Lecture (04)
Diode applications, cont.

By:

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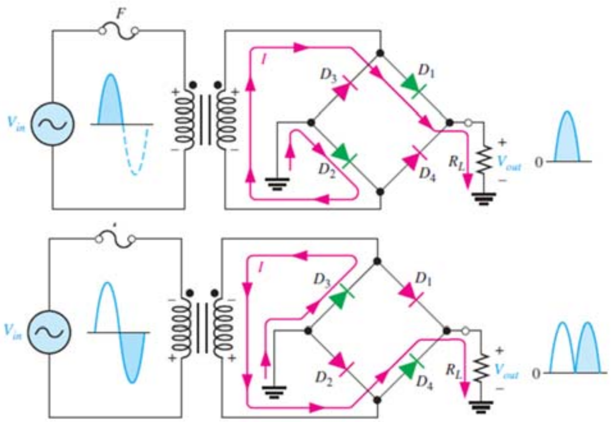
Agenda

- Full wave rectifier, cont.,..
- Filters
- Voltage Regulators
- Diode limiters
- Diode Clampers

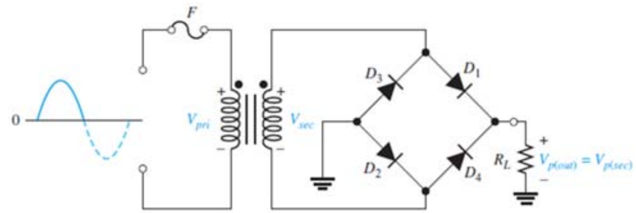
Bridge Full-Wave Rectifier Operation

- uses four diodes connected as shown



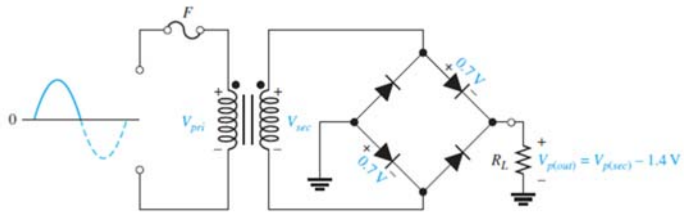
- Neglecting the diode drops, the secondary voltage appears across the load resistor.

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



- two diodes are always in series with the load resistor during both the positive and negative half-cycles. If these diode drops are taken into account, the output voltage is

$$V_{p(out)} = V_{p(sec)} - 1.4\text{ V}$$



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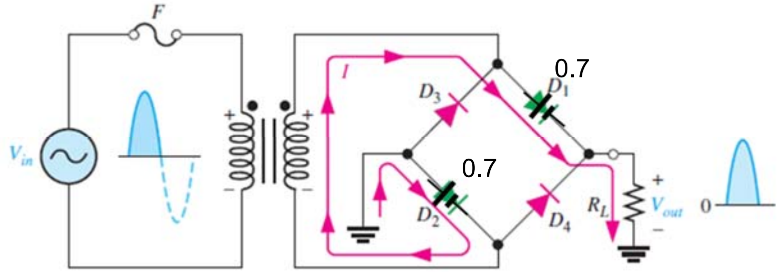
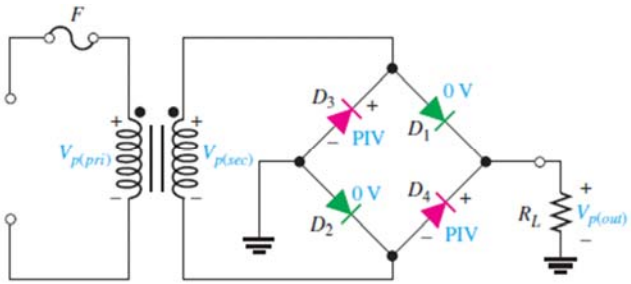


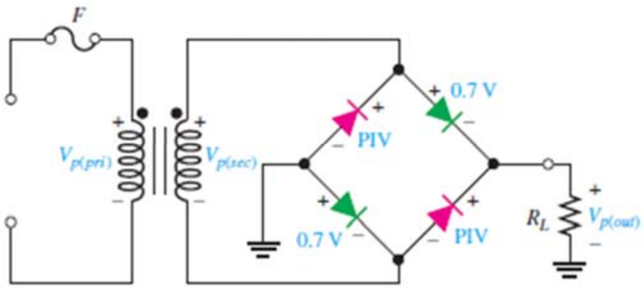
- ***Peak Inverse Voltage***
- If diodes in forward bias are ideal

$$\text{PIV} = V_{p(out)}$$



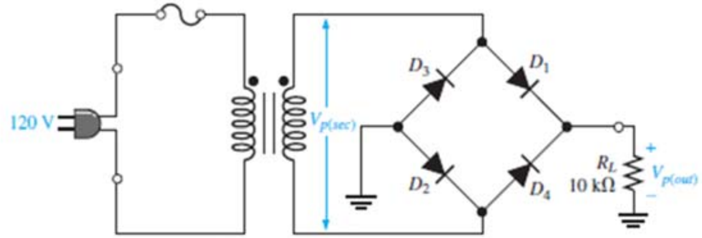
- If the diode drops of the forward-biased diodes are included

