Analog-circuit design often requires a constant-current sink. An example would be for a TRIAC (triode-for-alternating current) dimmer holding current in fluorescent or solid-state lighting. Other examples include a precise current sink at the end of a long line, such as a cable or an ADSL (asymmetric digital-subscriber-line) modem, which produces a “signature” current value that alerts the device at the source end, such as an exchange office or a cable center, that the remote equipment is attached. The trick is to make a circuit that gives a constant current over a variety of terminal voltages.

A common circuit for achieving this task uses a sense resistor, a transistor, and a power device. Figure 1 shows the circuit using a power transistor, Q1. The circuit provides an approximate constant current at high voltages, but it doesn’t enter regulation until it reaches nearly 60V due to the base current the transistor requires.

Unfortunately, the current-sense resistor, R1, in figures 1 and 2 doesn’t sense the bias current. As the terminal voltage increases, the terminal current also increases because of the increased bias current. A simple way to improve the regulation of both circuits is to add smaller biasing resistors, and the circuit comes into regulation at a much lower terminal voltage.

A MOSFET provides the same performance as the transistor, but with smaller biasing resistors. Figure 2 shows the circuit using a MOSFET, Q1, for the power device. With a MOSFET, you can use smaller biasing resistors, and the circuit comes into regulation at a much lower terminal voltage.

Unfortunately, the current-sense resistor, R1, in figures 1 and 2 doesn’t sense the bias current. As the terminal voltage increases, the terminal current also increases because of the increased bias current. A simple way to improve the regulation of both circuits is to add re-
The negative temperature coefficient of the base-to-emitter junction of transistor Q2 causes another problem with this kind of circuit. The temperature coefficient is approximately $-1.6 \text{ mV/°C}$, which causes the current value to vary widely with temperature.

One way to approach this problem is to add a 6.2V zener diode, D1, in series with the emitter of Q2, which increases the sense voltage (Figure 4). A 6.2V diode has a positive temperature coefficient, which counteracts the negative temperature coefficient of the transistor. Furthermore, the total sense voltage is much larger, so 100 mV or so of voltage change with temperature does not seriously affect the regulated current.

Figure 5 shows a PSpice simulation of the circuit that uses a MOSFET for Q1.

Limit inrush current in low-to medium-power applications

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When switched-mode power supplies, including those for notebook computers, turn on, the bulk capacitor of the uncontrolled rectifier is completely discharged. This can result in a large charging current for a high instantaneous line voltage because the discharged capacitor temporarily short-circuits the power supply’s diode bridge.

With a large bulk capacitor, the current spike can trigger the mains breaker or even destroy rectifier diodes. Capacitor and line ESRs (equivalent series resistances) and inductances help to reduce the initial spike. Even so, current peak can reach tens of amperes. The rectifier-diode selection must account for this nonrepetitive spike. An initial spike also affects the lifetime of the bulk capacitor. The circuit in Figure 1 lets you avoid the large initial spike.

At turn-on, if the instantaneous rectified ac-line voltage is greater than about 14V, MOSFET Q1 is on, ensuring that IGBT (insulated-gate bipolar transistor) Q2 is off. In this situation, no current flows through charging the bulk capacitor.

Whenever the rectified ac-line voltage is lower than the voltage across the bulk capacitor plus approximately 14V ($V_i = V_{in} - V_{out} \leq 14V$), Q1 is off, and Q2...
DACs are therefore set to midscale after PRE2, are grounded. Both resistive potentiometers (Reference 1). The DAC’s preset pins, PRE1 and PRE2, are grounded. Both resistive DACs are therefore set to midscale after power-on. The driver contains two resistive DACs, IC3 and IC5, which function as potentiometers. Voltage follower IC8A ensures that the voltage at potentiometer IC1 remains a constant reference voltage regardless of the position of wiper P1. Voltage follower IC8A is necessary because the resistance between the A1 and B1 terminals of IC1 varies from 10 kΩ for wiper P1, when grounded, to 3.33 kΩ for the A1 position of P1. In this way, the drivers for the red, green, and blue LEDs generate the same value of current of VREF/3RF, where VREF is the reference voltage. Thus, you get white light at power-on.

