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2-Terminal Current Source Boasts High Accuracy, Programmability and Stability

A monolithic current source uses two external resistors to program its output from 0.5 mA to 200 mA with 1% initial accuracy and a low temperature coefficient.

LINEAR TECHNOLOGY'S recently introduced LT3092 is a 2-terminal programmable current source, typically defined as a circuit that delivers or absorbs current. Several applications for current source circuits include but are not limited to:

- **Voltage regulator without output capacitors**
- **AC current limiter**
- **Voltage clamp**
- **Active load**
- **Remote temperature sensor**
- **LED driver.**

Before the LT3092, the simplest current source was merely a voltage source with a resistor in series feeding the load resistance. Assuming the load resistance is much smaller than the series resistor, the current available from this circuit is the ratio of the voltage source to the series resistor. Unfortunately, the only way to vary the current is to change the value of the series resistor, which doesn't provide much circuit flexibility.

An improvement over the voltage source-resistor approach is to configure a 2-terminal current source using discrete components, as shown in *Fig. 1*. Here, the temperature coefficients of the LT1004 Zener and 1N457 diode don't provide a perfect match for the two transistors, so drift and accuracy are subject to their parameter changes over temperature. Also, changing the output current requires a discrete circuit modification.

Now, the monolithic LT3092 (*Fig. 2*) requires only two external resistors (R_{OUT} and R_{SET}) to set an output current between 0.5 mA and 200 mA. It is stable without input and output capacitors, offering high dc and ac impedance, which allow operation in intrinsically safe applications. Current regulation is better than 10 ppm/V for a V_{IN} of 1.5 V to 40 V. The IC exhibits 1% initial accuracy and a low temperature coefficient. Protection features include reverse-voltage, reverse-current, short-circuit and thermal shutdown with hysteresis. The LT3092 requires a 0.5-mA minimum load or its output will not regulate. The *Table* lists the possible relationships between R_{SET}, R_{OUT} and the output current. Depending on the designer's application, the R_{SET} and R_{OUT} resistors can be changed. If the designer does not want to use low value resistors for R_{OUT}, then make R_{SET} and R_{OUT} larger. If there is a need for more headroom, the resistors can be lower. If certain resistors have a better temperature coefficient and stability with time, you can adjust the values to work with them. The 3092 has high enough gain and good frequency stability, so it is "user's choice" for resistors.

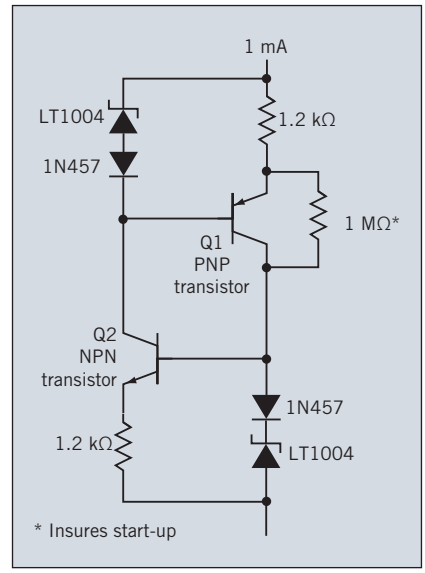

Fig. 1. 2-terminal current source using discrete components does a reasonable job, but its accuracy is limited to a few percent. (The top is I_{OUT}; the bottom is V_{IN}.)

PROGRAMMING THE CURRENT

The IC uses a precision "0" TC 10-µA reference current source to program the output current. As shown in Fig. 2, this 10-µA current source connects to the noninverting input of a power operational amplifier. The power operational amplifier provides a low impedance buffered output of the voltage on the noninverting input.

The 10-µA reference current from the SET pin uses R_{SET} resistor to generate a voltage in the range of 100 mV to 1 V. This voltage is applied across the R_{OUT} resistor that connects from the OUT pin to the R_{SET} resistor. Fig. 2 shows connections and the formula to calculate a current source output.

With a 10-µA current source generating the reference, it is important to minimize board leakage by encircling the SET pin and circuitry with a guard

ring operated at a potential close to the SET pin, and tying the guard ring to the OUT pin. Guarding both sides of the circuit board is required. Bulk leakage reduction depends on the guard ring width. A 10 nA of leakage into or out of the SET pin and its associated circuitry creates a 0.1% reference current error. Leakages of this magnitude, coupled with other sources of leakage, can cause significant offset voltage and reference current drift — especially over the possible operating temperature range.

