THINK TANK

By John J. Yacono

Triacs and Power Control

A while back, I received a letter from someone that had a question about a Triac-operated project that appeared in this magazine. Apparently the sender was concerned that once a Triac was activated, it wouldn't shut off unless the power was cut off. That letter and another (which will appear here this month) prompted this months topic: Triacs and power control. As usual, I'll throw in a circuit with an inventive twist to further illustrate their operation before we get to this month's letters.

Triacs are useful devices because they can switch current on. They are multi-layered three-terminal semiconductor devices. The three terminals consist of a gate and two "main terminals" (denoted G, MT1, and MT2, respectively) as shown in Fig. 1. When using Triacs, don't get confused between the two main terminals, they perform entirely different jobs in most circuits. Always remember that MT1 is always illustrated closer to the gate in a schematic.

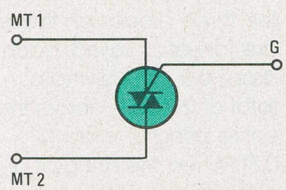

Fig. 1. Triacs are multi-layered, three-terminal semiconductor devices. Each terminal has a different function.

To help you to understand how they do their job, take a look at Fig. 2, which is a "characteristic curve" of a Triac. The plot illustrates the relationship between current (I) flowing from one main terminal to the other and the voltage (V) across them. Let's consider quadrant I—the upper right—of the graph first. That's where the conventional current flows from MT2 to MT1, and the voltage at MT2 is more positive then the voltage at MT1.

As you can see, the main terminals do not conduct significant amounts of current until the voltage reaches a certain value called the "breakdown voltage." At that point, the Triac's resistance suddenly drops, allowing current to flow freely with very little voltage drop across the main terminals. The Triac is then said to be "on." As you can see, that behavior forms a "knee-bend" in the characteristic curve. Current will continue to flow in such an uninhibited fashion unless it falls back down into the knee-bend region. The current level at that transition point is called the "holding current" because it is the minimum current needed to hold the Triac on.

If a voltage is applied to make the gate more positive than main-terminal 1, current flows through the gate. The flow of gate current causes a decrease in the value of break-down voltage needed to turn on the Triac. You can increase the gate current to the point where the knee-bend is hardly noticeable. At that point, it only takes a small voltage across the main terminals to turn on the Triac, so the Triac acts like a low-value resistor. That is called "quadrant-I operation."

The same knee-bend behavior can be seen when the polarity of the voltage across the Triac is reversed, which is represented by the lower half of the plot. In that situation, applying voltage to the gate still reduces the break-down voltage, but the gate voltage must be more *negative* than main-terminal 1. As you may have guessed this is called quadrant III operation.

For the sake of simplicity and brevity, I won't discuss quadrant II and quadrant IV operation since not all Triacs can operate in those modes. Suffice it to say that for such operation the gate-voltage polarity will be just the opposite of what it is for the quadrant I and quadrant III modes.

If you use a Triac to control the flow of current in a 60-Hz AC circuit, since the current drops below the holding-current level 120 times a second (*i.e*, during each alternation of the AC line), the Triac must be turned back on 120 times each second.

Furthermore, the gate voltage must be positive with respect to MT1 when MT2 is more positive than MT1, and negative with respect to MT1 when MT2 becomes more negative. That is almost always accomplished by connecting some electrical component or components between MT2 and the gate. That has the effect of pulling the gate voltage toward MT2, and thus away from MT1, providing the necessary potential with the right polarity between the gate and MT1.

A good example of that technique is shown in Fig. 3. In that circuit, when the LED in the optoisolator receives current it lights up. The light

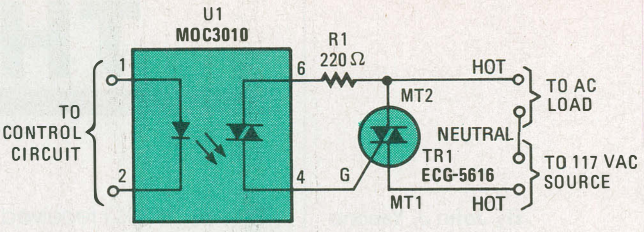

Fig. 3. Triacs can be controlled by low-power circuits through Triac-driver optoisolators as shown here.

