

AC / DC Power supplies

{ ELTN 130
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Power Supplies are electronic systems that convert Alternating Current (AC) into Direct Current (DC). The main two types of power supplies are *linear* and *switching* or “switch-mode.”



Small unregulated DC adapter



Regulated PC Power supply

Alternating Current (AC)

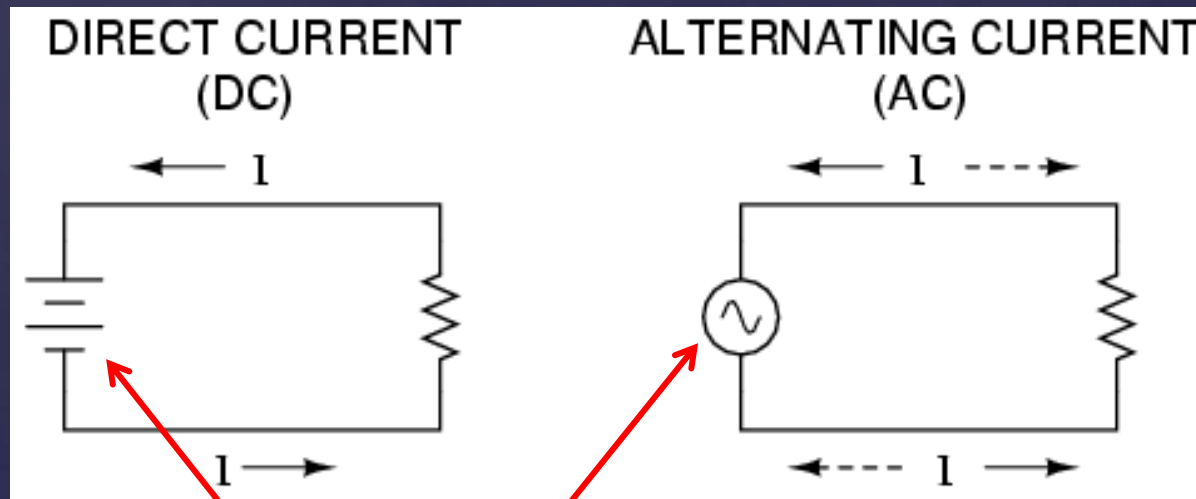
The most commonly available high-voltage source of current is AC.

Most large appliances, motors and industrial systems use this type of voltage.



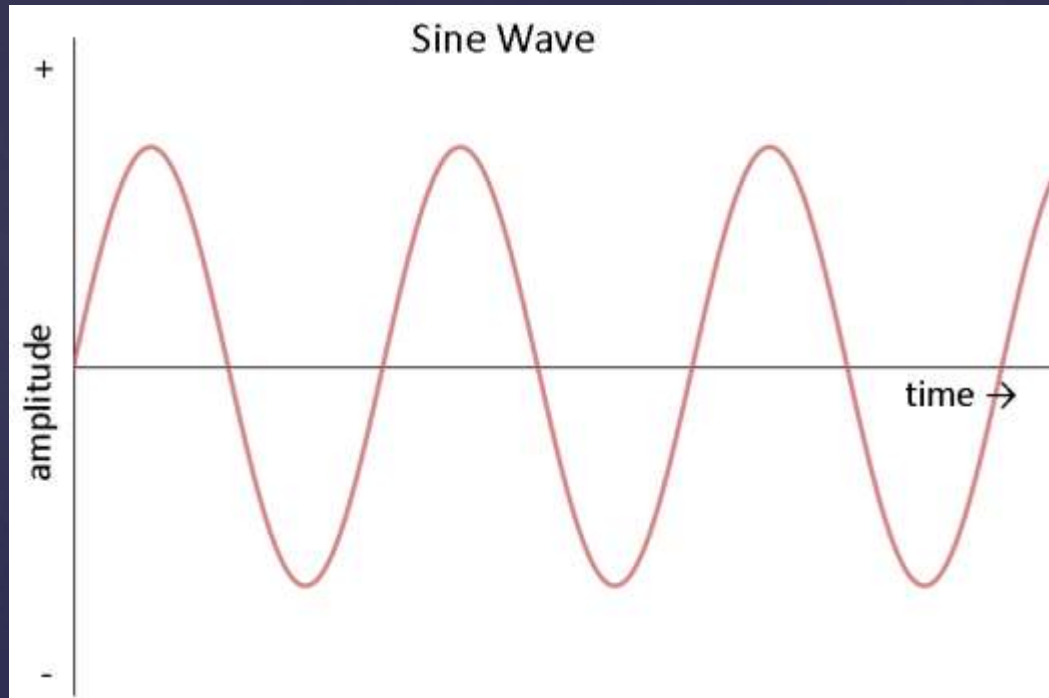
What is the difference between DC and AC?

With DC circuits, the current is always flowing in one direction.
“Alternating” means that the current is changing direction in the circuit over time.

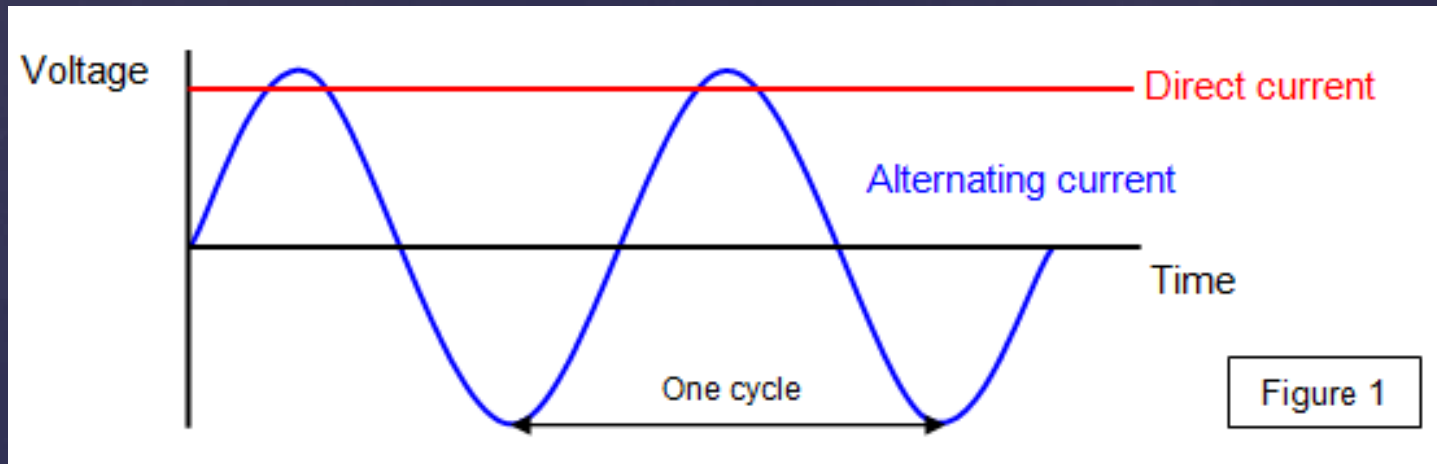


Notice the different symbols!

