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designideas

READERS SOLVE DESIGN PROBLEMS

Triac tester allows for manual or automatic operation

Abel Raynus, Armatron International, Malden, MA

Triacs are bidirectional ac switches that can control loads with currents as high as 25A rms at voltages as high as 600V. They find wide use in motor-speed, heater, and incandescent-lamp controls. Logic triacs are especially attractive for microcontroller-driven devices. You can activate a triac directly from microcontroller-output ports because of the triac's trigger current of only 3 to 10 mA. As with any electronic device, triacs can have some internal problems that you can detect before using them in a design.

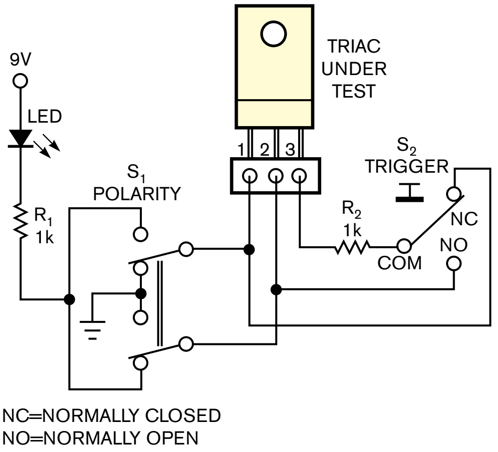

Figure 1 A triac tester uses a switch to reverse the polarity of the test signal.

Figure 1 shows a simple and inexpensive test fixture that tests the L2004F31, L2004F61, L2004L1, and L4004V6TP triacs from Littelfuse (www.littelfuse.com), but you can use it to test any other leaded triac because all the standard packages, including TO-220AB, TO-202AB, TO-251, and IPak, have the same pin layout. An IC socket provides easy insertion of a triac under test. You can also apply this idea to SMDs (surface-mount devices), provided that you can find or create an appropriate test socket. Polarity switch S_1, a DPDT (double-pole/double-throw) device, lets you check conductivity in both directions. Trigger switch S_2, a momentary SPST (single-pole/single-throw) pushbutton device, activates the triac under test by connecting the gate (Pin 3) with MT_2 (Pin 2) through resistor R_2 (**Figure 1**).

The test takes less than 5 seconds and comprises four steps (**Table 1**). An LED indicates the result of each step to the test operator. A triac is good if

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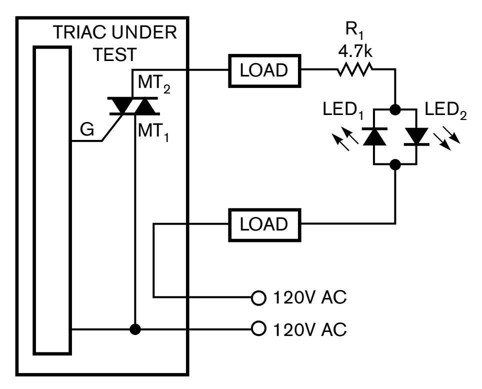

Figure 2 With a resistive load, the tester uses two LEDs to indicate pass and fail in both directions.

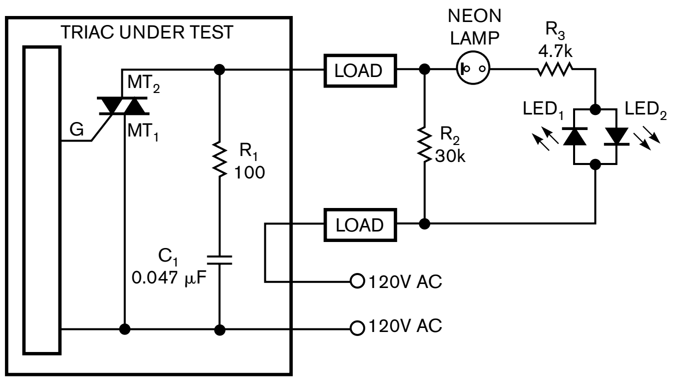

Figure 3 For an inductive load, add a neon lamp to minimize leakage current.

