electronics fundamentals

circuits, devices, and applications

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Lesson 1: Diodes and Applications

Center-Tapped Full-wave Rectifier

The center-tapped (CT) full-wave rectifier uses two diodes connected to the secondary of a center-tapped transformer.

The ac on each side of the center-tap is ½ of the total secondary voltage. Only one diode will be biased on at a time.

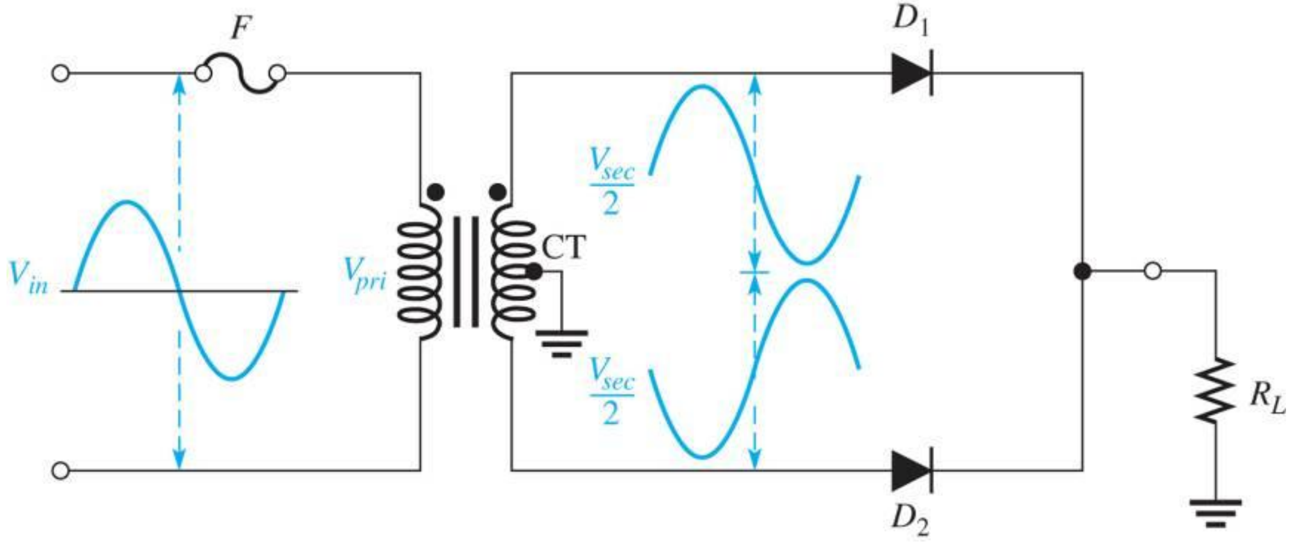
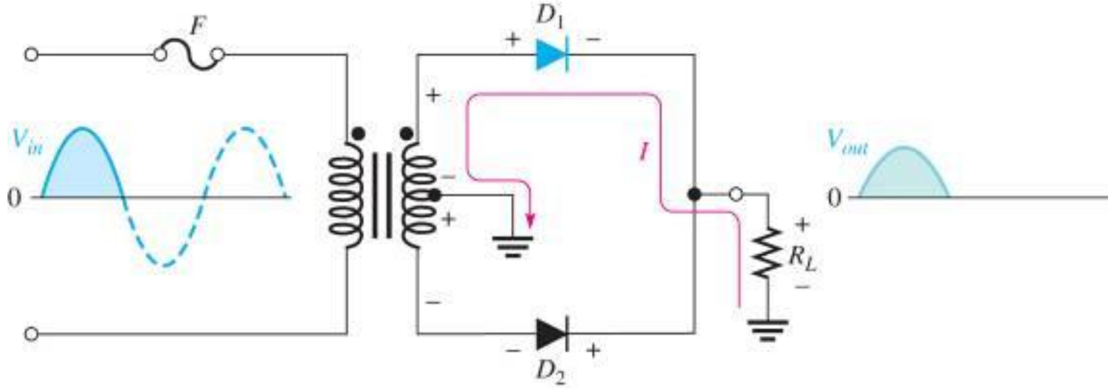
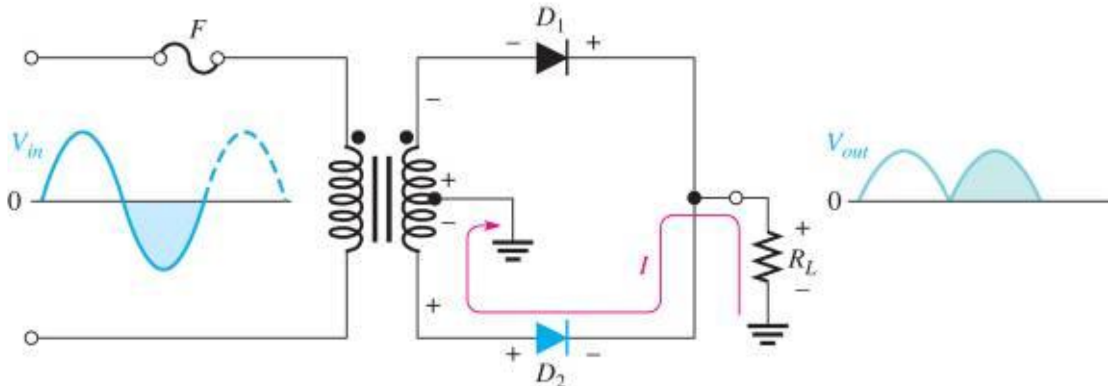


FIGURE 16–30 A center-tapped full-wave rectifier. $V_{pri} = V_{in}$.

