Chapter IX

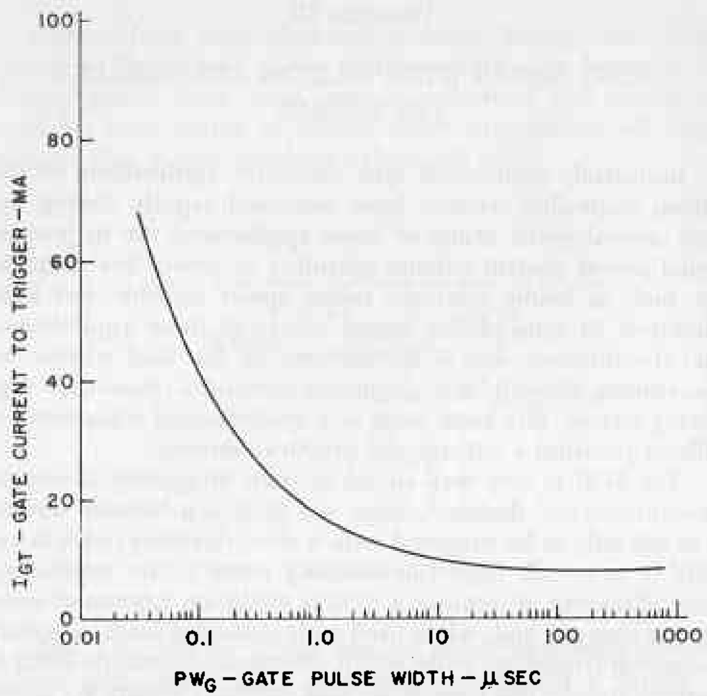
USING NEONS WITH SILICON CONTROLLED RECTIFIERS

Industrial, commercial and consumer applications of the silicon controlled rectifier have increased rapidly during the past several years. Many of these applications are in proportional power control circuits operating at power-line frequency, such as heater controls, motor speed controls and light dimmers. In spite of the varied nature of these applications, and the different size SCR's dictated by the load current requirements, they all have a common need for a phase-shift triggering circuit. The neon lamp in a synchronized relaxation oscillator provides a natural and practical answer.[1]

The SCR is very well suited to pulse triggering, if certain precautions are observed. Since the SCR is a bistable device, it needs only to be triggered with a short duration pulse to enable it to switch from the blocking state to the conducting state. However, it requires a certain minimum amount of energy (or charge) and, when used with inductive loads, a certain minimum triggering pulse width (dependent upon its latch-in current and the rise time of the load current.) Figure 9-1 shows a typical curve for I_{GT} vs PW for the Texas Instruments TI 40A2 industrial type SCR. This curve assumes a resistive load. The curve shows that a pulse width greater than 10μsec should normally be used. But when inductive loads are controlled, the triggering pulse width must be longer than the time required for anode load current to reach the anode latch-in-current.

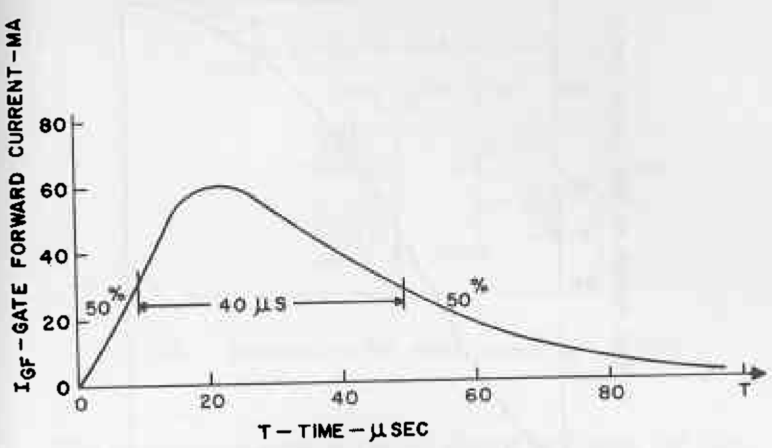
The AO 57B neon glow lamp is designed to operate with a 75 ma recurrent peak surge current at a 10% duty cycle, and is capable of providing sufficient triggering energy for all but the

1. McKenna, R. G., Manager of Power Device Characterization, Texas Instruments, Inc., "Neon Lamp Triggering of SCR's in Proportional Power Control Applications," *Signalite Application News*, Vol. 2, No. 4; and McKenna, Robert, Texas Instruments, Inc., and Bauman Edward, Signalite Inc., "Neon Lamp Triggering of SCR's," *Electro-Technology*, March 1965.