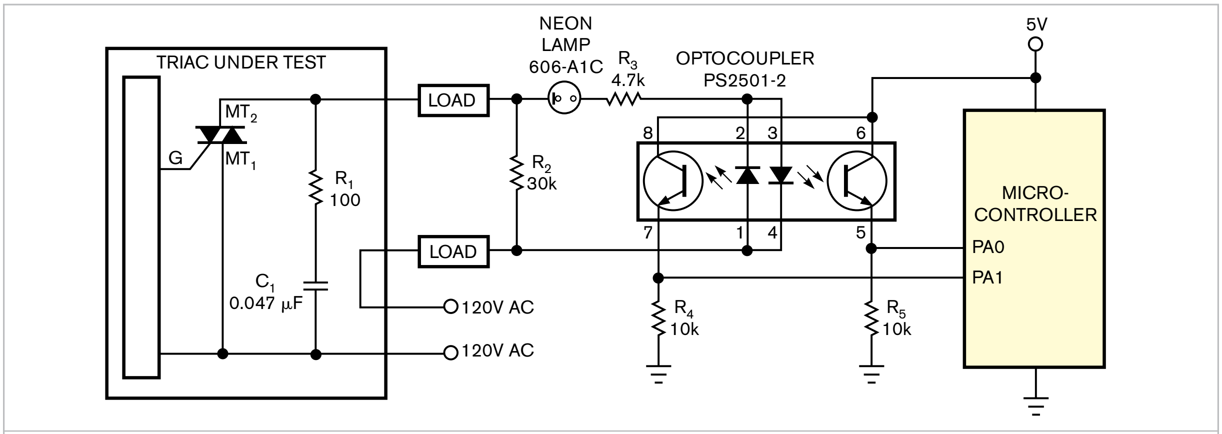

Figure 4 An optocoupler isolates the triac from ground.

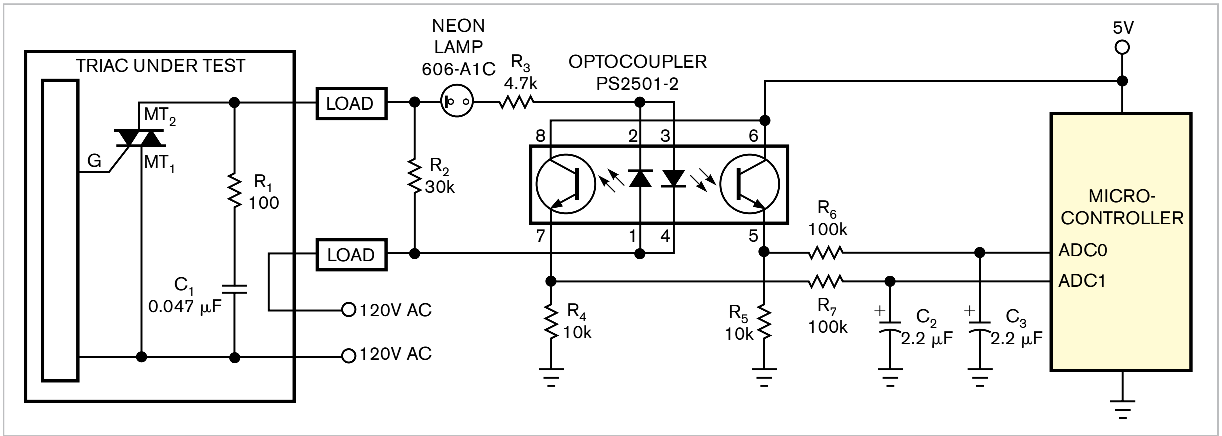

Figure 5 RC filters let you use PWM signals.

it passes all four tests. You should perform another triac test during manufacturing to ensure that there is no problem with the subassembly board and that the triac works properly. This test saves time and labor in case you detect a problem after assembling the entire product. You perform this test with the triac soldered into place on the board. You use the nominal power-supply voltage of 120/220V ac. The test should have minimal influence on the DUT and should use minimal time and labor. This test uses the triac tester in place of a load. The connection from the tester to the DUT can vary, and be sure to take some safety measures when connecting 120/220V ac.

