Diodes

Ch. 10 of Allan R. Hambley's Book

Brief Summary

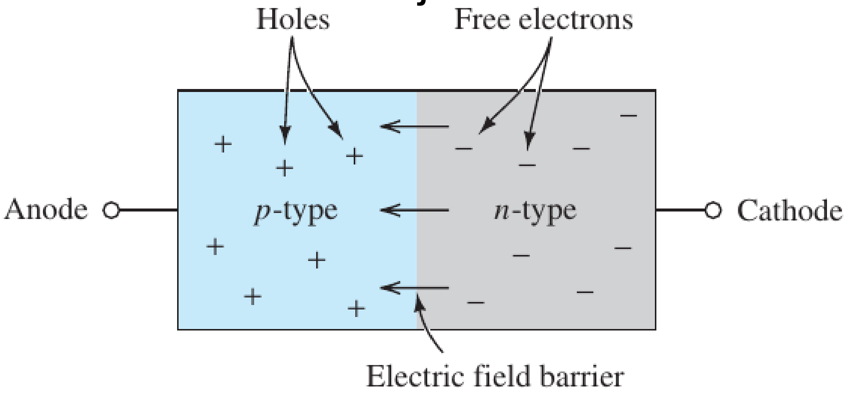
In this lecture we will

- **Understand the operation of a diode.**
- **Analyze and design simple voltage-regulator circuits.**
- **Understand various rectifier and wave-shaping circuits.**

Basic Concepts

The diodes, we consider, consist of a junction between two types of semiconducting material (usually, silicon with carefully selected impurities). Diodes conduct current from anode to cathode but does allow current to flow in the opposite direction

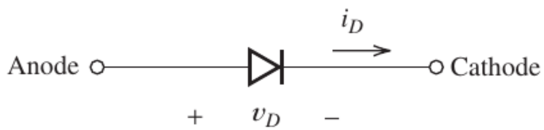
On one side of the junction, the impurities create *n-type* material, in which large numbers of electrons move freely. On the other side of the junction, different impurities are employed to create (in effect) positively charged particles known as holes. Semiconductor material in which holes predominate is called *p-type* material. Most diodes consist of a junction between *n-type* material and *p-type* material.



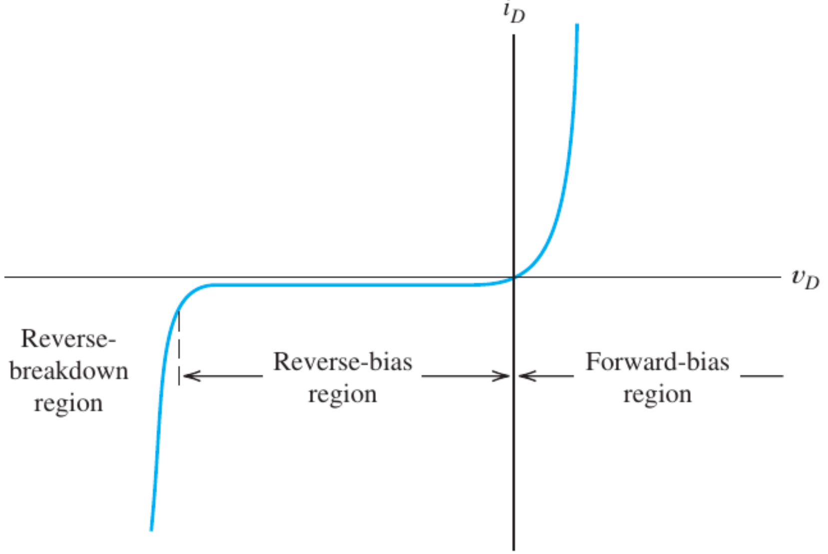
Simplified physical structure

Circuit Representation and Characteristics

When v_D applied to the diode is positive, relatively large amounts of current flows for small voltages (forward-bias region). For moderate negative values of v_D the current i_D is very small (reverse-bias region). If sufficiently large reverse-bias is applied to the diode it enters reverse-breakdown region where large amounts of current flows. Provided that the power dissipated in the diode is not too high, break-down region is not destructive to the device, some diodes are specifically designed to operate in this region.



(a) Circuit symbol



(b) Volt–ampere characteristic

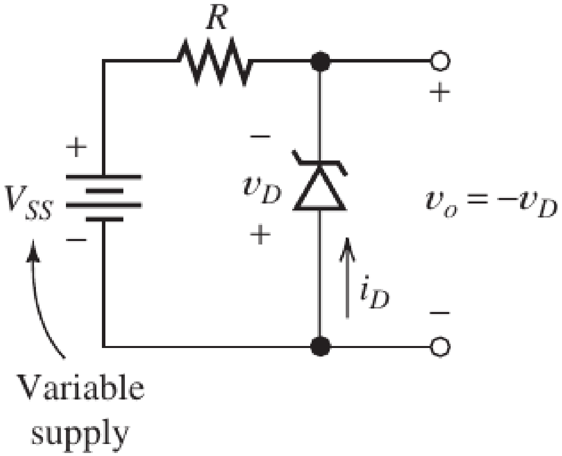
Zener Diodes

Diodes that are intended to operate in the breakdown region are referred as **Zener Diodes.** These devices are useful in applications where a constant voltage in breakdown is desirable.

Manufacturers try to optimize Zener diodes for a nearly vertical characteristics in breakdown region.

For circuits that produce constant output voltage while operating from a variable voltage source (voltage regulators) Zener diodes are might be a good choice.

