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 . 7

EXPERIMENT NA . SCR & RC PHASE CONTROL .

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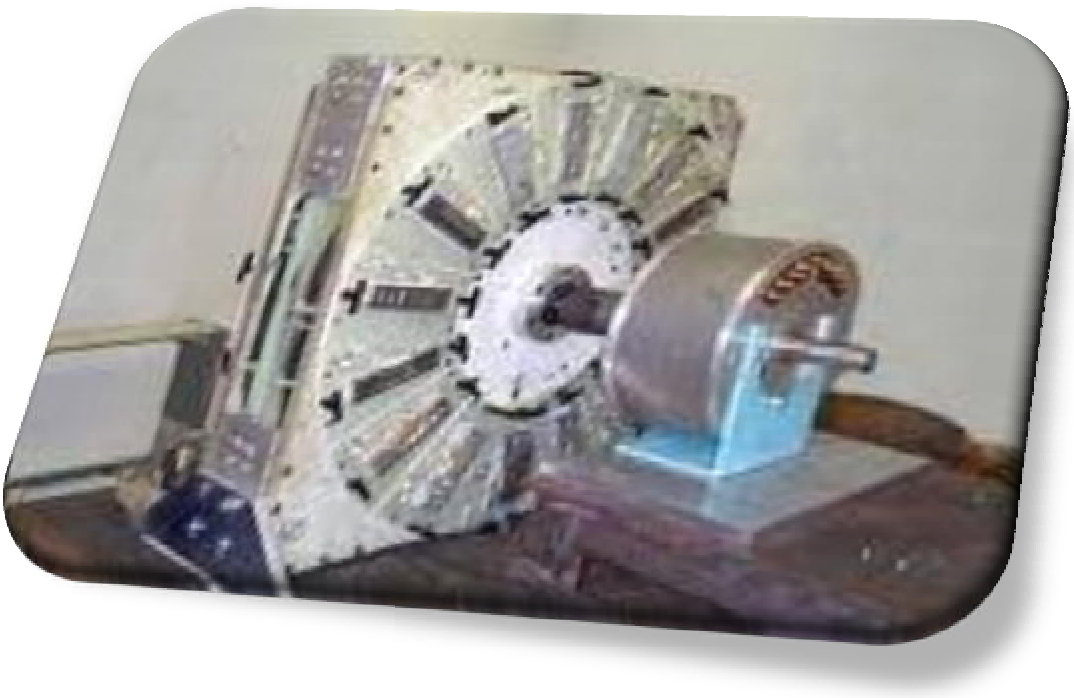

EXPERIMENT 7

SCR & RC 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 s c r & r c phase control. 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 construction and characteristics of an SCR.
2. Understanding the operation of an SCR.
3. Measuring an SCR with ohmmeter.
4. Understanding the gate triggering modes of SCR.

DISCUSSION

The silicon-controlled rectifier (SCR) is the most important thyristor in the family of PNPN devices. It was developed by General Electric in 1957. The SCR acts as a switch in an AC power control circuit.

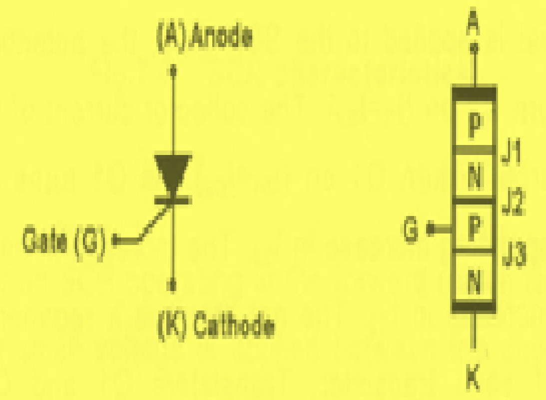

Fig.7-1 SCR. (a) circuit symbol, (b) PNPN structure.

SCR Operation

The SCR is a PNPN four-layer semiconductor device having three terminals: anode (A), cathode (K), and gate (G). The symbol and construction for an SCR are shown in Fig. 7-1. In most control applications, the control signal is applied between the gate and the cathode while the load is connected to either the anode or the cathode in series. The circuit symbol of the SCR is illustrated in Fig. 7-1(a). The direction of arrow refers the direction of anode current.

The PNPN four-layer structure for the SCR, shown in Fig. 7-1(b), can be considered as PNP and NPN transistors connected as the manner of Fig. 7-2. We will discuss the operation of an SCR by referring to this equivalent two-transistor circuit.

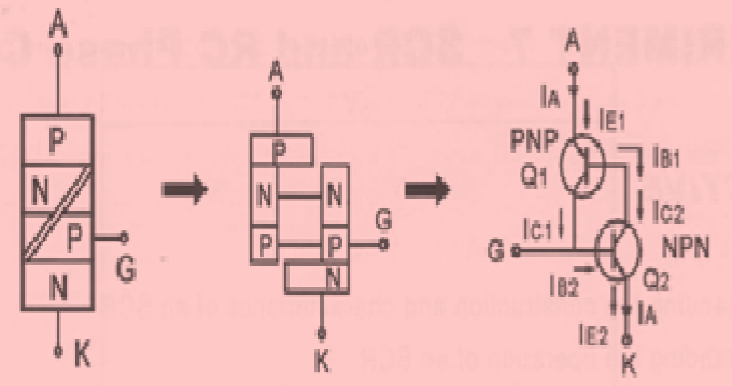

Fig.7-2 Two-transistor analogy of PNPN structure

When the gate is open and a forward voltage is applied between the anode and cathode (terminal A is positive with respect to terminal K), the SCR is in off state due to the absence of base currents of transistors Q1 and Q2. Such a situation only a small leakage current flows through the SCR.

If a positive potential is applied to the SCR gate, the potential VG will produce a gate current I_G to turn Q2 on ($I_G=I_{B2}$). The collector current of Q2 will then rise to a value sufficiently large to turn Q1 on ($I_{B1}=I_{C2}$). As Q1 turns on, I_{C1} will increase, resulting in a corresponding increase in I_{B2}. The increase in base current for Q2 will result in a further increase in I_{C2}. The net result is a regenerative increase in the collector current of each transistor. Transistors Q1 and Q2 will conduct into saturation in a very short time. The resulting anode-to-cathode resistance of an SCR is then very small so that a very large current flows from the anode to cathode. Thus the SCR is turned on. Obviously, removal of the gate signal will not result in the SCR turning off as long as there is sufficient forward anode-to-cathode voltage to maintain a holding current I_H. In other words, once conduction has been initiated, the gate signal serves no useful purpose and may be removed. The methods used to turn off the SCR will be introduced later.