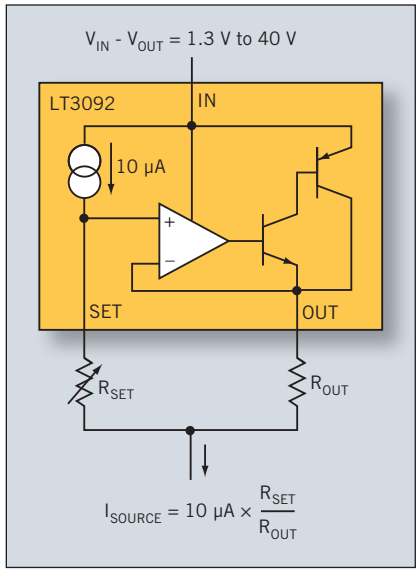

Fig. 2. The LT3092 uses two resistors (R_{OUT} and R_{SET}) to set an output current between 0.5 mA and 200 mA.

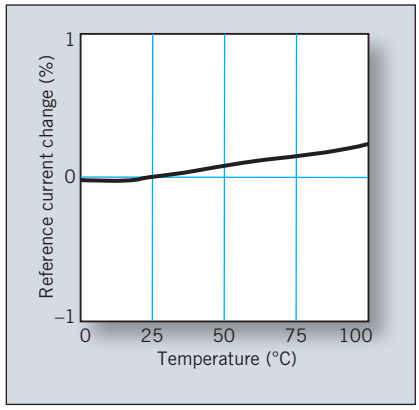

Fig. 3. Temperature change of the current source at 1-mA output current.

The LT3092 does not require input or output capacitors for stability in many applications. Clean, tight PCB layouts provide a low-reactance, well-controlled operating environment for the IC without requiring capacitors for frequency compensation.

Some applications require a capacitor in parallel with R_{SET} to lower current source noise. This capacitor also provides a soft-start for the current source.

Although the LT3092 is stable without any capacitors over a variety of operating conditions, it may be necessary to add capacitors because of the input and output impedances encountered by the LT3092. These impedances may include resistive, capacitive and inductive components, and may be complex distributed networks. In addition, the current source's value will differ between applications, and its connection may be ground referenced, power supply referenced or floating in a signal line path.

If an application uses GND referred capacitors on the input or output (particularly the input), pay attention to the length of the lines powering and returning ground from the circuit. In the case where long power supply and return lines are coupled with low ESR input capacitors, application-specific voltage spikes, oscillations and reliability concerns may be seen. This is not an issue with LT3092 stability, but rather the low ESR capacitor forming a high-Q resonant tank circuit with the inductance of the input wires. Adding series resistance with the input of the LT3092, or with the input capacitor, often solves this. Resistor values of 0.1 Ω to 1 Ω are often sufficient to dampen this resonance.

Give extra consideration to the use of ceramic capacitors. The X5R and X7R dielectrics result in more stable characteristics and are more suitable for use as the output capacitor. The X7R type has better stability across temperature, while the X5R is less expensive and is available in higher values.

Higher output current can be obtained by paralleling multiple LT3092s together. The simplest approach is to run two current sources side by side with both of their inputs and outputs tied together. This allows the sum of the current sources to deliver more output current than a single device can deliver.

Another method of paralleling devices requires fewer components and helps to share power between devices. Do this by tying the individual SET pins together and tying the individual IN pins together. Then, connect the outputs in common using small lengths of circuit board trace as ballast resistors to promote equal current sharing.

The LT3092's internal power and thermal limiting circuitry protects itself under overload conditions. For continuous normal load conditions, do not exceed the 125°C maximum junction temperature. Account for all thermal resistance sources from junction-to-ambient. Furthermore, consider all adjacent heat generating sources on the PCB within proximity of the LT3092.

The LT3092 is housed in the 8-lead TSOT-23, 3-lead SOT-223 and 8-lead 3-mm × 3-mm DFN packages.

Table. (below) Possible relationships between R_{SET}, R_{OUT} and the output current.

R_{SET} (Ω)	R_{OUT} (Ω)	OUTPUT CURRENT (mA)
20,000	1.0	200.0
10,000	1.0	100.0
5,000	1.0	50.0
2,500	1.0	25.0
1,000	1.0	10.0
500	1.0	5.0
50	1.0	0.5