Experiment 4: Study of the Power Thyristor (SCRs).

OBJECTIVE

- To demonstrate the use of the power thyristor for switching dc and ac.
- To observe the signal waveforms in power thyristor circuits.

DISCUSSION

Thyristor operation (dc switching)

The thyristor or SCR (silicon controlled rectifier) is a diode which can be turned on by a current pulse on the gate. The symbol for this device is shown in Figure 3-1. It has three electrodes: the anode A, the cathode K, and the gate G. The anode and the cathode play the same role as in an ordinary diode. The gate electrode provides the means for turning on the thyristor.

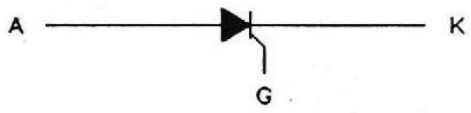

Figure 3-1. The symbol for the thyristor.

As in the case for the power diode, the power thyristor operates as a high-speed switch except that it is more sophisticated. The thyristor circuits examined in this exercise also belong to the class of half-wave rectifier circuits. The following set of rules apply to the operation of the power thyristor:

Rule 1. There is no applied voltage.

When there is no voltage applied between the anode and the cathode, the thyristor operates as an open switch and does not let current flow from A to K.

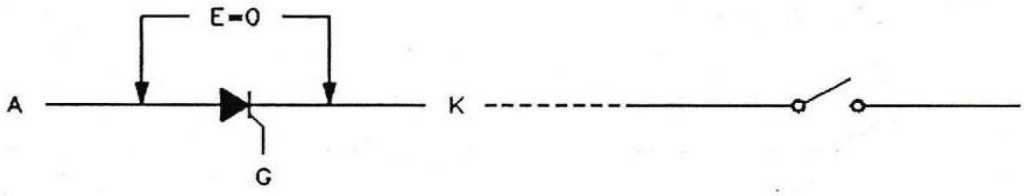

Figure 3-2. Rule 1 for the operation of a thyristor.

Rule 2. A reverse voltage E_R is applied.

When a reverse voltage is applied and the voltage at the anode is less than the voltage at the cathode, the thyristor also operates as an open switch. In this case we say that the thyristor is reverse biased.

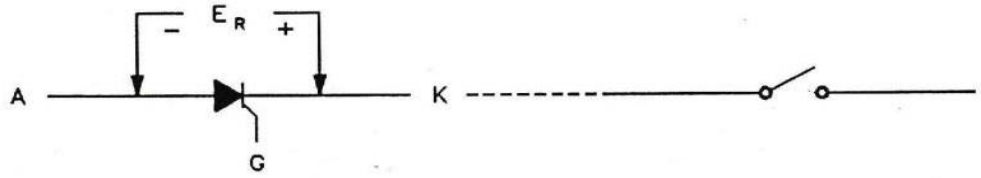

Figure 3-3. Rule 2 for the operation of a thyristor.

Rule 3. A forward voltage E_F is applied.

When a forward voltage is applied and the voltage at the anode is greater than the voltage at the cathode, the thyristor operates again as an open switch. This case is termed forward bias. However, when a current pulse I_G flows from the gate to the cathode, the thyristor turns on and current I_A flows from the anode to the cathode.

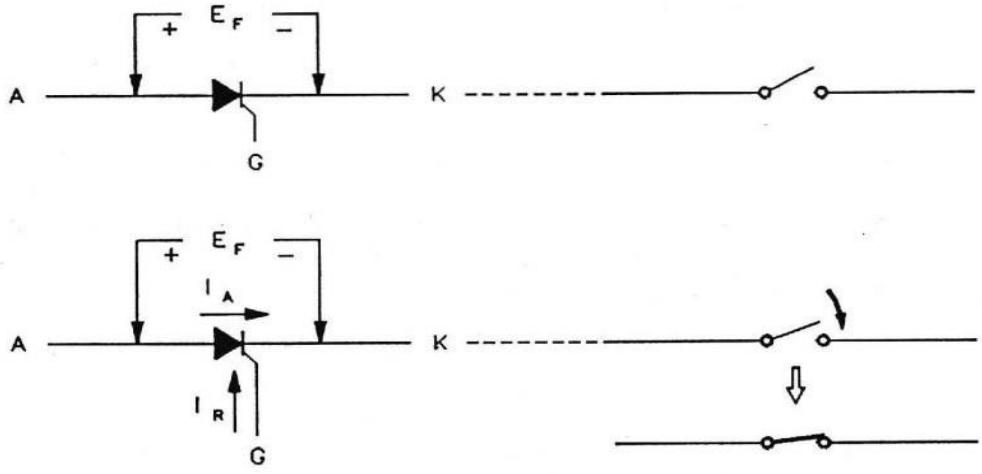

Figure 3-4. Rule 3 for the operation of a thyristor.