You use a different test fixture for triacs that drive a resistive load, such as an incandescent lamp or a heater (**Figure 2**). Each LED checks conductivity in one direction. When the triac is closed, both LEDs should be off. When it is open, both LEDs should be on. In the case of an inductive load, such as a motor, use an RC snubber circuit comprising C_1 and R_1 in parallel with the triac (**Figure 3**). Unfortunately, the snubber circuit introduces a small current leakage into the test circuit even when the triac is closed. The circuit in **Figure 3** shows you how

TABLE 1 TEST FOR TRIACS

Step no.	Operations	LED status	Result
1	Insert triac under test into the socket; turn on power	Off	OK
		On	Shortage inside triac
2	Push and release trigger switch S_2	Off	Break inside triac
		Stays on	OK
		On but goes off after you release S_2	Bad "hold" function in triac
3	Move polarity switch S_1 into another position	Off	OK
		On	Shortage inside triac
4	Push and release trigger switch S_2	Off	Break inside triac
		On	OK
		On but goes off after you release S_2	Bad "hold" function in triac

to avoid this problem using resistor R_2 and a neon lamp with an ac breakdown voltage of 95V.

The indicators of the test result in **figures 1**, **2**, and **3** are LEDs. Sometimes, the triac test is part of a multitasking test system that checks other components or parameters of the whole device, which includes the triac. This test involves a sequence of measurements, and a system operator gets only one of two possible signals: pass or fail. These tests use a microcontroller-based system. Thus, all the interface signals should be in digital format: high or low.

You can also use analog signals by activating the microcontroller's ADCs. This approach is less preferable, however, because of the limited number of ADCs in low-end microcontrollers and more complicated software. Interfacing the triac under test with the microcontroller creates no problem if the triac's MT_1 pin is grounded. In most cases, MT_1 and MT_2 are isolated from the ground. When this scenario occurs, you can use an optocoupler, such as the PS2501-2 from California Eastern Laboratories (www.cel.com, **Figure 4**). It comprises two optically coupled isolators containing LEDs and NPN phototransistors with a maximum voltage of 80V.

If the triac output comprises a sequence of pulses, such as a PWM (pulse-width-modulated) signal for motor-speed or lamp-brightness control, then use a lowpass RC filter before the microcontroller's ADC inputs (**Figure 5**). The time constant of this filter, $\tau=R_6\times C_2$, depends on the PWM signal period and duty cycle. The measurement in the chain of tests should start no earlier than $3-5\tau$. Using the microcontroller's ADC requires additional firmware. To avoid this requirement, you can compare the voltage after the filter with a reference voltage with a comparator, such as the LM393 from National Semiconductor (www.national.com), to produce a logic-high level for the microcontroller's input. **Reference 1** describes an alternative approach with minimal external components for the expense of the firmware complication.**EDN**

REFERENCE

1 Raynus, Abel, "Microcontroller detects pulses," *EDN*, July 24, 2008, pg 58, www.edn.com/article/CA6578137.

Handheld DMM copes with logic nanosecond-pulse-width waveforms

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When testing sequential-logic circuits, you may find that, although the repetition frequency of a logic signal is within the range of your DMM (digital multimeter), you can't measure it. The displayed frequency value is either dubious or chaotically changing in time. The DMM may also behave as if there were no signal. Any of these undesired states might appear when the duty cycle of the measured waveform is either close to zero or is approaching one—in other words, when the width of a pulse—high or low—is much narrower than the repetition period of these pulses. This problem occurs because you can't expect a DMM with an upper frequency limit of perhaps 200 kHz to measure 100-nsec-wide pulses, even if the repetition rate of these pulses is well below the upper limit of the DMM's frequency range—perhaps just 5 kHz. For a rough estimation of bandwidth for measuring at a pulse width of 100 nsec, consider this pulse to be a half-period of a square-wave signal. Use the following **equation** to calculate the required bandwidth:

