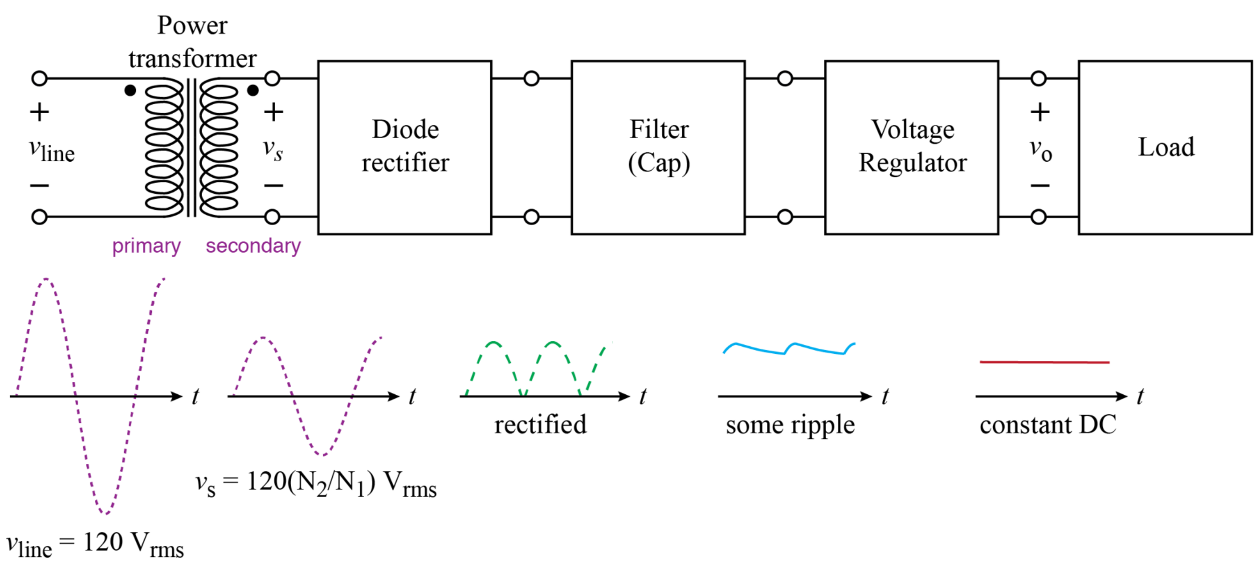
TOOL: Diodes may be used to turn an AC voltage waveform into a rectified wavefrom that may then be smoothed to produce a DC voltage waveform with a small amount of ripple. Creation of a power supply in presented here in stages of increasing complexity.

POWER SUPPLY BLOCK DIAGRAM:



The diode rectifier may take various forms, as shown below. The rectifier produces a voltage of only one polarity.

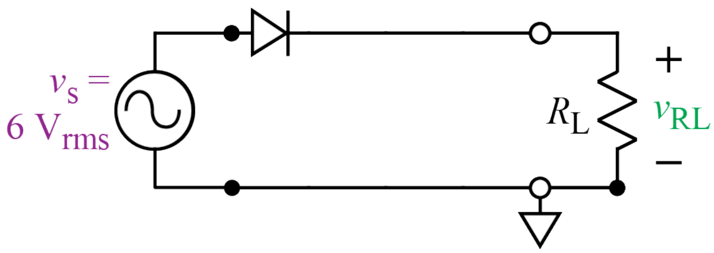
The filter is a large electrolytic capacitor. Its job is to store charge and act like a power source when the rectified signal starts to drop. The capacitor gets charged up again the next time the rectified signal rises.

