Application Brief

How Do I Achieve a More Accurate Current Limit and Avoid Damaging My Device Under Test?

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In test and measurement applications a major concern is that excess current through a device under test (DUT) can cause load damage to the device. Since the output current drive capability of a power op amp may exceed the specific and intentionally lower current level to be applied to the DUT, output current limiting may be required to prevent damage to the DUT. In modern systems, current-limiting circuitry must be added to prevent this overcurrent incident. However, by utilizing Texas Instruments' user-settable current-limiting (ILIM) technology you are able to reduce the test system complexity and cost by eliminating the need for the external current-limiting circuitry.

This is the final installment in a four-part series discussing how to increase system accuracy and efficiency with op amps built on TI's proprietary complementary metal-oxide semiconductor precision process technology.

Most amplifiers rely on their short-circuit output transistor capability, or an electronic design, to limit the output current to a maximum level. However, in either case the current is an intrinsic maximum and not settable. Beyond that, TI's power op amps that are capable of providing hundreds of milliamperes or even amperes include a user-settable current-limiting provision. This provision was included in the OPA54x and OPA56x designs and provides a protective current limit for both the op amp and its load. These devices are accurate in the range of about ±10 to ±15%, or better, at a specified output current, and a specified case or junction temperature condition.

The new OPA593 current-limit accuracy is specified as ≤ 5% for the current-limit range of 50 mA to 250 mA, and ≤10% accuracy for a range of 25 mA to 250 mA (T_A = 25°C). The current-limit accuracy applies when the output is either sinking or sourcing load current. Current programming is accomplished with the ISET pin, whose current setting establishes the current-limit (ILIM) level. The current limit of a device is roughly programmed initially, and then trimmed to be 4000 times the sinking current of ISET pin. The bias current for I_{SET} is referenced to an internal sub-regulated value of approximately 3.687 V. The bias current is established by the external resistor connected between the pin and negative supply rail. If the ISET pin is left floating, the default current limit is approximately 25 mA.

The OPA593 has specialized circuitry to sense the output stage current and clamp it to the current limit set to and established by I_{SET}. The internal 56.7-kΩ resistor is precisely laser trimmed to account for any small deviation in the precision 3.687-V internal reference so that the I_{SET} current is correct. The current is correct for the external current-limit resistor (R_{CL}) value settled upon.

Figure 1 and Figure 2 show how the current-limit ILIM is readily established in either current or voltage mode. Note that R_{CL} can be referenced to a voltage level other than V–, but the voltage must be less than the +3.687 V so that an I_{SET} current can be established and sunk through R_{CL} to that supply.
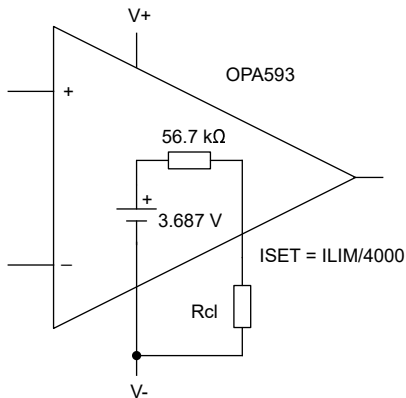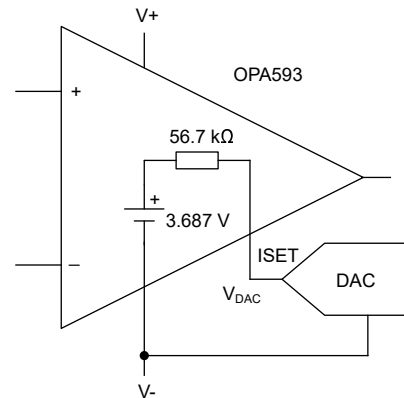

Figure 1. Current-Limit ILIM, Current Mode

Figure 2. Current-Limit ILIM, Voltage Mode

$$R_{CL} = \frac{(3.687\ V \times 4000)}{ILIM} - 56.7\ k\Omega \qquad (1)$$

$$V_{DAC} = 3.687\ V\ - \left(\frac{ILIM \times 56.7\ k\Omega}{4000}\right) \qquad (2)$$

Equation 1 and Equation 2 are set up so that the current-limit ILIM is established based on the value of R_{CL} for the Figure 1 method, or the DAC output voltage (VDAC) for the Figure 2 method. The DAC circuit allows the current limit to be changed as needed and on the fly. The *4000* constant in the equations represents the mentioned 4000:1 ratio of the ILIM to ISET pin current.