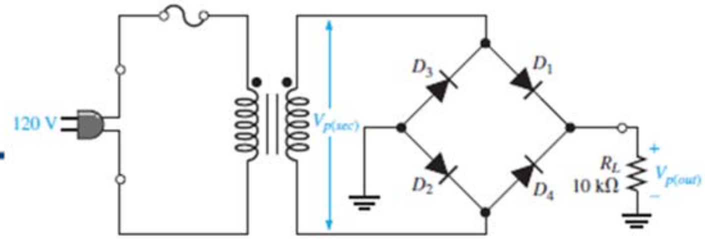
$$\text{PIV} = V_{p(out)} + 0.7\text{ V}$$



Example 04

- Determine the peak output voltage for the bridge rectifier in Figure. Assuming the practical model, what PIV rating is required for the diodes?
- The transformer is specified to have a 17V peak secondary voltage for the standard 120 V across the primary



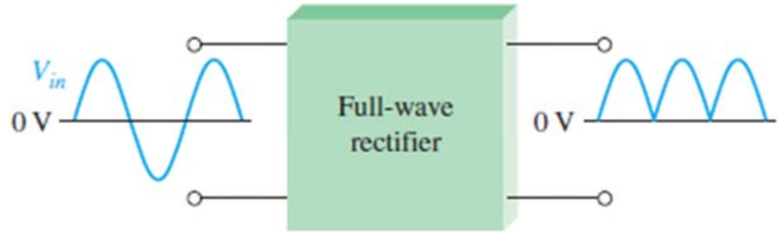


- $$V_{p(out)} = V_{p(sec)} - 1.4\text{ V} = 17\text{ V} - 1.4\text{ V} = \mathbf{15.6\text{ V}}$$

$$\text{PIV} = V_{p(out)} + 0.7\text{ V} = 15.6\text{ V} + 0.7\text{ V} = \mathbf{16.3\text{ V}}$$

power supply filters and regulators

- A power supply filter ideally eliminates the fluctuations in the output voltage of a halfwave or full-wave rectifier and produces a constant-level dc voltage
- Filtering is necessary because electronic circuits require a constant source of dc voltage and current to provide power and biasing for proper operation.
- Filters are implemented with capacitors,



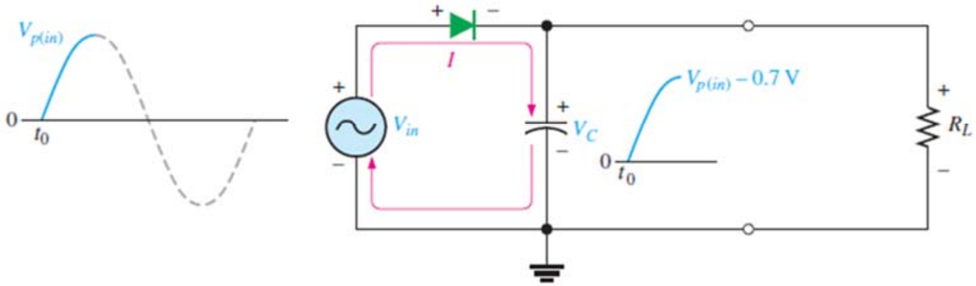
(a) Rectifier without a filter

- The 60 Hz pulsating dc output of a half-wave rectifier or the 120 Hz pulsating output of a full-wave rectifier

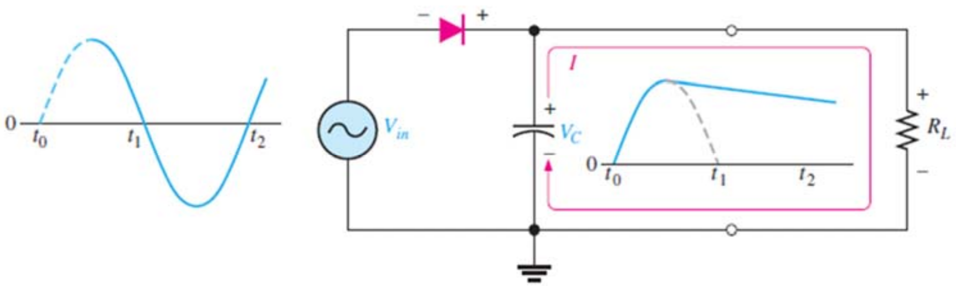
(b) Rectifier with a filter (output ripple is exaggerated)

- Figure shows filtering concept giving a nearly smooth dc output voltage from the filter.
- The small amount of fluctuation in the filter output voltage is called *ripple.*