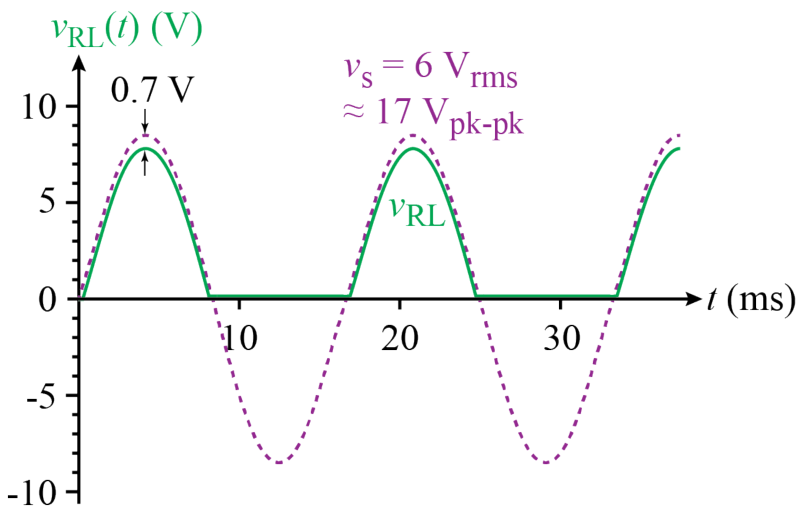
The voltage regulator is typically based on a Zener diode that can produce a nearly constant voltage from its reverse breakdown voltage. Inexpensive three-terminal (v_{in}, v_{out}, and $v_{reference}$) regulators are available for a variety of voltages.

To model the load, we use a resistor.

HALF-WAVE RECTIFIER

Using one diode lets positive half-cycles through to load resistor R_L but blocks negative half-cycles. The positive half-cycles after the diode are one diode voltage-drop below the input voltage waveform. Thus, the voltage at the load, v_{RL}, is now always positive although a bit bumpy and starts rising after v_s exceeds the 0.7 V turn-on voltage of the diode. The next step is to smooth out the bumps.

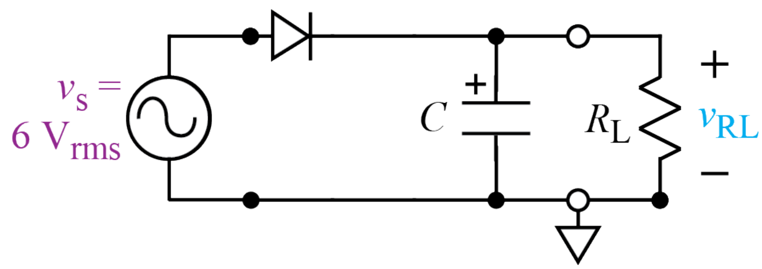


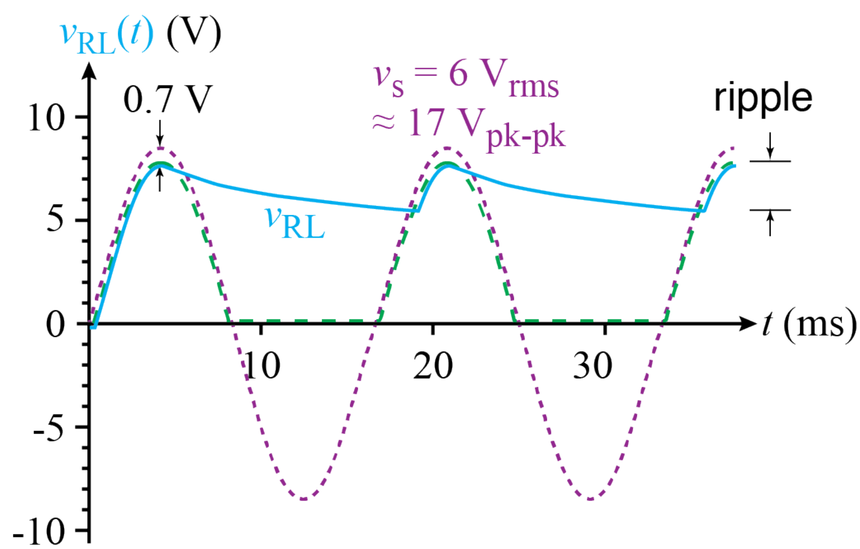


Rectification is the process of making DC from AC. Usually, the AC is derived from the AC wall outlet (often through a transformer) and the DC is needed for electronic circuitry, modeled by R_L here.