What does AC “look like”?



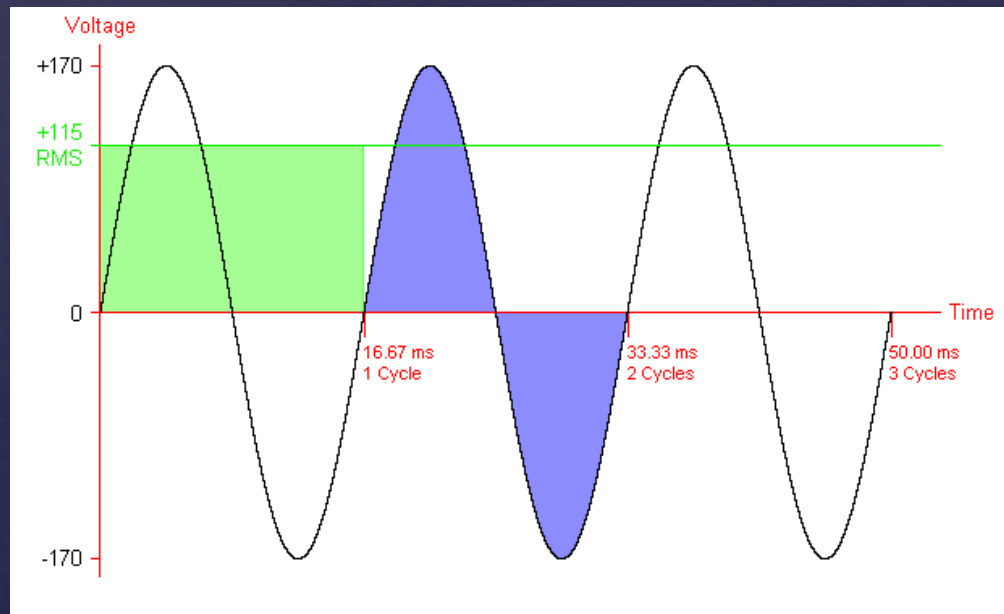
If we plotted both DC and AC over time on the same graph, it would look like this:



A closer look at AC waveforms:

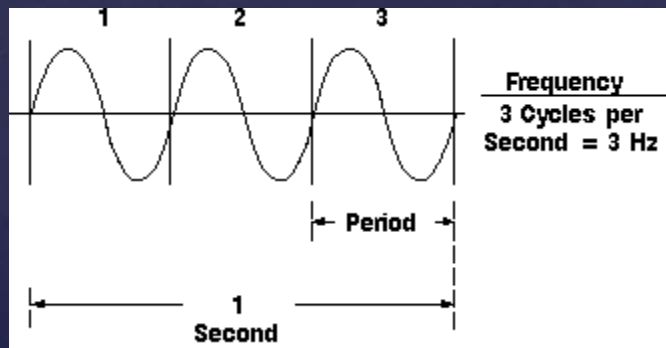
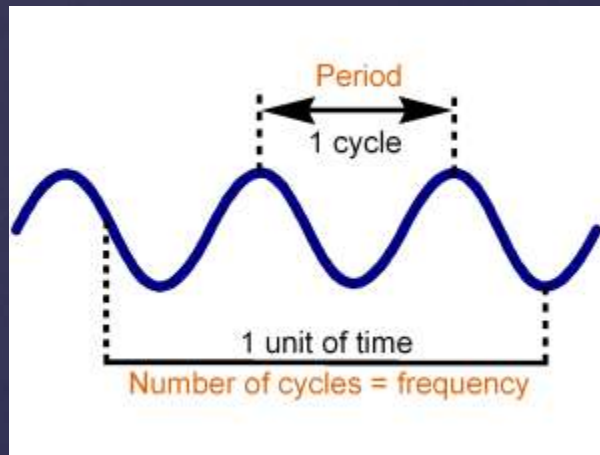
Because the voltage is changing over time, there is a *frequency* associated with the voltage.

In the U.S. the frequency of AC power is 60 Hertz, or 60 cycles / second. This means that every 16.67 milliseconds, the voltage completes one complete cycle or period:



A quick note on Hertz and time:

Time (T) and frequency (f) are *reciprocals*:



● $f = 0.5 \text{ Hz}$
 $T = 2.0 \text{ s}$

● $f = 1.0 \text{ Hz}$
 $T = 1.0 \text{ s}$

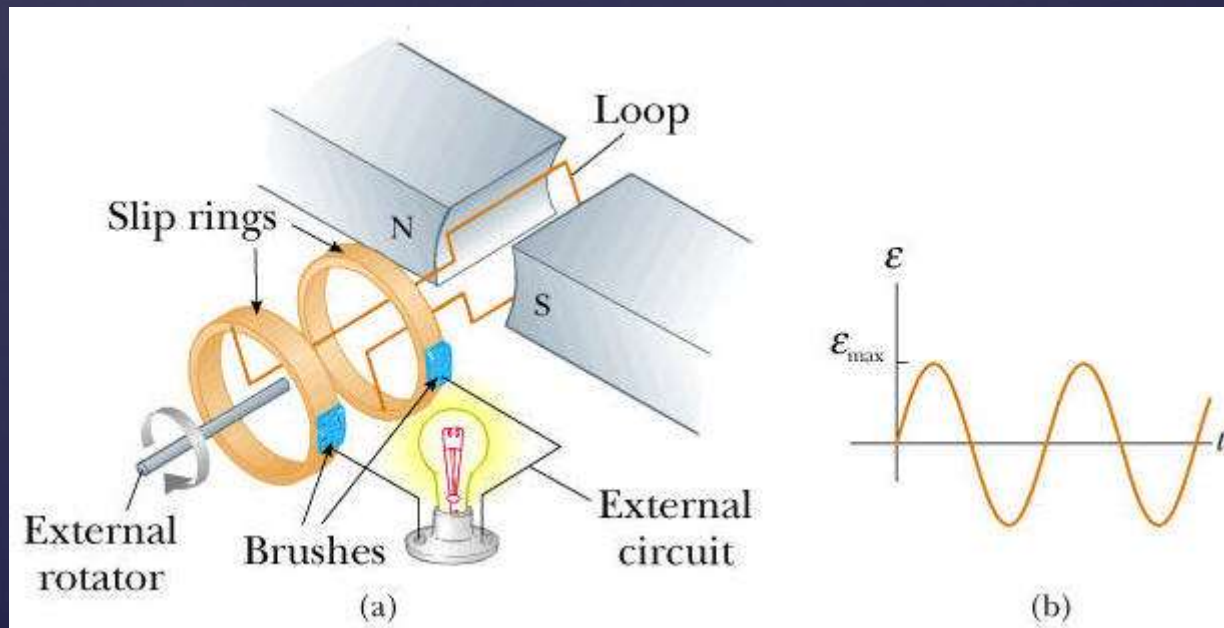
● $f = 2.0 \text{ Hz}$
 $T = 0.5 \text{ s}$