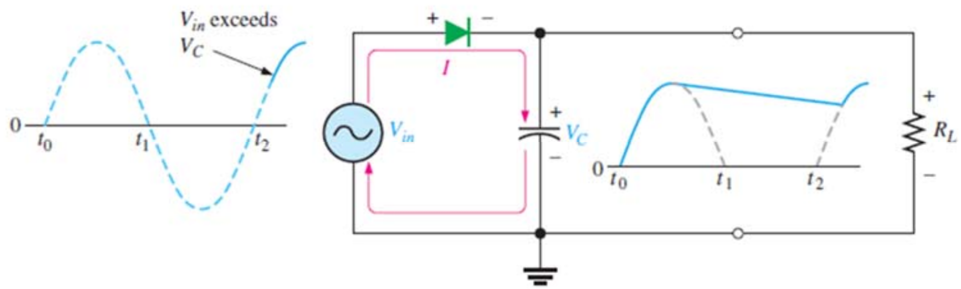
- **Capacitor-Input Filter**
- During the positive first quarter-cycle of the input, the diode is forward-biased, allowing the capacitor to charge to within 0.7 V of the input peak



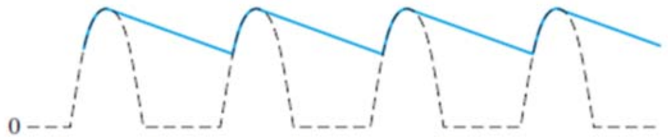
- When the input begins to decrease below its peak,, the capacitor retains its charge and the diode becomes reverse-biased because the cathode is more positive than the anode.
- During the remaining part of the cycle, the capacitor can discharge only through the load resistance at a rate determined by the *RLC* time constant, which is normally long compared to the period of the input.
- The larger the time constant, the less the capacitor will discharge.



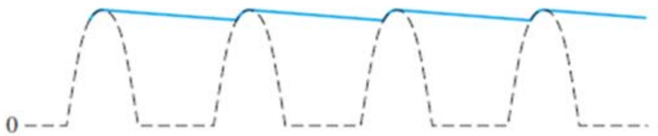
- During the first quarter of the next cycle, as illustrated , the diode will again become forward-biased when the input voltage exceeds the capacitor voltage by approximately 0.7 V.



- ***Ripple Voltage***
- The variation in the capacitor voltage due to the charging and discharging is called the **ripple voltage**

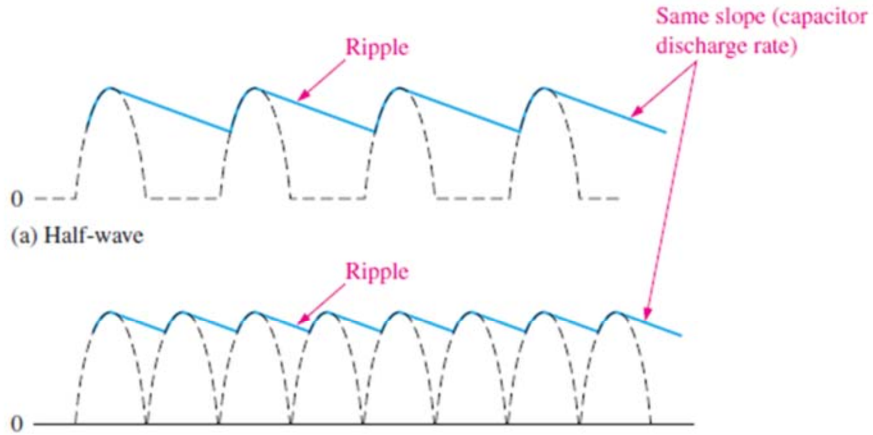


(a) Larger ripple (blue) means less effective filtering.



(b) Smaller ripple means more effective filtering. Generally, the larger the capacitor value, the smaller the ripple for the same input and load.

- a full-wave rectifier is twice that of a half-wave rectifier, easier to filter because of the shorter time between peaks.



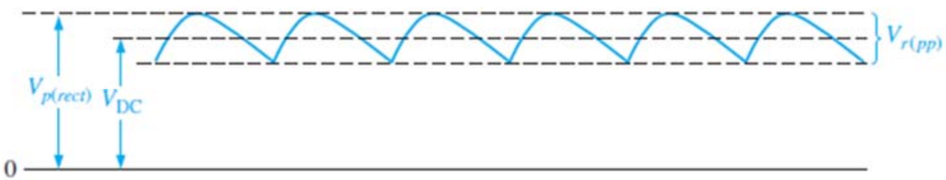
(a) Half-wave

(b) Full-wave

- ***Ripple Factor*** The **ripple factor (*r*)** is an indication of the effectiveness of the filter and is defined as

$$r = \frac{V_{r(pp)}}{V_{DC}}$$

- where $V_r(pp)$ is the peak-to-peak ripple voltage and V_{DC} is the dc (average) value of the filter's output voltage,