Center-Tapped Full-wave Rectifier



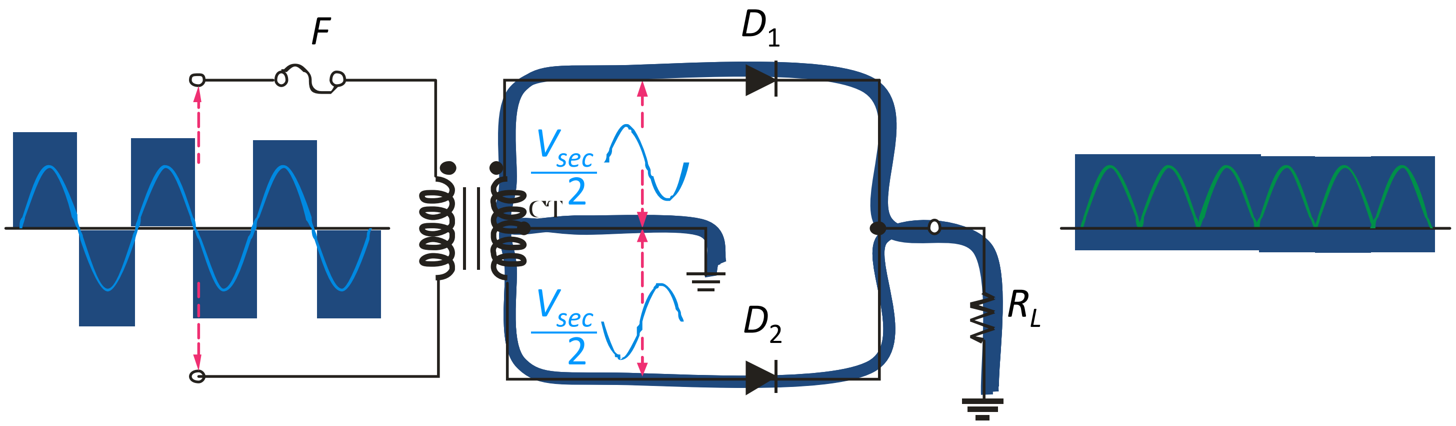
(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.



(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

FIGURE 16–31 Basic operation of a center-tapped full-wave rectifier. Note that the current through the load resistor is in the same direction during the entire input cycle.

Center-Tapped Full-wave Rectifier



Center-Tapped Full-wave Rectifier

Effect of the Turns Ratio on Full-Wave Output Voltage The output voltage is determine by the turns ratio, *n* of the transformer.

If you do not know the voltage, but do know the turns ratio of the transformer, you can calculate the peak output voltage for a full-wave rectifier from the following equation:

$$V_{p(out)} = \frac{nV_{p(in)}}{2}$$

Center-Tapped Full-wave Rectifier

Example: Specify the turns ratio and type of transformer required for a full-wave rectifier if the input voltage is 120 V rms and the required output is 17 V peak?

Solution:

The input peak voltage is

$$V_{p(in)} = \frac{V_{rms(in)}}{0.707} = \frac{120V}{0.707} = 170V$$

Rearranging Equation and substituting,

$$n = \frac{2V_{p(out)}}{V_{p(in)}} = \frac{2(17V)}{170V} = 0.200$$

Thus, a **center-tapped step-down** transformer with a turns ration of 0.2 is required.

Related Problem: What is the peak output if the turns ratio is 0.15?

Note:

rms value The value of a sine wave that indicates its heating effect, also known as the effective value. It is equal to **0.707** times the peak value. RMS stands for root mean square.

$$V_{rms} = 0.707V_p$$

peak value The voltage or current value of a waveform at its maximum positive or negative points.

$$V_{pp} = 2V_p$$

Center-Tapped Full-wave Rectifier

Peak Inverse Voltage (PIV) The maximum reverse voltage that each diode must withstand is the peak value of the total secondary voltage ($V_{p(sec)}$) as illustrated in the FIGURE 16-32 .

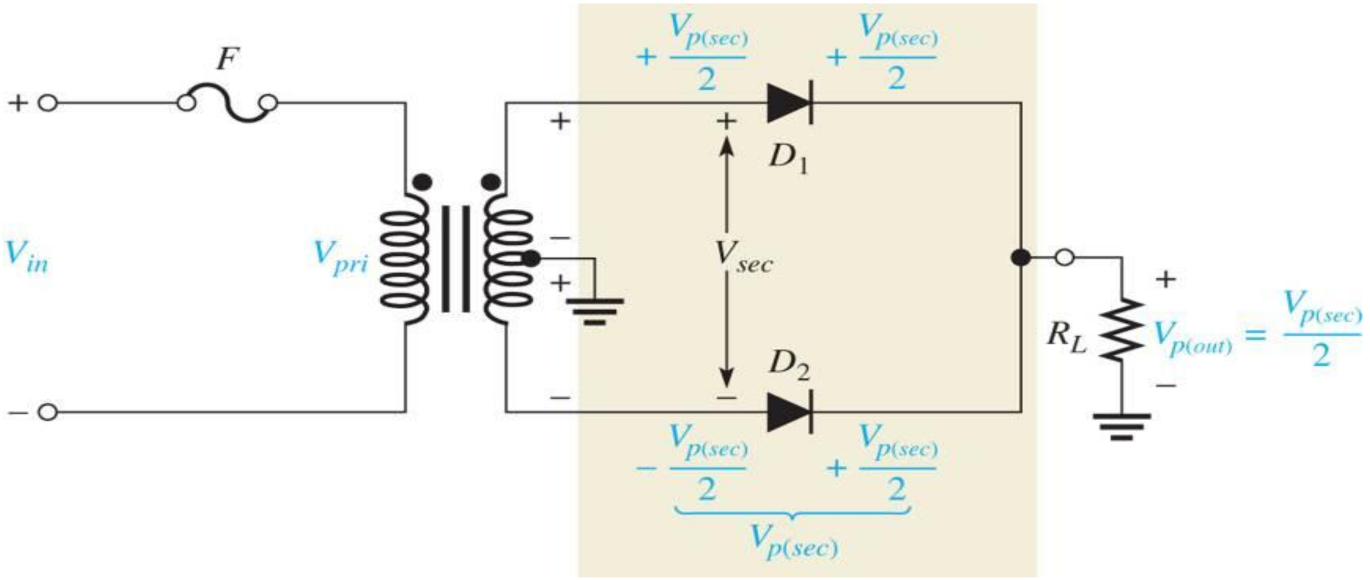


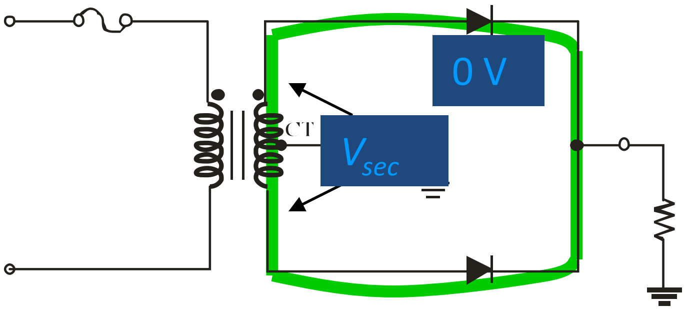
FIGURE 16–32 Diode D_1 is shown forward-biased and D_2 is reverse-biased with PIV across it. The PIV across either diode is equal to the peak secondary voltage, which is twice the peak output voltage.