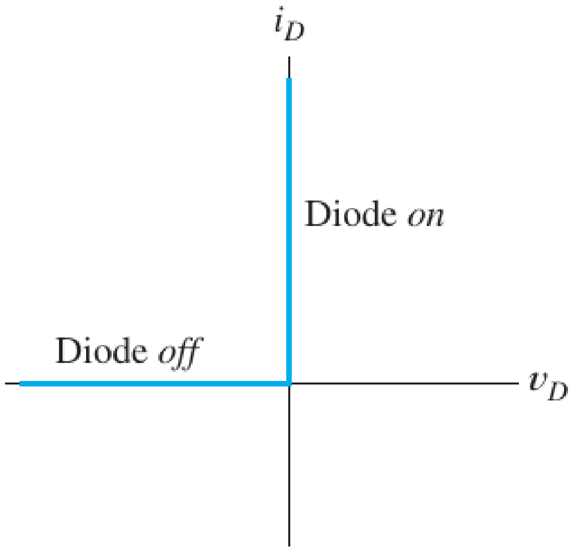
Circuit Representation



Ideal-Diode Model

In ideal-diode model we assume that the diode acts as short circuit for forward currents and as open circuit for reverse .

The volt- ampere characteristics is as shown in the figure



Ideal-Diode Analysis

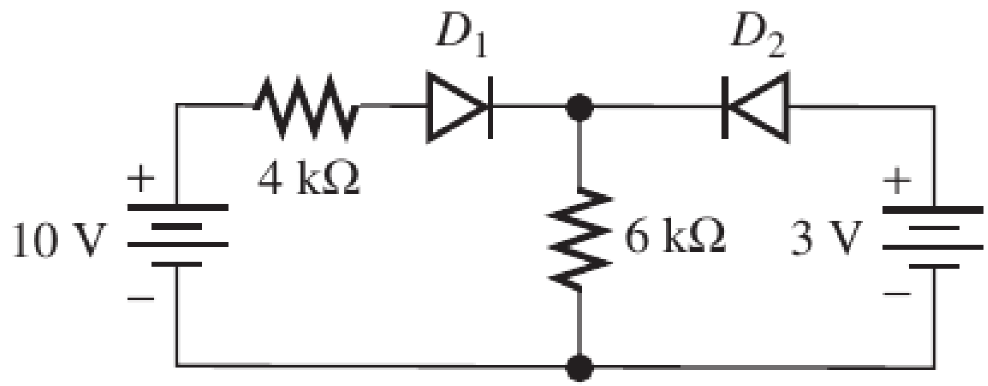
A step-by-step procedure for analyzing circuits that contain ideal diodes are as follows :

- Assume a state for each diode (either on or off). Note that for *n* diodes there is 2^n possible combinations for diode states
- Analyze the circuit to determine the current through the diodes assumed to be on and the voltages across the diodes assumed to be off.
- Check to see if the result is consistent with the assumed state of each diode. Current must flow in the forward direction for diodes that are on and voltage across the off diodes must be positive at the cathode (reverse bias)
- If the results are consistent with the assumed state finish else return to the top and try another combination.

Example:

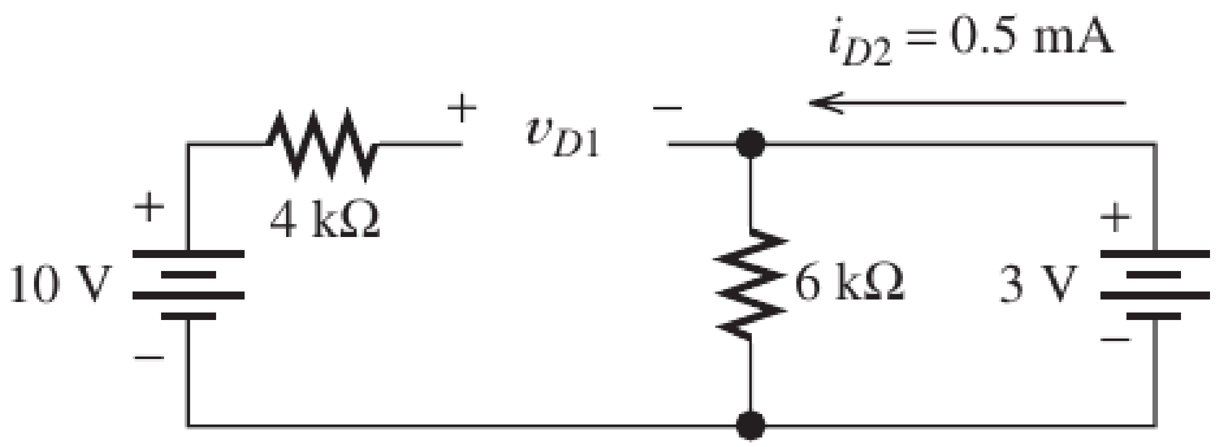
Find the states of the diodes

Use ideal diode model to analyze the given circuit.
Start bu assuming D1 off and D2 on



Example: Diode States

D1 off and D2 on



$$i_{D2} = \frac{3V}{5K} = 0.5mA$$

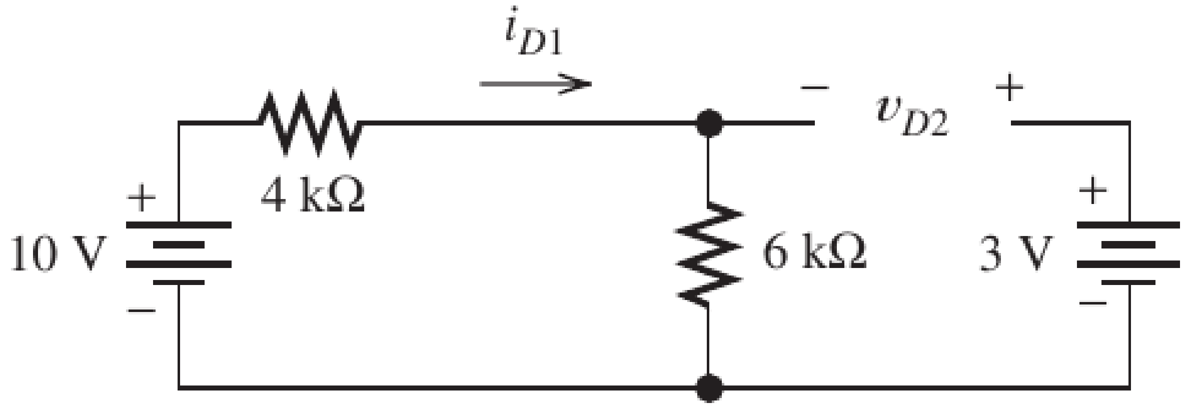
OK

$$v_{D1} = 10V - 3V = 7V$$

Uppss !!!