$$B \approx \frac{1}{2T_W} = \frac{1}{2\times10^{-7}} = 5\text{ MHz}.$$

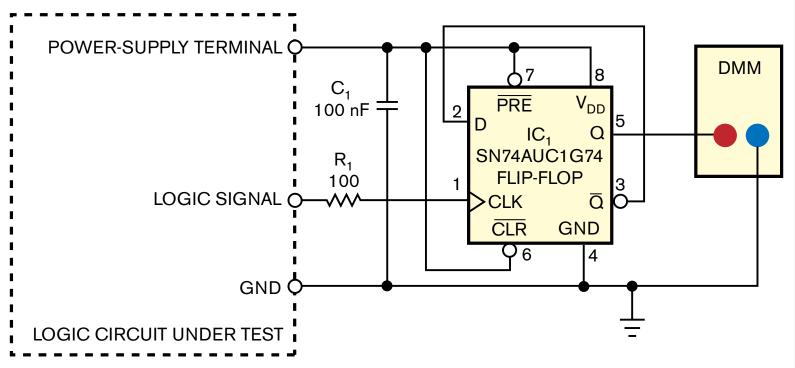

Figure 1 A binary divider turns low- or high-duty-cycle waveforms into square wave so that you can measure their frequencies.

This frequency is well beyond the bandwidth of most DMMs. The second cause of failing to measure the repetition rate of logic waveforms with too-low or too-high duty cycles lies in the internal ac coupling of the DMMs during frequency measuring. Due to this coupling, the decision threshold of an internal comparator, which you derive from the mean value of the measured waveform, is close to either the low or the high level of this waveform. In the case of narrow pulses, the operation of the internal comparator becomes ambiguous, and any noise in the measured waveform or that the comparator itself generates may cause an error.

You can address the problem by placing a binary divider between the source of a logic signal and the DMM. The binary divider comprises IC_1, a positive-edge-triggered, D-type flip-flop (**Figure 1**). The supply pin of IC_1 connects to the supply terminal of the tested logic circuit. Therefore, you can run the logic at any industry-standard supply voltage of 1.2, 1.5, 1.8, or 2.5V. In testing 3.3V logic, use an external 2.5V source to supply IC_1. The internal protective diodes at Pin 1 of IC_1, along with resistor R_1, reduce the voltage swing at Pin 1 to an acceptable level in such a case.

A square-wave signal is at the output of the binary divider (**Figure 2**). The DMM no longer sees nanosecond pulses at its measuring terminal. You have only to multiply the displayed frequency value by two to obtain the correct frequency. Due to relatively low values of R_1 and of the input capacitance, approximately 2.5 pF, at the clock input of the flip-flop, you need not worry about frequency compensation. The time constant of $R_1 \times C_{IN}$ is merely 0.25 nsec. The width of pulses—either low or high—at the input of the circuit can decrease to 1 nsec.**EDN**

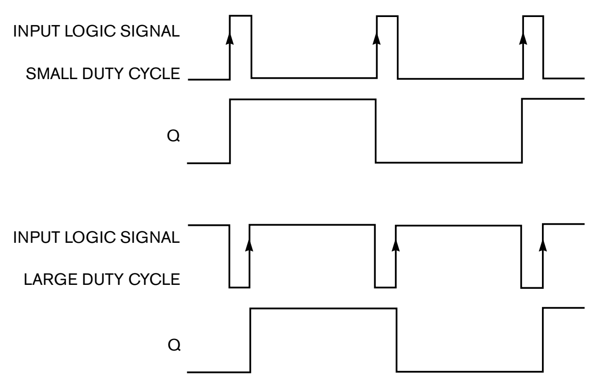

Figure 2 The flip-flop output, Q, produces a signal with a 50% duty cycle.

