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 $V_{HYST} = V_H - V_L$.)

<table>
<thead>
<tr>
<th>APPROXIMATE EQUATIONS</th>
<th>EXACT EQUATIONS</th>
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<tr>
<td>$R_1 = R_2 \left( \frac{V_L}{V_{REF}} - 1 \right)$</td>
<td>$\frac{R_2 + R_3}{R_2 R_3} = \frac{1}{R_1} \left( \frac{V_H}{V_{REF}} - 1 \right)$</td>
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<tr>
<td>$R_3 = R_2 \left( \frac{V_L - V_{REF}}{V_{HYST}} \right)$</td>
<td>$\frac{R_1 (R_3 + R_{OUT})}{R_1 + R_3 + R_{OUT}} = \frac{R_2}{R_1} \left( \frac{V_L}{V_{REF}} - 1 \right)$</td>
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In the approximate equations, you disregard $R_{OUT}$ because its value is negligible 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: \( R_1 = R_2 (V_L / V_{\text{REF}} - 1) \), and \( R_3 = R_1 (V_{\text{REF}} / V_{\text{HYST}}) \). Now, you add a timing circuit to the hysteretic comparator (Figure 3). When \( V_{\text{OUT1}} \) assumes a low level, \( V_{\text{OUT2}} \) switches to a low level and discharges \( C_{\text{RST}} \). When \( V_{\text{OUT1}} \) switches high, comparator IC\(_3\) switches to its high-impedance state, and \( C_{\text{RST}} \) begins to charge through \( R_{\text{RST}} \). \( V_{\text{OUT2}} \) follows an exponential curve and arrives at a value, \( V_{\text{RSTEND}} \), which signals the end of the reset signal (Figure 4). You can modify the \( t_{\text{RST}} \) by adjusting the values of \( C_{\text{RST}} \) and \( R_{\text{RST}} \). Now, if you add another comparator, IC\(_3\) (Figure 5), you obtain the waveforms of Figure 6.

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: \( R_1 = R_2 (V_L / V_{\text{REF}} - 1) \), and \( R_3 = R_1 (V_{\text{REF}} / V_{\text{HYST}}) \). 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. \( R_{\text{REF}} \) 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 choose \( V_L = 4.75 \text{V}, V_{\text{HYST}} = 0.1 \text{V}, \) and \( R_2 = 10 \text{kΩ} \), you obtain \( R_1 = 29.6 \text{kΩ} \) and \( R_3 = 355 \text{kΩ} \). For timing the reset, you use the capacitor-charging equation, \( V = V_{\text{CC}} (1 - e^{-t/RRST/CRST}) \).

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

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

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