

University of Technology, Sydney Faculty of Engineering and Information Technology

Subject:

#### 48521 Fundamentals of Electrical Engineering

Assessment Number:

Assessment Title:

Lab 2 – Diode Circuits

2

**Tutorial Group:** 

Students Name(s) and Number(s)

Student Number	Family Name	First Name

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#### **Statement of Collaboration:**

Signature(s)

Lab work	/1
Analysis	/2
Questions	/2
TOTAL	/5

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#### Assessment Submission Receipt

Assessment Title:	Lab 2 – Diode Circuits
Student's Name:	
Date Submitted:	
Tutor Signature:	

# Lab 2 – Diode Circuits

Diode characteristic. Half-wave rectifier. Clamp circuit. Voltage doubler. Limiting circuit.

### Introduction

The diode is one of the simplest electronic devices available. However, it's terminal i-v characteristic is non-linear, and we need to sometimes *model* the diode to determine a circuit's behaviour.

We will measure a diode's characteristic, then model the diode (obtain equivalent circuits for the forward-bias and reverse-bias cases). Then we will examine some very important diode applications, and relate what we get in practice to what is predicted from our diode model.

One of the most important applications of the diode is in rectification. We will examine the operation and performance of a simple half-wave rectifier.

Three other useful applications of diodes will then be examined: the clamp, the voltage doubler, and a limiting circuit.

We will also measure the terminal characteristics of a Zener diode, and examine its operation as a voltage regulator.

### **Objectives**

- 1. To measure a signal diode's and a Zener diode's *i-v* characteristic, and to derive linear models for each (in both the forward and reverse biased cases).
- 2. To observe the behaviour of some simple diode circuits, and to compare experimental behaviour of the circuit with that predicted by the model.

# Equipment

- 1 Digital Storage Oscilloscope (DSO) Hewlett Packard HP54621A
- 1 function generator (FG) GFG-8016G or GFG-8020G or GFG-8016D
- 1 curve tracer adapter (CTA) –Goodwill GCTA-1212A
- 1 digital multimeter GW GDM-8045G or GW GDM-8135
- 2 x 1N914 signal diodes
- 1 x 4V7 Zener diode
- $1 \ge 1 \le \Omega$  resistor
- $1 \ge 10 \text{ k}\Omega$  resistor
- 2 x 1 µF capacitors
- 1 Breadboard
- Hook-up wire
- 2 x 4mm to BNC leads

### Safety

Cat. A lab

This is a Category A laboratory experiment. Please adhere to the Category A safety guidelines (issued separately).

# Lab Work [1 mark]

## **Diode Characteristics**

To examine a diode's characteristic, we will use a curve tracer. This will give us both the forward-bias and reverse-bias characteristic from which we can derive linear models.

#### In the Lab – Setting up the Curve Tracer

1. Set the following on the curve tracer:

POWER	OFF
POLARITY	DIODE FORWARD
CURRENT LIMIT	SIGNAL
H-LENGTH	fully clockwise
BASE CURRENT	10 µА
COLLECTOR SWEEP VOLTAGE	10 V
TRANS / FET	TRANS
SELECTOR	А

On the left-hand side, the 1N914 signal diode should be connected to the terminals labelled C and E. The signal diode package has a coloured band (usually black) at the cathode end. The signal diode is smaller than the Zener diode.

Setting up the CTA

Setting up the DSO

#### In the Lab – Setting up the DSO

- 1. Turn the DSO on.
- 2. In the File section, press the Save-Recall button, then choose the softkey Default Setup. This will ensure the DSO is a known state, e.g. all probe ratios are restored to 1:1, trigger set to Ch 1, etc.
- 3. Connect Channel 1 of the DSO to the HORIZONTAL output of the CTA. Connect Channel 2 of the DSO to the VERTICAL output of the CTA.
- 4. Set the DSO to X-Y mode (Push the Main-Delayed button, then choose the softkey XY). This now means that the two signals applied to Channel 1 and 2 will provide the X deflection and Y deflection. (Normally the X deflection is an internally generated signal that sweeps across in a certain amount of time).
- 5. Push the Acquire key (in the Waveform section) and choose Averaging to reduce the noise on the display.