SCR Characteristic Curves

The basic anode characteristic of the SCR is provided in Fig. 7-3 for $I_G = 0$. The reverse characteristic in quadrant III (the anode to the negative, the cathode to the positive) is similar to the characteristic of a diode operating in reverse bias. The peak reverse breakdown voltage (PRV) is defined as the maximum instantaneous negative voltage that should ever be applied at the anode under any conditions. The value of PRV depends on the coefficient of resistance of semiconductor and the thickness of base of PNP transistor. When the applied reverse voltage is smaller than the PRV value, the SCR is in off state and only a very small leakage current flows in the anode. If the reverse voltage is greater than PRV, a large amount of current will flow and result in the damage to the SCR.

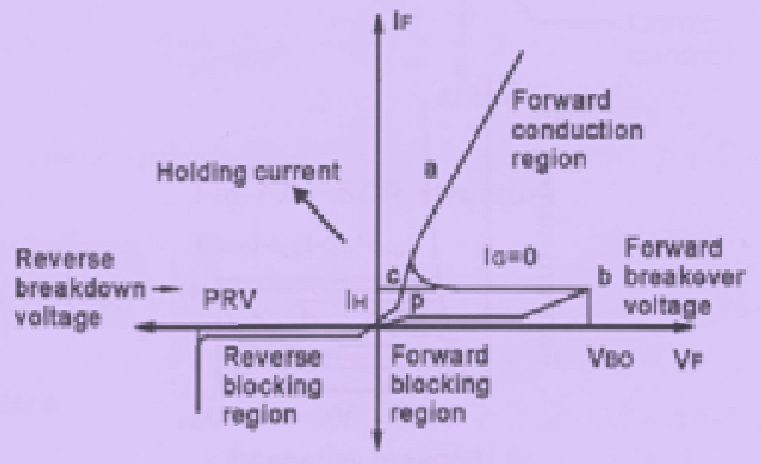

Fig.7-3 SCR characteristics

The characteristic of an SCR operating in the forward region is shown in quadrant I of Fig. 7-3. When a small voltage is applied between the anode and cathode, the SCR is not turned on and only small leakage current flows in the anode. As the voltage between the anode and cathode (V_{AK}) is increased to a specified value called V_{BO}, the SCR is turned on and a large amount of current flows in the anode. The V_{BO} is known as the forward breakover voltage of the SCR at $I_G=0$.

The value of V_{BO} depending on the α values of internal transistors and PRV value is given by

$$V_{BO} = PRV(1-\alpha 1-\alpha 2)^{\frac{1}{n}} \quad \text{.......(7-1)}$$

where n is constant and lies between 2 and 3 for a silicon material. From Eq. (7-1), it is seen that the magnitude of V_{BO} should be slightly smaller than the PRV rating for an ideal SCR. In practical applications, these two values are usually considered as the same.

Consider the SCR conducting in its forward conduction region. A decrease in the anode voltage V_{AK} will cause the anode current to decrease, as indicated on the line a of Fig. 7-3. When the anode current is smaller than the current value at point P, the SCR is therefore turned off. The current value at P is called the holding current, I_{HO}, which is the minimum anode current to maintain the SCR in on state.

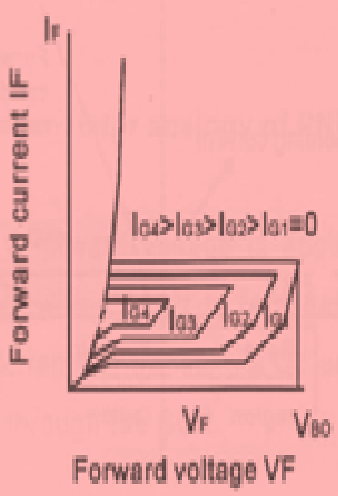

Fig.7-4 SCR output characteristics with variable gate current

The SCR characteristic curve in Fig. 7-3 is plotted with the gate open. If the external signal is applied to the gate, the gate current will change the forward breakover voltage of the SCR. As shown in Fig. 7-4, an increase in I_G will cause the V_{BO} to decrease. That is, the greater the I_G, the smaller the V_{BO}. In other words, the magnitude of gate current determines the voltage to fire the SCR.

SCR Structure

The SCR is a PNPN four-layer semiconductor device. The performance and reliability of SCR depend on materials, processes, and designs. Some processes of semiconductor technology are commonly used to produce an SCR. These are grown, alloy, and diffusion. The impurity diffusion processing, as shown in Fig. 7-5, is made by diffusing p-type impurities into the n-type material under high temperature condition.

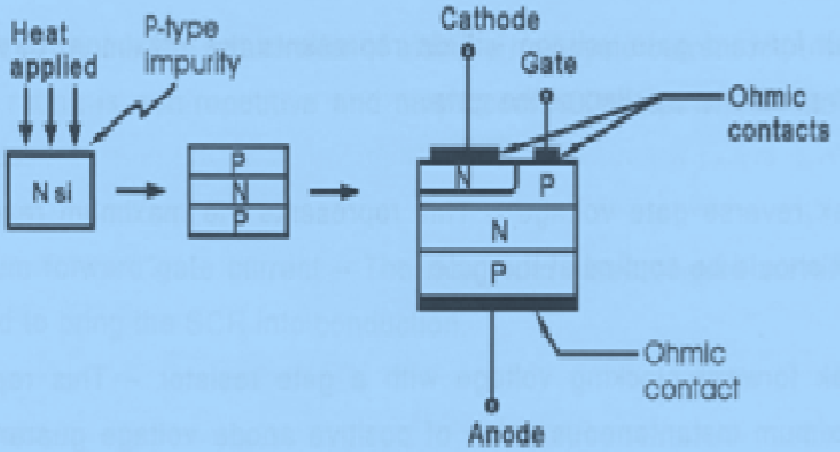

Fig.7-5 SCR structure

SCR Parameters and Definitions

Voltage Parameters

V_{RRM}: Repetitive peak reverse voltage – This represents the maximum reverse voltage that can be repeatedly applied to the SCR with the gate circuit open and still block current flow. It is also called peak reverse breakdown voltage (PRV).

V_{RSM}: Non-repetitive peak reverse voltage – This represents the maximum transient reverse voltage level that should be applied to the SCR under reverse blocking conditions with the gate circuit open.

V_{FOM}: Peak forward blocking voltage – This represents the maximum instantaneous value of positive anode voltage guaranteed by the manufacturer to maintain the blocking capability of the SCR with the gate circuit open. If this voltage value exceeded, even by transients, the SCR might go into condition. It is also called the forward blockover voltage (V_{BO}).

PFV: Peak forward voltage – This represents the maximum instantaneous positive voltage that should ever be applied at the anode under any conditions. If this voltage is exceeded, even under transient conditions, then the SCR might be permanently damaged.

