EE 462G Laboratory # 3

Diode Clipping Circuits

by
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(Lab 2 – Report due at beginning of lab period) (Pre-lab 3 and Lab-3 Datasheet due at the end of the lab period).

I.   Instructional Objectives
*   Design and implement clipping circuits based on the attributes of semiconductor diodes. (See Horenstein 4.1 and 4.2)

II.   Transfer Characteristics
This lab introduces diode circuits that alter input waveform shapes (wave shaping) and the graphical modeling of their transfer characteristics. Clipping circuits are used to restrict an output voltage to a particular range of values. The output voltage will be proportional to the input voltage as long as the input voltage lies within the desired range. Outside this range the output is clipped (held) to a constant value until the input falls within the "linear" range, where the output follows the input. The nonlinear switch-like properties of the diode can be used to implement this function. Clipping circuits are used in signal processing applications, radio modulation systems, and power supplies.

III.   Pre-Laboratory Exercises
Transfer Characteristic of Diode
1) Use data from the previous lab (Lab 2), and plot the following on the same graph (use different line styles to distinguish the plots):
    *   The measured I-V curve obtained with the curve tracer
    *   The result of the Shockley diode equation with the best-fit parameters. (Note the diode current can get very large from this equation and cause the vertical axis to get so large that it obscures the curve tracer data plot. **Do not let this happen**. Limit the range of the values evaluated on the Shockley equation to those of the curve tracer data so differences between the model and measured data in the critical regions can be seen clearly).
    *   A vertical line at the forward bias voltage value that was estimated in the last lab. This line should appear somewhat tangential to the exponentially increasing diode current.
    *   Make sure the axes of the plot are properly labeled.

    This plot will be used for discussing observed results between the predicted and measured results of the clipping circuit.
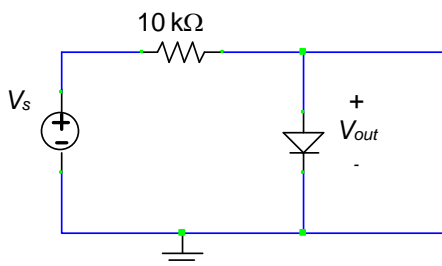
Clipped Sine Wave Generation

2) For the circuits shown in figures 1a, b, and c, where battery voltages V_1 and V_2 are to be treated symbolically, but have values of 1.2V, assuming ideal diodes (negligible internal resistance and a forward bias voltage of V_f, treated symbolically, but with a value of .7V):
   - Sketch the input and output waveforms (V_s, V_{out} versus **time**) for a 250Hz input sine wave of amplitude 2.8 **Vrms**. **DO NOT USE SPICE (see question 3), DERIVE the equations for the output by hand.**
   - Label the input and output waveforms with their functional representation (in the case of V_{out} this will be a piecewise function with inequalities, where the output is a specific value or function over a range of input voltage values)
   - Sketch the transfer characteristic (v_{out} versus v_s) for v_s ranging between -5V and +5V. Be sure to label any slopes and mark on the axis the values where the transfer characteristic

3) For the same source as described in the previous problem, use SPICE to graph the output of the circuit in Fig.1c for several periods where $V_1=V_2=$ 1.2 V. Use SPICE to obtain the transfer characteristic of the circuit in Fig. 1c for V_s between -5V and +5V.

4) The circuit in Fig. 1b is modified to result in the circuit in Fig. 1d. Describe how the measured output may change as a result of this modification **IN A REAL WORLD CIRCUIT**. (Hint - read the lecture slides again)

Power Distribution

5) For the circuit in Fig. 1a, assuming V_S is a 250Hz sine wave at 2.8 Vrms, write a **MATLAB** script to:
   - Determine the average power delivered by the source, and absorbed by the resistor and diode.
   - Modify the circuit in Fig. 1a by adding a 5.1kΩ load resistor. Determine the power absorbed by all elements and delivered by the source.

This can be done two ways in MATLAB: symbolically, or with some form of numerical integration. Both require deriving the equations for the voltage and current through each element or provided by the source, and the finding the average power using the formula found in the lecture slides. Those interested in numerical integration could start by looking up the trapezoid rule.
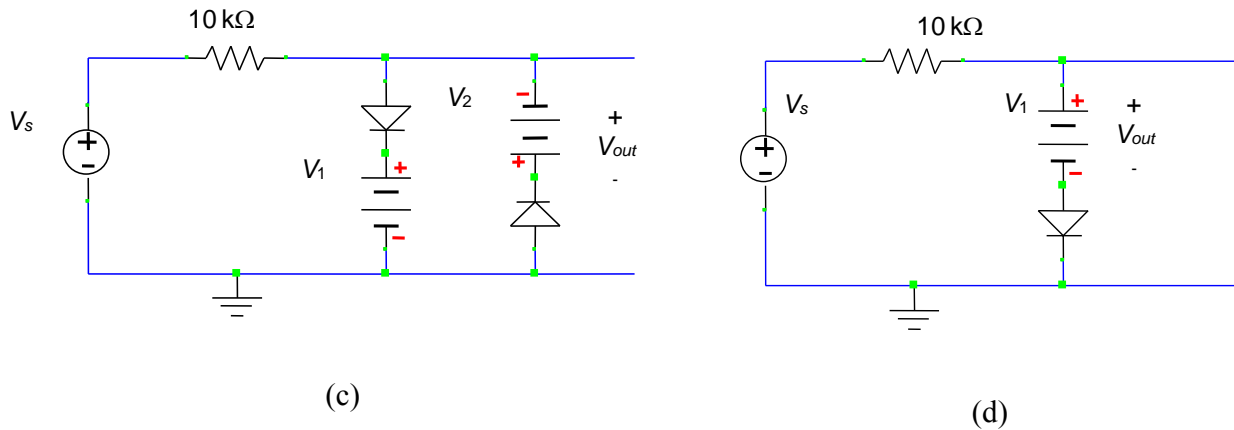

