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IC OP-AMP COOKBOOK

SECOND EDITION

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IC Op-Amp Cookbook

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TEN

Signal-Generation Circuits

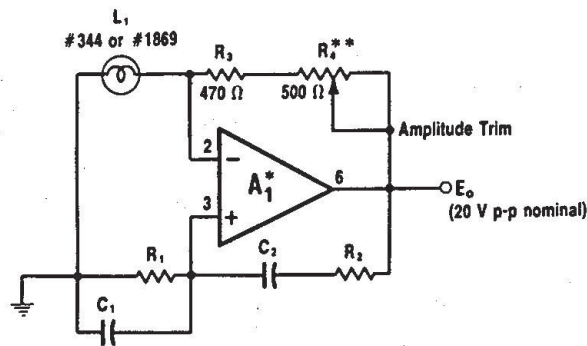
This chapter deals with the generation, shaping, and control of various kinds of signal waveforms. Discussed are signal-generation circuits such as sine-wave oscillators; multivibrators; triangle, ramp, and sawtooth generators; pulse generators; voltage-controlled oscillators; and voltage-controlled timers. These circuits will involve both new material and much of the circuit knowledge gained in previous chapters.

10.1 SINUSOIDAL OSCILLATORS

The most familiar waveform in electronics is the sine wave, and sine-wave signals of different frequencies are as fundamental to circuit work as dc supply potentials are. Generating a sine wave is not hard to do in concept, as we have already seen by the ready tendency of op amps to oscillate when amplification is really the prime intent. This section concerns itself with the controlled form of sine-wave oscillator, having a defined and predictable frequency, amplitude, and in some cases, phase.

10.1.1 Wien-Bridge Oscillators

One of the most familiar types of sine-wave generators is the Wien-bridge circuit shown in Fig. 10-1. This circuit is a classic one in electronics and has been used since the days when it was realized in vacuum-tube versions. The Wien network, composed of R_1 - C_1 and R_2 - C_2 , provides a positive feedback path around A_1 , while R_3 and L_1 provide negative feedback. At some fundamental frequency, f_o , the overall phase shift is zero and transmission at this frequency



Set $R_1 = R_2$, $C_1 = C_2$; then $f_o = \frac{1}{2\pi R_1 C_1}$

*Select A_1 according to operating frequency and value of R_1 ; see text.

**Use R_4 to correct for lamp tolerance and set output level, or fix $R_3 + R_4$ at 750 Ω.

Fig. 10-1. Wien-bridge oscillator.

is maximum in relation to all others. Positive feedback causes the circuit to oscillate at f_o , where

$$f_o = \frac{1}{2\pi R_1 C_1}$$

and $R_1 = R_2$, $C_1 = C_2$.

The attenuation of the Wien network at the frequency of oscillation is equal to 3. If the attenuation in the negative feedback path (R_3 - L_1) is also 3, the bridge will be in balance and the differential input to A_1 will be small. It is this condition that must be maintained because, if the positive feedback is greater, oscillation will quickly build up until amplifier saturation is reached. On the other hand, if the negative feedback is greater, the oscillations will die out. In a practical Wien-bridge oscillator, it is therefore necessary to provide some means of automatically balancing the feedback so that the amplitude of the oscillations can be regulated. In this state the purity of the output waveform will be at a maximum, as will the frequency stability. Another requisite is that the amplifier gain be large at the frequency of oscillation—the input error will then be small, which guarantees that the Wien network operates close to its natural frequency and is stable.

Any means of stabilizing the amplitude of a Wien-bridge oscillator must involve adjustment of the negative feedback divider to maintain the attenuation at 3. Typically, this can take the form of nonlinear elements: thermal types such as lamps or thermistors, nonlinear resistors, diode clippers, zener diodes, and so on. In Fig. 10-1, the nonlinear resistance of a lamp (L_1) is used to regulate the amount of negative feedback. L_1 responds to the average (not instantaneous) output level of A_1 , adjusting its terminal resistance in

inverse proportion. If the output level of A_1 rises, L_1 increases resistance, counteracting the rise. Similarly, a reduction in output results in a decrease of lamp resistance, stabilizing the oscillation level.

Lamp and thermistor stabilization schemes are popular ones, due mainly to their simplicity. They have several drawbacks, however, such as an inherent thermal time constant that limits usefulness to the lower frequencies.

Resistors R_3 - R_4 trim the negative feedback to accommodate lamp tolerances. If precise amplitude control or optimum stability for individual lamps is not necessary, let $R_3 + R_4 = 750 \Omega$. For frequency-tunable generators, either R_1 - R_2 or C_1 - C_2 can be ganged as a pair (with good tracking characteristics). If C_1 - C_2 are selected as the tunable elements, large values for R_1 - R_2 are required to cover the lower frequencies, which raises the network impedance. In such cases, C_1 - C_2 should be in a shielded enclosure and stray capacitance to ground should be minimized for best results.

The circuit of Fig. 10-1 is quite useful as a general-purpose Wien oscillator; with the appropriate amplifier, it can be used over a wide range of frequencies. Amplifiers most suitable (over the widest frequency range) are high-slew-rate FET-input units such as the TL071, AD544, 353, 3140, and 771. These devices can be useful up to 100 kHz. Lowest distortion will be realized with high-slew-rate, high-GBP types such as the 5534, 318, 2505, 2507, 2605, and 2607.

10.1.2 FET-Stabilized Wien Oscillators

Another popular method of achieving amplitude control is by using the variable channel resistance of a field-effect transistor. By sampling and rectifying the output voltage, a dc signal proportional to the output amplitude can be made to control the resistance of a FET. This technique works well within limits, but the channel resistance of the FET itself is nonlinear at high signal levels, and appreciable distortion can occur.

Fig. 10-2 is a Wien-bridge oscillator rearranged to effectively utilize the FET channel resistance as a gain control. In this circuit R_1 - R_2 and C_1 - C_2 again comprise the Wien network, but with the impedance of the legs scaled so that R_1 - C_1 see a voltage lower than R_2 - C_2 . This allows the voltage level at R_1 - C_1 to be of lower amplitude. The circuit uses two amplifiers in the inverting mode; gain control is accomplished by FET Q_1 , which is placed at the summing point of A_2 (a point of minimum voltage). Q_1 can then operate at a level low enough to make its distortion negligible. A_2 provides a nominal gain of 2, which is trimmed by the agc and R_5 so that Q_1 is operating in the most linear portion of its characteristic.

The circuit has dual outputs available with two amplifiers; level differences are determined by the Wien network (R_1 - R_2). E_{o_1} will