V_{GFM}: Peak forward gate voltage – This represents the maximum forward voltage that should be applied at the gate.

V_{GRM}: Peak reverse gate voltage – This represents the maximum reverse voltage that should be applied at the gate.

V_{DRM}: Peak forward blocking voltage with a gate resistor – This represents the maximum instantaneous value of positive anode voltage guaranteed by the manufacturer to maintain the blocking capability of the SCR with a gate resistor added.

V_{GT}: DC gate trigger voltage – This represents the dc voltage applied to the gate and the cathode required producing the gate trigger current.

V_F: Instantaneous forward voltage drop – This represents the voltage drop between the anode and the cathode when the SCR is in on state, typically 1~2V.

Current Parameters

$I_{F(av)}$: Maximum average forward current – The maximum continuous average value of current that the SCR may conduct for various conduction angles. It is also called the forward dc current I_{DC}.

$I_{F(RMS)}$: Maximum RMS forward current – The maximum value of RMS current that the SCR may conduct. It is frequently called I_F.

I_{GT}: DC gate trigger current – The minimum DC gate current required to switch an SCR from off state to on state.

I_H: Holding current – That value of forward anode current which allows the device to remain in conduction. Below this value the device will return to a forward blocking state at the prescribed gate conditions.

I_{HO}: Holding current with gate open – That value of forward anode current which allows the device to remain in conduction with the gate open.

I_{surge}: Surge current – The peak value of a single half cycle current impulse at 60 Hz. This rating is non-repetitive and may occur 100 times within the life of the device.

I_{GF}: Maximum forward gate current – The maximum value of gate current that may be used to bring the SCR into conduction.

Miscellaneous

I^2t: I square t – This term describes the maximum, forward, non-repetitive overcurrent capability of the SCR. It is normally used to describe device capabilities for 1/2 cycle of 60Hz current impulse.

P_{GM}: Peak gate power dissipation – The maximum instantaneous product of gate current and gate voltage allowed to exist during any or all forward bias conditions.

t_d: Delay time – The time interval between the 10% point of the leading edge of the gate current pulse and the 10% point of the anode current waveform as indicated in Fig. 7-6.

t_r: Rise time – The term is defined as the time required for the anode current to rise from 10% of its final value to 90% as indicated in Fig. 7-6.

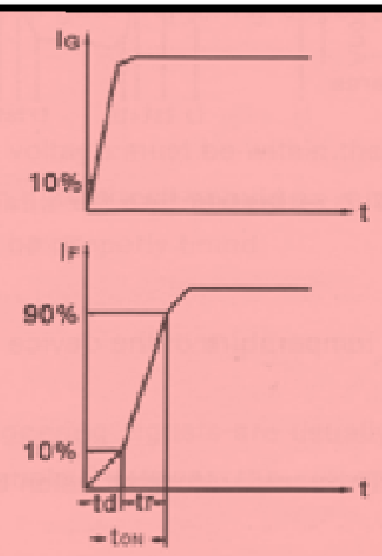

Fig.7-6 Illustration for t_{on}, t_d and t_r

t_{on}: Turn-on time – The time interval between a specified point at the beginning of the gate pulse and the instant when the device voltage (current) has dropped (risen) to a specified low (high) value during switching of an SCR from off-state to the on-state by a gate pulse. Referring to Fig. 7-6, $t_{on} = t_d + t_r$.

t_{off}: Turn-off time – The time interval between the instant when the SCR current has decreased to zero after external switching of the SCR voltage circuit, and the instant when the SCR is capable of supporting a specified voltage wave from without turning on, as shown in Fig.7-7.

t_{rr}: Reverse recovery time – The time required for the device current or voltage to recover to a specified value, usually 10% of maximum value, after instantaneous switching from an on-state to a reverse voltage or current, as shown in Fig.7-7.

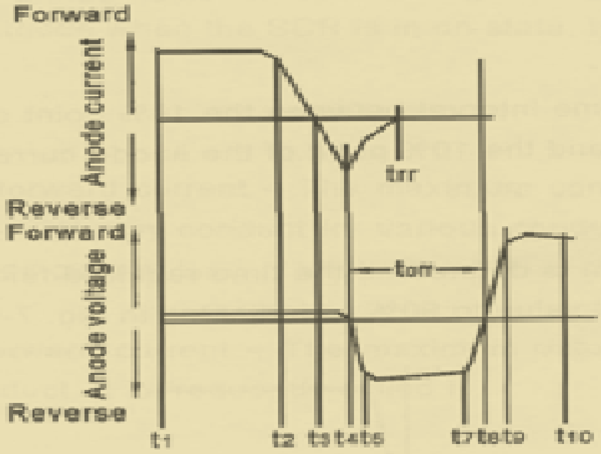

Fig.7-7 Illustruction for t_{rr} and t_{off}

T_C: Case temperature – The temperature of the device case under specified load conditions.

T_{stg}: Storage temperature – The temperature at which the device may be stored without harm.

dv/dt : Critical rate of rise of off-state voltage – The minimum value of the rate of rise of forward voltage which will cause switching from the off-state to the on-state.

di/dt: Critical rate of rise of on-state current – The maximum value of the rate of rise of on-state current which an SCR can withstand without being harmed. Initially when a gate signal is applied to the SCR, conduction is limited to a relatively small area near the gate, and the initial flow of anode current as the device begins to conduct will be concentrated in this area. Conduction spreads across the cathode area of the SCR at a rate of about 1 cm per 100 μsec. As a result, if the rate at which the anode current increases is far greater than the rate at which the conduction area is increasing, there will be a high power density in this area, resulting in local hot spots with excessively high temperatures and possibly permanent damage to the SCR. The di/dt rating is usually defined in the data sheets. Typical values are from 100A/μS to 200A/μS.

SCR Triggering Characteristics

From the characteristics of the SCR mentioned above, it can be seen that two conditions must be met to fire an SCR. They are:

(1) Anode voltage should be positive with respect to the cathode;
(2) Gate voltage should be positive with respect to the cathode.

We have found that successful gate triggering depends on the satisfaction of three conditions:

(1) Trigger current and voltage must be within the triggering area;
(2) Power dissipation in gate circuit should be minimized;
(3) Trigger signal must be properly timed.

SCR Gate Triggering

Three basic types of gate triggering signals are usually used. These are dc signals, pulse signals and ac shift signals. However, the pulse triggering is the most popular type.

DC Triggering

DC triggering signal is rarely used in practical SCR applications. The circuit of Fig. 7-8(a) shows an SCR operating with dc supply and dc triggering signal. When switch S is closed, a sufficient gate current causes the SCR to turn on. The current-limiting resistor R is used to ensure the gate dissipation within its rating. This circuit acts as a dc switch, which uses a low power signal to control a high power load. If a high power load such as a power relay is used, this circuit can control an ac power with a dc signal.

