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Voltage reference sets current limit

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Power op amps have a real need for active output-current limiting. Most power-amplifier designs rely on the voltage drop across a user-supplied sense resistor to turn on an internal transistor. This method has several drawbacks, notably, an inability to change the current-limit point under program control. The current-limit circuit in **Figure 1** allows you to establish the setpoint by applying a voltage to one of the amplifier's pins. With this design, it is possible to set the current-limit point with the output of a DAC, possibly under the control of an embedded μC.

The OPA547 is a true op amp; thus, it does not need a connection to power ground. The current-limit-setting voltage for this IC uses the negative supply as a reference. For single-supply applications in which the negative supply is ground, this referencing technique presents no problem, but for circuits that use a negative supply below ground potential, you need a different technique. The circuit in **Figure 1** shifts the reference potential for the control signal from ground to the negative supply. For simplicity, **Figure 1** shows the OPA547 as an inverting amplifier, but you can use any op-amp application circuit. The circuit uses an OPA340 for reference shifting because it is capable of rail-to-rail operation on both input and output.

To understand the operation of the reference-shifting circuit, first recognize that the R_3-to-R_4 voltage divider sets the voltage at IC_2's Pin 3. Thus, the intermediate voltage (V_i), as measured from the negative supply, is given by

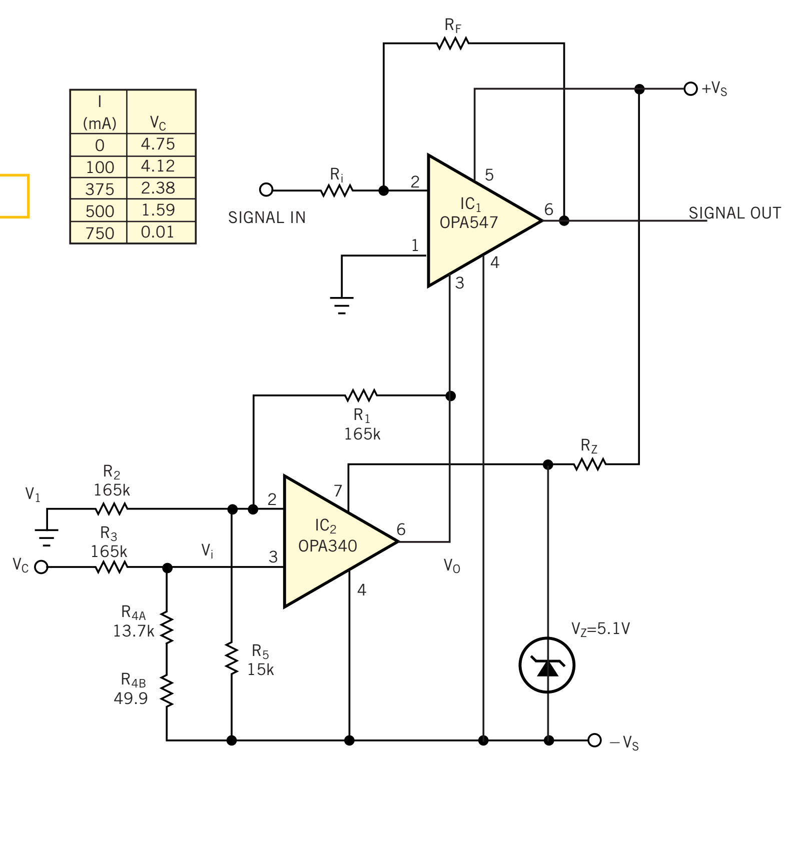
$$V_i = V_C \frac{R_4}{R_3 + R_4}. \qquad (1)$$

To find the voltage at IC_2's pin 2, note that the current through R_3 equals the sum of the currents in R_1 and R_5, leading to the following expression:

$$\frac{V_1 - V_i}{R_2} = \frac{V_i - V_O}{R_1} + \frac{V_i}{R_5}. \qquad (2)$$

As long as op amp IC_2 operates in the linear region, the voltage at Pin 2 equals the voltage at Pin 3, so the value of V_i in each of the expressions is equal. When you substitute the first term into the sec-

Figure 1



I (mA)	V_C
0	4.75
100	4.12
375	2.38
500	1.59
750	0.01

You can use a difference amplifier with wide common-mode range to control a power amplifier's current limit.

ond, set R_1 equal to R_2, and combine terms, the resulting expression is

$$V_O = V_C\left(\left(2+\frac{R_1}{R_5}\right)\left(\frac{R_4}{R_3+R_4}\right)\right) - V_1. \qquad (3)$$

In **Figure 1**, V_1 connects to ground, and you obtain unity gain by setting the coefficient of V_C in **Equation 3** to 1. If you expand and combine terms, the expression becomes

$$1+\frac{R_1}{R_5} = \frac{R_3}{R_4}. \qquad (4)$$

To change the scalar relationship between the controlling voltage applied to the power op amp, simply set the coefficient term to the desired value and solve **Equation 3**. To determine the resistor values, consider the worst-case common-mode voltage that IC_2 can encounter. OPA547 allows a maximum supply differential of 60V. In an extreme case, the positive supply of the OPA547 connects to ground and the current-limit set voltage is +5V. **Equation 1** becomes

$$5 = 65\frac{R_4}{R_3+R_4}, \qquad (5)$$

which reduces to $R_3=12R_4$. Applying this ratio to **Equation 4** and setting R_3 equal to R_1 produces $R_1=11R_5$. Selecting from a list of standard 1% resistor values yields the values in **Figure 1**. Note that the stage operates with a common-mode voltage that equals the negative supply. Errors in the resistor values can produce a significant offset shift. With this circuit, it is possible to set the current limit of the power op amp to a known, repeatable value under program control. (DI #2270).

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