Experiment # 1
Diode (Uncontrolled) Rectifiers

Objectives

- Setting up various types of rectifier circuits and understanding their operation
- Measuring and interpreting various performance parameters of rectifier circuits
- Investigating the effect of capacitor smoothing on the performance of rectifier circuits

Components and Accessories

1	735 09	Load, Power Electronics
1	735 012	Phase commutated converter
1	524 013S	Sensor-CASSY 2 – Starter
1	735 190	Phase Control Noise Filter 3X4.5A
1	726 80	Transformer 45/90, 3 N
1	500 59	Set of 10 safety bridging plugs, black
1	500 591	Set of 10 Safety Bridging Plugs with Tap, black
2	500 640	Safety Connection Lead 100 cm yellow/green
4	500 641	Safety Connection Lead 100 cm, red
1	735 012 – 01 M1/M3	Mask (Bridge Topology)
1	735 012 – 04 B2	Mask (Bridge Topology)
1	735 012 – 08 B6(C)	Mask (Bridge Topology)

Theory

Rectifiers

They are power electronic circuits designed to convert an AC voltage (or current) into a DC voltage (or current). The output of these rectifiers consists of an average voltage or current (a DC component), plus other (undesirable) AC components called *harmonics*.

- The average output voltage of a single-phase half-wave rectifier is:

$$V_{dc} = \frac{V_m}{\pi} = 0.318\, V_m$$

- The average output voltage a single phase full-wave wave rectifier is:

$$V_{dc} = \frac{2V_m}{\pi} = 0.636\, V_m$$

- **Note that, other performance Parameters are presented in Appendix C**

- The average output voltage of a three-Phase half-wave rectifier is:

$$V_{dc} = \frac{3\sqrt{3}V_m}{2\pi} = 0.828V_m$$

- The average output voltage a three-phase full-wave wave rectifier is:

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi} = 1.654V_m$$

Capacitor Smoothing (Filter)

- With the addition of a capacitor smoothing (filter) at the output, the peak-to-peak voltage ripple at the output of any type of rectifiers depends on the frequency of the ripple (f_r) at output, and the maximum value of the output voltage (V_{max}), as:

$$\Delta V = \frac{V_{max}}{f_r RC}$$

- The average output voltage with capacitor smoothing (filter) is:

$$V_{dc} = V_{max} - \frac{\Delta V}{2}$$

- The AC ripple at the output with a capacitor filter is:

$$V_{ac} = \frac{V_{max}}{2\sqrt{2}(f_r RC)}$$

- The Ripple Factor, therefore, is:

$$RF = \frac{V_{ac}}{V_{dc}} \Rightarrow RF = \frac{\frac{V_{max}}{2\sqrt{2}(f_r RC)}}{V_{max}\left(\frac{2f_r RC-1}{2f_r RC}\right)} \Rightarrow RF = \frac{1}{\sqrt{2}(2f_r RC-1)}$$

Symbols Table:

i_s : the input current

u_{s01} : the input voltage

u_V : the diode (valve) voltage

i_v : the valve current

u_d : the output voltage

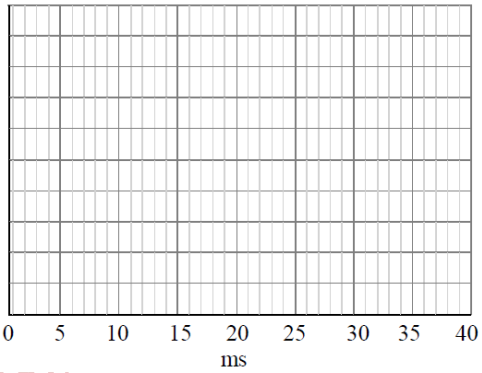
i_d : the output current

Experimental Procedure

1.1 Single–Phase Half–Wave Rectifier

Notes:

