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Overview:

The objective of this experiment is to study a controlled thyristor-based half-wave rectifier at different firing angles. The average output voltages for different angles is compared to study the effect of controlling the turn-on time on the average DC output voltage.

ATTENTION: During this experiment, do not touch any part of the circuit while energized. Do NOT ground the VARIAC.

Principles:

Similar to diodes, thyristors or silicon controlled rectifiers (SCRs) pass current from their anode to cathode and block it in the other direction. However, current passage can be controlled through a "gate" terminal that takes a small current pulse to turn on the SCR so it can start conducting. The SCR only conducts under the same conditions as a diode, in addition to the additional condition of having a gate pulse to trigger the conduction process. For example, if an AC source is connected in series with an SCR and a resistive load, the positive half cycle of the source is not enough to forward bias the SCR; the SCR will remain reverse biased or off until a gate pulse is applied and then it will start conducting during that half cycle. The SCR thus has three terminals, the anode, cathode, and gate. Gate pulses are generated by "gate drive" circuits that drive current into the gate. The delay between the AC source zero crossing the gate pulse command is termed the "firing angle" which is an electrical angle.

Procedure:

1. For this experiment the variable transformer (VARIAC) at a low frequency of 60 Hz and peak of 35V is used as the main AC source.
    1.1 Before you start, connect the differential probe to one scope channel.
        1.1.1 Set the button on the differential probe to 1/20 (or 20X) attenuation.
    1.2 On the scope channel menu, set the probe to be at 10X unless 20X is available for the differential probe. If 10X is chosen, you will need to manually multiply any measurements or results by two to reach the 20X desired.
    1.3 To setup the VARIAC, make sure the VARIAC output (looks like a regular receptacle) is not connected to any cable.
        1.3.1 Keep the VARIAC OFF and make sure its knob is set to zero.
        1.3.2 Slowly adjust the VARIAC knob to around 15% output.
    1.4 Before connecting the differential probe to the circuit, tie the probe's terminals together and adjust its measured waveform on the screen to show zero offset voltage.
    1.5 Connect the output cable to the VARIAC, and the differential voltage probe across the VARIAC output banana plugs.
        1.5.1 Turn the VARIAC ON.
        1.5.2 Slightly adjust the VARIAC to achieve 35V peak.

1.6 Take a copy of V_{IN} to use as your reference. Show two to five fundamental cycles.

1.7 Turn the VARIAC OFF. Do not adjust its knob setting for the rest of the experiment.

2. Half-Wave Rectifier SCR Circuit with Resistive Load and Zero Firing Angle

2.1 The main rectifier component is the SCR (S) which is a TYN058. The load resistor (R) is 51Ω. The SCR control circuit is enclosed in the dotted box of Fig. 1.

2.2 The control circuit uses diodes (1N4004), a 1kΩ resistor (R1), a control resistor that we is manually changed (R2), and a ceramic (no polarity) 1μF capacitor (C).

   2.2.1 Make sure the SCR and diode polarities are correct. The dash on the diode is at the cathode while the SCR pin assignment is shown in Fig. 2.

2.3 On the proto board, build the circuit shown in Fig. 1. Use a short circuit instead of R2.

2.4 Connect the differential voltage probe across the load resistor to observe the output voltage VO.

2.5 Turn the VARIAC ON.

2.6 Adjust the time base on the scope to show VO for the same number of fundamental cycles you captured for VIN. Make a copy of the waveforms.

   2.6.1 Measure the average or mean VO.

   2.6.2 Zoom in between the SCR turn-off point and the next SCR turn-on point. Measure the time difference using the scope cursors. Make a copy of the waveform.

