MINISTRY OF HIGHER EDUCATION & SCIENTIFIC RESEARCH
DIYALA UNIVERSITY
COLLEGE OF ENGINEERING
ELECTRICAL POWER & MACHINE DEPARTMENT

INDUSTRIAL POWER ELECTRONIC LABROTORY

PRACTICAL EXPERIMENTS IN POWER ELECTRONIC

FOR STUDENTS OF THIRD STAGE

EXPERIMENT NO . 10

EXPERIMENT NA . UJT - SCR PHASE CONTROL .

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EXPERIMENT 10

UJT - SCR PHASE CONTROL .

A WORD OF THE CHIEF OF ELECTRICAL POWER & MACHINE DEPARTMENT

Dear students

I'm hoping you will be benefit from studying this experiment. ask your teacher about all problems that will accrued in connection of the experiment circuit &

look please ....

You must success in all measurements you followed according to the experiment procedure & You must getting about the products to be enabled in **phase control by using ujt-scr.** the discussion will help you in understanding & conclusion ,be remembered your answers must be right & limited.

Good luck

the Chief of electrical power & machine department

PH.D

NISREAN KHAMMASS SABAE

OBJECTIVE

1. Understanding the principle of phase control.
2. Understanding the operation of RC phase control circuit.
3. Studying the application of UJT relaxation oscillator in SCR phase control.

DISCUSSION

The basic purpose of industrial electronic controls is to regulate the transfer of energy from a source to a load. It may be a weld control to control the conversion of electrical energy to heat; it may be a motor control to control the conversion of electrical energy to mechanical force; or it may be a safety alarm to convert electrical energy to sound. If the energy transfer is at a constant rate, then the control may be as simple as an ON-OFF switch. Quite often it is necessary to adjust the rate of energy transfer to control the output, such as speed of a motor, loudness of an alarm, or brightness of a lamp.

The most convenient way to control the rate of energy transfer from an ac source is to control the portion of each cycle that current is allowed to flow into the load. This is accomplished in SCR and TRIAC circuits by controlling the phase angle at which the thyristor is turned on during each cycle of the ac voltage. The technique is called phase shift control.

Basic Phase Control Circuits

There are many forms of phase control possible with the thyristor, as shown in Fig. 10-1. The simplest form is the half-wave control of Fig. 10-1(a) which uses one SCR for control of current flow in one direction only. This circuit is used for loads which require power control from zero to one-half of full-wave maximum and which also permit (or require) direct current. The addition of one rectifier diode D, Fig. 10-1(b), provides a fixed half-cycle of power which shifts the power control range to half-power minimum and full-power maximum but with a strong dc component. The use of two SCRs, Fig. 10-1(c), controls from zero to full-power and requires isolated gate signals, either as two control circuits or pulse-transformer coupling from a single control. Equal triggering angles of the two SCRs produce a symmetrical output wave with no dc component. Reversible half-wave dc output is obtained by controlling symmetry of triggering angle.

An alternate form of full-wave control is shown in Fig. 10-1(d). This circuit has the advantage of a common cathode and gate connection for the two SCRs. While the two rectifiers prevent reverse voltage from appearing across the SCRs, they reduce circuit efficiency by their added power loss during conduction.