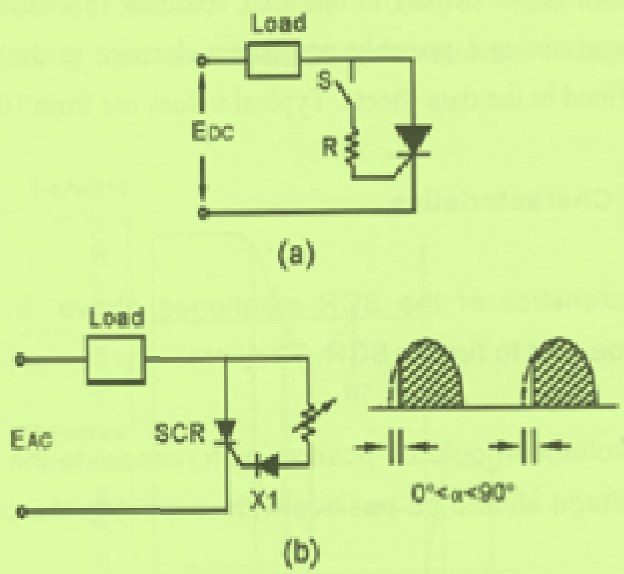

Fig.7-8 DC triggering circuits

Fig. 7-8(b) shows the SCR circuit operating in ac supply and dc triggering. The SCR conducts in the positive half cycle of ac supply voltage and cuts off in the negative half cycle. Therefore the maximum conduction angle of the SCR is 180°. During the positive half cycle, the diode X1 is forward-biased and thus the gate current turns on the SCR. The gate current is controlled by the variable resistor in gate circuit. By adjusting the resistance value the firing angle α can be changed between the limits of 0 and 90°.

AC Phase Shift Triggering

The basic SCR phase shift control is shown in Fig. 7-9(a). The purpose of the ac phase shift circuit is to delay application of triggering voltage at the gate until the ac voltage reaches the phase angle α. The α is called the firing angle. Current is supplied to the load for the remaining portion of the positive anode voltage. The portion of the positive anode cycle when load current flows, θ, is called conduction angle. Now let's take a look at the ac phase shift circuits that are commonly used.

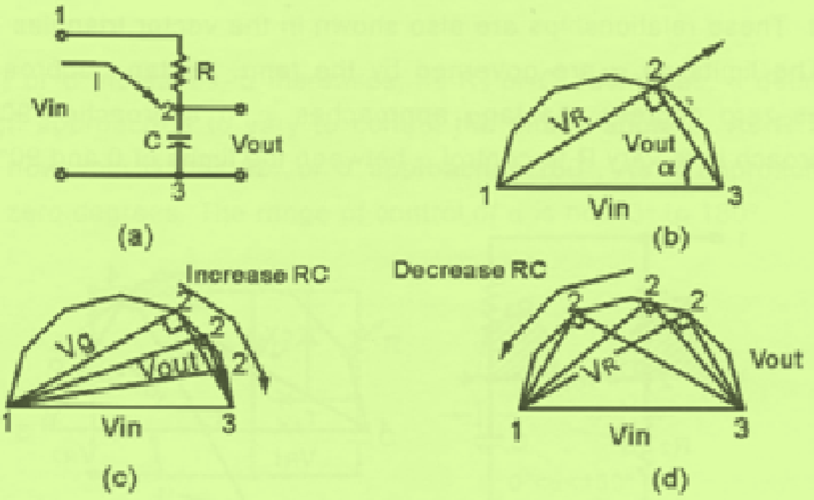

Fig.7-9 Basic RC phase shift circuit and phasor diagram

Fig. 7-9(a) shows the basic RC phase shift circuit. Fig. 7-9(b) shows the vector diagram of voltage relationships if the output is taken across the capacitor. The input voltage $V_{1\text{-}3}$, is used as the reference. The voltage across the resistor, $V_{1\text{-}2}$, will be in phase with the current in the loop, thus leading $V_{1\text{-}3}$. Since $V_{1\text{-}3}$ must be the sum of $V_{1\text{-}2}+V_{2\text{-}3}$, the triangle must be closed, so the vector 2-3 is drawn from the tip of $V_{1\text{-}2}$ to the tip of $V_{1\text{-}3}$. You will recall that the current through the capacitor must lead the voltage across the capacitor by 90° in an ac circuit. This accounts for the right angle that must occur at the intersection of $V_{1\text{-}2}$ and $V_{2\text{-}3}$. The phase angle between V_{out} and V_{in} is the delay angle, α. From the triangle of Fig. 7-9(b)

$$\tan\alpha = \frac{VR}{Vout} = \frac{IR}{IXc} = \frac{R}{Xc} = \frac{R}{1/\omega C} = R\omega C \quad \text{.......................(7-2)}$$

where R = resistance in ohms

C = capacitance in farads

ω = radian frequency in rad/s

From Eq. (7-2), as R or C is increased, α is increased; as R or C is decreased, α is decreased. These relationships are also shown in the vector triangles of Fig. 7-9(c) and (d). The limits on α are governed by the tanα. As tanα approaches zero, α approaches zero degrees. As tanα approaches ∞, α approaches 90°. The usual circuit approach is to vary R to control α between the limits of 0 and 90°.

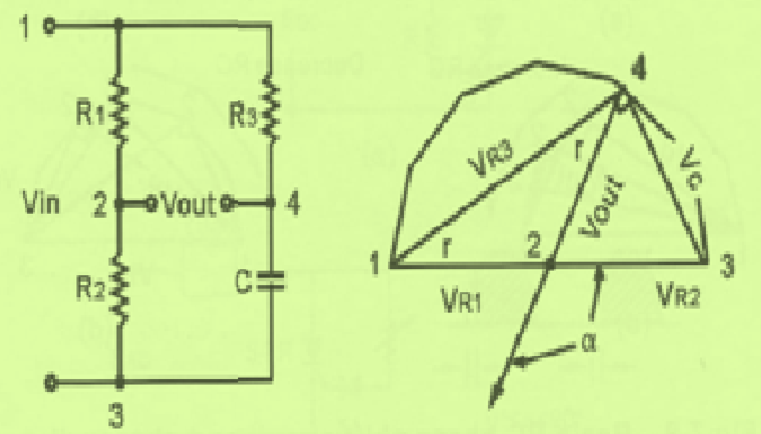

Fig.7-10 Extend RC phase shift circuit and phasor diagram

The range of control of α can be extended by using the circuit of Fig. 7-10(a). The bridge circuit is formed by placing two equal resistors across the input. The output is then taken across the bridge. The voltage relationships are shown in Fig. 7-10(b). It can be shown that the locus of point 4 lies on a semicircle whose diameter is $V_{1\text{-}3}$. The magnitudes of $V_{1\text{-}2}$, $V_{2\text{-}3}$, and $V_{2\text{-}4}$ are all equal. The angle γ is the impedance angle of the RC circuit. Then

$$\tan\gamma = \frac{X_C}{R3} = \frac{1}{R3\omega C}$$

From the triangle 1-2-4

$$\alpha = 180° - 2\gamma = 2\,(90° - \gamma)$$

or

$$\frac{\alpha}{2} = 90° - \gamma$$

Using the trigonometric relationship,

$$\tan\frac{\alpha}{2} = \tan(90° - \gamma) = \cot\gamma = R3\omega C \qquad \text{(7-3)}$$