- For a full-wave rectifier with a capacitor-input filter

$$V_{r(pp)} \cong \left(\frac{1}{fR_LC}\right)V_{p(rect)}$$

$$vdc = vp - \frac{vr}{2}$$

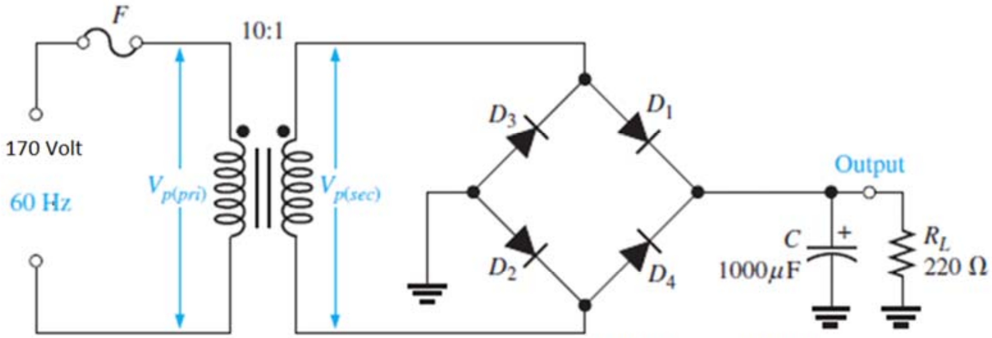
$$vdc = vp - \frac{vp}{2Rfc}$$

$$vdc = vp(1 - \frac{1}{2rfc})$$

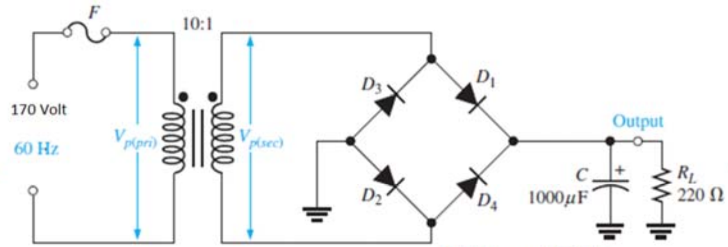
$$V_{DC} \cong \left(1 - \frac{1}{2fR_LC}\right)V_{p(rect)}$$

Example 05

- Determine the ripple factor for the filtered bridge rectifier with a load as indicated in Figure



All diodes are 1N4001.



All diodes are 1N4001.

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$$V_{p(sec)} = nV_{p(pri)} = 0.1(170\text{ V}) = 17.0\text{ V}$$

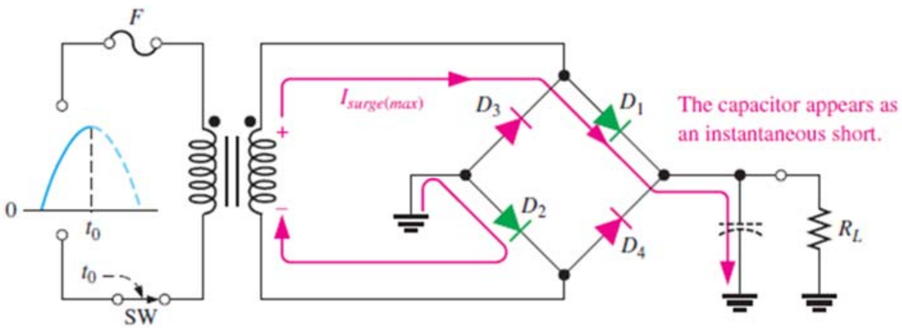
$$V_{p(rect)} = V_{p(sec)} - 1.4\text{ V} = 17.0\text{ V} - 1.4\text{ V} = 15.6\text{ V}$$

$$V_{r(pp)} \cong \left(\frac{1}{fR_LC}\right)V_{p(rect)} = \left(\frac{1}{(120\text{ Hz})(220\ \Omega)(1000\ \mu\text{F})}\right)15.6\text{ V} = 0.591\text{ V}$$

$$V_{DC} = \left(1 - \frac{1}{2fR_LC}\right)V_{p(rect)} = \left(1 - \frac{1}{(240\text{ Hz})(220\ \Omega)(1000\ \mu\text{F})}\right)15.6\text{ V} = 15.3\text{ V}$$

$$r = \frac{V_{r(pp)}}{V_{DC}} = \frac{0.591\text{ V}}{15.3\text{ V}} = \mathbf{0.039}$$

- ***Surge Current in the Capacitor-Input Filter***
- At the instant the switch is closed, voltage is connected to the bridge and the uncharged capacitor appears as a short
- This produces an initial surge of current, *Isurge*,



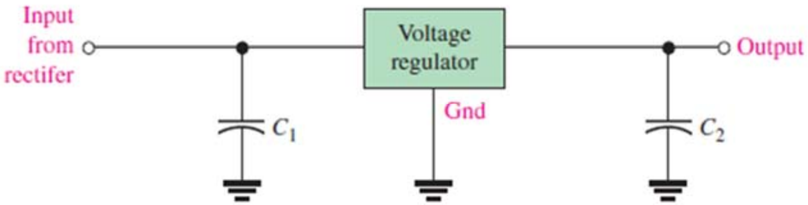
- The worst-case situation occurs when the switch is closed at a peak of the secondary voltage and a maximum surge current, *Isurge*(*max*),
- A fuse is generally used because of the surge current that initially occurs when power is first turned on.
- The fuse rating is determined by power calculation.
- in an ideal transformer *Pin* = *Pout*

$$I_{pri} = \frac{P_{in}}{220\text{V}}$$

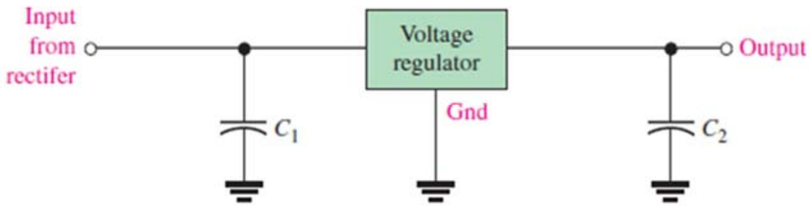
- The fuse rating should be at least 20% larger than the calculated value of *Ipri.*