Peak inverse voltage

Diodes must be able to withstand a reverse voltage when they are reverse biased. This is called the peak inverse voltage (PIV). The PIV depends on the type of rectifier circuit and the maximum secondary voltage.

For example, in a full-wave circuit, if one diode is conducting (assuming 0 V drop), the other diode has the secondary voltage across it as you can see from applying KVL around the green path.

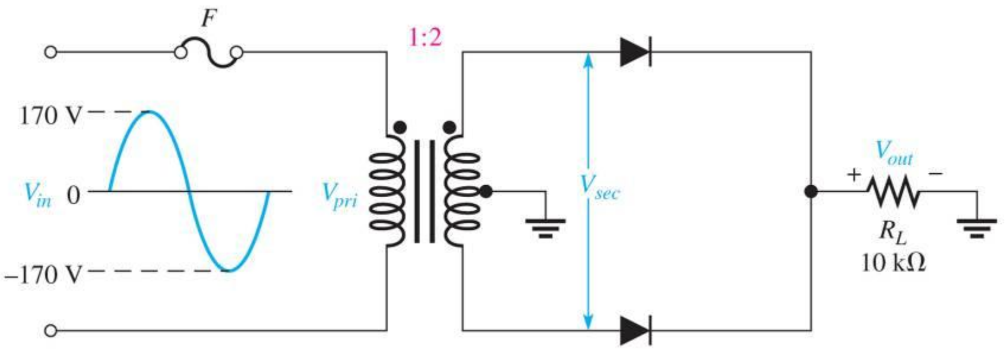
Notice that $V_{p(sec)} = 2V_{p(out)}$ for the full-wave circuit because the output is referenced to the center tap.



Example:

(a) For ideal diodes, show the voltage waveforms across the secondary winding and across R_L when a 120V rms sine wave is applied to the primary winding in the figure below.

(b) What minimum PIV rating must the diodes have?



Solution:

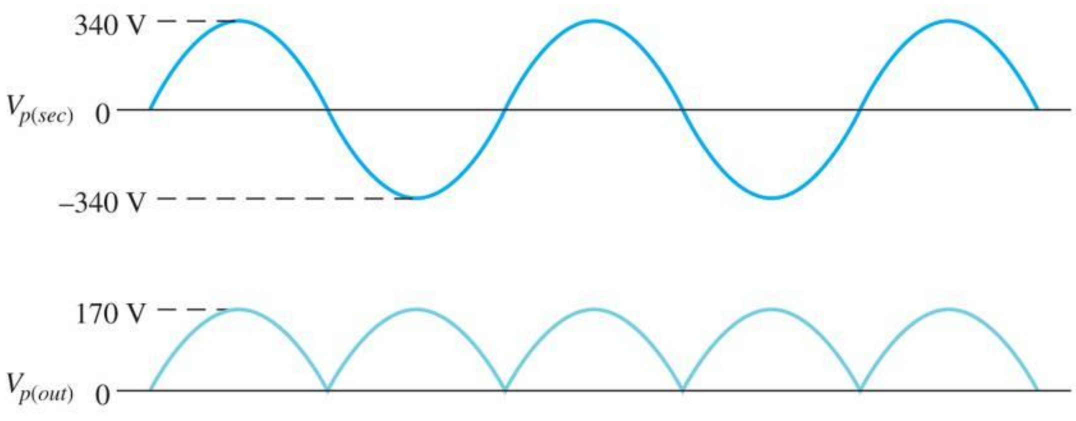
(a) The peak input voltage is $V_{in} = V_{p(pri)} = \dfrac{120V}{0.707} = 170V$

$$V_{p(\sec)} = nV_{p(pri)} = 2(170V) = 340V$$

To calculate the peak output voltage.

$$V_{p(out)} = \frac{nV_{p(in)}}{2} = \frac{2(170V)}{2} = 170V$$

Example *continued…*:



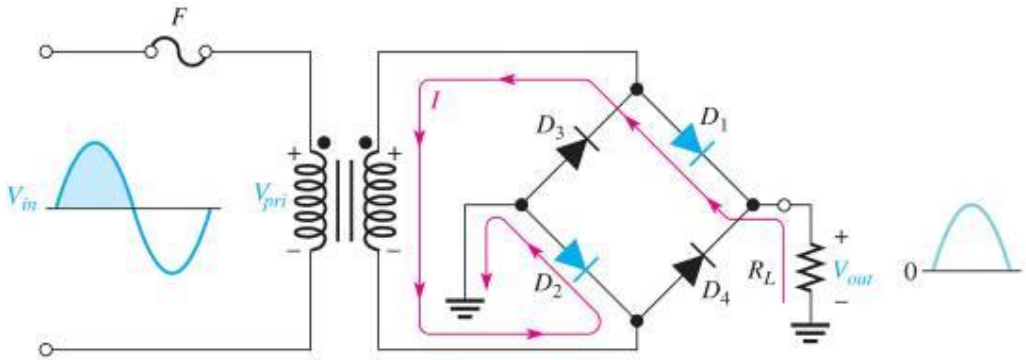
Solution:

(b)

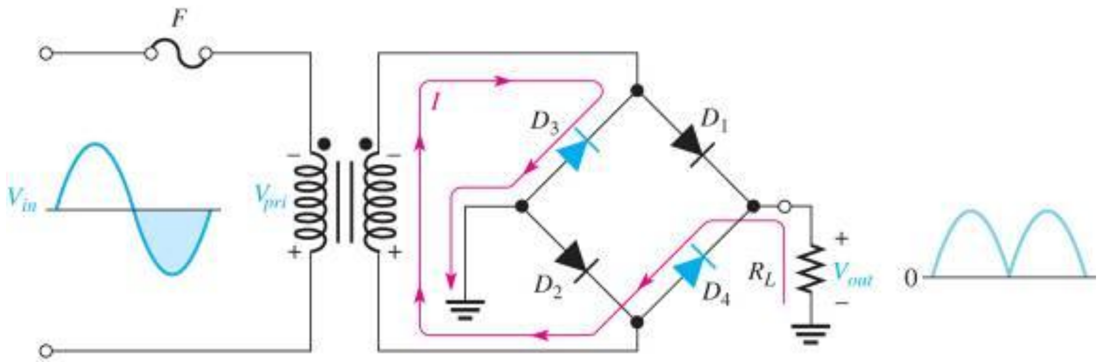
$$PIV = 2V_{p(out)} = 2(170V) = 340V$$

Related Problem: What diode PIV rating s required to handle a peak input of 185 V?

