

# Thyristor & Power Control Circuits

**FACET®**



Student Workbook



**FOURTH EDITION**

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## Introduction

This Student Workbook provides a unit-by-unit outline of the Fault Assisted Circuits for Electronics Training (F.A.C.E.T.) curriculum.

The following information is included together with space to take notes as you move through the curriculum.

- ◆ The unit objective
- ◆ Unit fundamentals
- ◆ A list of new terms and words for the unit
- ◆ Equipment required for the unit
- ◆ The exercise objectives
- ◆ Exercise discussion
- ◆ Exercise notes

The **Appendix** includes safety information.



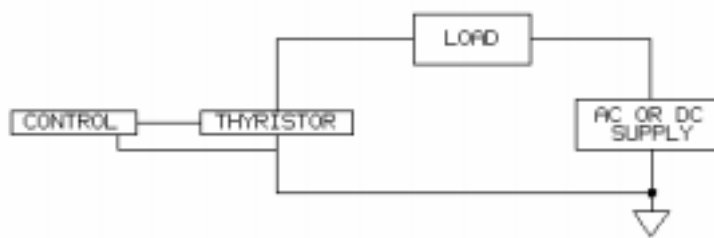


## UNIT 1 – THYRISTORS & POWER CONTROL CIRCUITS

### UNIT OBJECTIVE

At the completion of this unit, you will be able to identify the thyristors and connect and operate circuits on the THYRISTOR & POWER CONTROL CIRCUITS circuit board by applying the information presented in this unit.

### UNIT FUNDAMENTALS



A **thyristor** is a semiconductor device. Electronically controlled switches use thyristors in industrial, military, aerospace, commercial, and consumer applications.

Thyristors can control power to many kinds of loads, such as a simple lamp, power supplies, voltage regulators, and industrial motors. Circuits using ac or dc can use thyristors for power control.

Following are the two most commonly used thyristors for power control:

1. the **silicon controlled rectifier (SCR)**, which is a reverse blocking triode thyristor, and
2. the **triac**, which is a bidirectional triode thyristor.

In the following two exercises, you will identify thyristors and connect and operate thyristor circuits on the THYRISTOR & POWER CONTROL CIRCUITS circuit board.

### NEW TERMS AND WORDS

**thyristor** - a bistable semiconductor device made of 3 or more junctions that can be switched from the off state to the on state or vice versa.

**silicon controlled rectifier (SCR)** - a gate triggered 3-terminal thyristor that has positive anode to cathode voltages and exhibits a reverse blocking state for negative anode to cathode voltages.

**triac** - a gate triggered, 3-terminal thyristor that switches for either positive anode to cathode voltages or negative anode to cathode voltages.

**EQUIPMENT REQUIRED**

F.A.C.E.T. base unit

Multimeter

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS

circuit board

**NOTES**

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## Exercise 1 – Thyristor Component Familiarization

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to identify thyristors and components in the circuit blocks on the THYRISTOR & POWER CONTROL CIRCUITS circuit board. You will verify your knowledge by answering the questions in the exercise.

### EXERCISE DISCUSSION

- There are five circuit blocks on the THYRISTOR & POWER CONTROL CIRCUITS circuit board.
- The following four circuit blocks contain thyristors:  
SILICON CONTROLLED RECTIFIER (SCR)  
TRIAC AC POWER CONTROL  
SCR DC GATE HALF-WAVE AND FULL-WAVE  
SCR AC GATE AND UJT HALF-WAVE AND UJT HALF-WAVE AND FULL-WAVE / MOTOR
- The DRIVER circuit block contains a circuit that interfaces an external signal generator with the ac input to three of the circuit blocks.
- Thyristors are labeled with the letter Q followed by a number (for example, Q1)
- The silicon controlled rectifier (SCR) is sometimes called a reverse blocking triode thyristor. The SCR is primarily used for switching in ac and dc power control. The SCR is a three terminal device.
- An SCR is very useful for switching because a few milliwatts applied at the gate (G) can control hundreds of watts to a load.
- Triacs are three terminal, gate (G) controlled thyristor switches. The triac is bi-directional and behaves like two inversely parallel connected SCRs.
- The triac conducts with positive or negative voltage at either terminal (MT1 and MT2) and is triggered by a gate (G) current of either polarity.
- A diac is another thyristor type. The diac is a 2-terminal, bi-directional thyristor switch which is generally used in SCR gate triggering applications. The diac operates like two inversely parallel connected diodes.
- The Unijunction transistor (UJT) is a single junction, three terminal transistor that can be used for delaying the triggering signal at the SCR gate.
- Thyristor specification sheets include all of the significant parameters unique to a particular thyristor and are very important tools when designing thyristor circuits.