Again, as R_3 or C increases, α increases; as R_3 or C decreases, α decreases. The useful design approach is to vary to control the phase angle α. As R approaches infinity, $\alpha/2$ now approaches 90° or α approaches 180°. As R approaches zero, α approaches zero degrees. The range of control of α is now 0° to 180°.

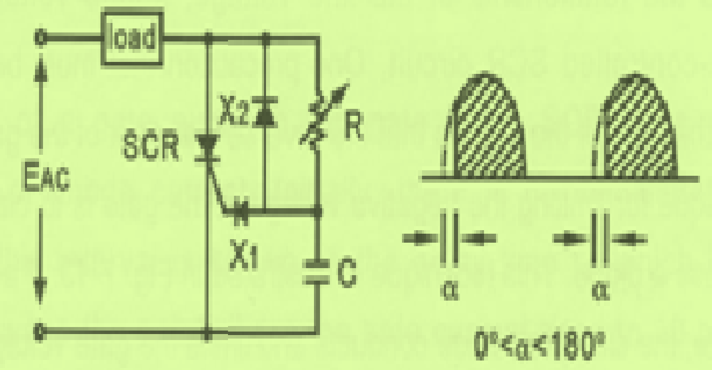

Fig.7-11 RC phase shifting control the firing angles of SCR

Fig. 7-11 shows the basic RC phase shift network used to trigger the SCR. The capacitor voltage lags the supply voltage E_{AC} in an angle of α controlled by R. Diode X1 is used to prevent the damage from the negative voltage applied to the gate. Diode X2 is used to ensure that the capacitor charges to the peak value on the negative half cycle.

Pulse Triggering

The gate-to-cathode junction of the SCR is essentially a PN junction. Whenever voltage is applied at the junction such that a forward bias is achieved, current flows across the junction and power is dissipated in the form of heat. Gate power dissipation can be minimized by using a pulse triggering source rather than a continuous signal.

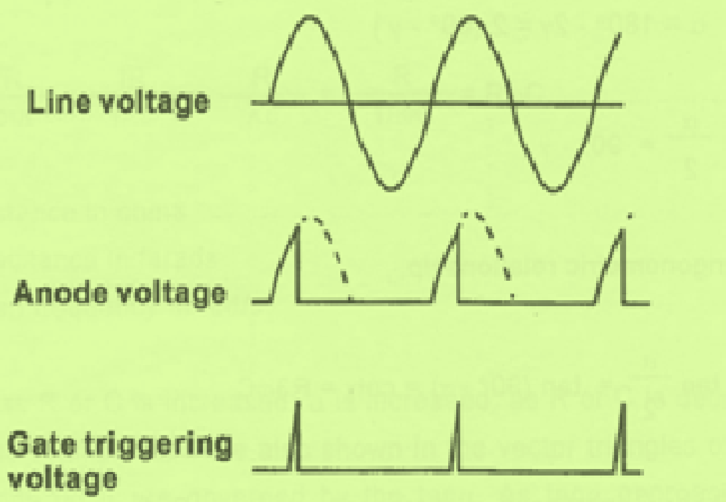

Fig.7-12 Waveforms in ac-controlled SCR circuit

Fig. 7-12 shows the relationship of the line voltage, anode voltage and triggering pulses in an ac-controlled SCR circuit. One precaution that must be taken in applying pulse sources at the gate of the SCR is that the reverse bias limit of the gate is not exceeded. A common technique for limiting the negative voltage at the gate is to clamp the gate to the forward drop across a diode. This technique is illustrated in Fig. 7-13. If a negative voltage is applied at the gate, the clamping diode conducts and limits the gate voltage to approximately -0.7V.

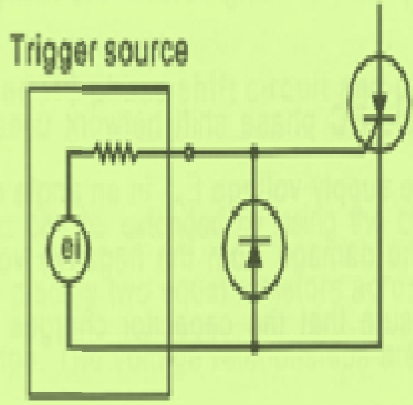

Fig.7-13 Clamping the gate reverse bias with a rectifier diode

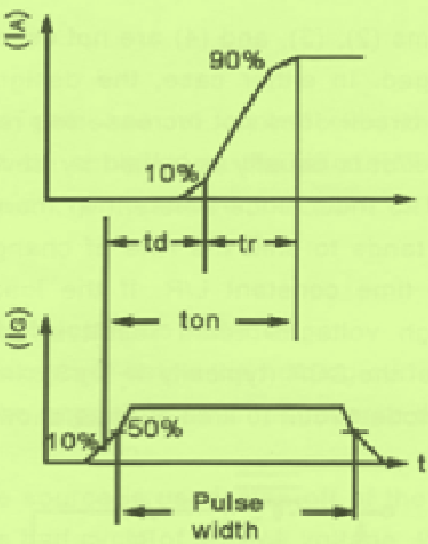

Fig.7-14 Relationship among t_d, t_r and t_{on}

The application of a gate pulse to the gate of an SCR does not result in the immediate flow of anode current. Initially, there is no significant increase in the anode current, this interval is known as the delay time t_d, which is defined as the time interval between the point where the gate current rises to 10 percent of its final value and the instant when the device current has risen to 10 percent of the final value of anode current. Similarly, the rise time t_r is the time interval between when the anode current has increased from 10 percent to 90 percent of its final value. The turn-on time t_{on} is equal to t_d+t_r, and is approximately 2μs. The relationship among t_d, t_r, and t_{on} is shown in Fig. 7-14.

