Solving Current Source Design Challenges

Simple, high performance two-terminal current source

Compared to other analog circuitry, current source design appears relatively easy on the surface, but in reality it is more complicated than meets the eye. While high quality voltage sources are commonplace, current sources, as components, have remained elusive. Furthermore, two-terminal current sources generate a new set of problems, especially if high accuracy and stability over temperature are desired.

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A current source must operate over a wide voltage range, have high DC and AC impedance when connected in series with unknown reactance and exhibit good regulation and a low temperature coefficient. For optimal two-terminal solutions, no power supply bypass capacitor should be used since it degrades AC impedance.

A new device, the LT3092 from Linear Technology, overcomes the problems of earlier two-terminal current sources. It has better than 1% initial accuracy and a very low temperature coefficient. Output currents can be set from 0.5mA to 200mA, and current regulation is typically 10ppm per volt. The LT3092 operates down to 1.5V or up to 40V. This gives an impedance of 100MOhms at 1mA or 1MOhm at 100mA. Unlike almost any other analog integrated circuit, special design techniques have been used for stable operation without a supply bypass capacitor, allowing it to provide high AC impedance as well as high DC impedance. Transient and start-up times are about 20µS.

Figure 1 shows a basic diagram of Linear Technology's LT3092 current regulator. The architecture is similar to Linear's LT3080 voltage regulator, but it uses a PNP transistor as the output

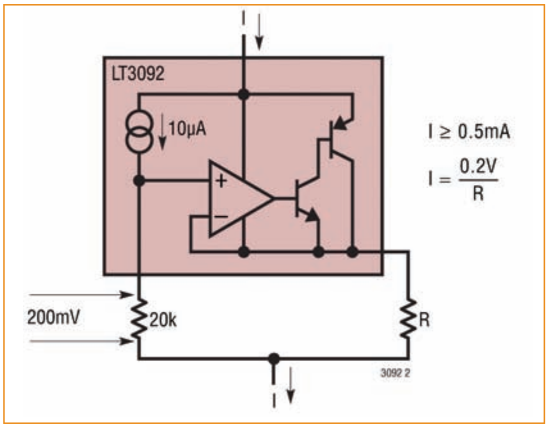

Figure 1: Two-terminal current source.

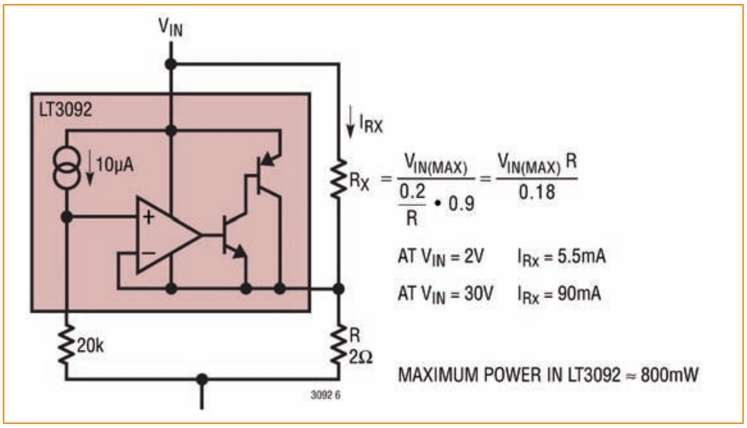

Figure 2: Reduced dissipation.

device instead of an NPN. Internal circuitry is differential and buffered, with a regulator to isolate it from power supply changes. This isolation allows stable operation without bypass capacitors. Additionally, for environments that may have power supply reversal, the LT3092 is immune to damage from reverse power supply voltage and does not conduct current, so it protects the load.

The internal current source and the offset of the amplifier are designed to reject power supply changes by 100dB or better, so the regulation is very good. Setting the RSet down to zero allows the output to be adjusted down to zero.

A small voltage is impressed upon an external set resistor, 20k in this case, to generate a 200mV reference. That forces 200mV across a current-determining resistor R, and the total current is then equal to 0.2V divided by R (plus 10µA). The current regulator works from about 1.5V across it up to 36V, and the current regulation and temperature stability is extremely good. As a two-terminal current source, the load can be either in the positive leg or in the ground leg of the circuit.

The 200mV generated reference is chosen to equalize the errors due to changes in the internal current source and in the offset of the amplifier with supply voltage. With supply changes, the internal current sources change approximately 50pA per volt. The offset of the internal op amp changes less than 5µV per volt. Assuming worst case for both the current source and the offset of the amplifier, a 200mV reference contributes equal error from both the amplifier and the internal current source. If the 200mV is increased to 500mV using a 50k resistor, the contribution of the