Rule 4. The current I_A drops to zero.

As long as current flows between the anode and the cathode, the thyristor operates as a closed switch. However, as soon as I_A drops below a certain value called the holding current I_H the thyristor turns off. It must be retriggered with a current pulse applied to the gate electrode in order to conduct again. The value of the holding current is very small compared to the nominal thyristor current.

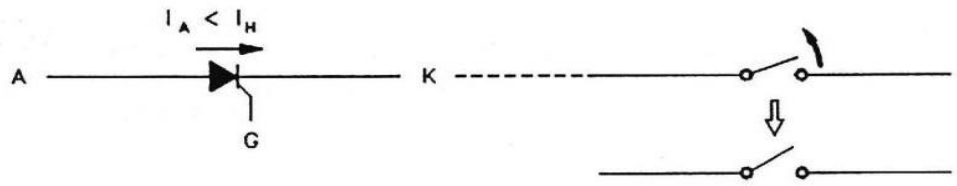

Figure 3-5. Rule 4 for the operation of a thyristor.

In summary, two conditions are necessary before a thyristor can turn on:

1. The voltage at the anode must be positive with respect to the cathode.
2. A current pulse must flow from the gate to the cathode.

The control gate current I_G flows from the gate to the cathode. This current is very small compared to that flowing between the anode and the cathode. It is not necessary that I_G continue to flow for the thyristor to stay turned on.

The power gain (power output/control power applied to the gate) is very high for a power thyristor. It can be as much as 100 000.

AC switching using two thyristors

Figure 3-6 shows schematically how a load is manually controlled using a magnetic contactor. It consists of:

A – the magnetic contactor composed of a coil and NO (normally open) contacts,

PB1, PB2 – Push Button switches.

Figure 3-6. Manual control of load using a magnetic contactor.

When PB1 is depressed, the coil of A is energized and the two sets of NO contacts close. One set maintains the coil's field current and the other connects the load to the power source. When PB2 is depressed, the contactor's coil is de-energized thus causing the contacts to open. This disconnects both the load and the coil from the line.

AC switching can also be done electronically using two power thyristors in an inverse-parallel (back-to-back) connection. The anode and cathode of the thyristor replace the NO contacts of the contactor. It is through the thyristor that the load is connected to the power source. The gate pulse firing signals take the place of the manual control signal. Figure 3-7 shows schematically how the circuit is set-up.

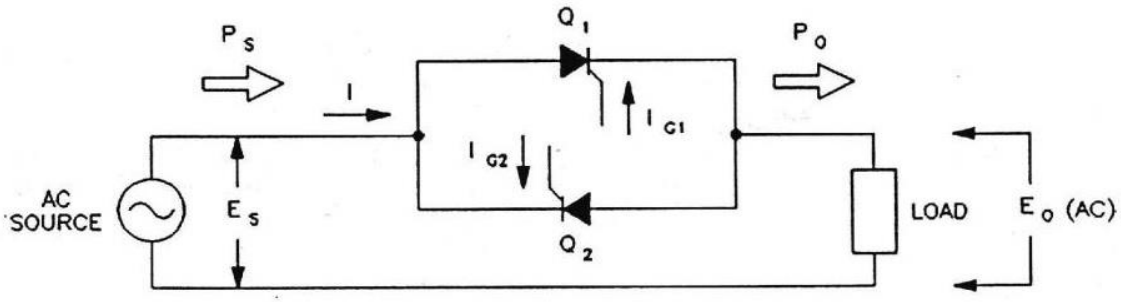

Figure 3-7. A simple electronic contactor.

Two thyristors, connected as in Figure 3-7 are required to assure complete control of the load. This is because a thyristor conducts only in one direction. Q_1 and Q_2 therefore conduct each in their turn, once each half-cycle.

This electronic contactor has no mobile contacts and is therefore completely silent in operation.