9-1 Typical gate current to trigger SCR vs gate pulse width

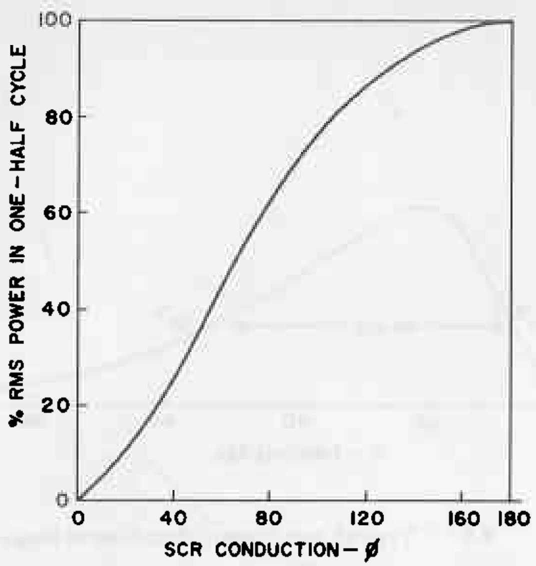
largest SCR's. Figure 9-2 shows the current wave shape into an SCR gate when a 0.1 μfd capacitor is discharged through the AO 57B. The 20-μsec pulse width is sufficient to trigger TI 40A2 series SCR's controlling resistive, capacitive, and most inductive loads. Such loads include universal motors used in most small hand tools and appliances. If more highly inductive loads must be controlled, a larger value capacitor may be used if care is taken to add limiting resistance in series with the neon lamp to limit its peak current to 75 ma.



9-2 Typical gate trigger circuit wave shape

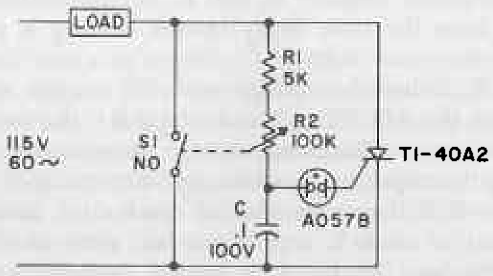
Figure 9-3 shows the RMS power supplied to a load by an SCR triggered by a phase shift circuit of the kind shown in Figure 9-4. This basic proportional power control circuit is capable of providing a minimum conduction angle of approximately 40°, and a maximum conduction angle of about 150°. This is a range of from 24% to 95% available power in a half-wave circuit supplied to the load.

In operation, resistors R_1 and R_2 in combination with capacitor C form the time delay circuit. During a positive half-cycle of sine wave voltage, C charges at a rate determined by R_1 plus R_2. When the voltage across C reaches the breakover voltage of the AO 57B (75 volts typical), the neon lamp will break back to a maintaining voltage of approximately 53 volts, allowing the capacitor to discharge into the gate of the SCR. Since the SCR is only capable of conduction in one direction, it can only be made to supply one-half cycle of sine wave current to the load. Switch S_1 is ganged to the potentiometer, so that it closes at the end of the clock-wise rotation of the pot, applying full power to the load.

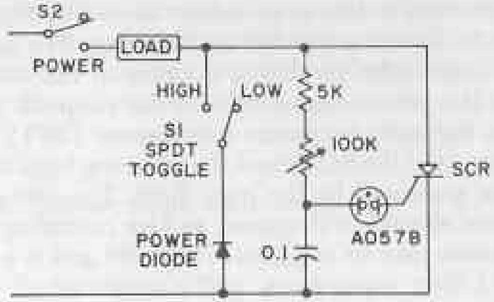


9-3 Percent RMS power in 1/2 cycle vs SCR conduction angle

A very simple way to modify the half wave control in Figure 9-4 into an inexpensive 360° full wave control is shown in Figure 9-5. This is accomplished merely by the addition of the power diode and the SPDT toggle switch. All other components are the same.

