
High Level Voltage Input (0 to +10V, ±10V)
Process Current Output (4-20mA/0-20mA)
High Accuracy: ±0.1%
Reliable Transformer Isolation: ±1500V CMV, CMR = 90dB
Meets IEEE-STD 472: Transient Protection (SWC)
Output Protection: 130V or 220V rms Continuous
Reliable Pin and Socket Connections
Low Cost Per Channel



GENERAL DESCRIPTION

Each output module accepts a high level analog signal from the system connector and provides a current output on the output screw terminals. When a +24V loop supply is used, loads up to 850Ω can be driven. If desired, +15V can be used to power the output modules with a smaller load (up to 400Ω). Each output module features high accuracy of ±1%. If isolation is required, the 3B39 provides ±1500V peak common-mode voltage isolation protection.

NONISOLATED OUTOUT MODEL 3B19

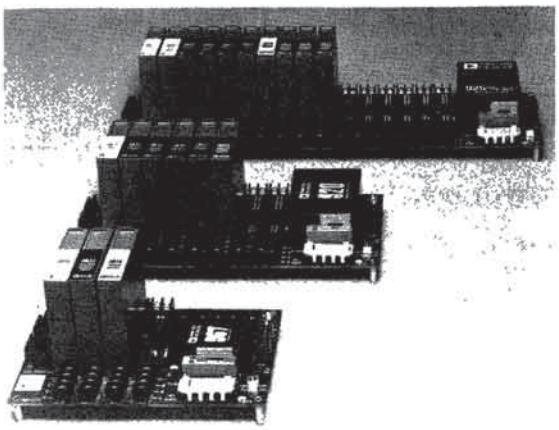
The 3B19 output module accepts a 0 to +10V or ±10V input signal and converts it to a proportional current output. Output ranges are jumper selectable for either 0-to 20mA or 4-to-20mA. The current output is protected to 130V rms continuous.

ISOLATED OUTPUT MODEL 3B39

Model 3B39 is an isolated module that accepts a 0 to +10V or ±10V input signal and converts it to a proportional current output. Output ranges are jumper selectable for either 0-to-20mA or 4-to-20mA. Input to output isolation is rated to 1500V pk continuous.

Backplanes

FEATURES
4-, 8-, or 16-Channel Versions Available
ac or dc Power Supply Options



GENERAL DESCRIPTION

The three backplane models, 3B01, 3B02 and 3B03 are designed for 16, 8 and 4 channels, respectively, to give users the flexibility to match the size of a system to specific applications. The 16-channel backplane can be mounted in a 19" × 5.25" panel space. The backplanes can be surface mounted, mounted on a rack or mounted in a NEMA enclosure.

POWER SUPPLY

The 3B Series Subsystem can operate from a common ac power supply or dc/dc (+24V input) power supply mounted on the backplane or an externally provided ±15V and +24V supply. The power supply is bussed to all signal conditioners in the system. The current consumption is a function of the modules that are actually used.

3B Series Subsystem Specifications

INPUT MODULES

Input Types
Thermocouples: J, K, T, E, R, S, B
Thermocouples: J, K, T, E, R, S, B (Linearized)
RTDs: 100Ω Platinum, 10Ω Copper, 120ΩNickel (Linearized)
Strain Gage Transducers: ±30mV and ±100mV spans
LVDT or RVDT: 4, 5, 6 Wire
Solid State Temperature Transducers: AD590 or AC2626
DC Voltage: ±10mV, ±50mV, ±100mV ±1V, ±5V, ±10V
DC Current: 4-to-20mA, 0-to-20mA
AC Voltage: 0-50mV rms, 0-100mV rms, 0-10V rms, 0-150V rms, 0-250V rms
Frequency: 0-25Hz, 0-300Hz, 0-1500Hz, 0-3000Hz, 0-25kHz

Outputs (Simultaneous)
0 to +10V or ±10V and
4-to-20mA or 0-to-20mA*

Performance
Accuracy: ±0.1% of span
Nonlinearity: ±0.01% of span
Bandwidth: 3Hz (−3dB)

Isolated Modules
Common-Mode Voltage, Input to Output: ±1500V pk continuous
Transient Protection: Meets IEEE-Std 472 (SWC)
Normal-Mode Input Protection: 220V rms continuous
Current Output Protection: 130V rms continuous
Common-Mode Rejection @ 50Hz or 60Hz: 160dB
Normal-Mode Rejection @ 50Hz or 60Hz: 60dB

Nonisolated Modules
Common-Mode Voltage: ±6.5V
Normal-Mode Input Protection: 130V rms continuous
Current Output Protection: 130V rms continuous
Common-Mode Rejection @ 50Hz or 60Hz: 90dB
Normal-Mode Rejection @ 50Hz or 60Hz: 60dB

OUTPUT MODULES

Input
0 to +10V or ±10V

Output
4-to-20mA or 0-to-20mA

Performance
Accuracy: ±0.1% of span
Nonlinearity: ±0.01% of span

Isolated Module
Common-Mode Voltage,
Input to Output: ±1500V pk continuous
Current Output Protection
Transient: Meets IEEE-Std 472 (SWC)
Continuous: 220V rms

Nonisolated Module
Current Output Protection: 130V rms continuous

*There is no current output on the 3B47.
Specifications subject to change without notice.

BACKPLANES

Channel Capacity
3B01: 16 channels
3B02: 8 channels
3B03: 4 channels

POWER SUPPLIES

Backplane Mounted:
100, 115, 220, 240V ac, 50/60Hz
or +24V dc
External Power Option
±15V dc and +24V dc

MECHANICAL

Input or Output Modules:
3.150″ × 0.775″ × 3.395″
(80.0mm × 19.7mm × 86.2mm)
Backplanes:
3B01: 17.40″ × 5.20″ × 4.37″
(442.0mm × 132.1mm × 111.1mm)
3B02: 11.00″ × 5.20″ × 4.37″
(279.4mm × 132.1mm × 111.1mm)
3B03: 7.80″ × 5.20″ × 4.37″
(198.1mm × 132.1mm × 111.1mm)

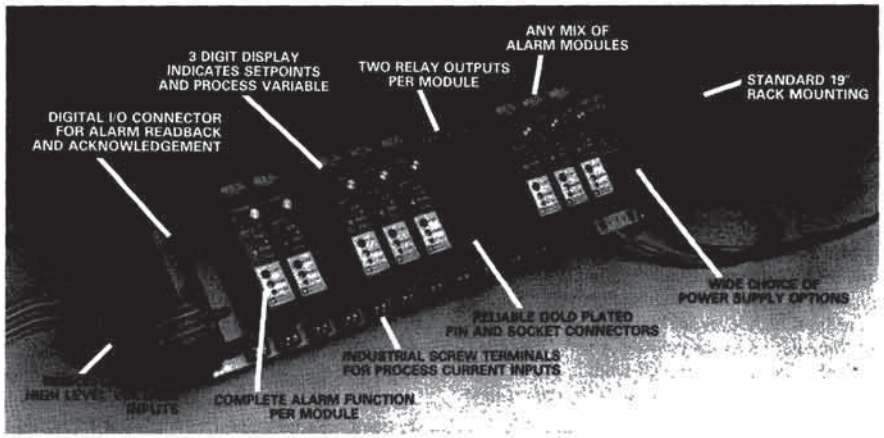
ENVIRONMENTAL

Temperature Range, Rated Performance:
−25°C to +85°C
Storage Temperature Range:
−55°C to +85°C
Relative Humidity: Conforms to MIL-STD 202, Method 103
RFI Susceptibility: ±0.5% span error, 5W @ 400MHz @ 3 ft.

ANALOG DEVICES

Alarm Limit Subsystem

4B Series



FEATURES/BENEFITS

- **Low Cost, Completely Integrated 12-Channel Modular Alarm Limit Subsystem**
  - **Selection of Alarm Limit Modules**
  - **Rugged Industrial Chassis, Rack or Surface Mounted**
  - **On-Board Power Supplies Available**
- **Alarm Modules Accept High Level Voltage and Process Current Inputs**
- **Complete Alarm Function per Module**
  - **High Accuracy of ±0.1%**
  - **Two Set Points, Adjustable Over 100% Span**
  - **Dead Band Adjustment per Set Point, Adjustable Over 0.5%–10.0% Span**
  - **Alarm Types are Configurable for HI or LO Operation**
  - **Two Relay Outputs**
  - **Three Digit Display Indicates Set Points and Process Variable as a Percent of the Input Span**
  - **LED per Set Point Provides Local Alarm Indication**
  - **Input Protection**
  - **High RFI/EMI Immunity**
- **Specifications Valid Over the 0 to +70°C Temperature Range**
- **Easy to Install, Calibrate and Service**
  - **Direct Connections to Industrial Screw Terminals**
  - **Modules Removable without Disturbing Field Wiring or Power**
  - **Front Panel Set Point and Dead Band Adjustments**
- **Convenient Connection to User's Equipment**
  - **Interfaces Directly to Analog Output Subsystems**
  - **Used for Single Board Computer Interfaces**
  - **Universal Adapter Board Allows Easy Interface to Any Equipment**

This two-page data summary contains key specifications to speed your selection of the proper solution for your application. Additional information on this product can be obtained from your local sales office.

GENERAL DESCRIPTION

The 4B Series Alarm Limit Subsystem is a low cost method of providing adjustable alarm limits. Used in conjunction with either the 5B Series, the 3B Series or a module in the 2B Series transmitter family, the 4B Series' modules provide alarms for a wide variety of process sensors and transducers. The Alarm Limit Subsystem accepts a high level signal and provides fully independent HI and LO relay outputs.

The subsystem consists of a 19" relay rack compatible universal mounting backplane and a family of plug-in (up to 12 per rack) alarm limit modules. A four channel backplane is also available. The modules, designed for voltage or current inputs, can be readily mixed and matched and interchanged without disturbing field wiring. Each backplane incorporates screw terminals for field wiring and a connector for high level single ended inputs from the user's equipment.

Each alarm module has two set points which are fully adjustable over the 100% span. It will accept a standardized high level analog input and will provide one or two ON/OFF outputs. The allowable input ranges are ±10V, 0 to +10V, 4-20mA and 0-20mA. All input types can be connected to either the voltage input connector or the input screw terminals.

The two set points within each module can be user configured with push-on jumpers for HI-LO, HI-HI or LO-LO use. If only one limit per channel is desired, the module can be used in a HI or LO state. The value of each set point and the process variable can be viewed with a 3 digit display which is controlled with a rotary switch. Each set point has an adjustable dead band (hysteresis) which can be adjusted up to 10% of span and can be used to eliminate nuisance alarms.

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DESIGN FEATURES AND USER BENEFITS

Direct interface via screw-terminals or ribbon cable, two screwdriver adjustable set points per module, adjustable dead band per set point, a three digit display that indicates the value of the process variable and set points, and the modular design make the 4B Series Subsystem extremely easy to use. The subsystem features rugged packaging for the industrial environment and can be easily installed and maintained.

All input screw terminals offer 130V rms normal mode protection. Connection reliability is assured by gold plated pin and socket connectors. The high quality alarm modules feature ±0.1% accuracy and a low drift with temperature (±0.005%/°C).

APPLICATIONS

The Analog Devices' 4B Series Alarm Limit Subsystem provides an easy and convenient solution to alarm/annunciation problems in measurement and control applications. When used with field transmitters or any other device that provides a process current or high level voltage output, it can provide either alarm indication or ON/OFF control. In a typical application, the 4B Series Alarm Subsystem provides alarm indication for any sensor input when used with the 3B Series Signal Conditioning Subsystem. The 3B Series interfaces directly to sensors and converts the inputs to the standardized high level analog signal that the 4B Series alarms. This modular approach provides a very flexible means to alarm indication since the same 4B module can be used to alarm a variety of sensors when used with the appropriate 3B module.

FUNCTIONAL DESCRIPTION

Each alarm module is a single channel unit that plugs into sockets on the backplane and accepts its signal from either the input screw terminals or the voltage input connector. All alarm modules provide input protection, filtering of the input signal, accuracy of ±0.1% and feature two relay outputs that are capable of driving loads up to 3A.

The choice of a specific 4B module depends on whether the input signal is a high level voltage or a process current. The voltage inputs can be connected to a 4B module by either the input screw terminals or the voltage input connectors. Process currents can also be connected through either the screw terminals or the voltage input connector, but must use a sensing resistor. The current input models are shipped with the required sense resistor, which is to be installed on the input screw terminals.

The transfer function provided by each alarm module is:
Inputs: High level voltage or process current
Outputs: Two independent ON/OFF Relay Outputs

Figure 1 shows a functional diagram for the model 4B10 alarm limit module which has been configured for HI-LO operation. The high level voltage input signal is filtered and compared against both set points. If the process variable is above the HI limit or below the LO limit, the appropriate relay is turned on.

Each set point has an adjustable dead band (0.5%–10.0% span), which is used to eliminate nuisance alarms. Dead band is the amount of signal change necessary, after an alarm has occurred, to return an alarm to its original condition. As an example, if the HI limit is set at 75% of span and the dead band is 2%, the alarm will turn on when the process variable is at 75% and will not turn off until the process variable falls to 73%. For a LO limit configuration, the dead-band relationship is reversed and the alarm would not turn off until the process variable has risen above the sum of the LO set point value and the dead-band value.

Each set point has an LED which turns on when an alarm condition occurs and provides local alarm indication.

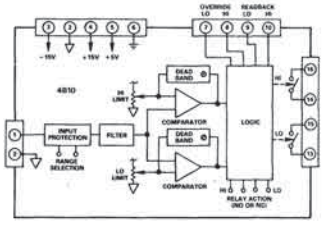


Figure 1. 4B10 Functional Block Diagram

The alarm status of both limits can be read externally from the digital I/O connector. When an alarm state exists which is TTL active high on the readback pins, the relay can be turned off with an external override signal (TTL active low) that connects to the digital I/O connector. The readback/override feature allows for external monitoring of the alarm states as well as for external control or alarm acknowledgement. When an override signal is used, the readback feature reads the alarm state and not the relay input signal so that the state of the process variable can still be monitored.

For the modules with a display, positive overload is indicated by]]] and negative overload is indicated by a [in the left most position.

The 4B modules have five user programmable jumper options. Each unit can be configured for unipolar or bipolar inputs, both set points can be configured for HI or LO limit operation, and both relays can be configured for Normally Open (NO) or Normally Closed (NC) operation. These options allow the user to readily tailor the 4B units to his specific needs. For instance, if HI-HI operation were required, it is available by changing the appropriate jumpers. All modules are shipped from the factory configured for unipolar input, NO relay action, and HI-LO operation.

4B MODULE SPECIFICATIONS

(typical @ +25°C and ±15V, +5V dc power)

Model	4B10, 4B20	4B11, 4B21	4B12, 4B22
Inputs[1]	0 to +10V, ±10V	0–20mA	4–20mA
Outputs (2 SPST Relays)	Resistive Rating. 3A @ 120V ac or 24V dc	*	*
Performance			
Accuracy[2]	±0 1% span	*	*
Temperature Stability	±0.005% span/°C	*	*
Bandwidth[3]	5Hz (−3dB)	*	*
Normal Mode Input Protection	130V rms	*	*
Normal Mode Rejection @ 50Hz or 60Hz	20dB	*	*
Input Resistance[4]	100MΩ	*	*
Warm-Up Time to Rated Performance	3 Minutes	*	*
Features			
Two Set Points per Module	Adjustable over 100% span by 25 turn potentiometers	*	*
Dead band per Set Point	0.5%–10.0% span, adjustable by 1 turn potentiometer	*	*
Relay Action	Field reversible by jumper change	*	*
Three Digit Display[5]	0–99.9% of input span	*	*
Alarm Status Readback	TTL Level	*	*
External Override Signal	TTL Level	*	*
Power Supply			
Voltage, Rated Performance	±15V, +5V	*	*
Voltage, Operating	±12V to ±18V, +4.5V to 5.5V	*	*
Current[6]	±12mA, +150mA	*	*
Size[7]	4.020" × 1.050" × 4.020"	*	*
Environmental			
Temperature Range, Rated Performance	0 to +70°C	*	*
Storage Temperature Range	−25°C to +85°C	*	*
Relative Humidity, Conforms to MIL Std 202, Method 103B	0 to 95% @ 60°C, noncondensing	*	*
RFI Susceptibility	±0.5% span error, 5W @ 400MHz @ 3 ft.	*	*

NOTES
[1]Voltage input range is jumper selectable
[2]Accuracy includes setability, repeatability, linearity, and hysteresis Models 4B10, 4B11, and 4B12 have a quantization error of ±1 dgit
[3]Unipolar inputs only Bipolar inputs have a bandwidth of 10Hz (−3dB)
[4]Unipolar inputs only Bipolar inputs have an input resistance of 400kΩ
[5]Only models 4B10, 4B11 and 4B12 have a three dgit display
[6]Only models 4B10, 4B11 and 4B12 Models 4B20, 4B21 and 4B22 require ±12mA for ±15V and +125mA from +5V
[7]Only applies to models 4B10, 4B11 and 4B12 Models 4B20, 4B21 and 4B22 measure 4 020" × 1 050" × 3 530"
*Specifications same as 4B10, 4B20
Specifications subject to change without notice

ANALOG DEVICES

Compact, Low-Cost Modular Signal Conditioners

5B Series

FEATURES

- **Rugged, Compact, Low Cost Signal Conditioners**
- **Analog Input Modules for Direct Interface to Sensors: Thermocouples and RTDs Millivolt and Voltage Sources 4-20mA or 0-20mA Process Current Inputs**
- **Analog Output Module 4-20mA or 0-20mA Process Current Output**
- **Complete Signal Conditioning Function 240V rms Field Wiring Protection, Filtering, Amplification, 1500V rms CMV Isolation, High Noise Rejection, RFI/EMI Immunity, and Wide Range Zero Suppression**
- **High Accuracy: ±0.05%**
- **Low Drift: ±1μV/°C**
- **−25°C to +85°C Temperature Range**
- **Mix and Match Module Capability**
- **Convenient Connection to User's Equipment**
- **Simplified Designer Application**



The 5B Series provides system designers with an easy to use solution for analog I/O in a minimum of board space. The modules' simple pinout and easy mechanical application simplify design.

There are also a number of backplanes which provide a complete signal conditioning solution for end users. Each backplane incorporates screw terminals for field wiring inputs and outputs and cold junction compensation sensors for thermocouple applications. Nineteen-inch relay rack compatible units that can hold up to sixteen modules are available.

GENERAL DESCRIPTION

The 5B Series represents a new generation of low cost, high performance plug-in signal conditioners. Designed for industrial applications, these modules incorporate a new circuit design utilizing transformer-based isolation and automated surface mount manufacturing technology. They are remarkably compact, economical components whose performance exceeds that available from more expensive devices. Combining 1500V rms continuous CMV isolation, ±0.05% calibrated accuracy, small size and low cost, the 5B Series is an attractive alternative to expensive signal conditioners and in-house designs.

All modules are hard potted and identical in pinout and size (2.25″×2.25″×0.60″). They can be mixed and matched, permitting users to address their exact needs, and may be changed without disturbing field wiring. The isolated input modules provide 0 to +5V outputs and accept J, K, T, E, R, S, and B thermocouples; 100Ω platinum, 10Ω copper and 120Ω nickel RTDs; mV, V, 4-20mA or 0-20mA, and wide bandwidth (10kHz) mV and V signals. These modules feature complete signal conditioning functions including 240V rms input protection, filtering, chopper stabilized low drift (±1μV/°C), amplification, 1500V rms isolation, linearization for RTD and thermocouple (with 5B47) inputs and sensor excitation when required. The output module converts a 0 to +5V input to an isolated 4-20mA or 0-20mA process current signal. All modules feature excellent common mode rejection and meet IEEE 472-1974 surge withstand specs.

APPLICATIONS

These signal conditioners are designed to provide an easy and convenient solution to signal conditioning problems of both designers and end users in measurement and control applications. Typical uses include mini- and microcomputer-based measurement systems, standard data acquisition systems, programmable controllers, analog recorders, and dedicated control systems. The 5B Series modules are ideally suited to applications where monitoring and control of temperature, pressure, flow, and other analog signals are required.

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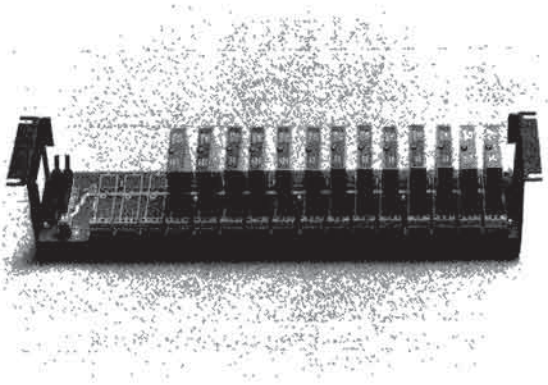
DESIGN FEATURES AND USER BENEFITS

System Design: It is easy for a system designer to apply the functionally complete 5B Series modules in his own circuit board or backplane. These modules feature a simple pinout, plug into widely available sockets and are secured with self-contained mounting screws. Other features, which can be used to minimize system interface cost, have also been incorporated in the 5B Series design. Each input module has an output switch which is controlled by a TTL-compatible enable input, eliminating the need for an external multiplexer. Each output module has a track and hold input which permits a single DAC to serve numerous current output channels. For thermocouple applications, cold junction compensation sensors are available.

Subsystem Solution: The 5B Series provides a complete signal conditioning solution. A family of backplanes, plug-in modules, factory precalibration of each unit, direct sensor interface via screw terminal connections, standardized high level outputs, and ribbon cable system interface result in easy integration into any system. For thermocouple applications, high accuracy cold junction compensation sensing is provided on each channel. A general susbsystem application is outlined in Figure 1.

Flexibility: The 5B Series can be easily tailored to meet each user's needs. These plug-in signal conditioners can be mixed and matched to provide I/O for various process sensors and actuators. Many standard configurations of each module are available, and, for added flexibility, factory laser trimmed custom units can be supplied. A wide zero suppression capability allows a user to map any portion of the input signal into the full ouput span permitting improved system resolution within a selected measurement range.

High Reliability: The 5B Series was designed to assure maximum reliability under real-world conditions. The modules are specified over the −25°C to +85°C temperature range. Each module is hard potted; there are no adjustment potentiometers which could introduce mechanical and human errors that impair system integrity. All field wired terminations, including sensor inputs, excitations and current outputs, are protected against continuous 240V rms line voltage. This prevents a fault from damaging not only the module itself but also the backplane and other devices connected to the system. The modules also provide protection



against high common-mode voltages and are designed to meet the IEEE standard for transient voltage protection (472-1974: SWC). Gold plated pin and socket connections are used throughout the system to assure connection reliability.

High Performance: The high quality signal conditioning features ±0.05% calibration accuracy, nonlinearity of only ±0.02% span, and chopper-based amplification which assures low drift (±1μV/°C) and excellent long-term stability. Low drift sensor excitation is provided when required, and the RTD module provides an output which is linear with temperature.

High Noise Rejection: The 5B Series Modules were designed to accurately process low level signals in electrically noisy environments by providing 1500V rms continuous transformer isolation which eliminates ground loops, protects against transients and solves common-mode voltage problems. To further preserve signal integrity, 160dB common-mode rejection, 60dB normal-mode rejection and excellent RFI/EMI immunity are provided.

Small Size: Each 5B Series module measures only 2.25″ × 2.25″ × 0.60″ resulting in space savings for both system designers and end users: each module occupies 1.35 square inches of board space and a 16-channel backplane occupies only 3.5 inches in a rack.

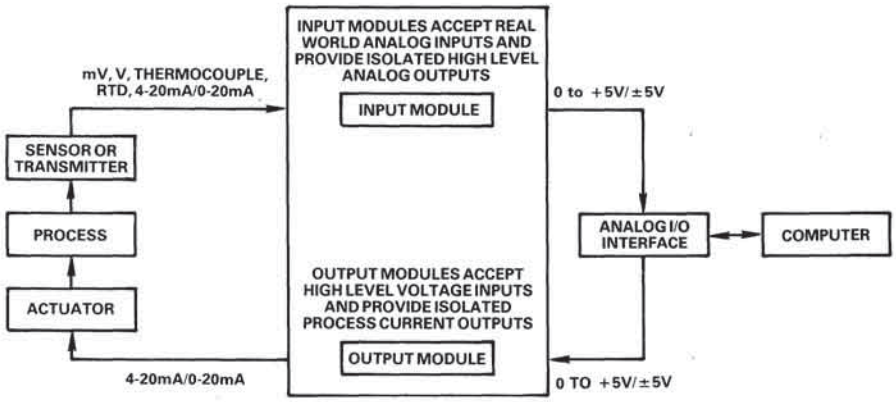
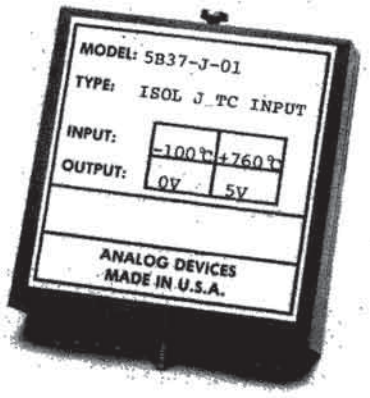


Figure 1. Functional Block Diagram of a General Measurement and Control Application Using the 5B Series

INPUT MODULE FEATURES

- **Variety of Signal Source Inputs**
  Sensors: Thermocouples and RTDs
  Millivolt and Voltage Sources
  4-20mA or 0-20mA Process Current Inputs
- **Mix and Match Input Capability**
- **High Level Voltage Output: ±5V or 0 to +5V**
- **High Accuracy: ±0.05%**
- **Low Drift: ±1μV/°C**
- **Reliable Transformer Isolation: 1500V rms CMV, 160dB CMR, Meets IEEE-STD 472: Transient Protection (SWC)**
- **Input Protection: 240V rms Continuous**
- **Factory Ranged and Trimmed, Custom Ranges Available**



GENERAL DESCRIPTION

The galvanically isolated 5B Series input modules are single channel, plug-in signal conditioners that provide input protection, amplification and filtering, series output switching, and a high level analog output. Key specifications include: 1500V rms isolation, accuracy of ±0.05%, ±0.02% span nonlinearity and low drift of ±1μV/°C. All modules operate from a single +5V supply with typical power consumption of 0.15W. The modules, which measure only 2.25″×2.25″×0.60″, are hard potted.

The transfer function provided by each input module is:
Input – specified sensor measurement range
Output – 0 to +5V or ±5V.

Each 5B Series input module is available in a number of standard ranges, and special ranges can be factory configured. Analog Devices will provide a special function when a model 5B__ __ -CUSTOM is ordered with the desired range.

5B37 FUNCTIONAL DESCRIPTION

Figure 2 shows a functional diagram for a typical input module, the 5B37 thermocouple conditioner. The module provides cold junction compensation for the associated screw terminals as well as a bias current to give a predictable (upscale) response to an open thermocouple. Input protection allows safe operation even in the event of a 240V rms power line being connected to the signal terminals. (In modules designed to work with sensors requiring excitation, low drift sensor excitation is provided and is protected at the same level).

A three-pole filter with a 4Hz cutoff provides 60dB of normal-mode rejection and CMR enhancement at 60Hz. One pole of this filter is located at the module input while the other two poles are in the output stage for optimum noise performance. A chopper-stabilized input amplifier provides all of the module's gain for ultra-low drift. This amplifier operates on the input signal after subtraction of a stable, laser trimmed zero-suppression signal which sets the zero-scale input value. It is, therefore, possible to suppress a zero-scale input which is many times the total span to provide precise expanded scale measurements.

Signal isolation is provided by transformer coupling, using a proprietary modulation technique for exceptionally linear, stable performance at low cost. A demodulator on the output side of the signal transformer recovers the original signal, which is then filtered and buffered to provide a clean, low-impedance output. A series output switch is included to eliminate the need for external multiplexing in many applications. This switch has a low output resistance (50Ω) and is controlled by an active-low enable input which is compatible with CMOS and LSTTL signals. In cases where the output switch is not used, such as single-channel and conventionally multiplexed applications, the enable input should be grounded to power common to turn on the switch.

A single +5V power supply input (as used for all 5B Series modules) operates a clock oscillator which drives power transformers for the input and output circuits. The input circuit is, of course, fully floating. In addition, the output section acts as a third floating port, eliminating many problems that might be created by ground loops and supply noise. The common-mode range of the output circuit is limited; however, output common must be kept within ±3V of power common, and a current path must exist between the two commons at some point for proper operation of the demodulator and output switch.

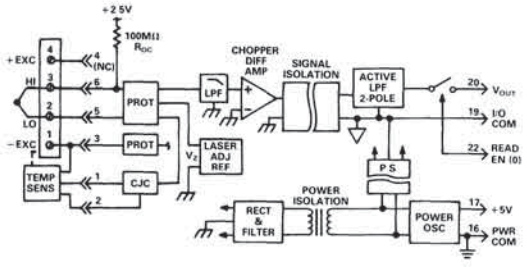


Figure 2. 5B37 Block Diagram

INPUT MODULE SPECIFICATIONS (typical @ +25°C and +5V power)

Model	5B30/5B31	5B32	5B34	5B37/5B47	5B40/5B41
Input Ranges	dc mV/dc V	Process Current	RTD	Thermocouple	Wideband dc mV/V
Output Ranges	±5V or 0 to +5V	0 to +5V	0 to +5V	0 to +5V	*
Accuracy[1]	±0.05% Span	*	*	*/0.10% Span	*
Nonlinearity	±0.02% Span	*	0.05% Span Conformity	*/NA	*
Stability vs. Ambient Temperature					
Input Offset	±1μV/°C/20μV/°C	±0.0025% Span/°C	±0.02°C/°C	±0.02°C/°C/μV/°C	±2μV/°C/±40μV/°C
Output Offset	±20μV/°C	*	*	*/NA	*
Span	±25ppm of rdg/°C	±35ppm of rdg/°C	±50ppm of rdg/°C	*	*
Common-Mode Voltage, Input to Output	1500V rms Continuous	*	*	*	*
Common-Mode Rejection@ 50Hz to 60Hz					
1kΩ Source Unbalance	160dB/150dB	*	*	*	100dB/90dB
Normal-Mode Rejection @ 50Hz or 60Hz	60dB	*	*	*	N/A
Differential Input Protection	240V rms Continuous	*	*	*	*
Output Resistance	50Ω	*	*	*	*
Voltage Output Protection	Continuous Short to Ground	*	*	*	*
Input Transient Protection	Meets IEEE-STD 472 (SWC)	*	*	*	*
Input Resistance	5MΩ/650kΩ	*	*	*	200MΩ/650kΩ
Bandwidth	4Hz	*	*	*	10kHz
Output Selection Time	20μs	*	*	*	*
Power Supply	+5V ±5%	*	*	*	*
Power Consumption	0.15W	*	*	*	*
Size	2.25" × 2.25" × 0.6"	*	*	*	*
Environmental					
Temperature Range, Rated Performance	−25°C to +85°C	*	*	*	*
Temperature Range, Operation	−40°C to +85°C	*	*	*	*
Storage Temperature Range	−40°C to +85°C	*	*	*	*
Relative Humidity Conforms to MIL Spec 202	0 to 95% @ 60°C Noncondensing	*	*	*	*
RFI Susceptibility	±0.5% Span Error, 5W @ 400MHz @ 3'	*	*	*	*

NOTES
*Specifications same as 5B30
[1]Accuracy specification includes the combined effects of repeatability, hysteresis and linearity and does not include sensor or signal source error
This specification is for the 5B Series family and may not apply to all ranges of all modules Consult the *5B Series User's Manual* for detailed specifications
Specifications subject to change without notice

Input Type/Span	Output	Model
dc, ±5mV to ±500mV	±5V	5B30, 5B40
dc, ±500mV to ±10V	±5V	5B31, 5B41
Process Current, 4-20mA or 0-20mA	0-5V	5B32
Thermocouple Types J, K, T, E, R, S, B	0-5V	5B37
Linearized Thermocouple Types J, K, T, E, R, S, B	0-5V	5B47
2, 3, 4 Wire RTDs – 100Ω Platinum, 10Ω Copper, 120Ω Nickel	0-5V	5B34

Table I. Input Selection

ISOLATED MILLIVOLT AND VOLTAGE INPUT MODELS 5B30, 5B31

Model 5B30 and 5B31 accept millivolt and voltage signals respectively and have a 4Hz bandwidth.