- *Do not turn on any part of the equipment without a prior notice from the supervisor*
- Connect one transformer secondary to produce a phase-to-neutral voltage of 90V
- Two types of load will be used: Resistive load of 200Ω (2 resistors of 100Ω each in series), and Resistive load of 1000Ω with a Capacitor Filter
- Mask (Bridge topology): "735 012 – 01 M1/M3"
- Use CASSY and its associate software (CASSY LAB) to measure/plot the currents and voltages in the rectifier. To plot the time profiles appropriately, open the CASSY Lab file Single_Pulse_R_0.labx, and adjust the new plots' settings to be similar to those in the file you have just opened; set the time interval to 40ms. For more details refer to Appendix A.



- **In all the circuits to be connected, ignore the measurement meters; instead of an Ammeter put a short circuit, and just open circuit the Voltmeter.**

I) Single–Phase Half–Wave Rectifier with Resistive Load

Connect the components as shown in Figure 1.1. The load is resistive of 200Ω (2 resistors in series of 100Ω each).

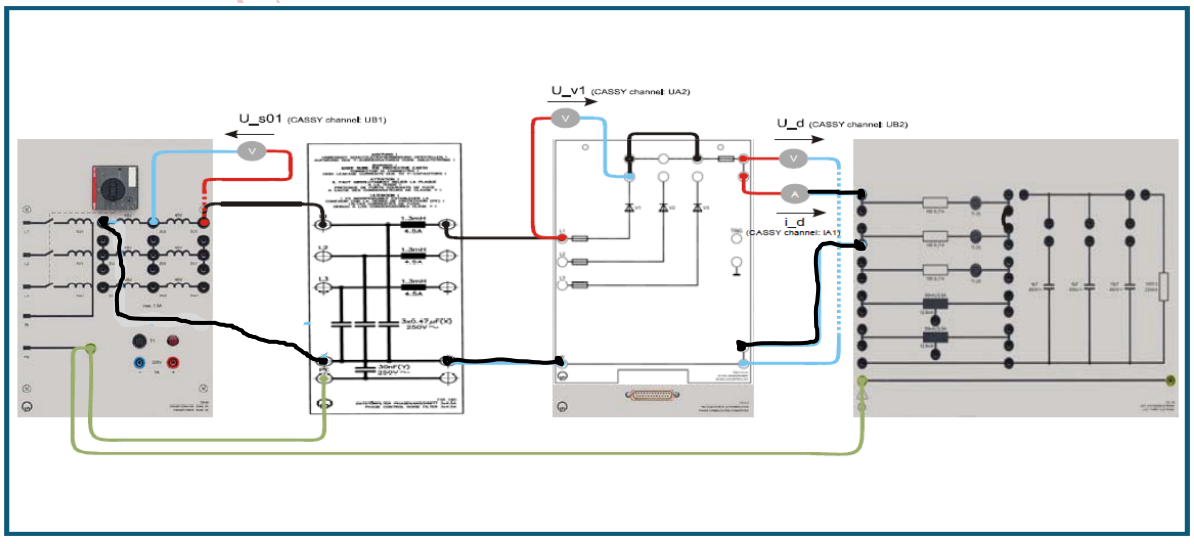


Figure 1.1 Configuration of a Single – Phase Half – Wave Rectifier supplying a resistive load

1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}), and diode current (i_d); using the CASSY LAB software. Refer to **Appendix A** for details.

Ask

2) Turn on the Transformer Supply Voltage Cat. No. 726 80
3) Plot the traces of the input voltage (u_{s01}), half its value, and the diode current (i_d); take screen shots of these plots!
4) Measure half the peak input voltage (u_{s01}); using the CASSY LAB software
5) Turn off the Transformer Supply Voltage Cat. No. 726 80
6) Connect the voltage probe of CASSY to measure/plot the diode (valve) voltage (u_v); leave the current probe's connection unchanged