#### In the Lab – Signal Diode Characteristic

- 1. Turn the CTA on.
- For Channel 1: Set the Volts / div to 0.2 V / div, and use the Vertical Position knob to set a 1 V offset.
- 3. For Channel 2: Set the Volts / div to 0.2 V / div, and use the Vertical Position knob to set a 0.6 V offset.
- 4. You should see the characteristic of the signal diode, which is similar to that shown below.

If your characteristic appears to be going "down" instead of "up", you will have to invert Channel 2 to obtain a correct polarity for the vertical scale (some CTAs have output inverters, some don't). To invert Channel 2, push the channel 2 button, then select the softkey Invert.



5. Accurately sketch the diode's forward  $i_D \sim v_D$  characteristic, noting both horizontal and vertical scales.

Signal diode forward characteristic

**Remember:** the vertical scale on the DSO is the voltage across the internal 100  $\Omega$  resistor of the CTA, so you will have to scale the vertical voltage to get the current.

- 6. Set the POLARITY switch of the CTA to PNP / P-CHANNEL / DIODE BACKWARD. This will give us the reverse-bias characteristic of the diode.
- Set the Channel 1 attenuation to 2 V/div, and move the trace to the right of the display using the Channel 1 position knob.
- 8. Accurately sketch the diode's reverse  $i_D \sim v_D$  characteristic, noting both horizontal and vertical scales.



9. Move the POLARITY switch on the CTA several times to observe both the reverse and forward characteristics.

Signal diode reverse characteristic

### **Questions – Signal Diode Equivalent Circuit**

1. Approximate the forward characteristic curve you have drawn with two straight lines. Derive an equivalent circuit model of the diode using a voltage source and a resistance in series. Show all component values.

Answer:	Signal diode forward- bias equivalent circuit

2. Approximate the reverse characteristic curve you have drawn with one straight line. Derive an equivalent circuit model of the diode using a linear circuit element. Show all component values.



#### In the Lab – Zener Diode Characteristic

- 1. Replace the 1N914 signal diode with the 4.7V Zener diode. Set the polarity switch of the CTA to "NPN / n-channel / diode forward". This will give us the forward-bias characteristic of the diode.
- 2. Set the Channel 1 attenuation knob to 0.2 V/div.
- 3. Accurately sketch the diode's forward i-v characteristic, noting both horizontal and vertical scales.



**Remember:** the vertical scale on the DSO is the voltage across the internal 100  $\Omega$  resistor of the CTA, so you will have to scale the vertical voltage to get the current.

- 4. Set the polarity switch of the CTA to "PNP / p-channel / diode backward". This will give us the reverse-bias characteristic of the diode.
- 5. Set the Channel 1 attenuation knob to 1 V/div.

Zener diode forward characteristic

Zener diode reverse characteristic

6. Accurately sketch the diode's reverse i-v characteristic, noting both horizontal and vertical scales.

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- 7. Move the "Polarity" switch on the CTA several times to observe both the reverse and forward characteristics.
- 8. Disconnect the CTA from the DSO.
- 9. Turn the CTA off and remove the diode.

#### **Questions – Zener Diode Equivalent Circuit**

1. Approximate the forward characteristic curve you have drawn with two straight lines. Derive an equivalent circuit model of the Zener diode when it is forward-biased. Show all component values.

Answer:			

2. Approximate the reverse characteristic curve you have drawn with two straight lines. Derive an equivalent circuit model of the Zener diode when it is reverse-biased. Show all component values.

Zener diode reversebias equivalent circuit

Zener diode forwardbias equivalent circuit

Answer:

### Half-Wave Rectifier (HWR)

Rectification of an AC voltage is used to make a DC power supply. An AM radio receiver uses a diode to "peak detect" the incoming radio signals. In both of these cases, a half-wave rectifier is an integral part of the circuit.