Full-Wave Bridge Rectifier



(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

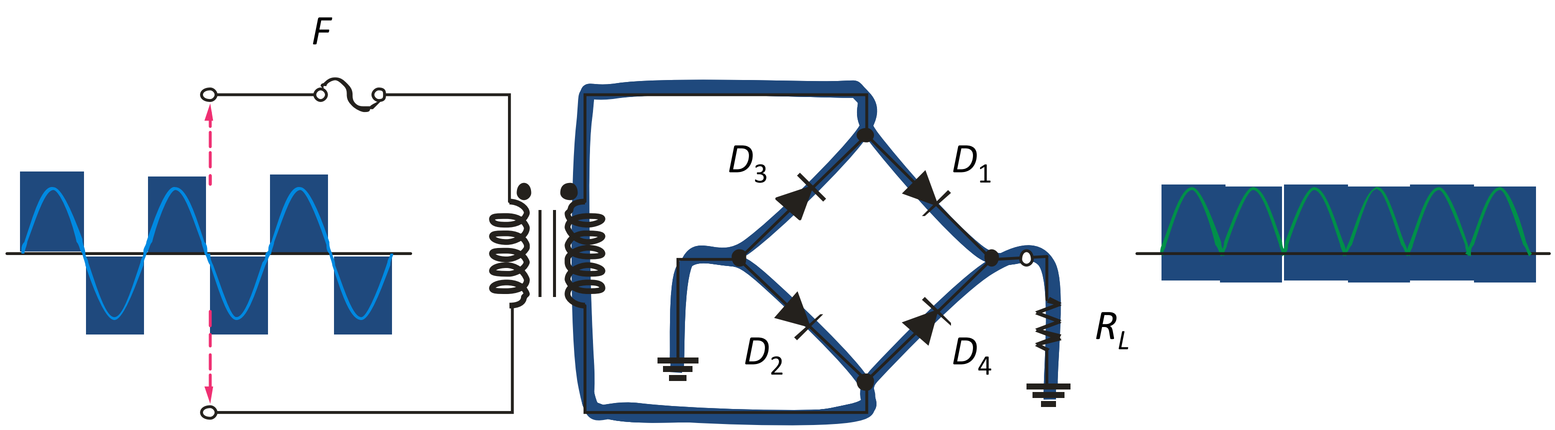


(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

Full-Wave Bridge Rectifier

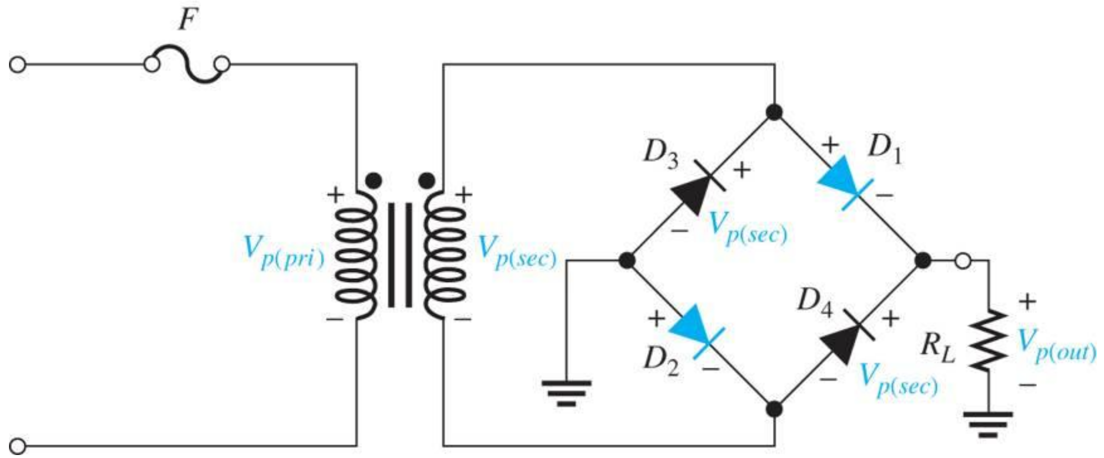
The bridge rectifier is a type of full-wave circuit that uses four diodes. The bridge rectifier does not require a center-tapped transformer.

At any instant, two of the diodes are conducting and two are off.



Full-Wave Bridge Rectifier

Bridge Output Voltage From transformer theory, the secondary voltage is equal to the primary voltage times the turns ratio.



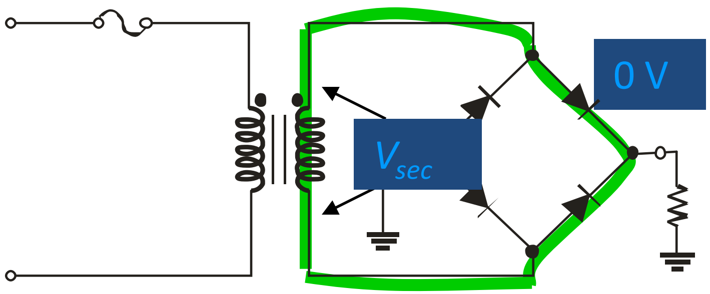
$$V_{\sec} = nV_{pri}$$

$$V_{p(out)} = V_{p(\sec)}$$

Peak inverse voltage

For the bridge rectifier, KVL can be applied to a loop that includes two of the diodes. Assume the top diode is conducting (ideally, 0 V) and the lower diode is off. The secondary voltage will appear across the non-conducting diode in the loop.

Notice that $V_{p(sec)} = V_{p(out)}$ for the bridge because the output is across the entire secondary.