Build a simple complementary-bracket-pulse generator

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When building push-pull switching power converters or motor controllers, you often need alternating pulses with a small amount of dead time between them to minimize simultaneous conduction in output-switching devices. Switching controller ICs have this feature, but they usually operate within closed loops to minimize IC pin count. When optimizing switching output stages, you may need open-loop control. **Figure 1** shows how you can build such a generator with just two common ICs. As a bonus, both the overlapping, P-channel drive and the nonoverlapping, N-channel drive are available simultaneously.

The circuit's input, Pin 10 of IC_1, comes from clock generator IC_{2F}. A slightly delayed and inverted version occurs at IC_1's Pin 9 from IC_{2A}. IC_1 then decodes the original and delayed inputs to form the desired outputs (**Table 1**). Because IC_1 is an analog demultiplexer, you can set its outputs either active high or active low with pull-up or pull-down resistors. You determine the high or low inactive state by tying the X or Y pins to either the power-supply voltage or ground. Depending on the state of IC_{1A}'s A and B inputs, internal switches in IC_1 close between X and X0 to X and X3, as well as from Y and Y0 to Y and Y3. Buffers IC_{2B} through IC_{2E} buffer and invert the resulting outputs. You can use the remaining gate as a variable-frequency or variable-duty-cycle generator. You determine the dead time,

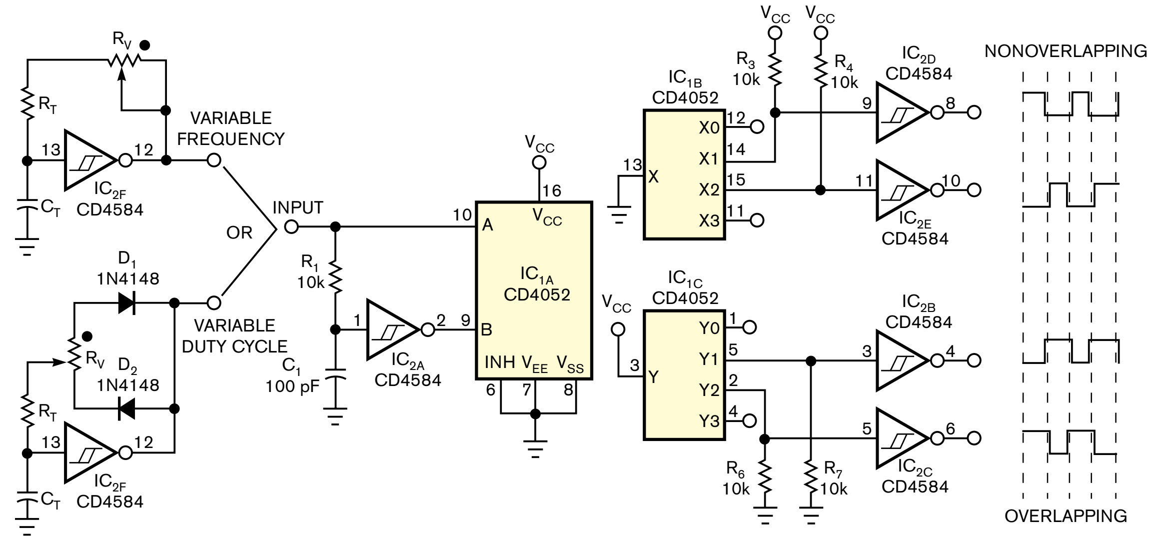

Figure 1 You can build a simple pulse generator with just two commonly available ICs.

which is independent of frequency or duty cycle, using the time constant of R_1 and C_1. Depending on output-device characteristics and switching frequency, output buffers may require an additional stage, or you can replace them with MOSFET-gate-driver devices. Supply voltage is not critical but should be high enough to guarantee that output devices fully turn on. In general, a higher supply voltage allows for higher-speed operation. The MC14xxx series of ICs is the same as the CD4xxx series. If you need higher-frequency operation at lower supply voltages, then use the 74HC4xxx-series devices. All of these ICs are available from a number of manufacturers, including Texas Instruments (www.ti.com, **Reference 1**) and On Semiconductor (www.onsemi.com, **Reference 2**).EDN

TABLE 1 ORIGINAL AND DELAYED INPUTS

Pin 9 (Input B)	Pin 10 (Input A)	Sequence
0	1	Phase A
1	1	Dead time
1	0	Phase B
0	0	Dead time

REFERENCES

1 "CD4051B, CD4052B, CD4053B," Texas Instruments, October 2003, http://focus.ti.com/lit/ds/symlink/cd4052b.pdf.