FILTER:

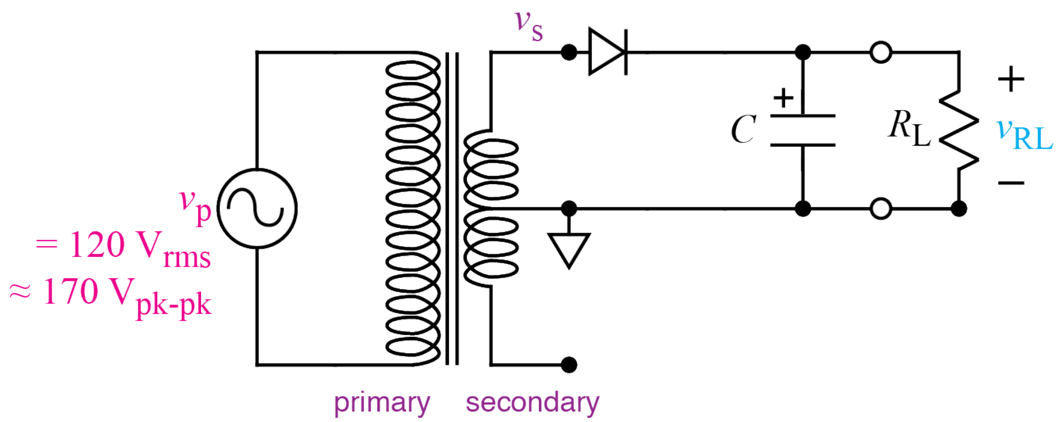
A "filter" capacitor (usually a big electrolytic) helps smooth out the bumps, although we could use a bigger one here to get less droop between the peaks. The capacitor charges up whenever v_s on the left side of the diode is 0.7 V, or more, higher than the capacitor voltage. When the diode turns off, the capacitor starts to discharge through R_L. The bumpiness in v_{RL} is called "ripple".

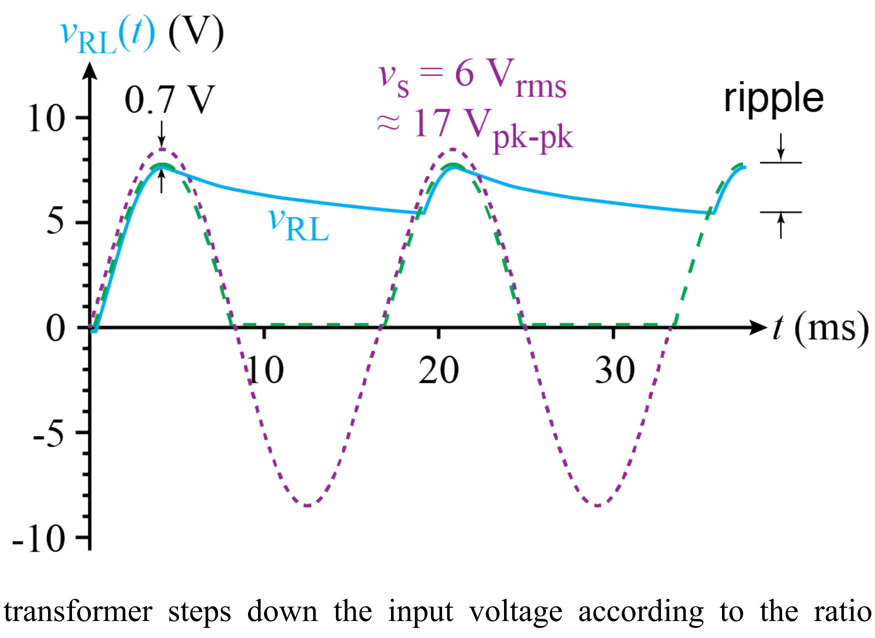




HALF-WAVE RECTIFIER:

Now we have added a transformer. We are using only one-half of a center-tapped transformer. We could double the input voltage by using the voltage drop across the outside taps and leaving the center tap of the secondary disconnected, (see bridge rectifier below).

