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READERS SOLVE DESIGN PROBLEMS

NE555 timer sparks low-cost voltage-to-frequency converter

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In 1971, Signetics—later Philips (www.philips.com)—introduced the NE555 timer, and manufacturers are still producing more than 1 billion of them a year. By adding a few components to the NE555, you can build a simple voltage-to-frequency converter for less than 50 cents. The circuit contains a Miller integrator based on a TL071 along with an NE555 timer (**Figure 1**). The input voltage in this application ranges from 0 to −10V, yielding an output-frequency range of 0 to 1000 Hz. The current of C_1 is the function of input voltage: $I_C = -V_{IN}/(P_1+R_1)$.

As the voltage on C_1 reaches two-thirds of V_{CC}, the 555's internal discharge transistor opens, and the voltage on C_1 returns to one-third the voltage of V_{CC}, the lower comparator threshold. At one-third this voltage, the discharge transistor switches off, and C_1 again starts charging. The NE555's output is high while C_1 is charging and low while C_1 is discharging. The product of the input voltage and the charging time of C_1 is constant. Because the discharge time is shorter than the charging time, the following **equation** results for the output frequency: $f_{OUT} \sim V_{IN}/(P_1+R_1) \times C_1 \times 1/3V_{CC}$.

P_1 calibrates the relationship between the output frequency and the input voltage. Because the discharge interval is approximately 30 µsec, the accuracy of the voltage-to-frequency conversion decreases as the frequency increases. If you assign 100 Hz to −1V and 1000 Hz to −10V, the error of conversion ranges from 0.3 to 3%. If you use P_1 to calibrate the output frequency in the middle of the input-voltage range at −5V, then the conversion error will be less than 1.3% over the entire range. To improve performance, C_1 should have a low dissipation factor. You can diminish temperature dependence if R_1 has a low temperature coefficient and P_1 is a multiturn, ceramic-metal potentiometer.EDN

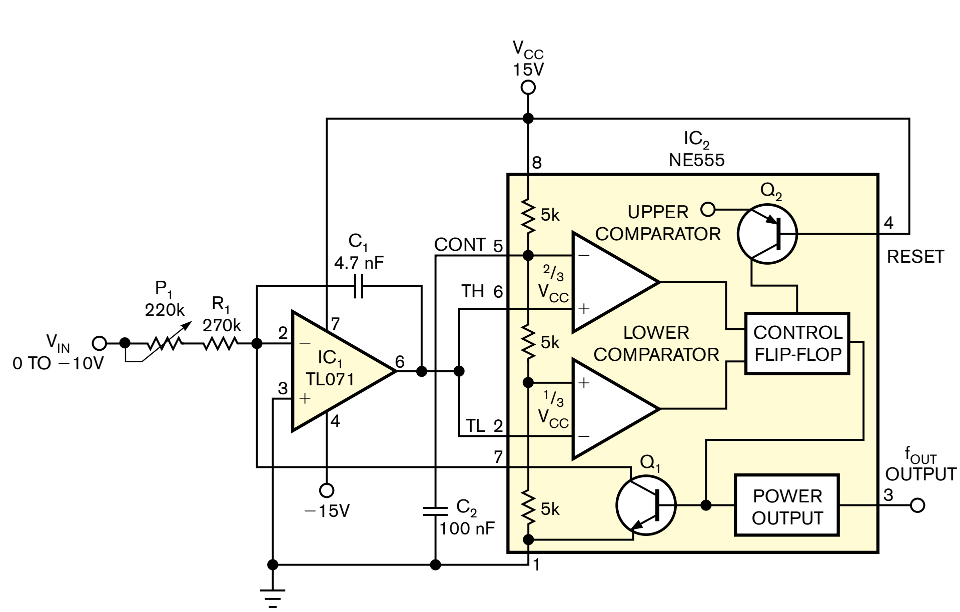

Figure 1 Preceding an NE555 timer with a Miller integrator yields a voltage-to-frequency converter that costs less than 50 cents.