$$f = \frac{1}{T} \quad f = \text{frequency}$$

$$T = \frac{1}{f} \quad T = \text{period}$$

Why does AC change amplitude and direction?

- Most AC electricity is generated by rotating the shaft of an AC generator, similar to a motor in reverse.
- This type of electricity can be transferred over large distances more easily than D.C.
- Also, AC can be easily “stepped” up or down using a transformer.



How do we convert the high voltage AC from an outlet into lower voltage D.C? 4 steps:

1. Convert from a high AC voltage to a lower AC voltage
2. Convert from AC to pulsed DC
3. Filter the pulsed DC
4. Regulate the voltage if necessary

Each one of these steps requires a specific electronic component to do each part...

Step 1: To convert from high AC voltage to low AC voltage we use a *transformer*

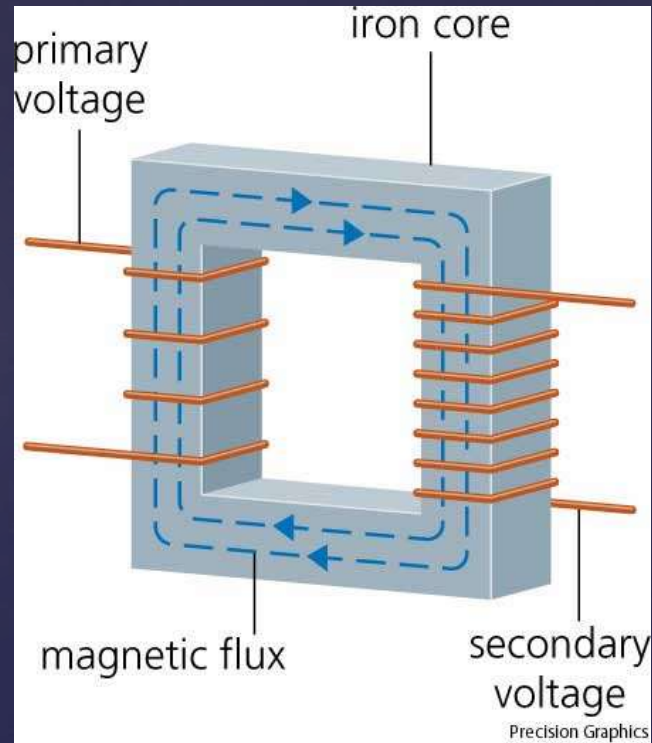


Small



Large

Transformers use induction (conversion of current to a magnetic field and back to current) to reduce the voltage:



Basic concept: The input voltage is connected to the *Primary* side, the output voltage is produced on the *Secondary* side.

Primary winding

N_p turns

Primary current I_p

Primary voltage V_p

$+$
 $-$

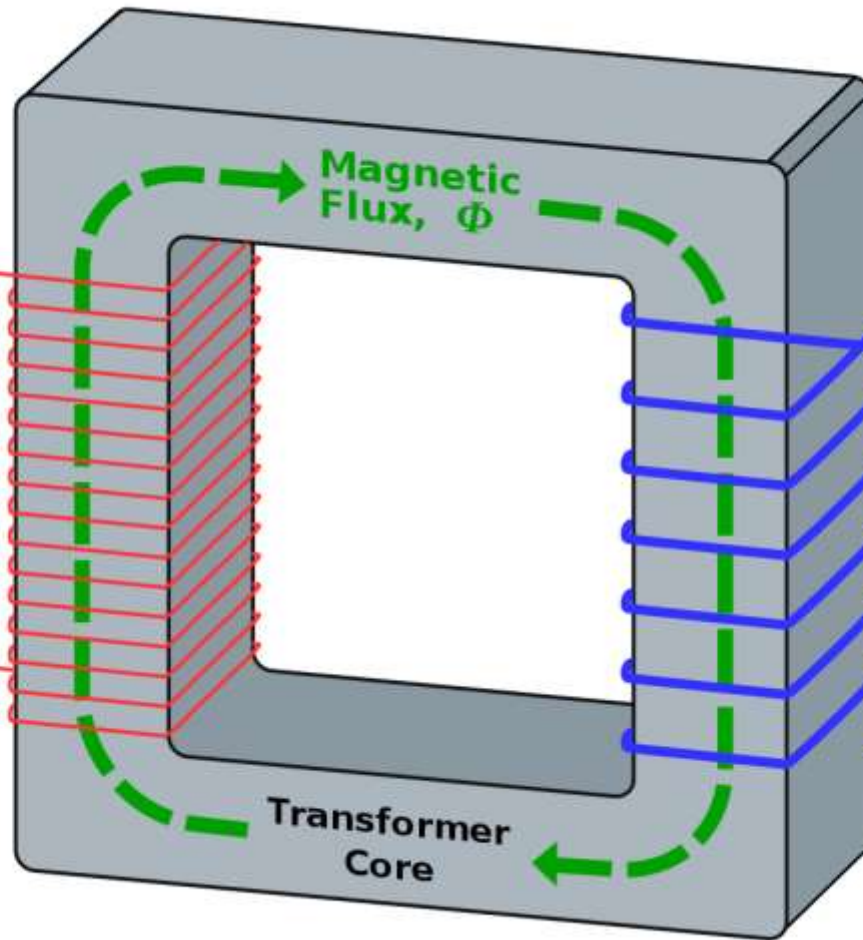
Secondary winding

N_s turns

Secondary current I_s

$+$
Secondary voltage V_s

$-$



Important terms:

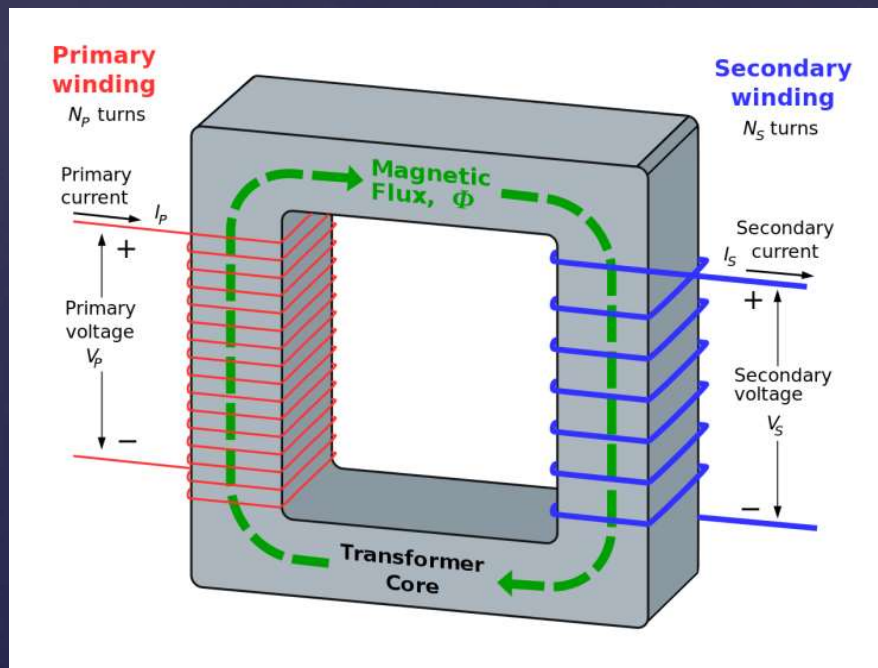
V_P = Primary Voltage (input voltage)

V_S = Secondary Voltage (output voltage)

N = Number of turns

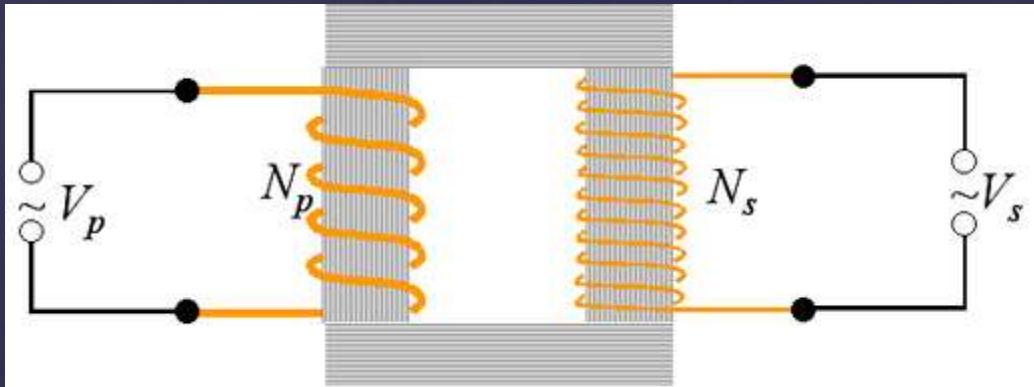
N_P = Number of turns on Primary

N_S = Number of turns on the secondary



The ratio of the input voltage to the output voltage is the ratio of N_p / N_s :

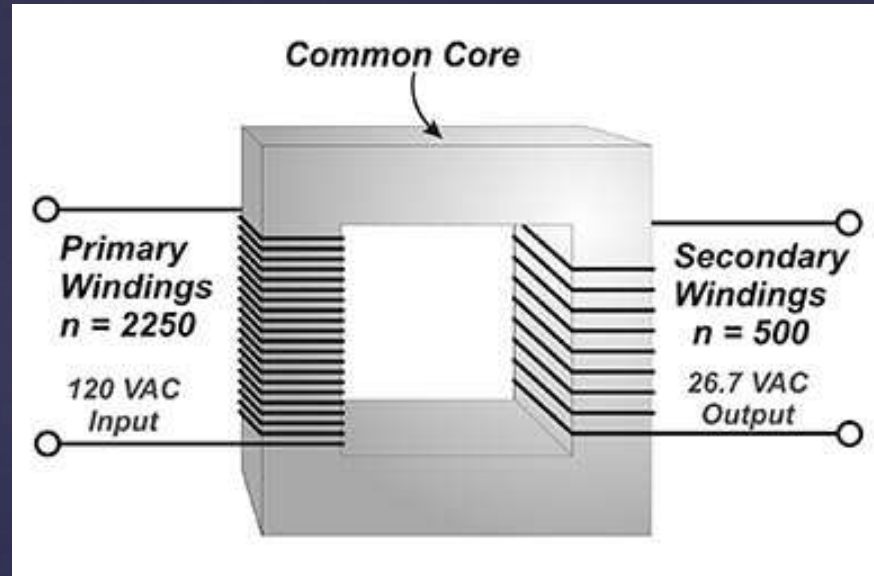
$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$



Transformers explained video:

<https://www.youtube.com/watch?v=XSuP3-Krdik>

Example:

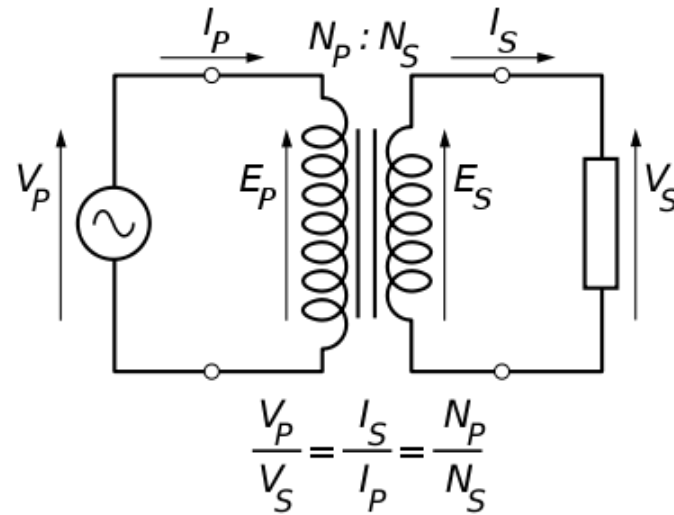
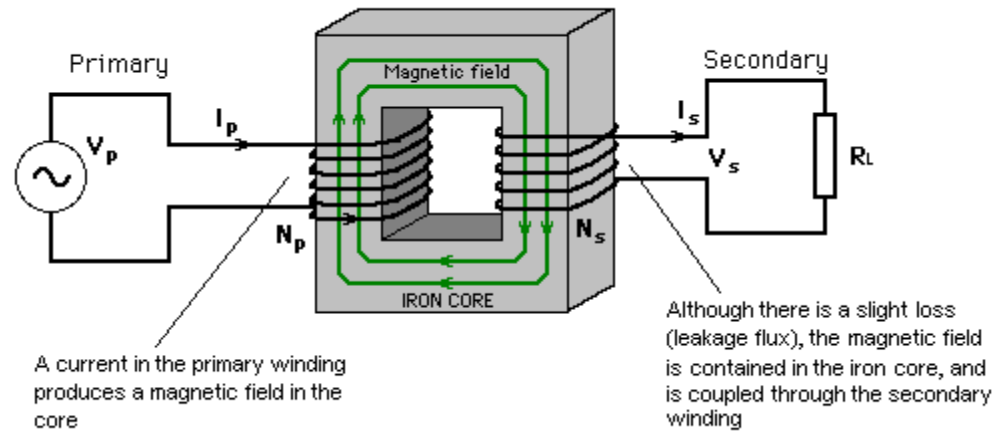