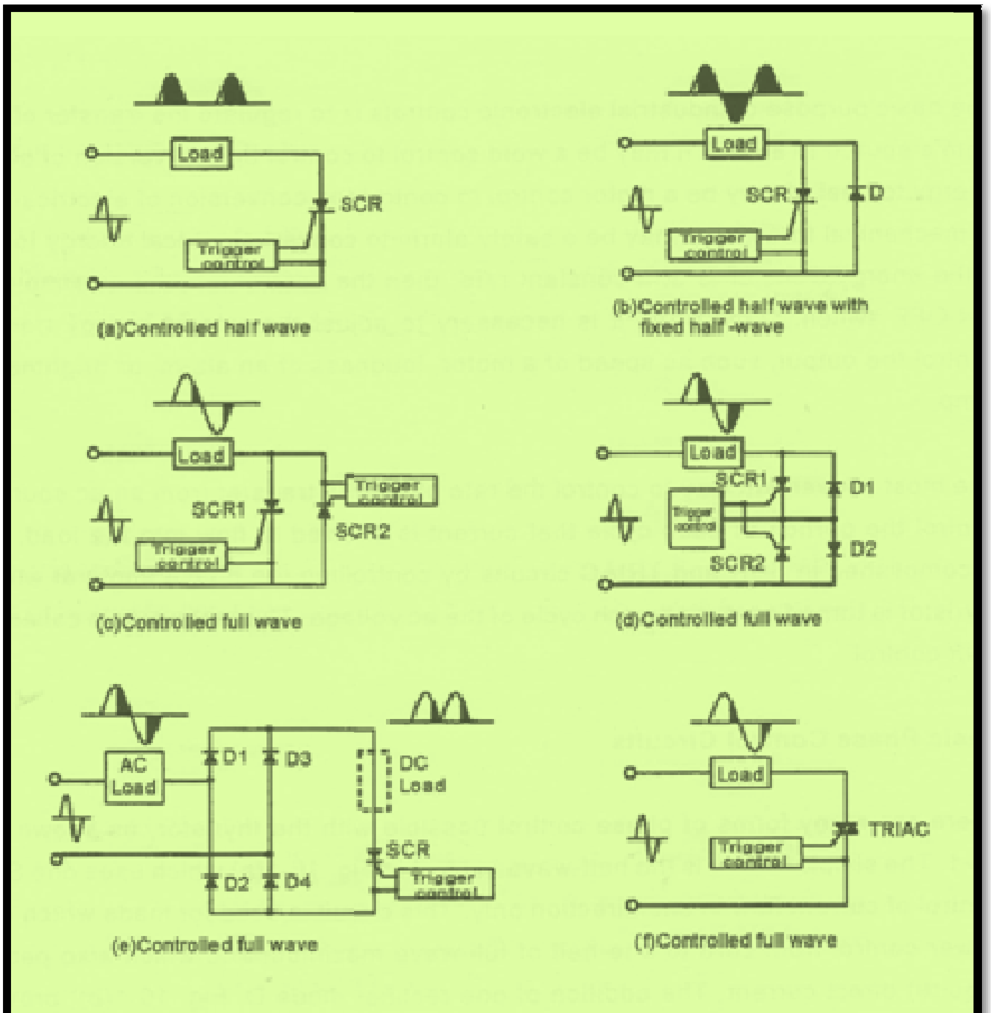


Fig.10-1 Basic types of AC phase control

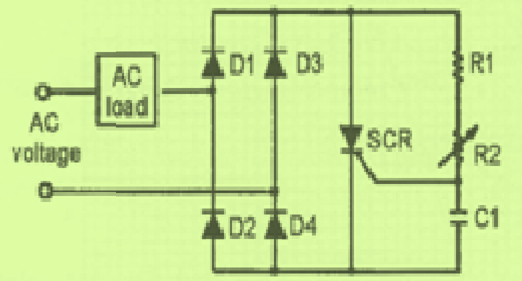


Fig.10-2 SCR power control with RC phase shift circuit

The most flexible circuit, Fig. 10-1(e), uses one SCR inside a bridge rectifier and may be used for control of either ac or full-wave rectified dc. When an AC load is used, it must be connected between ac voltage and bridge rectifier. If a DC load is desired, it should locate at the dotted block in Fig. 10-1(e). Losses in the rectifiers, however, make this the least efficient circuit form, and commutation is sometimes a problem.

By far the most simple, efficient and reliable method of controlling AC power is the use of the bidirectional triode thyristor, the TRIAC, as shown in Fig. 10-1(f). We will discuss the operation of this circuit in the description of experiment circuit section.

Analysis of Phase Shift Controls

1. Half-wave Control

Fig. 10-3 shows the voltage on the resistive load in SCR half-wave control circuit of Fig. 10-1(a). The average load voltage, E_{AVG}, is determined by controlling the firing angle of SCR. The relationship between E_{AVG} and α can be expressed by

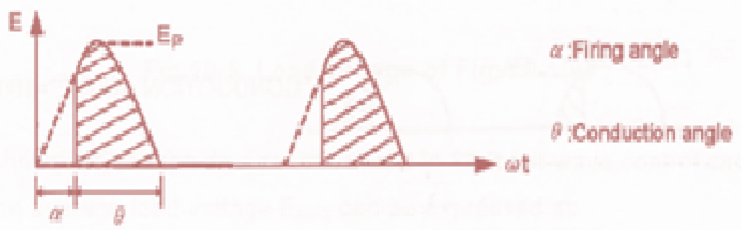


Fig.10-3 Load voltage of Fig.10-1(a)

$$E_{AVG} = \frac{1}{2\pi}\int_{\alpha}^{\pi} E_P \sin\omega t\, d\omega t$$
$$= \frac{E_P}{2\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$
$$= \frac{E_P}{2\pi}(1+\cos\alpha) \quad \text{------------------------- (10-1)}$$

