Aim

(i) To verify the I-V characteristics of a Junction diode and a Zener diode and calculate cut-in (general-purpose diode) and breakdown voltage (Zener)

(ii) To measure ripple factor in half-wave and full-wave rectifiers (with and without capacitive filters)

Introduction

A. Diode

The diode current I_D as a function of the voltage V_D across it (with its polarity given by that of the p-region with respect to the n-region) is given by: $I_D = I_S[\exp(V_D/\eta V_T) - 1]$, where I_S is called the *reverse saturation current* of the diode (typically ranging from pA to μA), V_T (= kT/q) is the *thermal voltage* (= 26 mV at 300 K), and η is called the *ideality factor* (typically ranging between 1 and 2). A typical diode characteristic is shown in Figure 1.

When a silicon diode is forward biased (i.e., positive V_D), very little diode current I_D flows until V_D reaches about 0.5 V. However, beyond this point (known as the *knee voltage* (V_γ) of the diode, as shown in Fig. 1), with further increase in V_D, I_D starts to increase rapidly with V_D.

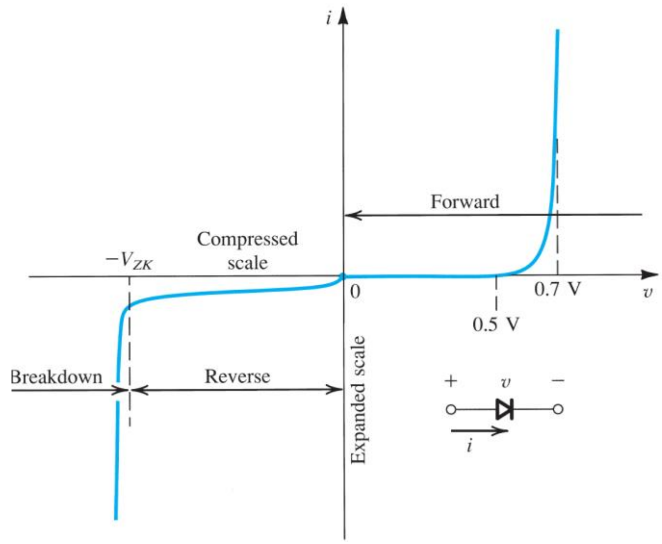


Figure 1

When the diode is reverse-biased (i.e., negative V_D), the diode current reverses its direction and maintains a nearly constant value of I_S. The magnitude of the reverse-bias across the diode should not exceed its *peak inverse voltage* (PIV), as shown in Figure 1, since it would result in a destructive breakdown of the diode.

Experiment (i)

