How to Design Semiconductor Switching Circuits

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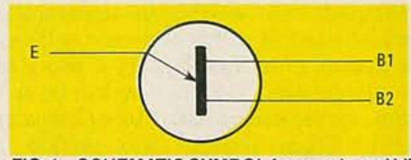

FIG. 1—SCHEMATIC SYMBOL for an n-base UJT.

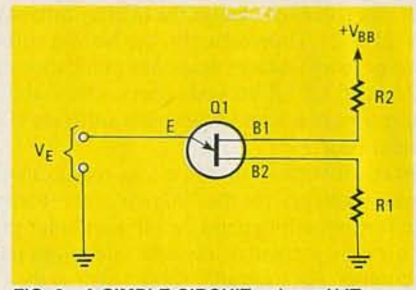

FIG. 2—A SIMPLE CIRCUIT using a UJT.

Here's a look at UJT's, PUT's, SCR's, triacs, and a host of other semiconductor switching devices.

Part 2

IN THE LAST PART OF this series, we saw how transistors are used in switching applications. Transistors, of course, are not the only solid-state devices that can be used in that way. Indeed, devices such as UJT's, PUT's, and SCR's can all be used in switching circuits. This month, we'll take a look at those devices, and others, and see what they are, how they work, and how you can use them in your own designs.

The UJT

The UJT (*Uni*J*unction* *T*ransistor) is a one-junction device that consists of a slab of n-type and a slab of p-type semiconductor material. In an n-type UJT, the two base terminals are connected to the n-type material. An emitter terminal is connected to the p-type material. The schematic symbol for the n-base UJT is shown in Fig. 1.

The n-type material connecting base terminal B1 to base terminal B2 has a resistance of between 5,000 and 10,000 ohms. It is convenient to think of that resistance as actually being made up of two resistances. One, RB1, is between the junction and B1; the second, RB2, is between the junction and B2. With that out of the way, we can now talk about an important characteristic of the UJT, the *intrinsic stand-off ratio*. That is defined as RB1/(RB1 + RB2) and denoted by the symbol η. The voltage at the junction, due to V_{BB}, is equal to ηV_{BB}.

Circuits

The UJT can be used in a simple circuit such as the one shown in Fig. 2. Pulses of sufficient voltage, V_E, must be applied between the emitter and ground for the UJT to conduct current from $+V_{BB}$ to ground through the n-type slab. When it conducts, output pulses that are in step with the input pulses are developed across R1 and R2, although R2's main purpose is to keep the circuit operating properly despite variations in temperature.

We will show you how to choose the values of R1 and R2 shortly. In any event, the values of R1 and R2 are usually much less than RB1 and RB2. Because of that, the external resistors used around the UJT can be ignored when analyzing the action of the transistor.

Getting back to the performance of the circuit in Fig. 2, we want the UJT to conduct when the voltage at the emitter reaches V_E. The device itself conducts when V_E is about ½ volt higher than the voltage at the junction. That occurs when V_E is greater than $0.5 + \eta V_{BB}$. That is why the intrinsic stand-off ratio is a critical factor in determining the behavior of the UJT.

Using that information, a relaxation oscillator can be designed. To do that, only an R-C network need be added to the circuit shown in Fig. 2. The resulting circuit is shown in Fig. 3.

Let's see how that circuit works. When the supply voltage is initially applied, 0 volts is across C1; that voltage increases with time. The time it takes for the voltage to increase to the level required to turn on the UJT is determined by R3, C1, and η, and is just about equal to the product of

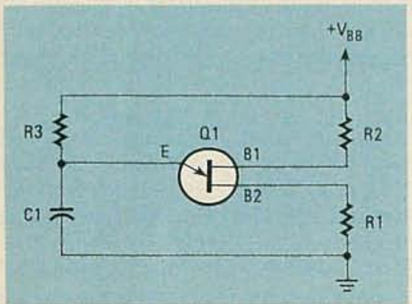

FIG. 3—ADDING AN R-C network to the circuit shown in Fig. 2 turns it into a relaxation oscillator.

R3 and C1. The oscillator frequency is about equal to the reciprocal of R3 × C1, or about 1/(R3 × C1).