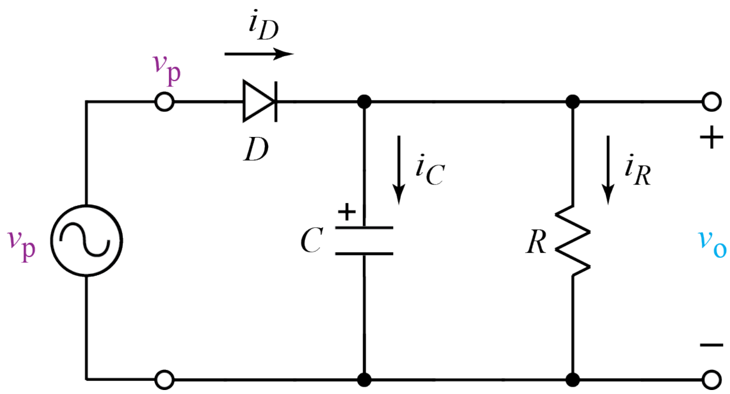




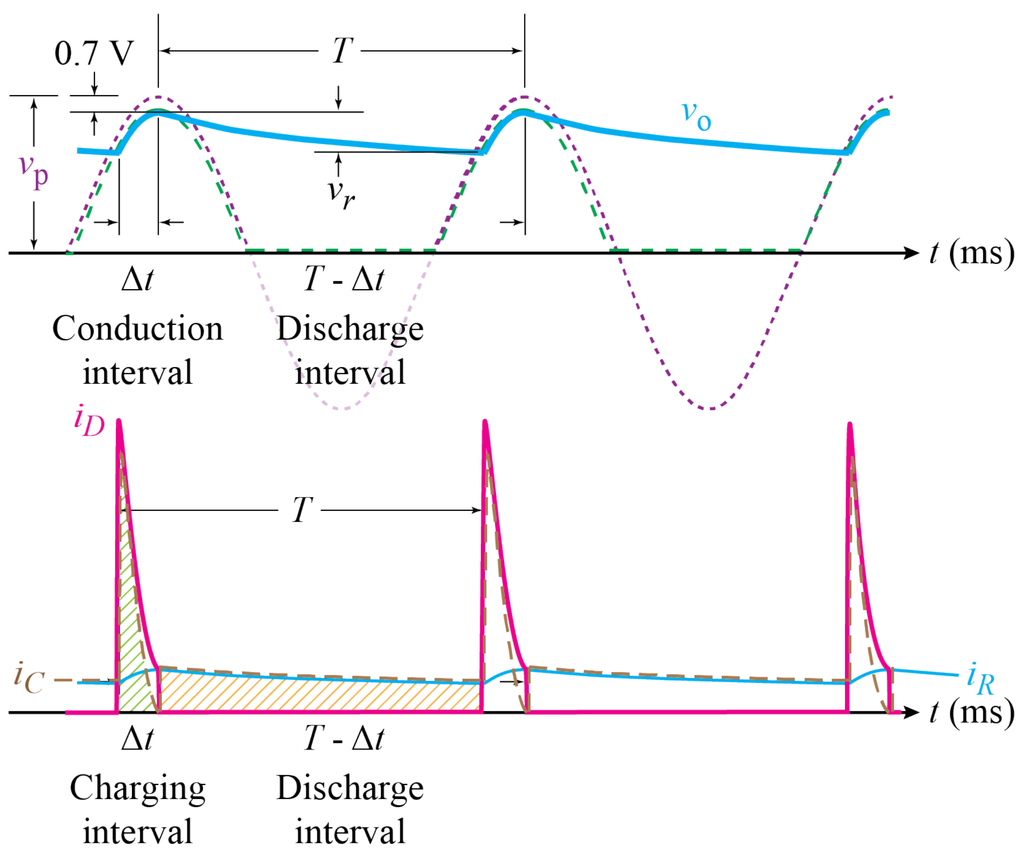
The transformer steps down the input voltage according to the ratio of the number of turns of the primary to secondary windings around a core that channels the magnetic field coupling the primary and secondary coils. Each turn has the same voltage drop on both sides of the transformer.