Procedure summary

In the first part of the exercise, you will set up the equipment.

In the second part, you will demonstrate the operation of a thyristor in a dc circuit.

In the third part, you will use two back-to-back thyristors for ac switching.

EQUIPMENT

1. Power Supply Module
2. Power Diode Module
3. Resistive load
4. AC Voltmeter / Ammeter Module
5. DC Voltmeter / Ammeter Module
6. Single Phase Wattmeter
7. Connecting Wires

PROCEDURE

Setting up the equipment

☐ 1. Install the Power Supply, the Enclosure / Power Supply, the Resistive Load, the DC Voltmeter/Ammeter, the AC Ammeter, the AC Voltmeter, the Three-Phase Wattmeter/Varmeter, and the Power Thyristors modules in the Mobile Workstation.

☐ 2. Install the Thyristor Firing Unit and the Current/Voltage Isolators in the Enclosure / Power Supply.

> **Note:** *Before installing the Thyristor Firing Unit, make sure that switches SW1 and SW2 (located on the printed circuit board) are in the O position.*

☐ 3. Make sure that the main power switch of the Power Supply is set to the O (OFF) position. Set the voltage control knob to 0. Connect the Power Supply to a three-phase wall receptacle.

☐ 4. Plug the Enclosure / Power Supply line cord into a wall receptacle. Set the rocker switch of the Enclosure / Power Supply to the I (ON) position.

☐ 5. On the Power Supply, set the 24-V ac power switch to the I (ON) position.

☐ 6. Make sure that the toggle switches on the Power Thyristors and the Resistive Load modules are all set to the O (open) position.

Thyristor operation

☐ 7. Set up the circuit of Figure 3-8. Connect the 0 V terminal on the Enclosure / Power Supply to the common terminal of the Power Thyristors module. However, do <u>not</u> connect the + 5 V jack of the Enclosure / Power Supply to FIRING CONTROL INPUT 1 of the Power Thyristors module yet. Note that the thyristor is reverse biased in this circuit.

☐ 8. On the Power Supply, set the Voltage Selector to 7-N. Make sure that the voltage control knob is set to the 0 position then set the main power switch to I (ON). Slowly turn the voltage control knob to increase the dc voltage to 100(%). Does the thyristor turn on? (Does current flow through the thyristor?) Explain.

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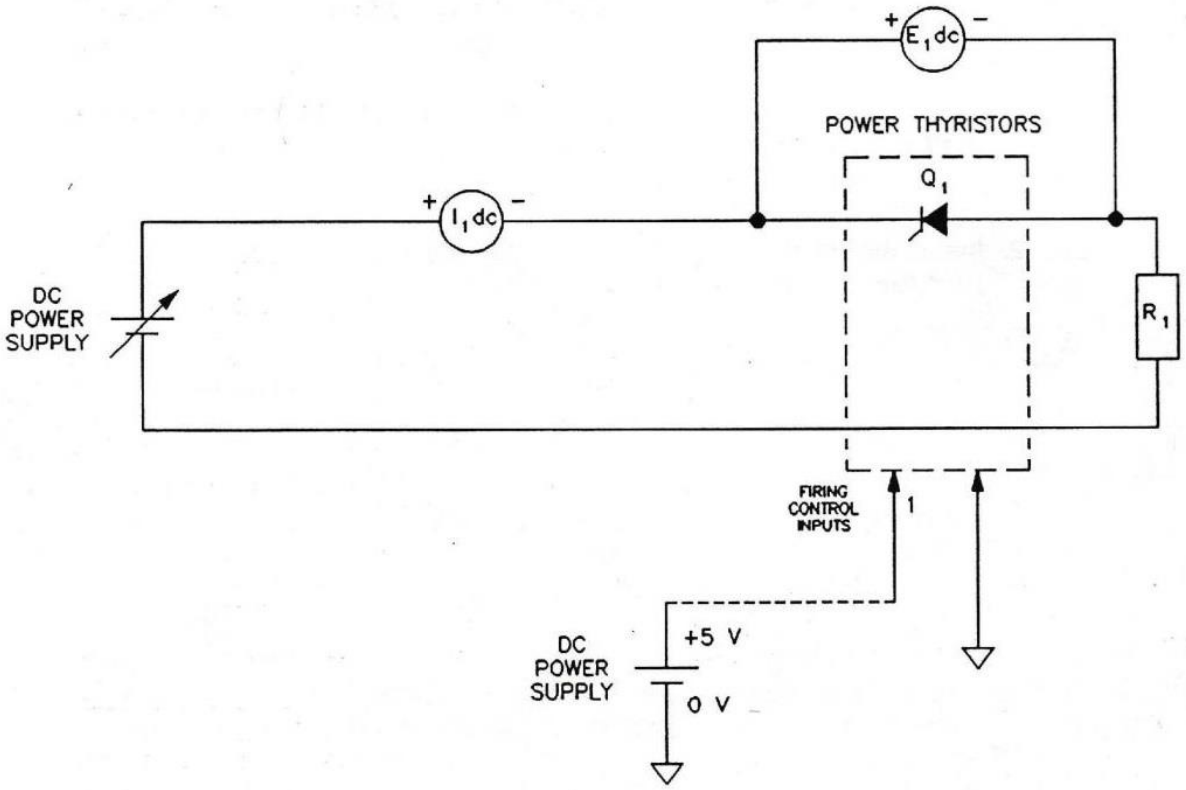

