Lab 2: Diode applications

1 Task

There are different types of diode tailored for various applications in our daily life. In this lab, you will need to use three most-popularly-used diodes (i.e. general purpose diode, Zener didoe and LED diode) as a) a rectifier, b) a precision voltage reference, c) an indicator respectively.

This lab consists of two parts. In the first part, you will play around with an envelop detector (a typical circuit commonly used in old Amplitude Modulated radio receiver) in LTspice to learn about the design procedure and also get familiarized with the LTspice..

In the second part, you need to design and build a voltage reference circuit with an indicator on breadboard to meet the given specifications. A general purpose diode, a zener diode, an LED diode and other components will be provided to you.

2 Pre-Lab:

<u>Envelop detector:</u>

It is believed that the first use for diode was the demodulation of amplitude modulated (AM) radio broadcasts. AM radio used to be very popular because of its simple circuits and its capability of transmitting in a long distance. However, due to its susceptibility to atmospheric and electrical interference, AM broadcasting now attracts mainly the radio amateur and finds application in walkie talkie, while the music radio and public radio mostly shifted to FM (Frequency Modulation) radio.

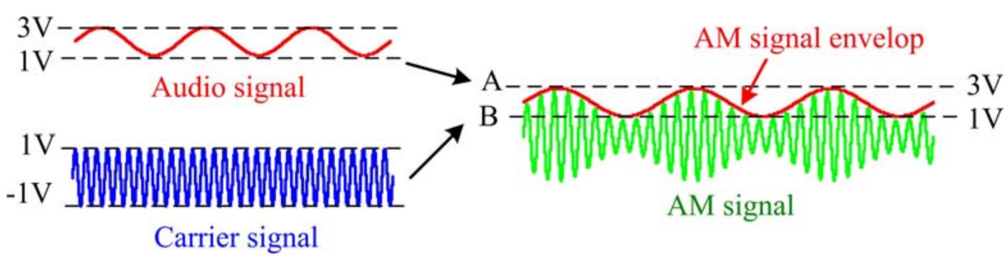

Figure 1: Amplitude Modulation Signals

In general, an AM signal is actually a short wave carrier signal at frequency f_c, whose amplitude or "envelope" is proportional to the original audio signal (f_a in the audible range of 20Hz~20 kHz). A parameter called "Amplitude Modulation Depth" is used to specify the AM signal as given by:

$$h = \frac{A-B}{A+B} \tag{1}$$

For example, in Figure 1, $A = 3V$ and $B = 1V$. Therefore the modulation depth is 50%.

When this signal is received by antenna, the high frequency carrier signal needs to be removed to recover the original audio envelope signal. The circuit to realize this function is called an envelop detector.

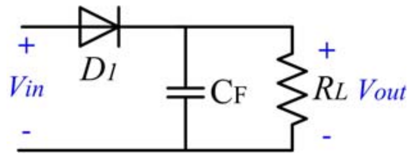

Figure 2: Diode Detector

The simplest form of envelope detector is the diode detector illustrated in Figure 1, where a diode works as a rectifier. It will only conduct when $V_{in} > V_{out}$. In order to remove the high frequency carrier component, a capacitor C_F is added in parallel of the load resistor R_L to form a RC filter, whose cutoff frequency is given as:

$$f_{cut} = \frac{1}{2\pi R_L C_F} \tag{2}$$

The choice of R_L and C_F is particular important to the output performance. A low cutoff frequency means more suppression of the carrier components, which smoothens the output voltage. However, if the cutoff frequency is too close to the audio frequency range, it will interfere and distort the original transmitted audio signal. Therefore, the practical design of the filter must satisfy the following conditions.

$$f_{a,max} < f_{cut} < f_c \tag{3}$$

Where $f_{a,max}$ represents the maximum frequency of the audio signal and f_c is the carrier frequency.

Types of Diodes

There are many different types of diodes available in market, which either emphasize a particular physical aspect of a diode such as zener diode, or simply has similar characteristics of diode but utilizing a completely different mechanism such as LED diode. Please do a study online and list at least ten types or applications of diodes below.

Types and applications of diodes:

Zener diode and zener shunt regulator:

Zener diode is named after its inventor Dr. Clarence Melvin Zener from Carnegie Mellon

University. Unlike normal diode, it is purposely designed to conduct under the reverse bias where the diode has a very small incremental resistance R_z to the current flow at a defined reverse bias voltage V_z. The current –voltage characteristic of the zener diode is illustrated in Figure 3 .