Turn-on of SCR

An SCR may be triggered into conduction by:

(1) applying a positive triggering signal to the gate;
(2) exceeding the anode forward blocking voltage V_{FOM} or V_{DRM};
(3) exceeding the maximum allowable temperature;
(4) excessive rate of change of anode voltage dv/dt.

The above methods of items (2), (3), and (4) are not used in normal operation since the SCR might be damaged. In either case, the designer must be sure that the current flow in the anode circuit does not increase too rapidly to the SCR might be damaged. The maximum di/dt is usually specified by device manufacturers in amps per microsecond, A/μS. The inductance inherent in many industrial loads such as motors and transformers tends to limit the rate of change of current in the anode circuit depending on the time constant L/R. If the load is highly resistive, then switching an SCR at high voltages could result in excessive di/dt due to the extremely short rise time of the SCR (typically 1~ 2μS). In such cases, an inductor is frequently connected in anode circuit to limit di/dt as shown in Fig. 7-15.

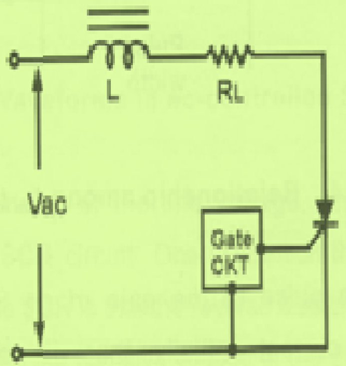

Fig.7-15 External inductance in the anode circuit to limit di/dt

An effective approach to suppress dv/dt is to use an RC snubber network in parallel with the SCR, as shown in Fig.7-16. The capacitor C absorbs the excess transient energy and the resistor R1 (100Ω typical) limits the current.

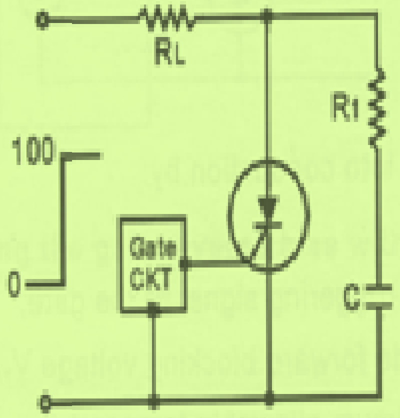

Fig.7-16 RC snubber network for dv/dt suppression

Turn-off of SCR

As mentioned above, the gate has no control over the SCR once it goes into conduction. Turn-off must be achieved in the anode-to-cathode circuit. There are three ways in which turn-off, or commutation as it is commonly called, can be achieved by:

(1) reversing the anode-to-cathode voltage;
(2) reducing the anode current below the holding current level;
(3) forcing current in the anode circuit in the reverse direction.

When a sinusoidal voltage source is used, turn-off of the SCR occurs automatically at the end of each positive half cycle of applied voltage. When a dc or unidirectional voltage source is used, the anode current must be interrupted or a passive energy storage element is used to attempt to force current through the anode circuit in the reverse direction, which reverses the anode voltage. Since the SCR is a PNPN junction semiconductor structure, a minimum time is required for the charges to reverse at the junction after conduction has been interrupted. This time interval is called the turn-off time of the SCR. The manufacturer will specify the minimum turn-off time t_{off} for each SCR under specified operating conditions. If forward voltage is applied to the anode before the turn-off time is expired, the SCR will go into conduction without a gate trigger signal. The turn-off time t_{off} for SCRs is typically 10 to 100µS.

Series and Parallel Applications of SCRs

Even though SCRs are currently available with voltage ratings of several thousand volts, many applications exist where it is necessary to operate the devices in series to block voltages in excess of the capability of the individual SCR. Similarly, in high-current applications, it is necessary to operate the devices in parallel in order to operate within their current ratings.

When SCRs are connected in series, because of their unequal static characteristics, unequal voltage sharing results, since they divide the voltage between them in inverse proportion to their leakage currents, and since in a series arrangement the leakage current is common to all the devices in series, the devices share the voltage unequally. As shown in Fig. 7-17(a), R1 and R2 represent the resistances of S1 and S2 in off state, respectively. If R1>R2, thus V1>V2.

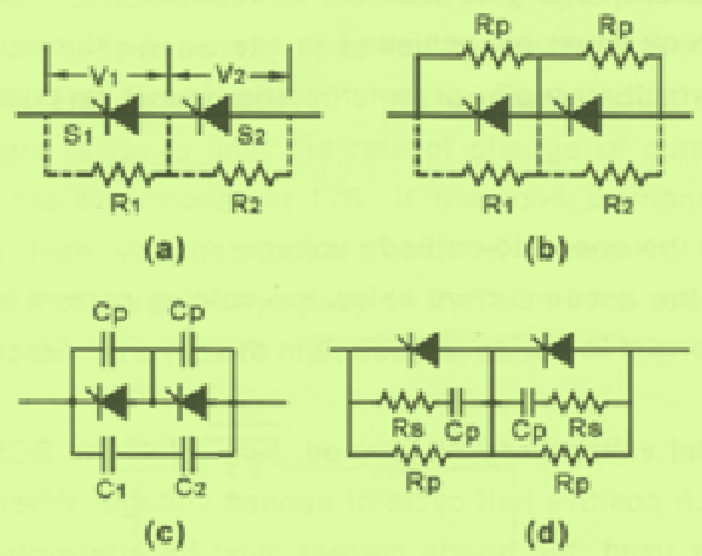

Fig.7-17 Voltage equalizing for seriesed SCRs

There are two ways to equalize the voltage sharing. These are:

(1) Resistor equalizing:

Equal sharing of the steady-state voltage can be forced by connecting a resistor in parallel with each SCR as shown in Fig. 7-17(b). The value of R_p is very small compared to R1 or R2 so that R_p // R1 ≅ R_p and R_p // R2 ≅ R_p. Therefore, V1 ≅ V2.

(2) Capacitor equalizing:

Under transient turn-on and turn-off conditions it is necessary to promote equal transient voltage sharing. The transient voltage distribution across the SCRs is inversely proportional to their capacitances. Transient voltage sharing is achieved by shunting each SCR by a capacitor greater than the SCR capacitance. In Fig. 7-17(c), since the SCR capacitances C1 and C2 are unequal and assuming C1>C2, the transient voltage across S2 is greater than the voltage across S1. If a capacitor C_p is connected in parallel with each SCR, then C_p +C1 ≅ C_p and C_p + C2 ≅ C_p so that the transient voltage across each SCR is equal. In order to reduce the surge of current from this capacitor through the SCR during turn-on a resistor R_s (typically 2Ω to 10Ω) is connected in series with each C_p as shown in Fig. 7-17(d).