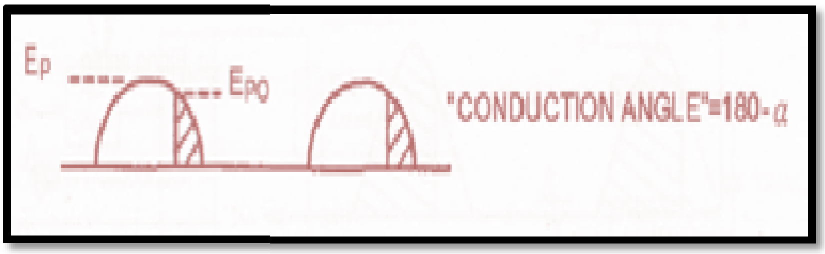
where E_P is the peak output voltage on the load. The rms value is calculated by

$$E_{RMS} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi} E_P \sin\omega t\, d\omega t}$$
$$= \sqrt{\frac{E_P^2}{2\pi}}\sqrt{\left[\frac{1}{2}(\omega t) - \frac{1}{2}\sin 2\omega t\right]_{\alpha}^{\pi}}$$
$$= \frac{E_P}{2\sqrt{\pi}}\left(\pi - \alpha + \frac{1}{2}\sin 2\alpha\right)^{\frac{1}{2}} \quad \text{------------------------- (10-2)}$$

Rearranging Eqs. (10-1) and (10-2), we obtain

$$\frac{E_{AVG}}{E_P} = \frac{1+\cos\alpha}{2\pi} \quad \text{------------------------- (10-3)}$$
$$\frac{E_{RMS}}{E_P} = \frac{1}{2\sqrt{\pi}}\left(\pi - \alpha + \frac{1}{2}\sin 2\alpha\right)^{\frac{1}{2}} \quad \text{------------------------- (10-4)}$$

Eqs. (10-3) and (10-4) shows the relationships between α, E_{AVG}, and E_{RMS} in an SCR half-wave phase control. They are very useful in designing phase shift control circuits. For convenience sake, the relationships can be indicated on a chart shown in Fig. 10-4.



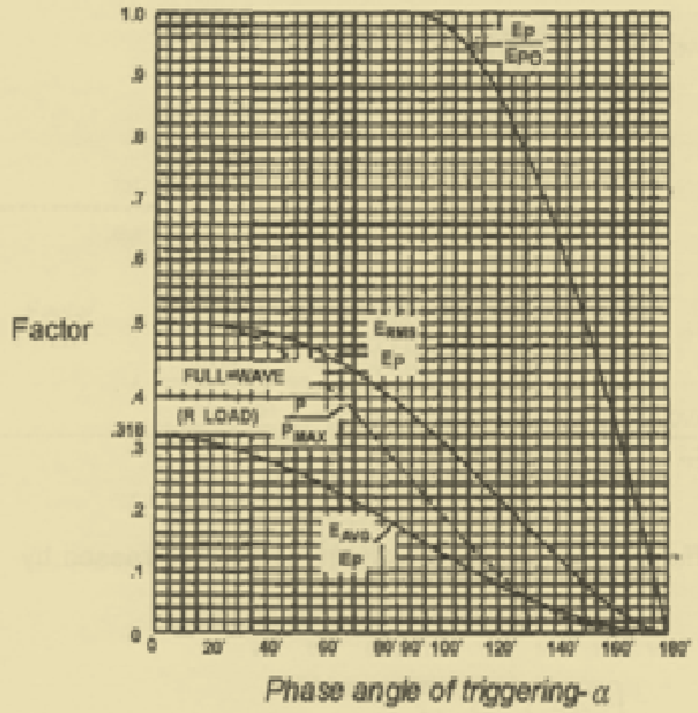


Fig.10-4 Chart for half-wave phase control analysis

In Fig. 10-4, the P/P_{MAX} curve indicates the ratios of full power supplied from ac source to the load power delivered to the resistive load. For example, the conduction angle of SCR is 180°, and the triggering angle is 180°-90°=0°, thus P/P_{MAX}=0.5.

2. Full-wave Control

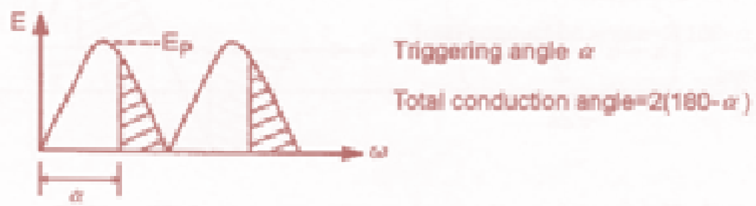


Fig.10-5 Load voltage of Fig. 10-1(e)

Fig. 10-5 shows the voltage on a resistive load in SCR full-wave control circuit of Fig. 10-1(e). The average load voltage E_{AVG} can be expressed as

$$E_{AVG} = \frac{1}{\pi}\int_{\alpha}^{\pi} E_P \sin\omega t \, d\omega t$$

$$= \frac{E_P}{\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$= \frac{E_P}{\pi}(1+\cos\alpha) \qquad \text{------------ (10-5)}$$

or

$$\frac{E_{AVG}}{E_P} = \frac{1+\cos\alpha}{\pi} \qquad \text{------------ (10-6)}$$

Therefore the effective value of load voltage can be expressed by

$$E_{RMS} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} E_P^{2} \sin^{2}\omega t \, d\omega t}$$