ISOLATED CURRENT INPUT MODEL 5B32

Model 5B32 accepts process current signals. A resistor is supplied to convert the signal current to a voltage, and, since that resistor cannot be protected against destruction in the event of inadvertent connection of the power line, it is provided in the form of a separate pluggable resistor carrier assembly. Extra current conversion resistors are available as accessories.

ISOLATED RTD INPUT MODEL 5B34

This RTD input module provides 3 wire lead resistance compensation and can be connected to 2, 3, or 4 wire RTDs. The lead resistance effect is ±0.02°C/Ω. It provides a low drift sensor excitation current of 0.25mA for the 5B34 or 5B34-N or 1.0mA for the 5B34-C and produces an output signal that is linear with temperature with a conformity error of ±0.05% of span and accuracy of ±0.05% of span.

ISOLATED THERMOCOUPLE INPUT MODELS 5B37, 5B47

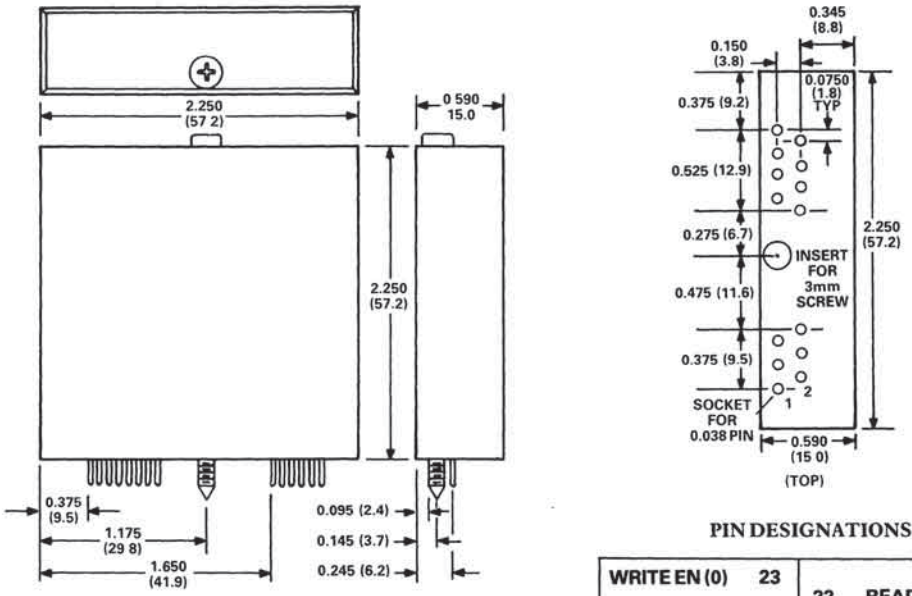
The isolated thermocouple model incorporates cold junction compensation circuitry which provides an accuracy of ±0.5°C over the +5°C to +45°C ambient temperature range. Open thermocouple detection (upscale) is also provided. Standard models are available for thermocouple types J, K, T, E, R, S, and B. Model 5B47 provides a linearized 0-5V output.

ISOLATED WIDEBAND MILLIVOLT AND VOLTAGE INPUT MODELS 5B40, 5B41

Models 5B40 and 5B41 accept millivolt and voltage signals respectively and have a 10kHz bandwidth for interface to dynamic signals.

5B SERIES MODULE OUTLINE

Dimensions shown in inches and (mm).



PIN DESIGNATIONS

WRITE EN (0)	23	22	READ EN (0)
RESERVED	21	20	V_{OUT}
I/O COM	19	18	V_{IN}
+5V	17	16	POWER COM
		6	IN HI
IN LO	5	4	+EXC
−EXC	3	2	SENSOR +
SENSOR −	1		

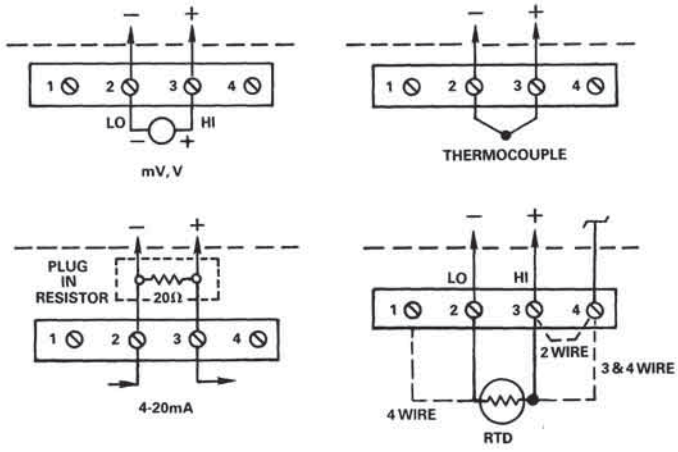


Figure 3. 5B Series Input Connections

OUTPUT MODULE FEATURES

- **Voltage Input Ranges: 0 to +5V or ±5V**
- **Process Current Output: 4-20mA or 0-20mA**
- **High Accuracy: ±0.05%**
- **Reliable Transformer Isolation: 1500V rms CMV, CMR=90dB**
- **Meets IEEE-STD 472: Transient Protection (SWC)**
- **Output Protection: 240V rms Continuous**

GENERAL DESCRIPTION

The 5B39 Current Output Module accepts a high level analog signal at its input and provides a 4-20mA or 0-20mA process current signal at its output. The module features high accuracy of ±0.05% and 1500V rms common-mode voltage isolation protection.

The transfer function provided by this module is:

Input – 0 to +5V or ±5V
Output – 4-20mA or 0-20mA.

To provide this range of functions four varieties of the 5B39 are available; unipolar or bipolar input and output range must be specified when ordering.

5B39 FUNCTIONAL DESCRIPTION

Figure 4 is a functional block diagram of the 5B39 current output module. The voltage input, usually from a digital-to-analog converter, is buffered and a quarter scale offset is added if a 4-20mA output is specified.

The signal is latched in a track-and-hold circuit. This track-and-hold allows 1 DAC to serve numerous output channels. The output droop rate is 80μA/s which corresponds to a refresh interval for 0.01% FS droop of 25ms. The track-and-hold is controlled by an active-low enable input which is compatible with CMOS and LSTTL signals. In conventional applications where one DAC is used per channel and the track-and-hold is not used, the enable input should be grounded to power common. This keeps the module in tracking mode.

The signal is sent through an isolation barrier to the current output (V-to-I converter) stage. Signal isolation is provided by transformer coupling using a proprietary modulation technique for linear, stable performance at low cost. A demodulator on the output side of the signal transformer recovers the original signal, which is then filtered and converted to a current output. Output protection allows safe operation even in the event of a 240V rms power line being connected to the signal terminals.

A single +5V supply powers a clock oscillator which drives power transformers for the input circuit and the output's high compliance, current loop supply. The output current loop is, of course, fully floating. In addition, the input section acts as a third floating port, eliminating many problems that might be created by ground loops and supply noise. The common-mode range of the input circuit is limited; however, input common must be kept with ±1V of power common, and a current path must exist between the two commons at some point for proper operation of the track-and-hold control input.

OUTPUT MODULE SPECIFICATIONS

(typical @ +25°C and +5V power)

Input Ranges	0 to +5V or ±5V
Output Ranges	4-20mA or 0-20mA
Load Resistance Range[1]	0 to 650Ω
Accuracy[2]	±0.05% Span
Nonlinearity	±0.02% Span
Stability vs. Ambient Temperature	
Zero	±0.5μA
Span	20ppm of Span/°C
Common-Mode Voltage, Output to Input and Power Supply	1500V rms Continuous
Common-Mode Rejection	90dB
Normal-Mode Output Protection	240V rms Continuous
Output Transient Protection	Meets IEEE-STD 472 (SWC)
Sample & Hold:	
Output Droop Rate	80μA/s
Acquisition Time	50μs
Over Range Capability	10%
Maximum Output Under Fault	26mA
Input Resistance	10MΩ
Bandwidth	400Hz
Power Supply	+5V dc ±5%
Power Consumption	0.85W (170mA)
Maximum Input Voltage Without Damage	±10V
Size	2.25" × 2.25" × 0.6"
Environmental	
Temperature Range, Rated Performance	−25°C to +85°C
Storage Temperature Range	−40°C to +85°C
Relative Humidity Conforms to MIL Spec 202	0 to 95% @ 60°C Noncondensing
RFI Susceptibility	±0.5% span error, 5W @ 400MHz @ 3 ft.

NOTES
[1]With a minimum power supply voltage of 4.95V, R_L can be up to 750Ω.
[2]Accuracy specification includes the combined effects of repeatability, hysteresis and linearity. Does not include signal source error.
Specifications subject to change without notice.

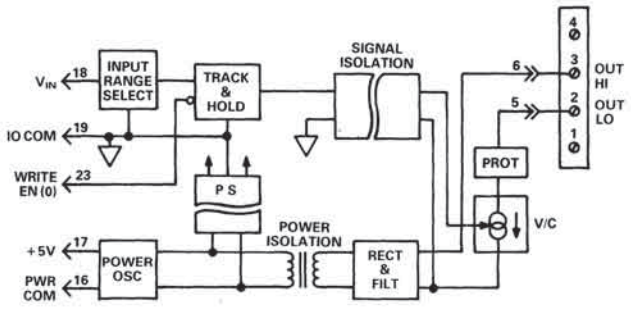


Figure 4. 5B39 Block Diagram

DESIGNER APPLICATION FEATURES

- **Module Pins Fit Widely Available Sockets**
- **Single Threaded Insert for Module Hold Down**
- **Cold Junction Compensation Sensors Available**
- **Input Modules Have Internal Series Output Switches**
- **Output Modules Have Track-and-Hold Inputs**

DESIGNER APPLICATION INFORMATION

The 5B Series was designed to facilitate integration by a system designer into his own circuit board or backplane. Only a single 3.0mm threaded insert is required for module hold down. Module pins are accommodated by widely available sockets, and temperature sensors for thermocouple cold junction compensation are available as one-piece precalibrated units.

The 5B Series was also designed to minimize system interface space and cost. Each input module has an internal series output switch which can be controlled by a TTL-compatible enable input eliminating the need for external multiplexers. Each output module has a track-and-hold input which allows a single digital-to-analog converter to serve numerous channels. In applications where it is desirable to do so, the module enable lines can be grounded, and the 5B Series input modules can be used with a conventional external mux and the output modules with a DAC per channel.

Ease of system application of these modules is enhanced by the fact that the output modules have enable and signal input pin assignments which do not coincide with the enable and signal output pins of the input modules, see Figure 5. This means that in a single mix-and-match backplane environment the reading of inputs and the writing and refreshing of outputs are completely independent and occur simultaneously. For example, the input system may dwell for a long time on a single channel to collect thousands of samples without having to interrupt the process to do an output refresh or set a new output value. Similarly, a "dumb" refresh circuit can be built which can maintain outputs without even knowing which channels have output modules; it can refresh all channels, and those that are really inputs will ignore the operation.

BASIC DESIGN GUIDELINES

Modules may be mounted in any position and will normally be placed next to the screw terminals connecting to the associated field wiring. The temperature sensor is only used by thermocouple modules, but it is normally installed in all channel locations in a "mix-and-match" application. This sensor must be physically close to the terminals where the thermocouple wire connects to copper. Because the low power dissipation of the 5B Series minimizes temperature gradients on the backplane, no special precautions are needed to get accurate temperature sensing. Provision must be made on each channel for the 5B32's current conversion resistor.

The width of the modules is intended to permit installation on 0.6" centers where required, but consideration must be given in each application to the required distance between backplane conductors where large interchannel voltages exist or where code requirements apply. The nature of the screw terminals used for field wiring will also factor in determining practical interchannel spacing.

The *5B Series User's Manual* includes an extensive discussion of system design issues. Design of backplanes which take full advantage of the 5B Series' capabilities by maintaining isolation is emphasized.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

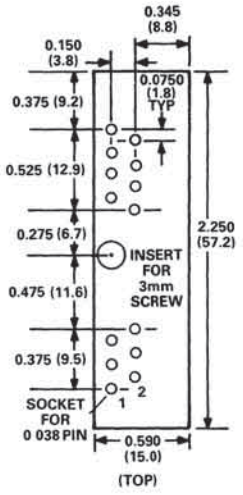


Figure 5. Module Footprint and Pinout

PIN DESIGNATIONS

WRITE EN (0)	23	22	READ EN (0)
RESERVED	21	20	V_{OUT}
I/O COM	19	18	V_{IN}
+5V	17	16	POWER COM
		6	IN HI
IN LO	5	4	+EXC
−EXC	3	2	SENSOR +
SENSOR −	1		

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BACKPLANE FUNCTIONAL DESCRIPTION

To address diverse applications, the 5B Series includes an expanding family of backplanes. Two 16 channel backplanes which can be mounted in a 19″ × 3.5″ panel space are available. Each channel has four screw terminals for field connections. These connections satisfy all transducer inputs, process current outputs, and provide transducer excitation when necessary. A cold junction sensor is supplied on each channel to accommodate thermocouple modules. A system interface connector provides high level voltage I/O for all channels. Both 5B Series backplanes require a +5V external power source. Other backplanes with integral power supplies are under development.

The 5B Series offers high density packaging to conserve mounting space and can be easily tailored to fit the user's needs. All modules feature universal pin out which assures interchangeability. The screw down design allows easy reconfiguration.

The 5B01, diagrammed in Figure 6, provides sixteen single ended input/output pins on the system connector. It is pin compatible with Analog Devices' 3B Series applications. (Note, however, that 5B Series modules provide a ±5V output swing rather than the ±10V swing provided by 3B Series modules).

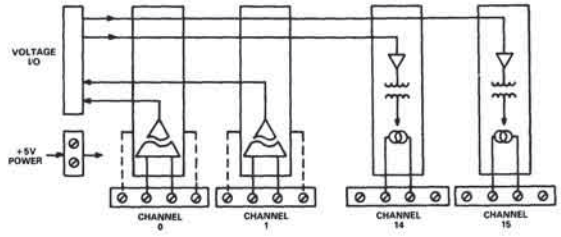


Figure 6. 5B01 Block Diagram

The 5B02, diagrammed in Figure 7, incorporates an input and an output bus which take advantage of the internal series output switches in the input modules and the track-and-holds in the output modules. Designers integrating the 5B02 into a measurement and control system do not need external multiplexers and can use a single digital to analog converter to serve numerous output channels.

For smaller applications, the 5B03 and 5B04 module sockets are available for one and two 5B Series modules, respectively. These module sockets may be clustered for groups of three or more signals, and they are DIN rail compatible using Phoenix Universal Module UM elements.

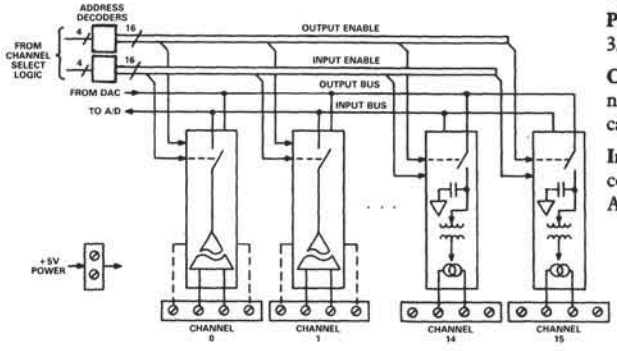


Figure 7. 5B02 Block Diagram

BACKPLANE SPECIFICATIONS

	5B01, 5B02	5B03/5B04
Channels	16	1, 2
External Power Requirement	+5V	*
Cold Junction Sensor	On Each Channel	*
Physical Size	3.5″ × 17.4″ 88.9mm × 442mm	4.25″ × 1.37″ 108mm × 34.7mm

*Same as 5B01, 5B02.

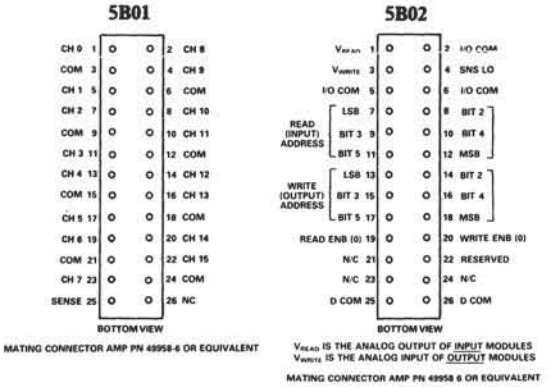


Figure 8. System Connector Pinout

ACCESSORIES

To ease the board design process for designers and to complete the 5B Series subsystem solution, the following accessories are available.

CJC Sensors. SIP temperature sensors are available to provide cold junction temperature measurement for thermocouple applications on user designed backplanes. These sensors are provided on each channel of the 5B01 and 5B02 backplanes. Model number AC1361.

Current Conversion Resistors. Supplied with each 5B32 Current Input Module, a replacement pluggable resistor (20Ω) assembly. Model number AC1362.

Single Channel Socket. A single channel test socket with screw terminals and cold junction compensation for module evaluation. DIN rail compatible. Model number AC1360.

Rack Mount. A single piece metal chassis for mounting 5B Series backplanes in a 19″ rack. Model number AC1363.

Power Supplies. Chassis mounted 1A (model number 955) and 3A (model number 976) 5V power supplies are available.

Cables. A 2′ (60cm) 26-pin cable with two connectors, model number AC1315. For daisy chaining 5B02 backplanes, a 26-pin cable with three connectors, model number CAB-01.

Interface Board. A universal interface board with a 26-pin connector in and 26 screw terminals out. Model number AC1324.

Digital Panel Instruments
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Selection Guide
Digital Panel Instruments

DIGITAL PANEL METERS

		AD2026-1	AD2010	AD2021	AD2026-2
Digits; F.S. Range	3; -99 to +999mV	•			•
	3½; ±199.9mV		•	•	
	±1.999V	•		•	
	±19.999V			•	
	4½; ±1.9999V *				
Input Type	Limited Differential	•	•	•	
	Floating				•
Data Outputs	Character Serial			•	
	Parallel BCD Latched		•		
Display Type	LED	•	•	•	•
Display Size in/mm		0.5/13	0.27/7	0.5/13	0.5/13
Max Case Depth[1] in/mm		0.65/17	1.4/36	1.9/48	2.44/63
Power Supply	+5V	•	•	•	
	AC Line				•
Page		12-13	12-9	12-11	12-13

NOTES

[1] Case depth includes mating connector. All logic powered DPMs use industry standard case with 3.175" X 1.810" (80.65 X 45.97mm) cutout. AC-powered AD2026-2 uses industry standard case with 3.930" X 1.682" (99.82 X 42.72mm) cutout.

* Other products that are still available are listed on page 17-4.

DIGITAL TEMPERATURE/TRANSDUCER METERS*

			AD2050	AD2051	AD2060	AD2061	AD2070	AD2071
Input	Number of Channels	1 *	•	•	•	•	•	•
Sensor (Determines Temperature Range)	Function	Switch Selected		•		•		•
		User Specified	•		•		•	
	Thermocouple Type	J, K, T	•	•			•	•
		E, R, S	•	•			•	•
		C, B, J DIN, T DIN					•	•
	RTD				•	•		
	Thermistor				•	•		
Features	Self-Calibration		•	•	•	•	•	•
	Cold-Junction Compensation		•	•			•	•
	Linearization		•	•	•	•	•	•
	Isolation		•[1]	•[1]	•[1]	•[1]	•	•
Readout	Digits	3½	•	•	•	•		
		4½					•	•
	LED Display Height	0.56", 14.3mm	•	•	•	•	•	•
Digital Data Output	7-Bit Character-Serial ASCII		•	•	•	•	•	•
	Isolated, 20mA Current Loop		•	•	•	•	•	•
	RS232/TTL						•	•
Analog Output	Voltage		•	•	•	•	•	•
Power Supply	AC Line		•	•	•	•	•	•
	DC +7.5V to +28V		•	•	•	•	•	•
Page			12-15	12-15	12-17	12-17	12-19	12-19

NOTES
[1] AC line-operated versions.

* Other products that are still available are listed on page 17-4.

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Orientation
Digital Panel Instruments

A digital panel instrument is a self-contained instrument designed for panel mounting. It contains circuitry for measuring analog quantities, converting them to digital and providing a numeric readout. In addition, it usually provides data outputs for interfacing with a printer and/or a computer system.

Digital panel instruments manufactured by Analog Devices fall into two classes: digital panel meters for voltage measurements and microprocessor-based digital thermometers to read out temperature measurements from user-chosen sensors. A *digital panel meter* measures voltage, generally with fractional-millivolt resolution. A *temperature meter* accepts inputs from standard thermocouples, RTDs, and thermistors, and provides readouts directly in temperature, to 3 1/2 or 4 1/2 digits; thermocouple meters provide reference-junction compensation and linearization, while RTD/thermistor meters also provide current excitation for RTDs and thermistors.

Two useful publications from Analog Devices may be helpful in understanding the issues involved in signal conditioning and data conversion: *Analog-Digital Conversion Handbook*, third edition (1986, $32.95) and *Transducer Interfacing Handbook* (1980, $14.50). Both are available from the Analog Devices Literature Center at P.O. Box 796, Norwood MA 02062.

A DPM samples the input voltage periodically, converts that voltage to digital, and displays the corresponding reading visually. A digital panel meter, then, consists of four basic functional sections: the input section, including signal conditioning and analog to digital conversion circuitry; the display; the data outputs and the power supply.

Processing the Input Signal
The primary function of the input section is to convert an analog input voltage into a digital signal for display. Besides this basic function, the input section also buffers the input to provide a high input impedance, prevent circuit damage in overvoltage conditions, reject both normal-mode and common-mode noise on the input signal, compensate for large variations in operating temperature and sometimes even measure the ratio of two separate input voltages.

The analog to digital conversion scheme used on most DPMs is the dual-slope type due to its inherent stability and normal-mode noise rejection. The dual-slope converter can also be used to measure the ratio of two input voltages in some DPM designs. Lower-resolution DPMs sometimes use staircase or single slope converters which require RC filtering of the input signal for a normal-mode-noise rejection.

The input of the DPM may be single-ended, differential or floating. Single-ended inputs measure the input voltage with respect to input common and may require some care in application to avoid ground loop problems. To prevent ground loops, some of Analog Devices' DPMs use a "limited differential input," where a resistor separates analog and digital grounds allowing up to 200mV of common-mode voltage and providing up to 60dB of common-mode rejection.

AC-powered DPMs can be floated on the power-supply transformer to provide isolation and CMR. For example, the line-powered AD2026-2 has floating inputs with 116dB of CMR and a 1,000-volt common-mode rating.

Displaying the Data – Digital Outputs
Once the input signal is digitized, it is decoded and displayed on a digital readout. Analog Devices DPMs use large seven-segment light-emitting diode (LED) displays.

DPM full-scale range, including *overrange*, is defined by the number of digits and polarity. In mixed-fraction designations (e.g., 3 1/2 digits), a full digit is one capable of displaying any numeral from 0 through 9. The fraction generally means the ratio of the display's maximum leading digit to the power of two that corresponds to the number of overrange bits; for example, a 3 1/2-digit meter's maximum reading is 1999, a 4 3/4-digit meter's maximum reading is 39999.

Since the visual display of a DPM must be in a decimal format, counter chips used in DPM conversion circuitry are generally binary-coded decimal (BCD) types. The data output format depends on the circuit design of the meter; for example, the AD2010 has parallel BCD data outputs with all BCD bits available simultaneously, while the AD2021 has character-serial outputs – each BCD digit is gated onto a single set of parallel output lines in sequence. The latter technique requires fewer connections and simplifies data interfacing.

Digital data outputs from DPMs are generally compatible with DTL or TTL logic systems; many DPMs are also compatible with CMOS logic.

Control
The kinds and number of control inputs and outputs – and their interpretation – may differ from one model to another, but they are well defined on the data sheets. Examples of typical control functions that may be found in DPMs include triggering of conversions, external *hold*, decimal points (jumper or logic-programmable), display blanking and *status* output.

DIGITAL TEMPERATURE METERS
Microprocessor-based devices in this class include the AD2050/AD2051 Thermocouple Meters, the AD2060/AD2061 Autoranging RTD/Thermistor Meters and the AD2070/AD2071 Autoranging Thermocouple Meters.

In addition to the basic panel-meter circuitry, these instruments have signal-conditioning front ends with overvoltage protection and open-sensor detection, automatic self-calibration and sophisticated output options. Besides linearization, their functions include cold-junction compensation for thermocouples and excitation for RTDs and thermistors. They read out in degrees Fahrenheit or Celsius, and the autoranging types choose between 0.1° and 1° resolution, depending on range.

The AD2050, AD2060, and AD2070 are dedicated instruments for optional specific sensor types (e.g., type K thermocouple), while the AD2051, AD2061, and AD2071 are "universal instruments" for any one of a set of specified sensors, programmable by the user to meet the needs of the application.

Communication options simplify temperature recording with computers, strip-chart recorders or printers. In addition to 7-bit character-serial ASCII outputs, the user has the option of a linearized analog output for strip-chart recorders, and serial ASCII output in two forms: isolated 20mA digital current-loop and/or nonisolated TTL. The AD2070/AD2071 has optional isolation for all data outputs, including RS-232.

Understanding Performance Specifications

Resolution, Accuracy and Stability – these three specs are very important in the selection of a DPM. Although more digits may mean more resolution, the digits themselves are useless unless the accuracy is sufficient for the digits to have real meaning. Therefore, accuracy and resolution should be comparable.

Besides temperature variations, there are three components of DPM inaccuracy: *zero offset error, gain error* and *quantization error*. In any device using a counter and clock to determine a digital output, there is always a potential ±1 count error in the output. This is caused by the timing of the input gate of the counter; when the gate closes asynchronously with the clock, a clock pulse that occurs just as the gate closes may or may not be counted, hence the fixed ±1 digit inaccuracy.

Zero-level offsets in the analog circuitry cause errors specified as a percentage of full-scale reading. These errors can be corrected by a zero-calibration potentiometer requiring periodic resetting, or by internal calibration circuits that set the zero level automatically between each pair of readings, assuring no zero-level contribution to the error.

Gain variations occur as a function of signal level in the analog circuitry and produce errors which are specified as a percentage of the reading. These are the hardest errors to design out of a DPM circuit, but they can be minimized by component specification and selection. A range potentiometer is used for periodic adjustment of the gain. Gain errors may also be calibrated out in "smart" instruments having an automatic internal calibration facility (e.g. AD2070).

Since all the electronic components used in the design of a DPM have some temperature dependence, one can expect the accuracy of the DPM to be affected by changes in operating temperature. If automatic zero correction circuitry is not used, the zero level may drift with temperature. Variations in the reference voltage circuitry and its associated switches will cause changes in the gain of the DPM, but careful selection and matching of components can minimize this error.

To illustrate these specifications, consider a 3 1/2 digit DPM (1999 counts full scale). The resolution of the unit is the value of one digit, 1 part in 2000 or 0.05% of full scale. If the accuracy is comparable to the resolution (exclusive of digital indecision), the DPM should have a maximum error of ±0.05% ±1 digit.

Temperature coefficient specifications for a DPM should be very good to maintain the accuracy. A tempco of only 50ppm/°C (0.005%/°C) will produce an additional error of ±0.05% over a range of only ±10°C.

Since each manufacturer tends to use a different method of specifying accuracy and temperature coefficients, specifications must be expressed in common terms to be comparable.

DEFINITIONS – DPM TERMS & SPECIFICATIONS

Accuracy (Absolute): DPMs are calibrated with respect to a reference voltage which is in turn calibrated to a recognized voltage standard. The absolute accuracy error of the DPM is the tolerance of the full-scale set point referred to the absolute voltage standard.

Accuracy (Relative): Relative accuracy error is the difference between the nominal and actual ratios to full scale of the digital output corresponding to a given analog input. See also: *Linearity*.

Automatic Zero: To achieve zero stability, a time interval during each conversion is provided to allow the circuitry to compensate for drift errors, thereby providing virtually no zero drift error.

Bias Current: The current required from the source at zero signal input by the input circuit of the DPM. Bias current is normally specified at typical and maximum values. Analog Devices' DPMs using transistor input circuitry are biased current sinks.

Binary Coded Decimal (BCD): Data coding where each decimal digit is represented by a group of 4 binary coded digits (called "quads"). Each quad has bits corresponding to 8, 4, 2 and 1 and 10 permissible levels with weights 0-9. BCD is normally used where a decimal display is needed.

Bipolar: A bipolar DPM measures inputs which may be of either positive or negative polarity and automatically displays the polarity as well as the magnitude of the input voltage on the readout.

Character Serial BCD: Multiplexed BCD data outputs, where each digit is gated sequentially onto four common output lines.

Common-Mode Rejection: A differential-input DPM will reject any input signals present at both input terminals simultaneously if they are within the common-mode voltage range. Common-mode rejection is expressed as a ratio and usually given in dB. (CMR = 20 log CMRR 120dB of common-mode rejection.) (CMRR = 10^6) means that a 10V common-mode voltage is processed as though it were an additive differential input signal of 10μV magnitude.