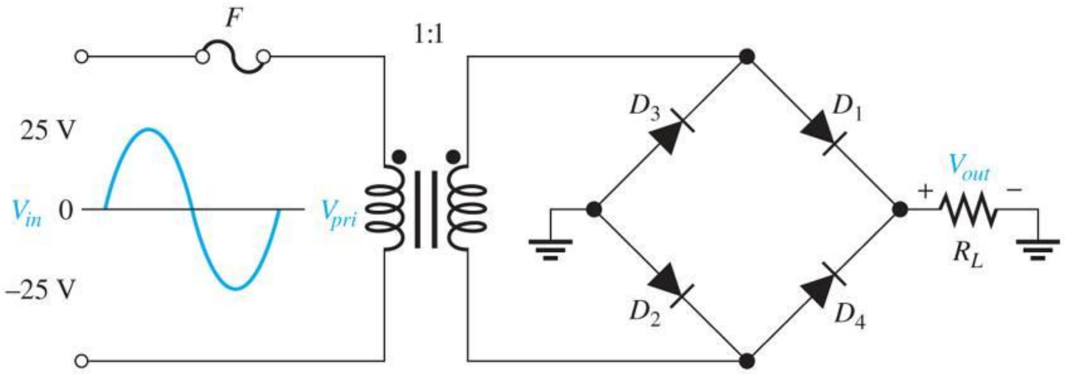


Full-Wave Bridge Rectifier

Example:

(a) Determine the peak output voltage for the bridge rectifier in Figure 16-37.

(b) What minimum PIV rating is required for the diodes?



Solution:

(a) The peak output voltage is

$$V_{p(out)} = V_{p(\sec)} = nV_{p(in)} = (1)25V = 25V$$

(a) The PIV for each diode is

$$PIV = V_{p(out)} = 25V$$

Related Problem: Determine the peak output voltage for the same bridge rectifier if the peak primary voltage is 170V. What is the PIV rating for the diodes.

Power supplies

The Basic DC Power Supply The dc power supply converts the standard 220 V, 60Hz ac available at wall outlets into a constant dc voltage.

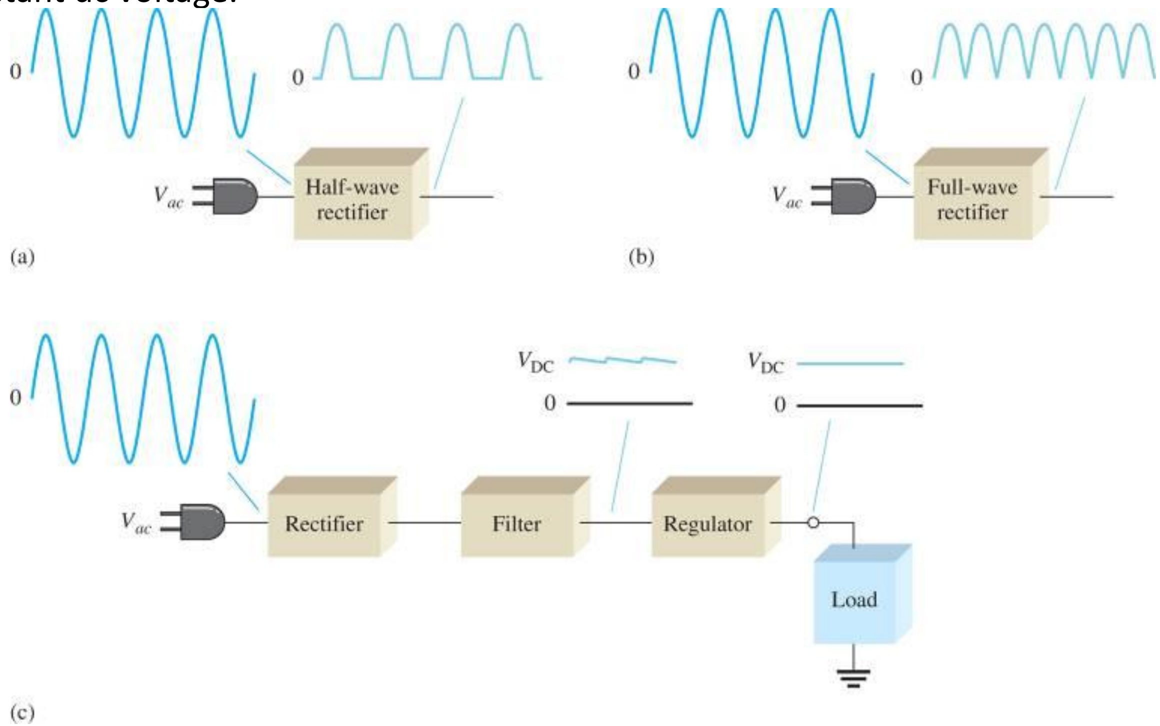


FIGURE 16–39 Block diagrams showing basic operation of rectifiers and a regulated dc power supply.