When the load current is in excess of the SCR ratings, parallel operation of the SCRs is used to share the current between equally rated SCRs as shown in Fig. 7-18(a). Unfortunately, differences in the forward conduction capabilities of the SCRs result in unequal current sharing. There are several ways of promoting equal current sharing. These are:

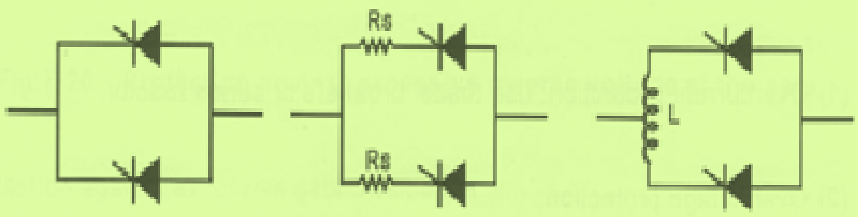

Fig.7-18 Current equalizing for paralleled SCRs

(1) Resistor equalizing:

A low value resistor R_S is connected in series with each SCR to equalize the current through each SCR as shown in Fig. 7-18(b). The major disadvantage is that the power dissipation on each resistor will reduce the power delivered to the load.

(2) Reactor equalizing:

As illustrated in Fig. 7-18(c), a center-tapped reactor is connected to SCRs to achieve a balance in current distribution.

SCR Protection

To obtain satisfactory operation of SCRs and their associated equipment, it is necessary to provide protection against high voltage transients and overcurrent.

A. SCRs may be damaged by:

(1) In on state, excessive forward current may be caused by
- load short-circuited .
- energizing current or starting current in an inductive load.
- one SCR turned on in paralleled SCR circuit.

(2) Excessive transient current from off to on

(3) Excessive triggering voltage or current at the gate.

(4) Excessive forward current or reverse voltage such as surge voltage in off state.

B. Protection strategies

(1) Overcurrent protection: use fuses, breakers or series reactor.

(2) Overvoltage protection:

- using the SCR with higher voltage rating.
- connecting another SCR or diode in series.
- using snubber network as shown in Fig. 7-19.

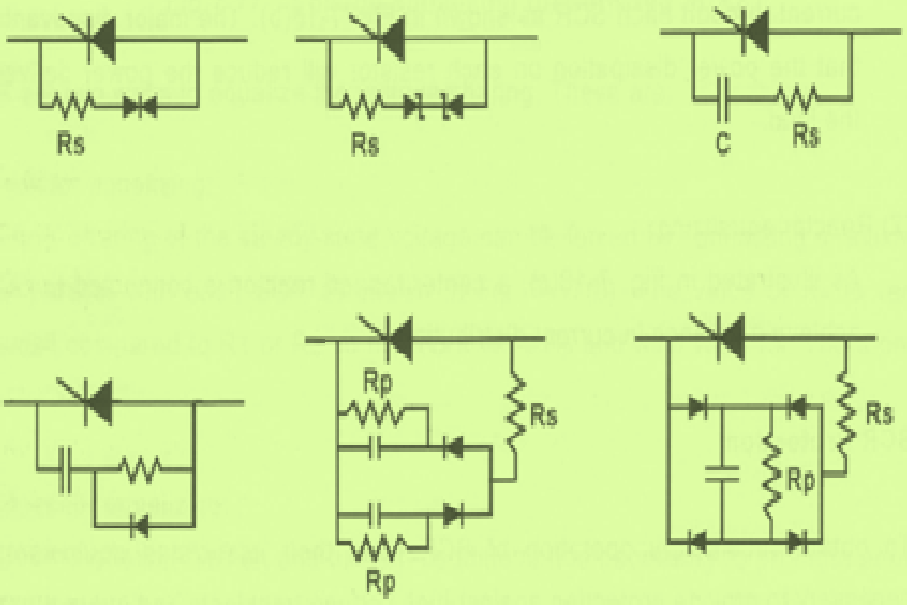

Fig.7-19 Snubber circuits

(3) Prevention against premature triggering

- applied -2 ~ -5V reverse bias to the gate, as shown in Fig.7-20(a)
- shunted a capacitor to the gate, as shown in Fig.8-20(b)

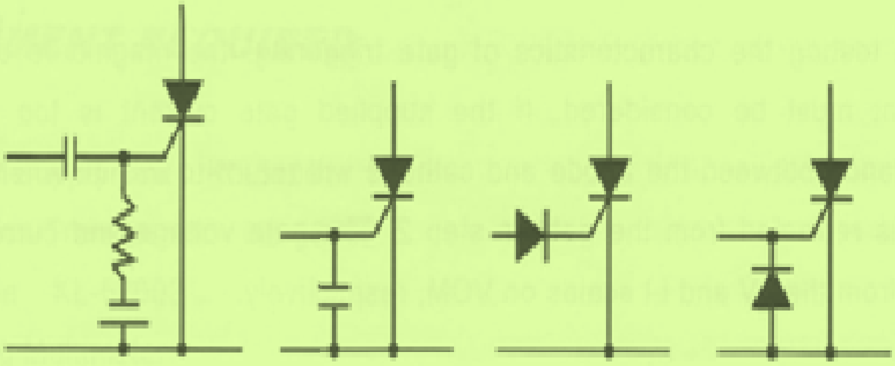

Fig.7-20 Protection against excessive reverse voltage at the gate

(4) Protection against excessive gate dissipation

- gate triggering voltage should be below V_{GFM}
- gate triggering current should be below I_{GFM}
- power of $V_{GF} \times I_{GF}$ should be less than P_{GFM} rating

(5) Prevention against excessive reverse voltage at the gate is shown in Fig. 7-20.

Testing SCR with Ohmmeter

1. Set the range selector of ohmmeter to R×100. Connect the black lead to G and the red lead to K. A low resistance reading should be indicated by the pointer. Reversing the polarity, the reading is infinite. In most cases, the anode of SCR is internally connected to heat sink.

2. With gate open, set the range selector of the ohmmeter to Rx1 position, and connect the black lead to the anode A and the red lead to the cathode K. The resistance reading should be infinite. At this time extend the black lead from the anode to the gate, the reading should indicate a low value. Retract the black lead from the gate and the reading should remain.

3. The above steps can be used to identify terminals and test an SCR with an ohmmeter. In general, a standard VOM at R × 10(15mA) range is suitable for measuring the SCR whose holding current is less than 15mA. To measure the SCR having a holding current greater than 15mA, the range of Rx1 (150mA) should be used.

4. When testing the characteristics of gate triggering, the magnitude of the gate current must be considered. If the supplied gate current is too small, the resistance between the anode and cathode will return to infinite when the black lead is retracted from the gate in step 2. The gate voltage and current can be read from the LV and LI scales on VOM, respectively.