2 "Semiconductor and Integrated Circuit Devices," On Semiconductor, www.onsemi.com/pub_link/collateral/mc14584b-d.pdf.

Power-miserly voltage reference needs just one pin

Peter T Miller, Applied Inspirations LLC, Bethlehem, CT

The supply rail normally powers a microcontroller's voltage-reference source. In power-critical battery-operated applications, the constant drain, even of a few 10s of microamps, can be prohibitive. This situation requires adding a pin to turn the reference voltage on and off. By adding a 0.1-µF capacitor in parallel with the voltage reference and a simple bit of software that you can download from the online version of this Design Idea at www.edn.com/090820dia, you'll need just one pin to both power and read the reference voltage.

When you connect the voltage reference as in **Figure 1**, the software configures the Microchip (www.microchip.com) PIC chip's V_{REF} (reference-voltage) pin as a switched-on output. After approximately 300 µsec, the voltage across the capacitor stabilizes at 1.225V.

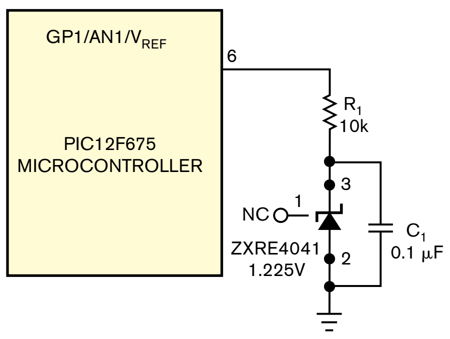

Figure 1 A voltage reference and a capacitor provide a reference voltage for a microcontroller.

There is an initial overshoot when the ZXRE4041 powers up. The pin is then reconfigured as an analog input for the ADC's reference-voltage source. The reference voltage quickly drops by 20 mV in the next 50 µsec as the ZXRE4041 shuts down. With a 0.1-µF capacitor, the voltage then slowly drops 60 mV over 2 msec because of leakage. Although this delay is exponential, the rate is so slow that, for practical purposes, you can consider it linear for this short time window.

You must also consider that the ADC also draws current through the 10-kΩ resistor during conversion, causing voltage drop. Although Microchip doesn't characterize this voltage drop in its documentation, tests consistently measured a drop of 80 mV for several devices, giving a calculated current of 6.67 µA. Using a conservative internal 4-MHz clock and allowing an ADC clock of frequency oscillation divided by 16 for operation at the minimum operating voltage, one conversion takes 45 µsec. This action slightly drains the capacitor, but this drainage appears to be only 2 or 3 mV. Calculations of initial watt-seconds minus watt-seconds used yield even lower values. Subtracting these fixed, repeatable losses from the initial steady-state 1.225V yields a new reference voltage of $1.225V_{REF}-0.020V$ shutdown drop-0.080 IR drop$=1.145V$.

Allowing 75 µsec to do the analog-to-digital conversion, store the value, and set up for the next conversion on another channel, 11 conversions will result in the last one's reference voltage being lower by 22.5 mV—that is, 10 conversions×75 µsec×(60 mV/2000 µsec). This error is only 1.9% compared with the first conversion's results.

If you just need an approximate voltage for a consumer product, for example, to warn of low battery voltage, you can use an LED instead of the ZXRE4041. Just change the value of R_1 to 300Ω to provide sufficient current to turn on the LED. Although LEDs lack the temperature stability of dedicated voltage-reference chips, the variation may be acceptable for the application because most consumer products find use within the comfort range of humans. If an LED is already part of the system, then the voltage-reference cost is only that of the software. Using this technique, an LED can now provide status-indicator, photodetector, and voltage-reference functions and enter a zero-power state using only software to reconfigure the changes.EDN