designideas

READERS SOLVE DESIGN PROBLEMS

Low-distortion discrete buffer amplifier handles bipolar signals

Peter Demchenko, Vilnius, Lithuania

Sometimes, the need arises for a low-distortion buffer amplifier capable of handling bipolar signals. You can use an op amp or integrated buffer for these applications, but for more flexibility, a discrete design may prove useful. Applications include buffering the input of an ADC or the output of a DAC, or an audio line driver.

The buffer in **Figure 1** provides unity gain, low output impedance, and low distortion. It uses two emitter followers configured as symmetrical class-A amplifiers; current sources replace the usual emitter resistors (**Figure 2**). To obtain the best results, you should use complementary transistors (Q_1 and Q_2) with closely matched dc gain (beta).

This topology has advantages over a conventional emitter follower. It produces a lower level of even-order harmonics and lower noise, it can provide low I_{BIAS} and V_{BIAS} at the input and low offset voltage at the output, and it exhibits a high power-supply rejection ratio. The circuit doesn't require temperature compensation and is dc stable. Like conventional voltage followers, it has local feedback only. This setup is advantageous in some applications where a long feedback loop can introduce additional distortions or instability.

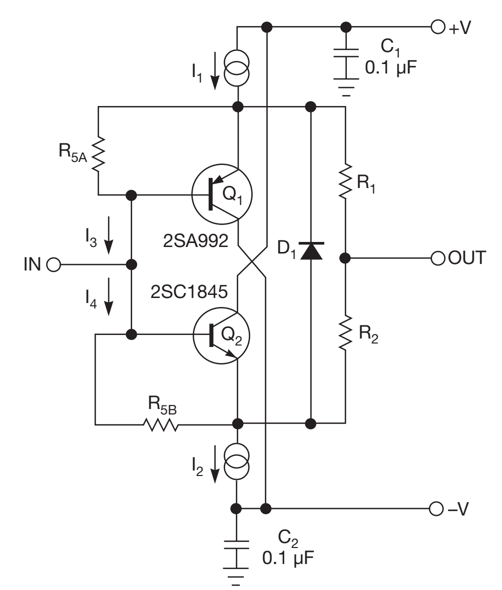


Figure 1 The buffer provides unity gain, low output impedance, and low distortion; see Figure 2 for details of the current sources in the transistors' emitters.

Resistors R_1 and R_2 sum the two outputs. For even harmonics cancellation, their values should be matched. Preferred devices—metal film/foil, for example—should be stable and linear, and should produce low noise.

The voltage drop across R_1 is equal to the base-emitter voltage, V_{BE}, of Q_1; thus, $R_1=K\times V_{BE}/I_1$, where K is in the range of 3 to 20.

R_2 is set equal to R_1. The same resistors also provide stability when driving a capacitive load, so the value of K depends on this capacitance. For the ac-equivalent circuit, these resistors appear to be connected in parallel, thus providing low output impedance. Diode D_1 protects the emitter junctions of both transistors from excess input voltages. When the buffer is used as an output stage, you can eliminate D_1.

The dc gains of the two transistors usually are not perfectly matched, resulting in a slight output offset voltage. To compensate, note the addition of base-emitter resistors R_{5A} and R_{5B} in **Figure 1**. To reduce the output offset voltage to almost zero, you can add R_{5A} or R_{5B}, not both. As an example, assume that $\beta_2>\beta_1$; R_{5B} is then used at Q_2. If Q_1 has the higher beta, R_{5A} would be used at Q_1. You can estimate R_5's value from the following **equation**: $R_5=\beta_1\times\beta_2\times V_{BE}/(I_1\times(\beta_2-\beta_1))$, where β_1 and β_2 refer to the beta of Q_1 and Q_2.

When the output is balanced with the help of R_5, input bias current is also minimized because the currents I_3 and I_4 cancel out each other.

The circuit shown in **Figure 3** is a version of the circuit shown in **Figure 1** that will automatically servo the output to a voltage close to zero. The integrator, IC_1, averages the output voltage but does not pass the ac signal, because it is acting like a high-pass filter; its corner frequency, f_C, can be calculated from this **equation**: $f_C=1/(2\times\pi\times R_3\times C_3)$. In this circuit, f_C is approximately 1.6 Hz.

DIs Inside

56 Single-ended-to-differential converter has resistor-programmable gain

59 Generate boost rails in a bridge-rectifier circuit

60 Standalone digital voltmeter uses a multichannel ADC

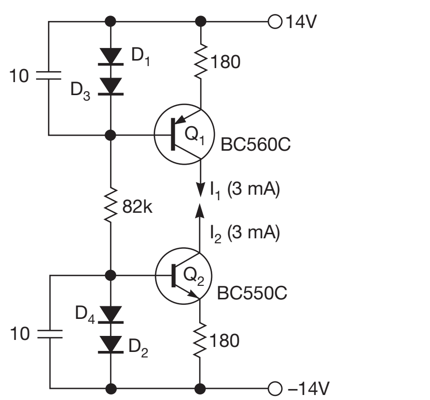
62 1-IC design monitors ajar doors

▶To see and comment on all of *EDN*'s Design Ideas, visit www.edn.com/designideas.

