# EE 330 Lab 11
# Thyristor Device Characterization and Applications

Fall 2024

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## Objective

The objective of this lab is to become familiar with the operation of thyristors, to develop methods for measuring key parameters of thyristors, and to investigate some basic applications of these devices.

## Components Needed

The following components will be provided by your lab TA:

1. S4010LS2 SCR
2. 12V 200mA dc motor
3. 12V, 500mA Incandescent Bulb

A datasheet for the SCR can be found online or on the EE 330 website. You will also need your other, standard electronic components.

## Objective

Thyristors are devices commonly used in high power applications and are used extensively throughout the power electronics field. These devices are unique in that a small gate current or gate voltage can trigger a large current flow, regardless of whether that base current remains on or not. In their most ideal form, they are electronic switches where a logic-level signal can rapidly turn the switch ON or OFF. Thyristors are designed to operate as switches over a wide range of voltage and current levels and can be used to switch resistive or reactive loads. Some additional circuit design issues become relevant when switching large reactive loads due to the extreme voltages or currents that are inherent when rapidly switching energy storage elements.

Specified voltage ratings of thyristors range from a few tens of volts up to multiple kV levels and rated current levels range from the sub 1A range up to many kA currents. In higher-power applications thyristors will dissipate considerable energy when in the conducting state so heat sinks are often required to keep the operating temperature low enough to avoid damaging or destroying the devices.

There are many types of thyristors available today with the major distinctions being in how the devices can be turned off. The most basic units are the SCR and the Triac and will be the focus of this experiment. The acronyms for some of the other types of thyristors, often considered more advanced devices, are BCTs, LASCR, RCT, GTO, FET-CTH, MTO, ETO, IGCT, MCT, and SITH. Regardless of whether working with the basic SCR or Triac or the more advanced devices, they all still use a 4-layer pnpn silicon stack comprising three series-connected pn junctions as the basic element that is used to switch large loads.

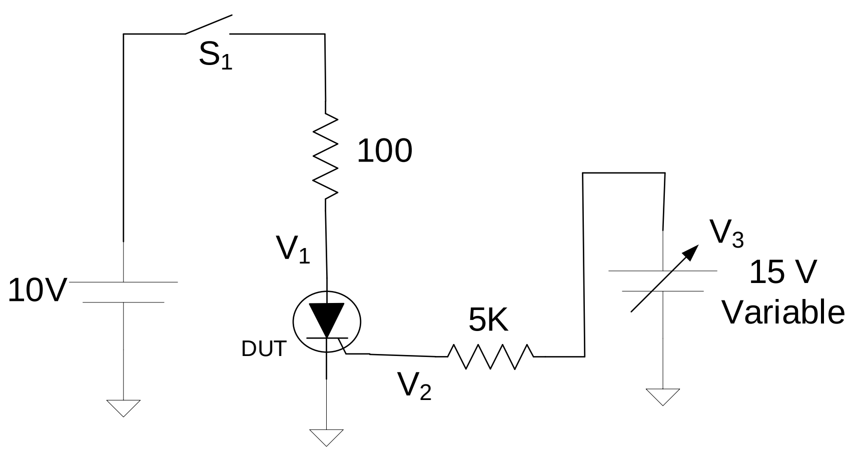
For safety reasons, we will restrict the investigations in this experiment to the 12V rms level though the devices used and the circuits discussed would work well at much higher voltage levels.

## Checkpoints

1. Demonstration of SCR behavior and parameter extraction from Part 1
2. Demonstration of motor speed controller from Part 2
3. Demonstration of light-controlled dimmer from Part 3
4. Demonstration of burglar alarm from Part 4
5. (Extra Credit) Demonstration of light-controlled dimmer from Part 5

## Part 1: Extraction of $V_{GT}$ , $I_{GT}$, and $V_{TM}$

Extract the parameters $V_{GT}$, $I_{GT}$, and $V_{TM}$ for the S4010LS2 SCR. A simple test circuit that can be used for extracting these parameters is shown below. Extract $V_{TM}$ at a current of 100mA. (Note: The power dissipation across the 100Ω resistor will be close to 1W so if you use ¼ watt resistors, you may need to put four 400Ω resistors in parallel to form the 100Ω resistor to avoid overheating the resistors.)