Common-Mode Voltage: A voltage that appears in common at both input terminals of a device, with respect to its ground.

Conversion Rate: The frequency at which readings may be processed by the DPM. Specifications are typically given for internally clocked rates and maximum permissible externally-triggered rates.

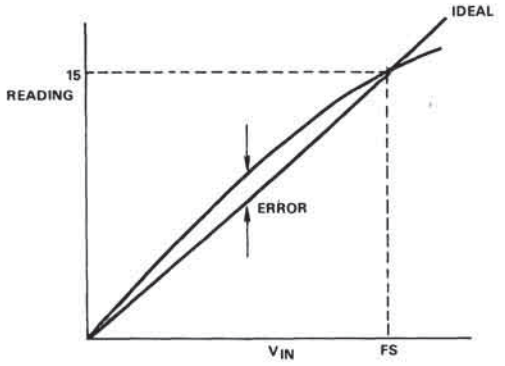
Conversion Time: The maximum time required for a DPM to complete a reading cycle, specified for the full-scale reading.

Dual-Slope Conversion: An integrating A/D conversion technique in which the unknown signal is converted to a proportional time interval, which is then measured digitally. This is done by integrating the unknown for a predetermined time.

Then a reference input is switched to the integrator, and integrates "down" from the level determined by the unknown, until a "zero" level is reached. The time for the second integration process is proportional to the average of the unknown signal level over the predetermined integrating period.

Input Impedance: The complex ratio of signal voltage to signal current at the input terminals. For dc measuring DPMs, the input is measured at dc. For ac measuring DPMs, it is expressed as a dc resistance shunted by a specified capacitance.

Linearity: The conventional definition for nonlinearity of a DPM is the deviation from a "best" straight line which has been fitted to a calibration curve. Analog Devices defines nonlinearity as the deviation from a straight line drawn between the zero and full-scale end points. Not only is this an easier method for customer calibration, it is also a more conservative method of specifying nonlinearity.



Linearity

Normal-Mode Rejection: Filtering or integrating the input signal improves noise rejection of undesired signals present at the analog *high* input. Normal-mode rejection is expressed as the ratio of the actual value of the undesired signal to its measured value over a specified frequency range. (NMR (dB) = 20 log NMRR, e.g. NMR = 40dB means an attenuation of 100:1.)

Overload: An input voltage exceeding the full-scale range of the DPM produces an overload condition. An overload condition is usually indicated by conspicuous manipulation of the display such as all dashes, flashing zeros, etc. On a 3 1/2 digit DPM with a range of 199.9mV, a ≥200mV, signal will produce an overload condition.

Overrange: An input signal that exceeds all nines on a DPM, but is less than an overload. On a 3 1/2 digit DPM with a full-scale range of 199.9mV, the all-nines range is 0-99.9mV, and signals from 100-199.9mV are said to fall in the 100% overrange region. Some DPMs have higher overrange capability. A 3 3/4 digit DPM has a full-scale range of 3.999 or 300% overrange.

Overvoltage Protection: The input section of the DPM must provide protection from large overloads. Specifications are given for sustained dc voltages that can be tolerated.

Parallel BCD: A data output format where all digital outputs are available simultaneously.

Range (Temperature Operating): The range of temperatures over which the DPM will meet or exceed its performance specifications.

Range (Full Scale): The range of input signals that can be measured by a DPM before reaching an overload condition. A 3 1/2 digit DPM's full-scale range consists of three digits (all-nines range) and 100 percent overrange capability.

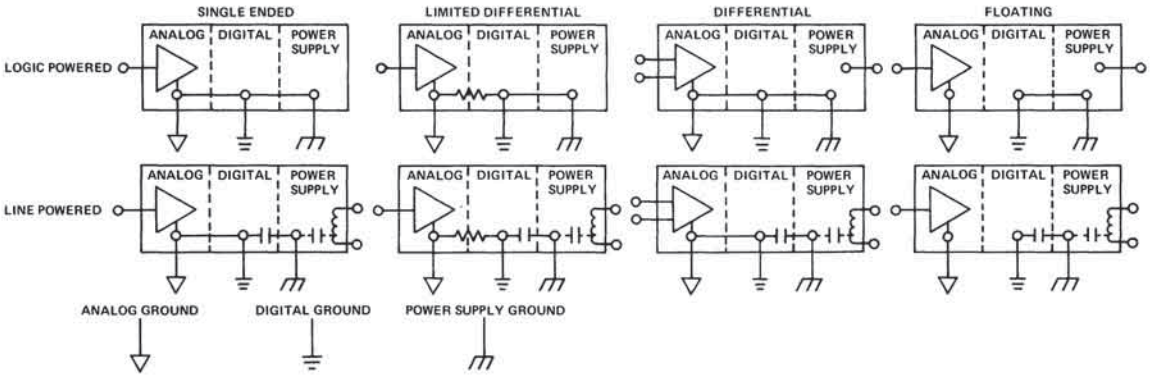
Ratiometric: Dual Slope DPMs compare voltage inputs to a stable internal reference voltage. In some systems, the voltage being measured is a function of another voltage, and accurate measurements should be made as the ratio of the two voltages. Some DPMs provide inputs for external reference voltages for ratiometric measurements.

Resolution: The smallest voltage increment that can be measured by a DPM. It is a function of the full-scale range and number of digits of a DPM. For example, if a 3 1/2 digit DPM has a resolution of 1 part in 2000 (0.05%) over a full-scale range of 199.9mV, the DPM can resolve 0.1mV.

Digits	Counts (F.S.)	Resolution (% F.S.)
2 1/2	199	0.5%
3	999	0.1%
3 1/2	1999	0.05%
3 3/4	3999	0.025%
4	9999	0.01%
4 1/2	19999	0.005%
4 3/4	39999	0.0025%

Temperature Coefficient: The additive error term (ppm/°C or % Reading/°C) caused by effects of variations in operating temperature on the electronic characteristics of the DPM.

Unipolar Input DPM: A DPM designed to measure input voltages of only one polarity.



Grounding Configurations of DPMs

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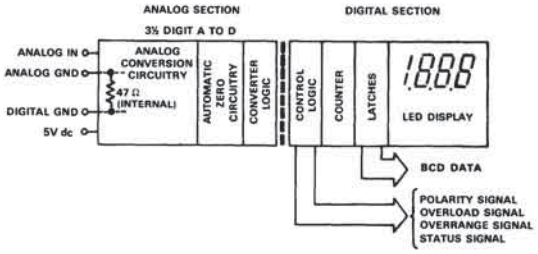
Low-Cost, 3 1/2 Digit DPM for OEM Applications

AD2010

FEATURES
LED Display with Latched Digital Outputs
Small Size, Lightweight
Automatic Zero Correction; Max Error: 0.05% ±1 Digit
High Normal Mode Rejection: 40dB @ 50 or 60Hz
Optional Ratiometric Operation
Leading "0" Display Blanking
5V dc Powered

APPLICATIONS
Medical/Scientific/Analytic Instruments
Data Acquisition Systems
Industrial Weighing Systems
Readouts in Engineering Units
Digital Thermometers

AD2010 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Analog Devices' model AD2010 represents an advance in price/performance capabilities of 3½ digit digital panel meters. The AD2010 offers 0.05% ±1 digit maximum error with bipolar, single ended input, resolution of 100μV, and a common mode rejection ratio of 60dB (CMRR) at ±200mV (CMV).

The AD2010 features a light-emitting-diode (LED) display with a full scale range of 0 to ±199.9 millivolts, latched digital data outputs and control interface signals, and leading zero display blanking. Automatic-zero correction circuitry measures and compensates for offset and offset drift errors, thereby providing virtually no error. Another useful feature of the AD2010 is its 5V dc operation. The AD2010 can operate from the users' 5V dc system supply, thereby eliminating the shielding and decoupling needed for line powered units when the ac line must be routed near signal leads.

To satisfy most application requirements, the conversion rate of the AD2010 is normally 4 readings per second. However, an external trigger may be applied to vary the sampling rates from a maximum of 24 readings per second down to an indefinite hold time. The AD2010 can also be connected for automatic conversion at its maximum conversion rate. During conversion, the previous reading is held by the latched logic. The numeric readout is available as BCD data. Application of the metering system in a computer or data logging system is made easy with the availability of the "overrange," "polarity," "overload," and "status" signals.

A simplified block diagram of the AD2010, illustrating the features described above is shown in Figure 1.

IMPROVED NOISE IMMUNITY, ACCURACY AND ZERO STABILITY

Dual-slope integration, as used in the AD2010 and as described in the theory of operation section, offers several design benefits.

- Conversion accuracy, for example, is independent of both the timing capacitor value and the clock frequency, since they affect both the up ramp and down ramp integration in the same ratio.
- Normal mode noise at line frequencies or its harmonics is rejected since the average value of this noise is zero over the integration period.
- To achieve zero stability, a time interval during each conversion is provided to allow the automatic-zero correction circuitry to measure and compensate for offset and offset drift errors, thereby, providing virtually no zero error.

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For detailed information, contact factory.

SPECIFICATIONS (typical @ +25°C and +5VDC unless otherwise noted)

DISPLAY OUTPUT
- Display consists of four LED's (0.27" (6.9mm) high). for data digits plus 100% overrange and polarity indication.
- Overload – three data digits display zeros and flashes.
- Decimal Points – selectable at input connector.
- Leading "0" Display Blanking – controlled externally.

INPUT
- Full Scale Range – 0 to ±199.9 millivolts
- Automatic Zero
- Automatic Polarity
- Bias Current – 3nA
- DC Impedance – 100MΩ
- Overvoltage Protection – 20V sustained, 50V momentary without damage.
- Decimal Points (3) – illuminate with logic "1", extinguish with logic "0".

ACCURACY
- Maximum Error – 0.05% of reading ±1 digit
- Resolution – 0.1 millivolt
- Temperature Range – 0 to +50°C operating
  -30°C to +85°C storage
- Temperature Coefficient – ±50ppm/°C

NORMAL MODE REJECTION
- 40dB @ 60Hz

COMMON MODE REJECTION
- 60dB @ ±200mV

CONVERSION RATE
- External Trigger – up to 24 conversions per second
- Internal Trigger – 4 conversions per second
- Automatic – A new conversion is initiated automatically upon completion of conversion in process; conversion rate will vary from 24/sec to 40/sec depending on input magnitude.
- Hold and Read upon command.

CONVERSION TIME
- Normal Conversion – 42ms max (full scale input)
- Overload Conversion – 62ms max

INTERFACE SIGNALS
- DTL/TTL Compatible

	IN	OUT
logic "0"	<0.8V	<0.4V
logic "1"	>2.0V	>2.4V

- Inputs

  External Trigger – Operation in the "External Trigger" mode requires that the "External Hold" input be a logic "0" or ground.

  Negative Trigger Pulses – Applying a logical "low" to the "HOLD" input disables the internal trigger. A negative trigger pulse (logic "1" to logic "0") of 1.0μs minimum applied to the "EXT TRIGGER" input will initiate conversion in the same manner as the internal oscillator. The external trigger should not be repeated, however, until the "status" indicates completion of the conversion in process.

  Positive Trigger Pulses – The "HOLD" input can be used to trigger the AD2010 from a "normally low" signal with the "EXT TRIGGER" input open or logic "1". Following a "hold" a new reading will be initiated on the leading edge of the "hold" signal. Thus, a momentary positive pulse on the "HOLD" input can be used to trigger the AD2010. The drift correct interval, however, begins on the trailing edge of the positive pulse, so if the pulse width exceeds 1ms, the conversion will actually be initiated by the internal trigger.

  Maximum Conversion Rate - Automatic – The AD2010 can also be connected for automatic conversion at its maximum conversion rate by connecting the "status" output back into the "hold" input. In this manner the status signal going high at the end of one conversion immediately initiates a new conversion. The pulses appearing on the status line can be used to step a multiplexer directly, since the built-in drift-correct delay of 8.33ms will allow settling of the input prior to conversion. A logic "0" applied to the "EXT TRIGGER" will inhibit the automatic trigger mode.

  External Hold – Logic "0" or ground applied to this input disables the internal trigger and the last conversion is held and displayed. For a new conversion under internal control the input must be opened or at logic "1". For a new conversion under external control, a positive pulse of less than 1.0ms can be applied (as previously explained).

OUTPUTS
- 3 BCD Digits (8421 Positive True) - latched - 3TTL loads
- Overrange - logic "1" - latched - 6TTL loads, indicates overrange.
- Overload - logic "0" indicates overload (>199.9mV) logic "1" - latched - 6TTL loads, indicates data valid.
- Polarity - logic "1" - latched - 6TTL loads, indicates positive polarity input.
- Status - logic "0" - conversion in process logic "1" - latched - 6TTL loads, indicates conversion complete.

POWER
- +5V dc ±5%, 500mA

WARM UP
- Essentially none to specified accuracy

ADJUSTMENTS
- Range potentiometer for full scale calibration. Calibration recommended every six months.

SIZE
- 3"W x 1.8"H x 0.84"D (76.2 x 45.7 x 21.3mm) (overall depth for case and printed circuit board extension is 1.40" (35.6mm)).

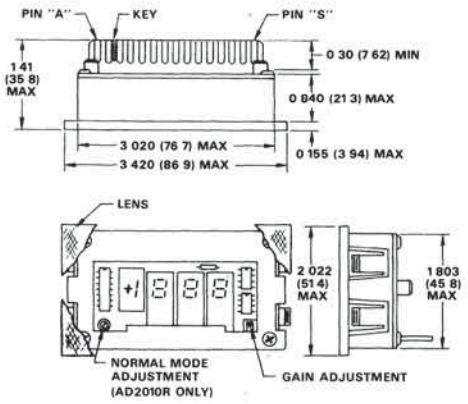
ORDERING GUIDE
- AD2010 - Standard AD2010 as described above - tuned for peak normal mode rejection at 60Hz and its harmonics.

WEIGHT
- 4 oz. (113.5gm)

Specifications subject to change without notice.

OVERALL DIMENSIONS

All dimensions are given in inches and (mm).



Low-Cost, 3 1/2 Digit Logic Powered DPM with LED Displays

AD2021

FEATURES
"Second Generation" MOS-LSI Design
Large 0.5" (13mm) LED Displays
+5VDC Logic Powered
±1.999V, ±199.9mV or ±19.99V Full Scale Ranges
Limited Differential Input
Low Power Consumption: 2.0 Watts
Small Size, Industry Standard Case Design

APPLICATIONS
General Purpose Logic Powered DPM Applications
Portable Applications Requiring Low Power Consumption

GENERAL DESCRIPTION
The AD2021 is a low cost, 3½ digit, +5V dc logic powered digital panel meter with large LED displays. While designed for general purpose DPM applications, the small size, light weight and low power consumption of the AD2021 make it an ideal digital readout for modern, compact instrument designs.

THE BENEFITS OF "SECOND GENERATION" DESIGN
The AD2021 is designed around MOS-LSI (Metal-Oxide-Semiconductor, Large Scale Integration) integrated circuits, which greatly reduce the number of components, and thereby the size, and reduce power consumption to 2.0 watts. Both the lower power consumption and fewer interconnections between components promise greatly increased reliability, and the circuit design maintains the performance and features of earlier DPMs. Large 0.5 inch (13mm) LED displays offer the visual appeal of gas discharge displays with the ruggedness and lifetime of all solid state devices.

EXCELLENT PERFORMANCE AND EASY APPLICATION
The AD2021 measures input voltage over a full scale range of ±1.999V dc or ±199.9mV dc ("S" option) with an accuracy of ±0.05% reading ±0.025% full scale ±1 digit. Using the "limited differential" input first used on Analog Devices' AD2010, the AD2021 prevents ground loop problems and provides 35 to 50dB of common mode rejection at common mode voltages up to ±200mV. Normal mode rejection is 40dB at 50Hz to 60Hz.

BCD data outputs are provided in a bit parallel, character serial format compatible to CMOS logic systems. For those applications requiring parallel BCD data, schemes for making the serial to parallel conversion are available. Controls to hold readings, select decimal points and blank the display are provided.

DESIGNED AND BUILT FOR RELIABILITY
The AD2021 is packaged in Analog Devices' logic powered DPM case size, only 1.25 inches (32mm) deep. The small size of this DPM makes it easy to accommodate in any instrument design, and since several other manufacturers now use the same panel cutout for logic powered DPMs, this industry standardization allows mechanical second sourcing. In addition, the



AD2021 uses the same pin connections as the AD2010 (except in BCD outputs, of course) as a convenience to allow updating designs to take advantage of the second generation design and larger display of the AD2021. Each AD2021 receives a full one week failure free burn-in before shipment.

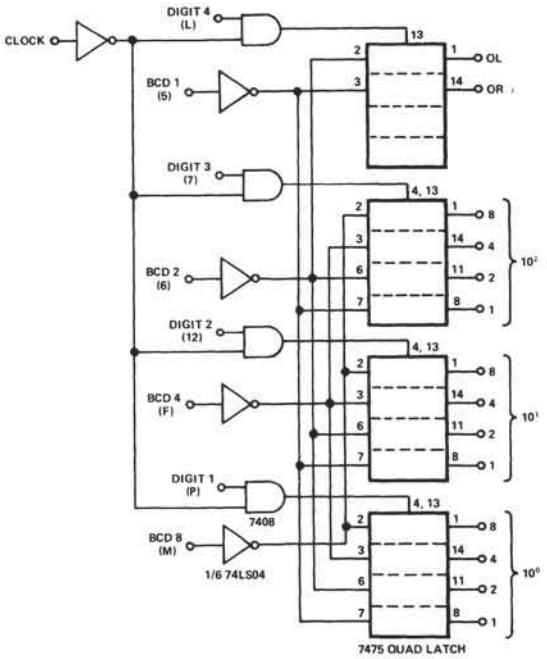


Figure 1. AD2021 Bit Parallel Character Serial to Full Parallel Data Conversion. AD2021 Pin Connections are Shown in Parentheses.

For detailed information, contact factory.

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SPECIFICATIONS (typical at +25°C and nominal power supply voltage)

DISPLAY OUTPUT
- Light emitting diode, planar seven segment display readouts, 0.5" (13mm) high for three data digits, 100% overrange and negative polarity indication. Overload indicated by flashing display, polarity remains valid.
- Decimal points selectable at input connector.
- Display blanking on three data digits (does not affect overrange digit, polarity sign of decimal points).

ANALOG INPUT
- Configuration: bipolar, limited differential
- Full Scale Range: ±1.999V or ±199.9mV ("S" option) ±19.99V ("V" option)
- Automatic Polarity
- Auto Zero
- Input Impedance: 100MΩ (1MΩ – "V" option)
- Bias Current: 50pA
- Overvoltage Protection: ±50V dc, sustained

ACCURACY
- ±0.05% reading ±0.025% full scale ±1 digit[1]
- Resolution: 1mV, 10mV ("V" option) or 100μV ("S" option)
- Temperature Range[2]: 0 to +50°C operating; -25°C to +85°C storage
- Temperature Coefficient: Gain: 50ppm/°C
  Zero: auto zero
- Warm-Up Time to Rated Accuracy: less than one minute
- Settling Time to Rated Accuracy: 0.4 second

NORMAL MODE REJECTION
- 40dB at 50–60Hz

COMMON MODE REJECTION
- AD2021: 35dB (dc -10kHz)
- AD2021/S: 50dB (dc -10kHz)
- AD2021/V: 15dB (dc -10kHz)

COMMON MODE VOLTAGE
- ±200mV

CONVERSION RATE
- 5 conversions per second
- Hold and read on command

CONTROL INPUTS
- Display Blanking: (TTL, DTL compatible, 2 TTL loads). Logic "0" or grounding blanks the three data digits only, not the decimal points, overrange digit (if on) and polarity sign. Logic "1" or open circuit for normal operation. Display blanking has no effect on output data and the display reading is valid immediately upon removal of a blanking signal.
- Hold: (CMOS, DTL, TTL compatible, 1LP TTL load). Logic "0" or grounding causes the DPM to cease conversions and display the data from the last conversion. Logic "1" or open circuit for normal operation. After the "Hold" input is removed, one to two conversions are needed before the reading is valid.
- Decimal Points: Grounding or Logic "0" will illuminate the desired decimal point. External drive circuitry must sink 35mA peak at a 25% duty cycle when the decimal points are illuminated.

DATA OUTPUTS (See Application Section for details on data outputs)
- BCD Data Outputs: (CMOS, LP TTL or LP Schottky compatible), bit parallel, character serial format.
- Digit Strobe Outputs: (CMOS, DTL, TTL compatible, one TTL load). Logic "1" on any of these lines indicates the output data is valid for that digit.
- Polarity Output: (CMOS, TTL, DTL compatible, one TTL load). Logic "1" indicates positive polarity input, logic "0" indicates negative polarity.
- Status: (CMOS or LP TTL compatible). When this signal is at Logic "1", the output data is valid.
- Clock: (CMOS, DTL, TTL compatible, one TTL load). The clock signal is brought out to facilitate conversion from character serial to parallel data.
- INTERFACING DATA OUTPUTS. The BCD data outputs are in a bit parallel, character serial format. There are four BCD bit outputs (1, 2, 4, 8) and four digit outputs (10^0, 10^1 10^2, 10^3). The BCD digits are gated onto the output lines sequentially, and the BCD bits are valid for the digit whose digit line is high. The data is valid except when being updated which occurs within 2 milliseconds after the status line goes low.

REFERENCE OUTPUT
- A 6.4V ±5% analog reference output is made available. This reference should be buffered and filtered if use in external circuitry is desired.

POWER INPUT
- +5V dc ±5%, 1.45 watts

CALIBRATION ADJUSTMENTS (See Application Section for calibration instructions)
- Gain
- Zero
- Recommended recalibration interval: six months

SIZE
- 3"W x 1.8"H x 1.33"D (76 x 46 x 34mm)
- 1.90" (48mm) overall depth to rear of card edge connector.
- Panel cutout required: 3.175" x 1.810" (80.65 x 45.97mm).

WEIGHT
- 4 ounces, (115 grams)

OPTIONS – ORDERING GUIDE
- Input Voltage Range: AD2021 – 1.999V dc Full Scale
  AD2021/S – 199.9mV dc Full Scale
  AD2021/V – 19.99V dc Full Scale

CONNECTOR
- 30 pin, 0.156" spacing card edge connector. Viking 2VK15D/1-2 or equivalent.
- Optional: Order AC1501

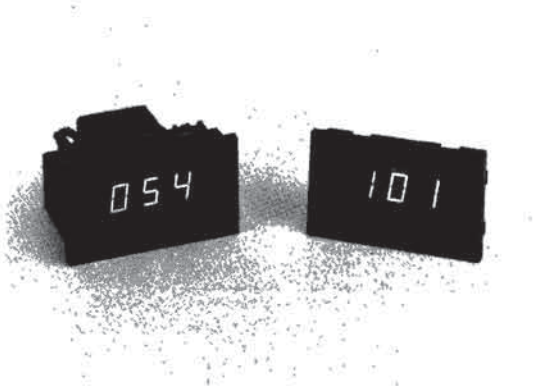
NOTES
[1] Guaranteed at 25°C and nominal supply voltage
[2] Guaranteed

Specifications subject to change without notice.

Low-Cost, 3 Digit AC Line or Logic Powered DPM

AD2026*

FEATURES
Third Generation I^2L LSI Design
Either Line Powered or Logic Powered
Large 0.56″ Red Orange LEDs
Balanced Differential Input/Floating 1000V, CMV
Terminal Block Interface (ac Version)
High Reliability: > 250,000 Hour MTBF
Small Size and Weight
Low Cost



GENERAL DESCRIPTION

The AD2026 is specifically designed to provide a digital alternative to analog panel meters. The AD2026 is available either logic powered (+5V dc) or ac line powered. Most of the analog and digital circuitry is implemented on a single I^2L LSI chip, the AD2020. Only 13 additional components are required to complete the AD2026 +5V dc version. The entire dc version is mounted on a single 3″ X 1 5/8″ PCB. AC line power is achieved with the addition of a second PCB containing the ac power transformer and power supply circuitry.

The AD2026, on both the ac line and logic powered versions, offers as a standard feature, 0.56″ high LED Displays. Brightness is enhanced on both versions due to the Red Orange lens. In addition to the Red Orange lens, the AD2026 is also available with a dark red lens for applications where maximum brightness is not required and minimum backlighting is desired.

A unique patented case design utilizes molded-in fingers, both to capture the PCB in the case and to provide snap-in mounting of the DPM in a standard panel cutout. No mounting hardware of any kind is used. The dc version occupies less than 1″ of space behind the panel. The line powered version offers the same mounting features but occupies 2 1/2″ of behind-panel space.

EXCELLENT PERFORMANCE

The AD2026 offers the instrument designer digital accuracy, resolution and use of readout while occupying less space than its analog counterpart. Other features of analog meters such as reliability and instantaneous response are retained in the AD2026.

The AD2026 measures and displays inputs from -99mV to +999mV, with an accuracy of 0.1% of reading ±1 digit. Zero shift is less than one bit over the full operating temperature range, resulting in the same performance as a DPM with auto zero. The balanced differential input of the dc powered AD2026 rejects common mode voltages up to 200mV, enough to eliminate most ground loop problems. The floating differential input inherent in the ac line powered version offers 1000V of common mode voltage rejection.

***Covered by patent numbers: 4,092,698; 29,992; 3,872,466; and 3,887,863.**

Optional 10.0V full scale (F.S.) range is available on the ac line version that will accept inputs from -0.99V to 9.99V.

WIRING CONNECTIONS

For Balanced Differential operation with the AD2026 dc version, connect input as shown in Figure 1. The common mode loop must provide a return path for the bias currents internal to the AD2026. The resistance of this path must be less than 100kΩ and total common mode voltages must not exceed 200mV.

For applications where attenuation is required, scaling resistors can be connected between pins 6 and 7 and between pins F and H. Pin 5 must be used as the High Analog Input when scaling resistors are used and pin 4 when they are not. Pin E is the Analog Low Input.

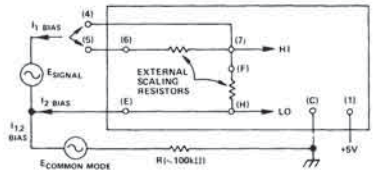


Figure 1.

Connection to the ac line powered AD2026 is via the terminal strip on the rear. AC line power is connected to terminals 4 and 5 and the signal input is connected to terminal 1 (Analog HI) and 2 (Analog Ground).

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SPECIFICATIONS (typical at +25°C and nominal supply voltage unless otherwise noted)

DISPLAY OUTPUT
- Light emitting diode, planar seven segment display readouts, 0.56" (14.6mm) high (orange)
- Overload Indication: EEE
- Negative Indication: -XX
- Negative Overload Indication: ---
- Decimal Points: three (3) selectable at input connector (dc version), internally on ac version

ANALOG INPUT
- Configuration: balanced differential input (dc version) single ended isolated (ac version)
- Full Scale Range. -99mV to +999mV
  -0.99V to +9.99V (10V option on ac version)
- Automatic Polarity
- Input Impedance: 100MΩ, 100kΩ (10V option)
- Bias Current. 100nA
- Overvoltage Production: ±15V dc, sustained

ACCURACY
- ±0.1% ±1 digit[1]
- Resolution 1mV or 10mV
- Temperature Range[2] -10°C to +60°C operating, -25°C to +80°C storage
- Temperature Coefficient Gain 50ppm/°C
  Zero 10μV/°C (essentially auto zero)
- Warm-Up Time to Rated Accuracy Instantaneous
- Settling Time to Rated Accuracy. 0.3 second for full input voltage swing (dc version), 0.75 second for full input voltage swing (ac version)

COMMON MODE REJECTION (1kΩ source imbalance, dc to 1kHz)
- 50dB, ±200mV common mode voltage (dc version)
- 116dB (96dB on 10V range), 1000V rms max CMV (ac version)

NORMAL MODE REJECTION
- 30dB at 50-60Hz (ac version)

CONVERSION RATE
- 4 conversions per second
- Hold and read on command (dc version only)

CONTROL INPUTS

Display Blanking/Display Power Input, (dc version only) The display of the AD2026 can be blanked by removal of power to the display power input, with no effect on conversion circuitry. If external logic switching is used, the display requires 110mA peak (85mA average) when illuminated.

Hold (dc version only) When the Hold input is at Logic "0", grounded or open circuit, the AD2026 will convert at 4 conversions per second. If a voltage of 0.6V to 2.4V is applied to this input, the DPM will stop converting and hold the last reading. A 12kΩ resistor in series with this input to +5V will provide the proper voltage input. (Consult factory for "HOLD" on ac version.)

DECIMAL POINT
- To illuminate decimal points on dc version, ground appropriate pin (A, B or 3).
- To illuminate decimal points on ac version, remove shroud and bridge appropriate solder pad (A, B or 3).

POWER INPUT LOGIC POWER[3]
- Converter. +5V ±5%, 0.2 watts typ, 0.33 watts max
- Display: +5V ±40%, 0.45 watts typ, 0.75 watts max

POWER INPUT AC LINE POWER
- AC line, 50-60Hz, 1.5 watts

CALIBRATION ADJUSTMENTS
- Gain
- Zero
- Recommended recalibration interval six months

SIZE[4]
- 3.43"W X 2.0"H X 0.85"D (87 X 52 X 22mm)
- 0.88" (22mm) overall depth to rear of connector
- Panel cutout required 3.175 ±0.015" X 1.810 ±0.015" (80.65 ±0.38 X 45.97 ±0.38mm)

WEIGHT
- 1.8 ounces (53 grams) (dc version)
- 7 ounces (198 grams) (ac version)

CONNECTIONS

A 10-pin T&B/Ansley 609-1000M with two feet of 10 conductor ribbon cable is available. Order AC2618 (dc version, only).

Conductor to pin A is color coded. Sequence of ribbon connections is A, 1, B, 2, C, 3, etc.