The ideal value for resistor R3 is somewhere between:

$$\frac{V_{BB}(1 - \eta) - 0.5}{2I_P}$$

and

$$\frac{2(V_{BB} - V_V)}{I_V}$$

Where I_P is the maximum current flow between the emitter and B1; V_V is the *valley voltage*, the voltage between the emitter and B1 just after the device has begun to conduct, and I_V is the *valley current*, the current between the emitter and B1 when the voltage between those points is V_V. In the equations, η and I_P are the maximum values specified by the manufacturer of the particular UJT being used, while V_B and I_V are the minimum specified values. The current reaches I_P when V_E reaches a peak; that peak voltage is called V_P. Voltage V_P is significantly higher than V_V.

The voltage and current between the emitter and B1 continue to increase beyond V_V and I_V respectively because RB1 decreases as the quantity of current flowing through it increases. When C1 has discharged through the emitter-RB1 circuit, conduction ceases. The capacitor then recharges and the sequence repeats.

Capacitor C1 is selected to obtain the desired oscillator frequency, after R3 has been determined. Because the value you select for C1 depends upon the η (as well as on other factors) of the specific UJT being used, that capacitor may have to be "tweeked" to get the exact desired time delay.

If the UJT is to operate properly, R2 should be about equal to (RB1 + RB2)/$2\eta V_{BB}$. The value of R1 should be less than (RB1 + RB2 + R2)V_{OUT}/(V_{BB} − V_{OUT}). In the equation for R1, the values of RB1 and RB2 are the minimum resistances for this particular device as specified by the manufacturer. Voltage V_{OUT} is the peak-to-peak output voltage across R1. The value of R1 is usually about 50 ohms and R2 around 500 ohms, although at times the values chosen may radically differ from those. An ordinary bipolar transistor may be wired across the resistor used to deliver the output from the UJT; its purpose would be to provide sufficient push for the circuit to be driven by the pulse(s).

Because the UJT keeps on oscillating, repetitive voltages are developed across C1, R1, and R2. The voltage across C1 is a rising ramp while C1 charges and is a relatively fast-dropping slope when it discharges. If that ramp is to be used to drive another circuit, a high impedance must be connected between the R-C network and the circuit that is being fed by the ramp, so that the driven circuit will not load the R-C network (and affect the frequency of oscillation).

The UJT can be used in a switching circuit because it does not conduct until the capacitor is charged to a specific level. If a mechanical switch is placed across the capacitor and shorts it, the capacitor remains discharged. Under those conditions, the UJT does not conduct. The capacitor begins to charge at the instant the switch is opened. But the UJT does not conduct until the capacitor is charged to a voltage that exceeds $0.5 + \eta V_{BB}$ volts; in other words, it behaves as a time-delay switch. Conduction ceases at the instant the switch is closed and the capacitor is discharged.

Designing a UJT circuit

Let's see how we can calculate the values for the circuit shown in Fig. 3. As an example, assume that for the UJT being used, η is specified as 0.55, but can vary from 0.5 to 0.6. Similarly, V_V is specified as 2 volts, but can vary from 1 to 3.5; I_V is specified as 20 mA, but can vary from 10 to 30 mA, and I_P is specified as 8 μA, but can vary from 4 to 12. The internal resistance of the UJT, RB1 + RB2, is equal to 9000 ohms. What we are looking for is a 2-volt output across R1 at a frequency of 500 Hz. For this circuit V_{BB} will be 10 volts.

Start by determining the value of R3, the resistor in the timing circuit. Substituting into the equations for R3 noted above, we find that the value of that resistor should be between 146,000 ohms and 1,800 ohms. A good choice for R3 is 50,000 ohms. Since f = 1/R3C1, C1 should be equal to about 1/Rf = 1/(50,000 × 500), or about 0.04 μF. Finally, substituting into our equations for R1 and R2 we find that they should be 2400 ohms and 820 ohms, respectively.

An interesting variation in the circuit shown in Fig. 3 would be to replace C1 with a phototransistor. The resistance of the phototransistor increases as the amount of light reaching it decreases. Thus, when there is very little light, the resistance of the phototransistor is high. Under those conditions, the UJT conducts and current flows. That current can be used to trigger a relay and turn on a light as night falls.