Ask

7) Turn on the Transformer Supply Voltage Cat. No. 726 80
8) Measure the Peak Inverse Voltage (PIV) of the diode, then compare its value with the peak value of the supply voltage! Explain! How does it compare to the expected theoretical value?
9) Plot the diode voltage (u_v) and the diode current (i_d); take screen shots of these plots!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Comment on the voltage and current waveforms of the diode!
12) Reconnect the CASSY probes to measure/plot the output voltage across the load (u_d); leave the current probe connection unchanged

Ask

13) Turn on the Transformer Supply Voltage Cat. No. 726 80
14) Plot the output voltage (u_d) and the diode current (i_d), take screen shots of these plots!
15) Measure the peak-to-peak ripple at the output voltage
16) Measure the average output voltage (u_d) and the average output current (i_d)
17) Measure the rms values of the output voltage and current
18) Calculate the Form Factor (FF) using the measured values
19) Calculate the Ripple Factor (RF) using the measured
20) Calculate the theoretical average, rms values of the output voltage, and then calculate FF and RF! Compare with the measured values! Comment!
21) What is the frequency of the output voltage? Comment!
22) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are**!

II) Single – Phase Half – Wave Rectifier with Capacitor Smoothing

1) Disconnect the resistive load of 200 Ω (2 of 100 Ω resistances in series), and connect a 1000Ω instead!
2) Connect a capacitor of 4μF in parallel with the resistive load (1000Ω)

Ask

3) Turn on the Transformer Supply Voltage Cat. No. 726 80

4) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
5) Measure the peak-to-peak ripple at the output voltage. Compare this value with the value obtained previously without the capacitor connected at the output!
6) Using the CASSY LAB software, measure the average and rms values of the output voltage (u_d), and the average and rms values of the output current (i_d)
7) Calculate the Form Factor (FF) using the measured values
8) Calculate the Ripple Factor (RF) using the measured values
9) Compare the measured Ripple Factor (RF) obtained from step 8) with the theoretical value! Comment!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Disconnect the load (1000Ω), whilst keeping the capacitor (4μF) connected, and repeat steps from 3) to 10) from this part! What do you notice?
12) Connect another capacitor of 16μF in parallel with the load (1000Ω)
13) Repeat steps from 3) to 11) from this part
14) Compare the results for the above **four** cases, with and without capacitor smoothing/load, and explain your results!

1.2 Three–Phase Half–Wave Rectifier

Notes:

- *Do not turn on any part of the equipment without a prior notice from the supervisor*
- Two types of load will be used: Resistive load of 200Ω (2 resistors of 100Ω each in series), and Resistive load of 1000Ω with a Capacitor Filter
- Mask (Bridge topology): "735 012 – 01 M1/M3"
- Use CASSY and its associate software (CASSY LAB) to measure/plot the currents and voltages in the rectifier. To plot the time profiles appropriately, open the CASSY Lab file Single_Pulse_R_0.labx, and adjust the new plots' settings to be similar to those in the file you have just opened; set the time interval to 40ms.

I) Three–Phase Half-Wave Rectifier with Resistive Load

- Connect the components as shown in Figure 1.2. The load is resistive of 200Ω (2 resistors of 100Ω in series). Ignore the probes connections; instead of the current probe place a short circuit, and instead of the voltage probe an open circuited.
- **Connect the transformer secondaries as Y, with a phase-to-neutral voltage of 45V**