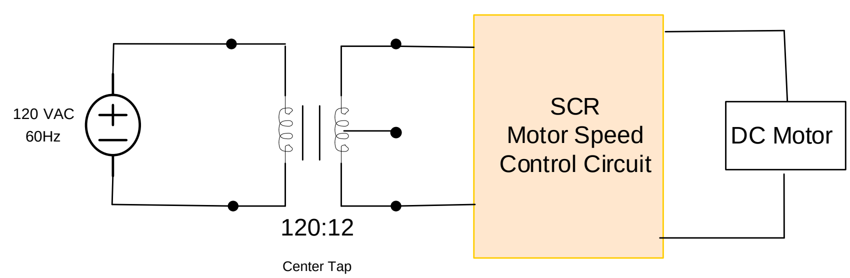

The switch $S_1$ can be as simple as a "wire switch" and serves as a reset for the circuit. It will be normally closed during testing. With $V_3$ set to $0V$, close the switch $S_1$. The SCR should be in the "OFF" state right after $S_1$ is closed. Monitor the voltage $V_1$ on an oscilloscope. The voltage $V_1$ should be $10V$ when the SCR is in the "OFF" state. Gradually increase $V_3$ until the voltage $V_1$ drops. The drop in $V_1$ will occur when the SCR is triggered and should be both abrupt and rapid. After triggering the SCR, measure both $V_2$ and $V_3$ that were present at the time of triggering. The gate trigger voltage is thus $V_2$ and the trigger current $I_{GT}$ is given by the following expression

$$I_{GT} = \frac{V_3 - V_2}{5k\Omega}$$

Also measure the on-stage voltage $V_{TM}$. Compare the measured parameters with what is given in the datasheet. (The datasheet contains parameters for a large number of parts. You need to identify the rows that correspond to the S4010LS2 to obtain the key parameters)

## Part 2: DC Motor Speed Controller

Build and test a circuit using the SCR that can serve as a dc motor RPM controller.



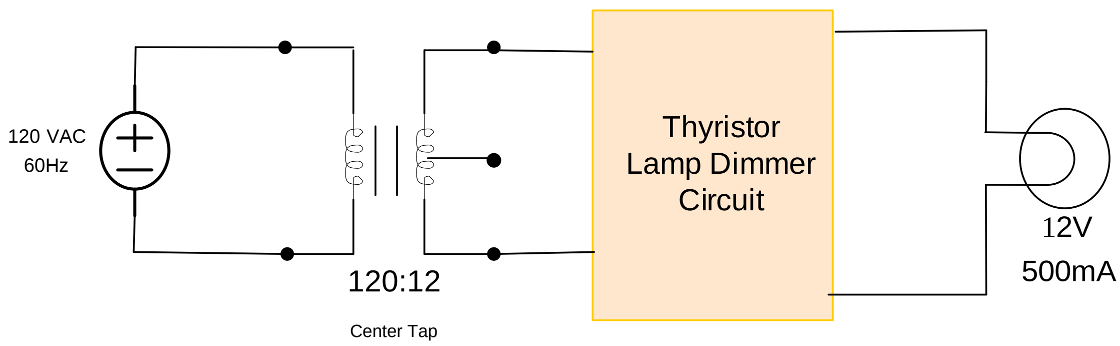

You should be able to continuously adjust the speed of the motor with a control device. You may use a potentiometer, a photo-resistors, a photodiode, or any other electronic component to do the adjustment but you may not use an adjustable DC power supply to adjust the motor speed.

Comment on the effectiveness of your circuit. Why might a circuit like this be used commercially for controlling the speed of a motor rather than using a voltage divider? How much voltage is lost across your SCR?

Note: The lab transformers have three output terminals. The voltage between the upper and middle terminals is $6.3V_{RMS}$, the voltage between the middle and lower terminals is $6.3V_{RMS}$, and the voltage between the upper and lower ports is $12.6V_{RMS}$. If you attach any instrument to the transformer, **be sure you are aware of the voltage levels you're connecting to** so that you do not burn out any components or damage any test equipment.

## Part 3: Light Dimmer

Build a circuit using the SCR that can be used to adjust the brightness of an incandescent lamp. Design your circuit so that it can drive a $12V$, $0.5mA$ incandescent lamp.




You should be able to continuously adjust the brightness of the bulb from no light output to full intensity. Since you are not controlling a large amount of current, the SCR that has been provided can operate safely without adding a heat sink. But be sure not to touch these devices when operating or immediately after turning off the power as they may be hot. You may use a potentiometer, a photo-resistors, a photodiode, or any other electronic component to do the adjustment but you may not use an adjustable DC power supply to adjust the brightness.

Comment on the effectiveness of your circuit. Why might a circuit like this be used commercially for dimming a lamp instead of using a voltage divider or modulator? How much voltage is lost across your SCR?

## Part 4: Burglar Alarm

Assume valuables are stored in a dark room and that a burglar alarm is to be installed to determine if a burgler has entered the room and is using a light to search for the valuables.  Build a light-sensitive burglar alarm that will trigger if light is detected in the room. This circuit should trigger a 12V incandescent lamp (in real life this could trigger a siren, etc) that signals the alarm has been tripped. The circuit should require a hard reset (a switch) to turn off. By default, the circuit should remain off in the dark and trigger when light is detected.

Hint: A photo-resistor is a great light detector!

## Part 5 (Extra Credit): Light Controlled Light Dimmer

Design, build, and test a circuit where the input to a separate photodetector (such as a photo-resistor or photodiode) can be used to modulate the intensity of an incandescent lamp. The intensity of the incandescent lamp should be adjustable from off to full brightness as the light level into the photodetector is varied between the minimum and maximum values.