LINE VOLTAGE (Vac)	I_1dc (mA)	E_1dc (V)	R_1 (Ω)
120	500	150	600
220	300	300	2200
240	300	300	2400

Figure 3-8. A simple thyristor circuit.

☐ 9. Connect the + 5 V jack of the Enclosure / Power Supply to FIRING CONTROL INPUT 1 of the Power Thyristors module. Does the thyristor turn on? Explain.

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On the Power Supply, set the voltage control knob to 0 then set the main power switch to O (OFF).

☐ 10. Disconnect the wire between the + 5 V jack of the Enclosure / Power Supply and FIRING CONTROL INPUT 1 of the Power Thyristors module.

Interchange the leads at the terminals of the thyristor on the Power Thyristors module. This will reverse the polarity of the voltage applied to the thyristor.

On the Power Supply, set the main power switch to I (ON). Slowly turn the voltage control knob to increase the dc voltage to 100(%). Does the thyristor turn on? Explain.

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☐ 11. Connect the + 5 V jack of the Enclosure / Power Supply to FIRING CONTROL INPUT 1 of the Power Thyristors module. Does the thyristor turn on? Explain.

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Disconnect the wire between the + 5 V jack of the Enclosure / Power Supply and FIRING CONTROL INPUT 1 of the Power Thyristors module. Does the conduction state of the thyristor change? Explain.

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With the wire still disconnected, progressively reduce the applied dc voltage. This will reduce I_A, the current flowing through the thyristor. What happens?