Description of Experiment Circuit

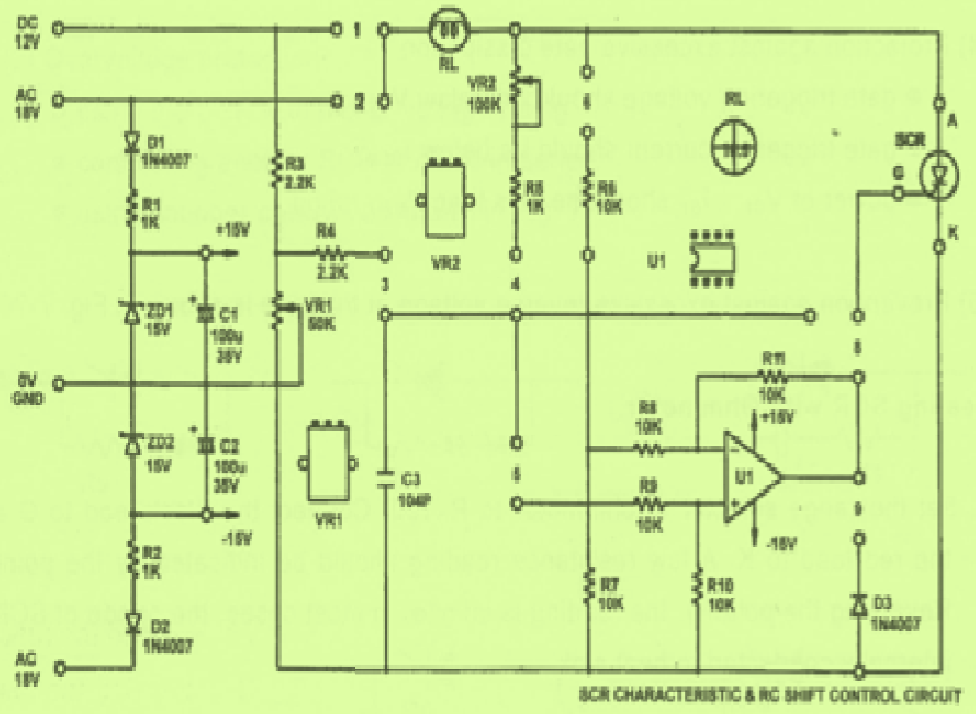

Fig.7-21 Experiment circuits

As shown in Fig. 7-21, the experiment circuits contains two major sections: dc triggering and ac phase shift triggering. In dc triggering section, when the gate voltage of SCR is 0V (VR1=0Ω), the SCR is off. If the increase in resistance of VR1 rises the gate voltage V_G to reach a sufficient level, the SCR will turn on. Once the SCR turns on, the gate voltage is not able to turn off it.

The basic RC network, (VR2+R5) and C3, performs the function of ac phase shifting. As mentioned above, the RC phase shift network varies the firing angles between 0 and 90 degrees. The triggering angle can be calculated by the equation $\alpha = \tan^{-1}R\omega C$. To extend the range of firing angles to 180 degrees, the bridge RC network must be used. The OPAMP U1 is used as a differential amplifier to amplify the differential output of bridge network.

EQUIPMENT REQUIRED

1 – Power Supply Unit KL-51001
1 – Isolation Transformer KL-58002
1 – Module KL-53003
1 – Analog Multimeter
1 – Dual-Trace Oscilloscope

PROCEDURE

1. Set the range selector of the ohmmeter to R×1 position. Connect the black lead to terminal A and the red lead to terminal G. Read and record the reading indicated by the pointer. R_{AG}= ________________ Ω. Reversing the leads, R_{AG} = ________________ Ω.

2. Connect the black lead to terminal G and the red lead to terminal K. Read and record the reading indicated by the pointer.
   R_{GK} = ________________ Ω.
   Reversing the leads, R_{GK} = ________________ Ω.

3. Connect the black lead to A and the red lead to K. Read and record the reading indicated by the pointer. R_{AK} = ________________ Ω. Reversing the leads, R_{AK} = ________________ Ω.

4. Connect the black lead to A and the red lead to K. Connecting G to A with a wire, read and record the resistance reading indicated by the pointer. R_{AK} = ________________ Ω
   The SCR is ________________ (go or no go).
   Read and record the voltage reading on LV scale as the forward voltage drop between the anode and cathode.
   V_{AK} = ________________ V.

5. Connect 12VDC and 18VAC power supplies to Module KL-53003. Place the 12-V lamp in RL socket.

6. Turn VR1 fully CCW and insert connect plugs in positions 1, 3, and 7.

7. Observe and record the state of RL. ____________________

Using the voltmeter, measure and record the anode and gate voltages. V_A= ________________ V

V_G= ________________ V

The SCR is operating in ________________ (on or off) state.

8. Slowly turning VR1 to the right, observe and record the change of V_G.

When the lamp lights, measure and record the gate voltage.

V_G = ________________ V

The SCR is operating in ________________ (on or off) state.

9. Using the voltmeter, measure and record the anode voltage of the SCR. This voltage is the forward voltage drop (V_F) between the anode and cathode of the SCR.

V_F = ________________ V

10. Turn VR1 fully CW. Observe and record the states of RL and SCR.

Turn VR1 fully CCW. Observe and record the states of RL and SCR.

Explain the changes. ______________________________

11. Remove the connect plug from position 1 and then insert it back. Observe and record the states of RL and SCR.

12. Remove connect plugs from positions 1 and 3. Insert connect plugs in positions 2, 4, and 7. Using the oscilloscope, measure the voltage waveform across RL. Turning VR2, observe and record the changes of the SCR conduction angle and lamp brightness.

13. Turn VR2 to get maximum conduction angle.

θ = ____________________ degrees.

Using the oscilloscope, measure and record the voltage waveforms of V_G and V_K in Table 7-1.

Table 7-1

V_G	V_K

14. Remove connect plug from position 7. Insert connect plugs in positions 5, 6, 8, and 9. Using the oscilloscope, measure the voltage waveform across RL. Turning VR2, observe and record the changes of the SCR conduction angle and lamp brightness.
15. Adjust VR2 to get the conduction angle of 90 degrees. Measure and record the voltage waveforms of V_G and V_K in Table 7-2.

Table 7-2

V_G	V_K

16. Remove the connect plug from position 9. Observe and record the changes of V_G and V_K.

CONCLUSION

You have experimented the dc triggering and ac phase shift triggering for the SCR. When an SCR operates in dc voltage, a dc voltage to the gate will turn on the SCR. The conducting SCR remains in on state even the gate signal is removed. When ac voltage is applied, the SCR is turned on by the gate triggering signal and is automatically turned off when the applied ac voltage reduces to zero voltage on each half cycle.