$$\frac{N_P}{N_S} = \frac{2250}{500} = \frac{120}{26.7}$$

The ratio of the input current to the output current is the opposite: N_S / N_P :

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

Why the difference? The power on the input is approximately equal to the power on the output.
 $P = V \times I$, so $V_S \times I_S = V_P \times I_P$

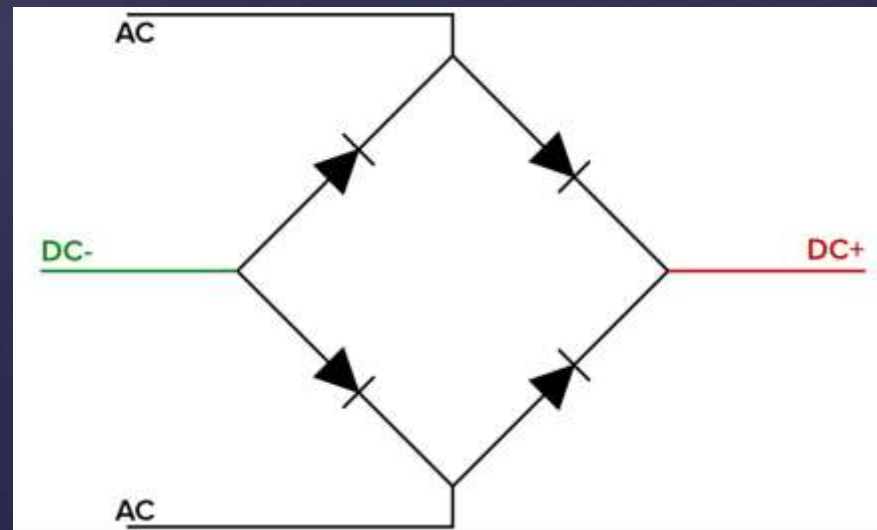


Step 2: Converting AC into DC

The next step is to take the reduced voltage and convert it into D.C.

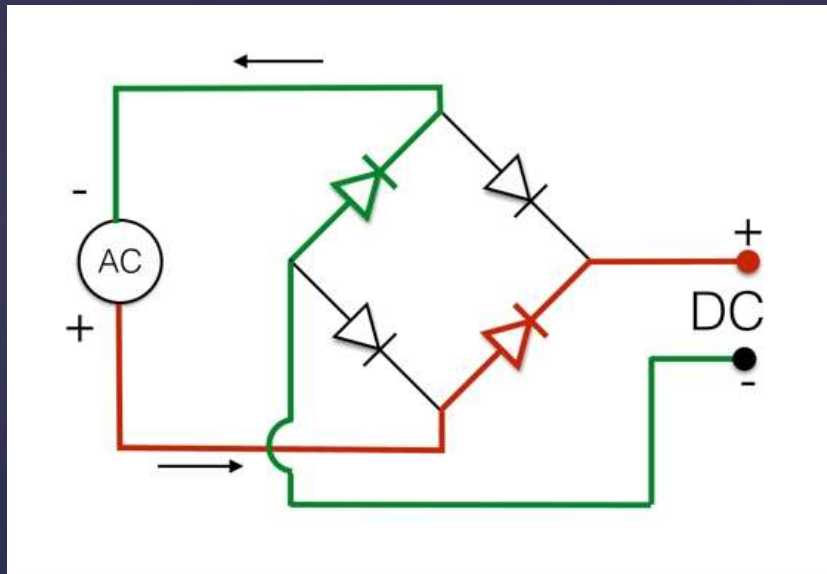
In other words, the current can only move in one direction.

This is done using four diodes in a configuration called a “Bridge Rectifier”



What does this do to the AC waveform?

Remember that current can only flow through a diode when the input voltage (Anode) is larger than the output voltage (Cathode).



Video explanation

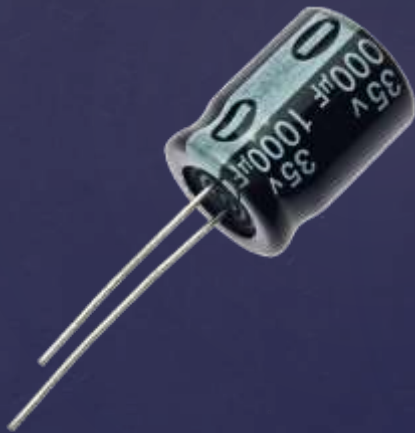
<https://www.youtube.com/watch?v=uw8ILSH-oE>

Animation:

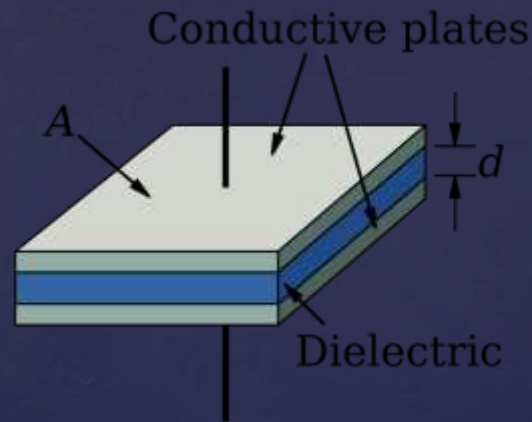
<https://www.youtube.com/watch?v=PKy5ghLiz6I>

Step 3: Filtering Capacitor...