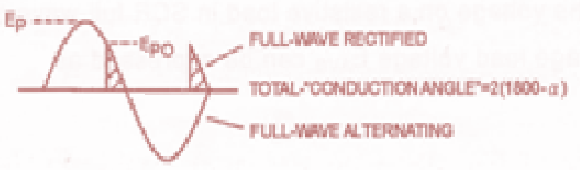
$$= \sqrt{\frac{E_P^{2}}{2\pi}}\sqrt{\left[\frac{1}{2}(\omega t) - \frac{1}{2}\sin^{2}\omega t\right]_{\alpha}^{\pi}}$$

$$= \sqrt{\frac{E_P^{2}}{2\pi}\left(\pi - \alpha + \frac{1}{2}\sin 2\alpha\right)} \qquad \text{------------ (10-7)}$$

or

$$\frac{E_{RMS}}{E_P} = \frac{\left(\pi - \alpha + \frac{1}{2}\sin 2\alpha\right)^{\frac{1}{2}}}{\sqrt{2\pi}} \qquad \text{------------ (10-8)}$$

Eqs. (10-6) and (10-8) can be indicated on the chart of Fig. 10-6.



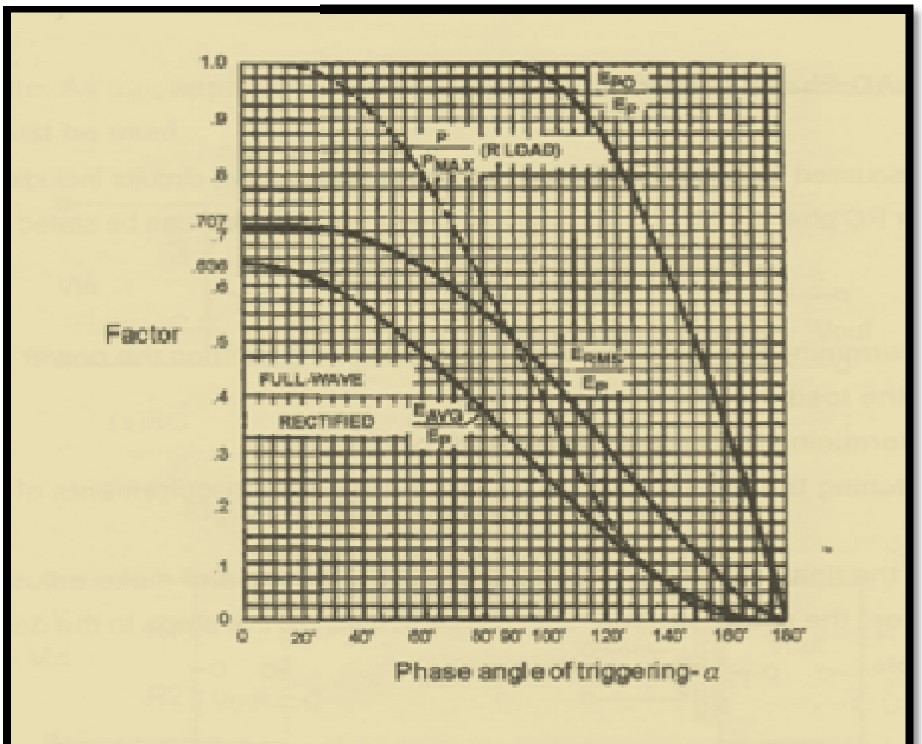


Fig.10-6 Chart for full-wave phase control analysis

Fig. 10-7 shows the voltage on a resistive load in the symmetrical full-wave control circuit of Fig. 10-1(c). The average load voltage E_{AVG} is zero. The effective load voltage E_{RMS} can be also calculated by Eqs. (10-7) and (10-8).

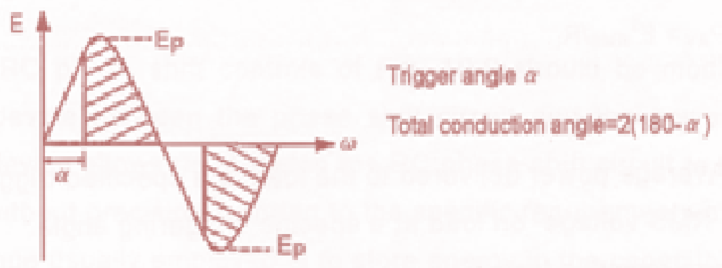


Fig.10-7 Load voltage of Fig. 10-1(c)

In the bridged SCR circuit of Fig. 10-1(e), from Fig. 10-6, the average load voltage at 113 degrees, is E_{AVG}= 0.194×340 = 66V and the average load current is 66 / 12 = 5.5A. ∴ Average current through each rectifier 5.5 / 2 = 2.75A.

If a TRIAC were used, Fig. 10-1(f), its rms current would be 10A with a conduction angle of 67° each half cycle.