PEAK RECTIFIER:

The size of the capacitor and the amount of current drawn by the load determines how much the capacitor voltage droops in between the peaks when it charges again.



Voltage (top) and current (bottom) waveforms are shown below.

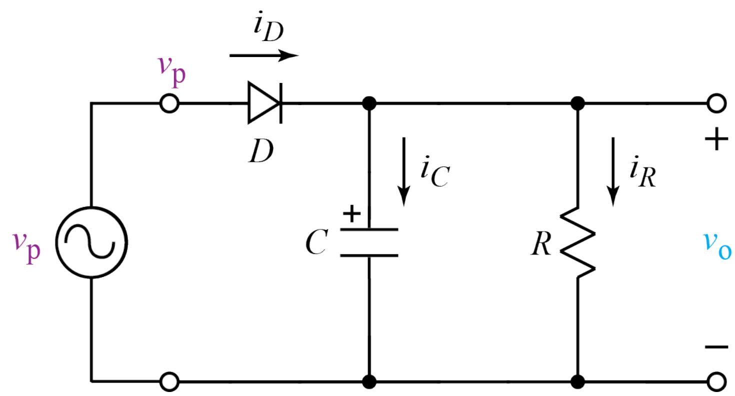


Calculation of the droop in capacitor voltage each cycle depends on three basic equations:

$i_C(t) = C\dfrac{dv_C(t)}{dt}$ governs diode current when C is charging from v_p

$i_C(t) = [i_C(0^+) - i_C(t \to \infty)]e^{-t/RC} + i_C(t \to \infty)$ gives droop waveform

$Q(t) = C \cdot v_C(t) = \displaystyle\int i_C(t)dt$ governs capacitor voltage if load not resistive



Exact calculation of the droop waveform is complicated by the following factors:

1) The exact diode voltage drop is unknown, although it may be approximated with reasonable accuracy (0.1 V error would be typical).

2) The current flow out of the diode as the voltage falls from the peak is nonlinear, although assuming the diode turns off immediately after the peak introduces only a very small error.

3) The load current may be a nonlinear function of the droop voltage. However, a maximum and minimum load current may be used in the design, leading to two cases to be considered. In this case, the droop is modeled as an exponential RC decay.

4) The exact point where the drooping curve meets the next rising input voltage waveform (minus a diode drop) would involve solving for the where an exponential RC decay curve intersects with a sinusoid. An iterative approach to solving this equation would probably be needed.