## NOTES

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## Exercise 2 – Circuit Block Familiarization

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to connect thyristor circuits by using the circuit blocks on the THYRISTOR & POWER CONTROL CIRCUITS circuit board. You will verify your results with a multimeter and an oscilloscope.

### EXERCISE DISCUSSION

- The DRIVER circuit block contains a transformer and amplification circuitry that amplifies the ac signal from an external signal generator.
- The signal generator connects to the DRIVER circuit block input at the terminals marked GEN.
- The DRIVER circuit block is used with thyristor circuits that have ac signal input. The DRIVER output is hardwired to the ac inputs identified by the ac source symbol on the circuit blocks.
- When you connect the generator to the DRIVER circuit block, the generator connects to the circuit block ac input through the DRIVER circuitry.
- All measurements for adjusting the signal generator (magnitude and frequency) are made at the circuit block ac input.
- The THYRISTOR & POWER CONTROL CIRCUITS circuit board has four thyristor circuit blocks. Each block uses at least one thyristor as the active circuit element.
- You can configure several types of thyristor circuits from the components in each circuit block.
- The SCR circuit block which includes provisions for monitoring different parameters of an SCR (Q1).
- The SCR DC GATE HALF-WAVE AND FULL-WAVE circuit block uses a dc voltage at the gate (G) to control turn-on of the SCR (Q1). You can configure SCR Q1 as a half-wave rectifier, to control a half-wave rectifier (CR1), or to control a full-wave bridge rectifier (CR2).
- When SCR Q1 controls half-wave rectification, diode CR1 is the half-wave rectifier.
- When SCR Q1 controls full-wave rectification, bridge rectifier CR2 is the full-wave rectifier.
- The SCR AC GATE AND UJT HALF-WAVE AND FULL-WAVE/MOTOR circuit block uses ac voltage with or without a UJT (Q1) at the gate (G) of an SCR (Q2).
- The SCR (Q2) controls conduction of a full-wave rectifier (CR3) to either a resistive load (R8) or a motor load (MOT). The circuit can also be configured for Q2 to function as a half-wave rectifier.

- The TRIAC AC POWER CONTROL circuit block uses a triac (Q1) to switch ac to the load (R6). The triac gate (G) circuit configuration determines if half-wave or full-wave ac switching occurs.
- As shown, the two-post connectors configure the circuit block so that the triac (Q1) gate (G) receives positive and negative alternations.
- On the F.A.C.E.T. Computer-Based Laboratory THYRISTOR & POWER CONTROL CIRCUITS circuit board, the circuit block commons connect to earth ground.
- Use the ADD-INVERT oscilloscope method to measure ac voltages across components that do not connect directly to earth ground on the circuit board.
- The oscilloscope is set to ADD, and channel 2 is set to INVERT. Because the ground probe clips connect to earth ground in the oscilloscope, the ADD-INVERT method is necessary to prevent shorts to ground.

## NOTES

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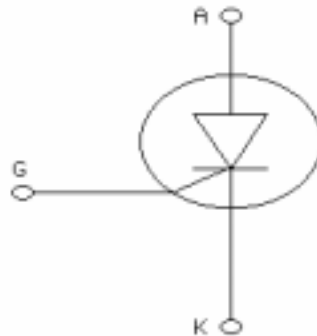
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## UNIT 2 – SILICON CONTROLLED RECTIFIER

### UNIT OBJECTIVE

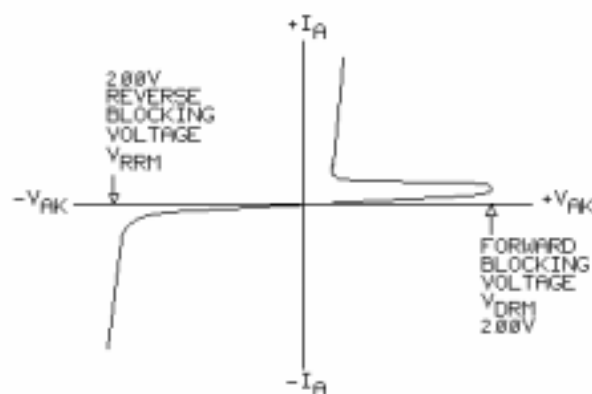
At the completion of this unit, you will be able to demonstrate the fundamental operation of a silicon controlled rectifier (SCR) by using dc measurements.