Design of AC Phase Controls

We have discussed many applications of ac phase shift control circuits including either pulse generator or RC phase shift. The design of ac phase shift controls can be stated simply in three steps.

(1) Determining the firing and conduction angles based on the power requirements of the load and the source voltage.
(2) Determining the proper phase shift circuit.
(3) Matching the phase shift circuit to the triggering requirements of the thyristor.

Of course, the final test of any design is to build a model and make adjustments in the circuit to meet the specifications. Let us look at each of the steps in the design of phase shift controls.

A. *Determining the Firing and Conduction Angles*

Control specifications are generally stated in terms of the average power or rms voltage requirements of the load. The average power on load can be calculated by the formula

$$P_{AV} = E^2_{RMS}/R_L \quad (10\text{-}9)$$

where

P_{AV} : Average power delivered to the load at a specified triggering angle.
E_{RMS} : RMS voltage on load at a specific triggering angle.
R_L : Pure resistive load.

B. *Determining the Proper Shift Circuit*

As discussed above, the basic phase shift circuit used as a trigger circuit is generally formed by RC or RL networks. However RC networks are the most popular circuits in practical applications.

The type of phase shift circuit used will depend on the maximum value of α. If α_{max} is less than 90°, a single RC or RL phase shift circuit similar to Fig. 10-8 would be adequate. As α_{max} approaches and exceeds 90°, a bridged RC circuit similar to Fig. 10-9 must be used.

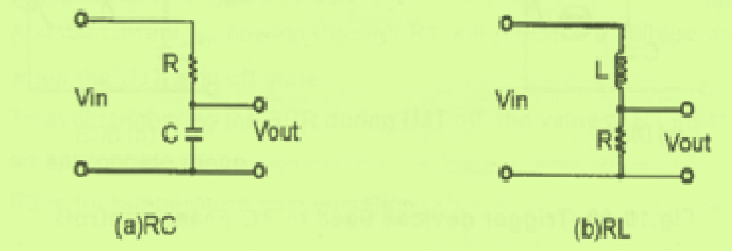


Fig.10-8 Simple phase shift circuits

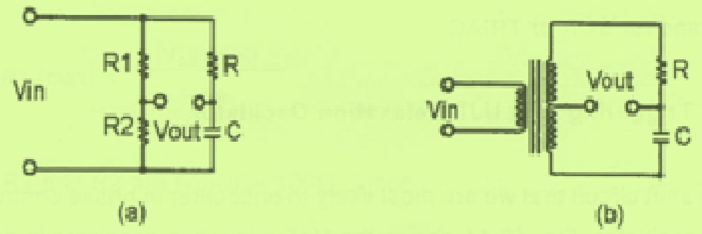
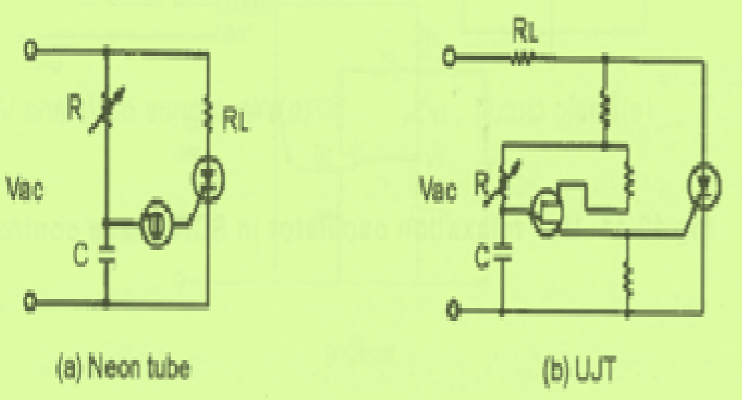


Fig.10-9 Bridged phase shift cirucits

C. Matching the Phase Shift Circuit to the Triggering Requirements of the Thyristor

The basic RC phase shift controls of Fig. 10-9 should be modified to show a triggering device between the phase shift circuit and the power thyristor. The triggering device allows us to match the RC phase shift circuit to a wide range of thyristors without precision tailoring to the specific requirements of each thyristor. The technique usually employed is to store energy in the capacitor and discharge the capacitor through the triggering device at the proper time. The resulting pulse of energy is usually sufficient to overdrive the gate of the thyristor.



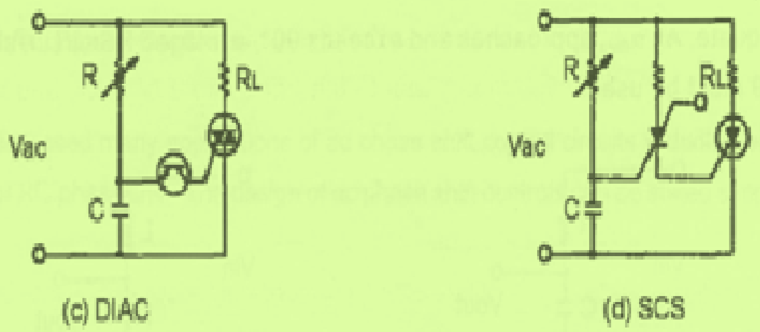


Fig.10-10 Trigger devices used in AC phase controls

Any semiconductor device with negative resistance characteristics can be used as a triggering device. Fig. 10-10 shows some basic applications of triggering devices often used for SCR or TRIAC.