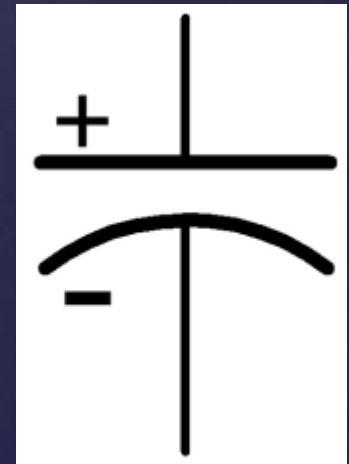
A *capacitor* is an electronic component that can charge up to a value equal to the source voltage and store the charge for a period of time.



Polarized Capacitor

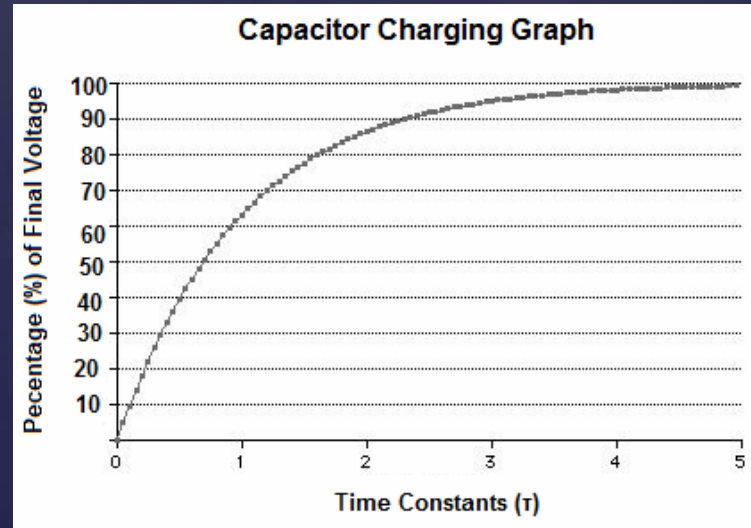
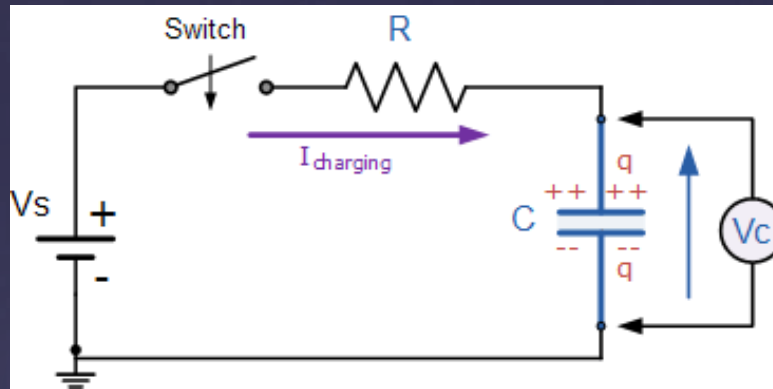


Physical construction



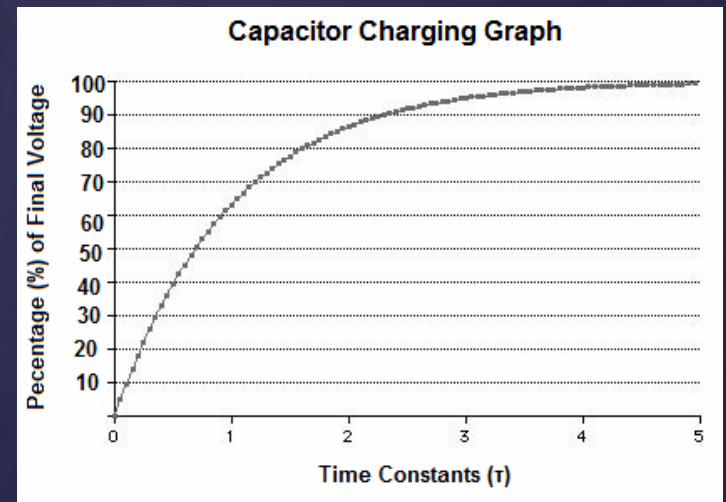
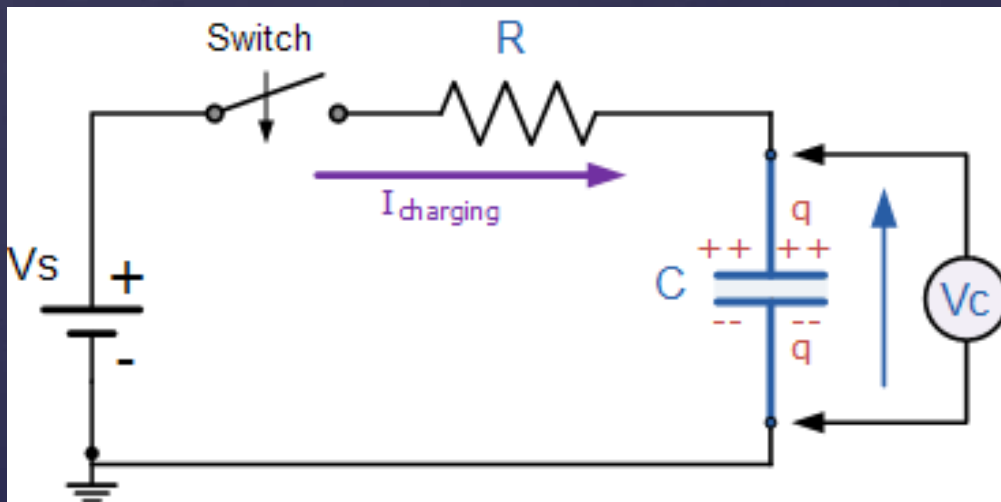
Schematic Symbol

When a voltage is applied across a capacitor it charges exponentially:



The rate that a capacitor charges is called tau (τ), and equals the product of the capacitor value and resistor value:

$$\tau = R \times C$$



The units of tau are seconds.

