Mains-driven zero-crossing detector uses only a few high-voltage parts

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The circuit in this Design Idea generates a zero-crossing pulse off the ac mains and provides galvanic isolation. The falling edge of the output pulse happens at approximately 200 μsec before the zero crossing. You can use the circuit to safely stop the triggering of a thyristor gate, giving it time to properly turn off. The circuit generates short pulses only when the mains voltage is approximately 0V, thereby dissipating only 200 mW at 230V and a 50-Hz input.

![Figure 1](image1.png)

**Figure 1** This zero-crossing detector uses low-voltage parts and consumes little power.

The circuit charges capacitor $C_1$ up to the limit that 22V zener diode $D_3$ creates (Figure 1 and Reference 1). You limit the input current with resistors $R_1$ and $R_5$. As the input-rectified voltage drops below the $C_1$ voltage, $Q_1$ starts conducting and generates a pulse a few hundreds of microseconds long. The coupling of $IC_1$ makes the response of $Q_1$ squarer. The rms operating voltage dictates the only requirement for $R_1$ and $R_5$. SMD, 1206-size resistors typically withstand 200V-rms operation. This design splits the input voltage between $R_1$ and $R_5$, for a total rating of 400V rms. $D_3$ limits the voltage across the bridge to 22V so that all of the subsequent components can have lower voltage ratings. A 22V zener diode can clamp as high as 30V, so this design uses a 50V, 470-nF ceramic capacitor. Ceramic capacitors have better reliability than electrolytic or tantalum capacitors, especially at higher temperatures. If you prefer a cheaper and smaller 25V part, you can change the zener diode’s voltage to 18V and still have a good margin for safety. Use $R_4$ to limit the peak current in the LED. The primary limit on the LED current is the slope of the rectified ac input. The gradual slope doesn’t let $Q_1$ generate current spikes when it
discharges $C_1$'s stored energy.

You can simulate the operation of the circuit in LTspice Version IV (Figure 2 and Reference 2). With a 230V input at 50 Hz, the simulation shows a 17-mA peak in the optocoupler LED. The simulation gives good results with inputs of 90 to 250V, both at 50 and 60 Hz. At 110V and a 60-Hz input, the LED current peak is 8.5 mA, so IC1 still works. If you need higher LED-drive currents, you can reduce the value of $R_3$ or increase the value of $C_1$.

Figure 2 In this LTspice simulation, as the input voltage drops through 0V, the LED current makes a pulse whose edges lead and lag the crossing point. The peak optocoupler-LED current is 17 mA.

Testing a physical circuit shows good correlation with the simulation (Figure 3). Driving the isolated output from a 5V logic supply yields a good pulse waveform (Trace 1). The mains input is fed to the scope with a 15V isolation transformer for safety (Trace 2). You can use the persistence feature of the oscilloscope to show the zero-crossing point when zooming in to the transition (Figure 4). This approach allows you to accurately measure the pulse timing relative to the input zero crossing.

Figure 3 Results for a prototype circuit correlate well with the simulation.
Figure 4 You can use the oscilloscope’s persistence function to relate the exact zero-crossing point to the output-pulse timing.

References
2. “LTspice IV,” Linear Technology Corp.