SCR Gate Triggering with UJT Relaxation Oscillator

The phase shift circuit that we are most likely to encounter in phase controls is the UJT relaxation oscillator. Fig. 10-11 shows the UJT relaxation oscillator in an SCR phase control. We discussed the design of the UJT relaxation oscillator circuit. Recall that the oscillation frequency is determined by the values of timing elements R_T and C_T, or $f \cong 1/R_TC_T$. The voltage waveform at the emitter, V_E, is a sawtooth wave and that at base one, V_{B1}, is a positive pulse train, as shown in Fig. 10-11(b). The pulse train is connected to the gate of the SCR to control the power delivered to the load. For operating properly, we should concern with the following notes.

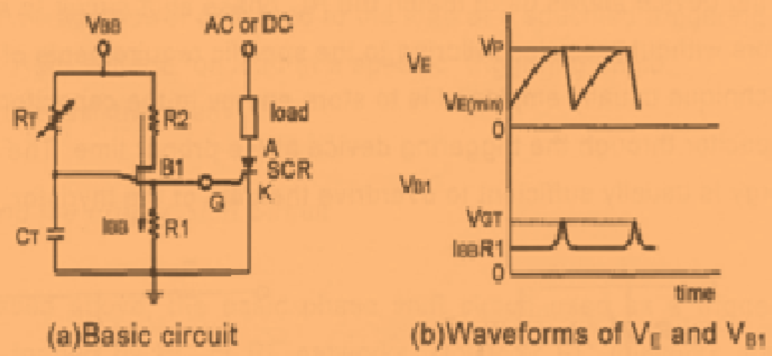


Fig.10-11 UJT relaxation oscillator in SCR phase control

(1) Time constant R_TC_T determines the conduction angle of SCR. The R_TC_T time constant is directly proportional to the firing angle of SCR, and is inversely proportional to the load power.

(2) A small current I_{BB} flowing through R1 will produce a voltage drop of I_{BB}xR1 when the UJT is in off state.

(3) To avoid triggering the SCR during UJT off, the value of R1 must be limited to an appropriate range.

(4) R2 is for temperature compensation.

The maximum value of R1 may be determined the minimum gate trigger voltage of SCR and the I_{BB} value. In Fig. 10-11(a), the mathematical relationship is:

$$R1\ (max) \leq \frac{V_{GK}\ (min)}{IBB} \qquad \text{.........(10-10)}$$

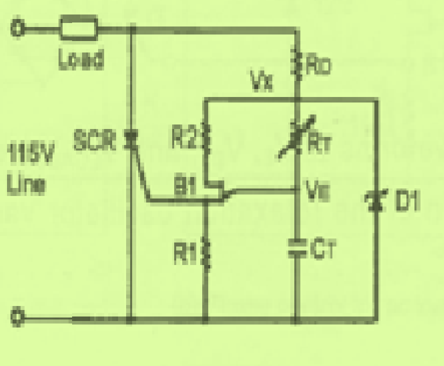
In practice, R1 and R2 are typically 100Ω. Since

$$rBB >> R1 + R2\ ;\ I_{BB} \approx \frac{V_{BB}}{rBB}$$

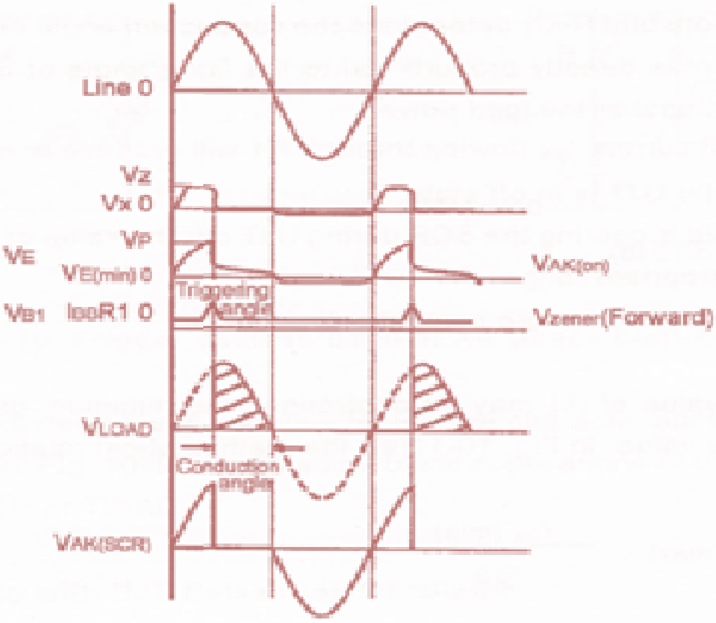
Substituting in Eq. (10-10),

$$R1\ (max) = \frac{V_{GK}\ (min)(rBB)}{V_{BB}} \qquad \text{.........(10-11)}$$

The main disadvantage of the circuit of Fig.10-11(a) is the use of split power supplies. The circuits of Figs.10-12 and 10-13 are available to improve the use of power supply in phase controls.



