Two transistors form high-precision, ac-mains ZCD

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Many applications that use 110V/230V-ac mains require a ZCD (zero-crossing-detection) circuit for the ac-line voltage, for example, to synchronize the switching of loads. One method of ZCD uses a high-value current-limiting resistor or a voltage-resistive divider to sense the ac voltage at the controller's I/O pin. However, depending on whether the I/O pin is in TTL or Schmitt-trigger mode, the ZCD has a delay that depends on the threshold swing of the I/O pin and the slew rate of the power line. For example, assume a 230V, 50-Hz ac system voltage and a voltage divider of 100—that is, $230V/100=2.3V$. Further, assume that the I/O pin triggers at 1V. This trigger level implies $1V\times100=100V$ referenced to the 230V-ac mains. Thus, $100=230\times\sin(2\times\pi\times50\times t)$ yields a delay of 1.43 msec, which represents 14.3% of the half-cycle period—a significant error.

Figure 1 shows a low-cost, efficient ZCD using two standard transistors. Coming directly from the ac mains, the supply network comprising C_1, C_2, D_1, D_2, and R_1 forms a simple half-wave rectifier, which powers the ZCD. Q_1 toggles with the ac-mains-voltage ZCD. To compensate for the base-emitter gap, Q_2 acts as a diode to block the ac-positive cycle. For efficiency, the detector must sense the ac-mains cycles at as high a voltage as possible. This requirement drives the choice of the transistor. Q_2 and Q_1, low-noise, small-signal BC549B transistors, have collector-to-emitter-voltage limits of 30V. With this choice, you must attenuate the ac-mains voltage from 230 to 30V. (For a BC546 transistor, you can attenuate 230 to 80V.) Thus, the voltage-divider ratio is 30V/230V=13.4%, and the values of the divider resistors are $R_2/(R_3+R_2)=13.4/100$, or $R_3=6.46\times R_2$. R_2 and R_3 must be high enough for current limiting. The normalized value of R_3, 820 kΩ, means that R_2 is 820 kΩ/6.46=126.9 kΩ or 120 kΩ, the nearest standard-value resistor. With these values, Q_2 can block $230V\times R_2/(R_2+R_3)=29.3V$, which is less than the transistor's maximum rating of 30V.

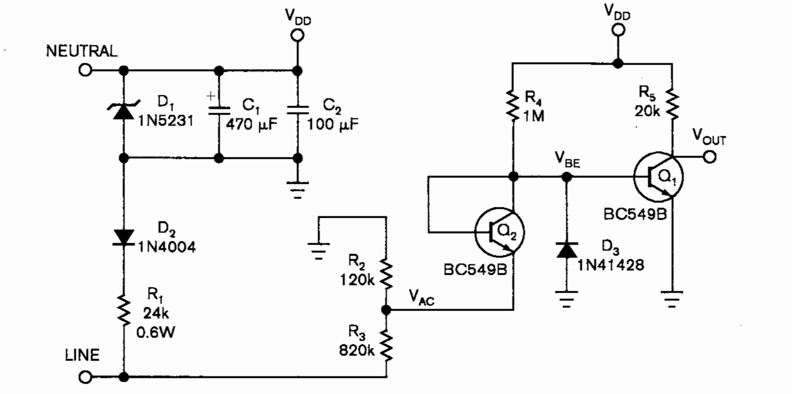

Figure 1 This simple two-transistor circuit accurately detects the zero crossing of the input ac mains.

Upon the ac-positive cycle, the base of Q_1 rises to approximately 0.6V through R_4. Q_2 acts as a simple diode. So, when the cycle voltage is higher than 0V, Q_2 is reverse-biased and blocks any current flow. At 0V, Q_2 is forward-biased, but it maintains 0.6V across the base-emitter junction, V_{BE}. Thus, the collector, or base, of Q_2, which connects to the base of Q_1, stays at 0.6V. Q_1 is saturated for the positive cycle, and the output voltage is low. At the ac's negative cycle, when the ac voltage is less than 0V, current flows through Q_2. Consequently, the base of Q_1, which connects to Q_2's collector, falls to less than 0.6V, which leads to the blocking of Q_1 and the output voltage's becoming high. Note that the base of Q_1 can reach about −30V from Q_2; you can add clamp diode D_3 for Q_1 junction protection higher than −1V. **EDN**