

POWER ELECTRONICS LAB: RECTIFIER CIRCUIT

A. BACKGROUND

Rectifier is a circuit that converts AC input power to DC output power. The input supply may be a single phase or a multi-phase supply. The output is DC voltage and current with certain amount of ripple components.

There are two types of rectifier, namely half wave and full wave. Each type can either be uncontrolled, half-controlled or fully controlled. An uncontrolled rectifier uses diodes, while a full-controlled rectifier uses thyristor or popularly known as Silicon Controlled Rectifier (SCR). A half controlled is a mix of diodes and thyristors. The thyristors need to be turned on using a special triggering circuit.

Half-Wave Rectifier

In practice, the half-wave rectifier is used most often in low-power applications because the average current in the supply will not be zero. This may cause problems in transformer performance. While practical applications of half wave rectifier are limited, the analysis is important because it will enable us to understand more complicated circuits such as full wave-and three-phase rectifiers.

Full-Wave Rectifier

Like half-wave, the objective of a full-wave rectifier is to produce a voltage or current which is purely DC or has some specified dc component. While the purpose of the full-wave rectifier is basically the same as that of the half-wave rectifiers have some fundamental advantages. The average current in the ac source is zero in the full-wave rectifier, thus avoiding problems associated with nonzero average source currents. The average (dc) output voltage is higher than half-wave. The output of the full-wave is inherently less ripple that the half-wave rectifier.

Commutating Diode

Mostly, for half or uncontrolled circuit they include also a diode across the load as shown in figure. This diode is variously described as a freewheeling diode (FWD), flywheel or bypass diode, but is best described as a commutating diode as its function is to commutate or transfer load current away from the rectifier whenever the load current away from the rectifier whenever the load voltage goes into a reverse state.

In this experiment an experimental set-up Details on their operation can be found in Reference [1] and [2].

B. LEYBOLD POWER ELECTRONICS EXPERIMENTAL MODULE.

In this experiment, the circuit will be built up using Leybold experimental modules. By connecting various modules, a functional system can be realized. Details on the important modules are described in APPENDIX 1. (Note: Module Number is mentioned in the bracket)

C. PROCEDURES.

1. Half-wave rectifier

1.1 Half wave rectifier with R load.

i) The circuit for half-wave rectifier with R load (module no.735 09) is shown in Figure 1. The supply voltage is obtained from the Transformer (module no. 725 73), which is tapped at 45V rms. To turn on the SCR/Thyristor (module no. 735 03), the firing pulses from the Reference Variable Generator (module no. 734 02) and Control Unit Two Pulse/Pulse Generator (module no. 735 12) must be connected. Refer to Figure A2 for connection of the SCR with these two modules.

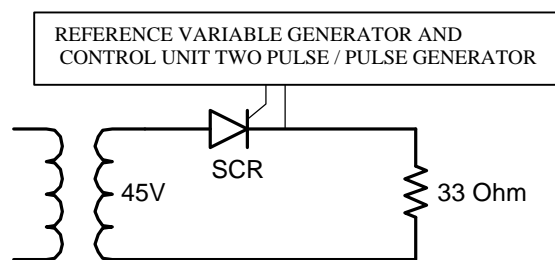


Figure 1

ii) The firing delay angle, (α), is set using the control knob of the Reference Variable Generator (module no. 734 02). By adjusting this knob, set the firing angle to 0 degrees. Measure the peak voltage of the output voltage, V_m , using oscilloscope.

iii) Adjust α of 0, 45, 90 and 135 degrees. Use oscilloscope to estimate α . Using the switch option on the RMS Meter panel (module no. 727 10), select the AV (DC) or RMS measurement and then fill up Table 1. Noting that $180^\circ = \pi$, compare the result with the theoretical formulas,

$$V_{o,DC} = \frac{V_m}{2p}(1 + \cos a), \quad V_{o,RMS} = \frac{V_m}{2} \sqrt{1 - \frac{a}{p} + \frac{\sin(2a)}{2p}}$$

Comment on the practical and theoretical results obtained in (iii)

α	$V_{o,DC}$ (V) (measured)	$V_{o,DC}$ (V) (calculated)	$V_{o,RMS}$ (V) (measured)	$V_{o,RMS}$ (V) (calculated)
0°				
45°				
90°				
135°				

Table 1

iv) Sketch the output voltage and current waveforms captured using an oscilloscope for $\alpha = 90$ degrees only. Make sure that horizontal and vertical scales are clearly marked.

1.2 *Half wave rectifier with R-L load.*

- i) The R-load is replaced with R-L load in series as shown in Figure 2.
- ii) Adjust α to 90 degrees. Sketch the output voltage and current obtained from the oscilloscope.
- iii) Place a Free-wheeling Diode (FWD) (module no. 735 02) across the R-L load as shown in Figure 3.
- iv) Adjust α to 90 degrees. Sketch the output voltage obtained from the oscilloscope. Compare and comment on the results obtained in (ii) with (iv).