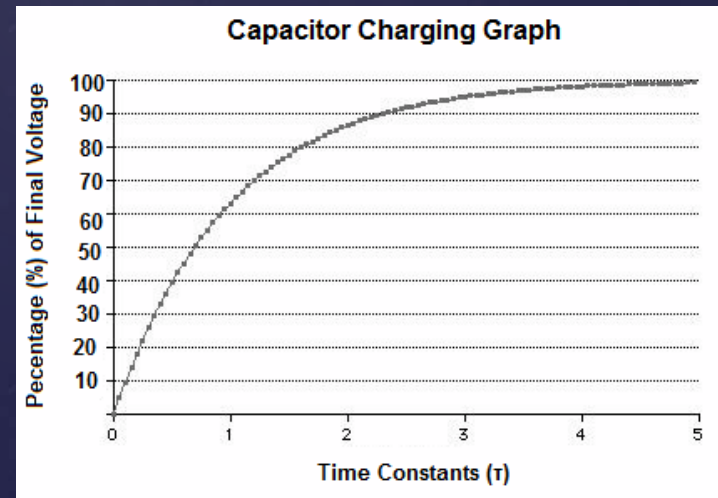
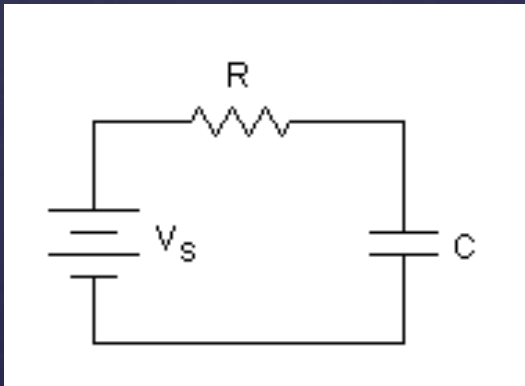
- **However**, for many circuits tau has a value typically in milliseconds.
- A capacitor charges to the source voltage in approximately 5 time constants. For example:

$$\tau = R \times C$$

If $R = 100\Omega$ and $C = 50\mu\text{F}$,

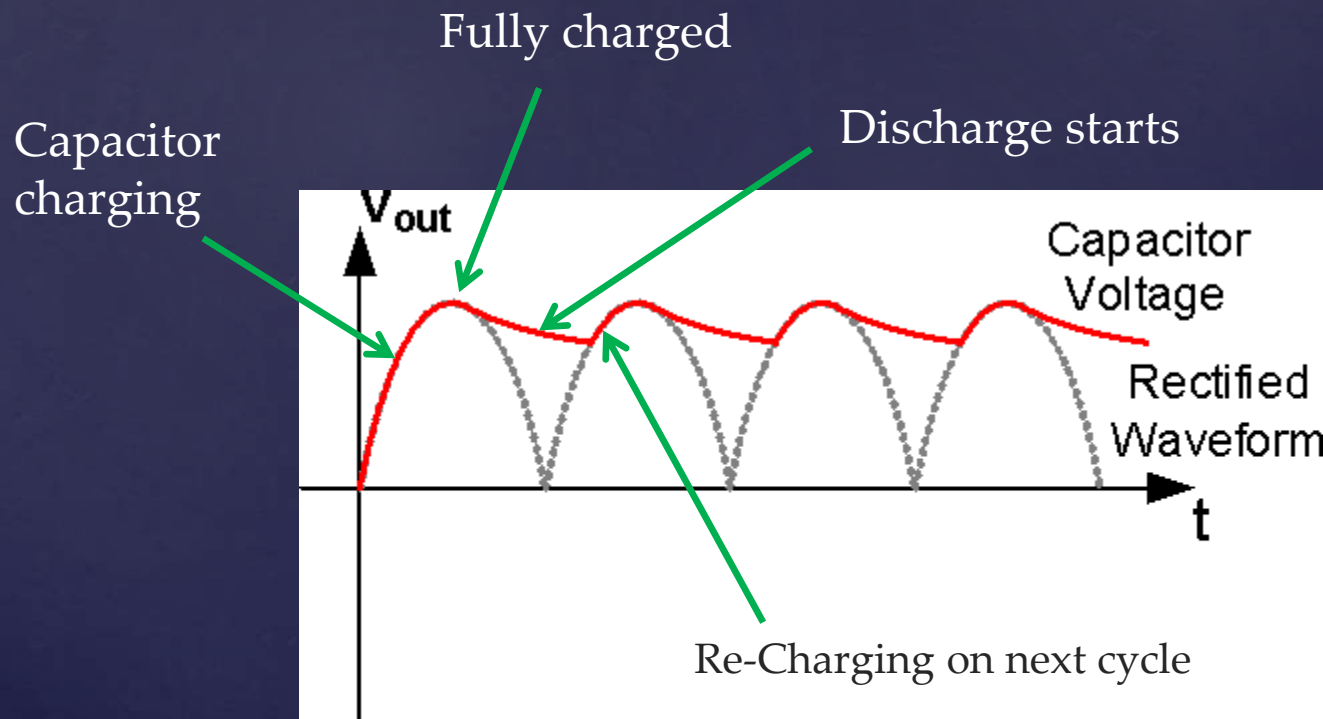
$R \times C = (100\Omega) \times (50 \times 10^{-6} \mu\text{F}) = 1 \text{ millisecond}$

So, in 5 milliseconds, the capacitor is fully charged.

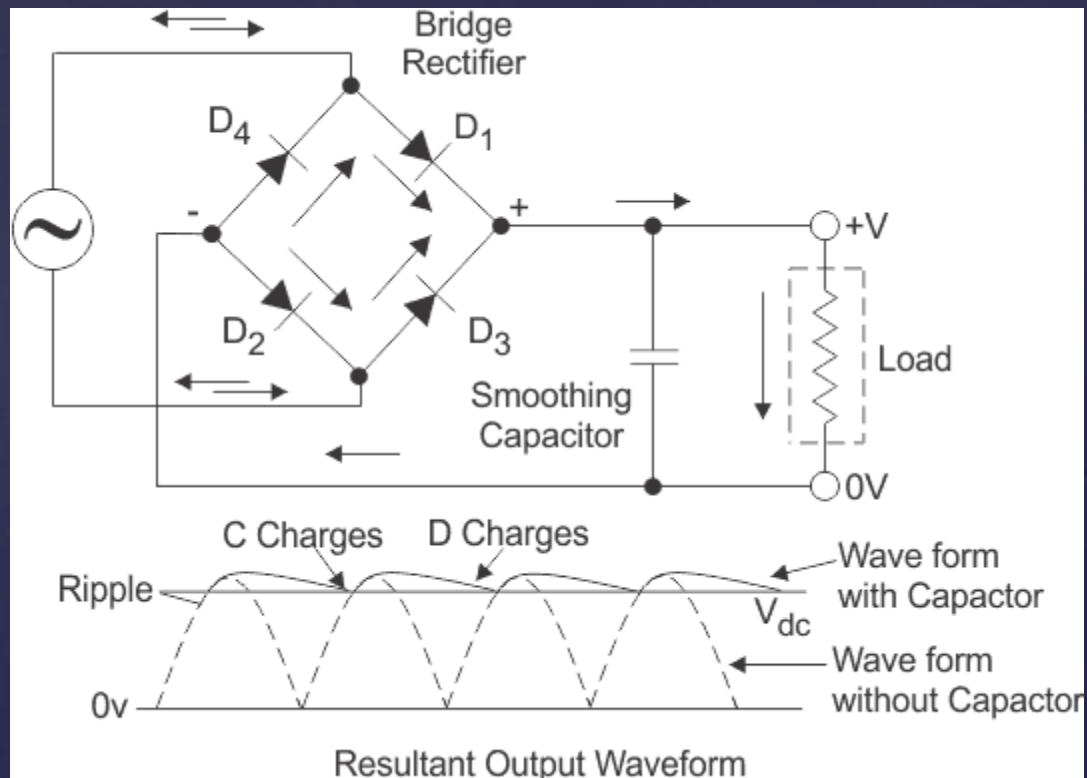


What does this have to do with power supplies?