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Optoisolators compute watts and volt-amperes

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A decade or so ago, I designed a simple circuit that included a quad optoisolator arranged in a full-wave analog-multiplier bridge (**Figure 1**). It sensed and calculated watts of ac-power consumption and ignored any reactive component in the load. The circuit's principle of operation relies on the fact that the LEDs of the bridge, like any other device with a semiconductor junction, have a dynamic conductance that's directly proportional to current: approximately 19 mS (millisiemens)/A at 25°C. Both the line voltage and load-current-proportional sense voltage, which the 0.001Ω copper shunt develops, modulate this current. The approximately 0.4%/°C temperature coefficient of the copper compensates most of the temperature dependence of the LEDs' conductances.

The circuit in this Design Idea is an elaboration on that older circuit. It acquires not only watts, but also volt-amperes and so makes possible an estimation of power factor—watts divided by volt-amperes. The right-hand side of the circuit in **Figure 2** is simply a half-wave version of the older circuit. The left-hand side is similar but substitutes rectified-dc excitation of its half-wave bridge for the ac excitation of the left-hand side. The analog product of instantaneous load current times the average voltage optically couples to phototransistor Q_4/D_4, which A_2 amplifies and the Q_5 through Q_8 transistor array rectifies to provide an analog voltage proportional to load volt-amperes. EDN

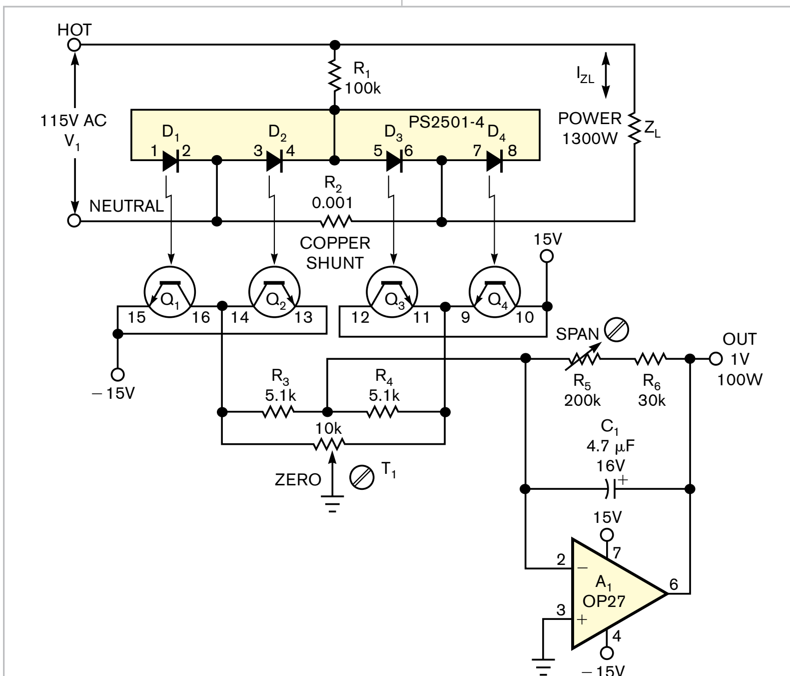

Figure 1 A quad optoisolator arranged in a full-wave analog-multiplier bridge senses and calculates watts of ac-power consumption and ignores any reactive component in the load.