#### In the Lab – HWR

- 1. Set the DSO back to normal operation (not X-Y mode) and set the time base to 0.5 ms/div.
- 2. <u>If you previously inverted channel 2 to measure the diode</u> <u>characteristics, then turn Invert for channel 2 off.</u>
- 3. Set the two channels' attenuations to 2 V/div.
- 4. Turn the function generator (FG) on.
- 5. Connect the FG's output to Channel 1 of the DSO. Set up a 500 Hz sinusoidal waveform with a 5 V amplitude. Ensure there is no DC component in the FG's output. (Adjust with DC offset knob if necessary).
- 6. Wire the following circuit on the breadboard.



7. Sketch the  $v_i$  and  $v_o$  waveforms below.

HWR waveforms

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8. Use the cursors of the DSO to measure the "cut-in" angle:

# **Questions – HWR**

1. Explain how the circuit works.

Answer:	Operation of HWR circuit

2. Explain the "cut-in" angle, and compare the experimental value with the theoretical value.

Answer:	Cut-in angle

### In the Lab – Filtered HWR (peak detector)

1. Add a capacitor in parallel with the load resistance as shown below.

Filtered HWR circuit



2. Sketch the  $v_i$  and  $v_o$  waveforms.

Filtered HWR waveforms

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3. Set the DSO channel 2 coupling to AC (AC Coupling). Set the DSO channel 2 attenuation to 0.2 V/div. Sketch the resulting ripple waveform.

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4. Measure the voltage from peak-to-peak:

$$V_r =$$

## **Questions – Filtered HWR (peak detector)**

1. Explain how the circuit works. Explain the unusual shape of the  $v_i$  waveform. Compare  $V_r$  with the theoretical value.

Operation of filtered HWR circuit	Answer:

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# **Clamp Circuit**

A clamp circuit is useful to prevent a waveform from either going negative or positive, or to restore a DC component of a waveform.

#### In the Lab – Clamp Circuit

- 1. Ensure the DSO's input couplings are set to DC (Direct Coupling).
- 2. Set the DSO's vertical attenuations to 5 V/div.
- 3. Wire the following circuit on the breadboard.



4. Sketch the  $v_i$  and  $v_o$  waveforms.



# **Questions – Clamp Circuit**

1. Explain how the circuit works.

Answer:		

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# **Voltage Doubler**

A voltage doubler is a convenient way to obtain a voltage higher than that normally available from a HWR. It is essentially a clamp circuit followed by a peak detector.

#### In the Lab – Voltage Doubler

1. Wire the following circuit on the breadboard.



2. Sketch the  $v_i$  and  $v_o$  waveforms.



Voltage doubler waveforms

# **Questions – Voltage Doubler**

1. Explain how the circuit works.

Operation of voltage doubler	Answer:		

## **Limiting Circuit**

A limiting circuit is useful to prevent a waveform from either going above or below a certain value. One use is in protecting other circuits which may be damaged by an excessive voltage, such as an A/D converter.

#### In the Lab – Limiting Circuit

- 1. Set the DSO's vertical attenuations to 5 V/div.
- 2. Wire the following circuit on the breadboard. Note that channel 1 of the DSO has moved, and that the source voltage has increased.



3. Sketch the  $v_i$  and  $v_o$  waveforms.



# **Questions – Limiting Circuit**

1. Explain how the circuit works.

Operation of limiting circuit	Answer:

### In the Lab – Packing Up

You don't complete the lab until you pack up

- 1. Please pack up all the equipment, and leave the bench tidy.
- 2. See a lab tutor to ensure your attendance at this lab is recorded.

# **Questions** [2 marks]

Encircle the correct answer, cross out the wrong answers. [one or none correct]

All questions are worth 0.2 marks each.



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**(x)** 

The ripple voltage of a loaded HWR with a filter capacitor is:

(a) 
$$\frac{\hat{v}_o}{2fRC}$$
 (b)  $\frac{\hat{v}_o}{fRC}$  (c) 0

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# Report

Only submit <u>ONE</u> report per lab group.

Complete the assessment cover sheet.

Ensure you have completed:

- 1. <u>*Lab Work*</u> waveforms, meter readings, calculations.
- 2. <u>Analysis</u> explanations where required.
- 3. <u>*Questions*</u> multiple choice questions.

<u>The lab report is due at the time stated in the Learning Guide.</u> <u>You should hand the report directly to your tutor.</u>