design ideas

Edited by Bill Travis

Supply delivers pin-programmable multiple references

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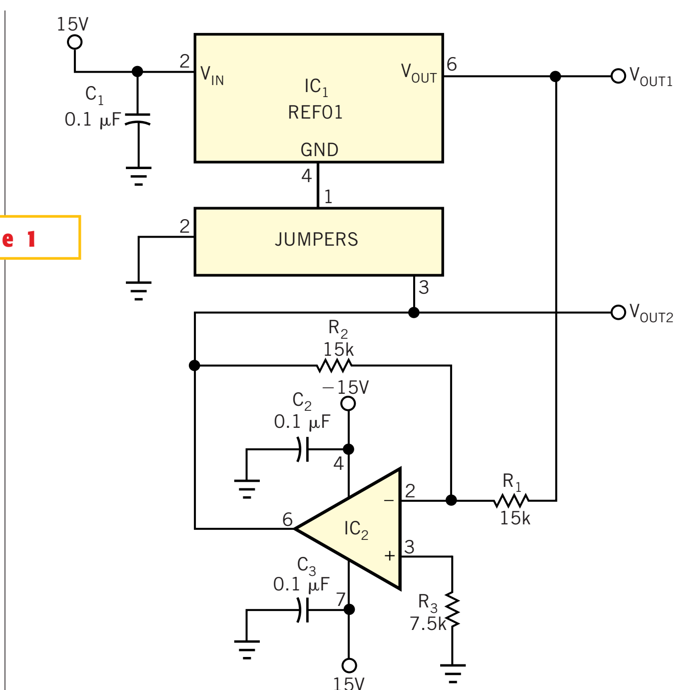
In the circuit of **Figure 1**, the REF01, IC_1, is a buried-zener-diode-based, precision 10V reference that features minimal noise and drift over temperature. The circuit provides not only the 10V output of the REF01, but also a 5V output that a REF02 reference would deliver. In addition, the circuit provides −5V, −10V, and an unbalanced dual reference, the sum of whose voltages is precisely 10V. In addition to the REF01, the circuit uses a highly precise, unity-gain inverting amplifier, IC_2. **Tables 1** and **2** define the output voltages as a function of the jumper connections and as a function of the optional use of a REF02 reference in place of the REF01. In **Figure 1**, assume the use of a REF01 reference, and that Point 1 connects to Point 2. (Pin 4 of IC_1 connects to ground.) IC_2 inverts the 10V output of IC_1 to deliver −10V at V_{OUT2}.

Now assume that Point 1 connects to Point 3. (Pin 4 of IC_1 connects to the output of IC_2). If V_{OUT1} is at X volts, V_{OUT2} assumes a level of −X volts. The REF01 forces exactly 10V between its output and Pin 4. Therefore, $X-(-X)=10$, $2X=10$, and $X=5V$. In this arrangement, 5V and −5V are simultaneously available at V_{OUT1} and V_{OUT2}, respectively. To obtain precisely −5V at V_{OUT2}, you must ratio-match R_1 and R_2 and also match their temperature coefficients. Now assume $R_2/R_1=A$ and Point 1 connects to Point 3. In this case, the gain of the inverting amplifier is A. Therefore, V_{OUT1} and V_{OUT2} deliver unbalanced outputs, the sum of which is 10V. You can easily derive that $V_{OUT1}=10/(1+A)$ and $V_{OUT2}=-10A/(1+A)$.

The flexibility of this circuit eliminates the need to design and inventory several voltage sources. Moreover, the circuit can serve as a dual reference. The circuit finds application in D/A converters needing external references, portable instruments, digital multimeters, and A/D converters. It is advisable to use the ultralow-offset-voltage OP07 or ultralow-noise OP27 for the inverting amplifier.□

Figure 1



This pin-configurable voltage reference delivers a variety of positive and negative output voltages.