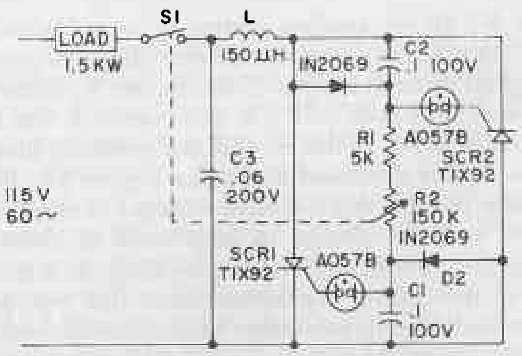


9-4 Half wave proportional power control



9-5 Inexpensive full wave proportional control

The symmetrical control circuit shown in Figure 9-6 uses two RC circuits with a common R to control the firing point of the two AO 57B's triggering the two SCR's. Diode D_1 shunts C_2 to supply the charging current to R_1 R_2 C_1 on the positive half-cycle, while D_2 performs a similar function on the negative half-cycle. When this circuit is used for an incandescent light dimmer, it may cause a small amount of flicker at initial stages of conduction at low light levels. This is due to variation in values of C_1 and C_2, as well as in the break-over voltages of the AO 57B's.



9-6 Direct coupled full wave power control

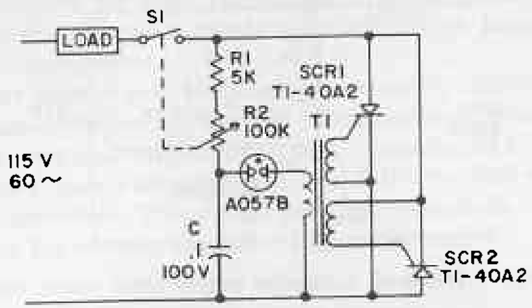
A solution to this is to reduce the value that allows minimum conduction angle before flickering. The lamp may then be dimmed to this level, and S_1 opens at full counterclockwise turn of the potentiometer to turn the lamp off. The LC_3 filter reduces the radio frequency interference (RFI) caused by the fast turn-on of the SCR's and the resulting high-frequency components generated by the high di/dt. The 150 μh shown is a minimum effective inductance, and for critical applications, 500 μh or more may be required. The 0.068 μfd is a good nominal value of filter capacitance, and a maximum of about 0.1 μfd could be used to prevent unnecessarily high surge currents through the SCR at turn-on.

A simple filter such as this is sufficient for proportional power control circuits used for home light dimmers and appliance controls. Proportional power controls used to control such inductive loads as universal motors do not need the filter, as the motor provides the inductance. (Usually, the RFI from the brushes is substantially higher than that from the SCR, so the RFI from the di/dt is insignificant.)

When a motor is controlled, it is wise to make R_1 an adjustable resistor, so that the maximum resistance in the timing circuit may be set to provide a minimum conduction angle for the SCR's. This allows the minimum speed of the motor to be set above the speed where it begins to "cog", or run with bursts of power.

Figure 9-7 shows another version of a symmetrical power control using a single timing circuit providing 120 pps pulses to the SCR gates through the pulse transformer T_1. Since the same timing circuit fires both SCR's in this circuit, it eliminates the unsymmetrical firing problem, and the resulting flicker of incandescent lamps discussed above for Figure 9-6. Because of the alternate positive and negative voltages to which capacitor C charges, and the change in magnitude of these voltages before and after the AO 57B neon tube fires, there is a hysteresis effect in the control characteristics of this type circuit. As R_2 is decreased from its maximum value, C is allowed to charge to a higher voltage on each half-cycle. When it charges to the firing voltage of the AO 57B, the SCR is turned on, shorting the control circuit voltage so that on the next half-cycle the capaci-

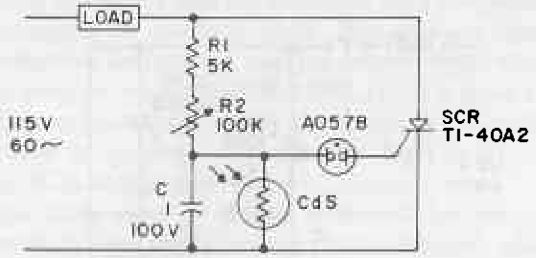
tor starts charging from a low voltage and will charge to the neon tube firing voltage at an earlier firing angle. The potentiometer resistance may now be increased to phase back the SCR firing angle, giving a hysteresis effect.