Example: Diode States

D1 on and D2 off



$$i_{D1} = \frac{10V}{4K + 6k} = 1mA$$

OK

$$v_{D2} = 3V - (6k \cdot 1mA) = -3V$$

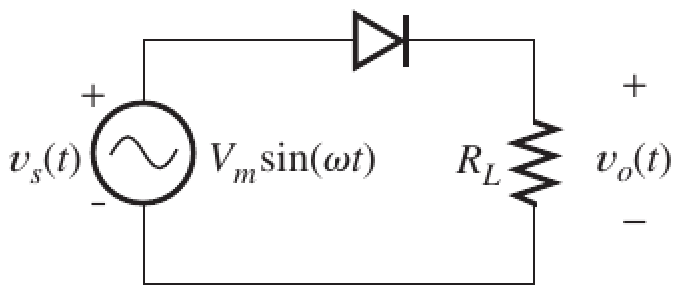
OK

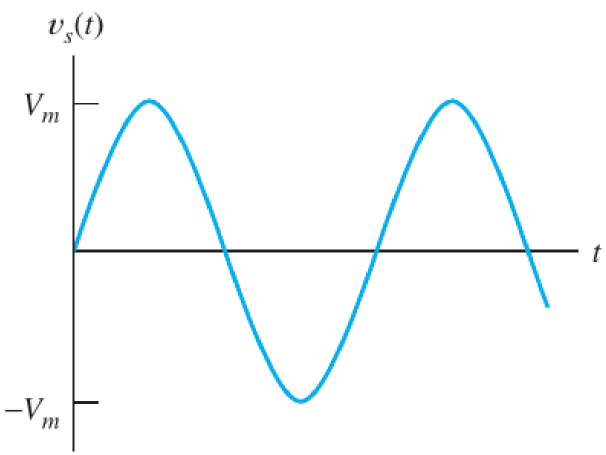
D1 on
D2 off

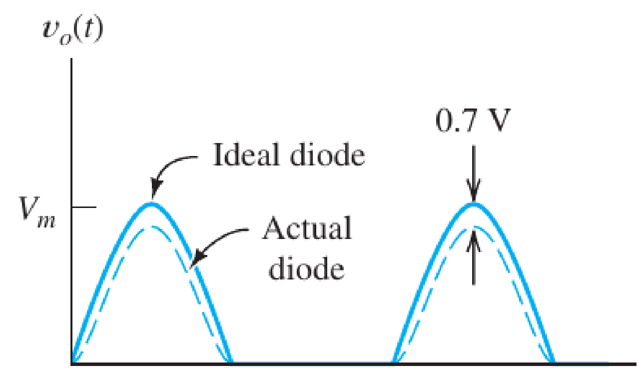
Rectifier Circuits

As we have introduced the diode, its main concepts and some methods for analysis of diode circuits, we are now ready to go for some practical diode circuits: like half wave rectifier and full wave rectifier

A **half wave rectifier** preserves only one side of a sinusoidal input (converts AC signal into DC), a simple version is given below