The output of the integrator drives an optocoupler that uses a photoresistive element on the output side. This resistor replaces the upper and lower R_5 resistors. The circuit in **Figure 3** provides an output offset voltage of almost zero even with an input offset voltage applied, as long as it isn't too high. The op amp, IC_1, should have low noise, low bias current, and low offset voltage; also, resistor R_3 and capacitor C_3 should be high-quality, stable devices.

One of the optocouplers in **Figure 3** will always be inactive, but unless you know in advance which of the two beta values is higher, you won't know which optocoupler is not active. High-quality photoresistor optocouplers can be rather expensive, so if you know the transistors' beta values, you can replace one device with a diode, D_2, as shown in **Figure 4**. In this version, $\beta_2 > \beta_1$, so the photoresistor shunts Q_2. R_4 also can be omitted if the optocouplers' LEDs can tolerate the maximum output current from the integrator.

Incidentally, an optocoupler with an incandescent (filament type) lamp can be used; in this case, the integrator is not needed, because the filament acts as an integrator. Change the integration capacitor to 1M and the input resistor value to 1k (**Figure 5**). The last circuit has low dc gain (compared with the integrator), so the output dc offset can be rather high—tens of millivolts. Diode D_2 prevents possible "latching" of the circuit. **EDN**



NOTE: D_1 AND D_2 SHOULD BE IN THE SAME PACKAGE TO MAINTAIN THERMAL TRACKING; D_3 AND D_4 ALSO SHOULD BE IN THE SAME PACKAGE.

Figure 2 Shown are details of the current sources used in the emitters of the transistors in Figure 1.

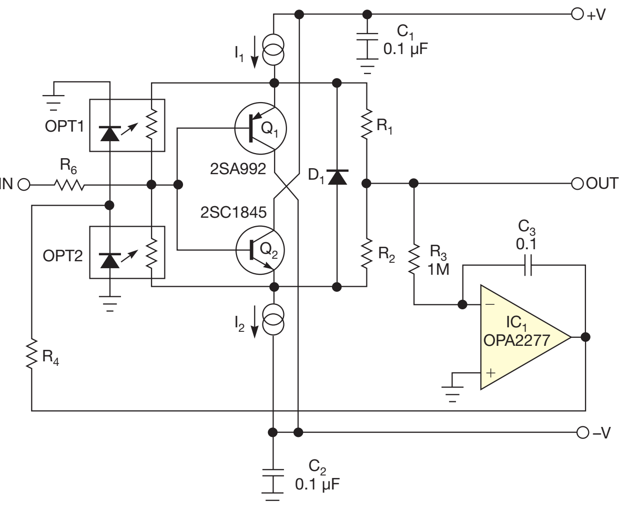


Figure 3 This circuit is a version of the circuit shown in Figure 1 that will automatically servo the output to a voltage close to zero.

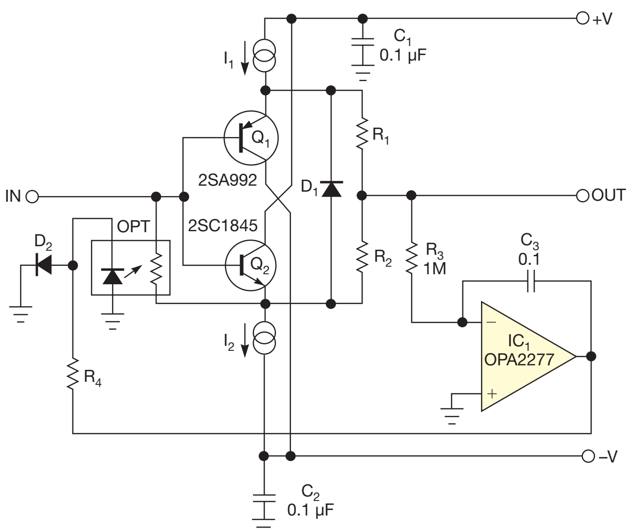


Figure 4 If you know which beta value is higher, you can replace one device with a diode, D_2.

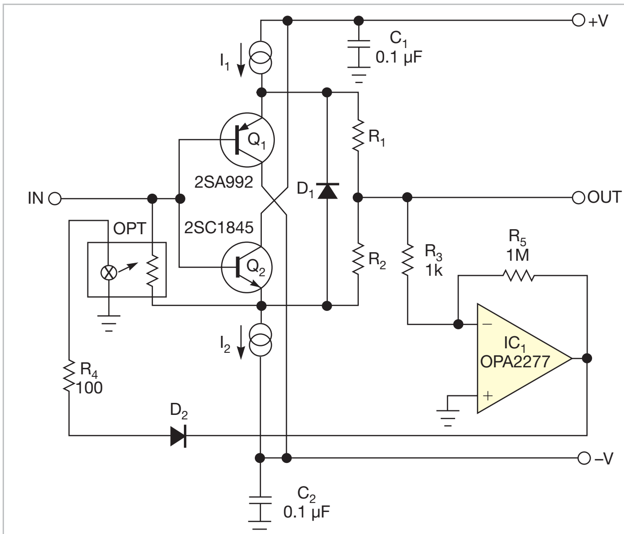


Figure 5 An optocoupler with an incandescent lamp can be used; in this case, the integrator is not needed, because the filament acts as an integrator.