1. Wire the circuit of Fig. 2 in the Falstad Circuit Simulator.

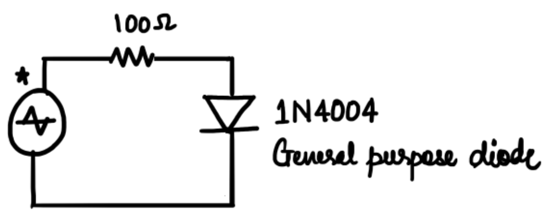


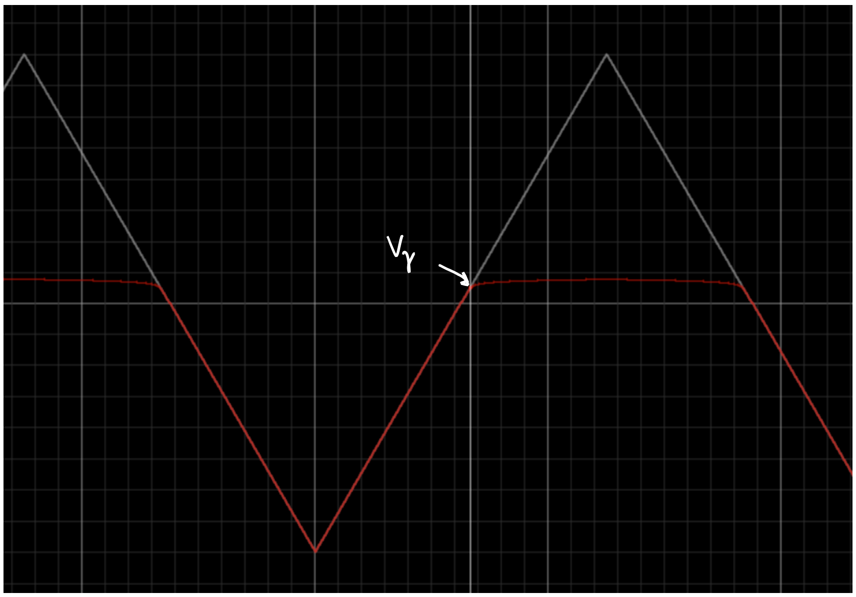
Figure 2

The source should be a 16-V_{pp} triangular waveform (zero DC offset) with a frequency of 200 Hz. Note that in the online simulator the terminal towards which a * is drawn is the positive reference, and you may need to flip the terminals to measure +ive wrt –ve side.

Choose the diode as 1N4004 from the list. The model also gives you the option of defining your own diode (with customizable values of reverse saturation current, forward voltage etc.) Proceed with the general purpose, diode 1N4004.

Please ensure a resistor of 100 Ω is connected in series with the diode to limit any excess flow of current.

2. Display the input voltage (+ive wrt to the other) in the scope. Superimpose the voltage across the diode on this plot and observe the waveform.
3. Identify the cut-in voltage $V\gamma$ from this waveform. Before the cut-in voltage, the voltage across the diode seems to be following the input voltage because the diode was OFF. However, when the input voltage reaches $V\gamma$, the diode is no longer reverse biased and the output across diode begins to slowly be limited to around 0.7 V. Save all waveforms.



4. Remove the scopes showing voltage waveforms, and now display a superimposed waveform of both voltage and current across the diode.
5. From the properties of plot, display the I-V characteristics of the diode and save the plot.
6. Repeat this experiment by replacing the General Purpose Diode 1N4004 with default Zener Diode. Explain the waveform and identify the Breakdown voltage of this Zener diode from the waveform.
7. Display the I-V characteristics of the Zener diode and save the plot.

Experiment (ii)

Half- and Full-Wave Rectifiers (without Capacitive Filter)

A. Half-Wave Rectifier

Wire the half-wave rectifier circuit of Figure 5. Observe and save the input and the output waveforms.

B. Full-Wave Rectifier (Centre-tapped)

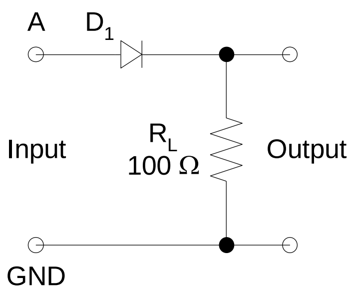


Figure 5

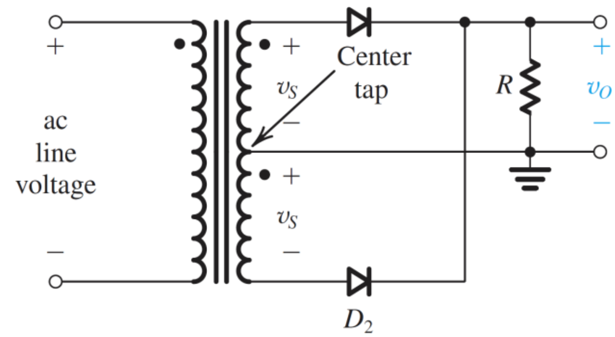


Figure 6

Wire the full-wave rectifier circuit of Figure 6. Use input source voltage as 220 V (rms) (i.e. 220√2 V Peak voltage, 50 Hz). Use a center-tapped transformer (under *Passive Components*) in the simulator and set the turn ratio as 0.1 (1:10) so that the secondary windings have about 10.9 V (rms) voltage each.

To view the voltage across the secondary windings, use a Voltmeter probe (under *Outputs and Labels*) as shown in Figure 7 below.