### UNIT FUNDAMENTALS



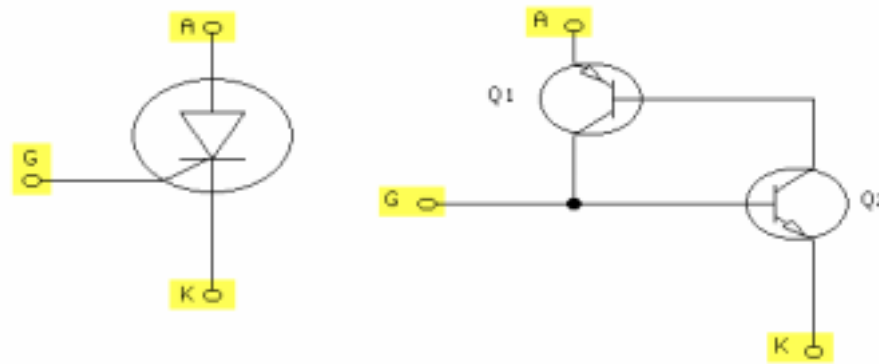
A thyristor is any semiconductor switch. A **silicon controlled rectifier (SCR)** is one type of thyristor. A **silicon controlled rectifier (SCR)** is a 3 terminal, unidirectional thyristor. The 3-terminals are the anode (A), the gate (G), and the cathode (K).

An SCR conducts when the anode to cathode is forward biased and a gate trigger signal is applied. After an SCR is turned on, it remains on as long as it has a minimum anode current. This minimum anode current that maintains conduction is the **holding current ( $I_H$ )**.

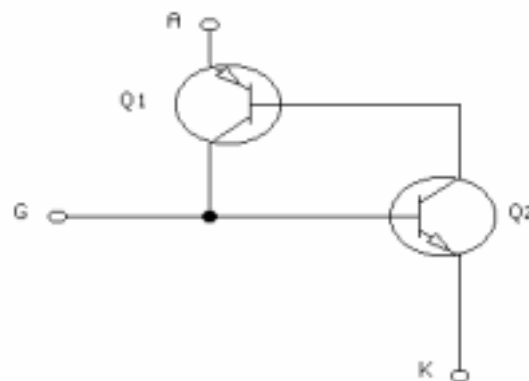


Shown are the voltage/current characteristics of an SCR with no gate current applied and with a forward and **reverse blocking voltage** rating of 200V.

When the **forward blocking voltage** is reached, the SCR turns itself on. The anode to cathode voltage decreases, and the anode current increases.



Internally, the SCR is similar to 2 cross-connected transistors. Above is the SCR symbol and its equivalent transistor circuit.



A gate trigger signal turns on transistor Q2. Q2 then forward biases the Q1 base-emitter junction, and both transistors turn on, providing a current path from the anode to the cathode. Both transistors are then latched on until the anode current is removed.

## NEW TERMS AND WORDS

**holding current ( $I_H$ )** - the minimum current required to keep an SCR conducting.

**reverse blocking voltage** - the maximum reverse voltage that may be applied without turning on an SCR.

**forward blocking voltage** - the maximum forward voltage that may be applied with turning on an SCR.

## EQUIPMENT REQUIRED

F.A.C.E.T. base unit

Multimeter

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS circuit board



## NOTES

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## Exercise 1 – Testing an SCR with a Multimeter

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to test a typical SCR by using a multimeter. You will verify your results with a multimeter.

### EXERCISE DISCUSSION

- The ohm function or diode function of the digital multimeter is required to test the SCR.
- If conditions permit, the SCR should be removed from the circuit when testing it with an ohmmeter.
- The gate-to-cathode junction of the SCR is the only junction that can be measured as a normal diode junction.
- Conduction between the anode and gate terminals or between the anode and cathode terminals indicates a defective SCR.