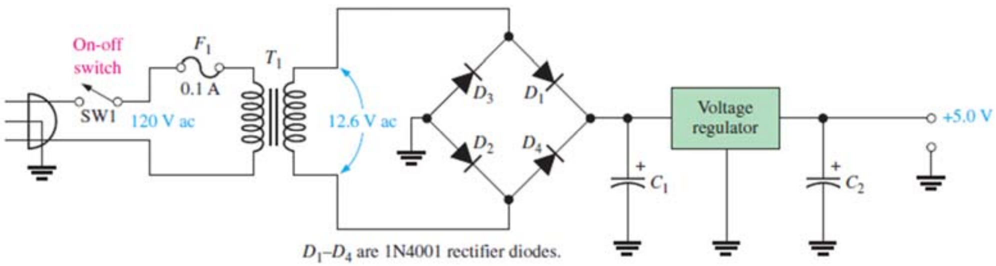
Voltage Regulators

- Three-terminal regulators designed for fixed output voltages require only external capacitors to complete the regulation portion of the power supply



- Filtering is accomplished by a large-value capacitor between the input voltage and ground.
- An output capacitor 0.1 uf to 1uf (typically) is connected from the output to ground to improve the transient response.





- **Percent Regulation**
- The regulation expressed as a percentage, It can be in terms of
  - input (line) regulation or
  - load regulation.
- ***Line Regulation:*** a ratio of a change in output voltage for a corresponding change in the input voltage expressed as a percentage

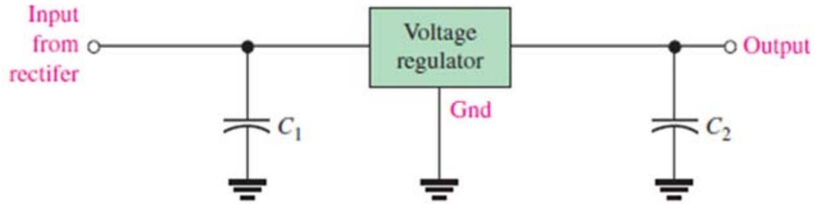
$$\text{Line regulation} = \left(\frac{\Delta V_{OUT}}{\Delta V_{IN}}\right)100\%$$

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

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

Example 06

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

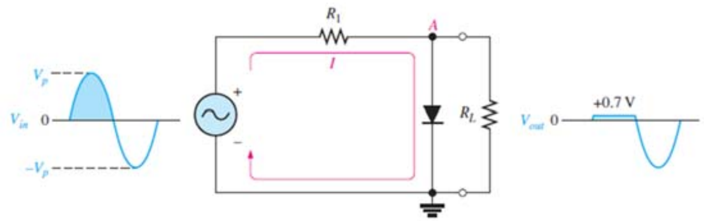


- A certain 7805 regulator has a measured no-load output voltage of 5.18 V and a fullload output of 5.15 V. What is the load regulation expressed as a percentage

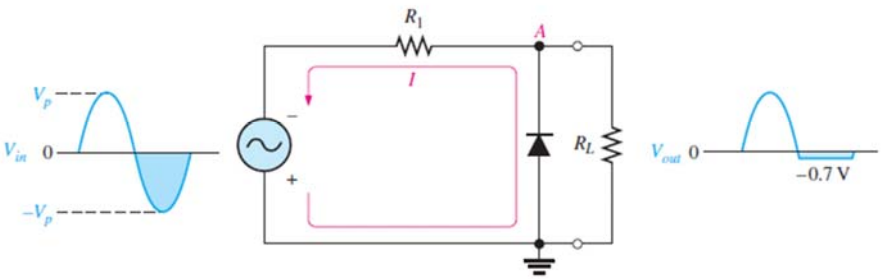
$$\text{Load regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}}\right)100\% = \left(\frac{5.18\text{ V} - 5.15\text{ V}}{5.15\text{ V}}\right)100\% = \mathbf{0.58\%}$$

Diode limiters

- Figure shows a diode positive **limiter** (also called **clipper**) that limits or clips the positive part of the input voltage.
- As the input voltage goes positive, the diode becomes forward biased and conducts current.
- Point *A* is limited to +0.7 V when the input voltage exceeds this value



- When the input voltage goes back below 0.7 V, the diode is reverse-biased and appears as an open.