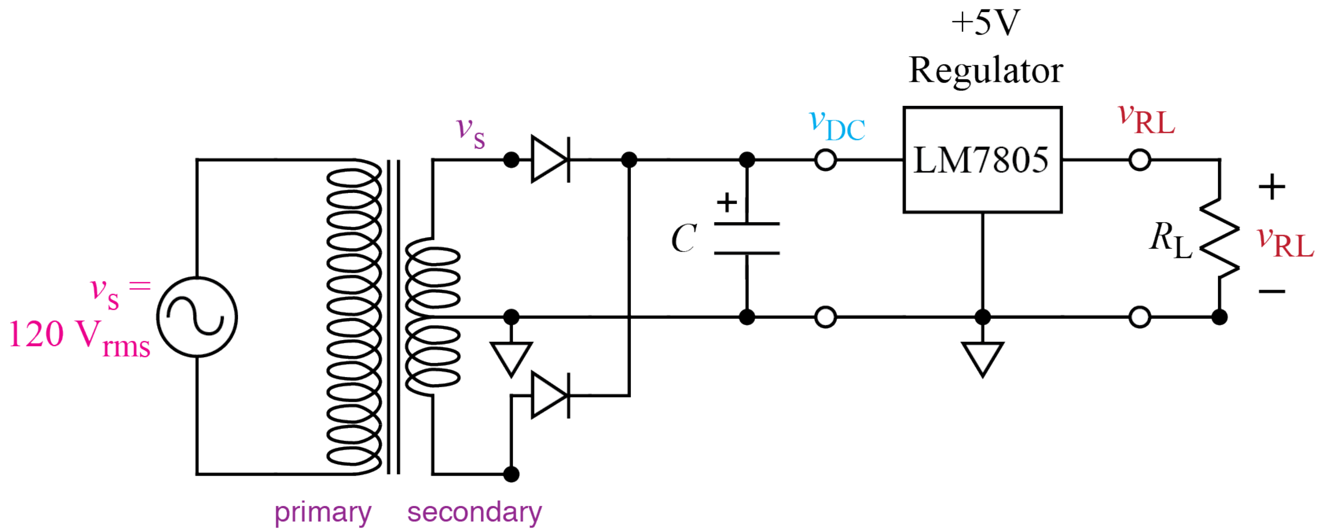
However, assuming a linear droop lasting from one peak to the next is accurate enough if a large capacitor is used.

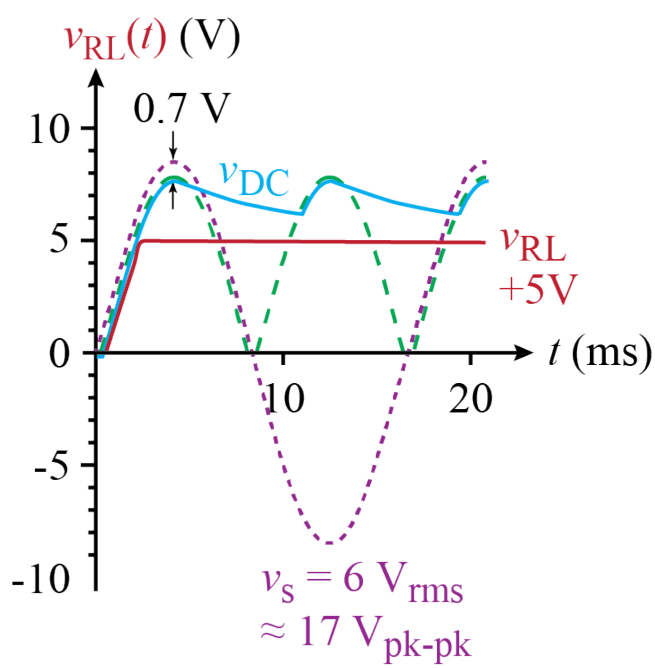
5) Even if Item (4) is solved exactly as stated, the diode turn-on is actually nonlinear too.

Fortunately, as alluded to in the above items, a simple approximation to the calculation of the drop is to assume a constant current drawn by the load, which gives a linear droop, and to assume the droop lasts from one peak to the next. That and a large capacitor will usually suffice.