TABLE 1—AVAILABLE OUTPUT VOLTAGES

Device IC_1	Jumper connection	V_{OUT1} (V)	V_{OUT2} (V)
REF01	1 to 2	10	−10
REF01	1 to 3	5	−5
REF02	1 to 2	5	−5
REF02	1 to 3	2.5	−2.5

TABLE 2—UNBALANCED OUTPUT VOLTAGES

Device IC_1	R_2/R_1	V_{OUT1}	V_{OUT2}
REF01	A	10/(1+A)	−10A/(1+A)
REF02	A	5/(1+A)	−5A/(1+A)

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Design an efficient reset circuit

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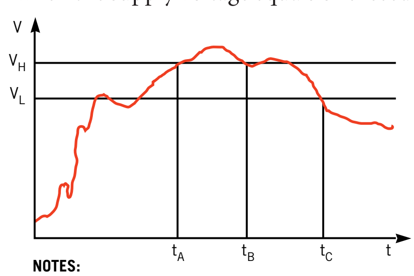
When you work with microprocessors, you must ensure that when the power-supply voltage fluctuates to the minimum permissible level, V_L, that the processor's ALU continues to operate normally. Also, when you switch on the power supply, the ALU must operate normally when the supply voltage equals or exceeds a certain high level, V_H. The minimum and high levels constitute a hysteresis band ($V_{HYST}=V_H-V_L$), and fluctuations in supply voltage within this band should not perturb the logic operations of the processor (**Figure 1**). A properly designed reset circuit can ensure proper operation of a microprocessor. One requirement of an efficient reset circuit is that it operates properly over the intended temperature range—for example, −40 to +85°C. Several reset circuits are available that meet the voltage conditions, but the temperature constraints render them unsatisfactory. This Design Idea proposes a small, inexpensive reset-circuit structure.

The supervisor circuit includes a comparator with hysteresis (**Figure 2**). The circuit represents a noninverting comparator; the voltage to supervise is V_{CC}. The comparator takes a sample of V_{CC} via the R_1-R_2 voltage divider and compares it with the reference voltage, V_{REF}. You obtain V_{REF} by using a battery voltage, V_{BAT}, but V_{CC} would work as well. The pullup resistor, R_{OUT}, is necessary to obtain a positive voltage at the output, because the comparator's output has an open-collector or open-drain structure. The following approximate and exact equations are based on selection of V_H and V_L. (Remember that $V_{HYST}=V_H-V_L$.)



NOTES:
IF t < t_A, THEN RESET.
IF t_B–t_A>t_{MIN} , THEN THE RESET DISAPPEARS.
t_C: RESET INSTANT APPEARS.

Figure 1

A proper reset signal plays an important role in microprocessor operation.

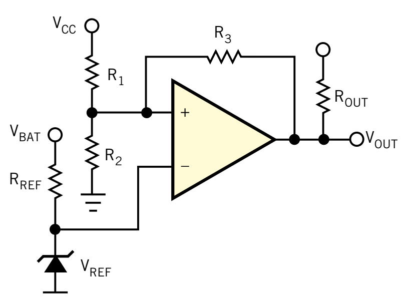


Figure 2

This comparator has built-in hysteresis to provide a reset signal when the supply voltage falls outside the limit band.

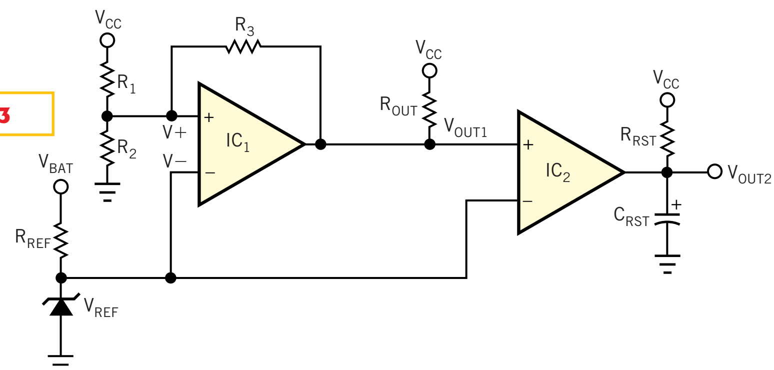


Figure 3

This circuit introduces a time constant in the reset function.

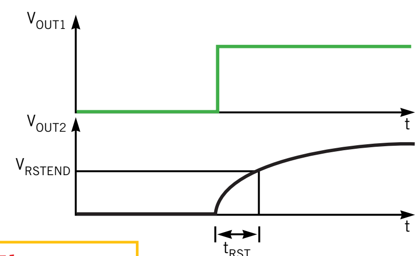


Figure 4

The reset signal ends after one time constant in the circuit of Figure 3.

