III. Diode Circuits

A. Objective
This lab will introduce you to several different types of diode circuits. We will focus on wave-shaping circuits (clippers) and on DC shifting circuits (clampers).

B. Needed Hardware
✓ Various resistors
✓ Various Caps
✓ 1N4004 diodes
✓ Graph paper
✓ A solderless breadboard
✓ Wire
✓ Wire cutter/stripper

C. Pre-Lab
✓ Read the lab.
✓ Sketch what each output signal will look like on graph paper.
✓ Generate SPICE netlists which will allow you to simulate all of the circuits that we will be discussing in this lab.

D. Background
Clippers: Often it is necessary to modify the shape of a particular waveform. Circuits which perform that function are called clippers. A positive clipper is shown in Figure III-1. Ideally the diode would clip off all of the positive components of any input signal. This circuit works as follows: When the voltage is
in the positive half of the cycle, the ideal diode will approximate a wire. Since you can't dissipate any voltage across a wire, the output voltage will be 0V.

During the negative half of the voltage cycle, the ideal diode is reverse biased and approximates an open circuit. The output will be the output of the simple voltage divider formed by \( R \) and \( R_L \).

Of course, the diode is not ideal, and it takes around 0.7V to turn the diode on. Therefore a small amount of the positive signal will get through.

![Figure III-1 Positive Clipper circuit. Shows the input, the ideal output, and the output one would expect from a real diode.](image)
Clippers are useful for protecting circuits from exceeding various voltages (either positive or negative).

**Clampers:** Sometimes you may want to leave the waveform unchanged, but modify its DC level up or down. To accomplish this, you use a clamper circuit. The beauty of clampers is that they can adjust the DC position of the waveform without knowing what the waveform actually is.

![Diagram of positive clamper circuit](image)

*Figure III-2 Positive Clamper adds a positive DC shift to the waveform without changing the shape of the waveform, except for the startup portion of the waveform.*

The positive clamper shown in Figure III-2 works as follows:

In the positive half of the first cycle, the voltage across the capacitor cannot change instantaneously; therefore as the voltage on the input moves up, the voltage on the top of the diode has to follow this voltage. This reverse biases the diode causing it to act as an open, thus the output voltage follows the input voltage.

As the input voltage drops into the negative half of the first cycle, the diode is going to be forward biased. This causes the diode to behave like a wire, which cannot dissipate any voltage. This causes inter-related effects. First, the output voltage is held steady at 0V. Second, because there are 0V dissipated across the diode (and resistor) all of the voltage has to be dissipated across the capacitor. This charges the capacitor to the magnitude of the input signal.
From the bottom of the first trough, as the input signal starts back up, the capacitor maintains this charge which keeps the diode always reverse biased from this point on. This makes the output voltage follow the input voltage, but with the DC point shifted due to the charge on the capacitor.

E. Experiment

1. Ideal Clippers

For all of the circuits shown in Figure III-3:

Use the oscilloscope to grab plots of the input and output (plot these on the same graph) of each of these circuits for $V_B = 0V$ and $V_B = 5V$ (8 plots). Use the DC power supply on your bench to supply the $V_B$ voltage. You only need to grab plots from the scope for these two values of $V_B$, however observe how the output waveform changes as you move the voltage from 0 to 5V.

- Make Vin a 20V peak to peak, 1kHz, sine wave (use the Agilent 33220A function generator). Before you hook this up, make sure that you set the 33220A to be in High Z mode. (Your TA should know how to do this). If you don’t set it to High Z mode, 20V p-p will actually be 40V!
- $R = 1k$
- $V_B = 0V$ and $5V$
2. Series Clippers

![Series Clipper Circuits Diagram]

Figure III-4 Series clipper circuits

For all of the circuits shown in Figure III-4:

Use the oscilloscope to grab plots of the input and output (plot these on the same graph) of each of these circuits for $V_B = 0V$ and $V_B = 3V$ (8 plots). Use the DC power supply on your bench to supply the $V_B$ voltage. You only need to grab plots from the scope for these two values of $V_B$, however observe how the output waveform changes as you move the voltage from 0 to 3V.

- Make $V_{in}$ a 10V p-p, 1kHz, sine wave (use the Agilent 33220A function generator). Before you hook this up, make sure that you set the 33220A to be in High Z mode. (Your TA should know how to do this). If you don’t set it to High Z mode, 10V p-p will actually be 20V!
- $R = 1k$
- $V_B = 0V$ and $3V$
3. Parallel Clipper

![Parallel Clipper Circuit Diagram]

**Figure III-5 Parallel clipper circuit.** This is used to clip the waveform at 2 different voltages.

For the circuit shown in Figure III-5:

Use the oscilloscope to grab a single plot of the input and output (plot these on the same graph) of this circuit. Use the DC power supply on your bench to supply the $V_B$ voltages. Observe how the output waveform changes as you move the $V_B$ voltages.

- Make $V_{in}$ a 20V p-p, 1kHz, sine wave (use the Agilent 33220A function generator). Before you hook this up, make sure that you set the 33220A to be in High Z mode. (Your TA should know how to do this). If you don’t set it to High Z mode, 20V p-p will actually be 40V!
- $R = 1k$
- $V_{B1} = 5V$ and $V_{B2} = -5V$

4. Clamper

![Clamper Circuit Diagram]

**Figure III-6 Clamper circuit.** You can use circuits like these to shift the DC level of various waveforms.

For the circuit shown in Figure III-6:

Use the oscilloscope to grab plots of the input and output (plot these on the same graph) of this circuit satisfying the specifications below. Use the DC power supply on your bench to supply the $V_B$ voltage.
• Make Vin a 20V p-p, 1kHz, sine wave (use the Agilent 33220A function generator). Before you hook this up, make sure that you set the 33220A to be in High Z mode. (Your TA should know how to do this). If you don’t set it to High Z mode, 20V p-p will actually be 40V!
• R = 1k
• Use a capacitor greater than 22uF

Grab a sketch for each of the following 4 conditions:

✓ As shown, with Vb = 5V
✓ As shown, with Vb = -5V
✓ With diode reversed, Vb = 5V
✓ With diode reversed, Vb = -5V
TA Check Off Sheet

Ideal Clipper
  8 Correct Plots

Series Clipper
  8 Correct Plots

Parallel Clipper
  1 Correct Plot

Clamper
  4 Correct Plots

TA Signature

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