### NOTES

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## Exercise 2 – SCR DC Operation

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to turn an SCR on and off by using a switch and a two-post connector. You will verify your results with an oscilloscope and a multimeter.

### EXERCISE DISCUSSION

- An SCR can be thought of as a triggered diode. The SCR can be forward biased but not conducting until it is triggered by a gate current.
- The anode-to-cathode voltage drops, once the SCR is turned on.
- Once the SCR is on, it conducts until the anode current is removed or falls below a minimum value, known as the holding current ( $I_H$ ).

### NOTES

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## Exercise 3 – SCR Gate Trigger and Holding Current

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to measure the gate trigger voltage and holding current of a typical SCR by using dc measurement methods. You will verify your results with a multimeter and an oscilloscope.

### EXERCISE DISCUSSION

- The gate trigger voltage ( $V_{GT}$ ) is the minimum gate voltage ( $V_{GK}$ ) required to turn on the SCR.
- To determine the value of the gate trigger voltage, monitor the SCR while increasing the gate voltage until the SCR turns on.
- The SCR holding current ( $I_H$ ) is the minimum forward anode current ( $I_A$ ) required to keep the SCR turned on.
- To determine the holding current, monitor the forward anode current while decreasing the current until just before the SCR turns off.

### NOTES

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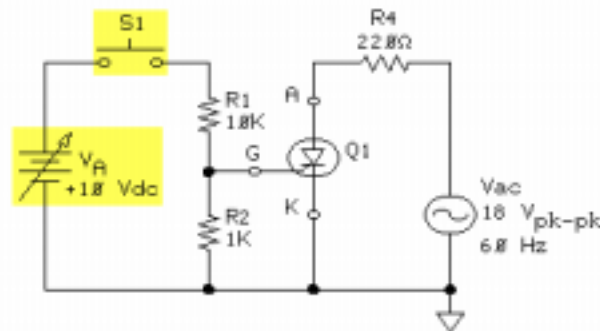
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## UNIT 3 – SCR DC CONTROL

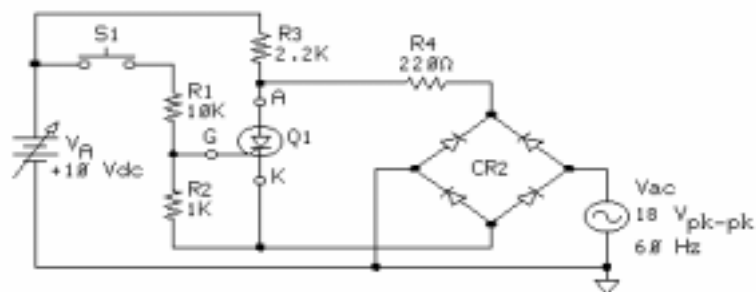
### UNIT OBJECTIVE

At the completion of this unit, you will be able to demonstrate the dc control of typical rectification circuits by using an SCR.

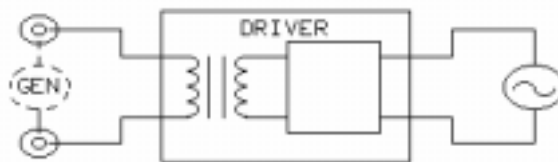
### UNIT FUNDAMENTALS



In this circuit, the SCR is a half-wave rectifier that is controlled by S1 and the dc supply ( $V_A$ ). The SCR turns off every negative half-cycle because the SCR becomes reverse biased.



In this circuit, the SCR is a switch in series with load resistor R4. When S1 is closed,  $V_A$  supplies the gate trigger voltage and turns on the SCR. The SCR then acts like a closed switch, and a full-wave rectified waveform appears across R4.



You will use the DRIVER circuit block in this unit to amplify the generator signal. You can then use the signal generator as the ac power source needed for the thyristor circuits.

**NEW TERMS AND WORDS**

None

**EQUIPMENT REQUIRED**

F.A.C.E.T. base unit

Multimeter

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS circuit board

**NOTES**

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## Exercise 1 – SCR Half-Wave Rectifier

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate how an SCR operates as a controlled half-wave rectifier. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- The SCR is used as a controlled half-wave rectifier.
- With S1 open, the SCR is off and no current flows through the load resistor R4.
- When S1 is closed, the SCR is triggered on and the current flows during the positive half-cycle of  $V_{ac}$ .

