Converting Current to Voltage

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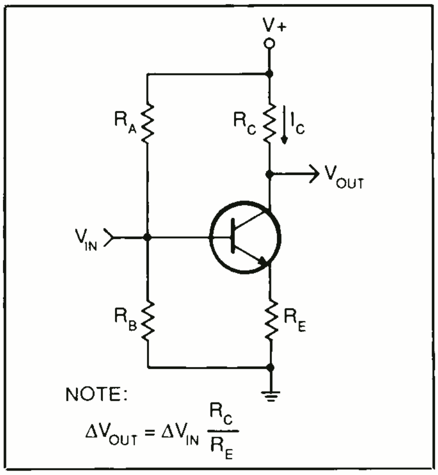

Fig. 1. An amplifier circuit that has a voltage input and a voltage output.

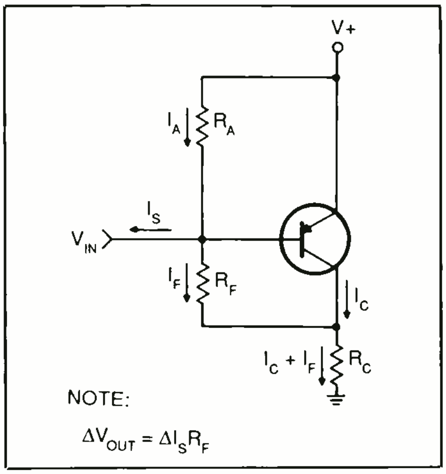

Fig. 2. An amplifier circuit that has a current input and a voltage output.

Electronic circuit design frequently required conversion of a variable current to a voltage. The current source (or sink) is often the collector of a transistor, but it could be the output of an integrated circuit or any device whose output is a variable current. The conversion is usually accomplished by inserting a resistor in the circuit so that the current flows through the resistance. The voltage drop across the resistance varies linearly with the current.

The transistor circuit shown in Fig. 1 illustrates this method. Since the collector current is relatively unaffected by changes in the collector-to-emitter voltage, the output voltage varies linearly with the input voltage. Distortion occurs when V_{ce} drops below the linear portion of the operating characteristics curves. As a practical matter, this means that the supply voltage must be significantly greater than the maximum peak-to-peak output voltage swing.

Given a current source or sink that requires an essentially fixed voltage at its output, is is not feasible to insert a resistor into the circuit. A transducer that acts as a variable resistance will produce a current that varies linearly with its resistance only if supplied with a fixed voltage.

The problems of nonlinearity and source-voltage limitation can be overcome by using a very low value of resistance, since this means that the output voltage swing will be very small. The signal voltage can be amplified by as much as necessary. However, this approach introduces new problems. The required amplifier may add significantly to the complexity and cost of the device, particularly if dc amplification is required. There is also the potential for noise problems if much amplification is required.

An Active Converter

The circuit in Fig. 2 shows an effective way to convert current to a dc voltage. If the input is a current source, use an npn transistor and reverse the supply voltage polarity. The V_{eb} drop is essentially fixed, thus providing a fixed voltage for the current source or sink. The relationships are shown as:

$$I_A R_A = V_{eb}$$
$$(R_F/R_C) >> \beta$$
$$\Delta I_F = -\Delta I_S$$
$$\Delta V_{out} = \Delta I_S R_F$$

A Practical Application

Figure 3 shows a practical amplifier circuit that illustrates the advantages of an active current-to-voltage converter. It is a dc amplifier with provision for nulling the offset by adjustment of *R4*. Input voltage V_{in} is converted to a current by *Q1*. The collector current of *Q1* is converted to a voltage by *Q2*. The offset is adjusted by adjusting *R4* so that the dc potential at V_{out} is at ground level when V_{in} is grounded. Output is referenced to ground by using a split supply or simply by using a voltage divider consisting of two resistors of equal value.

The collector current of *Q1* will be about 2.3 milliamperes when the output is nulled. Accordingly, R3 + R4 will be about 4,900 ohms. The calculated amplification factor is given by:

$$\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{\dfrac{15\Delta V_{in} \times 10^3}{4.9 \times 10^3}}{\Delta V_{in}} = 3.06$$

As actually measured, the voltage gain is closer to 2 because the voltage at the base of *Q2* is not absolutely fixed. The very small variation in the V_{eb} of *Q2* results in negative feedback that is amplified by the beta of transistor *Q2*.

With no reactive components in the circuit, other than the small capacitances inherent in the transistors and the conductors of the circuit itself, bandwidth is very large. High-frequency cutoff will depend largely on the transistors actually used, but it should be well above 1 MHz. An undistorted peak-to-peak output of about 15 volts is attainable.

Other Applications

Certain integrated circuits source or sink a current that must be converted to a voltage. Usually, the output terminal is connected to one or more transistor collectors internally. Two examples are the DAC-801 digital-to-analog converter and the MC1350 i-f amplifier. The circuit in Fig. 2 can be used with these ICs. The MC1350 is a high-gain dc amplifier with a large bandwidth. Potential applications are much broader than the intended use as an i-f amplifier.

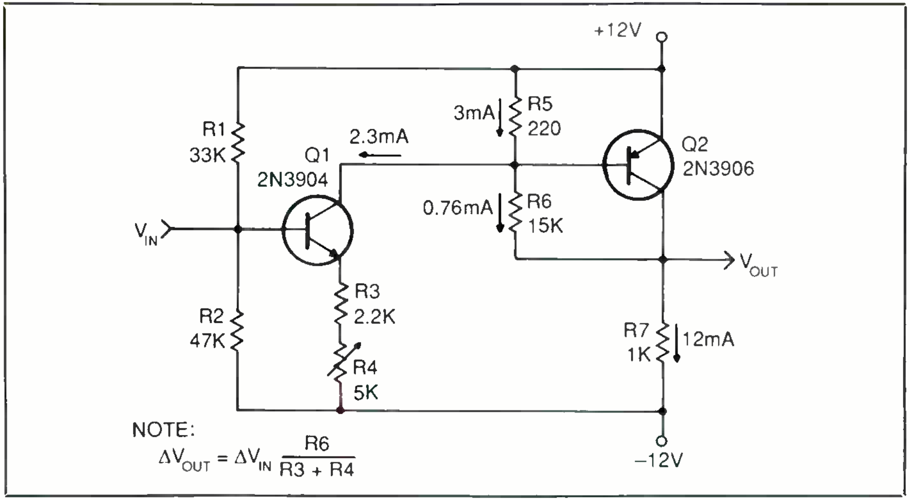

Fig. 3. A practical dc amplifier, with offset milling, for converting an input current to an output voltage.

Summing up, the circuit in Fig. 2 is an amplifier with a current input and a voltage output. It has negative current feedback that stabilizes the dc current, provides for linear amplification and reduces output impedance. In many applications, it has advantages over the voltage-to-voltage amplifier illustrated in Fig. 1. We expect that readers whose interests include circuit design will find that these simple circuits can be effectively used to solve certain problems. **ME**