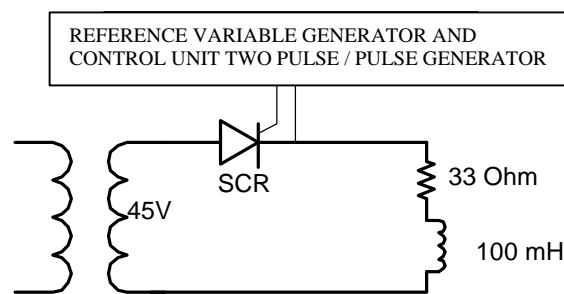


Figure 2

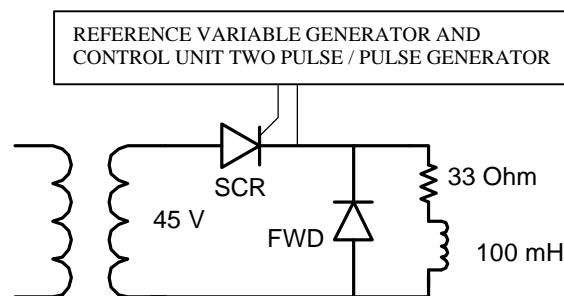


Figure 3

2. *Full wave rectifier*

2.1 *Full wave rectifier with R load*

- i) Connect the circuit as shown in Figure 4. Set α to 0, 45, 90 and 135.
- ii) Measure the output DC and RMS voltages and compare the theoretical values given by:

$$V_{o,DC} = \frac{V_m}{\pi}(1 + \cos \alpha), \quad V_{o,RMS} = V_m \sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

Fill up Table 2 and comment on the results.

α	$V_{o,DC}$ (V) (measured)	$V_{o,DC}$ (V) (calculated)	$V_{o,RMS}$ (V) (measured)	$V_{o,RMS}$ (V) (calculated)
0°				
45°				
90°				
135°				

Table 2

iii) Adjust the firing angle to 90 degrees. Sketch the output voltage and current waveforms.

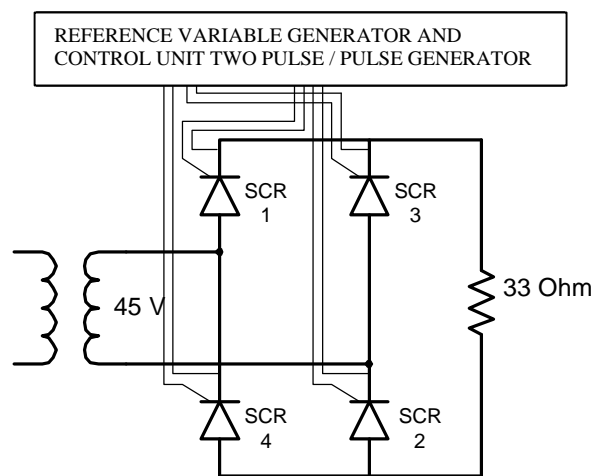


Figure 4

2.2 Full wave rectifier with R-L load

i) The R-load is replaced with R-L load in series as shown in Figure 5.

ii) Adjust the firing angle to 90 degrees. Sketch the output voltage obtained from the oscilloscope. Comment on the results.

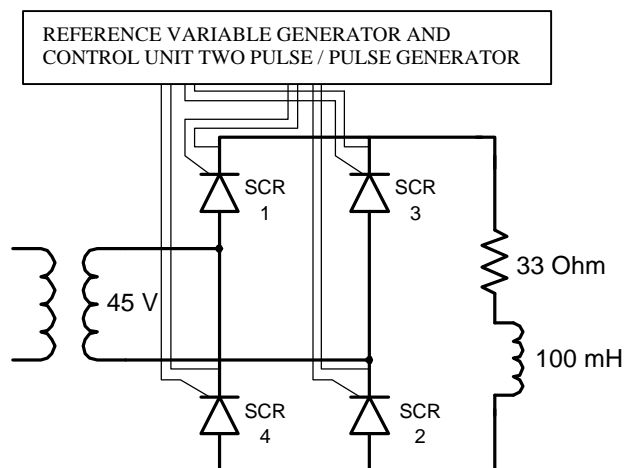


Figure 5

APPENDIX 1: LIST OF LEYBOLD'S EQUIPMENT USED IN THIS EXPERIMENT

1. **REFERENCE VARIABLE GENERATOR (734 02)**: This module is used to determine firing angle by tuning the control knob. It contains input connection for DC voltage (+15V, 0V, -15V) and control knob.

2. **THYRISTOR/SCR (735 03)** : Thyristor or Silicon Control Rectifier (SCR), shown in Figure A1, is a controllable semiconductor switches. The thyristor will turn on when the voltage across its anode (A) to cathode (K) is positive and a positive pulse current is triggered at the gate (G).



Figure A1

3. **THYRISTOR/SCR BRANCH PAIR (735 07K)** : This module consists of two thyristors/SCRs connected in series. The operation is similar with the single thyristor.