### NOTES

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## Exercise 2 – SCR Control of a Half-Wave Rectifier

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate how an SCR controls a half-wave rectifier by using a typical half-wave rectifier circuit. You will verify your results with an oscilloscope.

### DISCUSSION

- This circuit uses an SCR to control a half-wave rectifier.
- Closing S1 triggers the SCR; it remains on because R3 supplies the holding current during the negative half-cycle of  $V_{ac}$ .
- While SCR conducts, CR1 acts as a half-wave rectifier because the load current flows through R4 on the positive half-cycle of  $V_{ac}$ .
- Turn the SCR off by removing the holding current; this is achieved by opening R3.

### NOTES

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## Exercise 3 – SCR Control of a Full-Wave Rectifier

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate how an SCR controls a full-wave rectifier by using a typical full-wave rectifier circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- This circuit uses an SCR to control a full-wave rectifier.
- When the SCR is not on, there is no current flowing through load resistor R4 or the SCR, Q1.
- Closing S1 turns the SCR on. Current now flows through R4 and the SCR.
- The SCR remains on because the holding current is supplied by R3.
- Full-wave rectification of the input signal occurs at CR2 after the SCR is triggered on.

### NOTES

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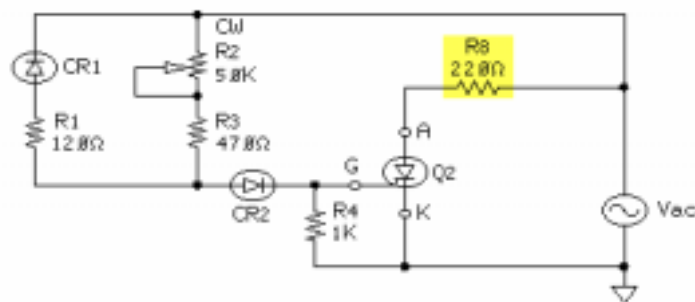
## UNIT 4 – SCR AC CONTROL

### UNIT OBJECTIVE

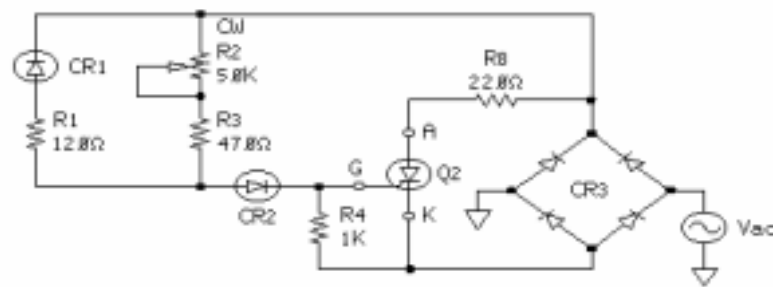
At the completion of the unit, you will be able to demonstrate ac control of an SCR by using half-wave and full-wave phase control circuits.

### UNIT FUNDAMENTALS

A phase control circuit controls the SCR **conduction angle**. The SCR conduction angle of a full-wave **phase control** circuit is shown. A phase control circuit can also be used with a half-wave rectifier.



This circuit is a half-wave SCR phase control circuit. Power to the load ( $R_8$ ) can be controlled during the positive half of the input cycle.



In this circuit, power to the load (R8) can be controlled on both halves of the input cycle. Therefore, the maximum power to the load is twice that of the half-wave circuit.

### NEW TERMS AND WORDS

**conduction angle** - the time an SCR conducts during one cycle of the source voltage measured in degrees.

**phase control** - control of the SCR conduction angle through controlling the phase of the SCR trigger signal with respect to the source voltage.

### EQUIPMENT REQUIRED

F.A.C.E.T. base unit

Multimeter

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS circuit board

## NOTES

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## Exercise 1 – SCR Half-Wave Phase Control

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe half-wave phase control by using a typical SCR ac control circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- The circuit is a half-wave phase control circuit.
- Power to the load resistor (R8) is controlled during the positive half-cycle of  $V_{ac}$ .
- The SCR's trigger point can be set between 0 and 90 on the positive half-cycle of  $V_{ac}$  by adjusting R2.
- The SCR is triggered and conducts during the positive half-cycle.
- When the source voltage is negative, the SCR turns off and becomes reverse biased for the negative half-cycle.
- There is a voltage drop across the load only when the SCR conducts.
- Capacitor (C1) with R2 and R3 cause a phase shift in the gate voltage.

