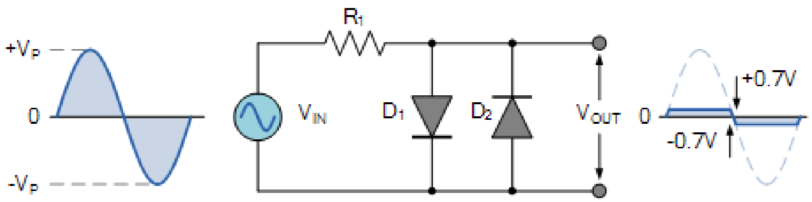
Lab 4.3 – Fun with Diodes II: Limiting and Clamping Circuits

When I was an undergraduate EE, there was a complete course called Wave Shaping Circuits (I still have that textbook in my home office). This lab investigates some of that material.

Limiters clip an incoming signal to prevent the voltage from exceeding a given value. If you severely clip a sinusoid, you get a signal that approximates a square wave.

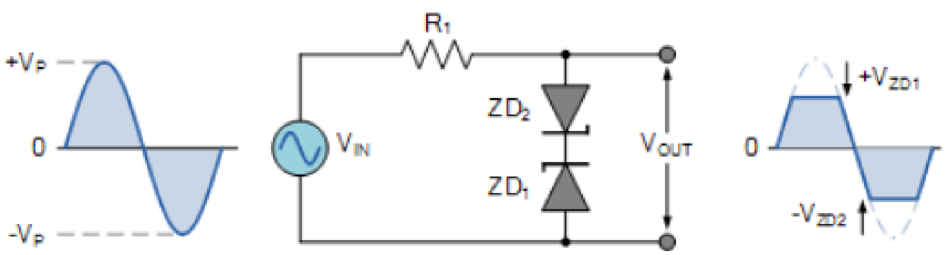
Circuit "a" – Diode limiter



Here two parallel diodes do the limiting. One clips the positive going part of the signal while the other clips the negative going part of the signal.

Note that the clipped signal has rounded transitions (why?) and that the peak of the clipped signal does have some shape (again, why?). What determines the approximate clipping level?

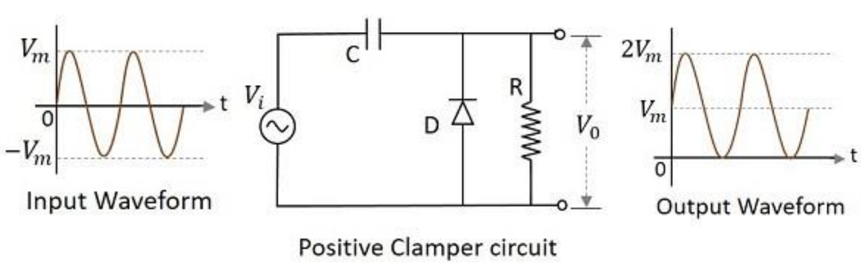
Zener Diode Clipping



Are the clipping voltages actually the Zener voltages as shown in this diagram?

First, what is a Zener diode? All diodes have a reverse breakdown voltage where the diode will conduct whatever current is necessary to stop the voltage from increasing further (note that operating a diode in breakdown destroys the diode if the power dissipation causes too high a temperature – The silicon melts). A Zener diode is designed to have a low, but controlled breakdown voltage. Two Zener diodes in series are used here for clipping (what is the actual clipping voltage? Why?). Zener diodes are also commonly used to provide a reference voltage in power supplies.

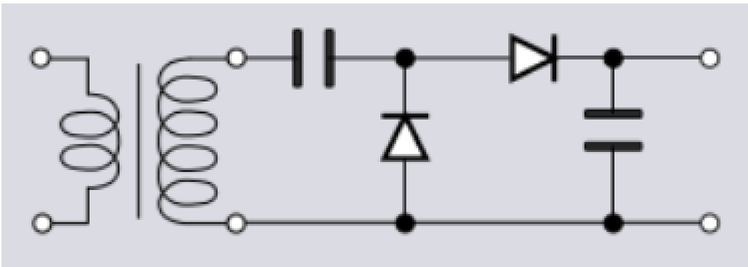
A Diode Clamping Circuit



Are the negative peaks of the output signal actually at 0 volts?