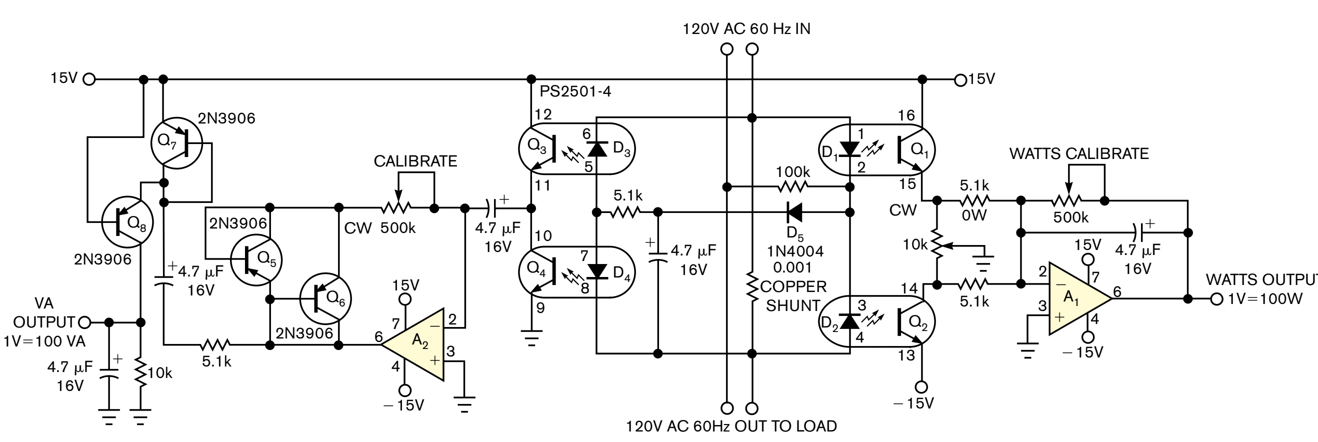

Figure 2 The right-hand side of this circuit is simply a half-wave version of the circuit in Figure 1. The left-hand side is similar but substitutes rectified-dc excitation of its half-wave bridge for the ac excitation of the right-hand circuit.

Single-supply circuit measures −48V high-side current

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The nominal −48V rail, which finds wide use in wireless base stations and other telecommunications equipment in network central offices, can vary from −48 to −60V. Measuring its current draw typically requires components that operate on ±15V dual supplies. Eliminating the negative supply would reduce system complexity and cost. This Design Idea uses an AD629 difference amplifier and an AD8603 operational amplifier, both from Analog Devices (www.analog.com), to measure current at −48 to −60V and operates from a single positive-power supply (**references 1** and **2**).

Figure 1 shows how the AD629 and AD8603 measure current in the presence of a −48V common-mode voltage. The following **equations** demonstrate how the AD629 difference amplifier can condition voltages beyond its supply ranges: $V_{COM\_MAX}=20\times(V_S-1.2)-19\times V_{REF}$, and $V_{COM\_MIN}=20\times(-V_S+1.2)-19\times V_{REF}$. With a 5V reference, the common-mode input range is −71 to +121V. The current, I, flows through the shunt resistor, R_S, causing a differential voltage, which the difference amplifier senses. The AD629 has a fixed gain of one, so the output voltage is $I\times R_S+V_{REF}$. The AD8603 functions as a subtractor so that it can reject the common-mode voltage, V_{REF}, and apply gain to the signal of interest, $I\times R_S$. A factor of 20 amplifies the signal to span the 2.5V full-scale range of the ADC.

This Design Idea uses the AD8603 because it has low input-bias current and low offset drift. In addition, the rail-to-rail output allows it to share the same supply as the ADC. In this stage, the subtractor rejects the 5V common-mode signal from the voltage reference. The four resistors that form the subtractor must have matched ratios to obtain maximum common-mode rejection. If you cannot obtain tightly matched resistors, you can use an AD623 single-supply instrumentation amplifier in place of the AD8603, ensuring high common-mode rejection.

Offset, input-bias-current, and common-mode-rejection errors from both amplifiers result in a 163-mV maximum error at the output of the AD8603. This calculation assumes resistors with a 0.01% ratio match. The circuit was verified on the bench using 50-, 100-, and 200-mΩ shunts for R_S. EDN

REFERENCES

1 "High Common-Mode Voltage, Difference Amplifier AD629," Analog Devices, 1999 to 2007, www.analog.com/UploadedFiles/Data_Sheets/AD629.pdf.

2 "Precision Micropower, Low Noise CMOS Rail-to-Rail Input/Output Operational Amplifiers AD8603/AD8607/AD8609," Analog Devices, 2005, www.analog.com/UploadedFiles/Data_Sheets/AD8603_8607_8609.pdf.

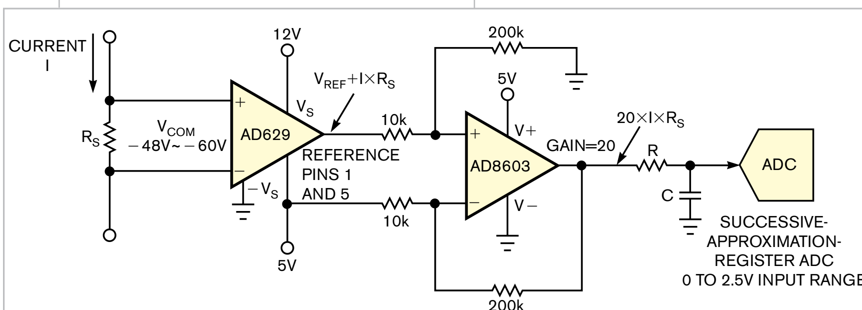

Figure 1 The AD629 and AD8603 measure current in the presence of −48V common-mode voltages.