If you require, for example, a pale-pink hue, you ground the PDT pin for a short period. Wiper P1 thus moves down by one step, decreasing the content of green light in the resulting light while increasing the contents from the red and blue LEDs. The sum of the I_r, I_g, and I_b currents remains constant, regardless of the positions of wipers P1 and P2. The luminous intensity of the output light holds constant. Any further short-term grounding of the PDT pin leads to a deeper violet hue of the output light. To get turquoise or bluish-green-tinted white light, you simply ground the PD2 pin for short periods. The relative content of the red component then decreases below one-third of full-scale. If you ground the PUT, PDI, PD2, or PD2 pins for short periods, you can arbitrarily set hues of the light. The color resolution comes from adding or removing current in approximately 3% steps while removing or adding an equal number of approximately 3% steps of the remaining basic color components. A 100% step equals the total light intensity, regardless of color. This intensity is constant because the sum of currents flowing through the red, green, and blue LEDs is constant and has a value of VREF/3RF. The resistive DACs have wiper-position margins.

The zero-scale relative margin is typically 1% of full-scale. The upper-position relative margin, or margin of the upper value of resistance between the B and the wiper terminals, is δ_r=2.4% of full-scale. Resistor RSH artificially increases the upper margin of the VOUT voltage. The following equation yields the maximum settable voltage for VOUT:

\[
V_{OUT\text{MAX}} = \frac{1}{1+3\delta_r} \times V_{REF} \\
\approx (1-3\delta_r) \times V_{REF}
\]
By evaluating the equation, you determine you can set 92.8% green and subdivide the remaining 7.2% between the red and blue components by grounding PU1 for a long time. If you also ground the PU2 pin for more than 4 seconds, you get a yellowish- or warm-green color. In contrast, if you ground the PD2 pin for more than 4 seconds, you get aqua or a cool-green color. Thus, changing even a moderate 7.2% of basic components of the light results in highly discernible hues.

Paralleling the $R_{SH}$ between the B1 and P1 terminals of resistive DAC IC3 causes these terminals to exhibit nonlinear behavior. The step change of voltage at wiper P1 decreases to two-thirds at the midscale of IC3 and gradually rises when moving the wiper from the midscale toward zero. At zero, this step change recovers fully to its original relative value of 1/32. When moving P1 from midscale toward full-scale, the step change rises and triples to a value of 3/32 at full-scale. This nonlinear behavior has, however, no detrimental effects. In contrast, close to the midscale, it makes the resolution 1.5 times that of the resistive DAC alone.

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**REFERENCE**


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**Figure 1** At power-up, the AD5228s are set automatically to their midscales, and the circuit produces white light. Short-term grounding of four control pins lets you tinge the light while holding intensity constant.
Transistor boosts regulator current
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Some circuits require a constant-current source that doesn’t necessarily connect to a power-supply rail or to ground. The circuit in Figure 1 shows a simple method for achieving that configuration.

The LM317 voltage regulator develops 1.25V between the OUT and the ADJ pins. Placing a resistor between those pins produces a constant current. Thus, the circuit’s output current is $1.25V/R_{\text{ADJ}}$. The transistor lets the circuit source more current than the regulator alone can provide once the current through $R_1$ creates enough voltage to turn the transistor on. Otherwise, the regulator supplies the load current.

Figure 1 This simple method achieves a constant-current source that doesn’t necessarily connect to a power-supply rail or to ground.

Detect live ac-mains lines
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You can use a simple battery-powered circuit to detect whether an ac-mains wire is live without making any electrical contact with it. The circuit uses a CD4011 NAND gate’s high input impedance to sense a magnetic field from a 50- or 60-Hz ac-mains line.

Figure 1 A battery-powered live-wire detector lights an LED in the presence of a field.

You simply bring the detector coil near the socket to see whether it has a proper ac connection. If it does, then the LED will illuminate (Figure 1).

The detector in this case is a coil of copper wire. When you place it near a live wire carrying ac current, the coil develops a voltage across the CD4011 at pins 1 and 2. This voltage produces square waves at the output of the gate, driving the LED active. In the absence of any hot ac wire near the detector plate, the 1N4148 diode connected to the first gate’s inputs keeps the gate biased. This bias ensures that, under normal conditions, the final output from the gates is low, keeping the LED off.

Placing the detector plate close to a live wire sets up an oscillating voltage at the gate’s input at pins 1 and 2. That voltage produces square waves corresponding to the ac-mains frequency. The remaining three gates of CD4011 connect in parallel, which increases the current through the LED enough to light it.

A rechargeable, 3.6V nickel-cadmium battery powers the circuit. You can assemble the detector into a convenient, pocket-sized glue-stick tube (Figure 2). The circuit consumes nearly no power when the indicator LED is off. Thus, you can also power the circuit using lithium cells, such as the popular CR2032.