When you design equipment that interfaces to a phone line, it is often desirable to be able to monitor the dc voltage on the line. This ability can be useful, for example, to determine whether a line is in use before attempting to go off-hook and possibly interrupting somebody's phone call. FCC regulations place strict limits on the amount of leakage current an on-hook device can draw from a phone line. The specifications work out to approximately the equivalent of 5 MΩ as the minimum leakage resistance. So, you have the challenge of monitoring the line voltage without exceeding the regulatory limits and also maintaining the galvanic isolation required between the phone line and your equipment. The circuit in Figure 1 shows a method of meeting this challenge with 100% margin. In other words, it presents approximately 10-MΩ leakage resistance across the line.

The basic relaxation oscillator has the LED of an optoisolator in the discharge path of the main capacitor. It delivers a pulse train, the frequency of which varies with the voltage on the phone line. By measuring the period between pulses, the equipment's microcontroller can easily determine the approximate line voltage. $C_1$ is the timing capacitor. It should be a film-type capacitor rather than ceramic for good results. It slowly charges through $R_1$, a 10-MΩ resistor. When the voltage across $C_1$ reaches approximately 3V, the remainder of the circuit turns on, causing $C_1$ to rapidly discharge through $R_4$ and the optoisolator's LED. This action causes the optoisolator's output transistor to briefly turn on, creating a low-going pulse approximately 200 µsec wide (the signal labeled LINE). This width is sufficient for even a slow microcontroller to capture an interrupt. When $C_1$ discharges to approximately 1.5V, the circuit turns off, and the cycle repeats.

$Q_2$ and $Q_3$ form an SCR (silicon-controlled-rectifier)-like regenerative pair. $D_2$ and $Q_2$ function basically as a current mirror. Normally, you construct a current mirror using two or more identical transistors. By using a 1N4148 diode rather than another 2N3906, you reduce the gain of the current mirror to well below unity. The 1N4148 functions as though it has many times the base-emitter diode area of the 2N3906. Reducing the gain in this fashion helps the regenerative pair to turn off at the appropriate point, keeping the oscillator from "sticking" on. $Q_1$ and the diode-resistor network driving its base function as the trigger circuit. When the voltage across $C_1$ gets high enough, $Q_1$ starts to turn on and inject current into $Q_3$. Once $Q_3$ starts to turn on, regeneration kicks in, and $Q_3$ and $Q_2$ turn on hard and stay turned on until the capacitor discharges sufficiently. $C_2$ provides additional positive feedback through $Q_1$; it improves the operating characteristics of the circuit.

This circuit assumes that Tip and Ring have protection against polarity reversal such that Tip is always more positive. The circuit of Figure 2 works with either polarity and reports the polarity of the line to the host microcontroller. This circuit is suitable when you need to know not only the magnitude, but also the polarity of the line voltage. As you can see, it has two outputs, one for each polarity. $Q_4$ and $Q_5$ are low-threshold n-channel MOSFETs, connected in such a way as to always connect the bottom rail of the relaxation circuit to the most negative side of the timing capacitor.
The positive rail of the relaxation circuit connects to the most positive side of the timing capacitor using diode isolation, taking advantage of the fact that the optoisolator LEDs are diodes.

**Figure 3** shows a plot of the frequency-versus-voltage response of the circuit of Figure 2. It shows the spread across a sampling of five units for both polarities of line voltage. Generally, the responses for the positive and negative voltages in a given unit are so close that the plot lines overlay each other. The unit-to-unit variations are larger and in production are mostly attributable to variations in \( C_1 \). Although not highly precise, the circuit is more than adequate for distinguishing between on-hook (typically, greater than 18V) and off-hook (typically, less than 12V) conditions. You can also use it to detect the small voltage changes that might be of interest in detecting barging in—when another device on the line goes off-hook while this device is using the line.

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