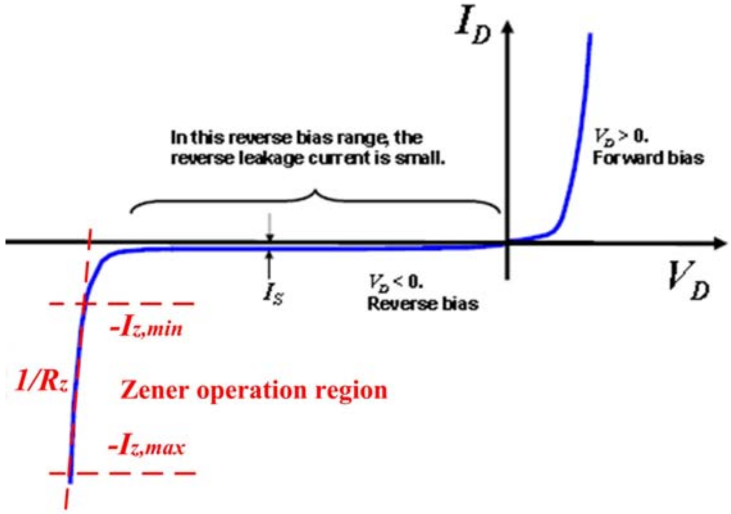

Figure 3: Reverse current-voltage characteristic of zener diode

All zener diodes have a voltage rating V_z, zener impedance R_z and a power rating P_z. $I_{z,min}$ represents the minimum current when the zener diode works in zener operation region, On the other side , the maximum current is given by $I_{z,max} = P_z / V_z$.

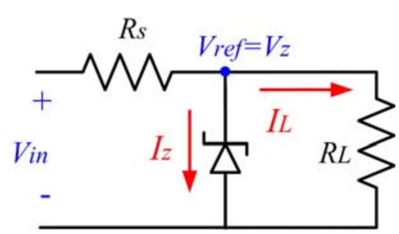

Figure 4: Circuit diagram of Zener shunt regulator

Figure 4 illustrates a zener shunt regulator, which is used to maintain a constant voltage (i.e. the specified zener voltage V_z) to the load regardless of any variations in the input voltage (V_{in}) and variations in the load current (I_L). This unregulated input voltage is usually obtained from the grid either by a full bridge rectifier or a half bridge rectifier. Here, the resistor R_s limits the current as given by:

$$R_s = \frac{V_{in} - V_z}{I_z + I_L} \tag{4}$$

Shunt regulators are normally only used for applications where the load power is not much because the shunt connection requires the zener diode to dissipate the full load power even under no load condition.

Therefore, to guarantee a proper operation of the regulator, the design of resistor R_s is critical. On one hand, R_s needs to be small enough to ensure the diode in zener operation mode at the minimum input voltage $V_{in,min}$ and the maximum load current $I_{L,max}$. On the other hand, R_s needs to be large enough to make sure the Zener diode current is below the power rating P_z even at the maximum input voltage $V_{in,max}$ under no load condition.

LED diode:

Light-Emitting Diode has the same current voltage characteristics of a normal diode. But when the diode is conducting, it emits photons, whose wavelength (or color) depends on the material used in the junction. The forward voltage of the LED also changes accordingly, for example, 2.1 V corresponds to red, 4.0V to violet. Therefore, at signal level, LED diode is commonly used as an indicator to indicate whether the current is on or not. One example is the LED indicators on the prototype board of NI's ELVIS platform. Similar to zener diode application, a resistor is connected in series with the LED diode to limit the current as shown in Figure 5

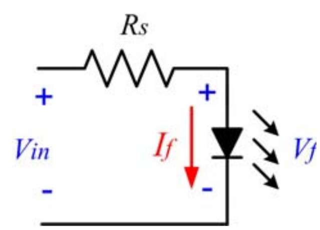

Figure 5: Symbol of LED diode and application circuit

Besides, LED also becomes a strong competitor to the conventional incandescent light sources in lighting application. This widespread trend of using LED is supported by its advantages in low energy consumption, smaller size, longer operation time and better reliability etc.