The AD2026 ac version is complete with terminal strip for easy interface

ORDERING GUIDE

AD2026
Power Input
- +5V dc 1
- 90-129V ac 2
- 198-264V ac 3

ENTER

Full Scale Input[5]
- 1V dc Full Scale 1
- 10V dc Full Scale[6] 2

ENTER

Lens[5]
- Red Lens 1
- Red Orange Lens 2

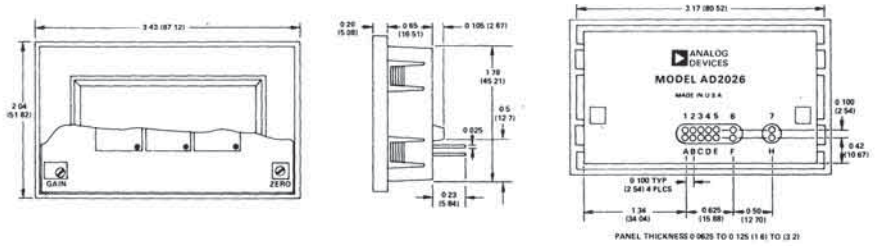
ENTER

NOTES
[1] Guaranteed at +25°C and nominal supply voltage.
[2] Guaranteed.
[3] When the same power supply is used to power both display and converter, +5V, ±5%, 0.65 watts typical, 0.9 watts max is required.
[4] Dimensions for ac line powered version 3.43"W X 2.0"H X 2.44"D (87mm X 52mm X 63mm)
[5] No Charge Options
[6] 10V dc full scale option is available on ac power only

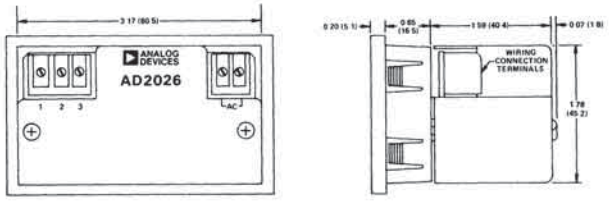
Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



AC VERSION



PIN CONNECTIONS

AC VERSION

PIN	FUNCTION
1	Input
2	Analog Ground
3	NC
4	AC HI
5	AC LO

DC VERSION

PIN	FUNCTION
1	+5V Power
2	+5V Display Power
3	Decimal Point X.XX
4	Input (When Scaling Resistors Not Used)
5*	Input (When Scaling Resistors Are Used)
6*	Series Arm of Scaling Resistor Divider
7*	Series Arm of Scaling Resistor Divider

PIN	FUNCTION
A	Decimal Point XX.X
B	Decimal Point XXX
C	Power Ground
D	Hold
E	Analog Ground
F*	Shunt Arm of Scaling Resistor Divider
H*	Shunt Arm of Scaling Resistor Divider

*NOT NORMALLY USED ALLOWS CONVENIENT MOUNTING OF SCALING RESISTORS

Microprocessor-Based Thermocouple Meters

AD2050/AD2051

FEATURES

- Automatic Self-Calibration for Gain, Offset, Cold Junction Compensation and Thermocouple Linearization
- J, K, T, E, R, S Thermocouple Selections (AD2050) Universal Meter (AD2051), User Programmable
- Character Serial ASCII Digital Output
- Optional Linearized Analog Output: 1mV/degree
- Optional Isolated 20mA Loop/TTL Serial Outputs
- Meets DIN/NEMA Dimension Specifications
- Temperature Ranges: −265°F to +1999°F
  −165°C to +1760°C
- Power Options: 120V ac, 240V ac, +7.5V dc to +28V dc

APPLICATIONS

- Temperature Monitoring in Laboratory, Manufacturing, and Quality Control Environments
- Process Control Temperature Measurements
- Remote Data Logging



GENERAL DESCRIPTION

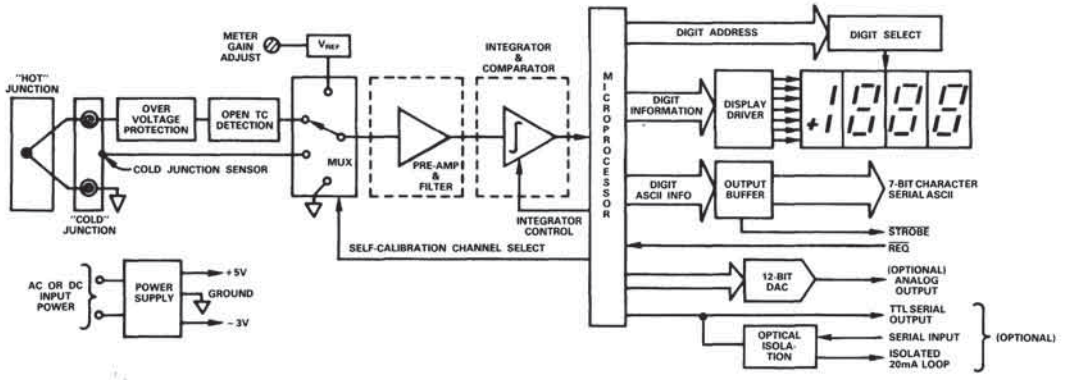
The AD2050 and AD2051 are high performance single channel 3½ digit thermocouple meters that can measure temperatures accurately between −265 and +1999 in degrees Celsius or Fahrenheit. The AD2050 is supplied factory programmed to interface directly with any of the following six thermocouple types: J, K, T, E, R and S. The AD2051 is a universal instrument in which the user selects one of the six thermocouple types via switch programming. Being microprocessor based, all gain and offset error correction, cold junction compensation, thermocouple linearization, and °C/°F scaling are automatically performed in firmware.

The AD2050 and AD2051 display temperature information on large 0.56″ (14.3mm) high LEDs. Digital information is provided in standard ASCII character serial format with rate selection for easy interface to printers, terminals, and other peripherals. For remote data acquisition applications, an optional isolated 20mA serial loop/TTL compatible interface is available. Also an optional analog output linearized to 1mV/degree is provided for driving recorders and other analog instruments. Selection of °C or °F scaling is accessed by removing the front panel lens and setting the selector switch to its proper position.

The AD2050 and AD2051 can also be ordered with any of the following power versions: 120V ac, 240V ac, or +7.5V dc to +28V dc. Input overvoltage protection for 300V peak (thermocouple to ac line shorts) and common mode voltages as high as 1400V peak (ac version) with overrange and open thermocouple detection are provided. These instruments are rated for operation over the +10°C to +40°C temperature range. Testing is performed per MIL-STD-202E Method 103B to insure specified operation over various relative humidity conditions. The AD2050 and AD2051 are supplied in rugged high impact plastic cases that meet DIN/NEMA standard dimensions.

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AD2050/AD2051 FUNCTIONAL BLOCK DIAGRAM



For detailed information, contact factory.

SPECIFICATIONS (typical @ +25°C and rated supply voltages unless otherwise specified)

THERMOCOUPLE INPUTS
- Thermocouple Types: J, K, T, E, S, R
- Input Impedance: >100MΩ
- External (Lead) Resistance Effect: <20μV per 350Ω of Lead Resistance
- Cold Junction Compensation Error: ±0.5°C max (+10°C to +40°C)
- Open Thermocouple: +EEE Display; +EEEE ASCII Digital Output; +2.048V Analog Output
- Thermocouple Short to ac Line: Internal Protection Provided to 300V peak (200V ac rms)
- Common Mode Voltage: 1400V peak (dc or ac), between Input and Power Line Ground (ac Versions)
- Common Mode Rejection Ratio: >130dB with 250Ω Source Imbalance (ac Versions); (dc to 60Hz)
- Normal Mode Rejection Ratio: >80dB @ 50/60Hz

DIGITAL OUTPUTS
- Character Serial ASCII
  Data: Nine transmitted characters, (each 7 bits plus strobe)
  Drive Capability: 2TTL loads, CMOS/TTL compatible
  Strobe: Negative transition determines when character serial data is valid. CMOS/TTL compatible.
  Character Rate: Selectable on P1 (pin 32)
  Grounded: 25 characters/sec. (SLOW)
  Open: 100 characters/sec. (FAST)
- Isolated Serial Output (Optional)
  Data: Asynchronous ASCII 20mA current loop
  (Optically isolated to ±600V peak)
  Baud Rate: Selectable on P1 (Pin 32)
  Grounded: 300 baud (SLOW)
  Open: 1200 baud (FAST)
  Distance: 10,000 ft. max
- Serial Output (Nonisolated, Optional)
  Data: Serial ASCII
  Drive Capability: 2TTL Loads, CMOS/TTL compatible
  Baud Rate: (same as Isolated Serial Output)
- Overrange: ±EEEE
- Minimum Time Between New Data Update: 150ms

DIGITAL INPUTS
- $\overline{\text{REQ}}$: Low-Level Triggered: Must go low at any time other than during data transmission to be recognized. $\overline{\text{REQ}}$ line taken low during data transmission will not be acknowledged and the ASCII digital output transmission will not occur. Display readings are not effected by $\overline{\text{REQ}}$.
- SERIAL INPUT (Optional): Edge Triggered, Current On to Current Off: Must be triggered at any time other than during data transmission to be recognized. Serial Input triggered during data transmission will not be acknowledged and the 20mA isolated/TTL compatible serial output transmission will not occur. Display readings are not effected by Serial Input.

ANALOG OUTPUT (OPTIONAL)
- Voltage: 1mV/degree, linearized
- Current: ±2mA max drive
- CMV: 1400V peak (ac or dc) Peak between Analog Output Ground & ac Power Line Ground
- Overrange: +2.048V, −0.512V

ACCURACY
- Temperature Resolution: 1°C/1°F
- All Ranges are Guaranteed Monotonic
- Range Temperature Coefficient: ±25ppm/°C typ, ±60ppm/°C max
- Readout Accuracy @25°C:

Sensor Type	Range	Accuracy	
J	−165°C to 760°C	±0.7°C	±1/2LSD
J	−265°F to 1400°F	±1.3°F	±1/2LSD
K	−50°C to 1250°C	±0.9°C	±1/2LSD
K	−58°F to 1999°F	±1.6°F	±1/2LSD
T	−150°C to 400°C	±0.8°C	±1/2LSD
T	−238°F to 752°F	±1.4°F	±1/2LSD
E	−100°C to 870°C	±1.0°C	±1/2LSD
E	−148°F to 1598°F	±2.0°F	±1/2LSD
S, R	+300°C to 1760°C	±1.5°C	±1/2LSD
	0° to 299°C	±6.0°C	±1/2LSD
S, R	+572°F to 1999°F	±3.0°F	±1/2LSD
	+32°F to 571°F	±12.0°F	±1/2LSD

ANALOG TO DIGITAL CONVERSION
- Technique: Offset Dual Slope with Gain and Offset Error Correction
- Rate: 2.5 Conversions/Second Typical
- Input Integration Period: 100ms for 50/60Hz Noise Rejection

POWER REQUIREMENTS (Choice of Three Supply Ranges)
- ac: 90V ac to 132V ac @ 25mA (47Hz to 500Hz)
  198V ac to 264V ac @ 12.5mA (47Hz to 500Hz)
- dc: +7.5V to +28V dc @ 200mA (Protected Against Supply Reversals)

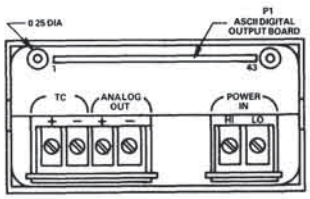
DISPLAY
- Type: Seven Segment Orange LED 0.56" (14.3mm) high
- Polarity Indication: "+" or "−" displayed
- Overrange Indication: ±EEE
- Display Test: At Power Turn-On, 3 Second Display of "+1888" Tests all Segments of Display

ENVIRONMENTAL
- Rated Temperature Range: +10°C to +40°C
- Operating Temperature Range: −10°C to +50°C
- Storage Temperature Range: −40°C to +85°C
- Relative Humidity: Meets MIL-STD-202E, Method 103B

DIMENSIONS
- Case: 3.78" × 1.89" × 5.13" (96.8mm × 48.9mm × 131.3mm), high impact molded plastic case. DIN/NEMA Standard
- Weight: 15.2 oz (431 grams) max, ac powered
  12.0 oz (341 grams) max, dc powered.

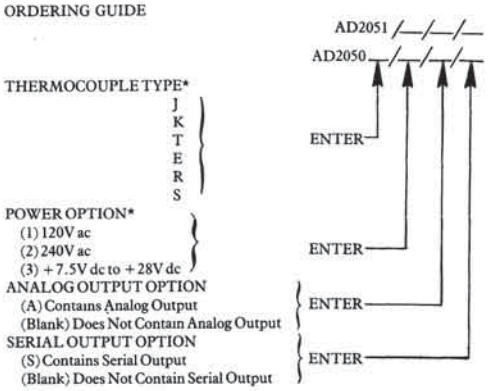
RELIABILITY
- Burn In: 168 Hours at +50°C and Power ON/OFF Cycles.
- Calibration: NBS Traceable
- Recalibration: Recommended 15-Month Intervals
- Warranty: 12 months

CONNECTOR
One 44 pin 0.1" (2.54mm) spacing card edge connector
Viking 3VH22/1 JN5 or equivalent
Optional: Order AC2630



Rear Panel View

ORDERING GUIDE



*Only one option can be ordered. The thermocouple type does not need to be specified when ordering the AD2051 since it is user programmable.

Specifications subject to change without notice.

Microprocessor-Based Autoranging RTD/Thermocouple Meters

AD2060/AD2061

FEATURES

Temperature Ranges: −328°F to +1562°F
−200°C to +850°C
Autoranging: 0.1° from −199.9° to +199.9°; 1°≥200°
Sensor Selection (AD2060): RTD 100Ω Platinum
α = 0.00385, 0.00390, 0.00392 or 2252Ω Thermistor
Universal Meter (AD2061) Sensor User Programmable
Switch Selectable Sensor Configuration: 2, 3 or 4-wire
7-Bit ASCII Character Serial Data Output
Automatic Self-Calibration for Gain, Offset, Excitation and Sensor Linearization
Optional Linearized Analog Voltage Output: 1mV/degree
Optional Isolated 20mA ASCII Loop/TTL Serial Outputs

APPLICATIONS

Temperature Monitoring in Laboratory, Manufacturing and Quality Control Environments
Process Control Temperature Measurements
Remote Data Logging



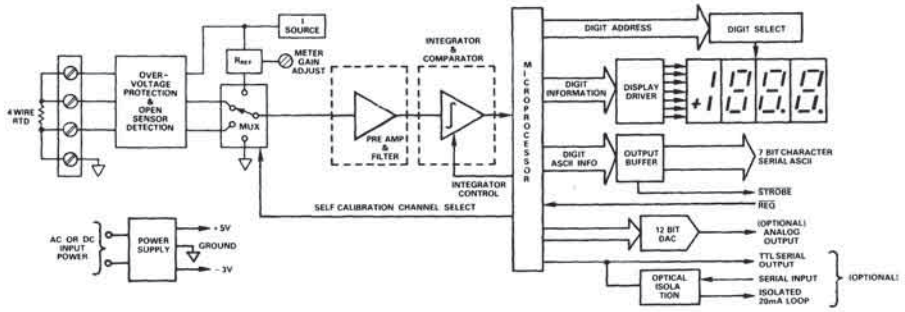
GENERAL DESCRIPTION

The AD2060/AD2061 are high performance single channel 3½ digit RTD/Thermistor meters that can measure temperature accurately between −328°F and +1562°F (−200°C and +850°C). Both meters offer autoranging from 0.1°C/F to 1°C/F. The AD2060 is supplied factory programmed for one of four sensor types: 100Ω Platinum RTDs: α = 0.00385, 0.00390, 0.00392 or a 2252Ω Thermistor. The AD2061 is a universal meter in which the user selects one of the four sensor types via switch programming. The microprocessor based AD2060/AD2061 provides gain, offset and excitation error correction, linearization and °C/°F scaling in firmware. The AD2060/AD2061 display temperature information on large 0.56"(14.3mm) high LEDs. Digital information is provided in 7-bit standard ASCII character serial format with baud rate selection for easy interface to printers, terminals and other peripherals. For remote data acquisition applications, an optional isolated 2-wire 20mA ASCII serial loop/TTL compatible interface is available. For driving recorders or other analog instruments, an optional linearized analog voltage output of 1mV/degree is available. Selection of °C or °F scaling is accessed by removing the front panel lens and setting the selector switch to its proper position.

The AD2060/AD2061 can be ordered in one of the following power versions: 120V ac, 240V ac or +7.5V dc to +28.0V dc. Input voltage protection of 180V peak (RTD short to ac line), common-mode voltage to 1400V peak (ac version) with overrange and open sensor detection is provided. These meters are rated for operation over the 0 to +40°C temperature range. Each AD2060/AD2061 is burned-in for 168 hours @ 50°C with on/off power cycles for increased reliability.The AD2060/AD2061 are supplied in rugged molded plastic cases that meet UL94V-0 and DIN/NEMA standard dimensions.

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AD2060/AD2061 FUNCTIONAL BLOCK DIAGRAM



For detailed information, contact factory.

SPECIFICATIONS (typical @ +25°C and rated supply voltages unless otherwise specified)

RTD INPUTS
- RTD Types: 100Ω Platinum
  α = 0.00385 (Per DIN 43760)
  α = 0.00390
  α = 0.00392
- Configuration: 2, 3 or 4 Wire
- Excitation Current: 0.25mA nominal
- External Lead
  Resistance Effect: Automatically Compensated for 3 & 4 wire configurations
- Lead Resistance: 50Ω/Lead max; RTD + Lead Resistance must be less than 400Ω
- 3 Wire Error: 2.8°C/Ω of impedance imbalance
- Open Sensor: DISPLAY +EEE
- RTD Short to ac Line: Internal protection provided to 180V peak (130V rms)
- Maximum Common-Mode Voltage: 1400V peak (ac or dc) between input and power line ground (ac version)
- Common-Mode Rejection Ratio: 100dB at power to RTD input
- Normal Mode Rejection: 60dB @ 50/60Hz

THERMISTOR INPUTS
- Thermistor Type: Series 400 R = 2252Ω
- Configuration: 2 Wire
- Open Sensor: DISPLAY -EEE

ACCURACY
- Temperature Resolution: Autoranging (0.1° from −199.9° to +199.9°, 1°≥200°)
- All Ranges Guaranteed Monotonic
- Range Temperature Coefficient: 20ppm/°C typ, 30ppm/°C max
- Readout Accuracy* @ +25°C

Sensor	Range	Accuracy
100Ω RTD α = 0.00385	−200°C to +850°C	±0.3°C ± 1/2LSD
	−328°F to +1562°F	±0.6°F ± 1/2LSD
100Ω RTD α = 0.00392	−200°C to +640°C	±0.3°C ± 1/2LSD
	−328°F to +1184°F	±0.6°F ± 1/2LSD
100Ω RTD α = 0.00390	−200°C to +640°C	±0.3°C ± 1/2LSD
	−328°F to +1184°F	±0.6°F ± 1/2LSD
Thermistor R = 2252Ω	−30°C to +100°C	±0.4°C ± 1/2LSD
	−22°F to +212°F	±0.8°F ± 1/2LSD

*Readout Accuracy: Includes Gain and Offset Errors. Recommended Recalibration Interval 15-MONTHS.

DIGITAL OUTPUTS
- Character Serial ASCII
  Data: Eleven transmitted characters, (each 7 bits plus strobe)
  Drive Capability: 2TTL loads, CMOS/TTL compatible
  Strobe: Negative transition determines when character serial data is valid. CMOS/TTL compatible.
  Character Rate: Selectable on P1 (Pin 32)
  Grounded: 25 characters/sec. (SLOW)
  Open: 100 characters/sec. (FAST)
- Isolated Serial Output (Optional)
  Data: Asynchronous ASCII 20mA current loop (Optically isolated to ±600V peak)
  Baud Rate: Selectable on J1 (Pin 32)
  Grounded: 300 baud (SLOW)
  Open: 1200 baud (FAST)
  Distance: 10,000 ft. max
- Nonisolated Serial Output (Optional)
  Data: Serial ASCII
  Drive Capability: 2TTL Loads, CMOS/TTL compatible
  Baud Rate: (same as Isolated Serial Output)
- Overrange: ±EEE.E
- Minimum Time Between New Data Update: 150ms

DIGITAL INPUTS
- $\overline{\text{REQ}}$. Low-Level Triggered: Must go low at any time other than during data transmission to be recognized. $\overline{\text{REQ}}$ line taken low during data transmission will not be acknowledged and the ASCII digital output transmission will not occur. Display readings are not effected by $\overline{\text{REQ}}$.
- $\overline{\text{SERIAL INPUT}}$ (Optional): Edge Triggered, Current On to Current Off: Must be triggered at any time other than during data transmission to be recognized. $\overline{\text{Serial Input}}$ triggered during data transmission will not be acknowledged and the 20mA isolated/TTL compatible serial output transmission will not occur. Display readings are not effected by $\overline{\text{Serial Input}}$.

ANALOG OUTPUT (OPTIONAL)
- Voltage: 1mV/degree, linearized
- Current: ±2mA max drive
- CMV: 1400V peak (ac or dc) between Analog Output Ground & ac Power Line Ground
- Overrange: +2.048V, −0.512V
- Accuracy: ±2mV from Display Reading

ANALOG TO DIGITAL CONVERSION
- Technique: Offset Dual Slope with Gain and Offset Error Correction
- Rate: 2.5 Conversions/Second Typical
- Input Integration Period: 100ms for 50/60Hz Noise Rejection

POWER REQUIREMENTS (Choice of Three Supply Ranges)
- ac: 90V ac to 132V ac @ 25mA (47Hz to 500Hz)
  198V ac to 264V ac @ 12.5mA (47Hz to 500Hz)
- dc: +7.5V to +28V dc @ 200mA (Protected Against Supply Reversals)

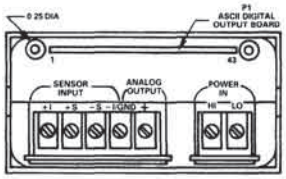
DISPLAY
- Type: Seven Segment Orange LED 0.56" (14.3mm) high
- Polarity Indication: "+" or "−" displayed
- Overrange Indication: ±EEE
- Display Test: At Power Turn-On, 3 Second Display of "+188.8." Tests all Segments of Display

ENVIRONMENTAL
- Rated Temperature Range: 0 to +40°C
- Operating Temperature Range: −10°C to +50°C
- Storage Temperature Range: −40°C to +85°C
- Relative Humidity: Meets MIL-STD-202E, Method 103B (0 to 90%, Noncondensing)

DIMENSIONS
- Case: 3.78" × 1.89" × 5.13" (96.8mm × 48.9mm × 131.3mm), rugged molded plastic case. Meets UL94V-0 and DIN/NEMA Standard dimensions
- Weight: 15.2 oz (431 grams) max, ac powered
  12.0 oz (341 grams) max, dc powered.

RELIABILITY
- MTBF: >55.000 hours calculated
- Burn In: 168 Hours at +50°C and Power ON/OFF Cycles.
- Calibration: NBS Traceable
- Recalibration: Recommended 15-Month Intervals
- Warranty: 12 months

CONNECTOR
One 44 pin 0.1" (2.54mm) spacing card edge connector Viking 3VH22/1 JN5 or equivalent
Optional: Order AC2630



Rear Panel View

ORDERING GUIDE

AD2061 /_/_/_
AD2060 /_/_/_/_/

SENSOR TYPE*
- (385) 100Ω Platinum RTD α = 0.00385
- (390) 100Ω Platinum RTD α = 0.00390
- (392) 100Ω Platinum RTD α = 0.00392
- (2252) Thermistor R = 2252Ω

} ENTER

POWER OPTION*
- (1) 120V ac
- (2) 240V ac
- (3) +7.5V dc to +28V dc

} ENTER

ANALOG OUTPUT OPTION
- (A) Contains Analog Output
- (Blank) Does Not Contain Analog Output

} ENTER

SERIAL OUTPUT OPTION
- (S) Contains Serial Output
- (Blank) Does Not Contain Serial Output

} ENTER

*Only one option can be ordered. The sensor type does not need to be specified when ordering the AD2061 since it is user programmable.

Specifications subject to change without notice.

Microprocessor-Based Autoranging Thermocouple Meters

AD2070/AD2071

FEATURES

- **Autoranging (0.1° – 1°)**
- **4 1/2 Digit Resolution**
- **Automatic Self-Calibration for Gain, Offset, Cold Junction Compensation and Thermocouple Linearization**
- **J, K, T, E, R, S, C, B, J DIN, and T DIN Thermocouple Selection**
- **Universal Meter (AD2071), User Programmable for all Thermocouple Types**
- **Four Port Isolation: Input, Power, Digital Output and Analog Output**
- **Optional Isolated and Linearized Analog Voltage Output 1mV/Degree**
- **Optional Isolated 20mA Loop/TTL Serial Data Output**
- **Optional Isolated RS-232/TTL Serial Data Output**
- **Heavy Gauge Rugged Metal Case**



GENERAL DESCRIPTION

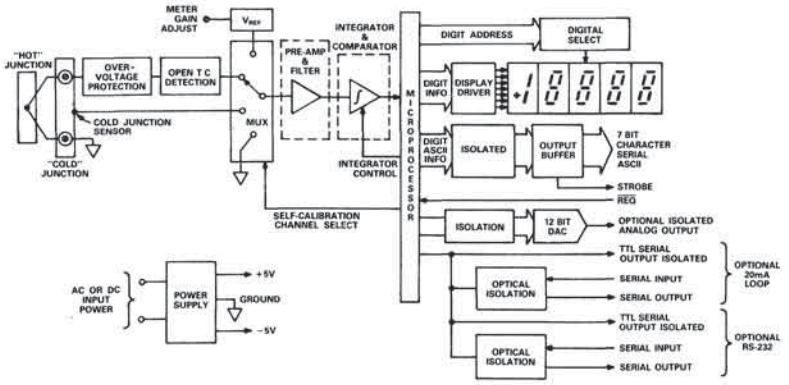
The AD2070/AD2071 are high performance, microprocessor based, autoranging, single channel thermocouple meters that can measure temperature accurately from −328°F to +4200°F (−200°C to +2315°C). The AD2070 is supplied factory programmed for any of the following ten thermocouple types: J, K, T, E, R, S, C, B, J DIN, and T DIN. The AD2071 is a universal meter in which the user selects one of the ten thermocouple types via switch programming. Both meters offer autoranging from 0.1°C/°F to 1°C/°F. The microprocessor based AD2070/AD2071 provides gain and offset error correction, cold junction compensation, thermocouple linearization and °C/°F scaling in firmware.

The AD2070/AD2071 display temperature information on large 0.56" (14.3mm) high LEDs. Digital information is provided in standard ASCII character serial format with rate selection for easy interface to printers. For remote data acquisition applications, an optional isolated 20mA serial loop or RS-232 compatible interface is available. For driving recorders or other analog instruments, an optional isolated and linearized analog voltage output of 1mV/degree is available. Selection of °C or °F scaling is accessed by removing the front panel lens and setting a selector switch.

The AD2070/AD2071 can be ordered in one of the following power versions: 120V ac, 240V ac or +7.5V dc to +28.0V dc. Input overvoltage protection rating is 300V peak (thermocouple to ac line shorts). The common-mode voltage rating is 1400V peak. Overrange and open thermocouple detection are provided in all models. Analog output and digital outputs are isolated to 500V peak from power, input and output sections. Each meter is burned-in for 168 hours at 50°C with on/off power cycles for increased reliability. These meters are rated for operation over a +10°C to +40°C range. The AD2070/AD2071 are supplied in a heavy gauge, rugged metal case that meets DIN/NEMA standard dimensions.

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AD2070/AD2071 FUNCTIONAL BLOCK DIAGRAM



For detailed information, contact factory.

SPECIFICATIONS (typical @ +25°C and rated supply voltages unless otherwise specified)

THERMOCOUPLE INPUTS

THERMOCOUPLE TYPES:
J, K, T, E, R, S, B, C, J DIN and T DIN
INPUT IMPEDANCE:
100MΩ
EXTERNAL LEAD RESISTANCE EFFECT:
<20μV per 350Ω of Lead resistance
COLD JUNCTION COMPENSATION ERROR:
±0.3°C max (+10°C to +40°C)
OPEN THERMOCOUPLE:
+EEEE Display; +EEEE.E ASCII DIGITAL OUTPUT: +3.500V ANALOG OUTPUT
THERMOCOUPLE SHORT TO AC LINE:
Internal Protection Provided to 300V peak, (200V ac rms)
COMMON-MODE VOLTAGE:
1400V peak (dc or ac), Between Input and Power Line Ground
COMMON-MODE REJECTION RATIO:
>130dB with 250Ω Source Imbalance (dc to 60Hz)
NORMAL-MODE REJECTION RATIO:
>80dB @ 50/60Hz

DIGITAL OUTPUTS

ISOLATED CHARACTER SERIAL ASCII (Standard)
DATA:
Eleven transmitted characters, each 7 bits plus strobe
DRIVE CAPABILITY:
2TTL Loads, CMOS/TTL compatible
OVERRANGE: ±EEEE.E
STROBE:
Positive transition determines when character serial data is valid. CMOS/TTL compatible.
ISOLATION:
500V Between Input, Analog Output and Power Input
CHARACTER RATE:
Selectable on P1 (Pin 20)
Grounded: 25 Characters/sec. (SLOW)
Open: 100 Characters/sec. (FAST)
ISOLATED SERIAL OUTPUT (Optional)
DATA:
Asynchronous ASCII 20mA current loop or RS-232
BAUD RATE:
Selectable on P1 (Pin 20)
Grounded: 300 baud (SLOW)
Open: 1200 baud (FAST)
OVERRANGE:
±EEEE.E
DISTANCE:
50 ft. (RS-232), 10,000 ft. (20mA loop)
ISOLATION:
500V Between Input, Analog Output and Power Input
ISOLATED SERIAL OUTPUT
DATA:
Serial ASCII TTL
DRIVE CAPABILITY:
2TTL Loads, CMOS/TTL Compatible
BAUD RATE:
(same as above)
OVERRANGE:
±EEEE.E
ISOLATION:
500V Between Input, Analog Output and Power Input
MINIMUM TIME BETWEEN NEW DATA UPDATE:
100ms

DIGITAL INPUTS

$\overline{\text{REQ}}$: LOW-LEVEL TRIGGERED:
Must go low at any time other than during data transmission to be recognized. $\overline{\text{REQ}}$ line taken low during data transmission will not be acknowledged and the ASCII digital output transmission will not occur. Display readings are not effected by $\overline{\text{REQ}}$.

$\overline{\text{SERIAL INPUT}}$: EDGE TRIGGERED, CURRENT ON TO CURRENT OFF
Must be triggered at any time other than during data transmission to be recognized. $\overline{\text{Serial Input}}$ triggered during data transmission will not be acknowledged and the isolated 20mA loop/TTL or isolated RS-232/TTL compatible serial output transmission will not occur. Display readings are not effected by $\overline{\text{Serial Input}}$.

ISOLATED ANALOG OUTPUT (OPTIONAL)

VOLTAGE:
1mV/degree, Fahrenheit or Celsius linearized
CURRENT:
±2mA max
OVERRANGE:
+3.500V, −0.328V
ACCURACY:
±2mV from Display Reading
ISOLATION:
500V Between Input, Digital Output and Power Input

ACCURACY

TEMPERATURE RESOLUTION:
Autoranging 0.1°C/°F – 1°C/°F
RANGE TEMPERATURE COEFFICIENT:
20ppm/°C typ, ±40ppm/°C max (of Reading)
All Ranges are Guaranteed Monotonic.

