I. Instructional Objectives

- Measure input-output transfer characteristic curves of instantaneous (non-dynamic) semiconductor circuits.
- Design and implement clipping circuits based on the attributes of semiconductor diodes.

See Horenstein 4.1 and 4.2

II. Transfer Characteristics

Dynamic circuit responses result from energy storage elements. Dynamic systems are characterized by transfer functions, differential equations, and/or impulse responses. For linear circuits these characterizations, along with the initial conditions, completely describe the input-output relationship. Circuits containing no energy storage elements are referred to as instantaneous or memoryless systems. Nonlinear instantaneous systems are completely characterized by their transfer characteristic, which describes the amplitude input-output relationship over a range of input amplitudes. Transfer characteristics for linear circuits can be expressed as an explicit mathematical function, while for most nonlinear circuits this is not possible. Thus, graphical and numerical methods are employed for analysis and design. This lab introduces simple 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 desired range, where 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

1) Draw the output waveform for Circuits in Fig. 1a, b, and c for a 1kHz input sine wave of amplitude 5 Vrms. Let $V_1$ and $V_2$ both equal to 5V, and assume ideal diodes with a 0.7V offset voltage in the forward direction.
2) Repeat Problem (1) with each circuit having a 5.1kΩ load.
3) For the circuits analyzed in Problem (1), draw the transfer characteristic ($V_{out}$ versus $V_s$) for $V_s$ ranging between -10V and +10V.
4) Repeat the Problem (3) with each circuit having a 5.1kΩ load.
5) Determine the instantaneous and average power delivered by the source in Fig. 1a ($V_s$ is a 1kHz input sine wave of 5 Vrms). Determine the instantaneous and average power absorbed by the diode and resistor.
6) The circuit in Fig. 1b is modified to result in the circuit in Fig. 1d. Describe how the output changes as a result of this modification.
7) Use SPICE to graph the output of the circuit in Fig.1c for several periods when $V_s$ is a 5 Vrms sine wave and $V_1=V_2= 5.0V$. Use SPICE to obtain the transfer characteristic of the circuit in Fig. 1c for $V_s$ between -10V and +10V.

![Circuit Diagrams](image)

**Figure 1.** Circuits for analysis and experiment.

**IV. Laboratory Procedure**

1) Use the curve tracer in the laboratory to measure the diode characteristic for forward bias ranging up to a voltage of 2V and/or current of 2mA. Record trace on the screen and from the trace, estimate the diode's forward offset voltage. In the **procedure section** clearly described the settings used in the curve tracer and how the forward offset voltage was estimated from the transfer characteristic on the curve tracer.
2) Assemble clipping circuit of Fig. 1a with no load. Connect a 3kHz, 5Vrms sine wave signal from the function generator for the $V_s$ input. Be sure the scope is in the Y-T mode (this is set using the scopes display menu) so it will display both the signal on Channel 1 and the signal on Channel 2 versus time. You can display $V_s$ and $V_{out}$ simultaneously using the two vertical scope channels. Record your results. (Discussion: Comment on the observed output waveform. Provide reasons for the result. How does it compare to your pre-lab prediction?) Grounding issues should be described in the procedure section.

3) Change the scope to the X-Y mode (this is set using the scope's 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 20 Vp-p so it will range from –10V to 10V. Record your results.

4) Apply a 5.1KΩ load to the output of the circuit in Fig. 1a and repeat Procedures 2 and 3. (Discussion: Described the change as a result of the load. Draw the Thévenin equivalent circuit with respect to diode terminals and use this to explanation why this change occurred).

5) Obtain the transfer characteristic of the circuit Fig. 1b in a similar manner as was done for the circuit of Fig. 1a. Use the function generator to generate a 20Vp-p triangle wave for $V_s$ and a DC power supply for $V_1$. Be sure to describe grounding issues involved in the experimental set up in the procedure section. (Discussion: Explain results and compare to pre-lab predictions.) Record the waveform showing the transfer characteristic.

6) Repeat Procedure 5 for the circuit of Fig. 1d. (Discussion: How do results change from those of the circuit in Fig. 1b? Provide reasons for the results.)

7) Repeat Procedure 5 for the circuit of Fig. 1c. Beware when connecting this circuit. If the polarity of the batteries (DC sources) are not as shown, you may fail both diodes. Explain grounding issues in the procedure section. Vary $V_1$ and $V_2$ to observe changes in the output voltage. (Discussion: Describe the effect of $V_1$ and $V_2$ on the output waveform). Record waveform for $V_1$ equal to 4V and $V_2$ equal to 3V.