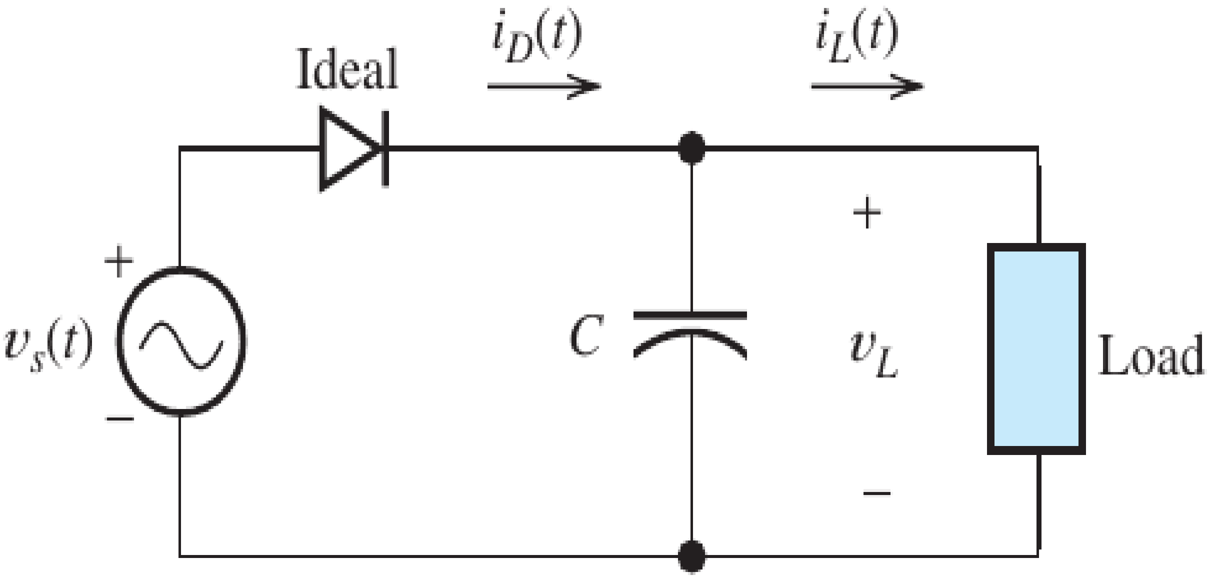






Rectifier Circuits

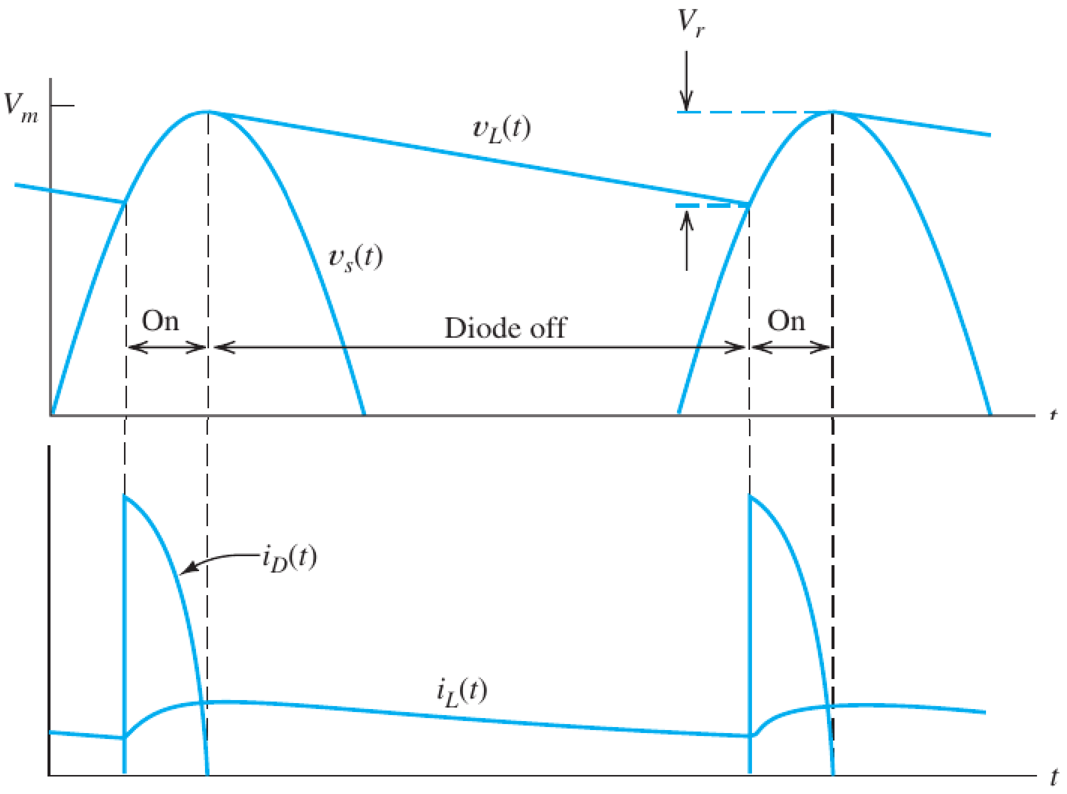
The previous circuit converts ac voltage into dc, but most of the time we prefer nearly constant dc voltages. One way to enhance the output of a half wave rectifier is to use it in conjunction with a capacitor (a large capacitance between the output terminals).



Rectifier Circuits

A half wave rectifier with a capacitor (smoothing effect)

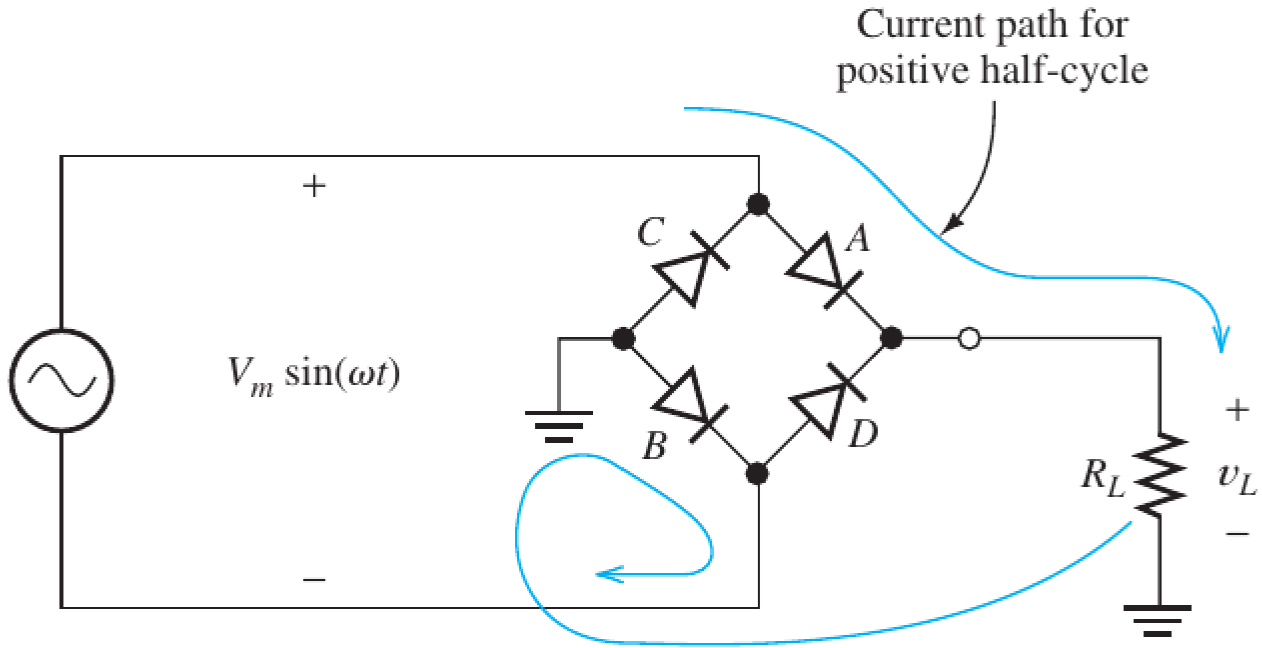
When ac voltage reaches a positive peak voltage, the capacitor is charged to the peak voltage.
When the source voltage drops below the stored voltage on the capacitor, the diode is reverse biased and no current passes through the diode. At this point capacitor continues to supply voltage to the load, slowly discharging until the next positive peak of the ac input.