APPROXIMATE EQUATIONS	EXACT EQUATIONS
$R_1=R_2\left(\frac{V_L}{V_{REF}}-1\right).$	$\frac{R_2+R_3}{R_2R_3}=\frac{1}{R_1}\left(\frac{V_H}{V_{REF}}-1\right).$
$R_3=R_2\left(\frac{V_L-V_{REF}}{V_{HYST}}\right).$	$\frac{R_1(R_3+R_{OUT})}{R_1+R_3+R_{OUT}}=R_2\left(\frac{V_L}{V_{REF}}-1\right).$

In the approximate equations, you disregard R_{OUT}, because its value is negligi-

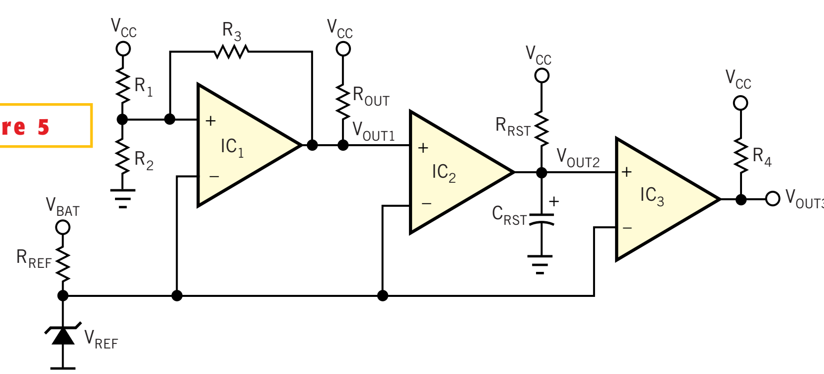
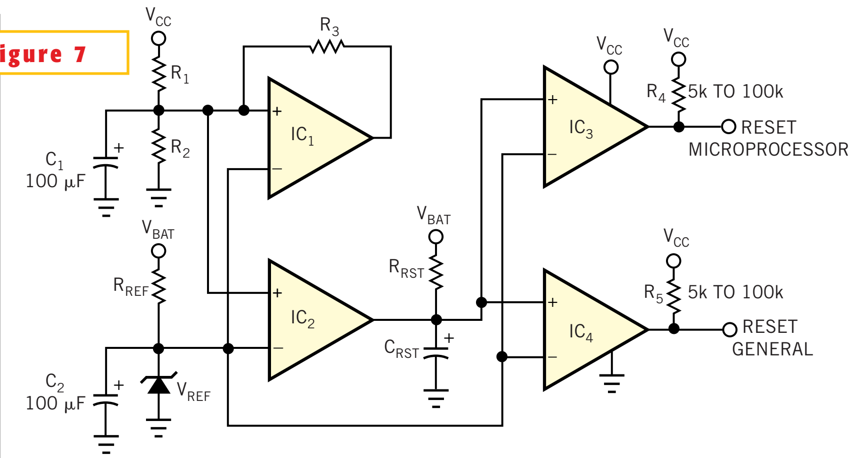


Figure 5

The additional comparator in Figure 5 switches when the exponential signal reaches V_{REF}.

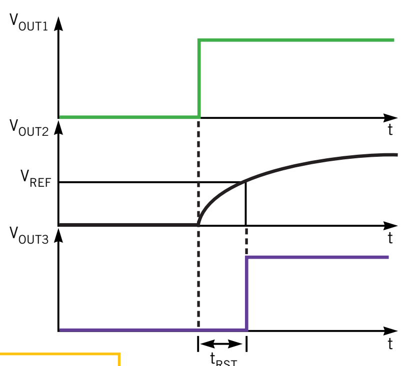
ble compared with that of R_3. But the value of R_{OUT} affects V_L, because R_{OUT} and R_3 are additive when the comparator is in the high-impedance (off) state. Choosing values for V_{HYST} and V_L and knowing V_{REF}, you obtain the following approximations: $R_1=R_2(V_L/V_{REF}-1)$, and $R_3=R_1(V_{REF}/V_{HYST})$. Now, you add a timing circuit to the hysteretic comparator (**Figure 3**). When V_{OUT1} assumes a low level, V_{OUT2} switches to a low level and discharges C_{RST}. When V_{OUT1} switches high, comparator IC_2 switches to its high-impedance state, and C_{RST} begins to charge through R_{RST}. V_{OUT2} follows an exponential curve and arrives at a value, V_{RSTEND}, which signals the end of the reset signal (**Figure 4**). You can modify the t_{RST} by adjusting the values of C_{RST} and R_{RST}. Now, if you add another comparator, IC_3 (**Figure 5**), you obtain the waveforms of **Figure 6**.