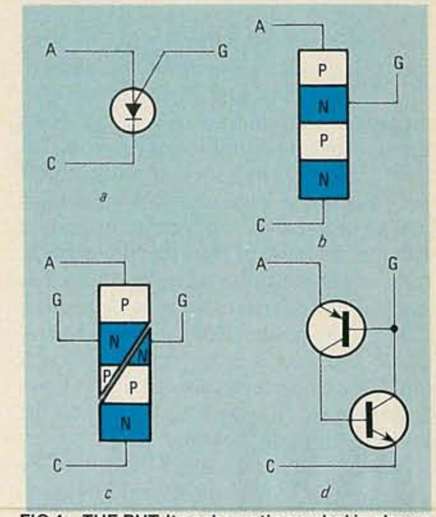

FIG 4—THE PUT. Its schematic symbol is shown in *a*, while its internal structure is shown in *b* and *c*. The equivalent circuit for that device is shown in *d*.

The PUT

The *P*rogrammable *U*nijunction *T*ransistor, or PUT, performs much like an ordinary UJT. The big advantage with the PUT is that η is not predetermined by the internal characteristics of the device. Instead, it can be set to a value between 0 and 1 using external resistors.

The PUT is a thyristor. It has three terminals, as shown in Fig. 4-a. A positive voltage is placed between the A (anode) and C (cathode) terminals. No current flows between the A and C terminals until a pulse that is negative with respect to the anode is applied to the G (gate) terminal.

Structure of the PUT

The device consists of four semiconductor slabs as shown in Fig. 4-b. To see how the PUT works, it is easiest to think of it as being split into two bipolar transistors—one NPN and the other PNP. The internal structure then would be as shown in Fig. 4-c. A schematic diagram of the two-transistor equivalent circuit is shown in Fig. 4-d.

Neither transistor is turned on when voltage is initially applied between A and C because current does not flow through either base-emitter junction. When G is made negative with respect to A, the base-emitter junction of the PNP transistor is turned on. Current can then flow through the collector lead of that transistor to the base of the NPN device. Because the voltage at the base of the NPN transistor is now positive with respect to the voltage at its emitter, current will also flow through the base-emitter junction of that device. The NPN transistor is therefore also turned on. Current from its collector flows through the base-emitter junction of the PNP device because its base voltage (and the collector voltage of the NPN section) is now negative with respect to its emitter voltage. Because of that, the PNP transistor stays on even after negative voltage has been removed from the gate terminal. Consequently, the NPN device also remains on. Because the paths between A and C have been completed, current flows from A to C. It ceases to flow when the anode current drops below I_V.

We can make a PUT act like a UJT by placing it in the circuit shown in Fig. 5. The maximum gate current, $I_{G(MAX)}$, allowed for turning on the PUT is specified by the manufacturer of the device and may be in the vicinity of 50 mA. Just what I_G actually is in a particular circuit, depends upon V_{BB}, R1, and R2, and can be determined from

$$I_G = \frac{V_G}{R1R2(R1+R2)}$$

where

$$V_G = V_{BB}\left(\frac{R_1}{R1+R2}\right)$$

The equations for calculating the time delay and the value of the resistor in the R-C circuit (in this case R4), are the same as the ones we used when we discussed the UJT. To determine R4, set η equal to $R1/(R1+R2)$, use the values of I_P and I_V provided on the device's data sheet, and let V_V be equal to about ¾ of V_F (the value of V_F, the forward voltage, can also be found on the data sheet). The value of V_V usually ranges somewhere between 0.6 and 1.2 volts so that 0.6 may be used for V_V in those equations without causing any unacceptable error.

Once the voltage across C1 is greater than that at the gate, the PUT conducts and current flows through R3. The output voltage that the current develops across R3 is called V_{OUT}. That voltage depends upon the voltage required to turn on the PUT, which, in turn, is about 1 volt higher than the voltage at the gate. That, in turn, is related to η, which is determined by the values chosen for resistors R1 and R2.

After the capacitor has been discharged and anode current has dropped below I_V, current ceases to flow through the junctions between A and C. The capacitor then gets recharged so that the current pulses through the PUT keep repeating. As was the case with the UJT, a switch can be placed across the capacitor to make this arrangement perform as a time-delay switching circuit.