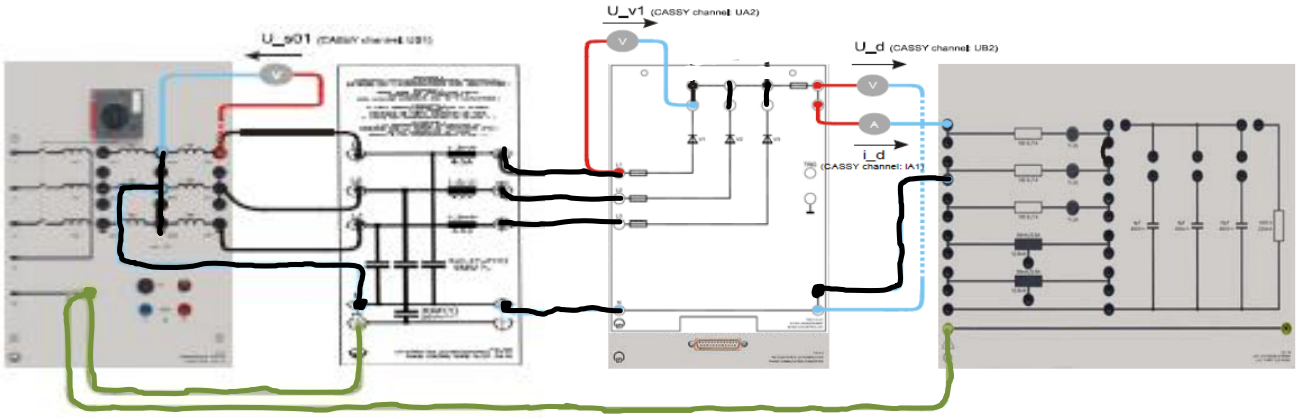


Figure 1.2 Configuration of a Three–Phase Half–Wave Rectifier supplying a resistive load

1) Initially, connect the CASSY probes to plot/measure the input phase voltage (u_{s01}), and the output current (i_d)

Ask 2) Turn on the Transformer Supply Voltage Cat. No. 726 80

3) Plot the traces of the input voltage (u_{s01}), and the diode current (i_d); take screen shots of these plots!
4) Measure half the peak input voltage (u_{s01}); using the CASSY LAB software
5) Turn off the Transformer Supply Voltage Cat. No. 726 80
6) Connect the voltage probe of CASSY to measure/plot the diode (valve) voltage (u_v); leave the current probe connection unchanged

Ask 7) Turn on the Transformer Supply Voltage Cat. No. 726 80

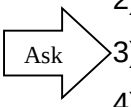
8) Measure the Peak Inverse Voltage (PIV) of the diode, then compare its value with the peak value of the supply voltage! How does it compare to the expected theoretical value? Explain!
9) Plot the diode voltage (u_v) and the diode current (i_d); take screen shots of these plots!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Comment on the voltage and current waveforms of the diode!
12) Reconnect the CASSY probes to measure/plot the output voltage across the load (u_d); leave the current probe connection unchanged!

Ask 13) Turn on the Transformer Supply Voltage Cat. No. 726 80

14) Plot the output voltage (u_d) and the diode current (i_d), take screen shots of these plots!
15) Measure the peak-to-peak ripple at the output voltage
16) Measure the average output voltage (u_d) and the average output current (i_d)
17) Measure the rms values of the output voltage and current
18) What is the frequency of the output voltage? Comment!
19) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are**!
20) Calculate the Form Factor (FF) using the measured values
21) Calculate the Ripple Factor (RF) using the measured values
22) Calculate the theoretical average, rms values of the output voltage, and then calculate the FF and RF! Compare with the measured values! Comment!

II) Three–Phase Half–Wave Rectifier with a Capacitor Smoothing

1) Disconnect the 200Ω - resistive load (2 resistors of 100Ω each in series), and connect a 1000Ω instead!
2) Connect a capacitor of 4μF in parallel with the resistive load.



3) Turn on the Transformer Supply Voltage Cat. No. 726 80
4) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
5) Measure the peak-to-peak ripple at the output voltage. Compare this value with the value obtained previously without a Capacitor Filter at the output!
6) Using the CASSY LAB software, measure the average and rms values of the output voltage (u_d), and the average and rms values of the output current (i_d)
7) Calculate the Form Factor (FF) using the measured values
8) Calculate the Ripple Factor (RF) using the measured values
9) Compare the Measured Ripple Factor (RF) obtained from step 8) with the theoretical value! Comment!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Connect another capacitor of 16μF in parallel with the load
12) Repeat steps from 3) to 10) from this part
13) Compare the results for the above three cases, with and without capacitor smoothing, and explain your results!