(a)Circuit



(b) Voltage waveforms

Fig.10-12 UJT-SCR half-wave phase control

Fig. 10-12(a) shows an UJT-SCR half-wave phase control circuit. Resistor RD and zener diode D1 regulate the ac line voltage to maintain a fixed potential V_Z for the UJT relaxation oscillator. The waveforms in the circuit are shown in Fig. 10-12(b). The operation of this circuit is similar to the circuit of Fig. 10-1. We summarize the operation as follows:

(1) The zener diode D1 provides a fixed dc voltage for the UJT relaxation oscillator and protects the UJT.

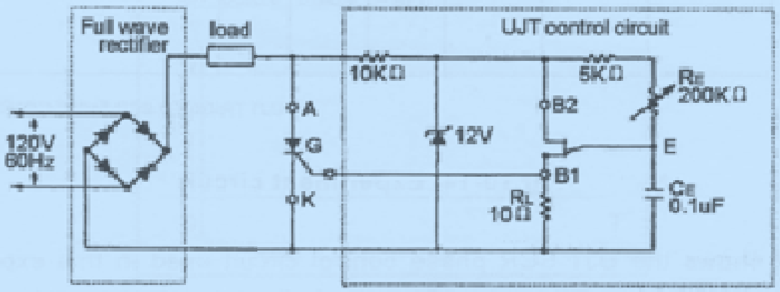
(2) The emitter voltage is a sawtooth wave and the voltage at B1 is a pulse train, see Fig.10-12(b).

(3) Comparing the waveforms of V_E, V_{B1}, and V_{LOAD}, we see that as R_T varies, the period of oscillation of the relaxation oscillator varies so the phase angle of triggering will vary.

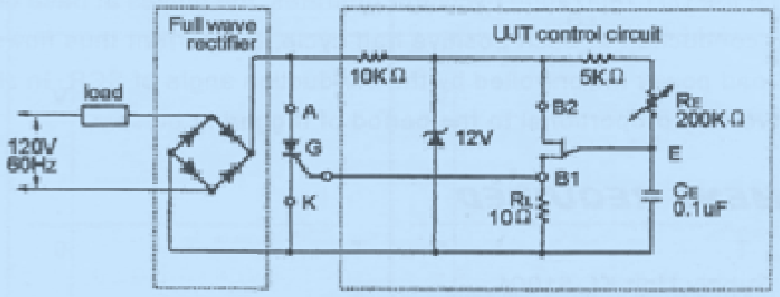
(4) Once the SCR is triggered to conduction during a positive half cycle, the voltage supplied to the UJT circuit will be lowered to a very small potential. Hence no trigger pulse occurs in the remainder portion of half cycle.

(5) When the SCR is off, the zener current still flows through the load and R_D. The zener current must be minimized by using an appropriate value of R_D, typically $R_D >> R_{load}$.

The circuit of Fig. 10-12 may use with a variety of loads such as motor, lamp, and electric heater. Taking power efficiency into consideration, full-wave phase control circuits shown in Fig. 10-13 are available in dc or ac loads. The circuit of Fig.10-13(a) is for dc loads and Fig. 10-13(b) is for ac loads.