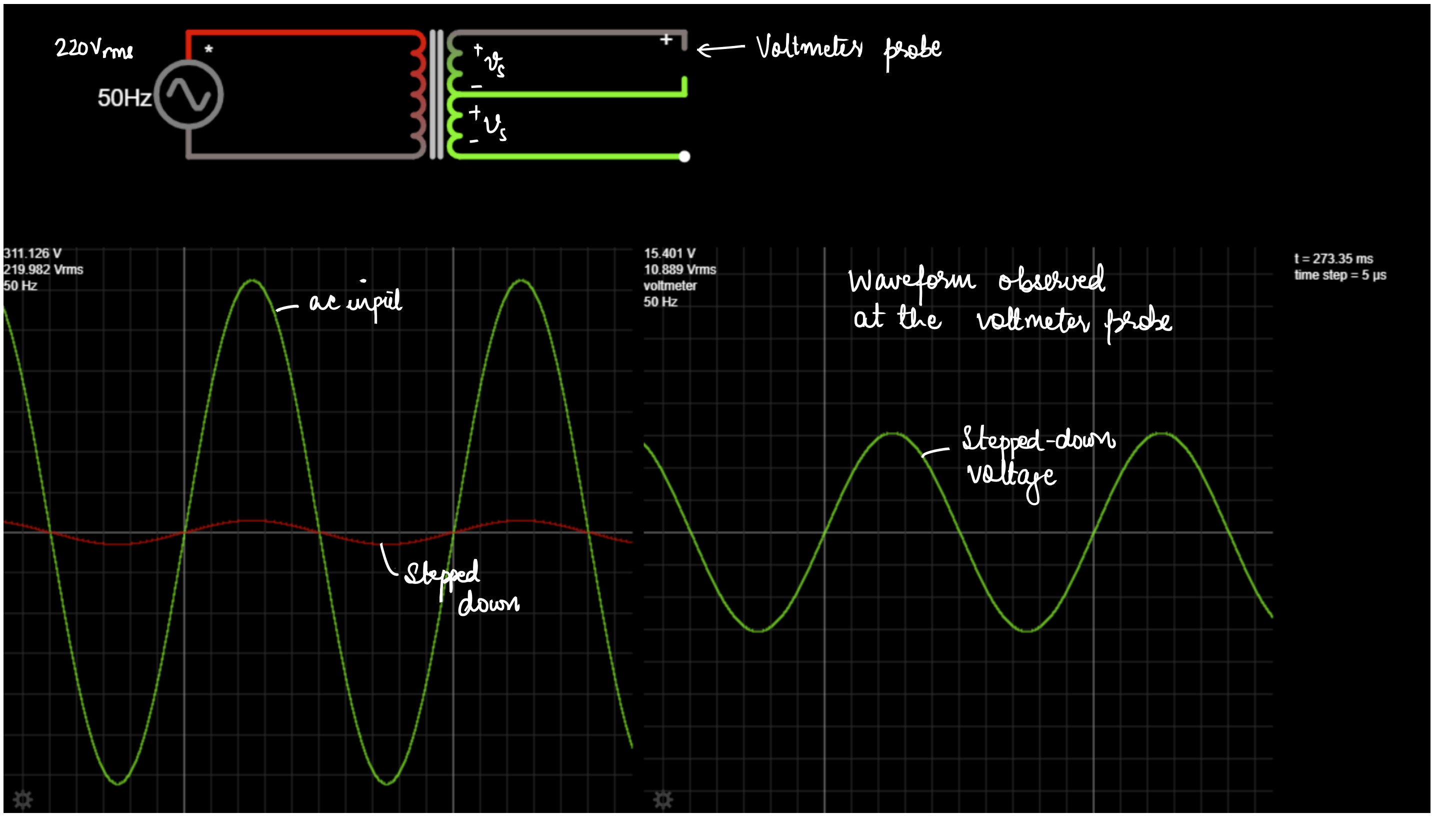


Figure 7

Complete the circuit with the two diodes as shown in Figure 8 below. Set properties to display both rms and average values.