1.3 Single–Phase Full–Wave Rectifier

Notes:

- *Do not turn on any part of the equipment without a prior notice from the supervisor*
- Two types of load will be used: Resistive load of 200Ω (2 resistors in series, of 100Ω each), and a Resistive load of 1000Ω with a Capacitor Filter
- Mask (Bridge topology): "735 012 – 04 B2"
- Use CASSY and its associate software (CASSY LAB) to measure/plot the currents and voltages in the rectifier. To plot the time profiles appropriately, open the CASSY Lab file Single_Pulse_R_0.labx, and adjust the new plots' settings to be similar to those in file you have just opened; set the time interval to 40ms.

I) Single–Phase Full–Wave Rectifier with Resistive Load

- Connect the components as shown in Figure 1.3. The load is resistive of 200Ω (2 resistors in series, of 100Ω each). Ignore the probes' connections!
- **Connect one transformer secondary to produce a phase-to-neutral voltage of 45V**

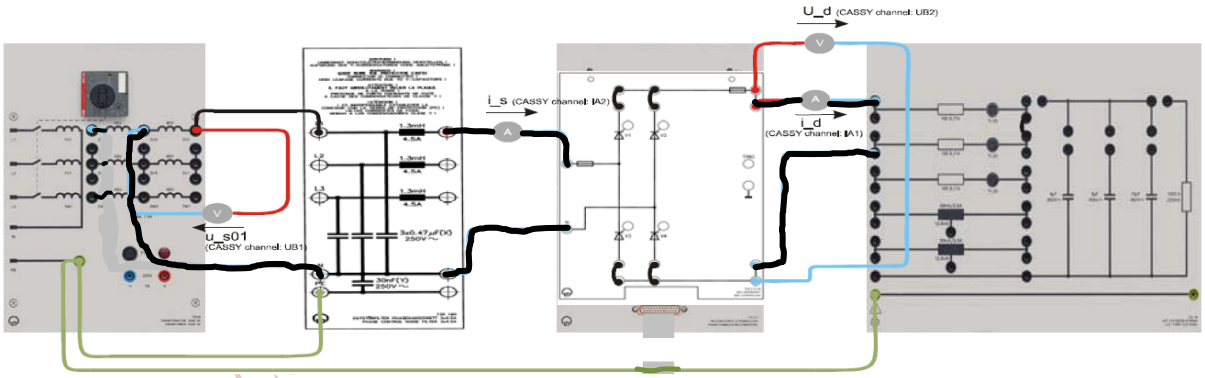


Figure 1.3 Configuration of Single-Phase Full-Wave Rectifier supplying a resistive load

1) Initially, connect the CASSY probes to measure/plot the input phase voltage (u_{s01}), and the source (input) current (i_s)

Ask

2) Turn on the Transformer Supply Voltage Cat. No. 726 80
3) Plot the traces of the input voltage (u_{s01}), and the source current (i_s); take screen shots of these plots!
4) Measure the peak input voltage (u_{s01}); using CASSY LAB software
5) Turn off the Transformer Supply Voltage Cat. No. 726 80
6) Connect the voltage probe of CASSY to measure the D_1 diode (valve) voltage (u_v), and the current probe to measure the diode D_1 current (i_v)

Ask

7) Turn on the Transformer Supply Voltage Cat. No. 726 80

8) Measure the Peak Inverse Voltage (PIV) of the diode, then compare its value with the peak value of the supply voltage! How does it compare with the expected theoretical value? Explain!
9) Plot the diode voltage (u_v) and the diode current (i_v); take screen shots of these plots!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Comment on the voltage and current waveforms of the diode!
12) Reconnect the CASSY probes to measure the output voltage across the load (u_d), and the output current (i_d)!