9-7 Transformer coupled full wave power control

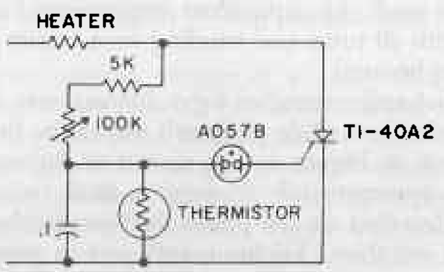
The transformer T_1 is not critical. The Sprague 31Z286, which is a 1:1:1 with $L_p \approx 10\mu$h designed for SCR triggering, may be used. An equivalent transformer, such as a simple 1:1:1 with 40 turns per winding on a ferrite or soft iron core, may also be used.

A photocell-controlled light dimmer may be made by adding a cadmium sulfide photocell across the timing capacitor of the circuit in Figure 9-4, as shown in Figure 9-8. The photocell has approximately 1 megohm dark resistance, which has very little effect on the phase shift circuit, but the light resistance of less than 1 kilohm is sufficient to prevent the capacitor from charging to the neon lamp firing voltage. This results in an out-of-phase light-controlled light dimmer. The light level may be set manually with R_2 when the CdS cell is dark, and the light will be dimmed below that level as the CdS cell is exposed to light, until the light is "dimmed off" completely. Variations in the component values may be made to set the light sensitivity level of the circuit. To reduce the sensitivity, a photocell with a higher light resistance range may be used, or a resistor may be added in series with it, or the capacitor value may be increased (with appropriate changes in R_1 and R_2). The opposite changes will tend to increase the circuit sensitivity.



9-8 Photocell controlled proportional power control

Substituting a thermistor for the cadmium sulfide photocell in Figure 9-8 results in a temperature controller. (Figure 9-9) A high resistance thermistor is mounted inside the area to be temperature-controlled. The 100K potentiometer can then be set to maintain a specific temperature.

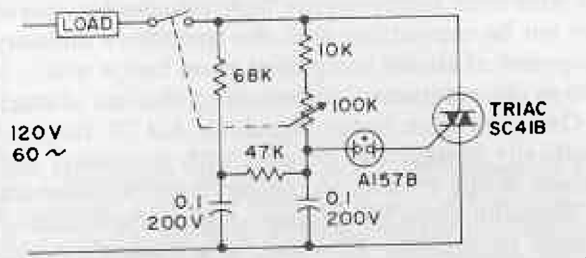


9-9 SCR temperature controller

Circuit possibilities are endless. Transistors may be introduced into the timing circuit to permit electronic control and feedback control circuits. However, in circuits of this type, the

stability of the firing angle becomes more critical. Since this is directly dependent upon the stability of the neon tube, it becomes a critical component. Lamps to meet such requirements with breakdown voltages held to within ± 3 volts are produced by Signalite as circuit components. The AO 57B is one of these and is designed for high current-pulse applications in electronic circuitry where a standard indicator-type lamp would be totally inadequate.

In some cases it may be possible to simplify full wave proportional circuits through the use of bidirectional triode semiconductor switches, such as the recently introduced G.E. Triac and others. Figure 9-10 shows a typical full wave 600 watt proportional controller. This circuit performs essentially the same function as the circuits shown in Figures 9-6 and 9-7.



9-10 Full wave proportional control using bidirectional semi-conductor switch

The semiconductor switch, being bidirectional, can be fired from either direction. Therefore, it is imperative that the breakdown voltage of the triggering neon lamp be the same in either direction. If the breakdown voltage in one direction differs from the breakdown voltage in the other direction, it can be seen that, when the phase angle is retarded for minimum power to the load, the power being delivered to the load will have a tendency to vary in a random fashion.

The A157B tube shown in this circuit was designed specifically to have symmetrical characteristics in this regard to within 5%. It will handle peak currents as high as 80 milliamperes and average currents of 2 milliamperes, well within the requirements imposed by the semiconductor switch.