Power supplies

Capacitor Input Filter

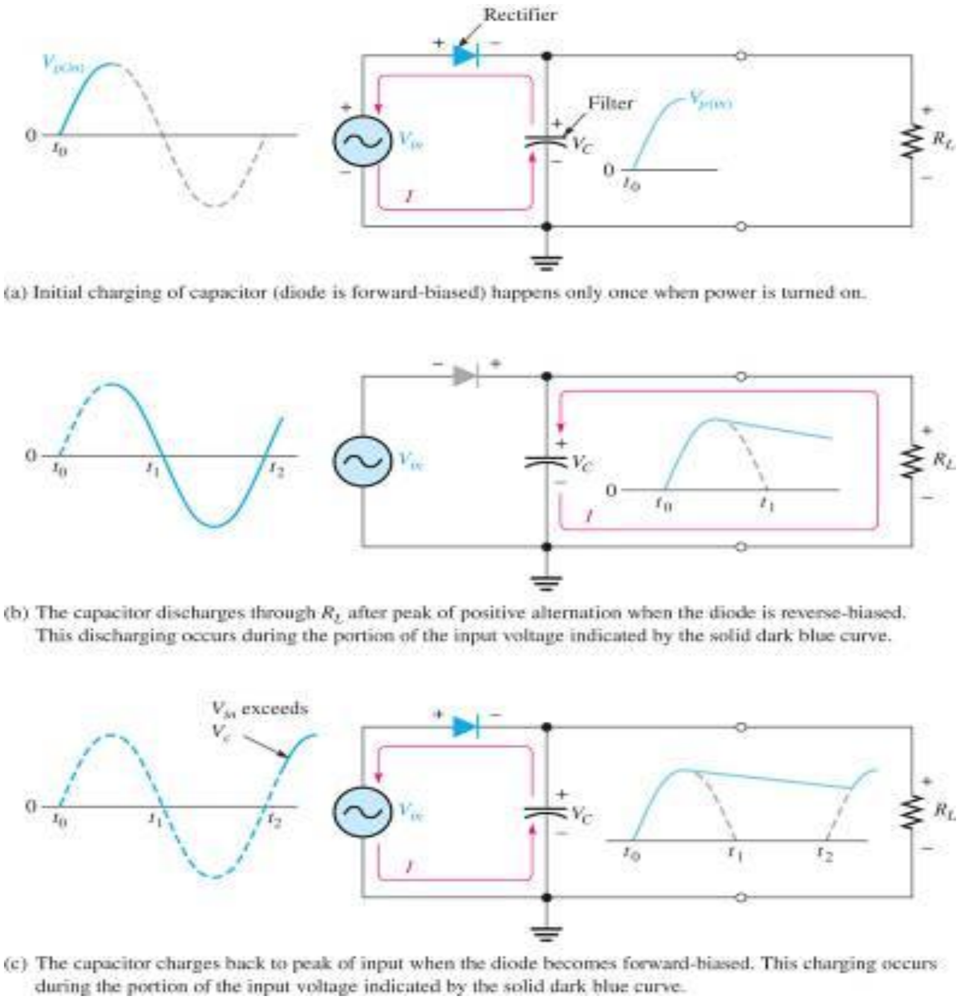


FIGURE 16–40 Operation of a half-wave rectifier with a capacitor-input filter.

Power supplies

Ripple Voltage

Is the variation in the output voltage due to the charging and discharging of the capacitor.

The smaller the ripple, the better the filtering acti

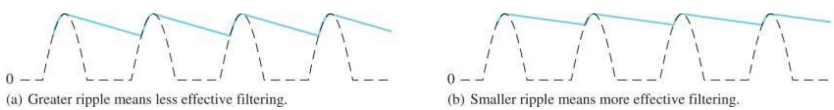


FIGURE 16–41 Half-wave ripple voltage (blue line).

$$r = \left(\frac{V_r}{V_{DC}}\right)100\%$$

The ripple factor *(r)* is an indication of the effectiveness of the filter.

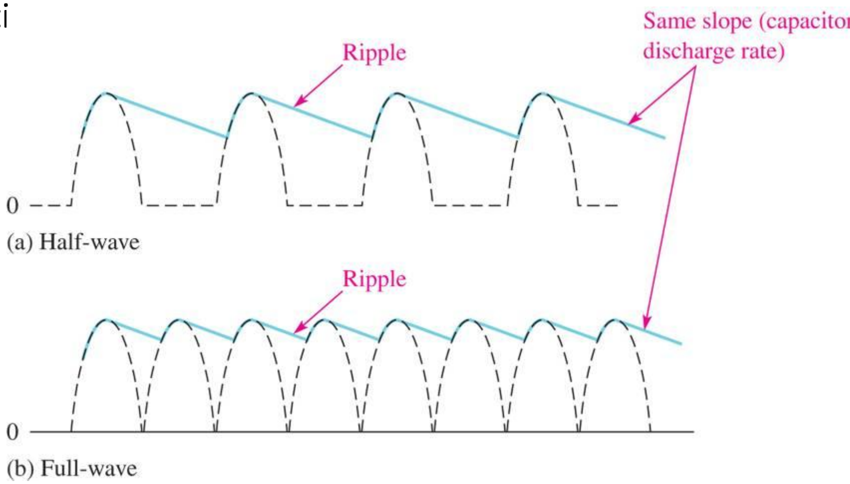
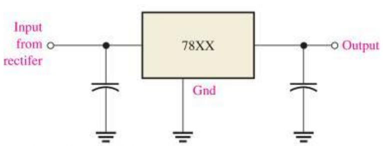


FIGURE 16–42 Comparison of ripple voltages for half-wave and full-wave signals with same filter and same input frequency. For clarity, the amount of ripple showed is exaggerated.

Power supplies

IC Regulated Power Supplies

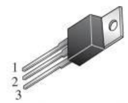
An integrated circuit regulator is a device that is connected to the output of a filtered rectifier and maintains a constant output voltage despite changes in the input, the load current, or the temperature.



(a) Standard configuration

Type number	Output voltage
7805	+5.0 V
7806	+6.0 V
7808	+8.0 V
7809	+9.0 V
7812	+12.0 V
7815	+15.0 V
7818	+18.0 V
7824	+24.0 V

(b) The 7800 series



(Heatsink surface connected to Pin 2)

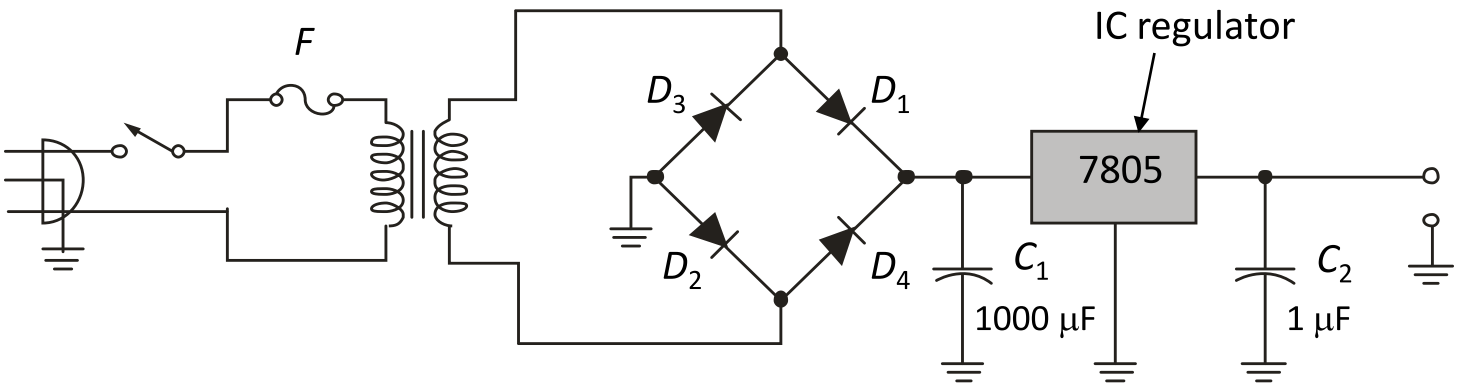
(c) Typical package

FIGURE 16–44 The 7800 series regulator.

Power supplies

By adding a filter and regulator to the basic rectifier, a basic power supply is formed.

Typically, a large electrolytic capacitor is used as a filter before the regulator, with a smaller one following the regulator to complete filtering action.