Ask

13) Turn on the Transformer Supply Voltage Cat. No. 726 80
14) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
15) Measure the peak-to-peak ripple at the output voltage
16) Measure the average output voltage (u_d) and the average output current (i_d)
17) Measure the rms values of the output voltage and current
18) What is the frequency of the output voltage? Comment!
19) Turn off the Transformer Supply Voltage Cat. No. 726 80, **and keep the connections as they are**!
20) Calculate the Form Factor (FF) using the measured values
21) Calculate the Ripple Factor (RF) using the measured values
22) Calculate the theoretical average, rms values of the output voltage, and then calculate the FF and RF! Compare with the measured values! Comment!

II) Single–Phase Full–Wave Rectifier with a Capacitor Smoothing

1) Disconnect the 200Ω - resistive load (2 resistors in series of 100Ω each), and connect a 1000Ω instead!
2) Connect a capacitor of 4µF in parallel with the resistive load

Ask

3) Turn on the Transformer Supply Voltage Cat. No. 726 80
4) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
5) Measure the peak-to-peak ripple at the output voltage. Compare this value with the value obtained previously without the capacitor being connected at the output!
6) Using CASSY LAB software, measure the average and rms values of the output voltage (u_d), and the average and rms values of the output current (i_d)
7) Calculate the Form Factor (FF) using the measured values
8) Calculate the Ripple Factor (RF) using the measured values
9) Compare the Measured Ripple Factor (RF) obtained from step 8) with the theoretical value! Comment!

10) Turn off the Transformer Supply Voltage Cat. No. 726 80

11) Connect another capacitor of 16μF in parallel with the load

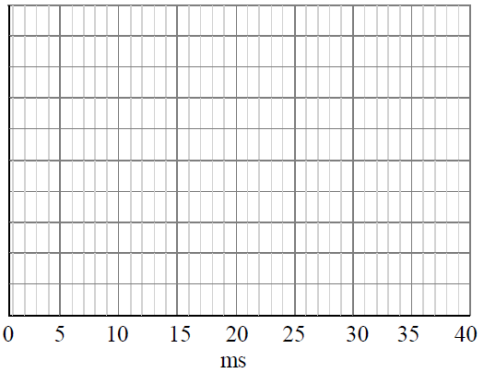
12) Repeat steps from 3) to 10) from this part

13) Compare the results for the above three cases, with and without capacitor smoothing, and explain your results!

1.4 Three–Phase Full–Wave Rectifier

Notes:

- *Do not turn on any part of the equipment without a prior notice from the supervisor*
- Two types of load will be used: a Resistive load of 200Ω (2 resistors in series, of 100Ω each), and a Resistive load of 1000Ω with a Capacitor Filter
- Mask (Bridge topology): "735 012 – 08 B6C"
- Use CASSY and its associate software (CASSY LAB) to measure/plot the currents and voltages in the rectifier. To plot the time profiles appropriately, open the CASSY Lab file Single_Pulse_R_0.labx, and adjust the new plots' settings to be similar to those in the file you have just opened; set the time interval to 40ms.



I) Three–Phase Full–Wave Rectifier with Resistive Load

- Connect the components as shown in Figure 1.4. The load is resistive of 300Ω (3 resistors in series, of 100Ω each).
- **Connect one transformer secondaries as Y to produce a phase-to-neutral voltage of 45V**