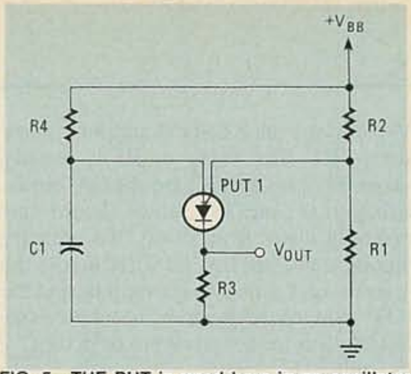

FIG. 5—THE PUT is used here in an oscillator circuit.

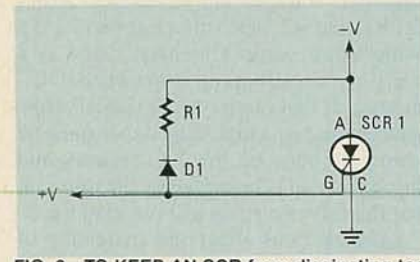

FIG. 6—TO KEEP AN SCR from dissipating too much power when the polarities of the voltages at its anode and gate are as shown, a series resistor-diode combination should be connected between those terminals.

The SCR

The structure of the silicon-controlled rectifier (SCR) looks like that of the PUT, except that the SCR gate is near its cathode rather than its anode. The SCR is composed of four semiconductor slabs arranged as shown in Fig. 4-b. The gate is connected to the second p-slab (the one located between two n-slabs) rather than at the first n-slab (the one nearest the anode). The equivalent transistor arrangement shown in Fig. 4-d still applies, except that the gate terminal is now at the base of the NPN device. A positive pulse at the gate with respect to C will turn on the SCR and let current flow from A to C when the anode is positive with respect to the cathode. The SCR will keep on conducting even after the trigger pulse has been removed. Conduction stops after the anode-cathode current drops below a particular current level specified by the manufacturer of the SCR. That current is identified as I_H, the holding current.

Triggering methods and precautions

Although gate triggering is the best method of turning on the SCR, it is possible to do it using other methods. For example, the SCR will be turned on if it is placed in a very hot environment. It will also be turned on if a specified maximum voltage that may be applied between the anode and cathode is exceeded. It will also be triggered if a sharp-rising voltage pulse is applied between A and C. As for the last case, it is frequently desired that the SCR not trigger under those conditions. Manufacturers therefore supply a dV/dT specification that indicates the maximum voltage change in a specific period of time that may be applied to the SCR without triggering it. Thus, if dV/dT is specified as 150 volts-per-microsecond, the SCR will probably be turned on by a pulse that changes at the rate of 175 volts-per-microsecond. To reduce the dV/dT factor of the pulse and avoid triggering the SCR, a 50,000-pF capacitor may be wired between the C and G terminals of the device.

If a voltage pulse that's applied between the A and C terminals triggers the SCR no damage will be done to the device. But it is also possible to apply a fast current pulse between the A and C terminals. That pulse may be used to trigger the SCR or may simply be present after the SCR has been turned on. But if that current pulse is faster than the dI/dT limit specified by the manufacturer of the SCR, the device can be destroyed. You must be sure that such current pulses do not occur at any time. To insure against such pulses a series R-C network can be connected between the anode and cathode of the SCR.

Some problems arise even when normal gate-triggering methods are used. If the leakage current is high, the SCR may be triggered inadvertently. To avoid that, a resistor should be wired between the cathode and gate of the device. The value of that resistor is normally specified by the manufacturer and can be found on a data sheet.

Precautions must also be taken so that the gate does not dissipate more power, P_{GM}, than is allowed by the manufacturer, or pass more current, I_{GFM}, than it was designed to do. Care must be taken so that the reverse voltage limit, V_{GRM}, between the gate and cathode is not exceeded.

Avoid applying a positive gate-cathode triggering voltage while a large negative voltage is at the anode of the SCR with respect to its cathode. Otherwise, the SCR will dissipate an excessive amount of power. To prevent failure, if that condition should occur, be sure to connect the diode-resistor circuit shown in Fig. 6 between the gate and anode. That circuit clamps the gate to the anode thereby reducing the conduction between the gate and the cathode.