V_r : Ripple Voltage

Rectifier Circuits

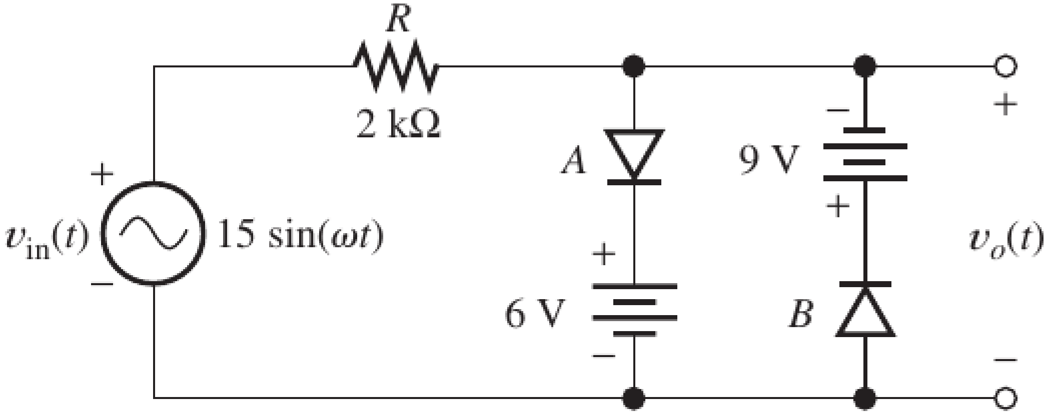
There are many forms for a full wave rectifier circuitry. One of the most commonly used one is the bridged rectifier :



Clipper Circuits

A clipper circuit “clips off” part of the input waveform to produce a desired output signal. Diodes can be used to form clipper circuits.

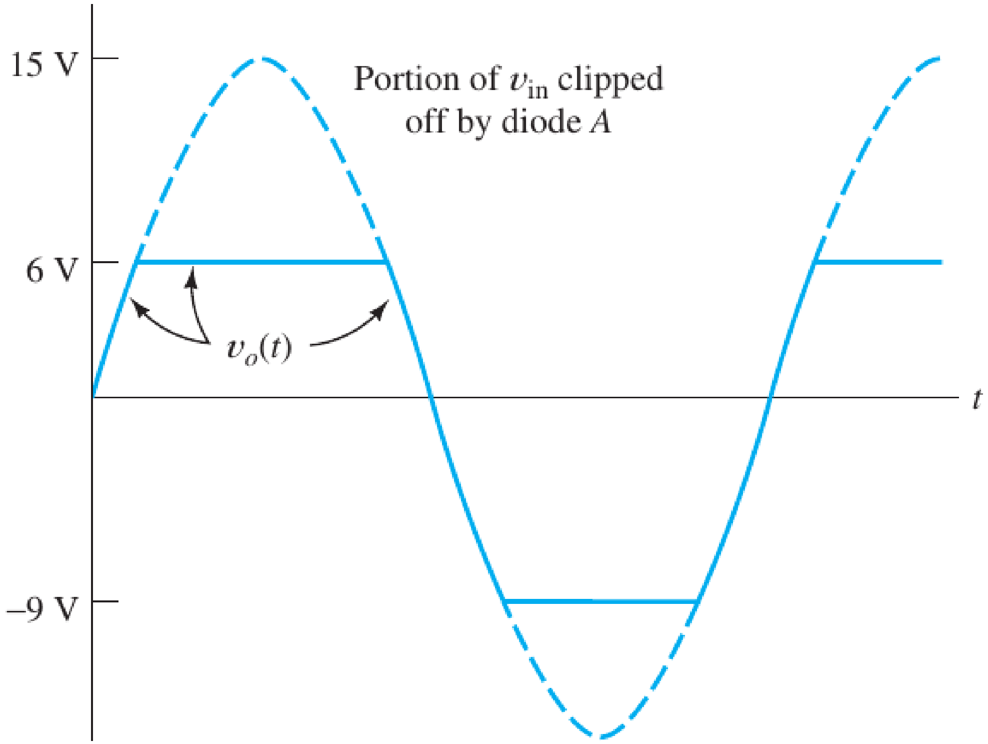
Here we introduce three different types of clipper circuits with different configurations.



Can you guess the waveform of $v_o(t)$?

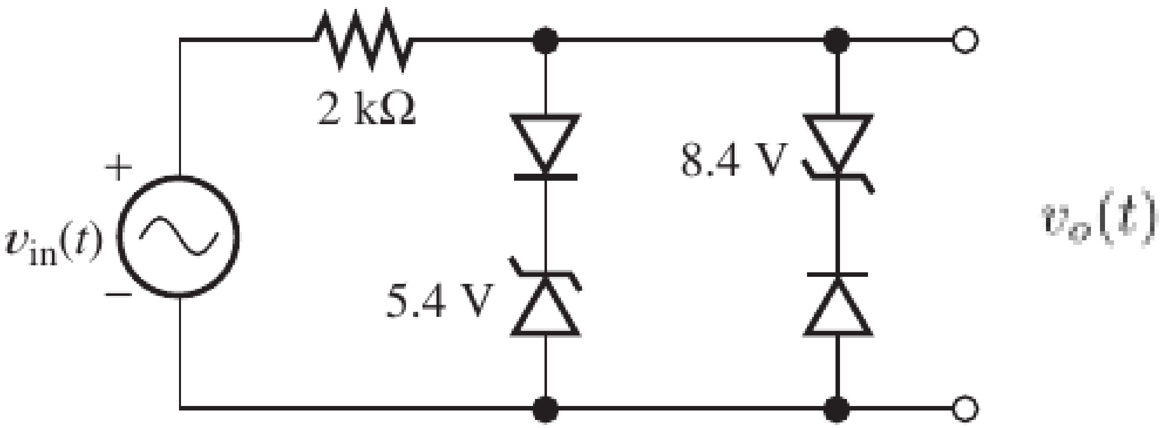
Clipper Circuits

Diode A will be off until the positive input voltage goes above 6 V (ideal case) and similarly diode B will turn on when the input voltage goes below -9V volts. Making the output waveform as follows