Figure 7



The complete reset circuit can handle microprocessors and other circuitry.

Figure 6



One additional comparator produces a positive signal at the processor's reset port.

The final reset circuit appears in **Figure 7**. The circuit has four comparators, one voltage reference, seven resistors, and three capacitors. To determine the resistor values, you can use the following equations: $R_1=R_2(V_L/V_{REF}-1)$, and $R_3=R_1(V_{REF}/V_{HYST})$. An appropriate comparator IC is the quad LM239 (−25 to +85°C) or the LM139 (−55 to +125°C). The voltage reference is the 1.2V ICL8069CMSQ (−55 to +125°C). C_1 and C_2 stabilize high-frequency fluctuations and have values of 100 nF and 10 μF, respectively. R_{REF} has a value of 50 kΩ, and R_4 and R_5 have values of 5 to 100 kΩ, depending on the circuit you wish to control. If you chose $V_L=4.75V$, $V_{HYST}=0.1V$, and $R_2=10$ kΩ, you obtain $R_1=29.6$ kΩ and $R_3=355$ kΩ. For timing the reset, you use the capacitor-charging equation, $V=V_{CC}(1-e^{-t/RRST/CRST})$.

The final instant of reset occurs when $V=V_{REF}=1.2V$. Choose 5V for V_{CC}. The equation then becomes $t=-R_{RST}C_{RST}\ln(1-V/V_{CC})$. If you choose t=1 sec and $C_{RST}=10$ μF, then

$$R_{RST}=\frac{t}{C_{RST}\left(1-\frac{V}{V_{CC}}\right)}.$$

You obtain $R_{RST}=36.4$ kΩ. If $C_{RST}=1$ μF, then $R_{RST}=364$ kΩ. It's preferable to have a low value for C_{RST} because of the low current in the comparator's output transistor. Solving for R_2, you obtain $R_2=10$ kΩ.□

One-shot provides frequency discrimination

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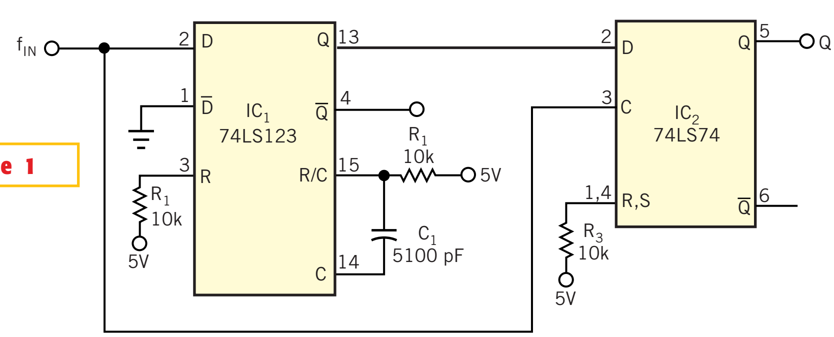
You use a frequency discriminator to compare one signal frequency with another one. A functional feature, retriggering, of a monostable, one-shot 74xx123 multivibrator can yield frequency discrimination. **Figure 1** shows a frequency discriminator that determines the relation of input-pulse frequency to a reference frequency. The external components, R_1 and C_1, set the reference frequency. These values determine the 74xx123's reference frequen-

