

LED driver circuits

Distribute the power loss in linear control systems favorably

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An IC in the car ensures that the LED provides stable brightness and responds to the control unit. We show how the power loss can be distributed.



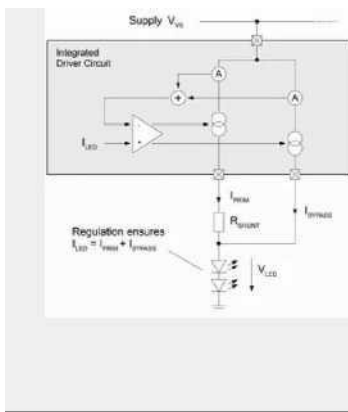
Linear regulator with power distribution: LEDs light up in the rear lights of a car. The light must provide stable brightness, display complex signals and respond quickly to the control unit.

(image: Elmos)

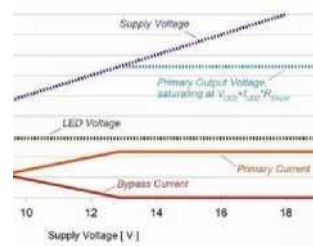
It has been some time since the rear lights on a car were used to identify a vehicle and indicate which way it was going. In today's cars, it is more of a visual distinguishing feature, a style element and quite clearly a status element. A modern blinker does not simply switch on but focuses on appearance and wipes to the side. The light of the future will be able to reproduce complex "welcome animations" as soon as the driver switches on.

driver visits the car. The basis for these developments is a flexible LED technology and can be seen on the road every day.

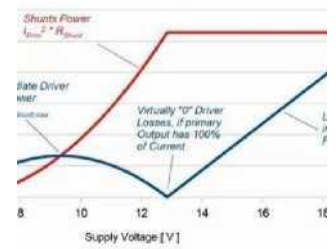
PICTURE GALLERY



ages and Current Distribution
with thermal Shunting & Bypass



Power Sharing between Driver and Shunt
versus Supply Voltage



A lighting function in a luminaire has to meet a variety of requirements: These include stable brightness, complex display and a fast response to requests from the control unit. In addition, manufacturers and buyers expect a high degree of robustness against environmental influences and voltage fluctuations as well as fault tolerances and diagnostics. At the same time, inexpensive solutions are sought for maximum efficiency etc.

Switching regulator solution vs. cheaper linear regulator

The electrical output of a rear light is also considerable with LED technology. Color or diffusion filters and optical fibers generate optical losses. The LED must be supplied with sufficient power to compensate for this. On the other hand, for cost reasons, there is a desire for high integration of as many driver strands as possible for LEDs, preferably in an integrated circuit.

In terms of topology, you can choose between switching regulator solutions, which tend to be expensive, or cheaper linear regulators. Integrated circuits quickly reach the limits of their own design technology. A power loss in the housing of an IC of more than two to three watts is rather rare. Added to this are the requirements of vehicle manufacturers to avoid pronounced hotspots on printed circuit boards. This can further reduce the power limits per component. Commercially available linear regulators for currents cause power losses in the order of: $P_V = I_{LED} * (V_{supply} - V_{LED})$ (Formula1).

The waste heat is therefore a linear function of the V_{SUPPLY} . Even if the board mains voltage in the car is a 12 V battery voltage on paper, static operation between 6 V and 18 V

must be possible. If you combine the assumed maximum power $P_{IC,MAX}$ of 2 W with an LED voltage V_{LED} of typically 6 V, the maximum linear total current is $I_{IC,MAX}$

$$I_{IC,MAX} = \frac{P_{IC,MAX}}{V_{SUPPLY,MAX} - V_{LED}} = \frac{2W}{18V - 6V} = 166mA$$

Formula 2

Linear regulators for complex lighting patterns with several output channels can therefore be designed as regulators for 3x 55 mA, 2x 80 mA or 1x 160 mA, for example. But how can the limits be extended? For example, to 3x 150 mA?

Modern linear regulators with a power distribution

As power loss is unavoidable in linear control systems, the question arises as to how this can be distributed differently in a cost-effective way. A very cost-effective solution is to connect resistors in series with the LED. However, this initially contradicts the desire to operate the LED at full brightness even with a low supply.

The resistor solution must preferably be extended. The functional principle of the solution in Fig. 1 is based on two outputs sharing a total current.

An internal distribution mechanism always favors a primary output. If this is no longer sufficient due to a lack of supply voltage, the missing current is automatically supplied by a parallel, second branch, the so-called bypass. Figure 2 shows the progression of voltages and currents on the driver module and the LED. At very low voltages, the LED does not yet carry any current. Only when the supply voltage $V_{SUPPLY} > V_{LED}$ is reached does the [diode](#) start to conduct current. The resistive, primary driver output and the bypass share the current. This results in a significantly lower power consumption for the driver module than in the classic linear regulator. Figure 3 shows this in more detail.

The three operating points of an LED driver

The course of the power loss in the driver is essentially characterized by three operating points: the first operating point is at $V_{SUPPLY} = V_{LED}$. Theoretically, no more power loss occurs in the driver at this operating point. There is a second operating point,

when the supply V_{SUPPLY} is just high enough to drive the expected current completely out of the primary branch. Here, too, the power loss in the driver is theoretically close to zero and the shunt resistor draws its maximum power $P_{SHUNT,MAX}$. The third relevant operating point is the maximum power loss between the two minima. This operating point occurs when the current is divided between the outputs in a ratio of exactly 50 percent: 50 percent. Quantitatively, the value is

$$I_{V,DRIVER} = R_{SHUNT} \cdot \left(\frac{I_{LED}}{2} \right) = \frac{1}{4} \cdot P_{SHUNT,MAX}$$

Formula 3

In theory, the two power zeros of the driver are as follows: $V_{SUPPLY,PV,ZERO1} = V_{LED}$ (Formula 4) and $V_{SUPPLY,PV,ZERO2} = V_{LED} + I_{LED} \cdot R_{SHUNT}$ (Formula 5). If we recall the goal of designing a driver circuit for 3x150 mA in the example, this can be realized using two resistors with 0.6 W (SMD 1206 design). An additional power dissipation capacity of 1.2 W per string is provided by these two resistors. This allows the power to be distributed on the circuit board or implemented at a suitable location, such as on a remote heat sink.

If, for example, the assumed power loss limit of 2 W in the driver is divided into three channels of 0.66 W each, the following relationship is obtained:

$$V_{SUPPLY,MAX} = V_{LED} + \frac{P_{SHUNT,MAX} + \frac{P_{IC,MAX}}{3}}{I_{LED}}$$

$$= \frac{1,2W + \frac{2W}{3}}{150mA} = 18,4V > 18V$$

(Formula 6)

The thermal design target for continuous operation at a voltage of 18 V has therefore been achieved. In the "bill of material" of the circuit, the need for integrated components is significantly reduced. In the example presented, the cost of three integrated driver components is reduced to just one, plus low-cost resistors.

Methods for distributing the power loss

Modern methods of distributing the power loss reduce the cost of integrated circuits by up to a third compared to conventional solutions. At the same time, the thermal design is extended by the possibility of allowing significant portions of the power loss to occur where it can be dissipated preferentially.

The Elmos Semiconductor portfolio includes a whole family of ICs with these advantages: The products E522.80 to E522.83 and E522.90 to E522.93 each provide three individually configurable and dimmable channels. The currents range up to 3x150 mA per IC. In addition to the power management shown, there are other design-simplifying functions such as diagnostics for the external circuitry, junction temperature management or overvoltage derating.

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