4. **CONTROL UNIT TWO PULSE / PULSE GENERATOR (735 12)** : This module generates and trigger the pulse signal. It contains input connection for DC voltage (+15V, 0V, -15V), output pulse signal connection and reference voltage connection (L1, N). This control unit, together with Reference Variable Generator is connected to the SCR/thyristor module shown in Figure A2 below.

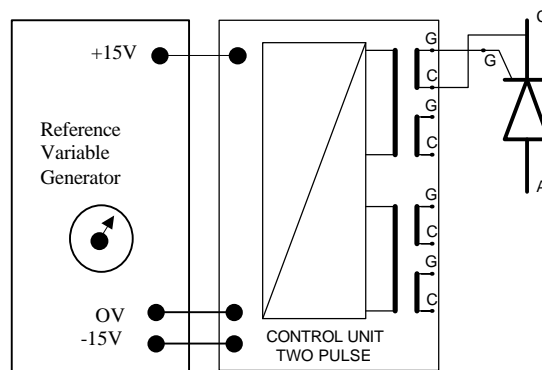


Figure A2: Connection of SCR with Control Unit Two Pulse and

5. **DC STABILIZER (725 81K)** : This module is used as a fixed DC supply. The output DC voltage is +15V and -15V.

6. **MAINS/SUPPLY UNIT (725 60K)** : This module contain socket for three phase voltage (L1, L2, L3, N)

7. **TRANSFORMER (725 73)** : This module will step down the voltage to 45Vrms or 90Vrms (at secondary). This is a center-tapped transformer and is used as voltage supply to the power circuit.

8. **DIODE (735 02)** : Diode is a semiconductor switches that conduct when positive current flow through it.

9. **ISOLATION AMPLIFIER FOUR CHANNEL (735 261)** : This module is used in conjunction with an oscilloscope or a computer interface for the potential-free, safe recording of measuring values in low and extra low voltage systems. Figure A3 shows the module configurations for Channel A in the isolation amplifier. Each channel has a similar configuration.

To observe the voltage waveform, connection is made at 'U' and 'O' while the output, which is point 'A', is connected to the oscilloscope. Figure A4 shows example circuit to observe the voltage waveform. To observe the current waveform, connection is made at 'I' and 'O' while the output, which is point 'A', is connected to the oscilloscope. Figure A5 shows example circuit to observe the current waveform.

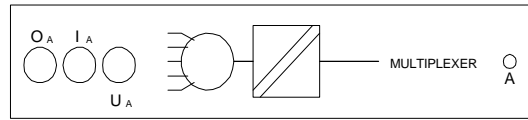


Figure A3: Isolation Amplifier

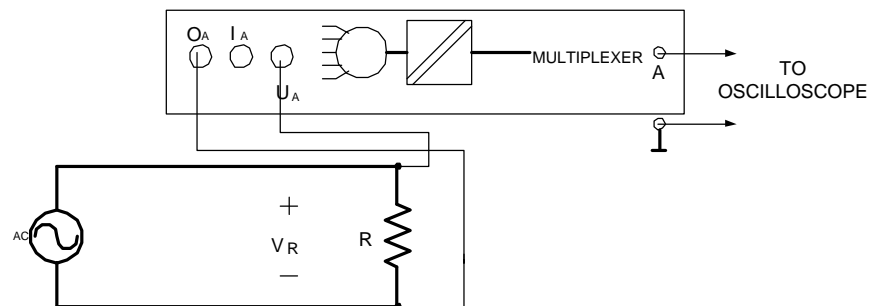


Figure A4: Isolation Amplifier for voltage measurement

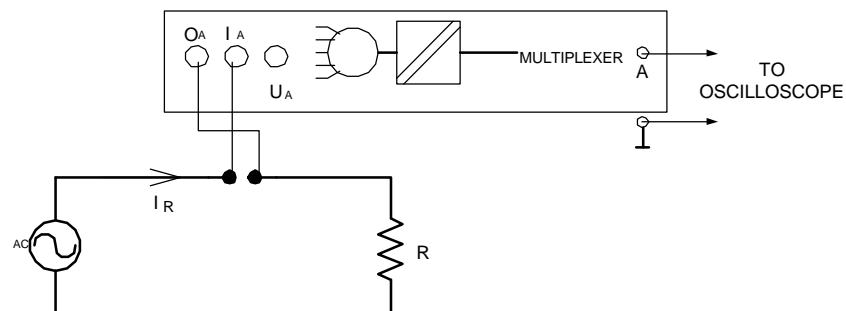


Figure A5: Isolation Amplifier for current measurement

10. RMS METER (727 10): This module is used to measure the RMS/DC value of voltage and current. To measure the voltage, connect to the 'U' and 'O'. To measure the current, connect to the 'I' and 'O'. The RMS and DC measurement can be made by selecting the RMS/DC switch on the main panel.

11. LOAD POWER ELECTRONIC (735 09): This module contains resistive, inductive and capacitive loads.

REFERENCE

- [1]. N. Mohan, T. M. Undeland, W. P. Robbins, "Power Electronics; Converters, Applications and Design", 2nd ed., John Wiley & Sons, 1995
- [2]. D. W. Hart, "Introduction To Power Electronics", Prentice Hall International

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