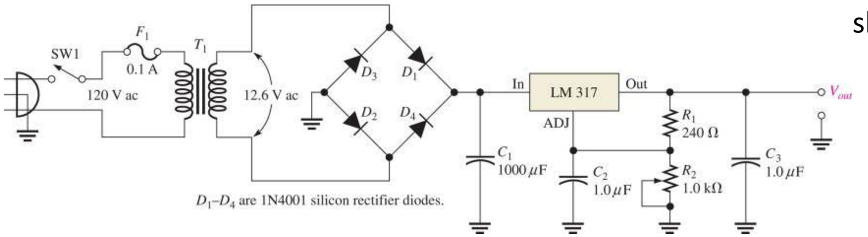
Power supplies

IC Regulated Power Supplies: Adjustable Regulators

LM117/LM317 series of adjustable positive regulators

LM137/LM337 series of adjustable negative regulators

These regulators only require two external resistors to set the output voltage, which can range from 1.2 V to 37 V for the positive regulator and up to 1.5 A output.



short circuit protection and have better specifications

$$V_{out} = 1.25V\left(\frac{R1 + R2}{R1}\right)$$

FIGURE 16–46 A basic power supply with a variable output voltage (from 1.25 V to 6.5 V).

Power supplies

Percent Regulation

The regulation expresses as percentage is used to specify the performance of a voltage regulator. It can be in terms of input (line) regulation or load regulation.

Line Regulation Specifies how much change occurs in the output voltage for a given change in the input voltage.

$$\textbf{Line Regulation} = \left(\frac{\Delta V_{out}}{\Delta V_{in}}\right)100\%$$

Load Regulation Specifies how much change occurs in the output voltage over a certain range of load currents values, usually from minimum current (no load, NL) to a maximum current (full load, FL)

$$\textbf{Load Regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}}\right)100\%$$

Power supplies

Example

Assume a certain 7805 regulator has a measured no-load output voltage of 5.18 V and a full-load output of 5.15 V. What is the load regulation expressed as a percentage?

Solution:

Load Regulation= $$\left(\frac{V_{NL}-V_{FL}}{V_{FL}}\right)100\% = \left(\frac{5.18V-5.15V}{5.15V}\right)100\% = 0.58\%$$

Related Problem:

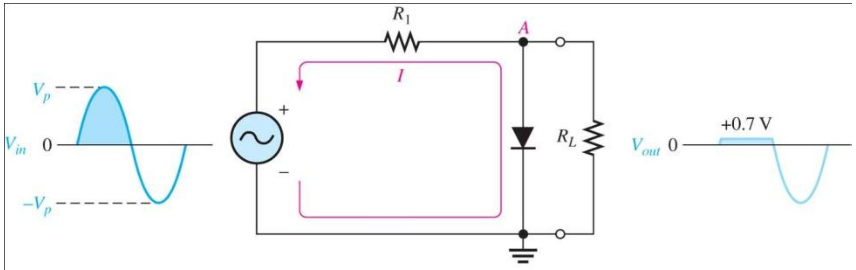
If the no-load output voltage of a regulator is 24.8 V and the full-load output is 23.9 V, What is the load regulation expressed as percentage?

Diode Limiting and Clamping Circuits

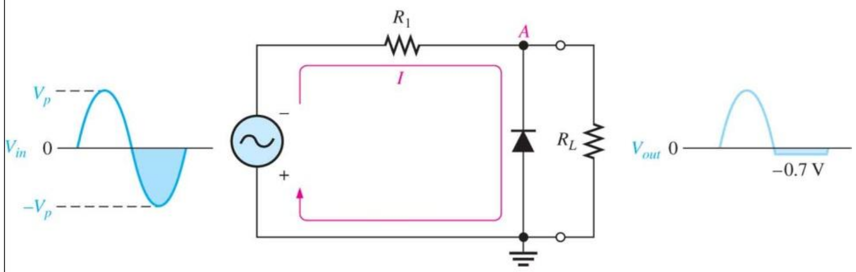
- Diode circuits, called limiters or clippers, are sometimes used to clip off portions of signal voltages above or below certain levels.
- A limiter application is commonly found in most circuits that have certain restrictions on the input level to avoid damaging the circuit.
- Another type of diode circuit, is called a clamper, is used to add or restore a dc level to an electrical signal.
- A clamper application is often used in analog television receivers as dc restorer.
- Another application is to prevent a signal from going negative and damaging a sensitive input circuit.

Clipper Circuits (Diode Limiters)

- ❑ Figure 2-34(a) shows a diode



(a) Limiting of the positive alternation. The diode is forward-biased during the positive alternation (above 0.7 V) and reverse-biased during the negative alternation.

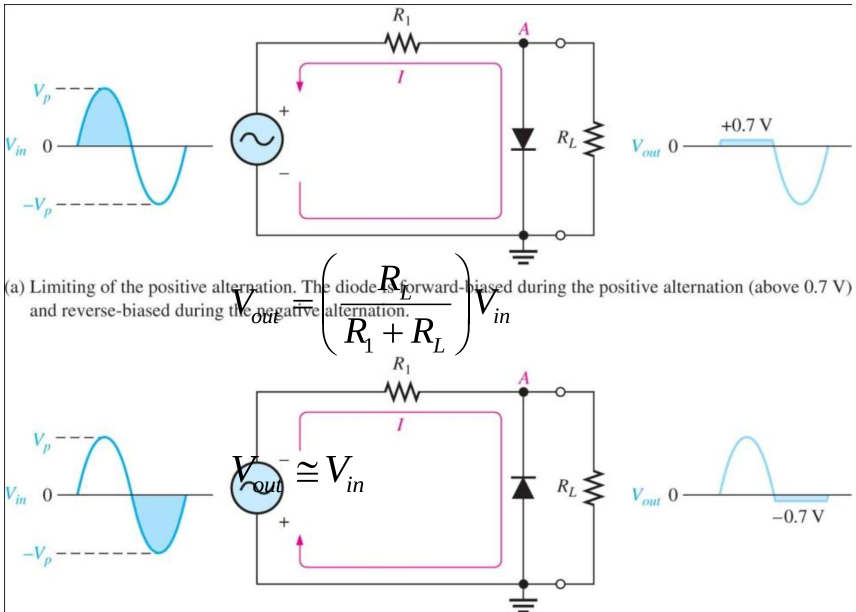


(b) Limiting of the negative alternation. The diode is forward-biased during the negative alternation (below −0.7 V) and reverse-biased during the positive alternation.

Figure 2-34 Examples of diode limiters (clippers).