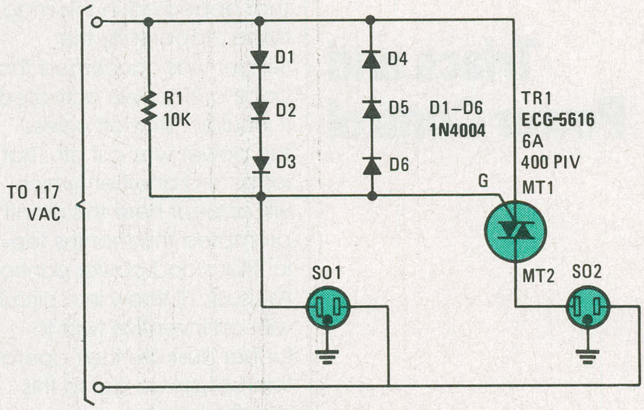

Fig. 4. This circuit to generate a trigger signal for a Triac looks odd, but it works very well. The diodes provide the Triac gate with a voltage-limited gate signal.

that forward-voltage drop is around 0.8 volts. So when the three diodes on the left are forward biased, each drops 0.8 volts, giving a total of 2.4 volts across the entire string of three (3 × 0.8). When the string of diodes on the right is forward biased, it also drops a total of 2.4 volts, but with the opposite polarity.

That voltage looks very much like an AC squarewave if viewed on an oscilloscope. That squarewave is sent to the gate of the Triac and used as a trigger signal. To summarize, if current flows through the device connected to SO1 the diode network supplies the Triac with a voltage-limited gate signal of the proper polarity. The Triac then turns on and supplies power to SO2.

There are brief intervals when the voltage across the diodes is above −2.4 volts, but below +2.4 volts. During those times both sets of diodes *do not* conduct. That would cause the Triac to shut off briefly once the current through the main terminals fell below the holding-current value. Resistor R1 allows some current to flow during those intervals so the Triac can deliver almost continuous current to SO2. Note that R1 can be a low-wattage unit because it never sees more than ±2.4 volts.

The nice thing about the circuit is that it will supply the same gate signal to the Triac regardless of the load connected to SO1. There is another advantage that is not readily apparent: the timing of the gate signal is so precise that the Triac generates almost no electrical noise when it turns on (an annoying characteristic of most Triac-based circuits).

I use a circuit based on this strange concept to power my computer set-up. My computer is plugged into SO1 and its peripherals are plugged into sockets controled by a Triac just like SO2 is. I leave all the peripheral's power switches in the "on" position so when my computer draws current (*i.e.*, is turned on) the peripherals "come to life" as well.

If you plan to play with Triacs, there are a few safety precautions that you should follow: First, any connections that carry heavy current should be made with 12-gauge wire. Also, keep in mind that substantial current through a wire junction tends to raise its temperature. Since solder will melt at relatively low temperatures, any connections between leads carrying respectable current should be made with a wire nut, not solder. Last, it's always a good idea to add a heat sink to all Triacs that you use.

Now let's look at a few power-control circuits submitted by some of you readers. As usual, their efforts will be rewarded with a Think Tank II book, or something similar from our selection.

WHAT IS IT?

I have a circuit (see Fig. 5) that I found recently at a yard sale. I bought it for only $1, but I've spent $100 in pure agony trying to figure it out. It seems to reduce the power to lamps and also works well as a wattage control for my soldering iron. Before I got it, my soldering iron would get hot enough to lift the traces right off a circuit board.

I really like the circuit because it adjusts my soldering iron from very low heat for IC's, to very high heat for chassis-grounding connections. Maybe this circuit would be of great use to other technicians, if only I knew what type of transistor TR1 was. Please help if possible.

—*James Lancaster, Waco, TX*

No problem (especially since you provided the ECG number)! The part you've labeled TR1 is a Triac. It receives a gate signal from a delay circuit composed of C1, R1, R2, and R3 at the junction of C1, R1, and R2. MT1 is connected to the AC line and MT2 is connected to the load. The delay circuit turns on the Triac during each alternation of the AC waveform. The longer the delay circuit takes to trigger the Triac (which is determined by the setting of R1), the later the Triac turns on in each alternation. The later the Triac turns on, the less average power is delivered to the load.

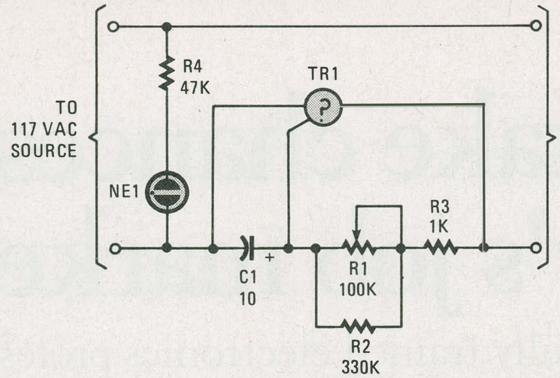

Fig. 5. This circuit is very useful for controlling power to lamps and soldering irons, but what is TR1?