Circuits using SCR's

A simple circuit involving an SCR and using an AC supply is shown in Fig. 7. Voltage is applied between the anode and cathode of the SCR. During the positive half of the cycle, a positive pulse is fed through R1 and diode D1 to the gate of the SCR and the device is turned on. Current flows through R_L, the load. Current stops flowing when the current passing through the SCR and R_L drops below I_H. During

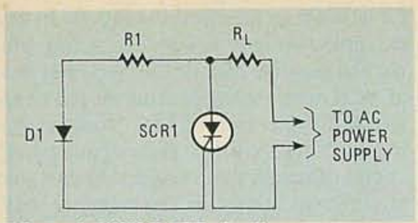

FIG. 7—A SIMPLE SCR circuit.

the negative half of the cycle—when the anode is negative with respect to the cathode—the diode prevents any current from passing to the gate, and the SCR remains turned off.

In the circuit shown, current flows for just about the full positive half of the cycle. Conduction starts when just enough current is available at the gate to turn on the SCR. The flow stops when the anode-cathode current falls below I_H, the holding current. But the circuit can be changed so that the conduction through the anode-cathode circuit can be made to start at any point during the rising 90° portion of the AC cycle and end when the current flow drops below I_H. Thus, the conduction of the SCR can be varied between a 180° period (when the SCR starts to conduct at the beginning of the positive half-cycle) and a 90° period (when it starts to conduct at the peak of the positive half-cycle).

The circuit in Fig. 8 can be used to set the conduction period. Variable resistor R2 sets the voltage applied to the R3-D1 series circuit. The voltage at the wiper of the potentiometer, in conjunction with R3, D1, and R1, determines the amount of current that flows into the gate of the SCR. When R2 is set so that sufficient gate current flows to turn on the device, the SCR conducts. That setting can be adjusted for conduction to start at any specific instant in the rising portion of the positive half-cycle.

The voltage being applied to the gate in the circuit in Fig. 8 is AC. In a similar fashion, a DC voltage can be used to determine the turn-on point of the SCR.

The turn-on points of the SCR do not have to be limited to between 0° and 90°. That range can be extended by adding a phase-shift network consisting of a resistor and capacitor to the original circuit. Doing so allows you to extend the range to from just above 0° to somewhat below 180°. Such a circuit is shown in Fig. 9.

Figure 10-a shows the phase relationship of the voltage across C1 (between the gate and cathode), V_{GC}, with the voltage at the input to the R2-C1 circuit. The current in a capacitor leads the voltage across that component by 180°. The voltage across a resistor is in phase with the current flowing through it. Because of that, when an AC voltage is applied to a circuit consisting of a resistor connected in series with a capacitor, the voltage across the

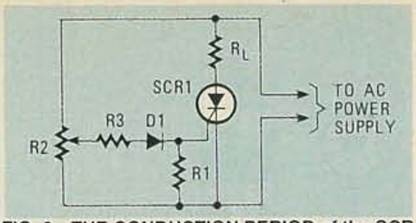

FIG. 8—THE CONDUCTION PERIOD of the SCR can be varied by changing the setting of R2.

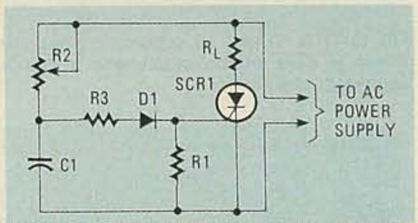

FIG 9—BY USING A PHASE-SHIFT NETWORK, the range of triggering points of the SCR can be extended.

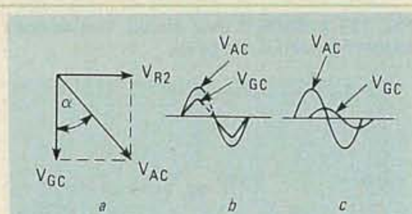

FIG. 10—PHASE RELATIONSHIPS. The graph in *a* shows that the magnitudes of V_{GC} and V_{R2} = V_{AC} only if their phases are taken into account. The relative phases and magnitudes of V_{AC} and V_{GC} in the case of a purely resistive load are shown in *a*, and in the case of a purely capacitive load in *b*.