POWER REQUIREMENTS (Choice of Three Supply Ranges)

ac:
90V ac to 132V ac @ 25mA (dc to 1kHz)
198V ac to 264V ac @ 12.5mA (dc to 1kHz)
dc:
+7.5V to +28V dc @ 600mA (Protected Against Supply Reversals)

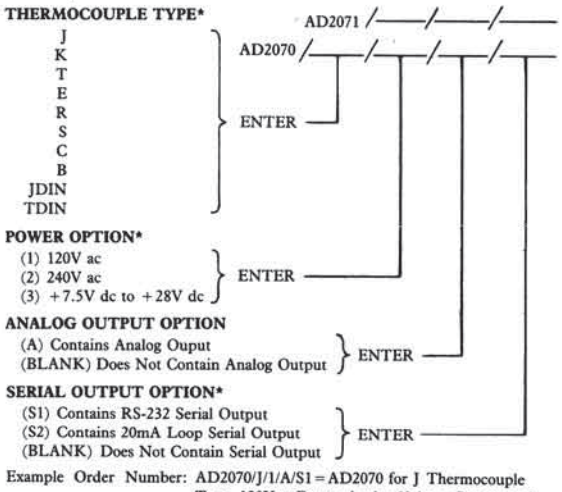
DISPLAY

TYPE:
Seven Segment Orange LED 0.56" (14.3mm) high
POLARITY INDICATION:
"+" or "−" displayed
OVERRANGE INDICATION:
±EEEE
DISPLAY TEST:
At Power Turn-On, 3 Second Display of "+1888.8." Tests All Segments of Display

DIMENSIONS

CASE:
3.78" × 1.89" × 6.75" (96.8mm × 48.0mm × 171.0mm), rugged aluminum case. DIN/NEMA Standard.
PANEL CUT OUT: $3.622^{\prime\prime}\ {}^{+0.031}_{-0.000}\ (92\ {}^{+,8}_{-,0})\text{mm} \times 1.771\ {}^{+0.024}_{-0.000}\ (45\ {}^{+,6}_{-,0})\text{mm}$
PANEL THICKNESS:
1/16" (1.5mm) to 3/16" (4.8mm)
WEIGHT:
23 oz. (650 grams) typ

ORDERING GUIDE



Example Order Number: AD2070/J/1/A/S1 = AD2070 for J Thermocouple Type, 120V ac Power, Analog Voltage Output and RS-232 Serial Output.

*Only one option can be ordered. The thermocouple type does not need to be specified when ordering the AD2071 since it is user programmable.

Specifications subject to change without notice.

Application Specific Integrated Circuits

Analog Devices offers a full spectrum of capabilities in application-specific integrated circuits (ASICs). These chip-level systems can implement designs with 12-bit accuracy and 16-bit resolution that formerly required board-level solutions.

Analog Devices can incorporate most of the functions of its standard monolithic parts in full-custom and semicustom ICs. Full-custom parts optimize performance and space requirements, while cell-based semicustom parts reduce development time and engineering expense. Development costs can be cut further by tailoring a generic predefined system-on-a-chip to your application.

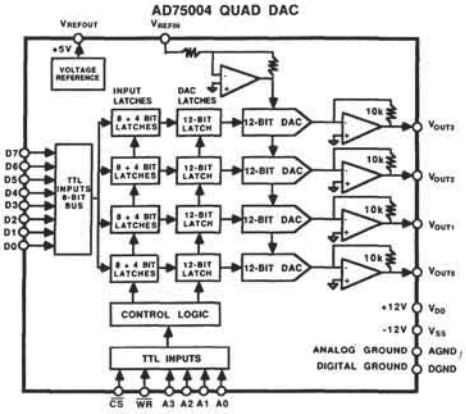
Analog's experienced design engineers work with powerful computer-aided design tools to design and lay out your circuit. Design centers are currently in Massachusetts, California and England.

Multiple locations for fabrication, assembly, and testing ensure a ready supply of production parts. Products can be processed in full MIL-38510 certified facilities.

DESIGN EXAMPLES

Analog Devices has created a variety of customer-specific and function-specific ASIC parts. Described here are two examples, a custom chip set and a semicustom chip.

AD75004 QUAD DAC



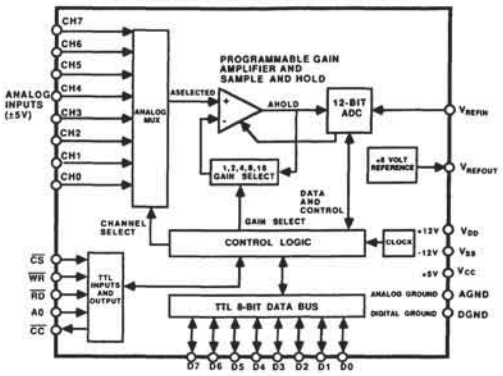
AD75004 Quad DAC

This circuit contains four separate 12-bit D/A converters with amplifiers for voltage output and an on-board reference. Double-buffering latches interface with an 8-bit parallel bus and permit updating of all four channels individually or simultaneously.

AD75003 Data Acquisition System

This DAS converts analog signals on 8 input channels to 12-bit values and interfaces via an 8-bit parallel bus. The chip integrates an 8-channel multiplexer, programmable-gain amplifier, sample-and-hold, and 12-bit A/D converter with internal voltage reference.

AD75003 DATA ACQUISITION SYSTEM



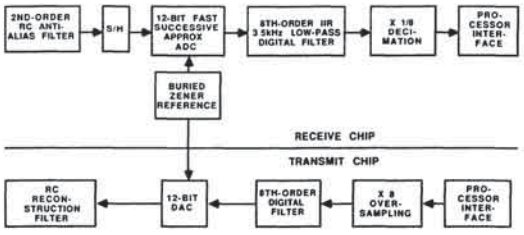
Derivative Circuits

The circuits outlined above can be modified to suit a specific customer's application. One such device is a serial-interface DAS. The AD75003 design was altered to have programmable gains of 1 to 20 instead of 1 to 16, and a serial UART instead of an 8-bit parallel interface. In addition to the AD75003 functions, this part contains a precision instrumentation amplifier, a programmable line-frequency notch filter, a 7-bit trim DAC, and a temperature sensor.

Modem Chip Set

Library cells can be combined to form macro building blocks for high-speed modems. This two-chip design concept filters and converts data to interface a digital signal processor with the analog circuitry of a 9600-baud modem. On one chip, the received signal passes through an anti-aliasing filter, sample-and-hold, 12-bit A/D converter, 8th-order digital filter and decimation. On the other chip, transmit data is 8× oversampled, then goes to an 8th-order filter, a 12-bit DAC and an active reconstruction filter.

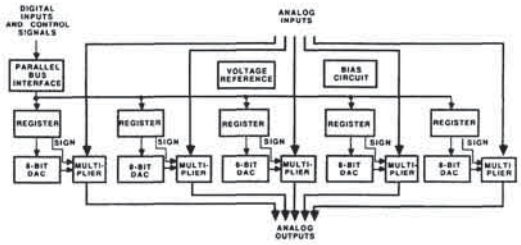
HIGH-SPEED MODEM CHIP SET



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Transversal Filter Element
This design implements 5 taps of a finite-impulse response filter. Each tap comprises an 8-bit DAC and a multiplier, which handle signals up to 40MHz. A parallel interface sets the tap weights.

TRANSVERSAL FILTER ELEMENT



HIGH-PERFORMANCE PROCESSES

Analog Devices' semicustom and custom circuits are fabricated using the same high-performance processes as our standard ICs. These technologies include two mixed bipolar-CMOS processes, a high-voltage CMOS process, and high-speed and low-power bipolar processes. These processes can include thin-film resistors, which may be laser trimmed for precise matching and stable performance over a wide temperature range.

The BiMOS II and Linear-Compatible CMOS (LC^2MOS) processes combine bipolar and CMOS devices on one chip. Functional density is an order of magnitude greater than previous mixed-signal processes; over 20,000 devices can be placed on a single chip. Bipolar transistors provide low-noise, low-offset input stages and high-power output stages. The CMOS devices offer high input impedance, and make dense logic and good switches for data converters and switched-capacitor filters. LC^2MOS also provides a JFET for very low input noise.

The bipolar-CMOS processes operate on supply voltages ranging from single +5 volts to split ±15V, with signal levels ranging from single-ended +3V to ±10V. These processes are ideally suited for applications in data acquisition, instrumentation, industrial automation and telecommunications.

The High-Voltage Switch (HVS) process provides quality analog switches that can operate with supply voltages up to ±22 volts. It can combine switches and multiplexers with CMOS logic.

The Flash bipolar process makes high-speed linear signal processing, data conversion, and ECL logic functions on one chip. Signal levels are ±4 volts with ±5V supplies or +10V with a +12V supply. Applications include disk-drive read/write circuitry and high-speed telecommunications equipment.

The Complementary Bipolar (CB) process features high-speed PNP and NPN devices for precision, low-power linear applications. It also offers low-noise buried-Zener references and dual-gate JFETs. CB runs on +5V to ±15V supplies.

The table below summarizes the processes available for designing ASICs. Other processes in development will offer even higher speed, denser logic and higher integration of analog and digital functions.

ANALOG DEVICES HIGH-PERFORMANCE PROCESSES FOR ASICs

Process	Power	Signal	Features
BiMOS II	±12V	±5V	Wide Variety of Precision Linear and Digital Functions
LC^2MOS	+5 to ±15	±3 to ±10	Wide Variety of Precision Linear and Digital Functions
HVS	+5 to ±22	+2 to ±18	High-Voltage Switches, Muxes and Logic Functions
Flash	±5 or +12	±4 or +10	High-Speed Linear and Digital Functions
CB	+5 to ±15	+2 to ±10	High-Speed, Low-Power Linear Functions

CELL LIBRARIES

Cell libraries for the bipolar-CMOS processes are described below. These libraries are growing with the development of new processes, macrocells and cells. Many new catalog parts will also be available as cells. Your local sales office can give you current information on the cell libraries and available generic circuits.

Operational amplifiers are available in bipolar and CMOS configurations. Representative bipolar opamp cells have performance characteristics similar to an AD OP-27 and a slew-enhanced AD741. The LC^{2}MOS process offers JFET op amps, including an AD544 equivalent.

Instrumentation amplifiers with performance comparable to the AD521 and AD524 are available. Comparators suitable for 12-bit-accurate applications are available. Linear comparators have response times down to 100 nanoseconds and strobed comparators have setup/access times down to 50 nanoseconds.

Digital-to-analog converters range in resolution from 8 to 14 bits, and include a cell similar to the AD667. Analog-to-digital converters vary from 8 to 12 bits in resolution, and include cells equivalent to the AD7572 and AD574. One half-flash ADC cell converts to 8-bit accuracy in 500 nanoseconds, and one successive approximation-cell converts to 12 bits in 5 microseconds.

Support cells include sample-and-hold amplifiers with performance comparable to the AD585, low-voltage bandgap references comparable to the AD584 and low-noise buried-Zener references.

RC active filters and programmable switched-capacitor filters are available with specifications in these ranges:

Topology: all classical filter types
Frequency Range: 200Hz to 20kHz (switched-cap)
Number of Sections: up to 10th-order (switched-cap) or 4th-order (RC)
Signal/Noise and THD: >72dB, compatible with 12-bit data acquisition.

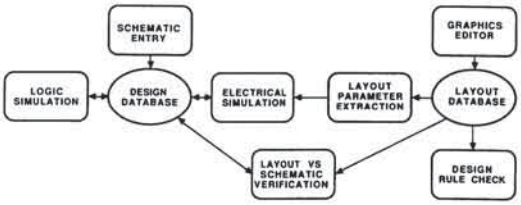
Logic cells include gates, counters, registers, PLA, RAM and ROM. Interface cells include 8- and 16-bit parallel I/O ports and UARTs.

DESIGN AND LAYOUT

Analog Devices engineers are available to design your integrated circuit, drawing on their years of experience and using powerful computer-aided design (CAD) tools. These comprehensive CAD tools help design, simulate and lay out the circuit and aid in generating test programs.

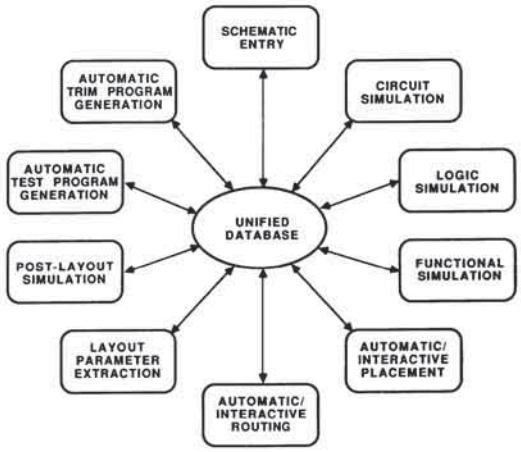
The following figure shows the standard design cycle, which begins with schematic entry. After logic and initial electrical simulation, the designer uses the graphics editor to lay out the circuit. Parasitics and other data are extracted from the layout and circuit operation is simulated again. Finally, the system checks that the layout follows process design rules and matches the schematic.

IC DESIGN WITH COMMERCIAL CAD SYSTEM



In addition to using these commercial CAD tools, Analog Devices has developed a proprietary compiler for mixed-signal IC design, called JANUS. By integrating all design functions into one environment with a common database, JANUS reduces design time by an order of magnitude.

IC DESIGN WITH JANUS PROPRIETARY CAD SYSTEM



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To speed schematic entry, the designer selects devices, cells and macrocells from comprehensive menus. Device generators allow the designer to specify devices for maximum performance and minimum size. Analog, logic and functional simulators verify the performance of individual cells and the overall chip design. Placement and routing algorithms complete circuit layouts automatically, yet allow interaction with the designer to handle special cases. When placing devices, JANUS considers thermal and electrical matching as well as die area. An expert system optimizes routing to minimize interconnect length and number of vias. Post-layout simulation comprehends the parasitics of the final routing and is more accurate than the initial simulation.

Future goals for JANUS include automatically generating programs for production trim and test of analog/digital ICs.

TEST AND TRIM

Analog Devices has over 20 years of experience in testing complex circuits and manufactures commercial test systems for precision linear ICs. In each fabrication facility, a computer network integrates Analog Devices, Teradyne and LTX test equipment. The design, wafer probe and test areas share data on the network for statistical analysis and device modelling.

All Analog Devices ASICs are tested at the wafer level, and most are laser-wafer trimmed to achieve high accuracy. Untrimmed thin-film resistors match within 1% to 0.1%, depending on area. Trimmed resistors can match to better than 0.01%. Wafers may be laser-drift trimmed with a hot-chuck probe to minimize the effects of temperature on accuracy.

After packaging, all parts are tested to assure that they meet guaranteed specifications. Environmental handlers can verify parts at multiple temperatures. Burn-in is performed as specified by the customer.

PACKAGING

Analog Devices ICs are available in most modern package types, including high-pin-count and surface-mount varieties. ASICs may be assembled in any of Analog Devices' standard packages, listed below. This list is constantly expanded and other packages may be used if they are suitable for high-performance applications.

Available Packages

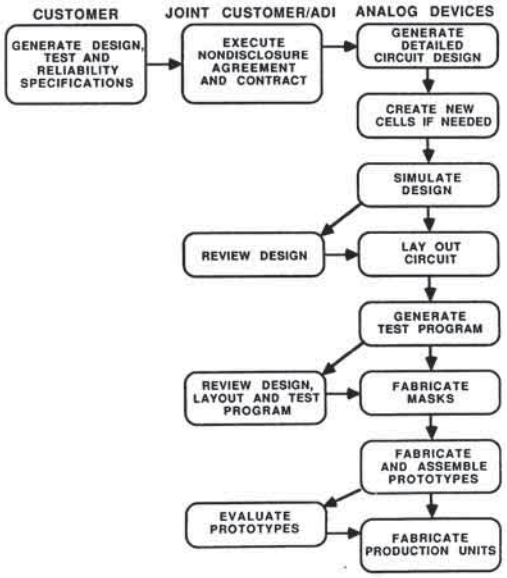
Pin-grid array (PGA): 68 to 144 pins
Leadless ceramic chip carrier (LCC): 20 to 68 pins
Plastic leaded chip carrier (PLCC): 20 to 44 pins
Plastic dual in-line package (DIP): 14 to 64 pins
Side-brazed DIP: 14 to 64 pins
Frit-seal DIP (Cerdip): 14 to 28 pins
Small outline (SO): 14 and 16 pins

PROGRAM RESPONSIBILITIES AND INTERFACES

The following chart shows the major phases in developing an ASIC, and responsibilities during each phase. The overall development time depends on the complexity of the circuit and on how custom the design is.

Your Analog Devices Sales Engineer is your first interface for ASIC development. Your local sales office can provide further information on Analog Devices' custom/semicustom capabilities.

PROGRAM RESPONSIBILITIES AND INTERFACES



Modular AC/DC Power Supplies

GENERAL DESCRIPTION

Analog Devices offers a broad line of modular ac/dc power supplies that provide both OEMs and designers a reliable, easy to use, low-cost solution to their power requirements. Models are available in PC mountable and chassis mountable designs with 5 volt to 15 volt (single, dual, triple) outputs and current ratings from 25mA to 3 amps. Since these modular supplies are fully encapsulated, no trimming or external component selection is necessary; simply mount the unit, connect power and output leads, and you're on the air! Most Analog Devices' power supplies are available from stock in both large and small quantities with substantial discounts being applied to large quantity orders.

AC/DC POWER SUPPLY FEATURES

- Current Limit Short Circuit Protection
- PC Mounted and Chassis Mounted Versions
- Single (+5V), Dual (±12V, ±15V), and Triple (±15V/+5V, ±15V/+1V to +15V) Output Supplies
- Current Outputs:
  25mA to 1000mA for Dual and Triple Output Supplies
  250mA to 3000mA for Single Output Supplies
- Wide Input Voltage Range
- Low Output Ripple and Noise
- Excellent Line & Load Regulation Characteristics
- High Temperature Stability
- Free-Air Convection Cooling; No External Heat Sink Required

GENERAL SPECIFICATIONS

Power Requirements	
Input Voltage Range:	105V ac to 125V ac
Frequency:	50Hz to 250Hz
Electrical Specifications	
Temperature Coefficient:	0.02%/°C
Output Voltage Accuracy:	±2%, max See Specification Table
Breakdown Voltage:	500V rms, min
Isolation Resistance:	50MΩ
Short Circuit Protection:	All ac/dc power supplies employ current limiting. They can withstand substantial overload including direct short. Prolonged operation should be avoided since excessive temperature rises will occur.
Environmental Requirements	
Operating Temperature Range:	−25°C to +71°C
Storage Temperature Range:	−25°C to +85°C

SPECIFICATIONS – Typical @ +25°C and 115V ac 60Hz unless otherwise noted*

	Type	Model	Output Voltage Volts	Output Current mA	Line Reg. max %	Load Reg. max %	Output Voltage Error max	Ripple & Noise mV rms max	Dimensions Inches
PC Board Mounted	Dual Output	904	±15	±50	0.02	0.02	±200mV −0mV	0 5	3.5×2 5×0.875
		902	±15	±100	0.02	0.02	+300mV −0mV	0 5	3.5×2 5×1 25
		902-2	±15	±100	0.02	0.02	+300mV −0mV	0 5	3 5×2 5×0.875
		920	±15	±200	0.02	0.02	+300mV −0mV	0.5	3 5×2.5×1.25
		925	±15	±350	0.02	0 02	±1%	0.5	3 5×2 5×1.62
		921	±12	±240	0.02	0.02	+300mV −0mV	0.5	3.5×2.5×1.25
	Single Output	905	5	1000	0.02	0 05	±1%	1	3.5×2.5×1.25
		922	5	2000	0.02	0.05	±1%	1	3 5×2.5×1.62
		928	5	3000	0 05	0.10	±2%	5 (typ)	3.5×2.5×1.25
	Triple Output	923	±15	±100	0.02	0.02	±1%	0 5	3.5×2.5×1.25
			+5	500	0.02	0 05	±1%	0.5	
		927	±15	±150	0.02	0.02	±2%	0.5 (typ)	3 5×2.5×1.62
			+5	1000	0 02	0.10	±2%	1.0 (typ)	
		2B35J	±15	±65	0 08	0 1	(−0, +300mV)	0 5	3.5×2.5×1 25
			+1 to +15**	125	0 08	0 1		0.25	
		2B35K	±15	±65	0.01	0.02	(−0, +300mV)	0.5	3.5×2.5×1.25
			+1 to +15**	125	0.01	0.02		0.25	
Chassis Mounted	Dual Output	952	±15	±100	0.05	0.05	±2%	1	4.4×2.7×1.44
		970	±15	±200	0 05	0.05	±2%	1	4.4×2.7×1.44
		973	±15	±350	0.05	0.05	±2%	1	4.4×2.7×2.00
		975	±15	±500	0.05	0.05	±2%	1	4.4×2.7×2.00
	Single Output	955	5	1000	0.05	0.15	±2%	2	4.4×2.7×1.44
		976	5	3000	0.05	0.10	±2%	5 (typ)	4.75×2.7×2.00
	Triple Output	972	±15	±150	0.02	0.02	±2%	0 5 (typ)	4.75×2.7×1.45
			+5	300	0 02	0.10	±2%	1.0 (typ)	
		974	±15	±150	0.02	0.02	±2%	0 5 (typ)	4.75×2 7×1.45
			+5	1000	0.02	0.10	±2%	1.0 (typ)	

*Consult Analog Devices Power Supply Catalog for additional information
**Resistor programmable.

Specifications subject to change without notice

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Modular DC/DC Converters

GENERAL DESCRIPTION

Analog Devices' line of compact dc/dc converters offer system designers a means of supplying a reliable, easy to use, low-cost solution to a variety of floating (analog and digital) power applications. These devices provide high accuracy, short circuit protected, regulated outputs with very low output noise and ripple characteristics.

Fourteen models are offered in five power levels of 1 watt, 1.8 watts, 4.5 watts, 6 watts and 12 watts. Input voltage versions include 5 volt, 12 volt, 24 volt and 28 volt with output ranges as follows: +5 volt, ±12 volts and ±15 volts at ±60mA to 1000mA output current capability.

Most models are high efficiency (typically over 60% at full load) and feature complete 6-sided continuous shielding for EMI/RFI protection. A π-type input filter is contained, in some models, which virtually eliminates the effects of reflected input ripple current. Most Analog Devices' dc/dc converters are available from stock in both large and small quantities with substantial discounts being applied to large quantity orders.

DC/DC POWER SUPPLY FEATURES

- Inaudible (>20kHz) converter switching frequency
- Continuous, Six-Sided EMI/RFI Shielding Except on 1 Watt and 1.8 Watt Models
- Output Short Circuit Protection (either output to common)
- Automatic Restart After Short Condition Removed
- Automatic Starting with Reverse Current Injected into Outputs
- Low Output Ripple and Noise
- High Temperature Stability
- Free Air Convection Cooling
  No external heat sink or specification derating is required over the operating temperature range.

GENERAL SPECIFICATIONS FOR 1W AND 1.8W MODELS

Line Regulation–full range: ±0.3% (±1% max, 949)
Load Regulation–no load to full load: ±0.4% (±0.5% max, 949)
Output Noise and Ripple: 20mV p-p (with 15μF tantalum capacitor across each output) (2mV rms max, 949)
Breakdown Voltage: 300V dc min (500V dc min, 949)
Input Filter Type: π
Operating Temperature Range: −25°C to +71°C
Storage Temperature Range: −40°C to +125°C (+100°C, 949)
Fusing: If input fusing is desired, we recommend the use of a slow blow type fuse that is rated at 150%–200% of the dc/dc converter's full load input current.

GENERAL SPECIFICATIONS FOR 4.5W, 6W, 12W MODELS

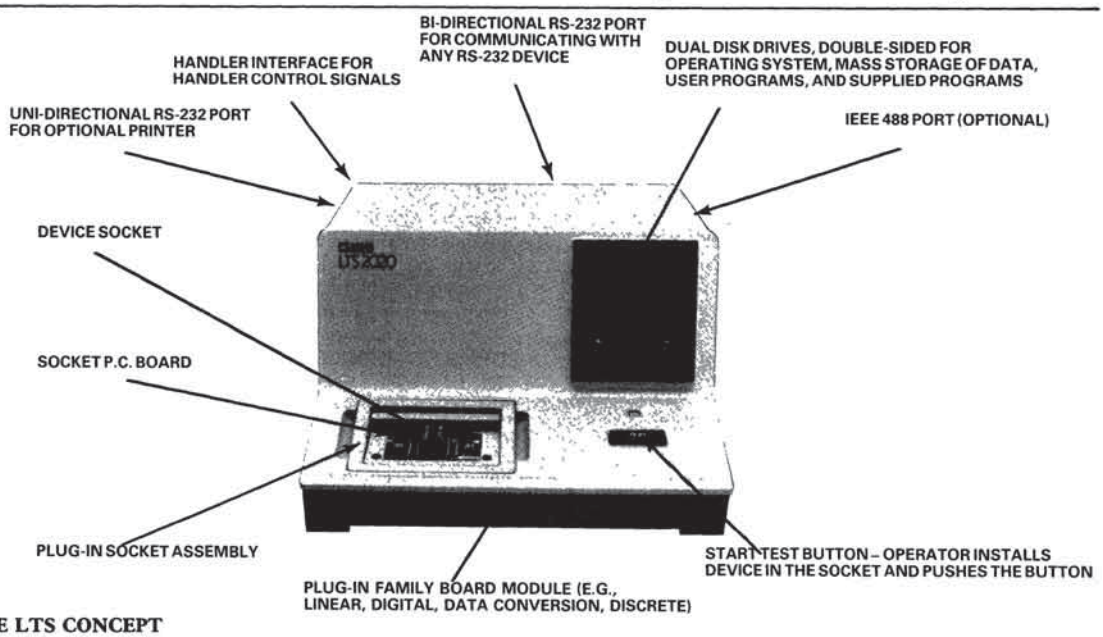
Line Regulation–full range: ±0.07% max (±0.02% max, 951, 960 series) (±0.1% max, 943)
Load Regulation–no load to full load: ±0.07% max (±0.02% max, 951, 960 series) (±0.1% max, 943)
Output Noise and Ripple: 1mV rms max
Breakdown Voltage: 500V dc min
Input Filter Type: π
Operating Temperature Range: −25°C to +71°C
Storage Temperature Range: −40°C to +125°C
Fusing: If input fusing is desired, we recommend the use of a slow blow type fuse that is rated at 150%–200% of the dc/dc converter's full load input current.

SPECIFICATIONS – Typical @ +25°C at nominal input voltage unless otherwise noted*

Model	Output Voltage Volts	Output Current mA	Input Voltage Volts	Input[1] Voltage Range Volts	Input Current Full Load	Output Voltage Error max	Temperature Coefficient /°C max	Efficiency Full Load min	Dimensions Inches
943	5	1000	5	4.75/5.25	1.52A	±1%	±0.02%	62%	2.0×2.0×0.38
958	5	100	5	4.5/5.5	200mA	±5%	±0.01% (typ)	50%	1.25×0.8×0.4
941	±12	±150	5	4.75/5.25	1.17A	±1%	±0.01%	58%	2.0×2.0×0.38
960	±12	±40	5	4.5/5.5	384mA	±5%	±0.01% (typ)	50%	1.25×0.8×0.4
962	±15	±33	5	4.5/5.5	396mA	±5%	±0.01% (typ)	50%	1.25×0.8×0.4
964	±15	±33	12	10.8/13.2	165mA	±5%	±0.01% (typ)	50%	1.25×0.8×0.4
965	±15	±190	5	4.65/5.5	1.7A	±1%	±0.005% (typ)	62% (typ)	2.0×2.0×0.38
966	±15	±190	12	11.2/13.2	710mA	±1%	±0.005% (typ)	62% (typ)	2.0×2.0×0.38
967	±15	±190	24	22.3/26.4	350mA	±1%	±0.005% (typ)	62% (typ)	2.0×2.0×0.38
949	±15	±60**	5	4.65/5.5	0.6A	±2%	±0.03%	58%	2.0×1.0×0.375
940	±15	±150	5	4.75/5.25	1.35A	±1%	±0.01%	62%	2.0×2.0×0.38
953	±15	±150	12	11/13	0.6A	±0.5%	±0.01%	62%	2.0×2.0×0.38
945	±15	±150	28	23/31	250mA	±0.5%	±0.01%	61%	2.0×2.0×0.38
951	±15	±410	5	4.65/5.5	3.7A	±0.5%	±0.01%	62%	3.5×2.5×0.88

NOTES
[1]Models 940 and 941 will deliver up to 120mA output current (and model 943 will deliver up to 600mA) over an input voltage range of 4.65V dc and 5.5V dc
*Consult Analog Devices Power Supply Catalog for additional information
**Single-ended or unbalanced operation is permissible such that total output current load does not exceed a total of 120mA
Specifications subject to change without notice.

LTS-2020 Component Test Systems



THE LTS CONCEPT

The LTS-2020 is a versatile component test system which tests a multitude of components to the manufacturer's specifications (linear, digital, data conversion and discrete devices). The system offers such features as RS-232 ports for networking, IEEE for compatibility with handlers and probers, dual disk drives for mass storage of data, automatic self calibration, and a full statistical analysis software package.

The LTS-2020 provides several data output formats – datalog, yield analysis and statistical analysis. The console provides the primary measurement and control functions to test a specific class of devices. The socket assembly is the mechanical and electronic interface for the family board and the DUT board. The DUT board plugs directly into the socket assembly and contains the circuitry and socket, specific to the actual device under test.

Analog Devices' component test systems are the first benchtop testers that are programmable in BASIC and fill-in-the-blanks CREATE. CREATE is menu-driven software which prompts the user for data sheet limits and conditions, then builds a completed test program for the specified device. Turnkey program libraries are available for each of the device families.

Far more than just comprehensive production testers, these test systems can handle complex engineering analysis and incoming inspection. They are the first systems that can provide all the capabilities of today's large centralized test systems at a price that is approximately one-third the cost. The LTS-2020 not only provides the flexibility of distributed or decentralized testing, it allows for cost effective multiple system purchases. They increase overall test reliability, since the threat of a single big failure is eliminated in a distributed testing environment.