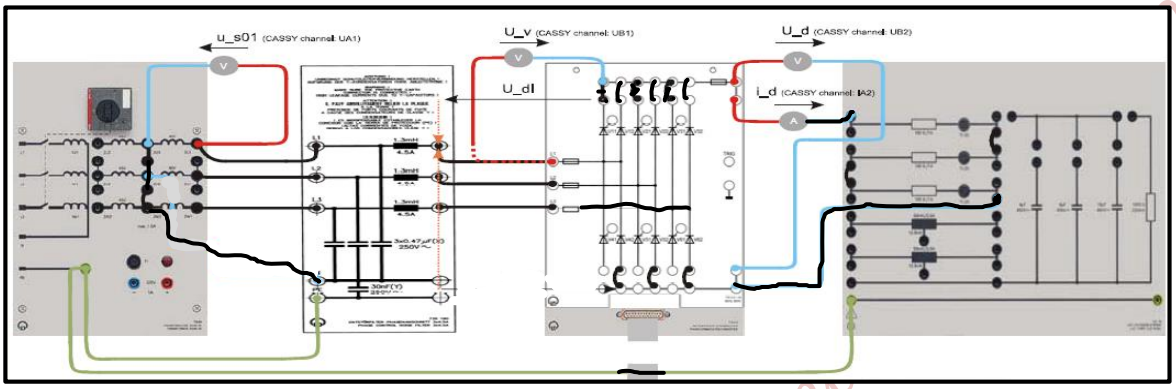


Figure 1.4 Configuration of a Three–Phase Full–Wave Rectifier supplying a resistive load

1) Initially, connect the CASSY probes to measure/plot the input phase voltage (u_{s01}), and the input current (i_s)

Ask 2) Turn on the Transformer Supply Voltage Cat. No. 726 80

3) Plot the traces of the input voltage (u_{s01}), and the input current (i_s); take screen shots of these plots!
4) Measure half the peak input voltage (u_{s01}); using CASSY LAB software
5) Turn off the Transformer Supply Voltage Cat. No. 726 80
6) Connect the voltage probe of CASSY to measure/plot the diode (valve) voltage (u_v), and the current probe to measure/plot the diode (valve) current (i_v)

Ask 7) Turn on the Transformer Supply Voltage Cat. No. 726 80

8) Measure the Peak Inverse Voltage (PIV) of the diode, then compare its value with the peak value of the supply voltage! How does it compare to the expected theoretical value? Explain!
9) Plot the diode voltage (u_v) and the diode current (i_v); take screen shots of these plots!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Comment on the voltage and current waveforms of the diode!
12) Reconnect the CASSY probes to measure/plot the output voltage across the load (u_d), and the output current (i_d)

Ask 13) Turn on the Transformer Supply Voltage Cat. No. 726 80

14) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
15) Measure the peak-to-peak ripple at the output voltage
16) Measure the average output voltage (u_d) and the average output current (i_d)

17) Measure the rms values of the output voltage and current
18) What is the frequency of the output voltage? Comment!
19) Turn off the Transformer Supply Voltage Cat. No. 726 80, and keep the connections as they are!
20) Calculate the Form Factor (FF) using the measured values
21) Calculate the Ripple Factor (RF) using the measured values
22) Calculate the theoretical average, rms values of the output voltage, and then calculate the FF and RF! Compare with the measured values! Comment!

II) Three–Phase Full–Wave Rectifier with a Capacitor Smoothing

1) Disconnect the resistive load of 300Ω (3 resistors in series, of 100Ω each), and connect a 1000Ω instead!
2) Connect a capacitor of 4μF in parallel with the resistive load.
Ask
3) Turn on the Transformer Supply Voltage Cat. No. 726 80
4) Plot the output voltage (u_d) and the output current (i_d), take screen shots of these plots!
5) Measure the peak-to-peak ripple at the output voltage. Compare this value with the value obtained previously without the capacitor being connected at the output!
6) Using CASSY LAB software, measure the average and rms values of the output voltage (u_d), and the average and rms values of the output current (i_d)
7) Calculate the Form Factor (FF) using the measured values
8) Calculate the Ripple Factor (RF) using the measured values
9) Compare the Measured Ripple Factor (RF) obtained from step 8) with the theoretical value! Comment!
10) Turn off the Transformer Supply Voltage Cat. No. 726 80
11) Connect another capacitor of 16μF in parallel with the load
12) Repeat steps from 3) to 10) from this part
13) Compare the results for the above three cases, with and without capacitor smoothing, and explain your results!