Three-state switch interface uses one microcontroller pin

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Human interfaces for electronic gadgets sometimes require three states for control. A single-axis joystick has states to define motions to the right, to the left, and with no motion. Similarly, a timer has control buttons that allow the timer to increment, decrement, and remain untouched. Engineers usually create these interfaces by using two independent pushbuttons, requiring two microcontroller pins. This Design Idea presents a way to sense three states of an SPDT (single-pole/double-throw) switch with a center-off state, using only a single pin of

TABLE 1 STATUS OF THE PIN FOR VALUES OF THE PORT AND THE DDR REGISTERS

	DDR bit=0 Port bit=0	DDR bit=0 Port bit=1
Pin connects to V_{DD} through a resistor	Pin bit=1	Pin bit=1
Pin connects directly to ground	Pin bit=0	Pin bit=0
Pin connects to ground through a very-high-resistance path	Pin bit=0	Pin bit=1

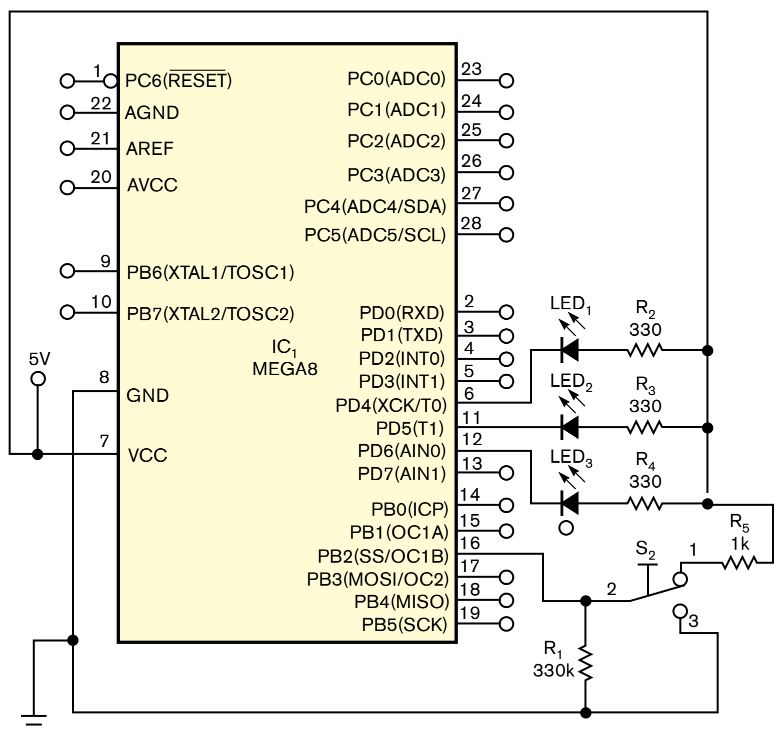

Figure 1 Using only one I/O pin, this circuit and a simple program can sense the state of a three-position switch.

Atmel's (www.atmel.com) ATmega8 microcontroller (**Reference 1** and **Figure 1**). **Listing 1**, which is available at the Web version of this Design Idea at www.edn.com/080221di1, is a simple program for the circuit.

The status of the pin of the microcontroller depends upon values of the DDR bit, the port bit, and its external connection. The microcontroller's pin connects to ground using pulldown resistor R_1 with resistance, typically, of a few hundred kilohms to impress the high-impedance state on the pin. You set the DDR register to zero. When the user toggles the switch to Position 1, the pin connects to V_{DD} through resistor R_5, and the pin bit is one, regardless of the value of the port bit. When the user toggles the switch to Position 3, the pin is grounded, and the pin bit is zero, regardless of the value of the port bit. In the center-off state, the pin bit follows the port bit. **Table 1** summarizes the states of the pin for different values of the port and the external input. EDN

REFERENCE

1 "ATmega8/ATmega8L 8-bit AVR with 8K Bytes In-System Programmable Flash," Atmel Corp, 2007, www.atmel.com/dyn/resources/prod_documents/2486S.pdf.

