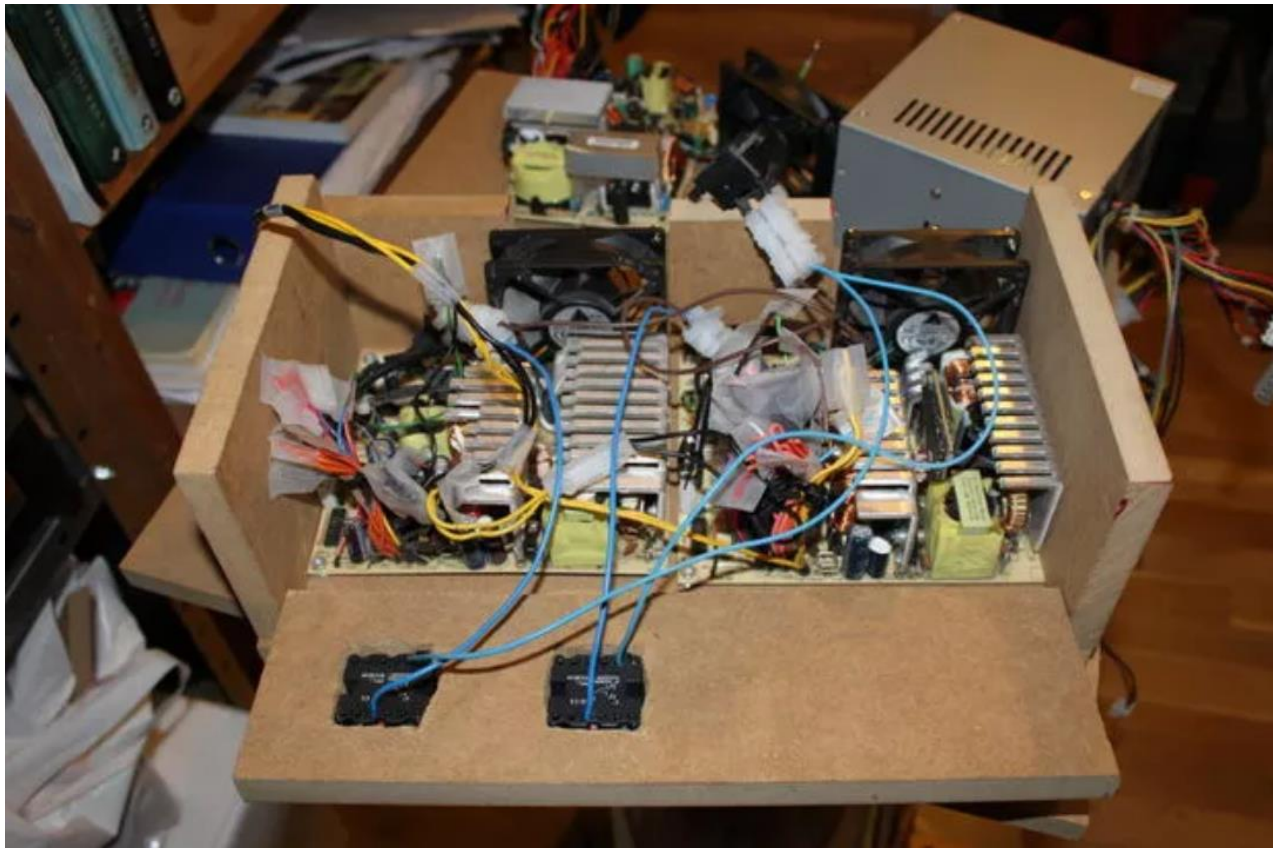
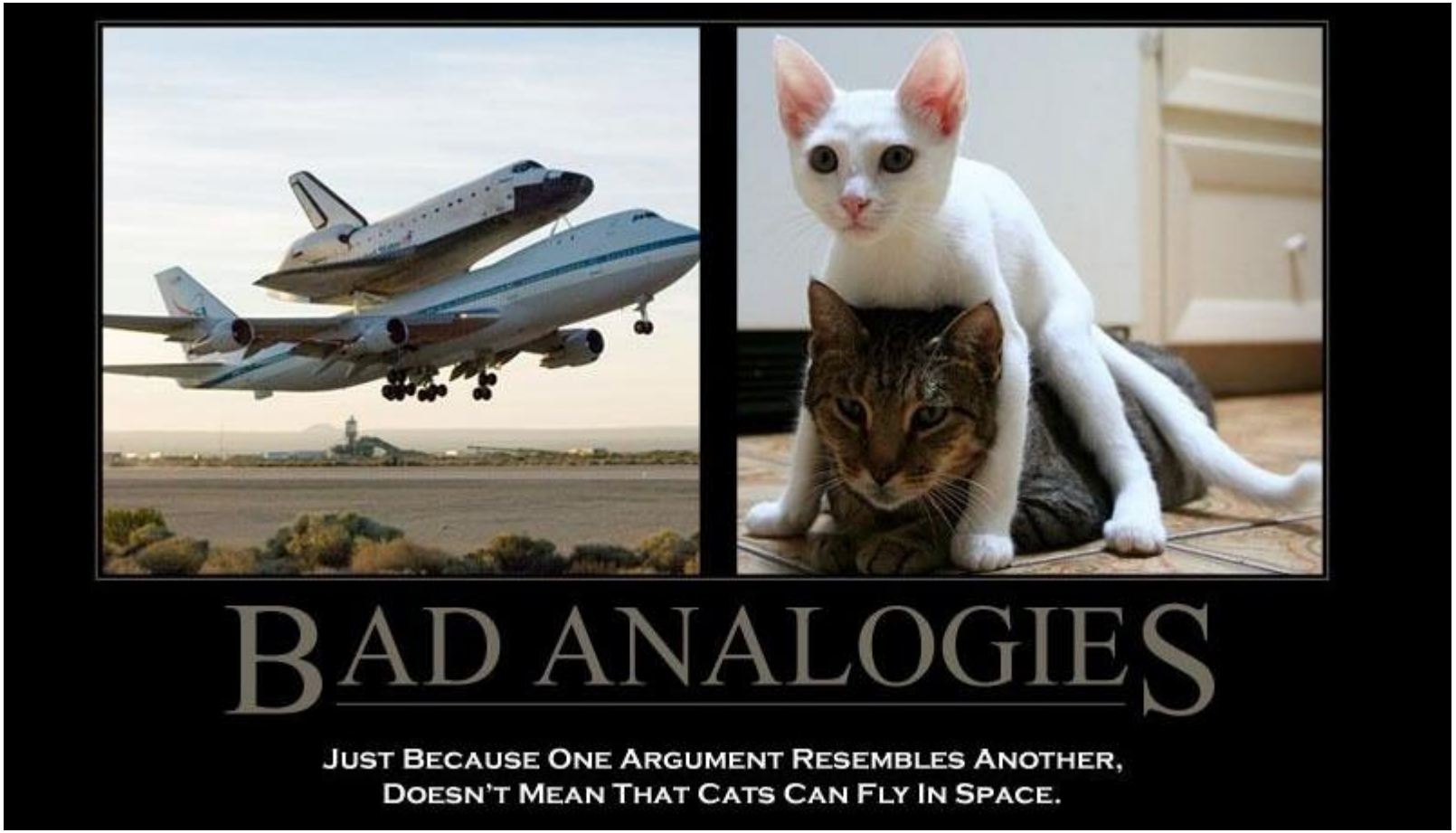
# Power Supplies 101
# AC-DC Converters