LTS-2020 CONSOLE SPECIFICATIONS

Voltage Measurement Range	Current Range	Resolution	Accuracy
±10V	HI Z	10μV	±(0.0015% + 150μV)
Current Measurement Range	**Voltage Range**	**Resolution**	**Accuracy**
10mA to +150mA	0 to +20V	2μA	±(2.5% + 100μA/V + 15μA)
−150mA to +10mA	0 to −20V	2μA	±(2.5% + 100μA/V + 15μA)
−1.0mA to +1.0mA	0 to +10V	0.2μA	±(0.5% + 10μA)
−10mA to +10mA	±10V	0.1μA	±(0.5% + 10μA)
Voltage Forcing Range	**Current Range**	**Resolution**	**Accuracy**
0 to +20V	−10mA to +150mA	100mV	±50mV
0 to −20V	−150mA to +10mA	100mV	±50mV
0 to +10V	−1.0mA to +1.0mA	50mV	±25mV
−10V to +10V	−10mA to +10mA	1mV	±500μV

Operating Voltage Range
105V to 125V ac @ 50Hz to 60Hz
210V to 250V ac @ 50Hz to 60Hz

System Reference Stability
10V ±25 ppm/1000hrs. noncumulative

Console Dimensions
W 19in. × D 26in. (66cm.) × H 12in. (31cm.)
Wt. 75lbs. (39Kgs.)

Operating Temperature Range
0 to +40°C, +32°F to 104°F

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LTS-2020 Test Capabilities

LINEAR DEVICE TEST CAPABILITY

The LTS-2101 Operational Amplifier Family Board tests today's very demanding high precision op amps, comparators and regulators. This board houses the test loop used in testing op amps and comparators and the pulse load circuitry used in developing the high currents needed for voltage regulator testing.

For testing devices under 100μV, the LTS-2101 offers a tight offset spec of ±(0.25% + 5μV). Use of low thermal Emf relays and a test loop gain of 10,045 ensures superior low level V_{OS} measurement performance for optimum repeatability of low level signals.

Testing of low current devices is achieved with the LTS-0614 Socket Assembly which is designed to test bias and offset currents with an accuracy of ±(5% + 25fA) for any FET amplifier, including quad devices. Program libraries containing prewritten test programs for many standard op amps, comparators and regulators are available on disk.

ANALOG–TO–DIGITAL TEST CAPABILITY

The LTS-2200 ADC Family Board provides the test circuitry required for testing monolithic, hybrid or modular ADCs. An on-board 16-bit microprocessor with 8K bytes of memory acts as a slave for the system console and executes preprogrammed test routines such as linearity, all codes existence, transition noise measurements and conversion time measurements at high speed. Absolute accuracy can be measured within 200μV. Linearity, differential nonlinearity, offset, gain and PSSR are tested to ±.05 DUT LSB +200μV. Turnkey test packages are available for many of the standard ADCs currently in use.

DIGITAL-TO-ANALOG TEST CAPABILITY

The LTS-2302 DAC Family Board utilizes advanced state of the art test techniques to provide comprehensive test capabilities for a wide variety of D/A converters. It will test both voltage and current output DACs, DACs with and without buffer registers and serial or parallel input DACs to 16-bit accuracy.

High repeatability on low level signals is achieved because of the grounding scheme on the LTS-2302. The incorporation of high level components in the V/I circuits ensures true accuracy. In addition, the methodology for measuring low bit currents allows appropriate testing of this parameter on CMOS DACs.

Output leakage current on the LTS-2302 is measured with the bit drivers to the DAC set to logic 0. Current is measured using the I to V converter. A 1mΩ resistor within the I to V circuitry ensures sensitivity, thereby measuring current down to ±1μA full scale.

DIGITAL DEVICE TEST CAPABILITY

The LTS-2510 Digital Device Family Board provides 24 pin driver/detectors and a precision, four quadrant V/I source for testing SSI/MSI TTL and CMOS digital devices. This board contains four programmable device supplies and switching circuitry necessary for performing accurate parametric measurements on all device pins.

Together with the LTS-0655 remote ac test fixture, dynamic parametric testing of 24-pin SSI/MSI TTL digital devices can be achieved. Accuracies are achieved down to ±4% + 1.5ns at a resolution of 500ps. Dynamic parameters tested are propagation delay, setup and hold times.

DISCRETE DEVICE TEST CAPABILITY

The LTS-2600 Transistor Family Board tests bipolar transistors, JFETs, diodes and optocouplers. An on-board 16-bit microprocessor with 4K bytes of memory acts as a slave for the LTS system and coordinates the timing and pulse width control of the stimulus and measurement signals. In addition, the microprocessor monitors the interlock circuitry to insure safe handling of high power test signals.

MOSFET software packages support the testing of N and P channel enhancement mode and N channel depletion mode devices. Tests which may be performed on MOSFET devices include Idss, Igss, Igssf, Igssr, Id (off), Id (on), B Vdss, B Vgss, B Vgssf, B Vgssr, Vds (on), Vgs (th), Vgsoff, Vsd, Rds (on) and Gsf.

ANALOG SWITCH TEST CAPABILITY

The LTS-2700 Analog Switch Family Board adds switch and multiplexer testing capability to the LTS-2020. This test capability, with CREATE software allows datalogged device testing at the incoming inspection and semiconductor manufacturing levels and includes software power for use in component evaluation applications.

The LTS-2700 tests on and off drain to source leakage currents with an accuracy of 250pA, while forcing differential voltages up to 50V (±25V from GND). Other tests performed are drain to source on resistance, greatest change in drain-source on resistance between channels, digital input current and supply current.

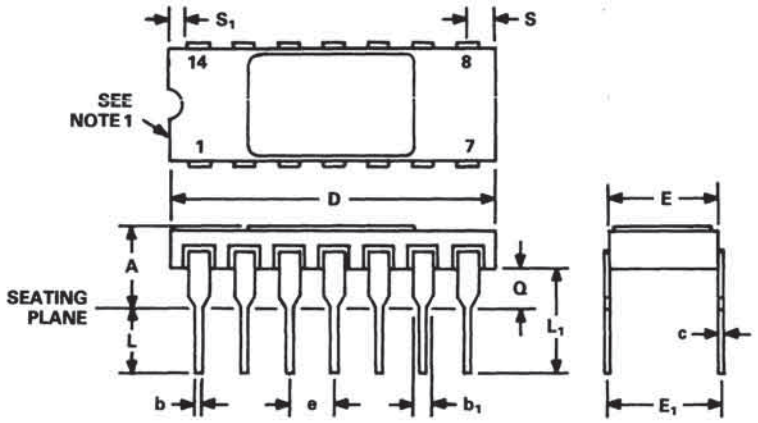
Twenty high integrity analog lines are provided – 4 to be used as drain connections and 16 for source connections. Also provided are 8 programmable digital drivers, 4 digital control bits, 6 variable power supplies and 1 fixed +5V supply. These combinations of sources provide testing of devices such as 4-channel switches, 16 to 1 multiplexers and other combinations of switches and multiplexers.

Package Information
Contents

ADI LETTER DESIGNATOR	DESCRIPTION	PAGE
Side Brazed DIP (Ceramic)		
D-14	14 Lead	16 – 2
D-16	16 Lead	16 – 3
D-18	18 Lead	16 – 4
D-20	20 Lead	16 – 5
Bottom Brazed DIP (Ceramic)		
DH-14A	14 Lead	16 – 6
Metal Platform DIP		
DH-14B	14 Lead	16 – 7
DH-16B	16 Lead	16 – 8
Leadless Chip Carrier (Ceramic)		
E-20A	20 Terminal	16 – 9
E-28A	28 Terminal	16 – 10
Flat Pack (Ceramic)		
F-2A	2 Lead	16 – 11
Metal Can		
H-03A	3 Lead (TO-52)	16 – 12
H-03B	3 Lead (TO-5 Style)	16 – 13
H-08A	8 Lead (TO-99)	16 – 14
H-08B	8 Lead (TO-99 Style)	16 – 15
H-10A	10 Lead (TO-100)	16 – 16
H-12A	12 Lead (TO-8 Style)	16 – 17
Plastic DIP		
N-8	8 Lead	16 – 18
N-14	14 Lead	16 – 19
N-16	16 Lead	16 – 20
N-18	18 Lead	16 – 21
N-20	20 Lead	16 – 22
Plastic Leaded Chip Carrier (PLCC)		
P-20A	20 Lead	16 – 23
P-28A	28 Lead	16 – 24
Cerdip		
Q-8	8 Lead	16 – 25
Q-14	14 Lead	16 – 26
Q-16	16 Lead	16 – 27
Q-18	18 Lead	16 – 28
Q-24	24 Lead	16 – 29
Small Outline (SOIC)		
R-8	8 Lead	16 – 30
Plastic		
TO-92	3 Lead	16 – 31
Single In-Line Package (SIP)		
Y-10	10 Lead	16 – 32

Package Outline Dimensions

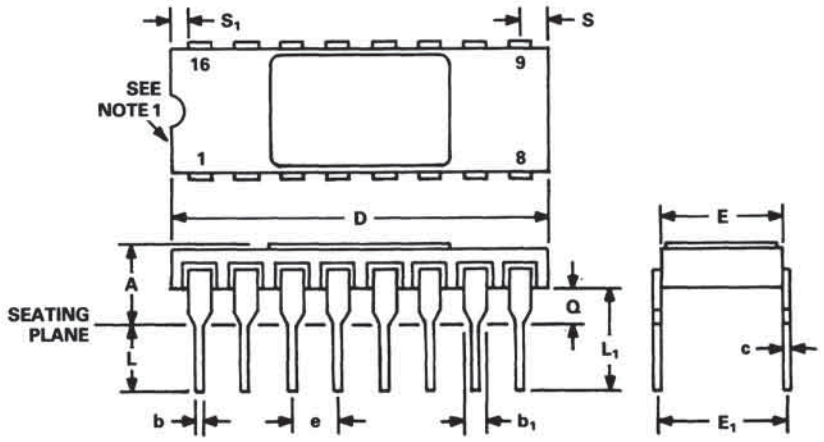
D-14
14-Lead Side Brazed Ceramic DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	6
b_1	0.030	0.070	0.76	1.78	2,6
c	0.008	0.015	0.20	0.38	6
D		0.785		19.94	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	
e	0.090	0.110	2.29	2.79	7
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5

NOTES
1. **Index area; a notch or a lead one identification mark is located adjacent to lead one.**
2. **The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.**
3. **Dimension Q shall be measured from the seating plane to the base plane.**
4. **This dimension allows for off-center lid, meniscus and glass overrun.**
5. **Applies to all four corners.**
6. **All leads – increase maximum limit by 0.003" (0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.**
7. **Twelve spaces.**

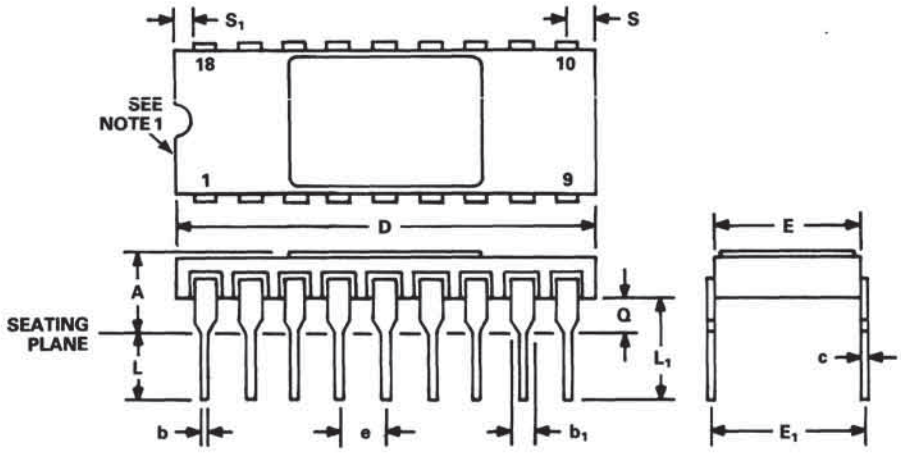
D-16
16-Lead Side Brazed Ceramic DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	6
b_1	0.030	0.070	0.76	1.78	2,6
c	0.008	0.015	0.20	0.38	6
D		0.840		21.34	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	
e	0.090	0.110	2.29	2.79	7
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.080		2.03	5
S_1	0.005		0.13		5

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. All leads – increase maximum limit by 0.003" (0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
7. Fourteen spaces.

D-18
18-Lead Side Brazed Ceramic DIP

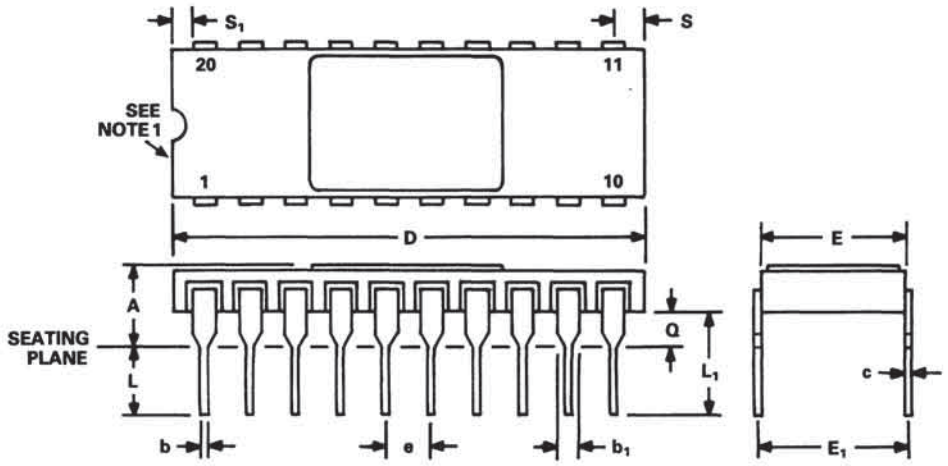


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	6
b_1	0.030	0.070	0.76	1.78	2, 6
c	0.008	0.015	0.20	0.38	6
D		0.960		24.38	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	
e	0.090	0.110	2.29	2.79	7
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. All leads – increase maximum limit by 0.003" (0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
7. Sixteen spaces.

D-20

20-Lead Side Brazed Ceramic DIP

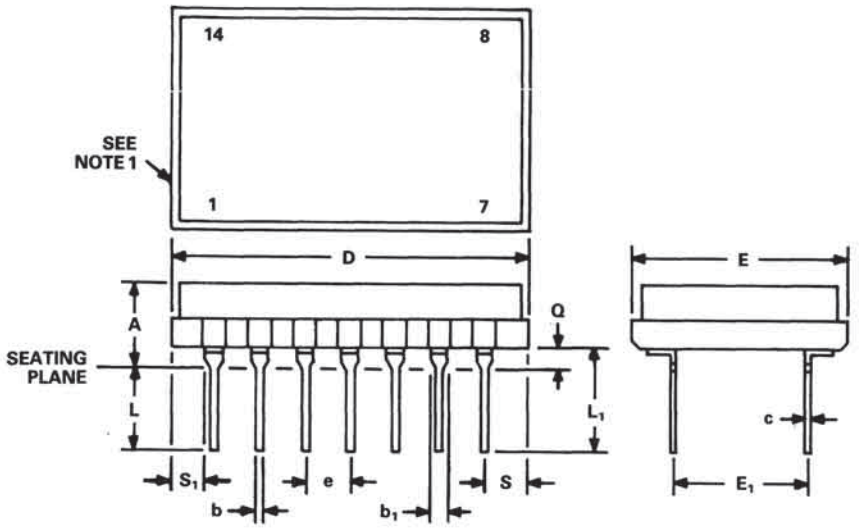


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	6
b_1	0.030	0.070	0.76	1.78	2,6
c	0.008	0.015	0.20	0.38	6
D		1.060		26.92	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	
e	0.090	0.110	2.29	2.79	7
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.080		2.03	5
S_1	0.005		0.13		5

NOTES

1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. All leads – increase maximum limit by 0.003" (0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
7. Eighteen spaces.

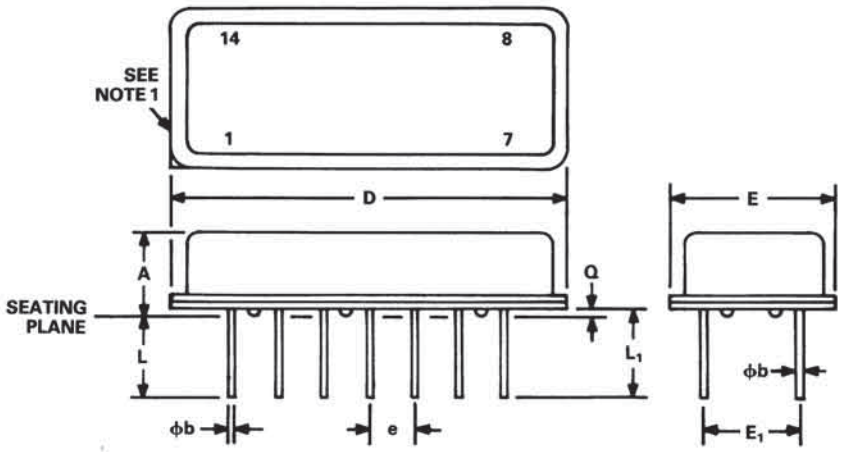
DH-14A
14-Lead Bottom Brazed Ceramic DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.220		5.59	
b	0.014	0.023	0.36	0.58	
b_1	0.030	0.070	0.76	1.78	2
c	0.008	0.015	0.20	0.38	
D		0.805		20.45	
E	0.480	0.505	12.19	12.83	
E_1	0.290	0.320	7.37	8.13	6
e	0.100 BSC		2.54 BSC		4,7
L	0.125	0.200	3.18	5.08	
L_1	0.180		4.57		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. The basic pin spacing is 0.100" (2.54mm) between centerlines.
5. Applies to all four corners.
6. E_1 shall be measured at the centerline of the leads.
7. Twelve spaces.

DH-14B
14-Lead Metal Platform DIP

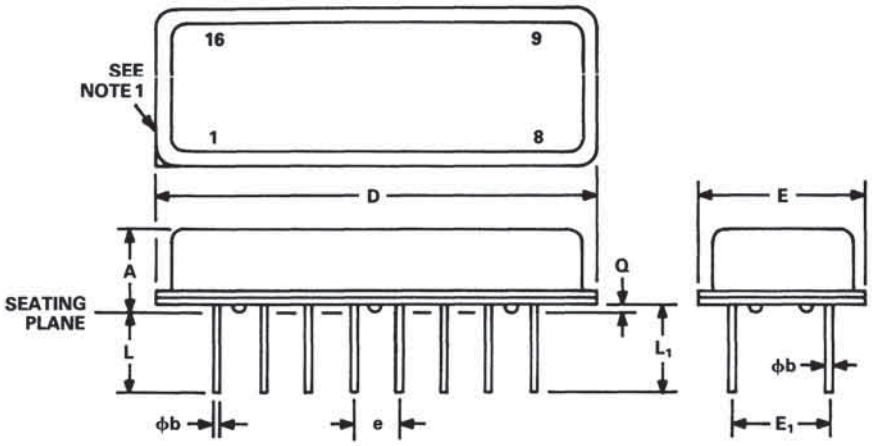


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.225		5.72	
ϕb	0.014	0.023	0.36	0.58	2
D		0.885		22.48	
E	0.490	0.520	12.45	13.21	
E_1	0.295	0.305	7.49	7.75	6
e	0.100 BSC		2.54 BSC		4, 7
L	0.140	0.200	3.56	5.08	
L_1	0.160		4.57		
Q	0.015	0.075	0.38	1.91	3

NOTES
1. Index area; a square corner or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. The basic pin spacing is 0.100" (2.54mm) between centerlines.
5. Applies to all four corners.
6. E_1 shall be measured at the centerline of the leads.
7. Twelve spaces.

16

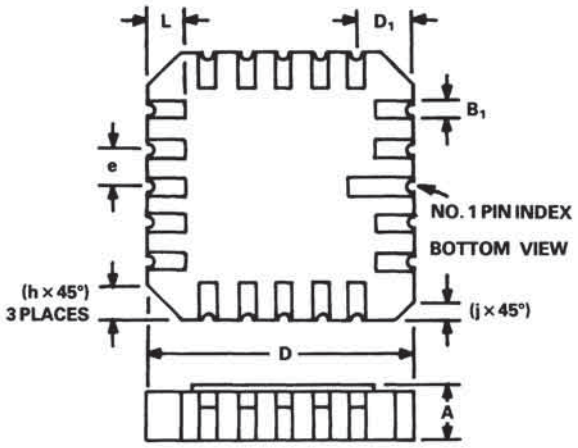
DH-16B
16-Lead Metal Platform DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.175	0.215	4.45	5.46	
ϕb	0.016	0.020	0.41	0.51	
D	0.960	0.985	24.4	25.0	
E	0.490	0.520	12.45	13.21	
E_1	0.295	0.305	7.49	7.75	4
e	0.095	0.105	2.41	2.67	5
L_1	0.160	0.255	4.06	6.48	

NOTES
1. Index area; a square corner or a lead one identification mark is located adjacent to lead one.
2. Pin 6 is electrically connected to the case.
3. Case has metal bottom surface.
4. E_1 shall be measured at the centerline of the leads.
5. Fourteen spaces.

E-20A
20-Terminal Leadless Ceramic Chip Carrier

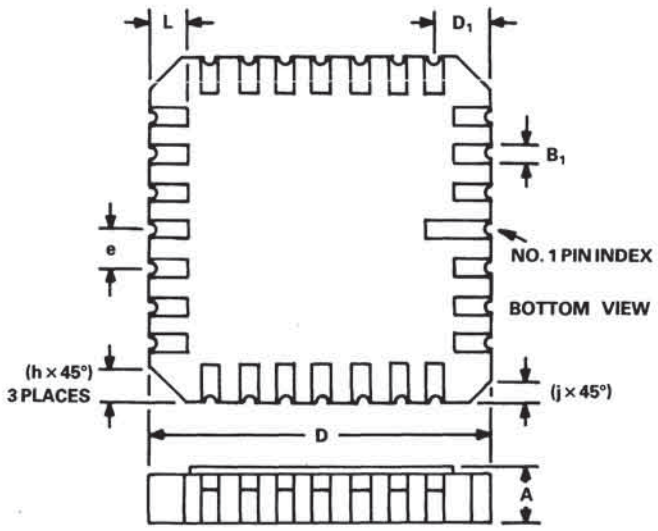


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.064	0.100	1.63	2.54	1
B_1	0.022	0.028	0.56	0.71	
D	0.342	0.358	8.69	9.09	2
D_1	0.075 REF		1.91 REF		
e	0.050 BSC		1.27 BSC		
j	0.020 REF		0.51		
h	0.040 REF		1.02		
L	0.045	0.055	1.14	1.40	

NOTES
1. Dimension A controls the overall package thickness.
2. Applies to all 4 sides.
3. All terminals are gold plated.

16

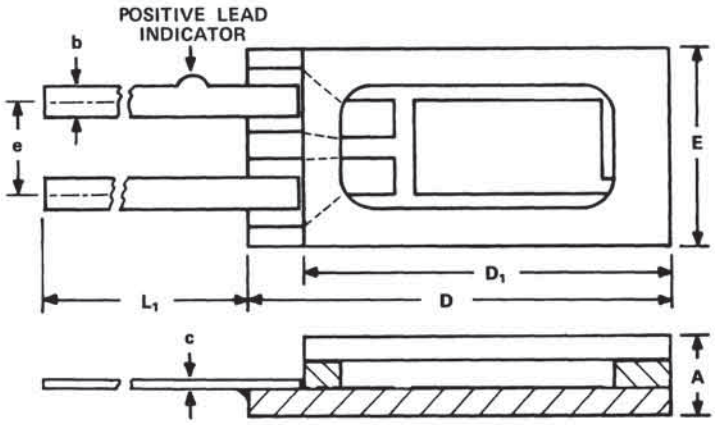
E-28A
28-Terminal Leadless Ceramic Chip Carrier



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.064	0.100	1.63	2.54	1
B_1	0.022	0.028	0.56	0.71	
D	0.442	0.458	11.23	11.63	2
D_1	0.075 REF		1.91 REF		
e	0.050 BSC		1.27 BSC		
j	0.020 REF		0.51		
h	0.040 REF		1.02		
L	0.045	0.055	1.14	1.40	

NOTES
1. Dimension A controls the overall package thickness.
2. Applies to all 4 sides.
3. All terminals are gold plated.

F-2A
2-Lead Flat Pack (Ceramic)

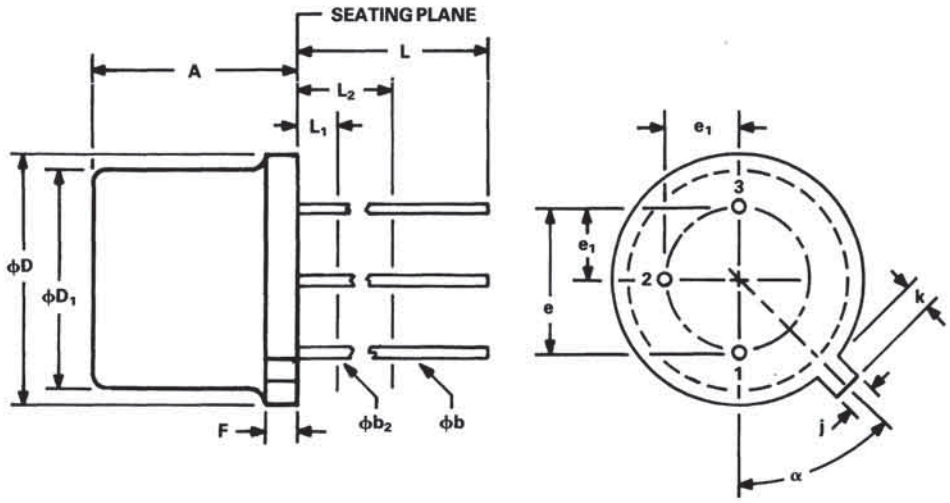


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.041	0.050	1.04	1.27	
b	0.015	0.019	0.38	0.48	
c	0.0045	0.0065	0.12	0.17	
D		0.250		6.35	1
D_1		0.220		5.59	
E	0.081	0.093	2.06	2.36	1
e	0.045	0.055	1.14	1.40	
L_1	0.500		12.69		

NOTE
1. **This dimension allows for off-center lid, meniscus and solder overrun.**

16

H-03A
3-Lead Metal Can (TO-52)

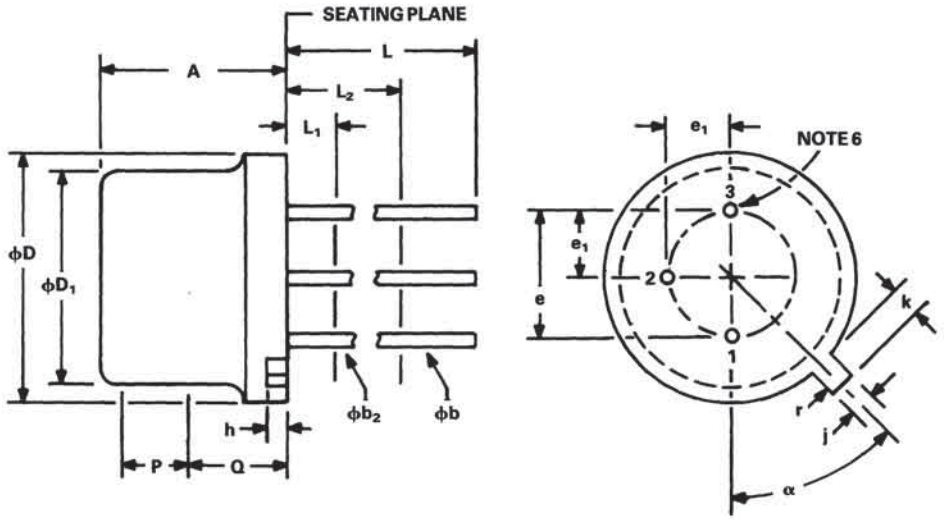


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.115	0.150	2.92	3.81	
ϕb		0.021		0.53	1, 4
ϕb_2	0.016	0.019	0.41	0.48	1, 4
ϕD	0.209	0.230	5.31	5.84	
ϕD_1	0.178	0.195	4.52	4.95	
e	0.100 T.P.		2.54 T.P.		2
e_1	0.050 T.P.		1.27 T.P.		2
F		0.030		0.76	
j	0.036	0.046	0.91	1.17	
k	0.028	0.048	0.71	1.22	3
L	0.500		12.70		1
L_1		0.050		1.27	1
L_2	0.250		6.35		
α	45° T. P.				

NOTES
1. (Three Leads) ϕb_2 applies between L_1 and L_2. ϕb applies between L_2 and 0.5" (12.70mm) from seating plane. Diameter is uncontrolled in L_1 and beyond 0.5" (12.70mm) from seating plane.
2. Leads having maximum diameter 0.019" (0.48mm) measured in gauging plane 0.054" (1.4mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the seating plane of the device are within 0.007" (0.18mm) of their true positions relative to a maximum-width tab.
3. Measured from maximum diameter of the actual device.
4. All leads – increase maximum limit by 0.003" (0.08mm) when hot solder dip finish is applied.

H-03B

3-Lead Metal Can (TO-5 Style)



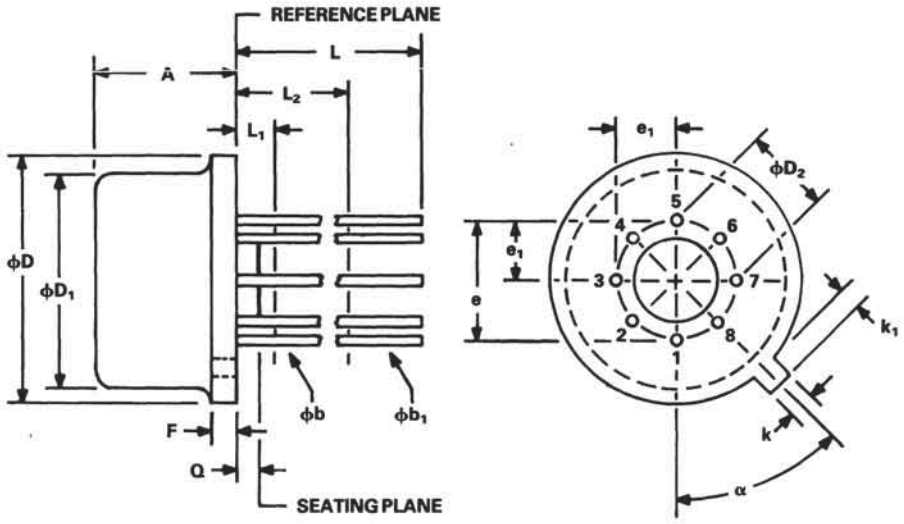
SYMBOL	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX	NOTES
A	0.165	0.185	4.19	4.70	
ϕb	0.016	0.021	0.41	0.53	2, 7
ϕb_2	0.016	0.019	0.41	0.48	2, 7
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4
e_1	0.100 T.P.		2.54 T.P.		
h	0.015	0.035	0.38	0.89	
j	0.028	0.034	0.71	0.86	
k	0.029	0.045	0.74	1.14	3
L	0.500		12.70		2
L_1		0.050		1.27	2
L_2	0.250		6.35		2
P	0.100		2.54		1
Q					5
r		0.007		0.18	
α	45° T.P.				