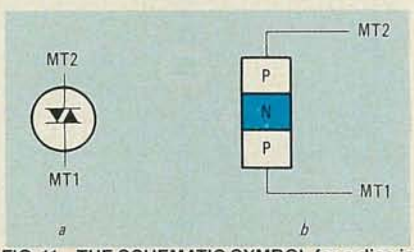

FIG. 11—THE SCHEMATIC SYMBOL for a diac is shown in *a*; its internal structure is shown in *b*.

capacitor lags the voltage across the resistor by 90°. The sum of the voltages across the two components must be equal to the voltage applied to the R-C combination, or V_{AC}. But that is the case only if the addition takes the relative phases of the two voltages into account.

That is all shown in Fig. 10-a. The voltage across C1, V_{GC}, lags the applied voltage, V_{AC}, by an angle α. When R2 is set equal to 0 ohms, the entire applied voltage is across the capacitor and α is equal to 0°. Thus, the voltage across C1 and at the gate-cathode junction of the SCR is in phase with V_{AC}. That relationship is shown in Fig. 10-b. Also, because R2 is 0 ohms, the magnitude of V_{GC} is just about identical to V_{AC}.

When the value of R2 is made very large, the applied voltage is primarily across the resistor and there's just about no voltage across the capacitor. In that situation, α is equal to nearly 90°. The relationship between V_{AC} and V_{GC} is shown in Fig. 10-c.

Assume that the SCR will just trigger when a voltage equal to that at the peak of the V_{GC} curve in Fig. 10-c is applied between the gate and cathode. Turning to Fig. 10-b, with that small voltage requirement, and noting the slope of the curves in Fig 10-b, it's clear that the SCR turns on soon after the applied voltage passes 0° because V_{GC} reaches the trigger point near 0°. In Fig. 10-c, the peak of the trigger curve must be reached, before the SCR turns on because of that curve's low amplitude. Triggering therefore does not occur until V_{AC} is near 180°. Trigger points are made to vary between 0° and 180° by changing the setting of R2. In all cases conduction stops when the anode-cathode current drops to I_H. That is close to the 180° point on the V_{AC} curve. Thus, the trigger-point setting is used to determine just how long the SCR will stay turned on.

Diacs

In a diac, whose schematic symbol is shown in Fig. 11-a, the arrangement of semiconductor slabs appears quite similar to that of an ordinary PNP transistor (see Fig. 11-b). But there are two big differences between the diac and bipolar transistor. First, there is no lead to the center slab of the diac. Second, the same amount of impurities due to doping are at both junctions of the diac, while quantities differ at the two junctions of an ordinary transistor.

If a very small voltage is applied between the two terminals of the diac, MT1 (*M*ain *T*erminal 1) and MT2, the diac does not conduct. The applied voltage must exceed a specified value before the device will conduct. After the diac is turned on, current flowing through the device increases rapidly as the voltage across the diac decreases. Regardless of which terminal is made positive with respect to the other, the diac will turn on at the same breakdown voltage. Should an AC voltage be placed across the device (through a resistor, of course, so that the diac will not dissipate excess power), it will conduct during each half-cycle after the breakdown voltages have been exceeded.

Triac

As you can see in Fig. 12-a, the schematic symbol for a triac is very similar to that of a diac. The difference, of course, is that a gate has been added. The true differences between the devices can be seen, however, in the structural diagram shown in Fig. 12-b.

If you just consider the connections that are made to the right halves of the MT1, MT2 and gate terminals, and ignore anything that's connected to the left half of those terminals, what you have is a PNPN SCR, with the gate connected to the lowest p-slab. Consider next the connections made to left side of those terminals, this time ignoring the connections to the right. What you have now is an NPNP SCR. Converting that into its equivalent circuit gives you the two-SCR combination shown in Fig 12-c.

When MT2 is positive with respect to MT1 and a pulse is applied to the gate, SCR 1 in the equivalent circuit turns on. If MT2 is negative with respect to MT1, SCR 2 turns on. Thus, each SCR conducts on alternate halves of a cycle. Unlike the individual SCR, the triac conducts current in both directions. But the SCR has one important advantage over the triac: The SCR can operate over a range of from 0- to several-hundred-Hertz while the triac is useful only to somewhat above 60 Hz.