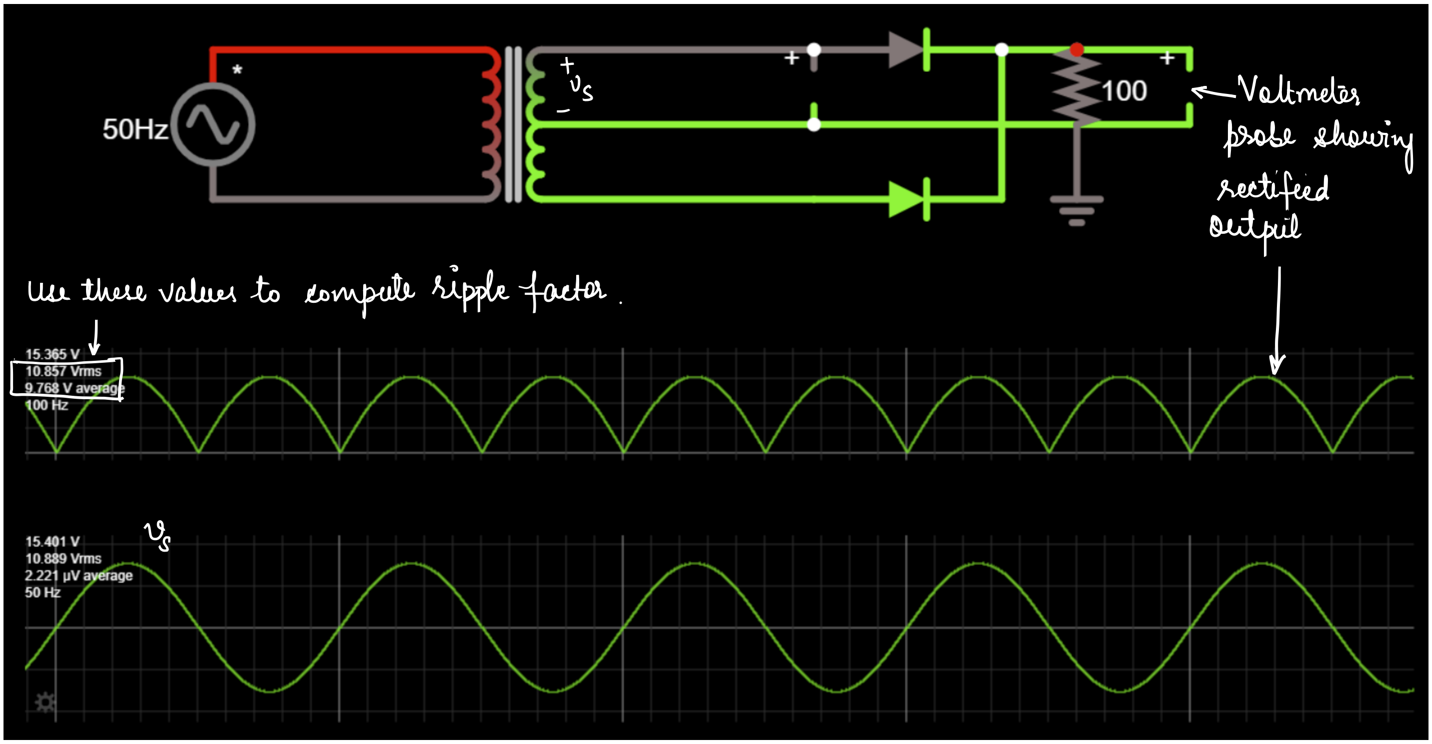


Figure 8

Observe and save the waveforms, and note the average (V_{dc}) and rms values (V_{rms}) in the Observation Table for computing the Ripple Factor (γ).

C. Bridge Rectifier

Make the circuit shown in Figure 9 in the online simulator (simple transformer ratio 1:10) as shown in the Figure 10.

