Supply delivers pin-programmable multiple references

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In the circuit of Figure 1, the REF01, IC₁, 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 \( \frac{V_{OUT1}}{V_{OUT2}} \), \( \frac{5V}{10V} \), 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, IC₂.

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 IC₁ connects to ground.) IC₂ inverts the 10V output of IC₁ to deliver \(-10V\) at \(V_{OUT2}\).

Now assume that Point 1 connects to Point 3. (Pin 4 of IC₁ connects to the output of IC₂). 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 \(R₁\) and \(R₂\), and also match their temperature coefficients. Now assume \(R₂/R₁ = A\) and Point 1 connects to Point 3. In this case, the gain of the inverting amplifier is \(A\). Therefore, \(V_{OUT1} = -10/(1+A)\) 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.

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**TABLE 1—AVAILABLE OUTPUT VOLTAGES**

<table>
<thead>
<tr>
<th>Device</th>
<th>Jumper Connection</th>
<th>(V_{OUT1}) (V)</th>
<th>(V_{OUT2}) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF01</td>
<td>1 to 2</td>
<td>10</td>
<td>-10</td>
</tr>
<tr>
<td>REF01</td>
<td>1 to 3</td>
<td>5</td>
<td>-5</td>
</tr>
<tr>
<td>REF02</td>
<td>1 to 2</td>
<td>5</td>
<td>-5</td>
</tr>
<tr>
<td>REF02</td>
<td>1 to 3</td>
<td>2.5</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

**TABLE 2—UNBALANCED OUTPUT VOLTAGES**

<table>
<thead>
<tr>
<th>Device</th>
<th>(R₂/R₁)</th>
<th>(V_{OUT1})</th>
<th>(V_{OUT2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF01</td>
<td>A</td>
<td>(10/(1+A))</td>
<td>(-10A/(1+A))</td>
</tr>
<tr>
<td>REF02</td>
<td>A</td>
<td>(5/(1+A))</td>
<td>(-5A/(1+A))</td>
</tr>
</tbody>
</table>
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 \( V_{HYST} = V_H - V_L \).)

\[
\begin{align*}
R_1 &= \frac{V_{REF}}{V_{CC}} \\
R_2 &= \frac{V_{BAT} - V_{REF}}{V_{HYST}} \\
R_{OUT} &= \frac{V_{OUT}}{V_{HYST}}
\end{align*}
\]

In the approximate equations, you disregard \( R_{OUT} \), because its value is negligi-
When \( V_{OUT1} \) switches high, the comparator enters a low impedance (off) state. Choosing values for \( V_{HYST} \) and \( V_L \), you obtain the following approximations: \( R_1 = R_1(V_{REF}/V_{HYST}) \), and \( R_2 = R_2(V_{REF}/V_{HYST}) \). 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 \( CRST \). When \( V_{OUT2} \) switches high, the comparator \( IC_1 \), which is in the off, retriggering, of a monostable, one-shot, begins to charge through \( RRST \). \( V_{OUT2} \) follows an exponential curve and arrives at a value, \( V_{RESETO} \), which signals the end of the reset signal (Figure 4). You can modify the \( t_{RST} \) by adjusting the values of \( CRST \) and \( R_{RST} \). Now, if you add another comparator, \( IC_2 \) (Figure 5), you obtain the waveforms of Figure 6.

The complete reset circuit can handle microprocessors and other circuitry.

The circuit has four comparators, one voltage reference, seven resistors, and three capacitors. To determine the resistor values, you can use the following equations: \( R_1 = R_1(V_{REF}/V_{HYST}) \), and \( R_2 = R_2(V_{REF}/V_{HYST}) \). 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 \( \mu F \), respectively. \( R_{REF} \) has a value of 50 k\( \Omega \), and \( R_1 \) and \( R_3 \) have values of 5 to 100 k\( \Omega \), depending on the circuit you wish to control. If you chose \( V_L = 4.75 \text{V}, V_{HYST} = 0.1 \text{V}, \) and \( R_2 = 10 \text{k}\( \Omega \), you obtain \( R_{RST} = 29.6 \text{k}\( \Omega \) and \( R_{RST} = 355 \text{k}\( \Omega \). 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 \( V = V_{REF} = 1.2 \text{V} \). Choose 5 V for \( V_{CC} \). The equation then becomes \( t = -R_{RST}/C_{RST}ln(1 - V/V_{CC}) \). If you choose \( t = 1 \text{ sec} \) and \( C_{RST} = 10 \mu F \), then:

\[
R_{RST} = \frac{t}{C_{RST} \ln \left(1 - \frac{V}{V_{CC}}\right)}
\]

You obtain \( R_{RST} = 36.4 \text{k}\( \Omega \). If \( C_{RST} = 1 \text{ \mu F} \), then \( R_{RST} = 364 \text{k}\( \Omega \). 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 \text{k}\( \Omega \).

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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-

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**One-shot provides frequency discrimination**

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cy as follows: $f_R = \frac{1}{t_W}$, 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 and using an exclusive-OR circuit results in a window discriminator.

Figure 2 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 ($V_{DS} = I_R R_X$; $I_{DS} = I_R$). 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-

Circuit forms novel floating current source

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Figure 1

This circuit is a classic configuration for biasing ISFET sensors.
This novel floating current source represents an improved way to bias ISFET sensors.

The currents \( I_0 \) and the current mirrors \( E_1 \) and \( E_2 \) use the Burr-Brown (www.ti.com) REF200. The REF200 has two 100-\( \mu \)A 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 2**

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

**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, IC1, requires only slight modifications. In place of the usual audio-signal input is a variable dc voltage that potentiometer R2 generates. Resistor R1 biases the potentiometer to match the input range of IC1. 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 L1, L2, C1, and C2. But, unless the control circuitry is near the motor, you should include the filter to reduce EMI.

![Figure 1](image-url)