FULL-WAVE RECTIFIER:

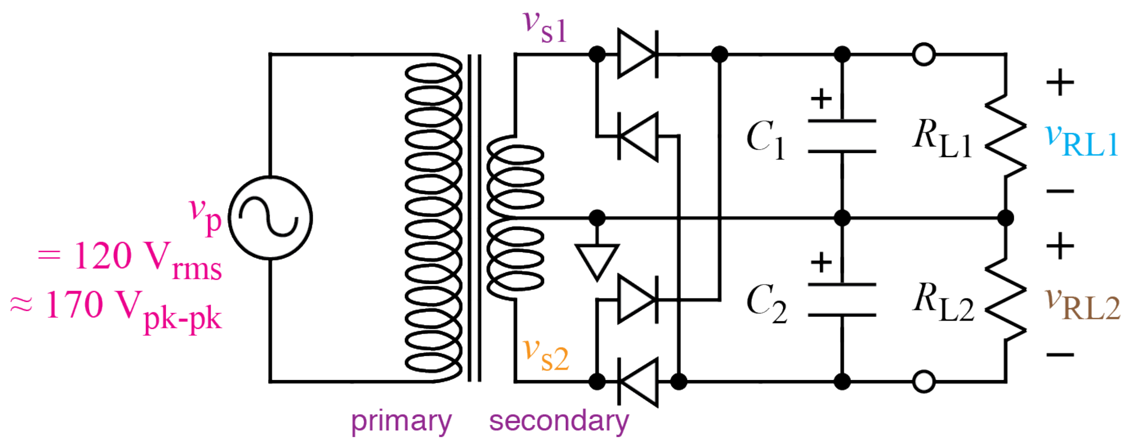
The center tap in the secondary of this transformer makes it easy to get full-wave rectification.

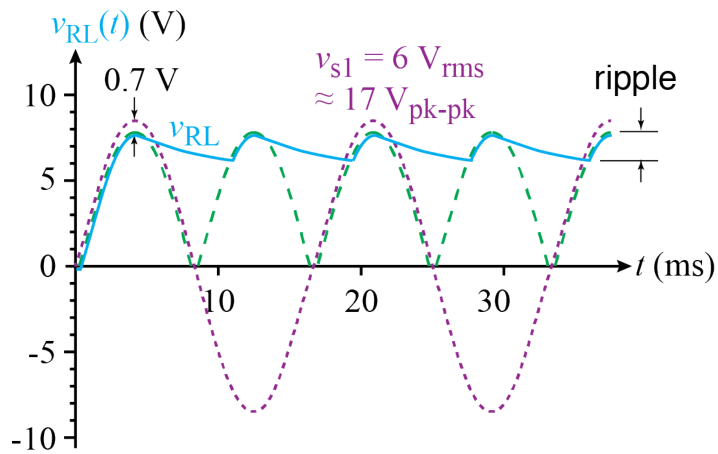


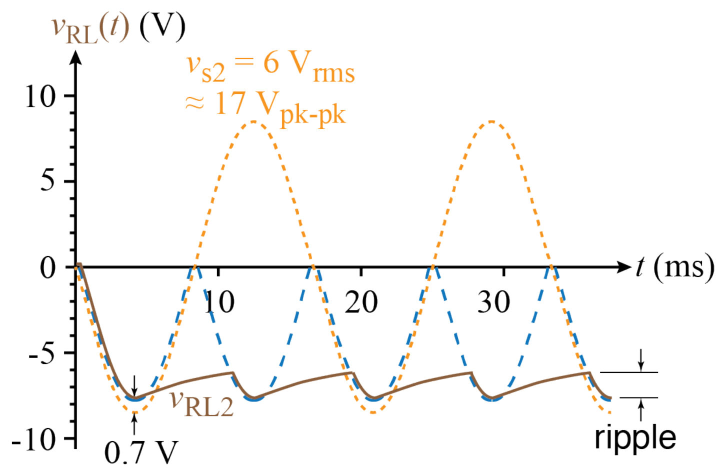


PLUS AND MINUS SUPPLY:

The center tap is also good for making + and - output voltage supplies.