NOTES

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010" (0.25mm).
2. (Three leads) ϕb_2 applies between L_1 and L_2. ϕb applies between L_2 and 0.500" (12.70mm) from seating plane. Diameter is uncontrolled in L_1 and beyond 0.500" (12.70mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019" (0.48mm) measured in gauging plane 0.54" (1.37mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the seating plane of the device are within 0.007" (0.18mm) of their true positions relative to the maximum-width tab.
5. Details of outline in this zone optional.
6. Lead #3 connected to case.
7. All leads – increase maximum limit by 0.003" (0.08mm) when hot solder dip finish is applied.

16

H-08A
8-Lead Metal Can (TO-99)

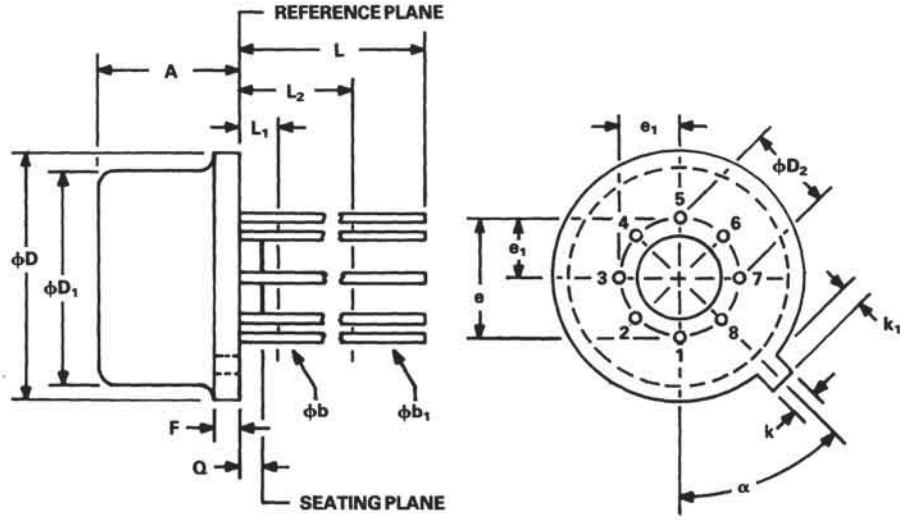


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.165	0.185	4.19	4.70	
ϕb	0.016	0.019	0.41	0.48	1, 4
ϕb_1	0.016	0.021	0.41	0.53	1, 4
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
ϕD_2	0.110	0.160	2.79	4.06	
e	0.200 BSC		5.08 BSC		3
e_1	0.100 BSC		2.54 BSC		3
F		0.040		1.02	
k	0.027	0.034	0.69	0.86	
k_1	0.027	0.045	0.69	1.14	
L	0.500	0.750	12.70	19.05	
L_1		0.050		1.27	
L_2	0.250		6.35		
Q	0.010	0.045	0.25	1.14	
α	45° BSC		45° BSC		3

NOTES
1. (All leads) ϕb applies between L_1 and L_2. ϕb_1 applies between L_2 and 0.500" (12.70mm) from the reference plane. Diameter is uncontrolled in L_1 and beyond 0.500" (12.70mm) from the reference plane.
2. Measured from the maximum diameter of the product.
3. Leads having a maximum diameter 0.019" (0.48mm) measued in gauging plane 0.054" (1.37mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the base plane of the product are within 0.007" (0.18mm) of their true position relative to the maximum width tab.
4. All leads – increase maximum limit 0.003" (0.08mm) when hot solder dip finish is applied.

H-08B

8-Lead Metal Can (TO-99 Style)

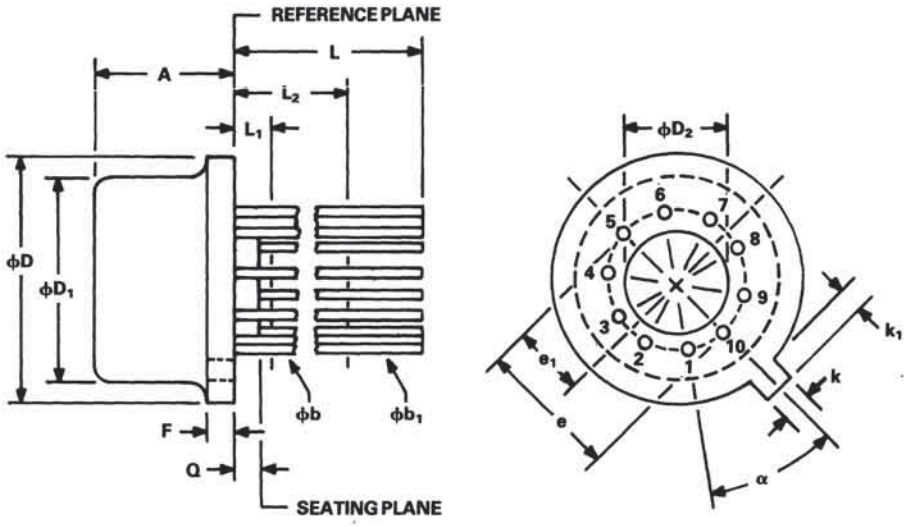


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.165	0.185	4.19	4.70	
ϕb	0.016	0.019	0.41	0.48	1,4
ϕb_1	0.016	0.021	0.41	0.53	1,4
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
ϕD_2	0.110	0.160	2.79	4.06	
e	0.230 BSC		5.84 BSC		3
e_1	0.115 BSC		2.92 BSC		3
F		0.040		1.02	
k	0.027	0.034	0.69	0.86	
k_1	0.027	0.045	0.69	1.14	2
L	0.500	0.750	12.70	19.05	1
L_1		0.050		1.27	1
L_2	0.250		6.35		1
Q	0.010	0.045	0.25	1.14	
α	45° BSC		45° BSC		3

NOTES

1. (All leads) ϕb applies between L_1 and L_2. ϕb_1 applies between L_2 and 0.500" (12.70mm) from the reference plane. Diameter is uncontrolled in L_1 and beyond 0.500" (12.70mm) from the reference plane.
2. Measured from the maximum diameter of the product.
3. Leads having a maximum diameter 0.019" (0.48mm) measued in gauging plane 0.054" (1.37mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the base plane of the product are within 0.007" (0.18mm) of their true position relative to the maximum width tab.
4. All leads – increase maximum limit 0.003" (0.08mm) when hot solder dip finish is applied.

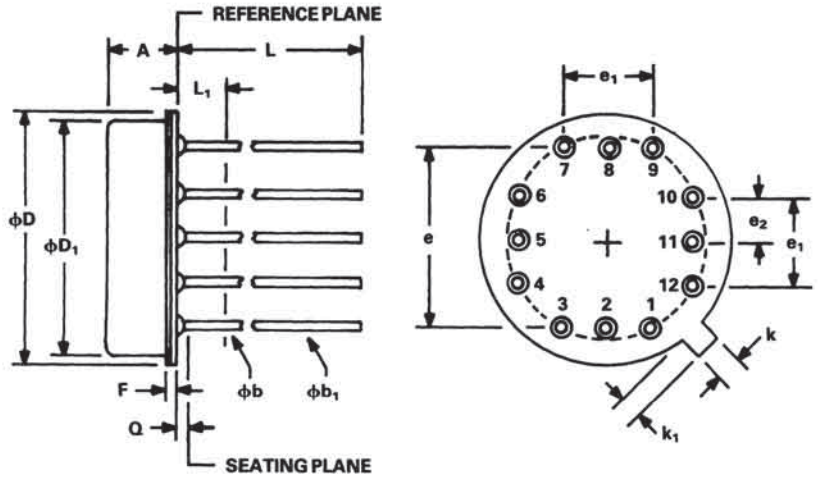
H-10A
10-Lead Metal Can (TO-100)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.165	0.185	4.19	4.70	
ϕb	0.016	0.019	0.41	0.48	1,4
ϕb_1	0.016	0.021	0.41	0.53	1,4
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
ϕD_2	0.110	0.160	2.79	4.06	
e	0.230 BSC		5.84 BSC		3
e_1	0.115 BSC		2.92 BSC		3
F		0.040		1.02	
k	0.027	0.034	0.69	0.86	
k_1	0.027	0.045	0.69	1.14	2
L	0.500	0.750	12.70	19.05	1
L_1		0.050		1.27	1
L_2	0.250		6.35		1
Q	0.010	0.045	0.25	1.14	
α	36° BSC		36° BSC		3

NOTES
1. (Three Leads) ϕb_2 applies between L_1 and L_2. ϕb applies between L_2 and 0.5" (12.70mm) from seating plane. Diameter is uncontrolled in L_1 and beyond 0.5" (12.70mm) from seating plane.
2. Leads having maximum diameter 0.019" (0.48mm) measured in gauging plane 0.054" (1.4mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the seating plane of the device are within 0.007" (0.18mm) of their true positions relative to a maximum-width tab.
3. Measured from maximum diameter of the actual device.
4. All leads – increase maximum limit by 0.003" (0.08mm) when hot solder dip finish is applied.

H-12A
12-Lead Metal Can (TO-8 Style)

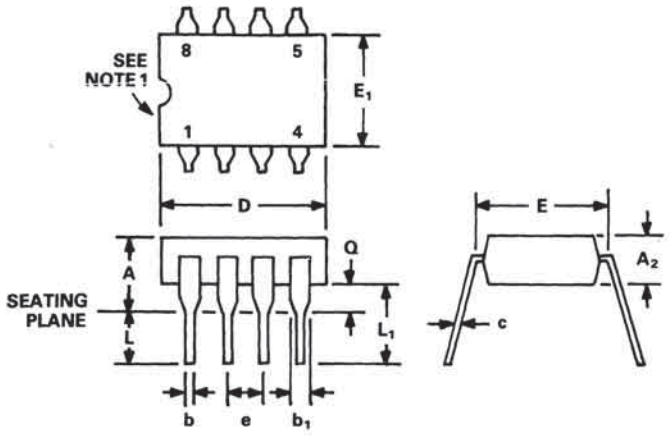


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.148	0.181	3.76	4.60	
ϕb	0.016	0.019	0.41	0.48	1
ϕb_1	0.016	0.021	0.41	0.53	1
ϕD	0.592	0.610	15.04	15.44	
ϕD_1	0.545	0.555	13.84	14.10	
e	0.400 BSC				3
e_1	0.200 BSC				3
e_2	0.100 BSC				3
F		0.040		1.02	
k	0.026	0.036	0.66	0.91	
k_1	0.026	0.036	0.66	0.91	2
L	0.375		9.50		1
L_1		0.050		1.27	1
Q	0.010	0.045	0.25	1.14	

NOTES
1. (All leads) ϕb applies between L and L_1. ϕb_1 applies between L_1 and 0.375" (9.50mm) from the reference plane. Diameter is uncontrolled in L_1 and beyond 0.375" (9.50mm) from the reference plane.
2. Measured from the maximum diameter of the product.
3. Leads having a maximum diameter 0.019" (0.48mm) measued in gauging plane 0.054" (1.37mm) + 0.001" (0.03mm) – 0.000" (0.00mm) below the base plane of the product is within 0.007" (0.18mm) of their true position relative to the maximum width tab.

16

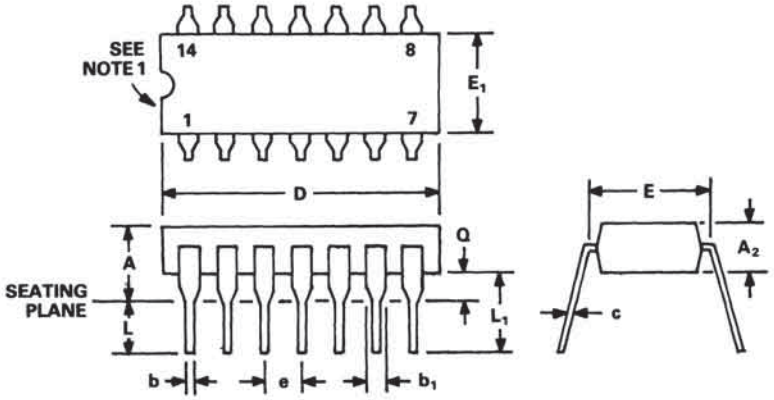
N-8
8-Lead Plastic DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.210		5.33	
A_2	0.115	0.195	2.93	4.95	
b	0.014	0.022	0.356	0.558	
b_1	0.045	0.070	1.15	1.77	
c	0.008	0.015	0.204	0.381	
D	0.348	0.430	8.84	10.92	2
E	0.300	0.325	7.62	8.25	
E_1	0.240	0.280	6.10	7.11	2
e	0.100 BSC		2.54 BSC		
L	0.125	0.200	3.18	5.05	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. This dimension does not include mold flash or protrusions.

N-14
14-Lead Plastic DIP

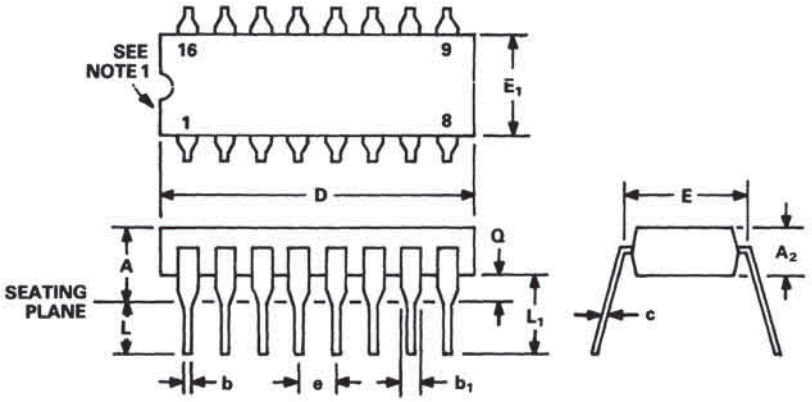


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.210		5.33	
A_2	0.115	0.195	2.93	4.95	
b	0.014	0.022	0.356	0.558	
b_1	0.045	0.070	1.15	1.77	
c	0.008	0.015	0.204	0.381	
D	0.725	0.795	18.42	20.19	2
E	0.300	0.325	7.62	8.25	
E_1	0.240	0.280	6.10	7.11	2
e	0.100 BSC		2.54 BSC		
L	0.125	0.200	3.18	5.05	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. This dimension does not include mold flash or protrusions.

16

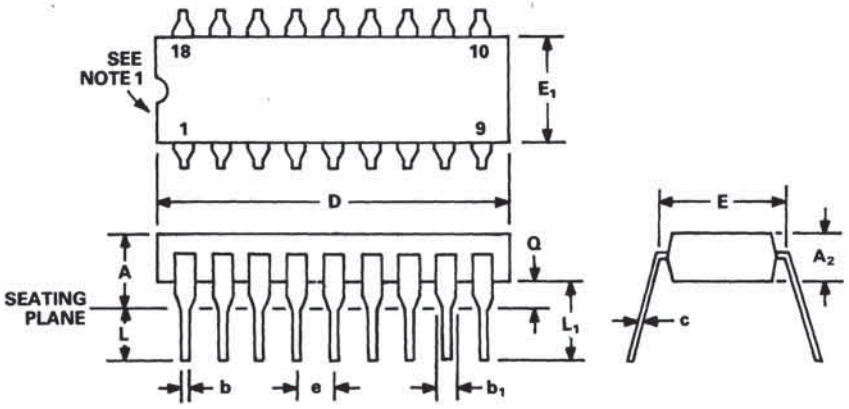
N-16
16-Lead Plastic DIP



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.210		5.33	
A_2	0.115	0.195	2.93	4.95	
b	0.014	0.022	0.356	0.558	
b_1	0.045	0.070	1.15	1.77	
c	0.008	0.015	0.204	0.381	
D	0.745	0.840	18.93	21.33	2
E	0.300	0.325	7.62	8.25	
E_1	0.240	0.280	6.10	7.11	2
e	0.100 BSC		2.54 BSC		
L	0.125	0.200	3.18	5.05	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. This dimension does not include mold flash or protrusions.

N-18
18-Lead Plastic DIP

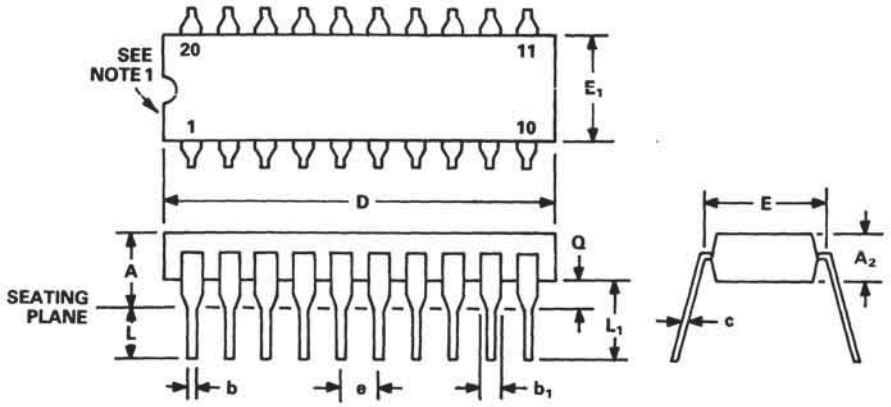


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.210		5.33	
A_2	0.115	0.195	2.93	4.95	
b	0.014	0.022	0.356	0.558	
b_1	0.045	0.070	1.15	1.77	
c	0.008	0.015	0.204	0.381	
D	0.845	0.925	21.47	23.49	2
E	0.300	0.325	7.62	8.25	
E_1	0.240	0.280	6.10	7.11	2
e	0.100 BSC		2.54 BSC		
L	0.125	0.200	3.18	5.05	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. This dimension does not include mold flash or protrusions.

16

N-20
20-Lead Plastic DIP

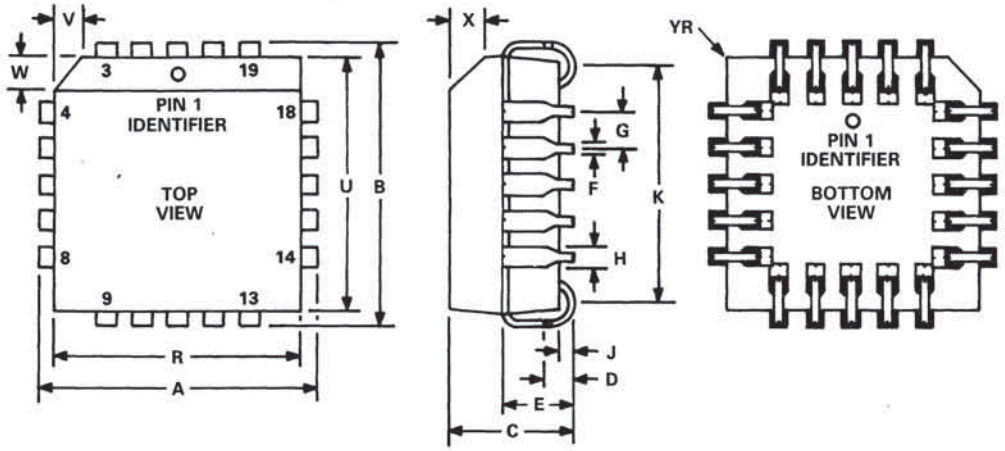


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.210		5.33	
A_2	0.115	0.195	2.93	4.95	
b	0.014	0.022	0.356	0.558	
b_1	0.045	0.070	1.15	1.77	
c	0.008	0.015	0.204	0.381	
D	0.925	1.060	23.50	26.90	2
E	0.300	0.325	7.62	8.25	
E_1	0.240	0.280	6.10	7.11	2
e	0.100 BSC		2.54 BSC		
L	0.125	0.200	3.18	5.05	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. This dimension does not include mold flash or protrusions.

P-20A

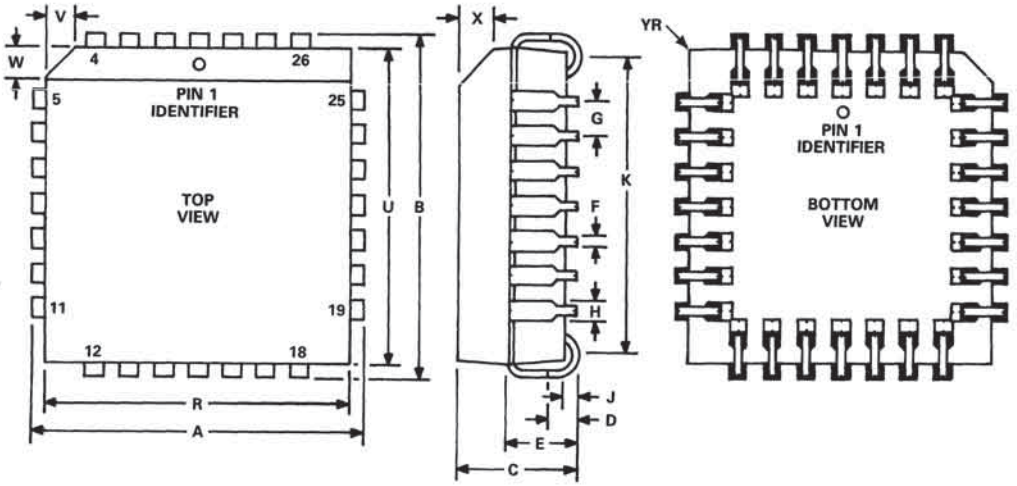
20-Lead Plastic Leaded Chip Carrier (PLCC)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.385	0.395	9.78	10.02	
B	0.385	0.395	9.78	10.02	
C	0.165	0.180	4.19	4.57	
D	0.025	0.040	0.64	1.01	
E	0.085	0.110	2.16	2.79	
F	0.013	0.021	0.33	0.53	
G	0.050 BSC		1.27 BSC		
H	0.026	0.032	0.66	0.81	
J	0.015	0.025	0.38	0.63	
K	0.290	0.330	7.37	8.38	
R	0.350	0.356	8.89	9.04	
U	0.350	0.356	8.89	9.04	
V	0.042	0.048	1.07	1.21	
W	0.042	0.048	1.07	1.21	
X	0.042	0.056	1.07	1.42	
Y		0.020		0.50	

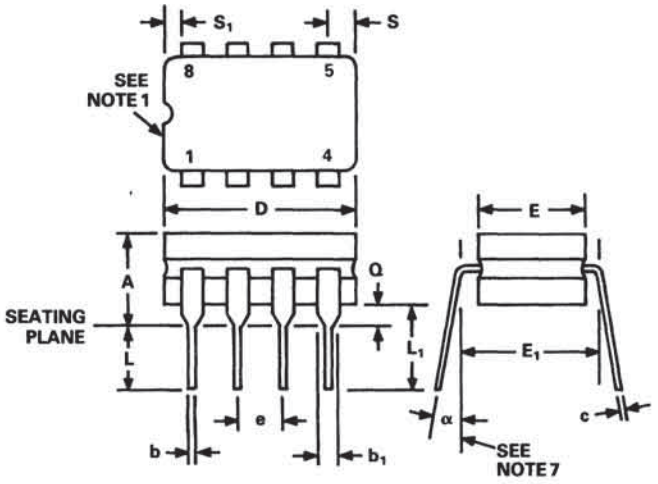
16

P-28A
28-Lead Plastic Leaded Chip Carrier (PLCC)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.485	0.495	12.32	12.57	
B	0.485	0.495	12.32	12.57	
C	0.165	0.180	4.19	4.57	
D	0.025	0.040	0.64	1.01	
E	0.085	0.110	2.16	2.79	
F	0.013	0.021	0.33	0.53	
G	0.050 BSC		1.27 BSC		
H	0.026	0.032	0.66	0.81	
J	0.015	0.025	0.38	0.63	
K	0.390	0.430	9.91	10.92	
R	0.450	0.456	11.43	11.58	
U	0.450	0.456	11.43	11.58	
V	0.042	0.048	1.07	1.21	
W	0.042	0.048	1.07	1.21	
X	0.042	0.056	1.07	1.42	
Y		0.020		0.50	

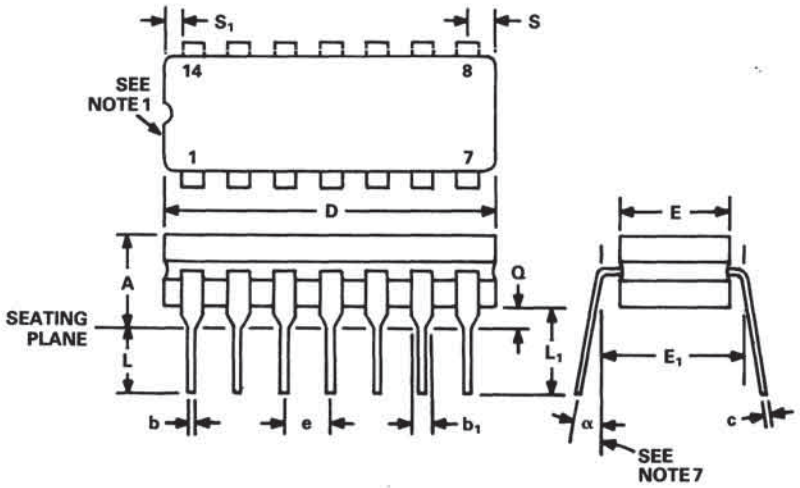
Q-8
8-Lead Cerdip



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	7
b_1	0.030	0.070	0.76	1.78	2,7
c	0.008	0.015	0.20	0.38	7
D		0.405		10.29	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	6
e	0.090	0.110	2.29	2.79	8
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.055		1.35	5
S_1	0.005		0.13		5
α	0°	15°	0°	15°	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. Lead center when α is 0°. E_1 shall be measured at the centerline of the leads.
7. All leads – increase maximum limit by 0.003"(0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
8. Six spaces.

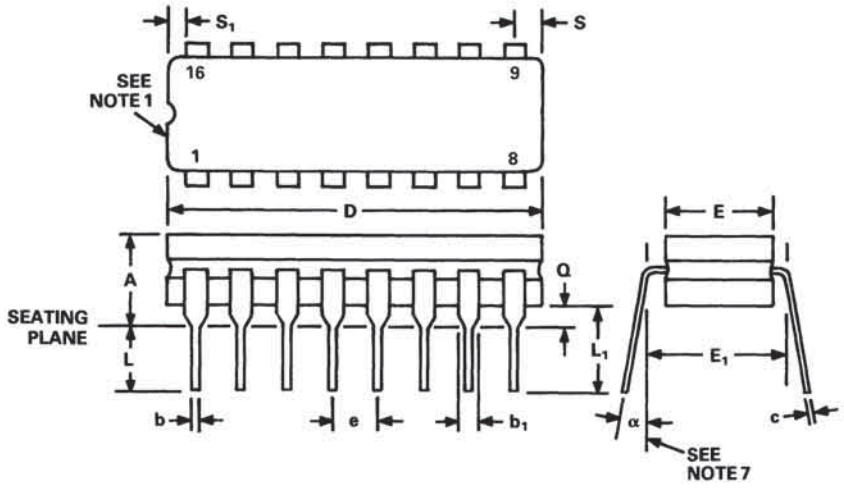
Q-14
14-Lead Cerdip



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	7
b_1	0.030	0.070	0.76	1.78	2,7
c	0.008	0.015	0.20	0.38	7
D		0.785		19.94	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	6
e	0.090	0.110	2.29	2.79	8
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5
α	0°	15°	0°	15°	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. Lead center when α is 0°. E_1 shall be measured at the centerline of the leads.
7. All leads – increase maximum limit by 0.003" (0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
8. Twelve spaces.

Q-16
16-Lead Cerdip

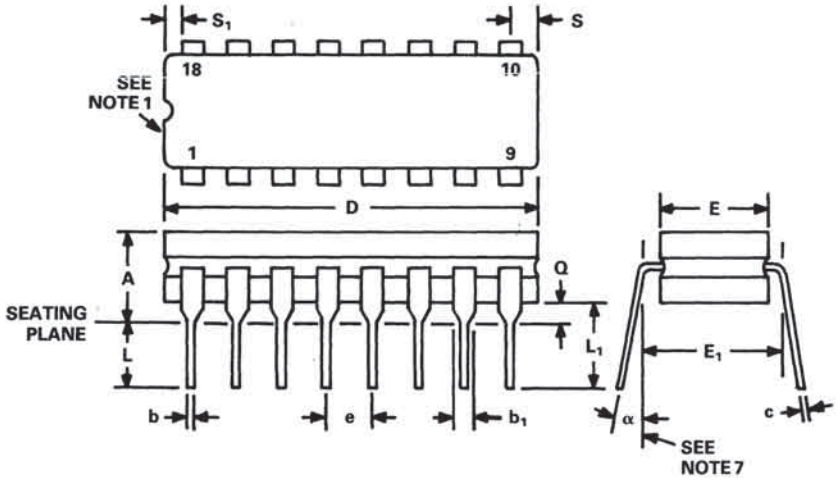


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	7
b_1	0.030	0.070	0.76	1.78	2,7
c	0.008	0.015	0.20	0.38	7
D		0.840		21.34	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	6
e	0.090	0.110	2.29	2.79	8
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.080		2.03	5
S_1	0.005		0.13		5
α	0°	15°	0°	15°	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. Lead center when α is 0°. E_1 shall be measured at the centerline of the leads.
7. All leads – increase maximum limit by 0.003"(0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
8. Fourteen spaces.