AC-continuity tester finds single-ended faults in cables

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An ac-based continuity tester for front-line test-and-repair jobs provides a simple go/no-go test for localizing faults in multiconductor cables (**Figure 1**). Open circuits are more likely to occur at the connector ends. This tool helps to identify the faulty end, thereby avoiding the risk of damaging a good connector by opening it. It's also useful for testing an installed cable for which both ends are in different locations. The circuit injects an ac signal on one wire of a cable and then looks for an absence of capacitive coupling to the other wires. After locating this fault, the circuit identifies the open wire and allows you to open and repair the correct cable end.

One end of a bad cable typically shows good ac continuity, and the other end typically has one or more connector pins with no ac continuity. Because a short in the cable appears as a good connection, the operator can easily confirm that the tester is operating correctly by simply shorting its test leads together. The first section of IC_1, a Maxim (www.maxim-ic.com) MAX9022 low-power dual comparator, forms a relaxation oscillator operating at approximately 155 kHz. It produces a peak-to-peak output signal approximately equal to the supply voltage, which feeds to a connector of the cable under test. The second section of the circuit processes any ac signal that the interlead capacitance picks up. A pair of silicon diodes first rectifies that signal and then integrates the rectified signal on storage capacitor C_5. Bleed resistor R_5 provides some noise immunity and helps to reset the capacitor between tests.

Output resistor R_4 and input capacitor C_4 provide limited circuit protection. The circuit indicates open for any test-cable capacitance below 100 pF. Thus, a standard mains-test lead, whose typical lead-to-lead capacitance is 200 pF, would test OK. The circuit is also immune to false triggering that the 60-Hz pickup from the power lines causes. Because the typical current draw of this low-power circuit is less than 40 μA, the circuit can usually operate from battery power in the form of three 1.5V AA or AAA cells. Many low-cost alternatives are available for the output device—for example, you could use a dc-activated piezoelectric buzzer—and most feature a suitably wide range of operating voltages. The 100-nF capacitors are standard ceramic decoupling capacitors, and the circuit contains no critical passive components. The comparator's high-side drive is somewhat better than its low-side drive, so it should source rather than sink current to the indicator device. D_1, D_2, and D_3 are silicon diodes.EDN

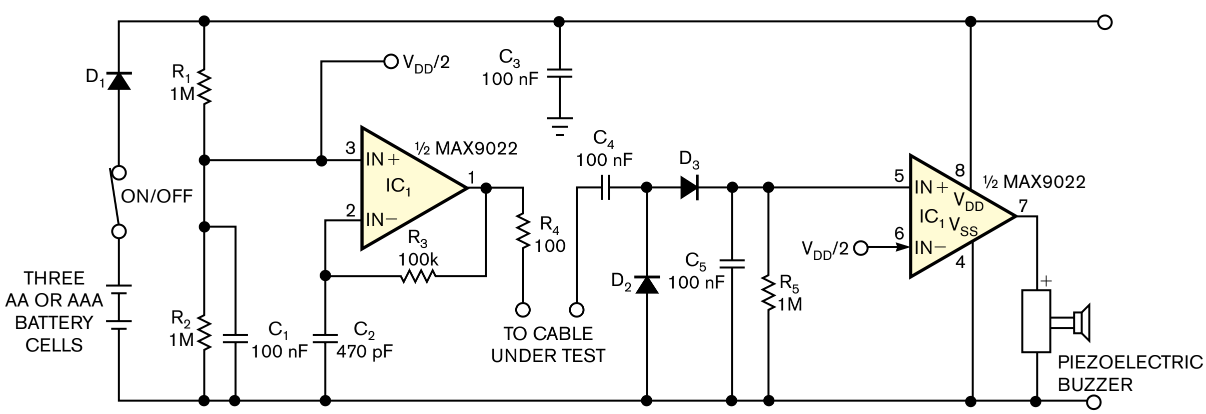

Figure 1 Based on a low-power dual comparator, this ac-continuity tester locates open-circuit pins in a cable.