Figure 1



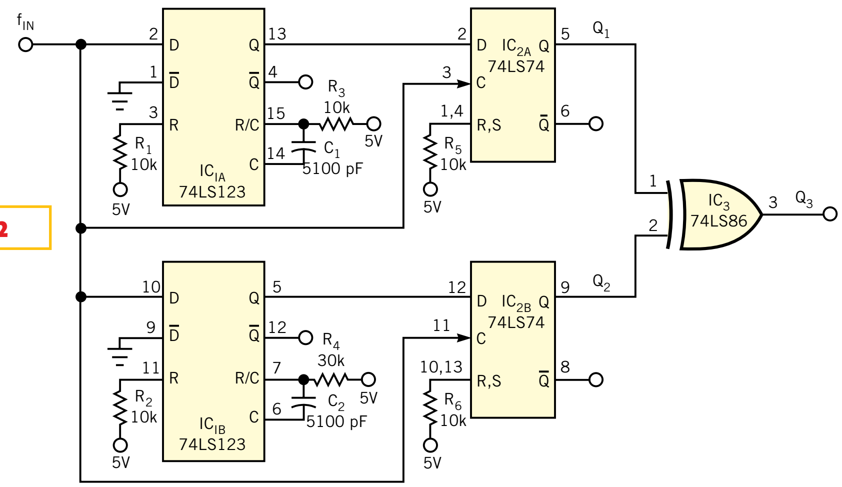
This simple circuit can reveal whether an input frequency is above or below a reference frequency.

cy as follows: $f_R=1/t_W$, and $t_W=kR_1C_1$. The multiplication factor k depends on C_1's value and the power-supply voltage. The rising edge of the input pulse starts the one-shot, whose output switches high for the interval t_W. The same pulse edge sets the 74xx174 flip-flop to the same state as the output of the one-shot. If the interval between pulses is longer than t_W, the next pulse arrives after the one-shot returns to its initial state. The one-shot's output is low, and the rising edge of the input pulse sets the flip-flop low. The low flip-flop output indicates that the input-pulse frequency, f_{IN}, is lower than f_R.

If the interval between input pulses is shorter than t_W, the next pulse arrives before the one-shot completes its cycle and returns to its initial state. The one-shot's output is high, and the rising edge of the input pulse sets the flip-flop high. A high flip-flop output indicates that the input-pulse frequency, f_{IN}, is higher than f_R. Doubling the circuit in **Figure 1** implements frequency discrimination with a "window" characteristic (**Figure 2**). Two pairs of R and C values determine the lower and upper reference frequencies.

An exclusive-OR circuit takes the outputs of the upper and lower flip-flops. The exclusive OR's output is high when f_{IN} is between f_{RL} and f_{RH}. When f_{IN} is outside the frequency band f_{RL} to f_{RH} the exclusive OR's output is low. **Figure 3** shows the frequency-discrimination characteristic. With R and C values as in **Figure 2**, and the use of a 74LS123 one-shot, $f_{RL}=16$ kHz, and $f_{RH}=46$ kHz. Other types of one-shots could produce different results.□

Figure 2



Doubling the circuit in Figure 1 and using an exclusive-OR circuit results in a window discriminator.

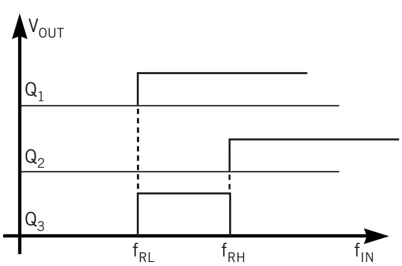


Figure 3

The output of the exclusive-OR circuit in Figure 2 is high only when the input frequency is between defined limits.

Circuit forms novel floating current source

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Figure 1 shows a polarization circuit applicable to ISFET (ion-sensitive field-effect-transistor) sensors. ISFETs are solid-state chemical sensors that measure the pH value of a solution in biomedical and environmental applications, for example. The circuit in **Figure 1** is extremely simple; it sets fixed-bias conditions for ISFET sensors ($V_{DS}=I_0R_X$; $I_{DS}=I_0$). When a sensor needs characterization, you must modify the bias conditions, thus increasing the cost and the complexity of the bias circuit. The low-cost auxiliary module in **Figure 2** implements a novel, voltage-controlled floating current source. The current range covers the interval 0 to 100 μA. You implement this module to control the ISFET sensor's bias voltage, but you can apply it to any sensor that needs bias of 100 μA or lower. The floating current source uses three operational amplifiers, all portions of a Texas Instruments (www.ti.com) TL084. The cur-