### NOTES

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## Exercise 2 – Full-Wave Phase Control

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe full-wave phase control by using a typical SCR ac power control circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- This circuit uses the SCR to control the full-wave bridge rectifier.
- When SCR (Q2) is conducting, a voltage appears across the load resistor (R8).
- Since CR3 is a full-wave rectifier, current flows through the load during both cycles of the ac input voltage (Vac).

### NOTES

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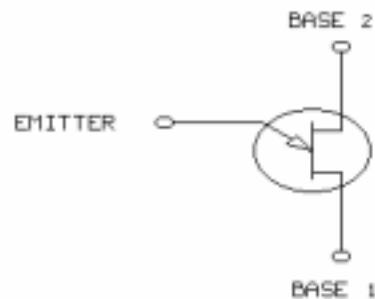


## UNIT 5 – UJT TRIGGERED SCR POWER CONTROL

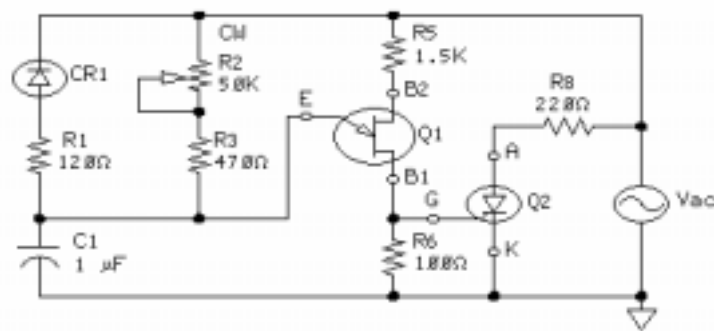
### UNIT OBJECTIVE

At the completion of this unit, you will be able to use a unijunction transistor (UJT) as the trigger device for an SCR by using a typical UJT-SCR circuit.

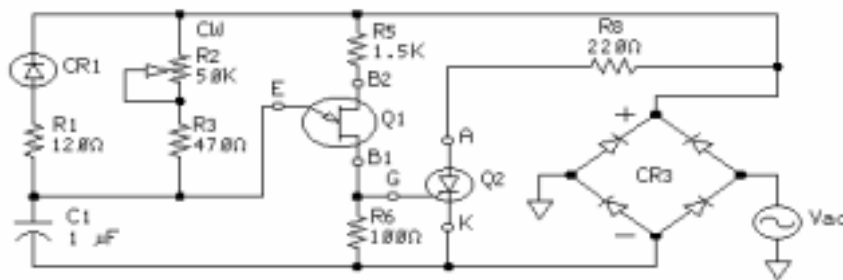
### UNIT FUNDAMENTALS



This is the symbol for a **unijunction transistor (UJT)**. The UJT has 1 PN junction and 3 terminals. In this unit, you will use the UJT to control the conduction angle of an SCR.



In this circuit, a UJT phase control is used with a half-wave rectifier.



The UJT makes a good trigger device for the SCR because it generates a sharp pulse at the B1 terminal. When the UJT is used with a variable RC phase control circuit, you can easily adjust the phase angle at which the B1 pulse occurs.

## NEW TERMS AND WORDS

**unijunction transistor (UJT)** - a 3-terminal device with 1 PN junction.

**firing voltage ( $V_P$ )** - the maximum emitter voltage at which the UJT turns on; also called the peak-point emitter voltage.

**valley voltage ( $V_V$ )** - the minimum emitter voltage just before the UJT turns off also called the valley-point emitter voltage.

## EQUIPMENT REQUIRED

F.A.C.E.T. base unit

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS circuit board

## NOTES

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## Exercise 1 – UJT Characteristics

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe the basic operating characteristics of a UJT by using ac measurements. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- A UJT is a three terminal device. The terminals are the emitter (E), base 1 (B1) and base 2 (B2).
- UJT's can be used as triggering devices for SCRs.
- UJT's generate a pulse at the B1 and B2 terminals.
- The UJT has only one PN junction.
- The equivalent circuit of a UJT consists of two series resistors and a diode connected to the junction of the two resistors.
- The firing voltage ( $V_P$ ) is the maximum emitter voltage at which the UJT turns on; also called the peak-point emitter voltage.