KEEPING IT COOL

I installed a compact ice maker in an enclosure beneath my wet bar. When making a large amount of ice cubes, the cabinet became unduly warm. My solution was to have the ice maker turn on an exhaust fan when it operates. My first idea was to connect the fan supply leads directly across the ice-maker's compressor motor. Upon inspection, that proved to be more of an undertaking than it originally seemed. My ultimate solution was to have a Triac turn on the fan when triggered by the current drawn by the ice-maker's compressor motor (see Fig. 6).

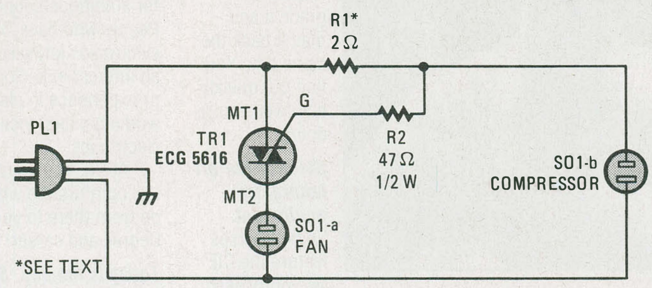

Fig. 6. When this Triac circuit senses current flow through SO1-a, it activates the device plugged into SO1-b. The values of the resistors must be chosen for the specific devices to be plugged in.

In the circuit, the value of R1 (2 ohms) was chosen so that the current to the compressor (about 2 amps) develops 4 volts across it. I used two 1-ohm 25-watt aluminum-cased resistors in series to produce that resistance. Their high wattage allows them to withstand the current surge of the compressor.

Resistor R2 is used to limit the current surge to the gate of the Triac, and was also selected for my particular application. The Triac was selected to easily handle the power requirements of the fan.

I installed R1 in the bottom of a 2-inch deep metal duplex outlet box that acts as a heat sink for R1 and the Triac (which is insulated from the box with a mica wafer). The sockets are on a standard duplex unit with the jumper tab on the hot terminals removed so that the sockets operate independently.

—*James W. Dowell, Chula Vista, CA*

Very nice. Everybody should keep in mind that this circuit was designed only for your particular compressor and fan. To use it on other equipment will take some experimentation on the part of the builder.

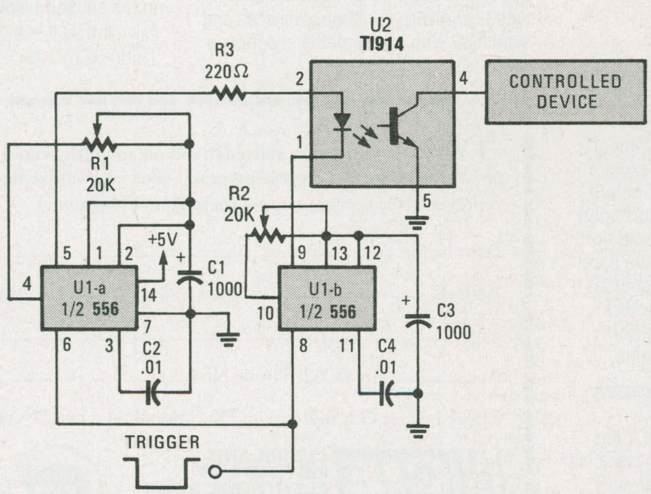

Fig. 7. This handy timer circuit has a turn-on delay and a turn-off delay. You can modify the circuit by replacing the optoisolator with a Triac-driver type and a Triac to control AC devices.

A SUPER TIMER

I've been reading **Popular Electronics** for several

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years and I noticed that we share an affection for simple but elegant circuits. Well, here's one that I came up with (see Fig. 7). It's a delay timer with *mucho* versatility.

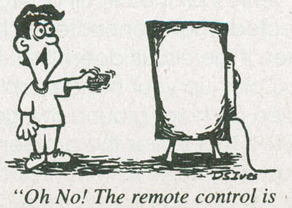
Both 556 sections are configured as monostable timers and are triggered simultaneously. Since both of their outputs go high when they are triggered, the optoisolator remains initially off. Assuming U1-b's period is set shorter than U1-a's, when U1-b times out it acts as a current sink while U1-a acts as a current source for the optoisolator, turning it on. The period of U1-b acts as a turn-on delay. The optoisolator will remain on until the remainder of U1-a's period passes.

You can use the circuit to control AC devices by replacing the transistor-output optoisolator with a MOC3010 Triac-driver optoisolator and a Triac. With a few modifications, this type of circuit can be used for many jobs. Think it's worth a book?

—*Mike Houston, Ridgecrest, CA*

I certainly do think it's worth a book. For those of you interested in using this circuit for AC-power control, replace the optoisolator with the circuit in Fig. 3.

Well, that takes care of another month. Remember, if you wish to participate in the fun, just write to *Think Tank*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735. ■



"Oh No! The remote control is broken—now I'll never turn on the TV set."