Remember that the output of the Bridge Rectifier is pulsed D.C. We need to change this to a “smoothed” voltage. When a capacitor is connected across the pulsed D.C. output it will charge and store voltage between cycles



Adding to the previous circuit:

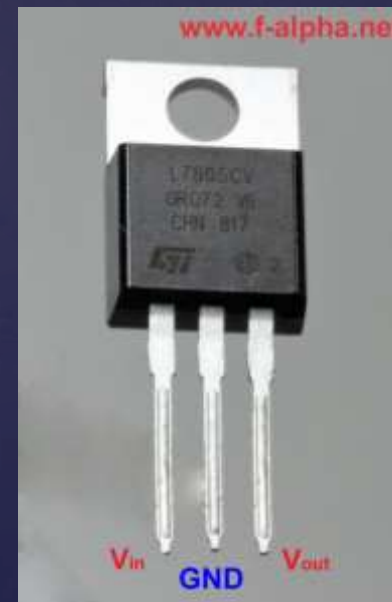
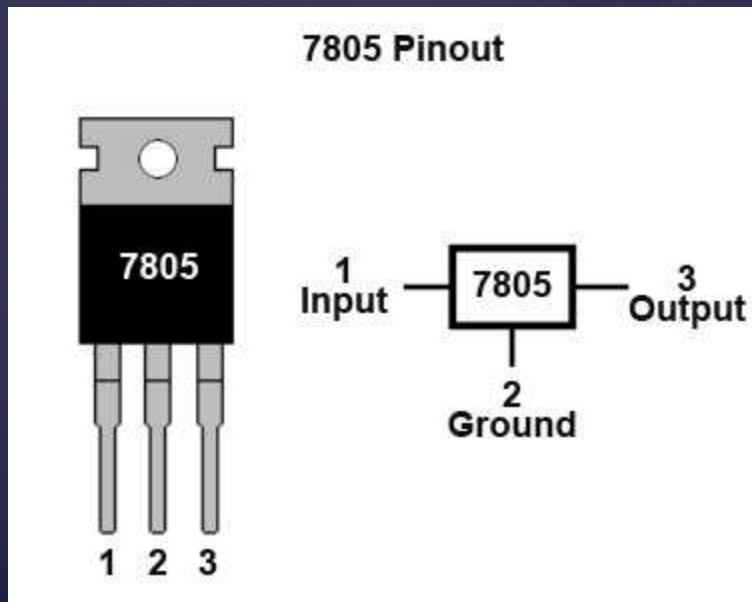


Power Supply video:

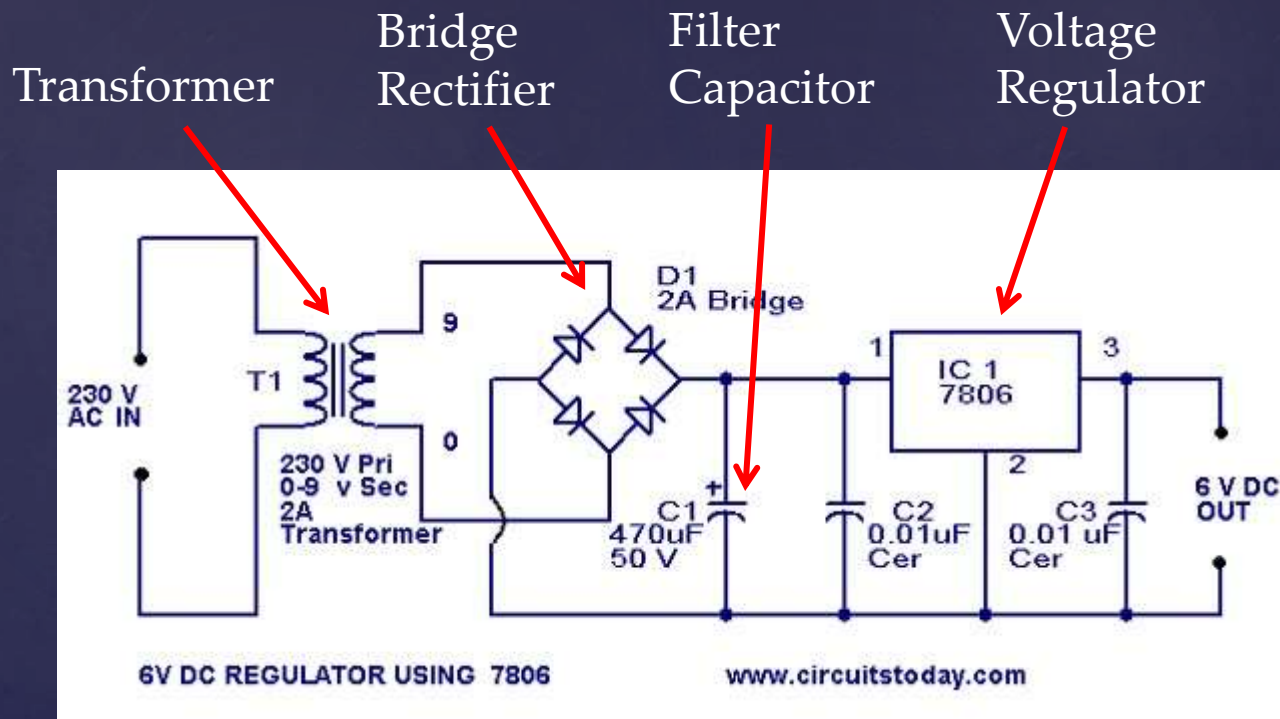
<https://www.youtube.com/watch?v=15b0ZgErKto>

The issue is the “ripple.” This is typical in an *unregulated* power supply.

- As the load resistance decreases, the capacitor discharges faster and more AC ripple is present.
- Ripple is corrected by using a voltage regulator I.C. (notice that it looks like a transistor).



The final Power supply circuit. Notice that this uses a 230V AC input, but the circuit is the same.



References

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