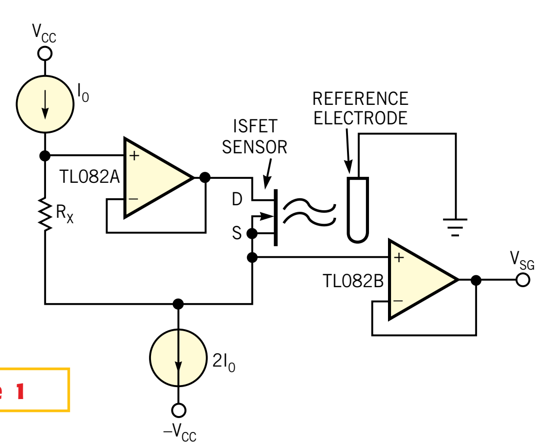
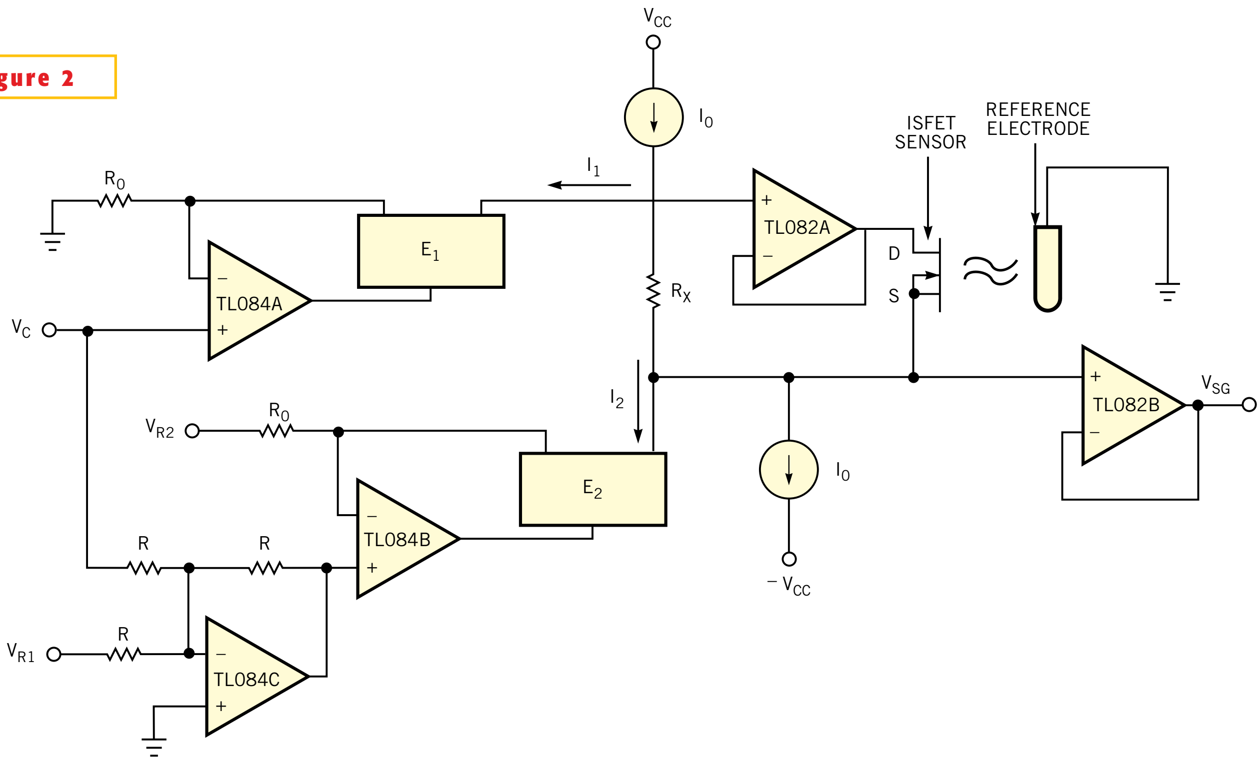


Figure 1

This circuit is a classic configuration for biasing ISFET sensors.

Figure 2



This novel floating current source represents an improved way to bias ISFET sensors.

rent sources (I_0) and the current mirrors (E_1 and E_2)use the Burr-Brown (www.ti.com) REF200. The REF200 has two 100-µA floating current sources (I_0) and one current mirror E_i (i=1, 2). The V_{R1} and V_{R2} voltages compensate the deviations arising from the operational amplifiers' offset voltages and the resistor tolerances. The V_C voltage controls the currents I_1 and I_2; therefore, in the circuit in **Figure 2**, V_C controls the sensor bias voltage V_{DS}.