2.7 Keep your differential probe connection and other circuit connections the same for the next part.

2.8 Turn OFF the VARIAC. Do NOT change the VARIAC voltage setting.
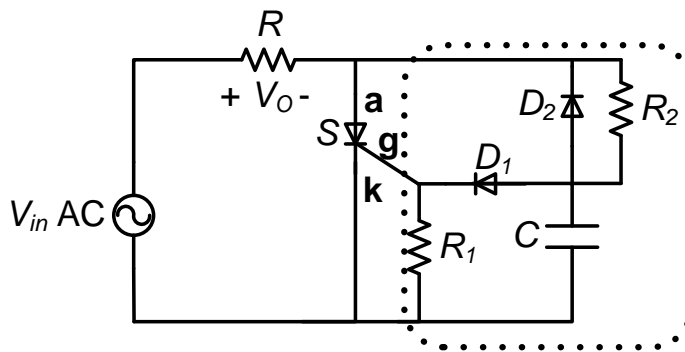

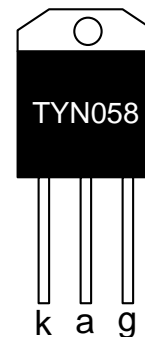Fig. 1. Half-wave rectifier with SCR and resistive load

Fig. 2. Pin assignment of the SCR

3. Half-Wave Rectifier SCR Circuit with Resistive Load and Non-Zero Firing Angle

Two different resistors will be used as R_2. The values should be between 100 and 1000Ω. You can read the resistance color code, or measure it with your digital multimeter.

3.1 Angle Setting #1 (small R_2)

    3.1.1 Remove the short circuit from which was used instead of R_2.
    3.1.2 Connect the small resistance value for R_2.
    3.1.3 Turn the VARIAC ON.
    3.1.4 Adjust the time base on the scope to show V_O for the same number of fundamental cycles you captured for V_{IN}. Make a copy of the waveforms.
        3.1.4.1 Measure the average or mean V_O.
        3.1.4.2 Zoom in between the SCR turn-off point and the next SCR turn-on point. Measure the time difference using the scope cursors. Make a copy of the waveform.
    3.1.5 Keep your differential probe connection and other circuit connections the same for the next part.
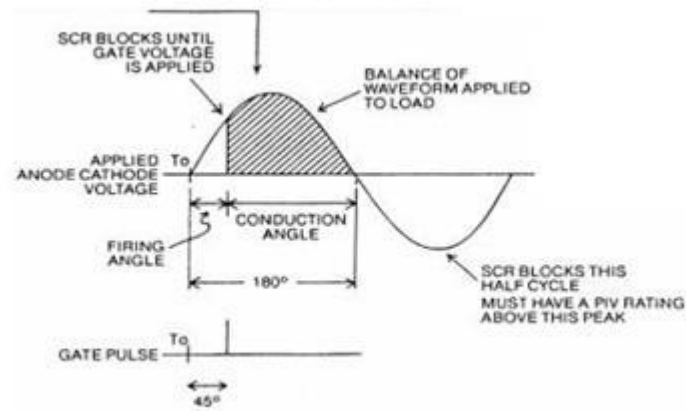   3.1.6 Turn OFF the VARIAC. Do NOT disassemble your circuit or change the VARIAC voltage setting.

3.2 Angle Setting #2 (small R_2)

    3.2.1 Replace R_2 with the larger value resistor.
    3.2.2 Turn the VARIAC ON.
    3.2.3 Adjust the time base on the scope to show V_O for the same number of fundamental cycles you captured for V_{IN}. Make a copy of the waveforms.
        3.2.3.1 Measure the average or mean V_O.
        3.2.3.2 Zoom in between the SCR turn-off point and the next SCR turn-on point. Measure the time difference using the scope cursors. Make a copy of the waveform.
    3.2.4 Turn OFF the VARIAC. Disassemble your circuit and return the VARIAC setting to zero.

Representative Results:

An example waveform showing the firing and conduction angles is shown in Fig. 5. The AC input voltage waveform is chopped until the firing angle. Important relationships of the average output voltage and firing angles for different SCR rectifiers with input $v_{in}=V_0\cos(\omega t)$ are:

- Single SCR and R load: $\langle v_{out}\rangle=V_0[1+\cos(\alpha)]/(2\pi)$
- SCR bridge and R load: $\langle v_{out}\rangle= V_0[1+\cos(\alpha)]/\pi$
- SCR bridge, current source load: $\langle v_{out}\rangle=2V_0\cos(\alpha)/\pi$

Reference for Fig. 5: https://www.elprocus.com/wp-content/uploads/2013/08/Firing-Angle.jpg