3 Hardware and Software:

Table 1: List of hardware and software

Name	**Qty**	**Description**
PC	1	For simulation, test and mathematical analysis
LTSpice	1	Circuit Simulation Software
DC power supply	1	Provide DC voltage
DMM	1	Digital Multi-meter for voltage and current test

Table 2: List of Components

Name	**Qty**	**Description**
Zener diode	1	Choose zener diode from 1N4728 to 1N4764
LED diode	1	Randomly choose a LED diode
1/4 W resistors	-	$R_L = 47\Omega$ and other resistance values by design
3W/5W/10W resistor	1	By design

4 In-Lab assignment:

4.1. Diode detector:

Assume an AM signal is received with an audio signal carried by a 10MHz radio signal. Use the diode model obtained in Lab 1. You will build an envelop detector in LTspice as shown in Figure 6 to recover the audio signal.

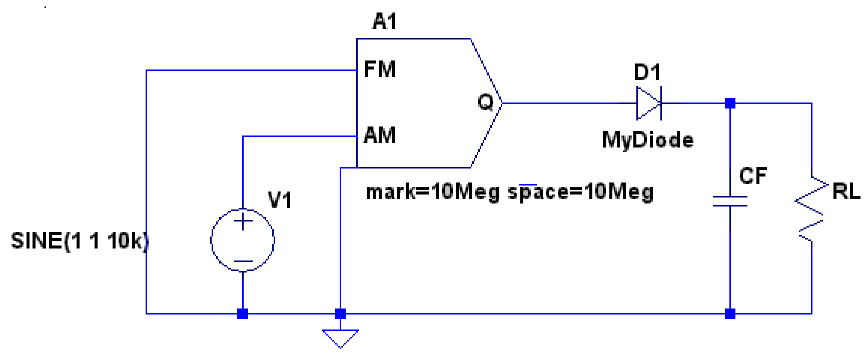

Figure 6: Simulation circuit of diode detector

Specifications:

- Carrier signal frequency: 10MHz.
- Audio signal: sinusoidal signal with amplitude of 1.5V with a DC offset of 2V in the frequency range of 20 Hz ~ 20 KHz.

1. Build two circuits in LTspice as shown in Figure 6.
   - Find out the maximum diode current of 1N4148 on datasheet;
   - Set the audio frequency to be 10kHz, compare A) $R_L = 100\Omega$ and $C_F = 1.6nF$ with B) $R_L = 100\Omega$ and $C_F = 16nF$;
   - Set the audio frequency to be 200kHz, compare A) $R_L = 100\Omega$ and $C_F = 1.6nF$ with B) $R_L = 100\Omega$ and $C_F = 16nF$.

2. Set the audio frequency to 10 kHz. Compare C) $R_L = 50\Omega$ and $C_F = 32nF$ With D) $R_L = 1k\Omega$ and $C_F = 1.6nF$.

4.2. Zener shunt regulator with an indicator:

In this part, you are going to design and build a zener shut regulator with an indicator. The specifications are given below.

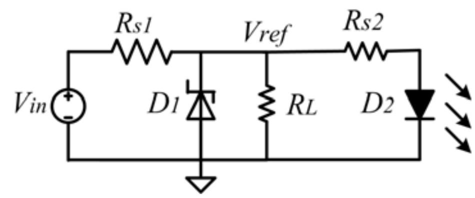

Figure 7: Circuit diagram

Specifications:

- Input voltage: $V_{in} = 8 \sim 12V$;
- Output voltage: $V_{ref} = 3.3V$;
- Load: $R_L > 47\Omega$;

1. Randomly choose a LED diode D_2. Connect it with multimeter (current measurement) and DC power supply as shown in Figure 8. Use R_{S1} of 47 Ω. Change DC power supply value to make LED diode current 10mA.

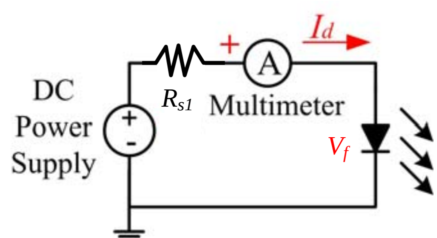

Figure 8：Test setup for characterization of LED diode

2. Design the values of R_{s1} and R_{s2}.

3. Build your circuit on breadboard. Use DC power supply to generate V_{in} and measure V_{ref} using DMM (Digital Multi Meter). Make sure the diodes are connected in the correct polarity. Let the GA check your design and breadboard connection before you turn on the power.

4. Verify your design by checking the following conditions:
   - Make $V_{in} = 8V$, $R_L = 47\Omega$;
   - Make $V_{in} = 12V$, $R_L = 47\Omega$;
   - Make $V_{in} = 8V$, no load (open circuit) ;
   - Make $V_{in} = 12V$, no load (open circuit) ;