Build an op amp with three discrete transistors

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You can use three discrete transistors to build an operational amplifier with an open-loop gain greater than 1 million (**Figure 1**). You bias the output at approximately one-half the supply voltage using the combined voltage drops across zener diode D_1, the emitter-base voltage of input transistor Q_1, and the 1V drop across 1-MΩ feedback resistor R_2.

Resistor R_3 and capacitor C_1 form a compensation network that prevents the circuit from oscillating. The values in the **figure** still provide a good square-wave response. The ratio of R_2 to R_1 determines the inverting gain, which is −10 in this example.

You can configure this op amp as an active filter or as an oscillator. It drives a load of 1 kΩ. The square-wave response is good at 10 kHz, and the output reduc-
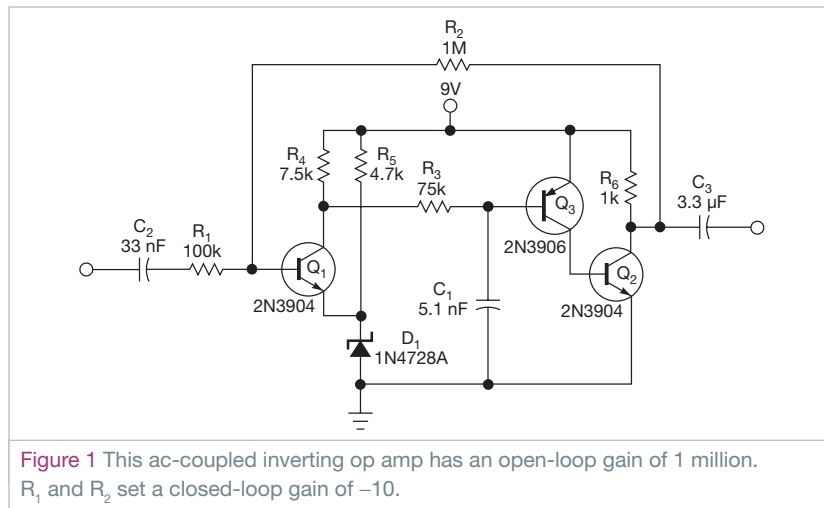

Figure 1 This ac-coupled inverting op amp has an open-loop gain of 1 million. R_1 and R_2 set a closed-loop gain of −10.

es by 3 dB at 50 kHz. Set the 50-Hz low-frequency response with the values of the input and the output capacitors. You can raise the high-frequency response by using faster transistors and doing careful layout.**EDN**