A triac can be used instead of an SCR in a circuit like the one shown in Fig. 7. Simply substitute MT2 for the anode and MT1 for the cathode. The diode is no longer necessary for the circuit to operate properly. The altered circuit is shown in Fig. 13.

The waveform output by the AC power supply is, of course, a sinewave. If a high-resistance potentiometer is used for R2, it can be adjusted so that the gate current will just barely turn on the triac when the applied signal is at its positive 90° point. It will stay on for the portion of the cycle from 90° to close to 180°. Near the 180° point, the positive voltage across the triac is just about zero, so that the current drops below I_H, the holding current and conduction ceases.

With the marginal turn-on signal available during the positive half-cycle, the triac will not turn on between 180° and 270°, the portion of the cycle when MT2 is negative with respect to MT1. That's because it requires a larger signal to turn the triac on during the negative half-cycle than it does during the positive half-cycle. If sufficient current should be applied to just-about turn the triac on during that negative half-cycle, it will conduct for the negative portion of the cycle between 270° and 360°. As was the case in the positive half-cycle, conduction will cease when the negative current drops below, $-I_H$, the holding current.

Should resistor R2 be set for a low value, sufficient current will be applied to the gate before the 90° point in the cycle is reached and the triac will be turned on at some point between 0° and 90°. Then current would flow for more than one half of each half-cycle.

There are four triggering modes used for turning on the triac. In two of those, MT2 is positive with respect to MT1. If the gate is positive with respect to MT1, relatively little gate current, I_{GT}, is

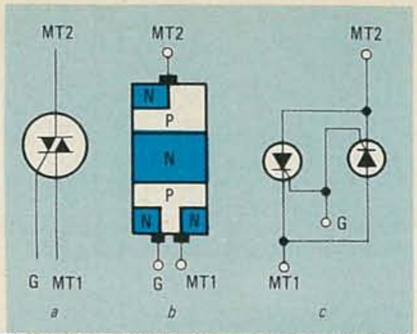

FIG 12—THE TRIAC. Its schematic symbol is shown in *a*, its internal structure in *b*, and its equivalent circuit in *c*.

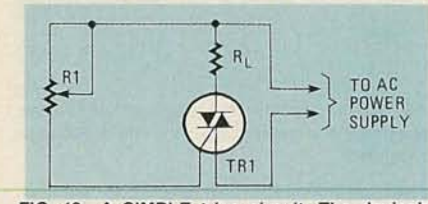

FIG. 13—A SIMPLE triac circuit. The device's triggering point is set by R2.

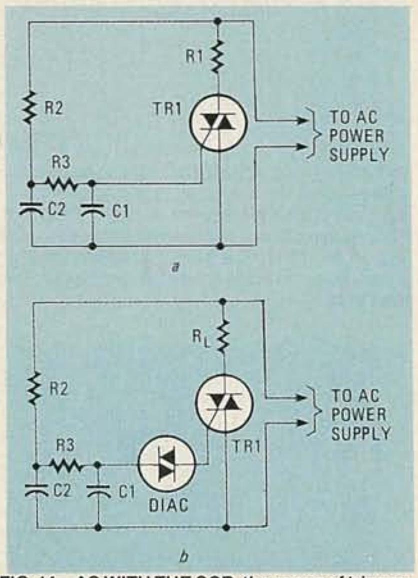

FIG. 14—AS WITH THE SCR, the range of triggering points of the triac can be extended by using the circuit in *a*. The conduction periods during the positive and negative half-cycles can be made symmetric by adding a diac as shown in *b*.

needed to turn on the triac. If it is negative with respect to MT1, at least five time that current is required to turn on the triac. Should MT2 be negative with respect to MT1, at least $2I_{GT}$ is needed to turn on the triac regardless of whether the gate current is positive or negative with respect to MT1. Considering that, it is obvious why when R2 is adjusted so that the triac will turn on just at the positive 90° point it is very unlikely that it will also turn on at the negative 270° point. That will be true unless a considerable amount of drive is added to the gate when the voltage goes negative.