Clipper Circuits (Diode Limiters)

- The output voltage looks like



(a) Limiting of the positive alternation. The diode is forward-biased during the positive alternation (above 0.7 V) and reverse-biased during the negative alternation.

$$V_{out} = \left(\frac{R_L}{R_1 + R_L} \right) V_{in}$$

$$V_{out} \cong V_{in}$$

(b) Limiting of the negative alternation. The diode is forward-biased during the negative alternation (below −0.7 V) and reverse-biased during the positive alternation.

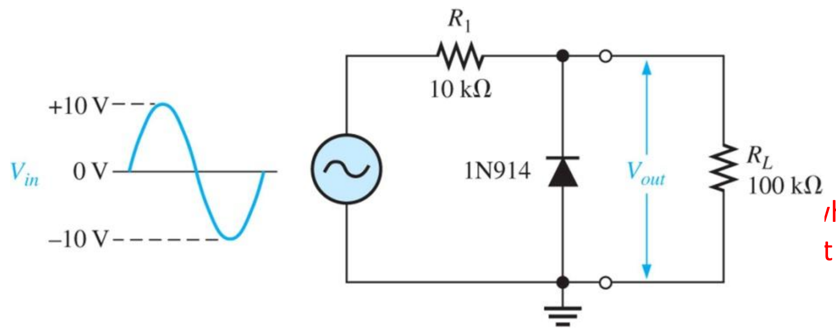
voltage is clipped off.

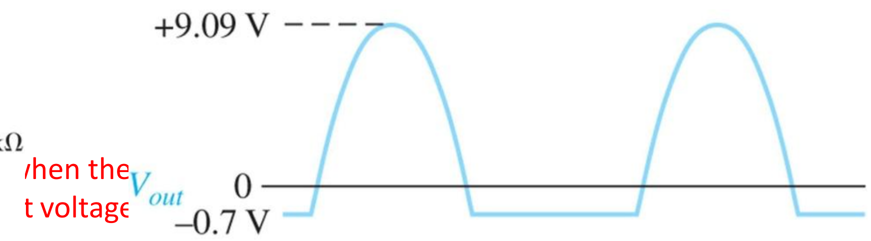
Figure 2-34 Examples of diode limiters (clippers).

Clipper Circuits (Diode Limiters)

Example

What would you expect to see displayed on an oscilloscope connected across R_L in the clipper circuit shown below.





$$V_{p(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{p(in)} = \left(\frac{100k\Omega}{110k\Omega}\right) 10V = 9.09V$$

Output voltage waveform

Related Problem:

Describe the output waveform for the same figure if R_1 is changed to 1kΩ

Clipper Circuits (Diode Limiters)

- **Biased Limiters**

  The level to which an AC voltage is limited can be adjusted by adding a bias voltage, V_{BIAS}, in series with the diode.

  The voltage at point A must equal V_{BIAS} + 0.7V before the diode will
  t.

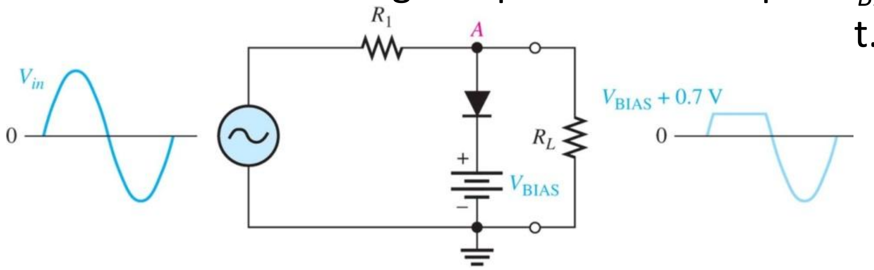


Figure 2-37 A positive limiter.

Clipper Circuits (Diode Limiters)

To limit a voltage to a specified negative level, the diode and bias voltage must be connected as in Figure 2-38.

In this case, the voltage at point A must go below $-V_{BIAS}$ - 0.7V to forward-biased diode and initiate limiting action as shown.

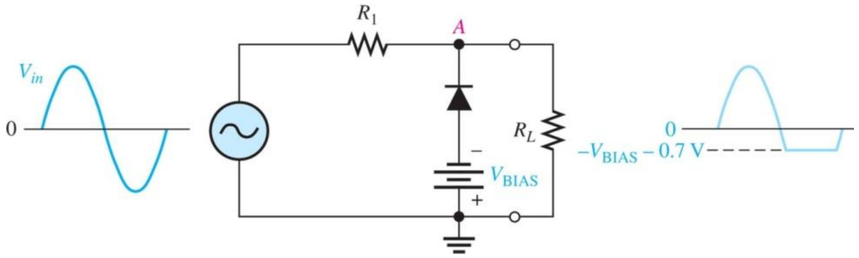
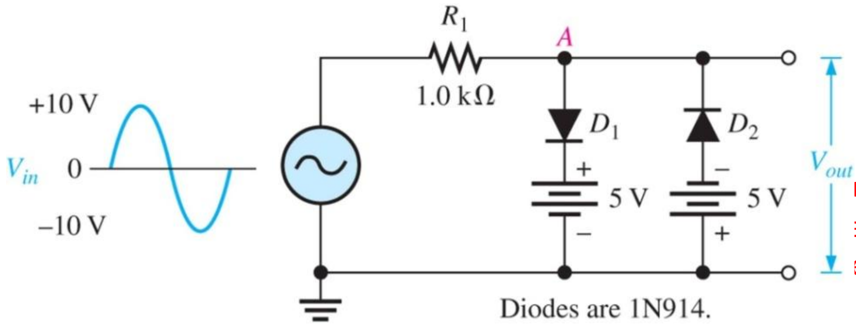


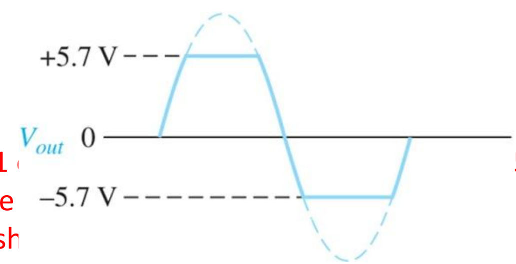
Figure 2-3 A negative limiter.

Clipper Circuits (Diode Limiters)

Example: The figure below shows a circuit combining a positive limiter with a negative limiter. Determine the output voltage waveform.



+5.7V, diode D1
erefore, positive
e waveform is sh



5.7V. Diode
tages

Related Problem:

Determine the output voltage waveform using the same figure if both DC sources are 10V and the input voltage has a peak value of 20V.