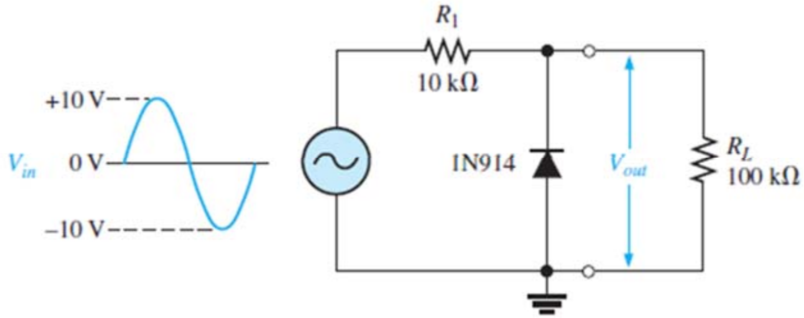


$$V_{out} = \left(\frac{R_L}{R_1 + R_L}\right)V_{in}$$

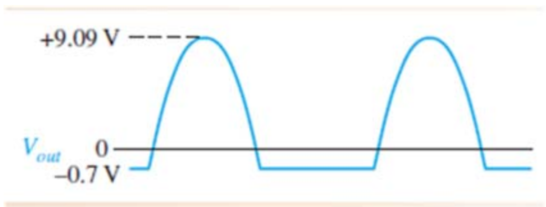
- If R1 is small compared to R1, then Vout=Vin

Example

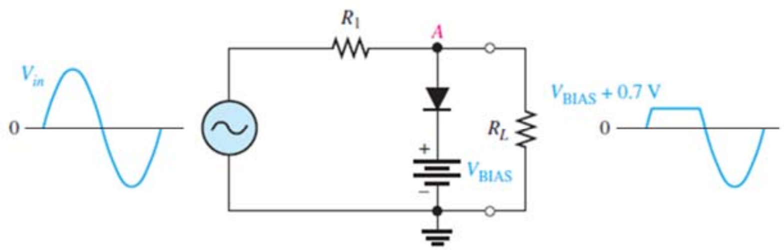
- What would you expect to see displayed on an oscilloscope connected across *RL* in the limiter shown in Figure

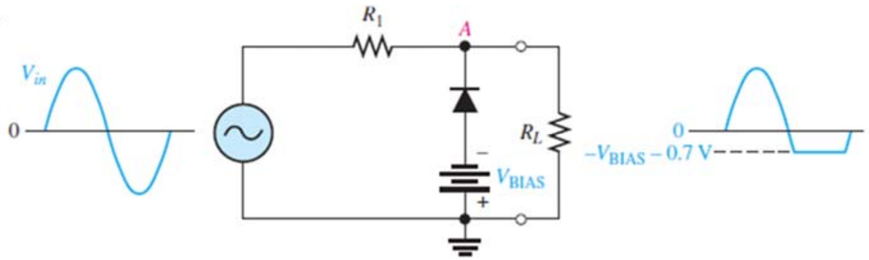


$$V_{p(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{p(in)} = \left(\frac{100\text{ k}\Omega}{110\text{ k}\Omega}\right)10\text{ V} = 9.09\text{ V}$$

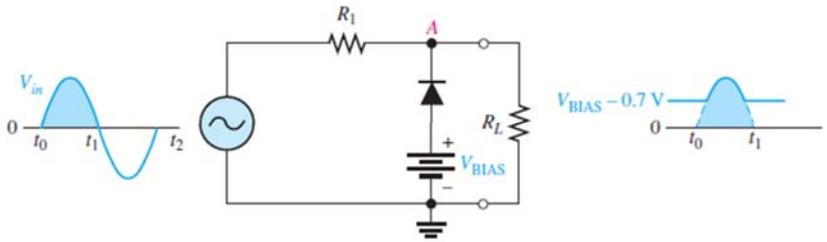


- ***Biased Limiters***
- The voltage at point *A* must equal *V*BIAS + 0.7 V before the diode will become forward-biased and conduct.

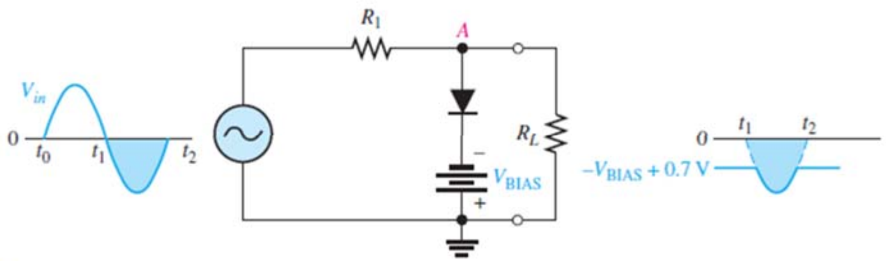




- the positive limiter can be modified to limit the output voltage to the portion of the input voltage waveform above

