Optocoupler simplifies power-line monitoring

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The use of a linear optocoupler and a capacitor-based power supply yields a simple, yet precise power-line-monitoring system. The circuit in Figure 1 converts the 110V-ac power-line voltage to an ac output voltage centered at 2.5V, covering 0 to 5V. The circuit isolates the output signal from the power line. You can connect the output directly to an A/D converter. For other power-line voltages, simply change the value of $R_1$. For a power-line voltage of 220V ac, use a value of 470 kΩ for $R_1$. The input stage is a nonisolated block that uses the neutral line as a ground reference. This block receives power from a capacitor-based power supply that provides a stabilized 5V-dc voltage and a 3.3V dc reference. The TLC2272 op amp, IC$_1$, and the TLC2272 linear optocoupler, IC$_3$, form a feedback amplifier in which the $I_{P1}$ current is proportional to the input voltage, $V_{IN}$.

![Figure 1](image)

**Figure 1** An isolated optocoupler circuit allows you to make dc measurements of the power-line voltage.

Resistor $R_2$ adds a dc offset current to allow for both polarities in $V_{IN}$. The match between the two photodiodes in the IL300, IC$_2$, ensures that $I_{P2}$ is closely proportional to $I_{P1}$. The output stage converts $I_{P2}$ to a voltage level isolated from the power line. Variable resistor $VR_1$ trims the overall gain, and $VR_2$ adjusts the output-voltage offset, which is nominally 2.5V. You can test this circuit using simulation the model in Listing 1 for IC$_2$. Typical values for $K_1$ and $K_2$ (optical transfer ratios) are approximately 0.007. The global optical transfer ratio is $K_3 = K_2/K_1$. After performing the simulation,
you can build and test a prototype. The power supply for the isolated block provides 5V dc and a
3.3V reference from an available voltage of 7 to 10V. You do not need the regulated 5V if that
voltage is already available in your system.

An important goal in this design is to obtain a stable dc voltage at the output. This property is crucial
for dc measurements of $V_{IN}$. Even if you suppose the ac power line to be free of dc voltage, some
types of loads drain dc currents, thereby introducing a small dc voltage because of voltage drops in
the ac lines. Thermal drifts in the output voltage stem principally from drifts in $K_3$. In tests of the
prototype, the $K_3$ temperature coefficient was 470 ppm/°C. Table 1 shows $V_{OUT}$ at different
temperatures. The TLC2272 op amp has rail-to-rail output, yielding a wide output-voltage range, and
low quiescent current, simplifying the capacitor-based power supply. Because the TLC2272 is a dual
device, you can connect the unused half as a voltage follower. When you monitor a three-phase
power line, you’d use one and one-half TLC2272s. Note that the op amps in the isolated block, IC$_3$, and
the nonisolated block, IC$_1$, cannot be halves of the same chip; otherwise, you’d lose the isolation.

![Table 1 – Output Offset-Voltage Drift](image)

<table>
<thead>
<tr>
<th>$T_{IL300}$ (°C)</th>
<th>$V_{OUT}$ (V)</th>
<th>$T_{IL300}$ (°C)</th>
<th>$V_{OUT}$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.5</td>
<td>2.496</td>
<td>37.5</td>
<td>2.506</td>
</tr>
<tr>
<td>20</td>
<td>2.497</td>
<td>40</td>
<td>2.507</td>
</tr>
<tr>
<td>22.5</td>
<td>2.498</td>
<td>42.5</td>
<td>2.509</td>
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<td>45</td>
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<td>27.5</td>
<td>2.501</td>
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</tr>
<tr>
<td>35</td>
<td>2.505</td>
<td></td>
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</tr>
</tbody>
</table>

The main specifications of the circuit are 5300V-ac-rms galvanic isolation, 0.08% linearity, 470-
ppm/°C thermal shifts in $V_{OUT}$, 2° phase shift at 50 Hz, and dc to 1-kHz bandwidth at –3 dB. If you
connect the output to a 10-bit A/D converter, one LSB is equivalent to 0.5V in the 110V power line.
You can add a Hall-effect sensor to the circuit for current measurements. The LTS series from LEM
is suitable for this purpose, because these devices operate from a single 5V supply and provide a
2.5V-centered output. Figure 2 shows a system that integrates voltage and current measurements.
The processor computes true-rms voltages and currents, apparent and active power, and power
factor.

![Figure 2](image)

**Figure 2** By adding two ADCs and a microcontroller, you can measure power-line voltage and
current parameters.

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Use a photoelectric-FET optocoupler as a linear voltage-controlled potentiometer
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