### NOTES

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## Exercise 2 – UJT Half-Wave/Full-Wave Phase Control

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe UJT half-wave/full-wave phase control by using a typical SCR UJT control circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- The half-wave UJT phase control circuit uses a UJT to trigger the SCR.
- A half-wave UJT phase control circuit controls power to the load during the positive half of the input cycle.
- A full-wave UJT phase control circuit controls power to the load during both halves of the input cycle.
- The full-wave UJT phase control circuit delivers more power to the load than the half-wave UJT phase control circuit.

### NOTES

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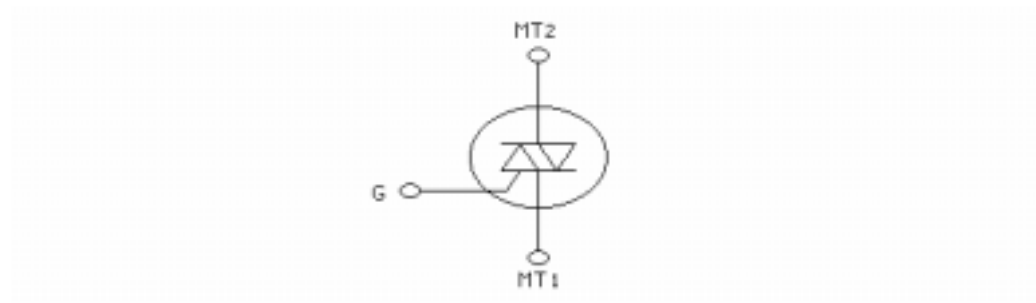


## UNIT 6 – TRIAC DEVICES

### UNIT OBJECTIVE

At the completion of this unit, you will be able to describe the operation of typical triac devices by using dc measurements.

### UNIT FUNDAMENTALS



A triac is a 3-terminal **bidirectional** thyristor. A thyristor is any solid state switch. The triac is a thyristor that, unlike the SCR, is capable of conducting in either direction between its main terminals.

A triac can be triggered on if **MT2** is positive with respect to **MT1** or if MT2 is negative with respect to MT1.



Similar to the SCR, a triac requires a minimum MT2 current to remain in conduction. This minimum current is the holding current.

A triac has 4 trigger modes. It can be triggered on with either a positive or negative gate trigger signal, with MT2 being either positive or negative.

**NEW TERMS AND WORDS**

**bidirectional** - capable of conducting in 2 directions.

**MT1** - main terminal 1 of a triac; the reference terminal of a triac.

**MT2** - main terminal 2 of a triac.

**NOTES**

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## Exercise 1 – Bidirectional Conduction

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate triac bidirectional conduction characteristics by using a typical triac circuit. You will verify your results with an oscilloscope and a multimeter.

### DISCUSSION

- The three terminals of a triac are gate, main terminal 1 (MT1), and main terminal 2 (MT2).
- A triac is a bidirectional device. The triac can have current flowing through it in either direction.
- When MT2 is positive and the device is triggered on, current flows from MT1 to MT2.
- MT1 is the reference terminal for the gate and MT2.
- When MT2 is negative and the device is triggered on, current flows from MT2 to MT1.
- Triacs are useful for controlling ac loads since load current can flow in either direction.

### NOTES

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## Exercise 2 – The Triac Triggering Modes

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate the four triggering modes of a triac by using dc measurements. You will verify your results with an oscilloscope.

### DISCUSSION

- A triac has four triggering modes.
- Mode I requires a positive gate signal when MT2 is positive with respect to MT1.
- Mode II requires a negative gate signal when MT2 is positive with respect to MT1.
- Mode III requires a positive gate signal when MT2 is negative with respect to MT1.
- Mode IV requires a negative gate signal when MT2 is negative with respect to MT1.