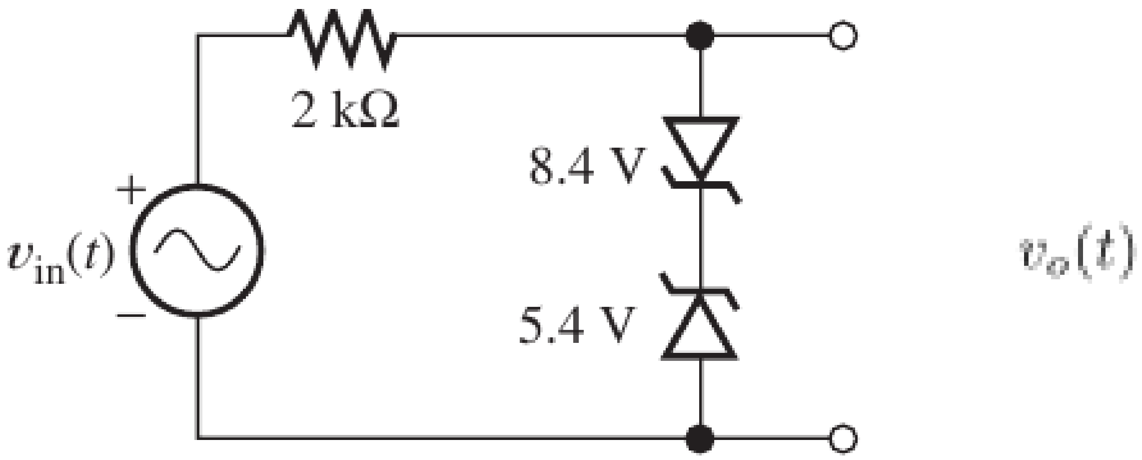
Clipper Circuits

How about the output of the following circuit, where the batteries are replaced with zener diodes and allowance made for a 0.6V forward diode drop ?



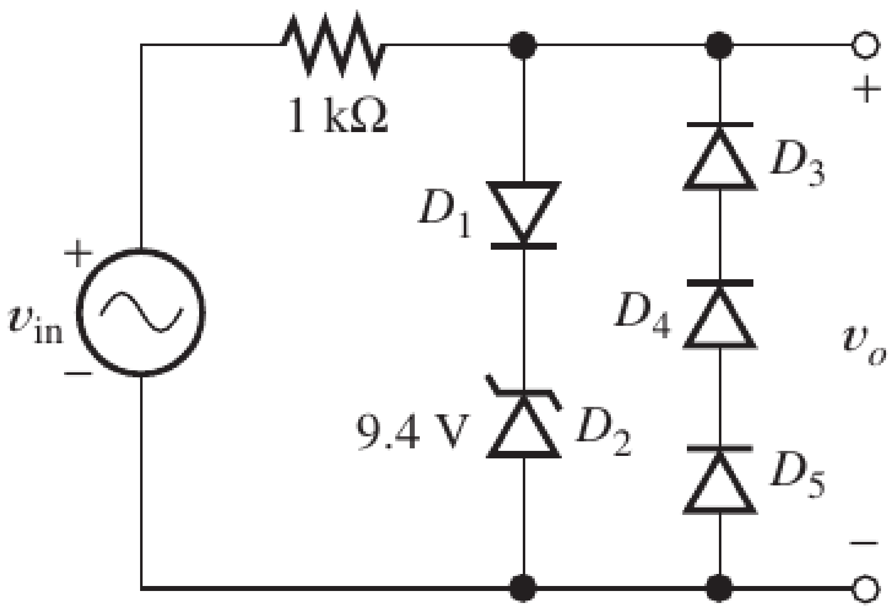
Clipper Circuits

Is it possible to replace the previous circuits with the following one ?