Figures 3 and **4** show the measured absolute errors occurring in the bias current and voltage, respectively. The main advantages of this current source are that it floats and that you can connect it to any circuit without changing its operating mode, because the currents I_1 and I_2 are complementary. Therefore, if I_1 diminishes, the I_2 current increases in the same proportion, and this action does not affect the other currents in the circuit. In the ISFET-sensor case, changing I_2 via V_C allows you to vary the bias voltage applied to the sensor without changing the bias current, I_{DS}.□

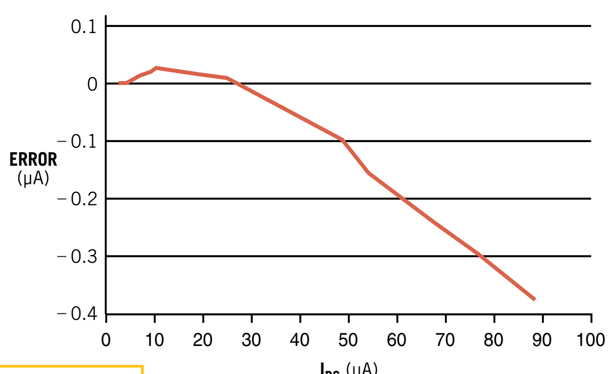


Figure 3

Very small measured errors appear in the ISFET's bias current.

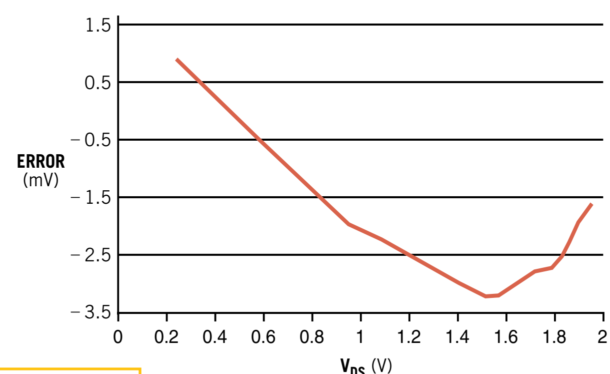


Figure 4

Only a few millivolts of error appear over the full range of V_{DS}.

Circuit provides Class D motor control

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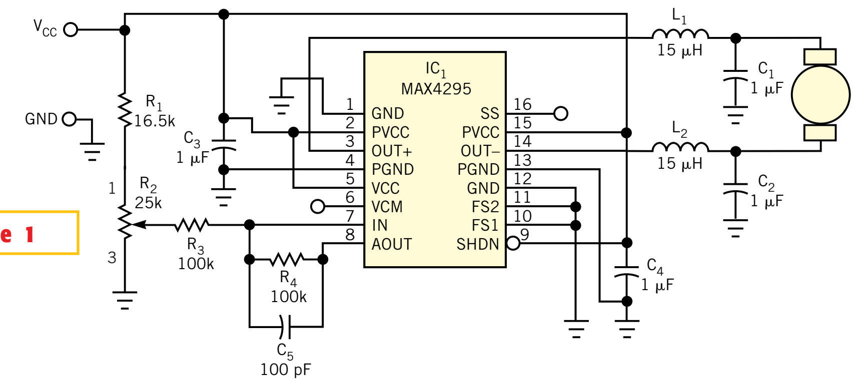
Class D audio amplifiers provide a dual benefit for battery-powered portable devices. They enhance battery life, and they produce much less power dissipation than do their linear cousins. Those features make Class D amplifiers ideal candidates for controlling speed and direction in small electric motors. The standard application circuit for a Class D audio amplifier, IC_1, requires only slight modifications. In place of the usual audio-signal input is a variable dc voltage that potentiometer R_2 generates. Resistor R_1 biases the potentiometer to match the input range of IC_1. Full-counterclockwise rotation of the potentiometer corresponds to maximum-speed reverse rotation of the motor. Midscale on the potentiometer corresponds to motor off, and full-clockwise rotation of the potentiometer produces maximum-speed forward rotation in the motor. The characteristics of a given motor may allow you to eliminate the amplifier's output filter, which comprises L_1, L_2, C_1, and C_2. But, unless the control circuitry is near the motor, you should include the filter to reduce EMI.□

Figure 1



A Class D audio amplifier, IC_1, helps implement this simple motor-speed controller.