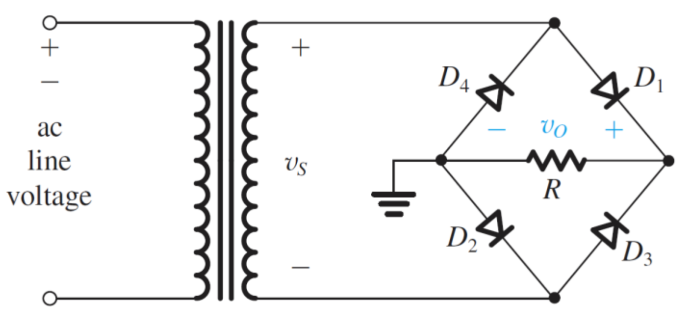


Figure 9 Bridge Rectifier

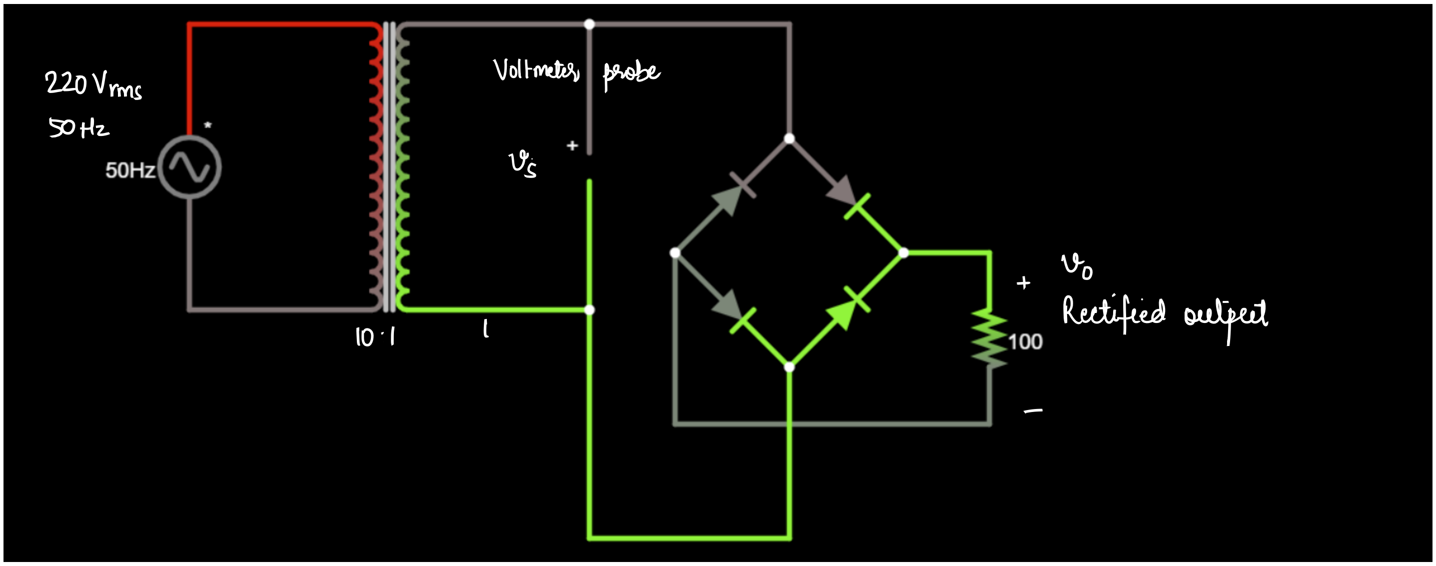


Figure 10

Display and save the combined (superimposed) waveforms (stepped down and rectified). Note the rms and average values and calculate the ripple factor.

D. Half-Wave Rectifier (with Capacitive Filter)

In this section, you will study the effect of capacitive filters on ripple voltage. Use a Switch (from the *Passive Components* in the online simulator) and draw a simple half-wave rectifier circuit using an input voltage (sinusoid of 50 Hz, V_{pp} = 10 V, zero DC offset) as shown in Figure 11 below. This part is to be performed only for half-wave rectifier.

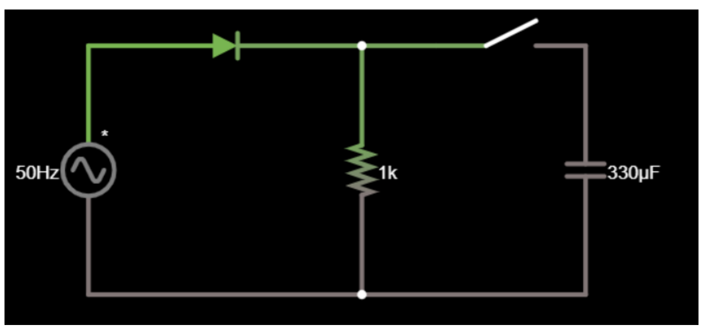


Figure 11

1. Display the voltage across the resistor when the switch is open, and save the waveform.
2. Now close the switch (ON) and observe the waveform. The waveform would display ripples, with a fixed ripple voltage.
3. Note the peak voltage (V_p) and the ripple voltage (V_{rpp}) (as shown in Figure 12) in the Observation Table and compute the ripple factor.