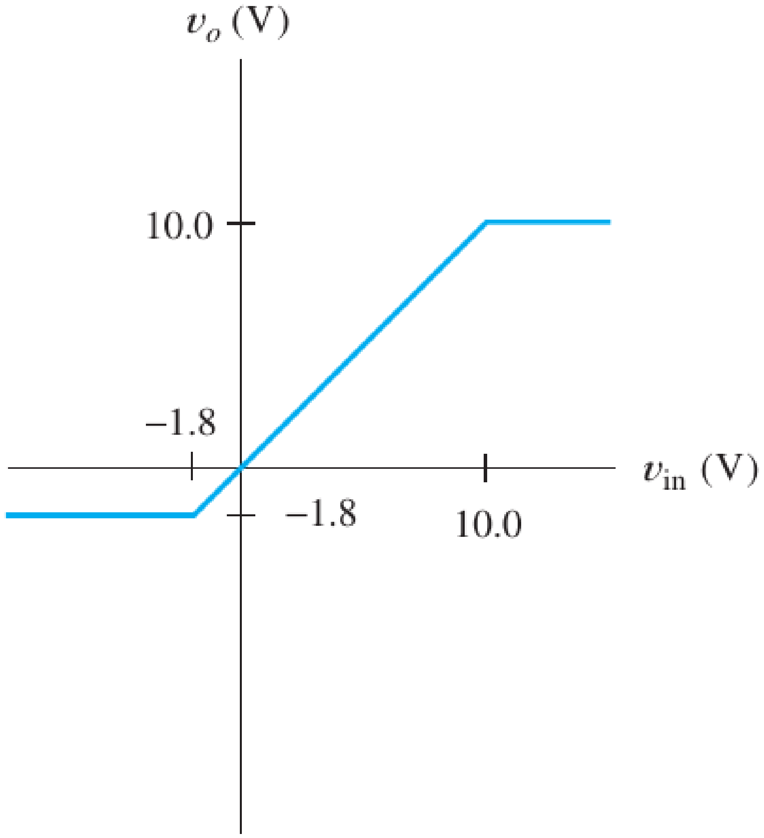


Example

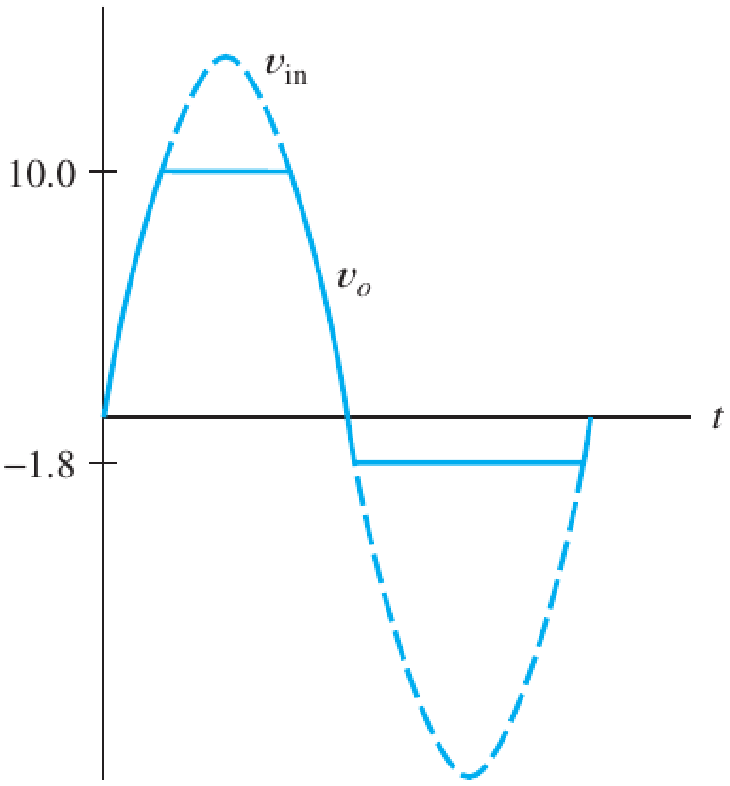
Sketch the output waveform when the input signal is $v_{in} = 15sin(\omega t)$



Example cont.