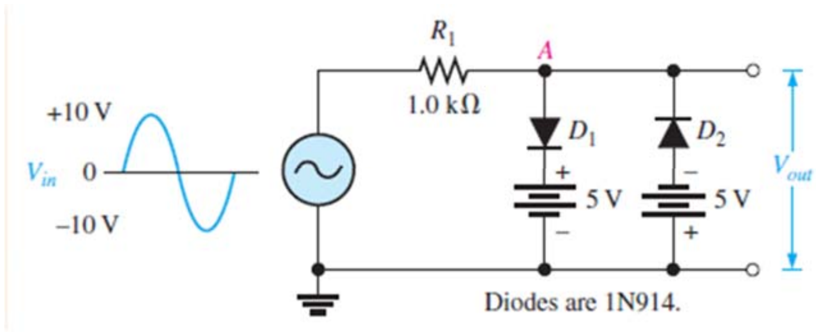


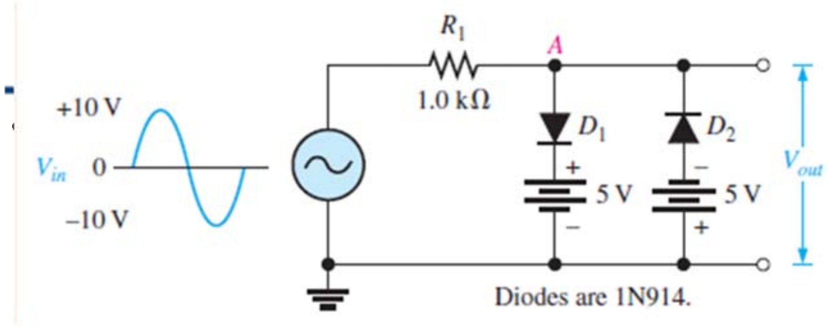
- the negative limiter can be modified to limit the output voltage to the portion of the input voltage waveform

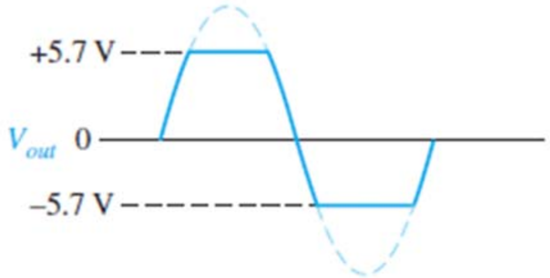


Example

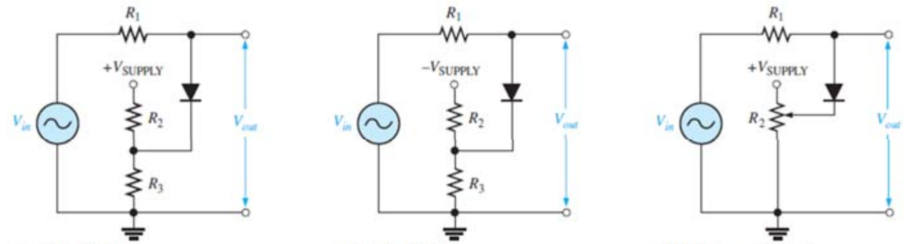
- shows a circuit combining a positive limiter with a negative limiter. Determine the output voltage waveform







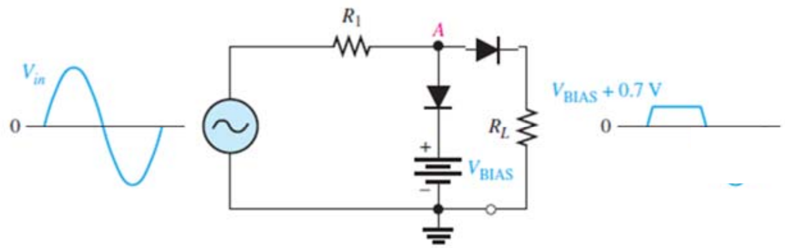
- ***Voltage-Divider Bias***



(a) Positive limiter (b) Negative limiter (c) Variable positive limiter

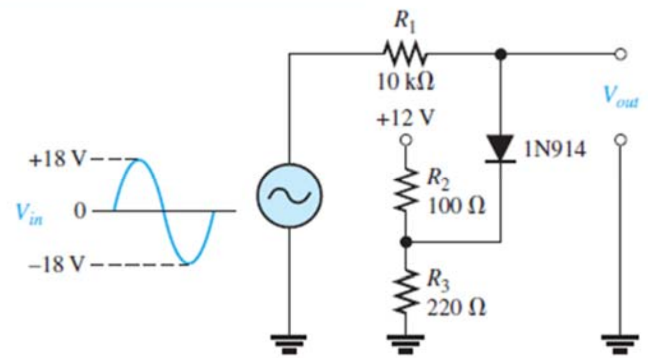
$$V_{BIAS} = \left(\frac{R_3}{R_2 + R_3}\right)V_{SUPPLY}$$

- ***A Limiter Application***
- almost all digital circuits should not have an input level that exceeds the power supply voltage. An input of a few volts more than this could damage the circuit.
- To prevent the input from exceeding a specific level, you may see a diode limiter across the input signal path in many digital circuits.