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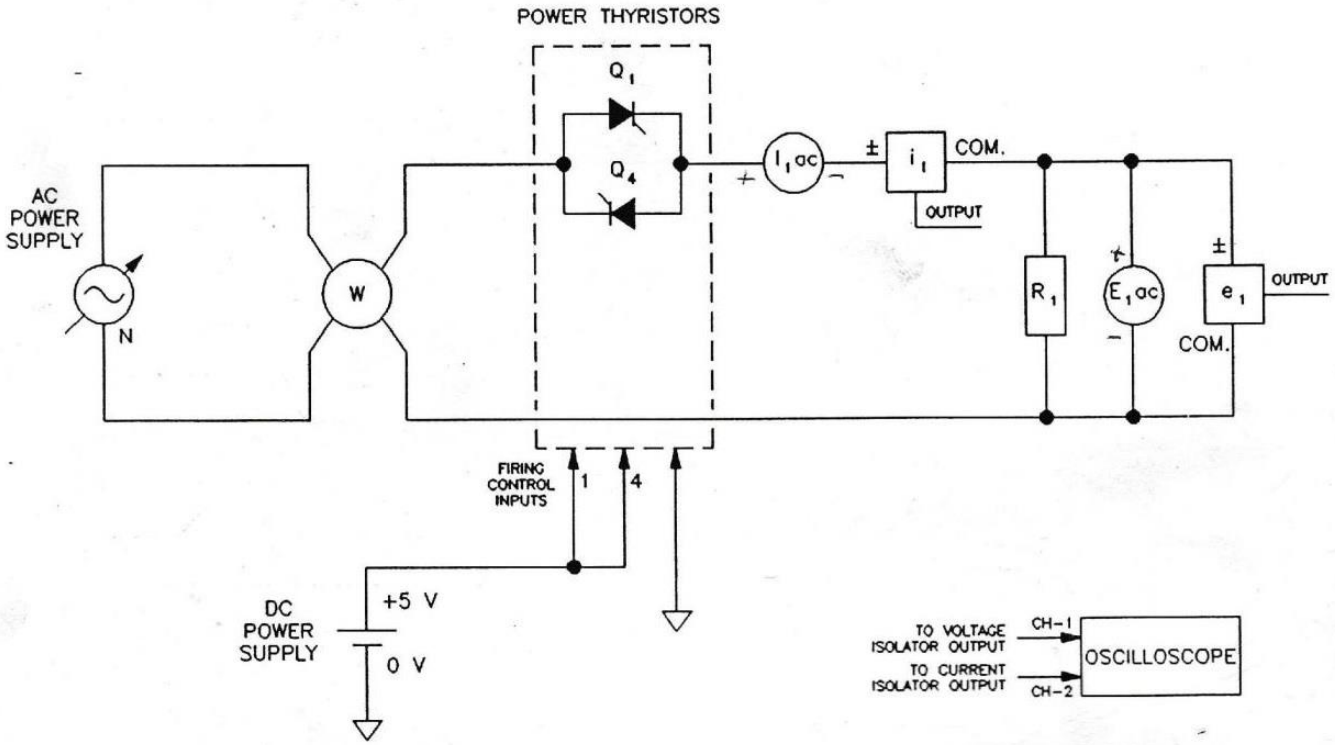
☐ 12. Repeat the previous step. What is the approximate value of the holding current I_H?

$I_H \approx$ _____ mA dc

On the Power Supply, set the voltage control knob to 0 then set the main power switch to O (OFF).

AC switching using two thyristors

☐ 13. Set up the circuit of Figure 3-9.



LINE VOLTAGE (Vac)	I_1ac (A)	i_1 (A)	E_1ac (V)	e_1 (V)	R_1 (Ω)
120	2.5	10	250	300	60
220	1.5	5	250	600	220
240	1.5	5	250	600	240

Figure 3-9. An ac electronic contactor circuit

☐ 14. Make the following settings:

On the Power Supply

Voltage Selector 4-N

On the Oscilloscope

Channel-1 Sensitivity . . . . . 5 V/DIV. (DC coupled)
Channel-2 Sensitivity . . . . . 2 V/DIV. (DC coupled)
Time Base . . . . . 5 ms/DIV.
Trigger . . . . . LINE

☐ 15. On the Power Supply, make sure that the voltage control knob is set to the 0 position then set the main power switch to I (ON). Set the voltage control knob to 100(%).

Observe the readings on the meters and the waveform on the oscilloscope. Is the circuit supplying ac power to the load?

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On the Enclosure / Power Supply, disconnect the wire from the + 5 V jack. This removes the gate current from the thyristors. What happens?

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Explain how this circuit could be used to switch the supply of ac power on and off.

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☐ 16. On the Power Supply, set the voltage control knob to 0 then set the main power switch and the 24-V ac power switch to O (OFF). Set the rocker switch on the Enclosure / Power Supply to the O position. Remove all leads and cables.

CONCLUSION

In this exercise, you observed the operation of a power thyristor. You have observed that a thyristor conducts only when it is forward biased and when a current pulse has been injected into the gate. You also demonstrated that two thyristors connected back-to-back can be used to switch ac power.

REVIEW QUESTIONS

1. What is the difference between a diode and a thyristor?

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2. What are the two conditions necessary for a thyristor to begin to conduct?

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3. Once a thyristor begins to conduct, what condition is necessary for conduction to cease?

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4. Indicate if the power thyristor will be on or off under the following conditions:

   a. The thyristor was reverse biased, then a current pulse was injected into the gate.

      The thyristor is _____.

   b. The thyristor was reverse biased, a current pulse was injected into the gate, then the thyristor was forward biased.

      The thyristor is _____.

   c. The thyristor was forward biased, then a current pulse was injected into the gate.

      The thyristor is _____.

   d. The thyristor was forward biased, a current pulse was injected into the gate, then the thyristor was reverse biased.

      The thyristor is _____.

5. Why are two thyristors required for ac switching?

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