(a) Phase control for dc load



(b) Phase control for ac load

Fig.10-13 AC phase control circuits

Description of Experiment Circuit

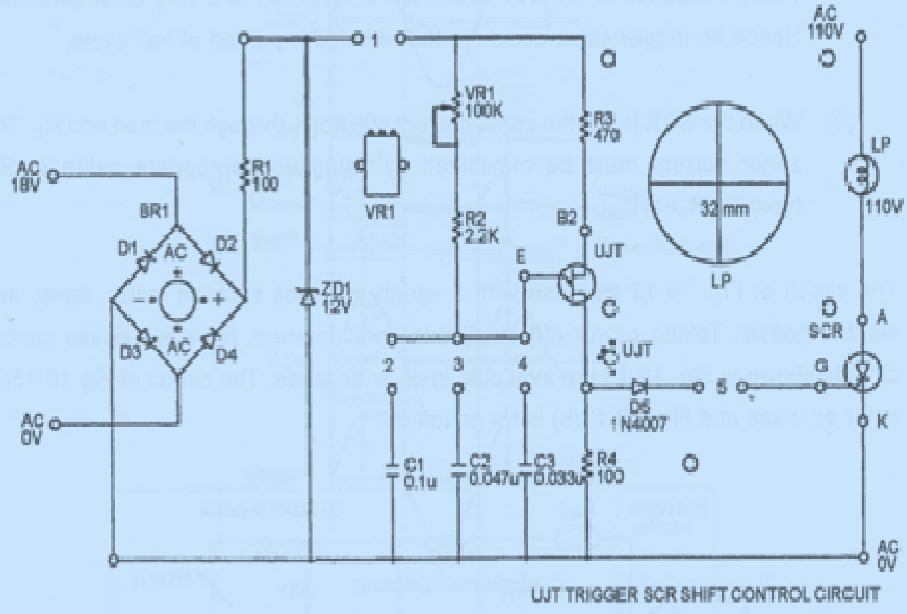


Fig.10-14 Experiment circuit

Fig. 10-14 shows the UJT-SCR phase control circuit used in this experiment. The bridge rectifier, D1 to D4, provides a pulsating dc form the 18V ac voltage. Zener diode ZD1 clamps the pulsating dc voltage at 12V for the relaxation oscillator. Resistor R1 protects the zener from over-current damage.

When no gate triggering pulse is applied to the gate of SCR, the SCR is in off state and lamp is off. If the UJT relaxation oscillator operates, the pulses at base one will trigger the SCR to conduction at each positive half cycle, the current thus flows through the lamp. The load power is controlled by the conduction angle of SCR. In short, the load power is inversely proportional to the period of triggering pulse.

EQUIPMENT REQUIRED

1 – Power Supply Unit KL-51001
1 – Isolation Transformer KL-58002
1 – Module KL-53005
1 – Oscilloscope

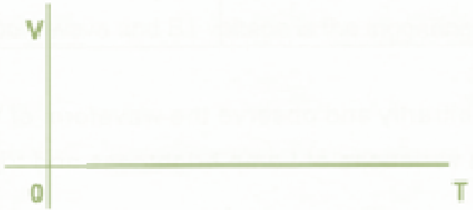
PROCEDURE

1. Locate the UJT trigger SCR shift control circuit, shown in Fig. 10-14,on Module KL-53005. Apply 18V AC voltage to this circuit from Power Supply Unit KL-51001 - KL-58002.

2. Insert the short-jumpers in positions 1, 2, and 5. Rotate the VR1 fully counterclockwise to get the minimum resistance.

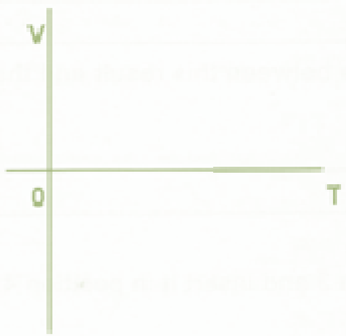
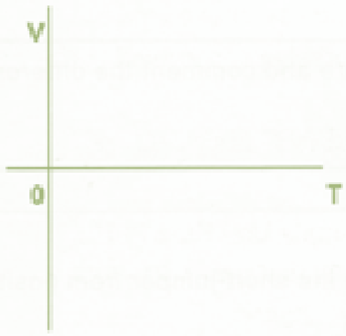
3. Using the oscilloscope, measure the voltage waveform across the zener diode ZD and record the result in Table 10-1.

Table 10-1

ZD


4. Using the oscilloscope, measure the voltage waveforms at the B_1 of UJT and across the anode-cathode (A-K) of SCR, and record the results in Table 10-2. Observe and record the brightness of lamp. ___________

Table 10-2

A	B1
	

5. Set the VR1 to the midposition. Repeat step 4 and record the results in Table 10-3.

Observe and record the brightness of lamp. ___________

Table 10-3

A	B1
	

6. Rotate the VR1 arbitrarily and observe the waveform of V_{AK} and the brightness of lamp. Record the variations of Lamp brightness and triggering angle.

7. Remove the short-jumper from position 2 and insert it in position 3. Repeat steps 4 and 5.

8. Rotate the VR1 arbitrarily and observe the waveform of V_{AK} and the brightness of lamp. Record the variations of lamp brightness and triggering angle.

Compare and comment the difference between this result and the result of step 6.

9. Remove the short-jumper from position 3 and insert it in position 4. Repeat steps 4 and 5.

10. Turn the VR1 arbitrarily and observe the waveform of VAK and the brightness of lamp. Record the variations of lamp brightness and triggering angle.

Compare and comment the difference between this result and the result of step 8.

CONCLUSION

In this experiment we found that as VR1 varies, the period of oscillation of UJT relaxation oscillator varies so the conduction angle of SCR will vary. The emitter voltage of UJT is a sawtooth wave and B1 voltage is the triggering pulse for SCR.