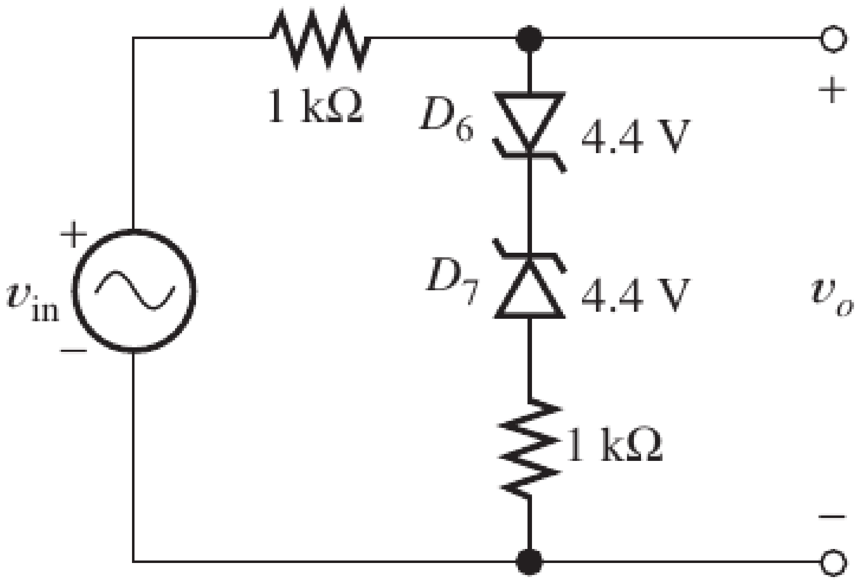
Input vs Output



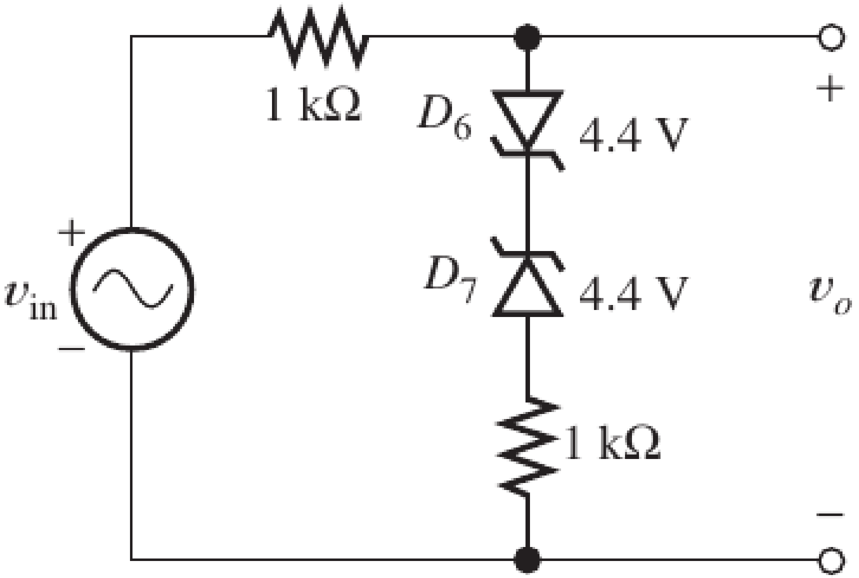
The waveforms

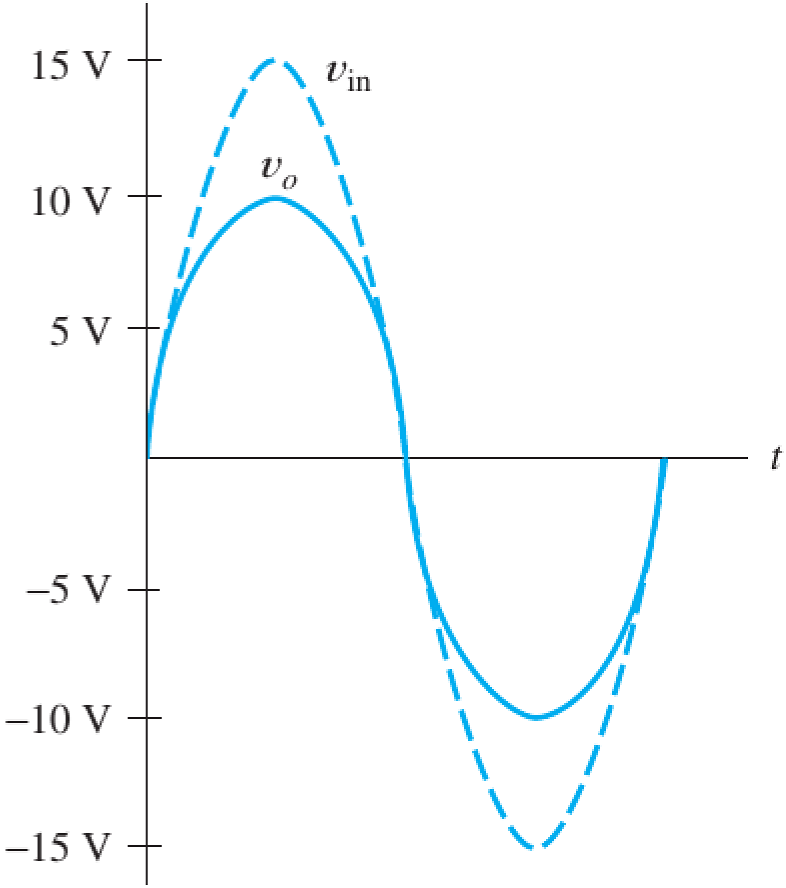
Example

Sketch the output waveform when the input signal is $v_{in} = 15sin(\omega t)$



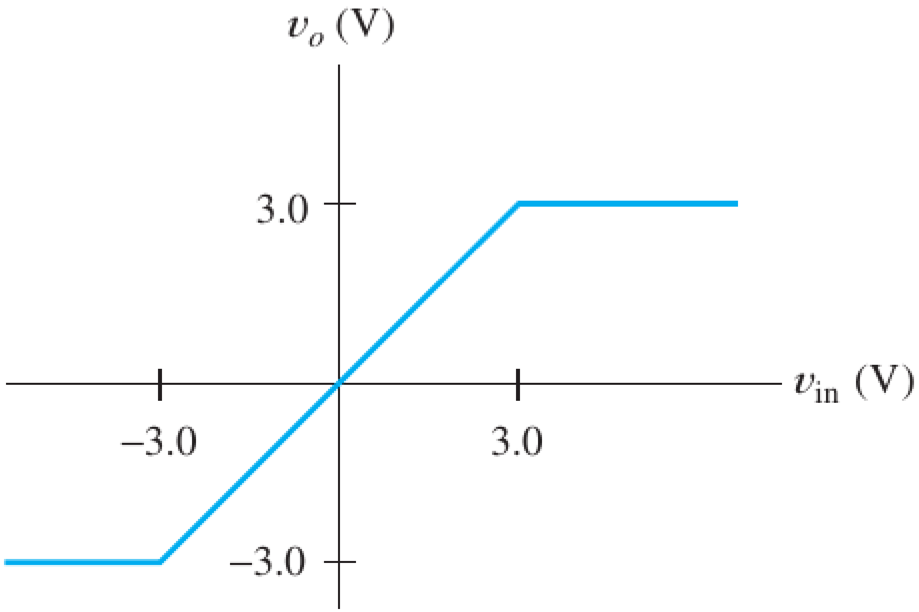
Example cont.





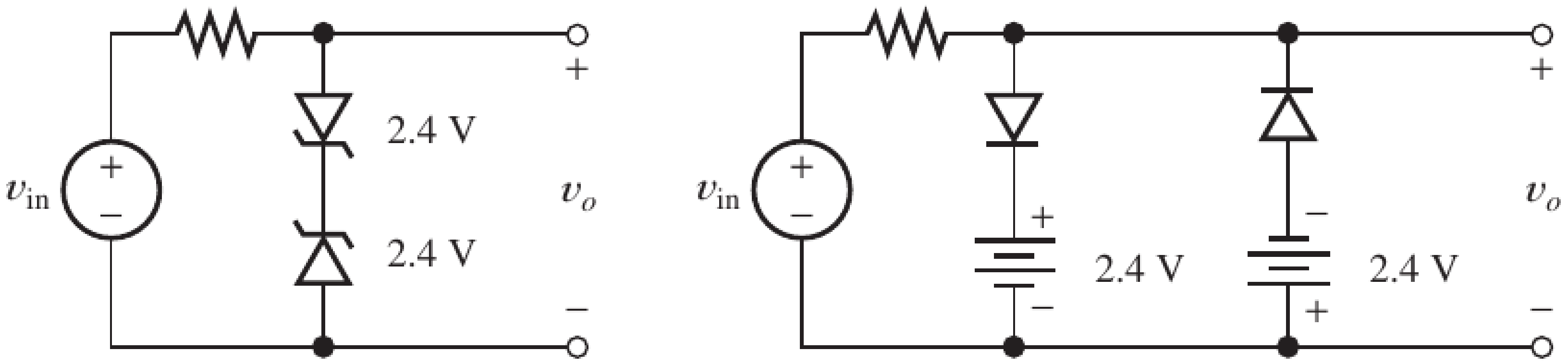
Design Example

Design a clipper circuit that have the following input to output characteristics (assume 0.6 V forward biasing voltage for diodes)



Design Example

Solution : (pick whichever you prefer)



Do this by yourself

Sketch the output signal when the input is a sinusoidal wave with amplitude of 15V