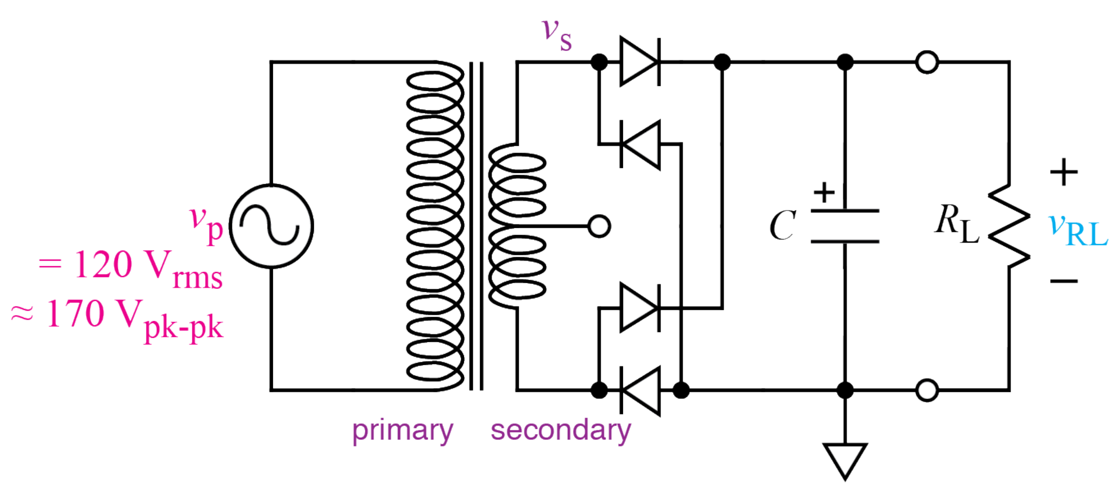


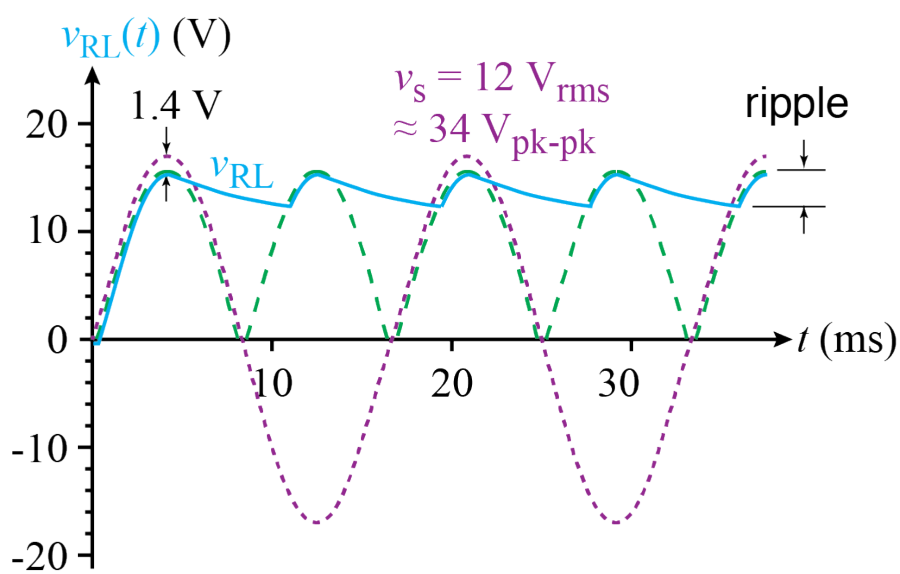




BRIDGE RECTIFIER:

A "bridge circuit" or "bridge rectifier" can give you full-wave rectification (twice as many bumps) without a center-tap transformer, but now you get two diode drops instead of one.





REGULATED POWER SUPPLY:

A regulator chip, based on a zener diode circuit surrounded by the rough equivalent of op-amp circuitry, can create a very smooth output voltage waveform. The regulator chip drops some voltage (i.e. wastes some power) in exchange for keeping the output voltage tightly regulated. The regulator chip monitors the output voltage and supplies more current or less current to keep the output voltage constant. In practice, we would also add a capacitor on the output side of the regulator to help stabilize the output voltage even more.