(a)

(b)

(c)

(d)
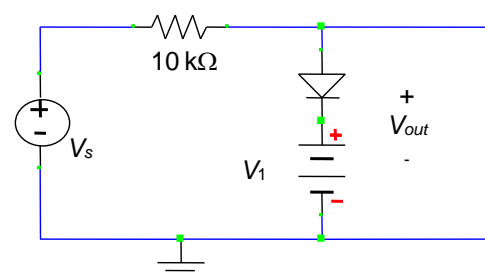
Figure 1. Circuits for analysis and experiment.

IV.   Laboratory Procedure

1. **Generate Clipped Sine Wave:** Assemble clipping circuits of Fig. 1a, b, and c with no load. Connect a 250Hz, 2.8Vrms sine wave signal from the function generator for the input V_s and use the power supply to make V_1 and V_2 equal to 1.2 volts. Beware of polarity and ground issues when using the power supply. **Be sure the scope is in the Y-T mode** (this is set using the scope's display menu, and Y-T is typically the default mode). This mode displays the signals on Channel 1 and Channel 2 versus time. V_s and V_{out} should be displayed simultaneously.
   - Record the waveforms displayed on the oscilloscope for later use.
   - Vary the voltages for V_1 and V_2 in order to determine their effect on the output.
   - **Datasheet:** Sketch output waveforms for each circuit. Describe qualitatively (in words) how v_1 and v_2 affect the output waveform.
   - **Procedure section**: Display recorded waveforms. Grounding issues with the power supply should also be described.
   - **Discussion section**: Comment on the observed output waveform for each circuit. Provide reasons for the particular results based on your diode models and data. Compare it to your pre–lab predictions. Describe the effect of V_1 and V_2 on the output waveform for the circuit of Fig 1c. and explain why the results appear as they do based on the diode models and data.

2. **Measure Transfer Characteristics of Circuits:** Assemble clipping circuits of Fig. 1a, b, and c as in Procedure 1. **Change the scope to the X-Y mode** (see display menu). Use the scope to display V_{out} versus V_s (V_{out} on the Y-axis). Adjust the function generator's amplitude to set V_s to a 10 V peak to peak sine wave that ranges from –5V to 5V.
   - Record the trace for each circuit.
   - **Datasheet:** Vary the frequency of the input waveform to determine its effect on the TC. Convey in words and sketches (if necessary) the reason for these effects.
   - **Procedure section:** Display recorded waveforms.

- **Discussion section**: Summarize how changing frequency of input affects the TC curve and explain why these changes (if any) occur.

3. **Generate Clipped Sine Wave with Load and Compare Power Distribution:** Apply a 5.1kΩ load to the output of the circuit in Fig. 1a.
   - Record the resulting waveform for V_s equal to a 2.8Vrms 250Hz sine wave.
   - The digital multimeter and oscilloscope can be used to measure rms current and voltages in each circuit branch so average power can be computed (Recall: $i_{rms}*v_{rms} = P_{av}$ and $v^2_{rms} / R = P_{av}$). Measure the power delivered by the source, and power absorbed in the resistors and diode.
   - Take the load resistor out and repeat power measurements.
   - **Discussion section**: Described the change of power distribution as a result of the load. Compare to pre-lab results.

4. **Demonstrate Effects of Series Power Supply Placement:** Compare the clipped sine wave outputs for the circuits of Figs. 1b and d by viewing input and output sine wave as done in Procedure 1. Vary the frequency of the sine wave input to find frequencies where a phase difference between input and output waveform can be easily observed.
   - Record the input and output waveforms for both circuits at this frequency.
   - This pattern is likely the result of capacitance. In order determine the capacitance values for each circuit set the voltage amplitude low enough so it is NOT clipped. Create a file with range for frequency values such that you see a phase and amplitude pattern similar to what you did in Lab 1. Try to find a frequency range where the phase shift passes through the 45 degree point. You will need to do some experimentation to figure out what a good range of frequencies should be for each circuit. Open the file of frequencies you created for Lab 1and let it run. Save the output to a file.
   - **Datasheet:** Attach the list of measurements
   - **Procedure section**: display recorded waveforms.
   - **Results section:** Estimate the capacitance value using the Matlab scripts written in Laboratory 1.
   - **Discussion**: Explain why capacitance exists in your circuits and explain why this capacitance is different between for the 2 circuits?