### NOTES

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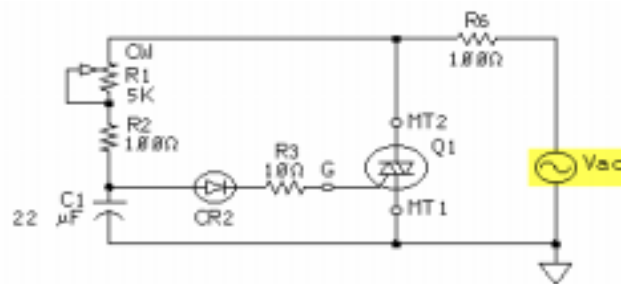
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## UNIT 7 – TRIAC AC POWER CONTROL

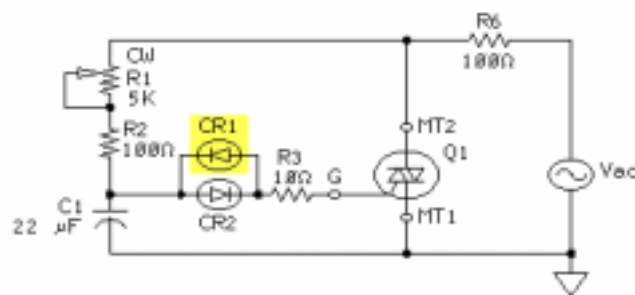
### UNIT OBJECTIVE

At the completion of this unit, you will be able to demonstrate ac power control by using typical triac control circuits.

### UNIT FUNDAMENTALS



This is a half-wave triac circuit. The triac can be turned on only when Vac is positive.



By adding CR1 to the circuit, it becomes a full-wave circuit. Since the triac can conduct on the positive and negative half-cycles, it is bidirectional.

### NEW TERMS AND WORDS

None.

**EQUIPMENT REQUIRED**

F.A.C.E.T. base unit

Multimeter

Oscilloscope, dual trace

Generator, sine wave

THYRISTOR & POWER CONTROL CIRCUITS circuit board

**NOTES**

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## Exercise 1 – TRIAC Half-Wave Phase Control

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe half-wave phase control by using a typical triac ac power control circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- The circuit shows a half-wave triac phase control.
- Diode CR2 blocks the negative half-cycle of source voltage ( $V_{ac}$ ) from reaching the triac gate.
- R1, R2, and C1 form a phase shift network. Adjusting R1 controls the phase angle of the triac's gate trigger voltage.
- The triac continues to conduct until the MT2 current falls below the holding current level of the device.

### NOTES

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## Exercise 2 – TRIAC Full-Wave Phase Control

### EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe full-wave phase control by using a typical triac as a power control circuit. You will verify your results with an oscilloscope.

### EXERCISE DISCUSSION

- The circuit is a full-wave triac phase control circuit.
- It is a full-wave circuit because the triac can conduct on the positive and negative half-cycle.
- R1, R2, and C1 form a phase control circuit for the triac gate.
- The gate trigger delay, with respect to  $V_{ac}$ , is minimum when R1 is fully clockwise.
- The approximate adjustment range of R1 for each half-cycle is greater than  $90^\circ$ .

### NOTES

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## APPENDIX A – SAFETY

Safety is everyone's responsibility. All must cooperate to create the safest possible working environment. Students must be reminded of the potential for harm, given common sense safety rules, and instructed to follow the electrical safety rules.

Any environment can be hazardous when it is unfamiliar. The F.A.C.E.T. computer-based laboratory may be a new environment to some students. Instruct students in the proper use of the F.A.C.E.T. equipment and explain what behavior is expected of them in this laboratory. It is up to the instructor to provide the necessary introduction to the learning environment and the equipment. This task will prevent injury to both student and equipment.

The voltage and current used in the F.A.C.E.T. Computer-Based Laboratory are, in themselves, harmless to the normal, healthy person. However, an electrical shock coming as a surprise will be uncomfortable and may cause a reaction that could create injury. The students should be made aware of the following electrical safety rules.

1. Turn off the power before working on a circuit.
2. Always confirm that the circuit is wired correctly before turning on the power. If required, have your instructor check your circuit wiring.
3. Perform the experiments as you are instructed: do not deviate from the documentation.
4. Never touch "live" wires with your bare hands or with tools.
5. Always hold test leads by their insulated areas.
6. Be aware that some components can become very hot during operation. (However, this is not a normal condition for your F.A.C.E.T. course equipment.) Always allow time for the components to cool before proceeding to touch or remove them from the circuit.
7. Do not work without supervision. Be sure someone is nearby to shut off the power and provide first aid in case of an accident.
8. Remove power cords by the plug, not by pulling on the cord. Check for cracked or broken insulation on the cord.