A randomly selected OPA593 was mounted in place on a newly developed OPA593EVM. The EVM has 5 R_{CL} resistor selections placed for 50, 100, 150, 200, and 250 mA limiting. The level is selectable by a 2-conductor, plug-in shunt. The OPA593 was configured as an inverting amplifier having a gain of –10 V/V. A DC voltage of ±2 V was applied to the input and a high-current 50-Ω load attached from the output to ground. Figure 3 shows the test circuit.
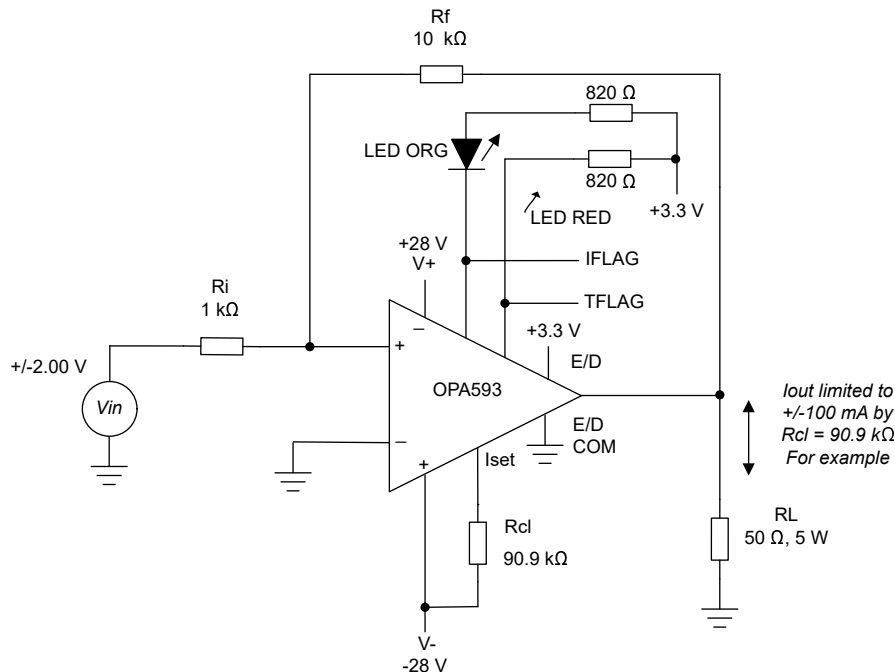

Figure 3. Current-Limit Accuracy Test Circuit Using OPA593EVM

The OPA593 current-limit accuracy test results are presented in Figure 4. The graph provides curves where the I_{SET} resistor was selected for decreasing 50-mA increments, starting at 250 mA through 50 mA. The tabulated results on which the curves are based indicated that the accuracy was between +0.8% to +3.8% both sinking and sourcing current - well within the 5% specification.
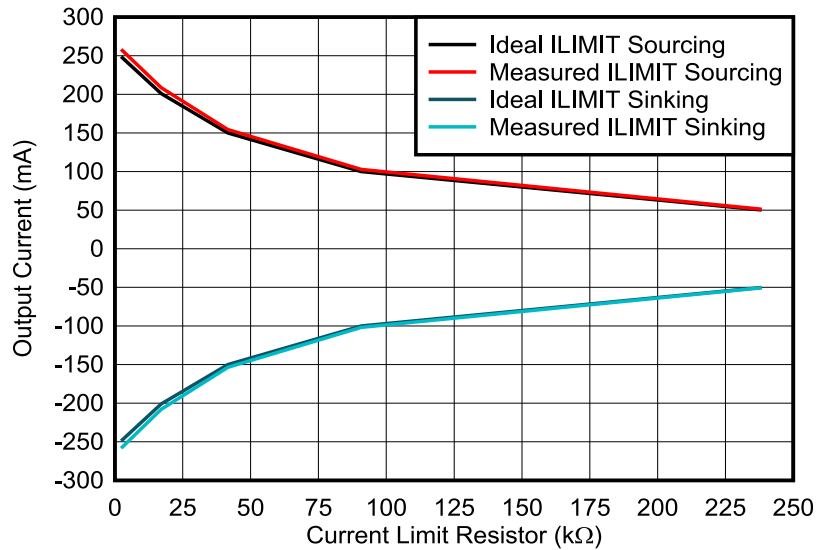

Figure 4. Ideal and Measured ILIM Current vs I_{SET} Resistance (R_{CL})

What are some of the applications that can take advantage of the OPA593 high-voltage, high-current accurate current-limiting capability? Here are some ideas where this feature should prove useful:

- Semiconductor testing where DAC control (VDAC) of ILIM is required
- Memory testing where +32 V and 100 mA or more current is needed to check the cells
- LCD test measurement where the LCD driver chip can have an output > 80 V and requires current limiting
- Linear power supplies with current limiting

And certainly, with the added benefit of accurate current limiting!

$$ILIM = \frac{3.687\,V \times 4000}{56.7\,k\Omega + R_{CL}}$$

(3)

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