In the case of the SCR, the 0°- to- 90° range of triggering points was extended to a 0°- to- 180° range through use of the R2-C1 network in the circuit in Fig. 9. In that example, we only needed triggering during the positive half of the cycle because an SCR does not conduct during the negative half-cycle. But the triac conducts during both the positive and negative half-cycles although that conduction can start at different points in the negative half-cycle due to the device's changing sensitivity to the gate signal. So, until R2 is set so that there will be sufficient voltage to trigger the triac in the negative half-cycle, it will conduct only up to 180°. When R2 is set so that the triac triggers on both half-cycles, conduction will take place during a longer interval during the first half of the cycle than in the second half.

The range of triggering points can be increased through the use of the circuit shown in Fig. 14-a. That arrangement uses two R-C phase-shift networks. With it, triggering can take place between 0° and 180° during positive half-cycle and between 180° and 360° during the second half-cycle.

The arrangement shown is similar to the one used for the SCR and shown in Fig. 9. But the circuit shown in Fig 14-a will not do anything to offset the differences in gate sensitivity and the device will trigger over different intervals during the positive and negative half-cycles. That situation changes when we add a diac to the circuit as shown in 14-b.

In that circuit, both the gate and MT2 are either positive or negative with respect to MT1. When the triac is operated in that manner, a diac can be used to compensate for the differences in the triac turn-on currents. That is, if the characteristics of the diac matches those of the triac gating circuit, the triac will turn on at relatively equal points during both halves of the cycle and the periods of conduction will be more or less equal during either half-cycle.

Other switches

The switching devices described above are the ones most commonly used, but there are many other types of semiconductor switching devices.

The schematic symbol for a CSCR (*C*omplementary *SCR*) is the same as that used for the PUT, but the two are quite different devices. The CSCR turns on when a negative voltage is applied to its gate with respect to its anode.

One big objection to use of the SCR, is that no means is provided to turn it off. The GSC (*G*ate *C*ontrolled *S*witch) is a device that overcomes that drawback. It behaves as an ordinary SCR when a positive pulse is applied to its gate. The difference lies in the fact that it turns off when a negative pulse is applied to the same gate.

The SCS (*S*ilicon *C*ontrolled *S*witch) is

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an SCR that can be turned on by either applying the usual positive pulse at the cathode-gate terminal with respect to the cathode or by applying a negative pulse to the anode-gate terminal with respect to the anode. By reversing the polarity of either pulse, the SCS can be turned off. The device then is a sort of combination of SCR and CSCR.

The four-layer diode has no gate. Its forward breakdown characteristics are similar to those of the SCR, as a specific voltage must be exceeded before it conducts any current. Once it conducts current, the voltage across the diode drops to a low value. Conduction increases at a rapid rate, while the voltage across it rises slowly. When the anode is negative with respect to the cathode, it does not conduct until a high voltage has been exceeded. While conducting in the reverse direction, the voltage across the device remains relatively constant, as if it were a zener diode.

There is also the LASCR (*L*ight *A*ctivated *SCR*). In the dark, the LASCR behaves as if it were an ordinary SCR with gate triggering. If light reaches the device, it will be triggered on even if no pulse is applied to its gate.

Finally, there's the SUS (*S*ilicon *U*nilateral *S*witch) and the SBS (*S*ilicon *B*ilateral *S*witch). The breakdown voltage of both devices is low—about 8 volts. That's much lower than the breakdown voltage for the SCR or the triac. While the SUS conducts in only one direction after breakdown, the SBS performs more like the triac, in that it conducts in both directions when gated with an AC voltage.

Applications

The circuits discussed can be used to control motor speed, used as light dimmers, and so on. Circuits can also be arranged to apply power through a load after different factors or conditions are used to turn on the gated device. It may be triggered by a thermistor in the gate circuit to sense and report a rise or drop in ambient temperature, by a circuit sensing if a battery supply voltage has dropped below a reasonable level, by a sick patient's excessively high or low blood pressure when the device is used in medical equipment, by an excessively high current flowing in a circuit, by excessive leakage current flowing between the power lines and ground, and so on.

Power supplies

Whatever the nature of a circuit, it's sure to have one requirement—a source of power from which to operate. We'll turn our attention to power supplies when we continue this series. **R-E**