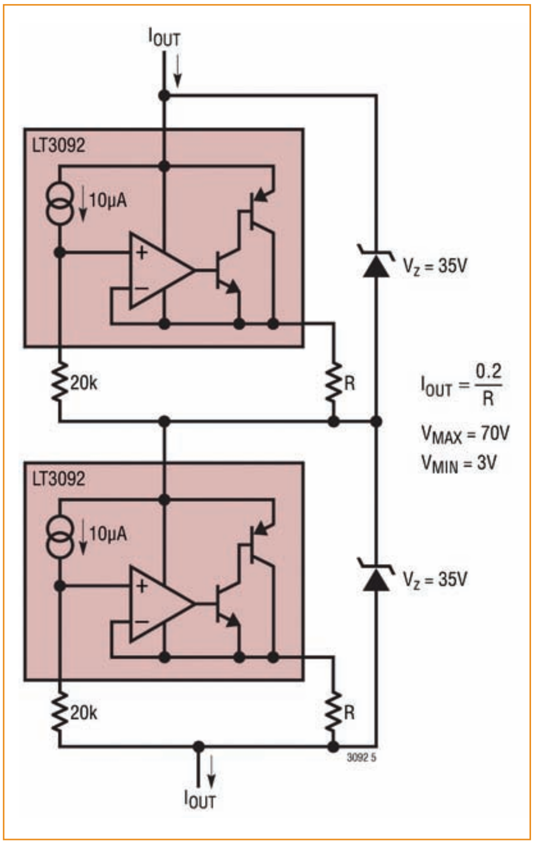

Figure 3: Stacked current sources for higher operating voltage.

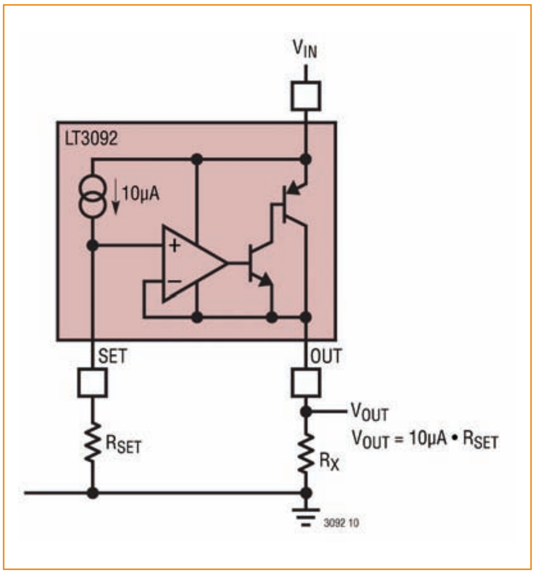

Figure 4: Intrinsically safe regulator—no capacitors needed.

internal op amp offset declines. This improves the regulation of the current source against supply changes.

However, the regulation of the loop is so good that in all but the most extreme cases, 100mV to 200mV across the set resistor will be fine.

Reducing power dissipation

For high set currents and high voltage, there is considerable power dissipation in the LT3092. For example, 30 volts and 100 milliamps equals 3 watts of dissipation, which can result in significant temperature rise depending on the thermal resistance of the PC board. An external resistor can shift a portion of the power to the resistor and reduce the power dissipation in the LT3092. Figure 2 shows the basic current source with a resistor RX from the input to the output of the device. As long as the total current is more than the current through RX, regulation is not impaired and the current source impendence does not change.

Current through RX is within the feedback loop and gets compensated as the voltage from input to output changes. The current flows through the internal PNP transistor or the external resistor while the feedback loop keeps the total current constant.

For good regulation and to ensure reasonable margin, the current through RX should not be any larger then 90% of the desired current for the device at the maximum voltage. The formulas in the illustration show how to choose RX so that the current through RX always leaves at least 10% of the current flowing through the LT3092. This drops the maximum internal power down by shifting some power to the external resistor. The result is a significant reduction in device dissipation, as well as a reduced rise in temperature. There is negligible effect on the performance of the circuit by including this external resistor.

Increasing voltage compliance

For higher voltages, current sources can be stacked to operate at a higher total voltage. Figure 3 shows stacked current sources.

Two current sources are set up for the same currents and a voltage-limiting Zener is placed across each of the current sources. At low voltage, whichever current source has the incrementally higher current will saturate and the current will be controlled by the other current source. As the voltage increases, at some point the Zener breaks down and starts to conduct. Then the voltage across the saturated current source starts to increase and it regulates the current as the voltage continues to increase. When the current control goes from one current source to the other, there is a small discontinuity in the output current equal to the error between the two current sources. Typically this is less than 1% and again no bypass capacitors are needed to make the device work.

Intrinsically safe as a voltage regulator

The LT3092 will act as a voltage regulator that needs no output capacitor. “Intrinsically safe” applications are usually designed with low current, and small or no capacitors. Figure 4 shows the LT3092 as a 200mA regulator. As a voltage regulator, the 10µA current that's generated internally flows through an external RSet resistor. This 10µA times the RSet value impresses a voltage on the Set pin. The internal voltage follower provides the same voltage at the output pin as the Set pin. The load is connected from the output pin to ground.

Conclusion

As a new IC, the LT3092 solves current source design, which is a more difficult challenge than a voltage regulator design. Current source values of 1mA up to high currents are achievable using a single unit or paralleled units. Regulation against line, load and temperature is excellent and unique design techniques have made the device operable without bypass capacitors even though there is a complex feedback circuit internally. This device adds a versatile component to a designer's toolbox.

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