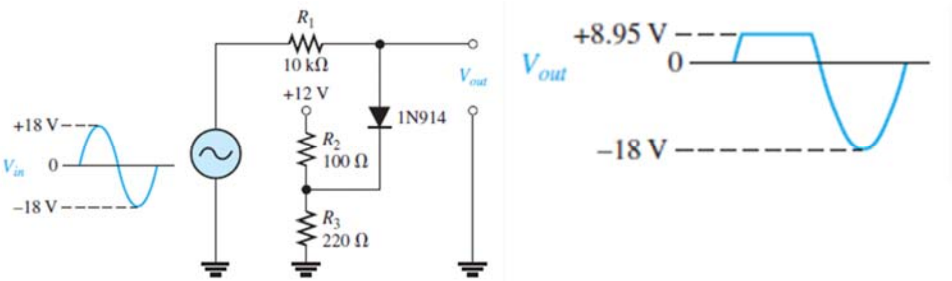


Example

- Describe the output voltage waveform for the diode limiter in Figure

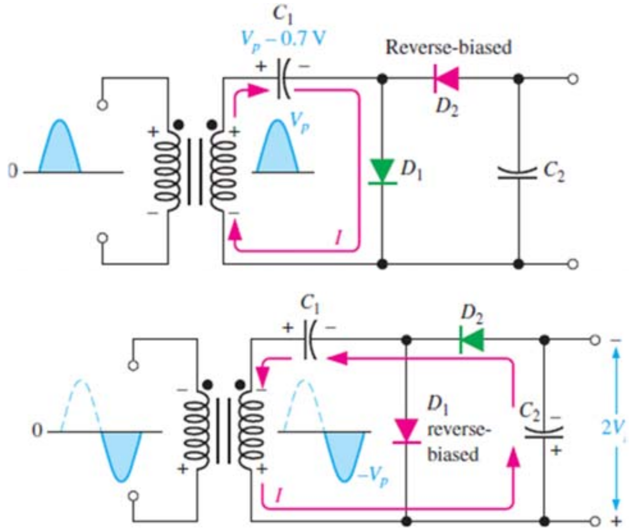


$$V_{BIAS} = \left(\frac{R_3}{R_2 + R_3}\right)V_{SUPPLY} = \left(\frac{220\ \Omega}{100\ \Omega + 220\ \Omega}\right)12\ V = 8.25\ V$$

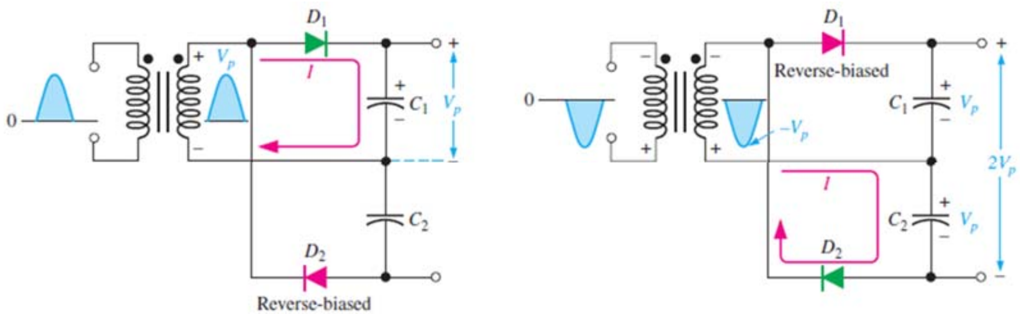


Voltage multiplier

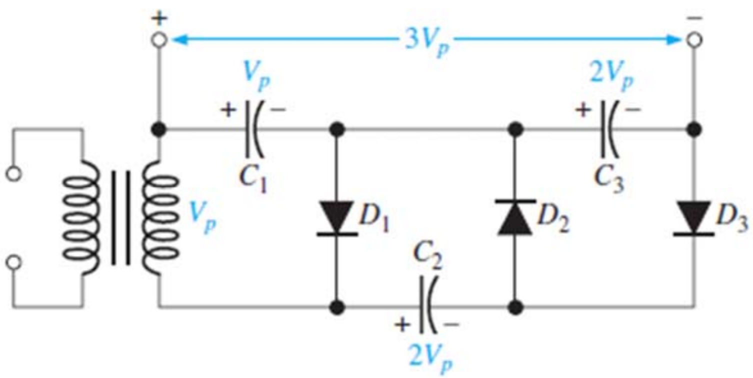
- Half-wave voltage doubler



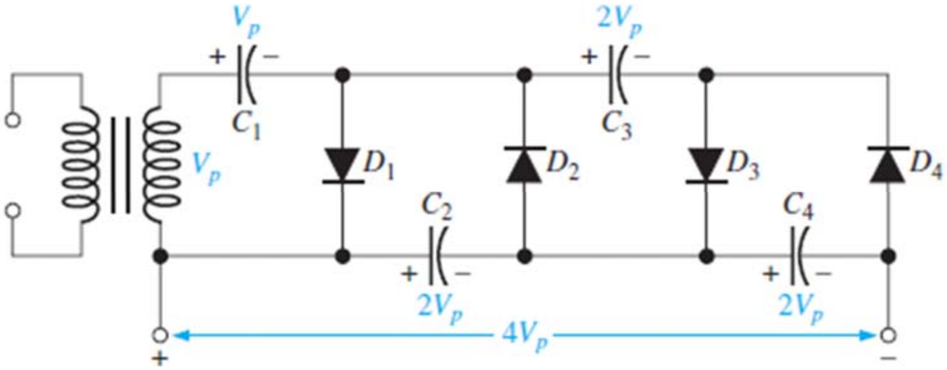
- ***Full-Wave Voltage Doubler***



- **Voltage Tripler**



- **Voltage Quadrupler**



Thanks,..

See you next week (ISA),…