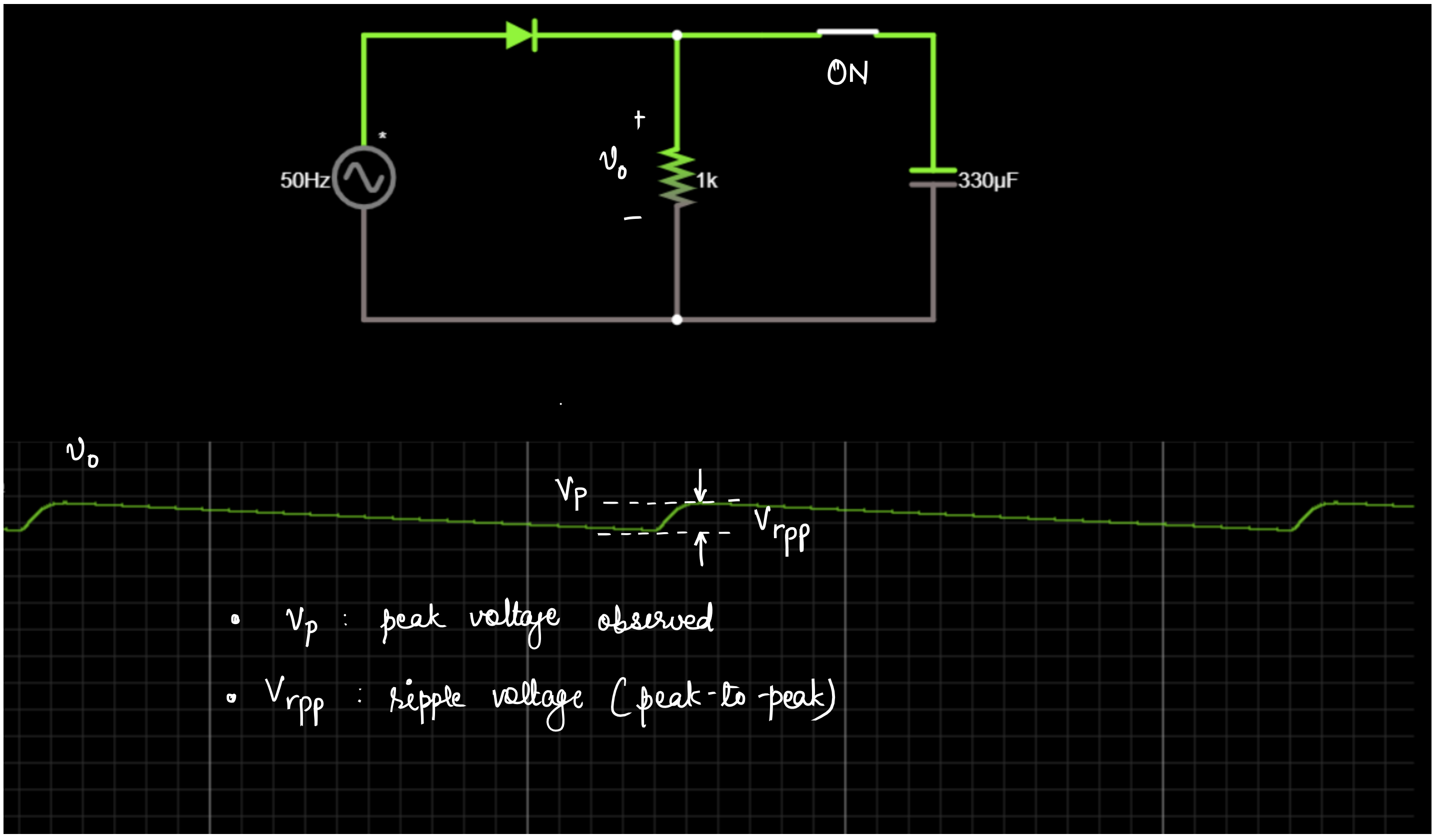


Figure 12

4. Repeat this experiment for *C* = 100 µF, 330 µF, and 1000 µF. What happen to ripple factor as capacitor value is increased? Explain your answer.

Observation Table
Half-wave Rectifier

	Theoretical	*Measured*		
	$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{V_m/2}{V_m/\pi}\right)^2 - 1}$	V_{rms}	V_{dc}	$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$
Without Filter				
With Capacitive Filter (*R* = 1000 Ω, *f* = 50 Hz)				
C	*Theoretical* $\gamma = \frac{1}{2\sqrt{3}fRC}$	*Measured*		
		V_p (*peak of output voltage*)	V_{rpp}	$\frac{V_{rpp}/(2\sqrt{3})}{V_p - 0.5V_{rpp}}$
100 μF				
330 μF				
1000 μF				

Full-wave Rectifier

	Theoretical	*Measured*		
	$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{V_m/\sqrt{2}}{2V_m/\pi}\right)^2 - 1}$	V_{rms}	V_{dc}	$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$
Center-tapped Transformer-based				
Bridge Rectifier				