Circuit "c" is a diode clamp. When the signal goes positive the diode is reverse biased. When the signal goes negative the diode starts to turn on and the capacitor charges which shifts the DC level of the output signal. After a few cycles, the clamping circuit reaches steady state and the lower peaks sit about one diode drop below 0 volts (why?). Again, try to capture and explain the transient behavior at start up (most easily done in simulation). When I was doing analog TV design, we used a diode clamp on the video signal to re-establish the "black" level of the picture by clamping the negative going peaks of the video signal.

A "Voltage Doubler"



The fourth and last circuit is called a Voltage Doubler as it attempts to output a DC level that approximates twice the peak value of the incoming sine wave. The actual output is less than twice the sinusoidal peaks for two reasons (what are they?). Again, examine the transient behavior of this circuit to aid in your understanding of its operation.

Fun with Diodes II: Limiting and Clamping Circuits

(See Section 4.6, p. 207 of Sedra/Smith)

OBJECTIVES:

To study diode-based limiting and clamping circuits by:

- Analyzing, simulating, and building several circuits, including peak detectors, clamp circuits, and limiter circuits.
- Noting that many diode-based circuits are easy to assemble, in this lab you will build several circuits that require only a few simple components.
- Using an oscilloscope's X-Y mode to plot output vs. input voltage.

MATERIALS:

- Laboratory setup, including breadboard
- Several junction diodes (e.g., 1N4003) and Zener diodes (e.g., 1N4733A)
- Several wires, resistors, and capacitors of varying sizes

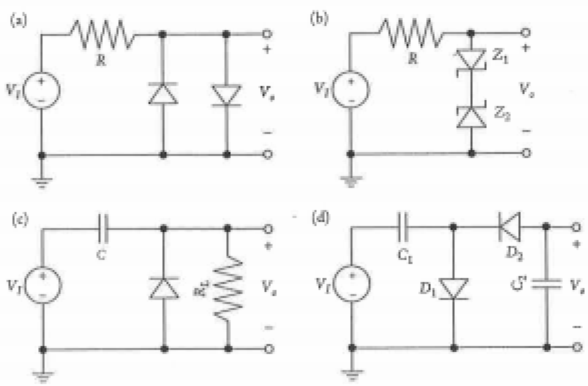


FIGURE L4.3: (a) Limiter, (b) Zener diode limiter, (c) clamping circuit, and (d) voltage doubler. Circuits are based on Figures 4.31 p. 209, Fig. 4.33 p. 212, and Fig. 4.34 p. 212 S&S.

PART 1: SIMULATION

Consider the circuits shown in Figure L4.3(a)–(d). Simulate each circuit with the parameters indicated next. For each simulation, provide a plot of v_I and v_O vs. t.

- Diode limiter (Figure L4.3(a)):
  - Use $R = 1$ kΩ and 1N4003 diodes.
  - Simulate using a 5-V_{pk-pk} 100-Hz input sinusoid with no DC component.
  - Use your simulator's X-Y mode to plot v_O vs. v_I
- Zener diode limiter (Figure L4.3(b)):
  - Use $R = 1$ kΩ and 1N4733A Zener diodes.
  - Simulate using a 15-V_{pk-pk} 100-Hz input sinusoid with no DC component.
  - Use your simulator's X-Y mode to plot v_O vs. v_I
- Clamped capacitor (Figure L4.3(c)):
  - Use $R_L = 10$ kΩ, $C = 47\ \mu$F, and a 1N4003 diode.
  - Simulate using a 2-V_{pk-pk} 100-Hz input square wave with no DC component.
  - What are the highest and lowest voltage values?
- Voltage doubler (Figure L4.3(d)):
  - Use $R_L = 100$ kΩ across the output $C_1 = C_2 = 47\ \mu$F, and 1N4003 diodes.
  - Simulate using a 5-V_{pk-pk} 100-Hz input sinusoid with no DC component.

PART 2: MEASUREMENTS

- For each circuit, build the circuit, apply the input waveform specified above using a function generator, and capture the output voltage waveform on an oscilloscope. For circuits (a)–(c), what are the highest and lowest output voltage values?
- For the limiter circuits, use the oscilloscope's X-Y mode to plot v_O vs. v_I.
- Using a digital multimeter, measure all resistors to three significant digits.
- Further exploration I: Can you change the limiting voltages for the first circuit to approximately +1.4 V and –1.4 V?
- Further exploration II: Can you turn the clamped capacitor into a negative clamp?

PART 3: POST-MEASUREMENT EXERCISE

- Do any of your measurement results differ significantly from what you expect and from the simulations? Explain.

PART 4 [OPTIONAL]: EXTRA EXPLORATION

- Can you modify the voltage doubler so it produces a positive output voltage?