16

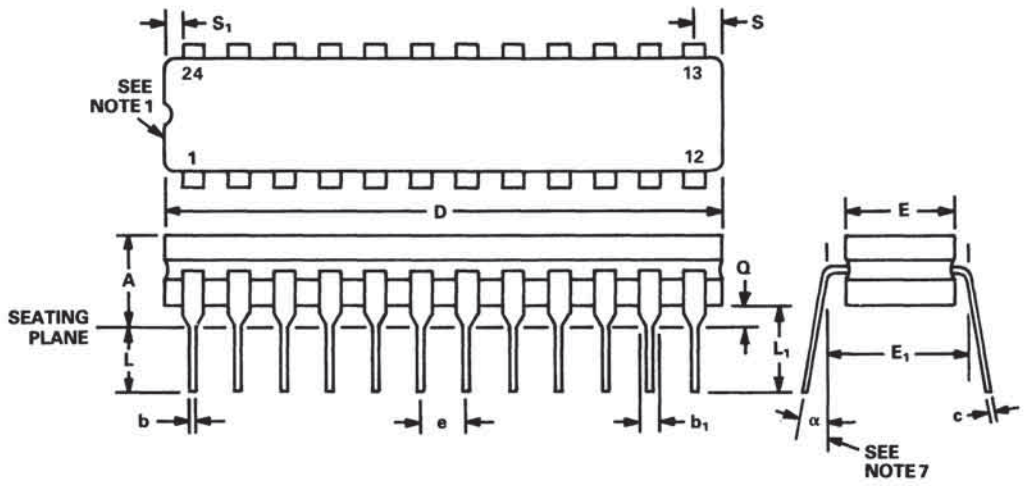
Q-18
18-Lead Cerdip



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	7
b_1	0.030	0.070	0.76	1.78	2,7
c	0.008	0.015	0.20	0.38	7
D		0.960		24.38	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	6
e	0.090	0.110	2.29	2.79	8
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5
α	0°	15°	0°	15°	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. Lead center when α is 0°. E_1 shall be measured at the centerline of the leads.
7. All leads – increase maximum limit by 0.003"(0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
8. Sixteen spaces.

Q-24
24-Lead Cerdip

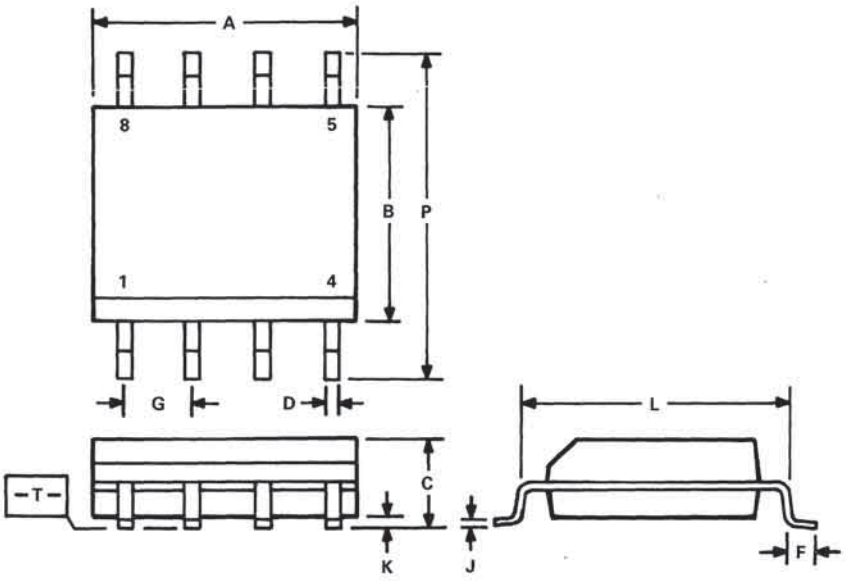


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A		0.200		5.08	
b	0.014	0.023	0.36	0.58	7
b_1	0.030	0.070	0.76	1.78	2,7
c	0.008	0.015	0.20	0.38	7
D		1.280		32.51	4
E	0.220	0.310	5.59	7.87	4
E_1	0.290	0.320	7.37	8.13	6
e	0.090	0.110	2.29	2.79	8
L	0.125	0.200	3.18	5.08	
L_1	0.150		3.81		
Q	0.015	0.060	0.38	1.52	3
S		0.098		2.49	5
S_1	0.005		0.13		5
α	0°	15°	0°	15°	

NOTES
1. Index area; a notch or a lead one identification mark is located adjacent to lead one.
2. The minimum limit for dimension b_1 may be 0.023" (0.58mm) for all four corner leads only.
3. Dimension Q shall be measured from the seating plane to the base plane.
4. This dimension allows for off-center lid, meniscus and glass overrun.
5. Applies to all four corners.
6. Lead center when α is 0°. E_1 shall be measured at the centerline of the leads.
7. All leads – increase maximum limit by 0.003"(0.08mm) measured at the center of the flat, when hot solder dip lead finish is applied.
8. Twenty-two spaces.

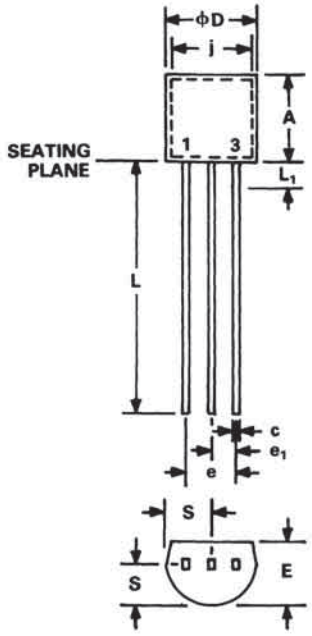
16

R-8
8-Lead Small Outline (SOIC)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.188	0.198	4.77	5.03	
B	0.150	0.158	3.81	4.01	
C	0.089	0.107	2.26	2.72	
D	0.014	0.022	0.36	0.56	
F	0.018	0.034	0.46	0.86	
G	0.050 BSC		1.27 BSC		
J	0.007	0.015	0.18	0.38	
K	0.005	0.011	0.125	0.275	
L	0.195	0.205	4.95	5.21	
P	0.224	0.248	5.69	6.29	

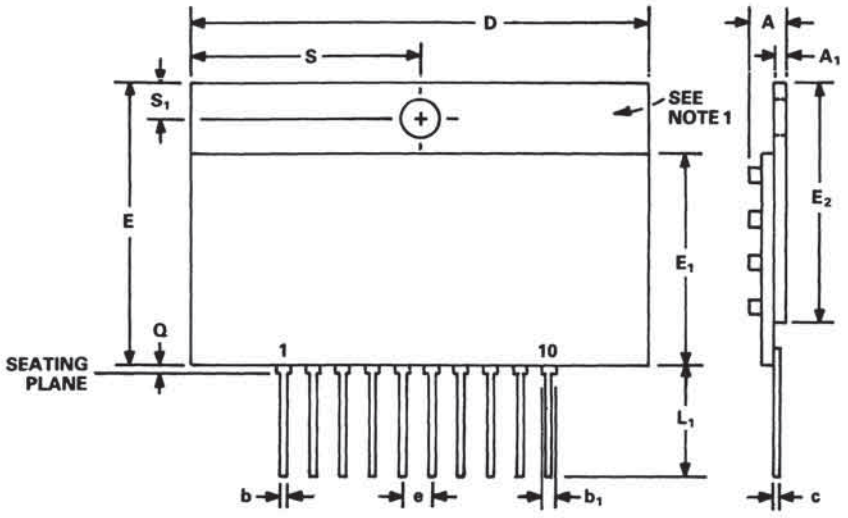
TO-92
3-Lead Plastic



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.170	0.210	4.58	5.33	
c	0.016	0.019	0.407	0.482	
ϕD	0.175	0.205	4.96	5.20	
e	0.095	0.105	2.42	2.66	
e_1	0.045	0.055	1.15	1.39	
E	0.125	0.165	3.94	4.19	
J	0.175	0.205	4.96	5.20	
L	0.500		12.70		
L_1		0.050		1.27	
S	0.080	0.105	2.42	2.66	

16

Y-10
10-Lead Single In-Line Package (SIP)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.123	0.150	3.12	3.81	
A_1	0.038	0.042	0.97	1.07	
b	0.016	0.020	0.41	0.51	
b_1	0.040	0.070	1.02	1.78	
c	0.009	0.012	0.23	0.31	
D	1.566	1.586	39.78	40.28	
E	0.990	1.050	25.15	26.67	
E_1	0.750 REF		19.05 REF		
E_2	0.810 REF		20.57 REF		
e	0.100 BSC		2.54 BSC		
L_1	0.150	0.350	3.81	8.89	
Q	0.060	0.080	1.52	2.03	
S	0.780 REF		19.51 REF		
S_1	0.115 REF		2.92 REF		

NOTE
1. Metal tab is electrically insulated from circuitry.

Appendix
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Ordering Guide

INTRODUCTION

This Ordering Guide should make it easy to order Analog Devices products, whether you're buying one IC op amp, a multi-option subsystem, or 1000 each of 15 different items. It will help you:

1. Find the correct part number for the options you want.
2. Get a price quotation and place an order with us.
3. Know our warranty for components and subsystems.

For answers to further questions, call the nearest sales office (listed at the back of the book) or our main office in Norwood, Mass. U.S.A. (617-329-4700).

MODEL NUMBERING

Many of the data sheets in the Databook for products having a number of standard options contain an Ordering Guide. Use it to specify the correct part number for the exact combination of options you want. I.C. and hybrid part numbers are created using one of these two systems:

Figure 1 shows the form of model number used for our proprietary standard monolithic ICs and many of our hybrids. It consists of an "AD" (Analog Devices) prefix, a 3-to-5-digit model number*, an alphabetic performance/temperature-range designator and a package designator. One or two additional letters may immediately follow the digits ("A" for second-generation redesigned ICs, "DI" for dielectrically isolated CMOS switches, e.g., AD536AJH, AD7512DIKD).

Figure 2 shows the somewhat different numbering scheme used by our Computer Labs Division for some hybrid circuits. The number starts with a three-character alphabetic prefix, followed by a hyphen, a three- or four-digit number, and alphabetic designators (as applicable) to indicate additional functional designations or options and packaging options.

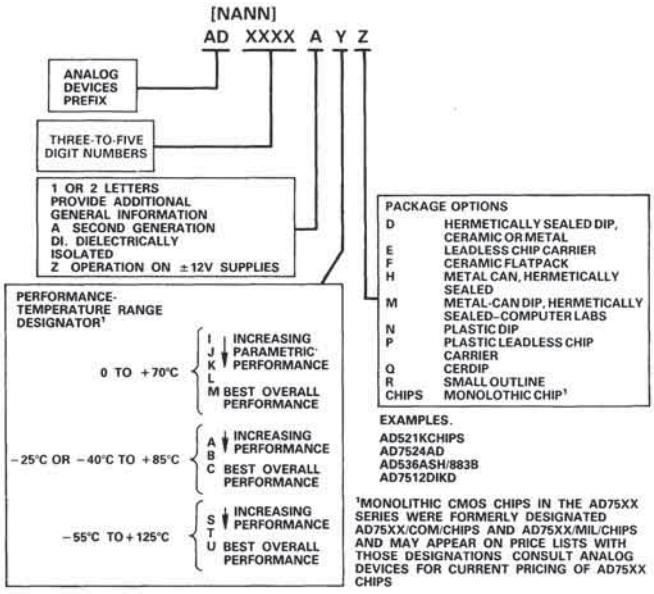


Figure 1. Model-Number Designations for Standard Analog Devices Monolithic and Hybrid IC Products. S, T and U Grades have the Added Suffix, /883B for Devices that Qualify to the Latest Revision of MIL-STD-883, Level B.

***For some models, the combination [digit][letter][two or three digits] is used instead of ADXXXX, e.g., 2S80.**

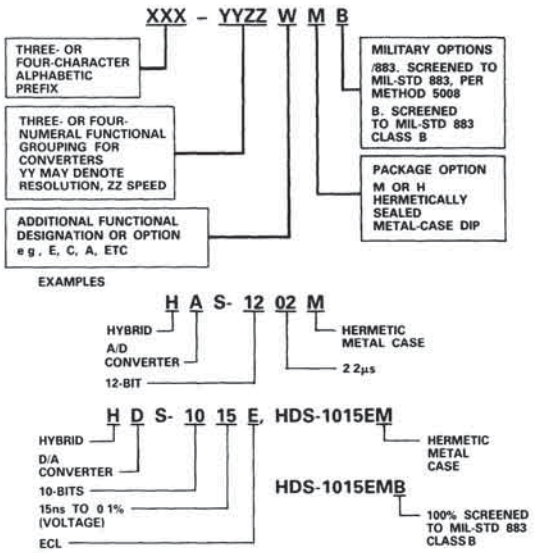


Figure 2. Computer Labs Video Hybrid Product Designations

SECOND SOURCE

In addition to our many proprietary products, we also manufacture devices that are fit-, form-, and function-compatible (and often superior in performance and reliability) to popular products that originated elsewhere. For such products, we usually add the prefix "AD" to the familiar model number (example: ADDAC85C-CBI-V).

ORDERING FROM ANALOG DEVICES

When placing an order, please provide specific information regarding model type, number, option designations, quantity, ship-to and bill-to address. Prices quoted are list; they do not include applicable taxes, customs, or shipping charges. All shipments are F.O.B. factory. Please specify if air shipment is required.

Place your orders with our local sales office or representative, or directly with our customer service group located in the Norwood facility. Orders and requests for quotations may be telephoned, sent via TWX or TELEX, or mailed. Orders will be acknowledged when received; billing and delivery information is included.

Payments for new accounts, where open-account credit has not yet been established, will be C.O.D. or prepaid. On all orders under fifty dollars ($50.00), a five-dollar ($5.00) processing charge is required.

When prepaid, orders should include $2.50 additional for packaging and postage (and a 5% sales tax on the price of the goods if you are ordering for delivery to a destination in Massachusetts).

WARRANTY AND REPAIR CHARGE POLICIES

All Analog Devices, Inc., products are warranted against defects in workmanship and materials under normal use and service for one year from the date of their shipment by Analog Devices, Inc., except that components obtained from others are warranted only to the extent of the original manufacturers' warranties, if any, except for component test systems, which have a 180-day warranty, and µMAC and MACSYM systems, which have a 90-day warranty. This warranty does not extend to any products which have been subjected to misuse, neglect, accident, or improper installation or application, or which have been repaired or altered by others. Analog Devices' sole liability and the Purchaser's sole remedy under this warranty is limited to repairing or replacing defective products. (The repair or replacement of defective products does not extend the warranty period. This warranty does not apply to components which are normally consumed in operation or which have a normal life inherently shorter than one year.) Analog Devices, Inc., shall not be liable for consequential damages under any circumstances.

THE FOREGOING WARRANTY AND REMEDY ARE IN LIEU OF ALL OTHER REMEDIES AND ALL OTHER WARRANTIES, WRITTEN OR ORAL, STATUTORY, EXPRESS, OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Product Families Not Included in the Databook (But Still Available)

The information published in this Databook is intended to assist the user in choosing components for the design of *new* equipment, using the most cost-effective products available from Analog Devices. The popular product types listed below may have been designed into your circuits in the past, but they are no longer likely to be the most economic choice for your new designs. Nevertheless, we recognize that it is often a wise choice to refrain from redesigning proven equipment, and we are continuing to make these products available for use in existing designs or in designs for which they are uniquely suitable. Data sheets on these products are available upon request.

Model	Model	Model	Model	Model
AD101	AD7522	DAS1128	SDC1702/RDC1702	234
AD108/208/308	AD7523	DAS1150	SDC1704/RDC1704	235
AD108A/208A/308A	AD7525	DAS1151	SDC1711/RDC1711	260
AD111/211/311	AD7530	DAS1155	SDC1721	261
AD293	AD7531	DAS1156	SDC1725/RDC1725	272
AD294	AD7541	DRC1765/66	SDC1726/RDC1726	273
AD351	AD7546	DSC1705/06	SDC1768/RDC1768	275
AD370/371	AD7550	DTM1716/17	SHA-1A	276
AD503	AD7552	HAS-0802	SHA-2A	277
AD506	AD7571	HAS-1002	SHA-4	285
AD510	AD7574	HDD-1409	SHA-5	288
AD515	AD ADC-816	HDH-0802	SHA-1114	310
AD518	ADC-8S	HDH-1003	SHA-1134	311
AD528	ADC-10Z	HDH-1205	SHA-1144	424
AD530	ADC-12QZ	HDL-3806	SSCT1621	426
AD531	ADC-14I/17I	HDS-0810E	STM Series	428
AD533	ADC1100	HDS-0820	TSL1612	429
AD535	ADC1102	HDS-1015E	2B24	432
AD545	ADC1105	HDS-1025	2B34	433
AD567	ADC1111	HDS-1240E	2B52	434
AD611	ADC1133	HDS-1250	2B53	435
AD651	ADC1143	IPA1751	2B56	436
AD801	ADC-QM	IRDC1730	2B57A-1	440
AD2004	AD DAC-08	IRDC1731	2B58A	442
AD2006	ADG201	IRDC1732	2B59A	450
AD2008	ADSHC-85	IRDC1733	2S20	452
AD2009	API1620/1718	MATV-0811	40	454
AD2016	BDM 1615/16	MATV-0816	43	456
AD2020	BDM 1617	MATV-0820	44	458
AD2022	CAV-0920	MCI1794	45	460
AD2023	CAV-1210	MDA-10Z	46	606
AD2033	DAC-M	MOD-1005	48	610
AD2036	DAC-QS	MOD-1020	50	752
AD2037	DAC-QZ	OSC1754	51	756
AD2038	DAC-10Z	RDC1721	52	903
AD2040	DAC1009	RTM Series	118	906
AD3554	DAC1106	SAC1763	141	915
AD3860	DAC1108	SBCD1752/53	165	926
AD6012	DAC1132	SBCD1756/57	171	944
AD7110	DAC1146	SCDX1623	183	946
AD7118	DAC1420	SCM1677	230	947
AD7520	DAC1422	SDC1604	232	959
AD7521	DAC1423	SDC1700/RDC1700	233	968

Substitution Guide for Product Families No Longer Available

The products listed in the left-hand column are no longer available from Analog Devices. In many cases, comparable functions and performance may be obtained with newer models, but – as a rule – they are not directly interchangeable. The closest recommended Analog Devices equivalent, physically and electrically, is listed in the right-hand column. If no equivalent is listed, or for further information, contact your local sales office.

Model	Closest Recommended Equivalent	Model	Closest Recommended Equivalent	Model	Closest Recommended Equivalent
AD501	AD711	DAC1118	None	2N3954	None
AD502	AD711	DAC1122	AD7541	2N5900	None
AD505	AD509	DAC1125	AD7533	41	AD515
AD508	AD517	HDL-3805	HDL-3806	47	48
AD511	AD711	HTC-0500	HTC-0300	101 (Module)	45
AD512	AD711	IDC1703	IRDC1730/1731	102	48
AD513	AD711	MAH-0801	HAS-0802	106	118
AD514	AD711	MAH-1001	HAS-1002	107	118
AD516	AD711	MAS-0801	HAS-0802	108	52
AD520	AD524	MAS-1001	HAS-1002	110	48
AD523	AD549	MAS-1202	HAS-1202	111	AD308
AD546	AD711	MDA-LB	None	114	119
AD555	AD7519	MDA-LD	None	115	43
AD559	None	MDA-UB	None	120	50
AD612	AD524	MDA-UD	None	142	48
AD614	AD524	MDA-8H	MDA-10Z	143	52
AD810-813	None	MDA-10H	MDA-10Z	146	AD382
AD814-816	None	MDA-11MF	AD7521	149	50
AD818	None	MDH-0870	None	153	AD517
AD820-822	None	MDH-1001	None	161	165
AD830-833	None	MDH-1202	None	163	165
AD835-839	None	MDMS-0801	AD9768	170	171
AD1408	None	MDMS-1001	HDM-1210	180	AD OP-07
AD1508	None	MDMS-1101	HDM-1210	220	234
AD2003	AD2021	MDS-0815	None	231	233
AD2024	None	MDS-0815E	None	274J	284J
AD2025	None	MDS-0830	HDS-0820	279	286J
AD2027	None	MDS-0850	HDS-0820	280	281
AD2028	None	MDS-1020	None	282J	292A
AD5010/6020	AD9000	MDS-1020E	None	283J	292A
AD7115	None	MDS-1040	HDS-1025	301 (Module)	52
AD7513	None	MDS-1080	HDS-1025	302	310 (Module)
AD7516	AD7510DI	MDS-1240	None	350	None
AD7519	None	MDSL-0802	HDS-0820	427	424
AD7527	None	MDSL-0825	None	602J10	AD524
AD7544	None	MDSL-1002	HDS-1025	602J100	AD524
AD7555	None	MDSL-1035	None	602K100	AD524
AD7560	None	MDSL-1201	HDS-1250	603	AD524
AD7570	None	MDSL-1250	None	605	AD524
AD7583	None	RTI-1200	RTI-711 Series	901	904
ADC1103	None	RTI-1201	RTI-711 Series	907	921
ADC1109	None	RTI-1202	RTI-711	908	921
ADC1121	AD7550	SERDEX	μMAC-5000	909	921
AD DAC100	None	SHA-3	None	931	None
ADG200	None	SHA-6	SHA1144	932	None
ADM501	ADM501/506	THC-0300	HTC-0300	933	None
ADP501	ADP511	THC-0750	None	935	None
ADSHM-5	HTC-0300	THC-1500	None	942	None
CAV-1020	MOD-1020	THS-0025	HTC-0300	948	947
DAC-100F	None	THS-0060	HTC-0300	956	None
DAC-10H	DAC-10Z	THS-0225	None	971	921
DAC1112	DAC12QS	TSDC1608-1611	TSL1612		

Technical Publications

TECHNICAL PUBLICATIONS

Analog Devices provides a wide array of FREE technical publications. These include Data Sheets for all products, Catalogs, Application Notes and Guides and four serial publications: *Analog Productlog*, a digest of new-product information; *DSPatch™*, a newsletter about digital signal-processing (applications); *Analog Briefings*, current information about products for military/avionics and the status of reliability at ADI; and *Analog Dialogue*, our technical magazine, with in-depth discussions of products, technologies and applications.

In addition to the free publications, three technical Handbooks, and *Synchro & Resolver Conversion*, are available at reasonable cost. System and subsystem products are supported with hardware, software and user documentation, at prices related to content.

Brief descriptions of typical publications appear below. For copies of any items, to subscribe to any of our free serials or to request any other publications, please get in touch with Analog Devices or the nearest sales office.

CATALOGS

DATA ACQUISITION PRODUCTS DATABOOKS. Contain selection guides, data sheets and other useful information about all Analog Devices ICs, hybrids, modules and subsystem components recommended for new designs. The 1988 series consists of:

DATA CONVERSION PRODUCTS DATABOOK – 1988. Data Sheets and Selection Guides on D/A, A/D, V/F, and F/V Converters, Sample-Track/Hold Amplifiers, Voltage References, Multiplexers & Switches, Synchro-Resolver Converters, Data-Acquisition Subsystems, Application-Specific ICs. (Available FREE with the Linear Products Databook as a 2-volume set.)

DSP PRODUCTS DATABOOK – 1987. Data Sheets, Selection Guides and Application Notes on DSP Microprocessors, Microcoded Support Components, Floating-Point Components and Fixed-Point Components. Available FREE.

LINEAR PRODUCTS DATABOOK – 1988. Data Sheets and Selection Guides on Op Amps, Instrumentation Amplifiers, Isolators, RMS-to-DC Converters, Multipliers/Dividers, Log/Antilog Amplifiers, RMS-to-DC Converters, Comparators, Temperature-Measuring Components and Transducers, Special Function Components, Digital Panel Instruments, Signal-Conditioning Components and Subsystems. (Available FREE with the Conversion Products Databook as a 2-volume set.)

1987 MILITARY PRODUCTS DATABOOK. 704 pages of information and data on products processed in accordance with MIL-STD-883C Class B.

APPLICATION NOTES AND GUIDES

Application Notes. All are available individually upon request.

A/D Converters:
- "AD670 8-Bit A/D Converter Applications."
- "Exploring the AD667 12-Bit Analog Output Port."
- "Interfacing the AD7572 to High-Speed DSP Processors."
- "The AD7574 Analog-to-Microprocessor Interface."

Amplifiers:
- "An IC Amplifier User's Guide to Decoupling, Grounding, and Making Things Go Right for a Change."
- "Applications of High-Performance BiFET Op Amps."
- "A User's Guide to IC Instrumentation Amplifiers"
- "How to Select Operational Amplifiers."
- "How to Test Basic Operational Amplifier Parameters."
- "Low-Cost, Two-Chip Voltage-Controlled Amplifier and Video Switch."
- "Using the AD9610 Transimpedance Amplifier."

D/A Converters:
- "AD7528 Dual 8-Bit CMOS DAC."
- "Analog Panning Circuits Provide Almost Constant Output Power."
- "CMOS DACs and Operational Amplifiers Combine to Build Programmable-Gain Amplifiers." *In two parts.*
- "CMOS DACs in the Voltage Switching Mode Can Work from a Single Supply."
- "CMOS D/A Converter Circuits for Single +5-Volt Supplies."
- "14-Bit DACs (AD7534/AD7535) Maintain High Performance Over Extended Temperature Range."
- "Gain Error and Tempco of CMOS Multiplying DACs."
- "Interfacing the AD7549 Dual 12-Bit DAC to the MCS-48 and MCS-51 Microcomputer Families."
- "Methods for Generating Complex Waveforms and Vectors Using Multiplying D/A Converters."
- "Simple Interface Between D/A Converter and Microcomputer Leads to Programmable Sine-Wave Oscillator."
- "The AD7224 DAC Provides Programmable Voltages Over Varying Ranges."

Digital Signal Processing (Note: Eight additional DSP Application Notes will be found in the DSP Products Databook):
- "A Guide to Designing Microcoded Circuits."
- "Implement a Writeable Control Store in Your Word-Slice™ System."
- "Variable-Width Bit Reversing with the ADSP-1410 Address Generator."

Resolver-to-Digital Conversion:
- "Dynamic Characteristics of Tracking Converters."
- "Dynamic Resolution-Switching on the 1S74 Resolver-to-Digital Converter."
- "Resolver-to-Digital Conversion – A Simple and Cost-Effective Alternative to Optical Shaft Encoders."
- "Why the Velocity Output of the 1S74 and 1S64 Series R/D Converters is Continuous and Step-Free Down to Zero Speed."

Sample-Holds:
- "Applying IC Sample-Hold Amplifiers."
- "Generate 4 Channels of Analog Output Using AD7542 12-Bit D/A Converters and Control It All with Only Two Wires."

Switches:
- "ADG201A/202A and ADG221/222 Performance with Reduced Power Supplies."

Analog DSPatch is a trademark of Analog Devices, Inc.

V/F Converters:
"Operation and Applications of the AD654 IC V-to-F Converter."
"Analog-to-Digital Conversion Using Voltage-to-Frequency Converters (AD651)."

Application Guides. All are available upon request.
Analog CMOS Switches and Multiplexers. A 16-page short-form guide to high-speed CMOS switches, CMOS switches with dielectric isolation, and CMOS multiplexers. Also included are reliability data and information on single-supply operation.

Applications Guide for Isolation Amplifiers and Signal Conditioners. A 20-page guide to specifications and applications of galvanically isolated amplifiers and signal conditioners for industrial, instrumentation, and medical applications.

CMOS DAC Application Guide 2nd Edition by Phil Burton (1986 – 63 pages). Introduction to CMOS DACs, Inside CMOS DACs, Basic Application Circuits in Current-Steering Mode, Single-Supply Operation Using Voltage-Switching Mode, The Logic Interface, Applications.

ESD Prevention Manual – Protecting ICs from electrostatic discharges. Thirty pages of information that will assist the reader in implementing an appropriate and effective program to assure protection against electrostatic discharge (ESD) failures.

High-Speed Data Conversion – A 24-page short-form guide to video and other high-speed A/D and D/A converters and accessories, in forms ranging from monolithic ICs to card-level products.

RMS-to-DC Conversion Application Guide 2nd Edition by C. Kitchin and L. Counts (1986 – 61 pages). RMS-DC Conversion: Theory, Basic Design Considerations; RMS Application Circuits; Testing Critical Parameters; Input Buffer Amplifier Requirements; Programs for Computing Errors, Ripple, and Settling Time.

Surface Mount IC – A 28-page guide to ICs in SO and PLCC packages. Products include op amps, rms-to-dc converters, DACs, ADCs, VFCs, sample-holds, and CMOS switches.

ADSP-2100 SUPPORT PUBLICATIONS – for the ADSP-2100 single-chip digital signal processor, available at no charge for single copies.

ADSP-2100 USER'S MANUAL – Introduction, Architecture, System Interface, Instruction Set, Appendix – 180 pages.

ADSP-2100 CROSS-SOFTWARE MANUAL – Development System, System Builder, Assembler, Linker, Simulator, PROM Splitter, Appendix – 102 pages.

ADSP-2100 APPLICATIONS HANDBOOK – Introduction, Fixed Point Arithmetic, Floating-Point Arithmetic, Fixed-Coefficient Digital Filters, FFTs, Adaptive Filters, Image Processing, Linear Predictive Speech Coding, High-Speed MODEM Algorithms, Bibliography – 178 pages.

BOOKS – Can be purchased from Analog Devices, Inc.; send check for indicated amount to One Technology Way, P.O. Box 796, Norwood, MA 02062. If more than one book is ordered, deduct a discount of $1 from the price of each book.

ANALOG-DIGITAL CONVERSION HANDBOOK: Third Edition, by the Engineering Staff of Analog Devices, edited by Daniel H. Sheingold. Englewood Cliffs, NJ: Prentice-Hall (1986). A comprehensive guide to A/D and D/A converters and their applications. This third edition of our classic is in hardcover and has more than 700 pages, an Index, a Bibliography, and much new material, including: video-speed, synchro-resolver, V/F, high-resolution, and logarithmic converters, ICs for DSP, and a "Guide for the Troubled." Seven of its 22 chapters are totally new. $32.95

NONLINEAR CIRCUITS HANDBOOK: Designing with Analog Function Modules and ICs, by the Engineering Staff of Analog Devices, edited by Daniel H. Sheingold. Norwood MA: Analog Devices, Inc. (1974). A 540-page guide to multiplying and dividing, squaring and rooting, rms-to-dc conversion, and multifunction devices. Principles, circuitry, performance, specifications, testing, and application of these devices – 325 illustrations. $5.95

SYNCHRO & RESOLVER CONVERSION, edited by Geoff Boyes. Norwood MA: Analog Devices, Inc. (1980). Principles and practice of interfacing synchros, resolvers, and Inductosyns* to digital and analog circuitry. $11.50

TRANSDUCER INTERFACING HANDBOOK: A Guide to Analog Signal Conditioning, edited by Daniel H. Sheingold. Norwood MA: Analog Devices, Inc. (1980). A book for the electronic engineer who must interface transducers for temperature, pressure, force, level, or flow to electronics, these 260 pages tell how transducers work – as circuit elements – and how to connect them to electronic circuits for effective processing of their signals. $14.50

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(602) 949-0048
*(303) 590-9952

Arkansas
*(214) 231-5094

California
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North Carolina
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North Dakota
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Oregon
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(615) 459-0743

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*(303) 590-9952

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*(614) 764-8795

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(604) 941-7707

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*(617) 329-4700

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(Austria)

Singapore
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