3-Feb-2018



WARNING WARNING WARNING WARNING WARNING

**Rules of thumb, assumptions and mixed-quality analogies to come!**



# Tonight's Agenda ***AC-DC Supplies***

Tonight's theory will help you understand:

- Classical AC-DC linear supplies
  - How they work
  - Component selection, supply design
- Switch mode AC-DC linear supplies
  - How they work at a very high level
- Switching vs linear trade-offs

Tonight's lab:

- Power up a switch mode AC-DC supply
- Build a linear AC-DC power supply
- Use an oscilloscope to measure AC and DC waveforms
- Measure load regulation

Next week:

- How regulation loops work
- More detail on how switch mode supplies work
- How 3-terminal linear regulators work and wire some up
- Use some DC-DC switching supplies

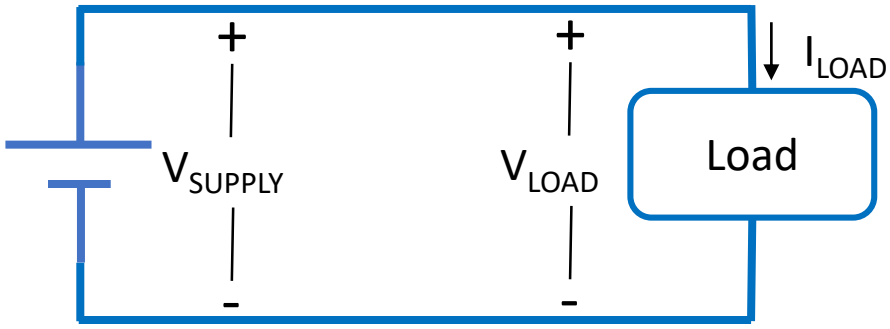
# Voltage, Current and Power Supplies

A power supply provides a constant voltage to its load at all times

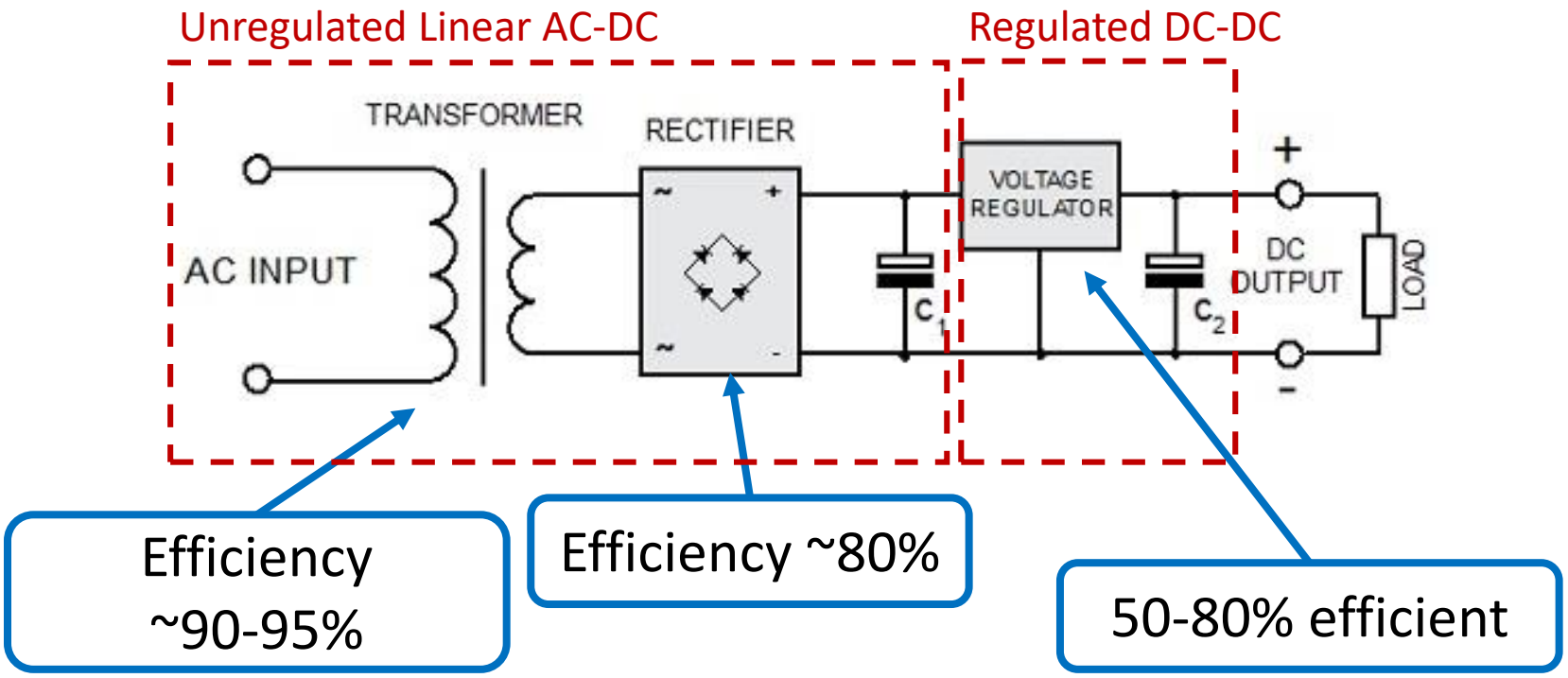
- Voltage rating of supply must be equal to what the load requires
- If the load needs 5V then the supply must be rated at 5V

The load draws however much current it needs, this varies with time

- An audio amp draws more current when a loud signal is being played than when a quiet signal is being played
- A blinking LED circuit draws more current when the LED is illuminated
- Supply current rating must be larger than or equal to what the load needs. A 1 million amp power supply will work with a load that only needs 1 amp

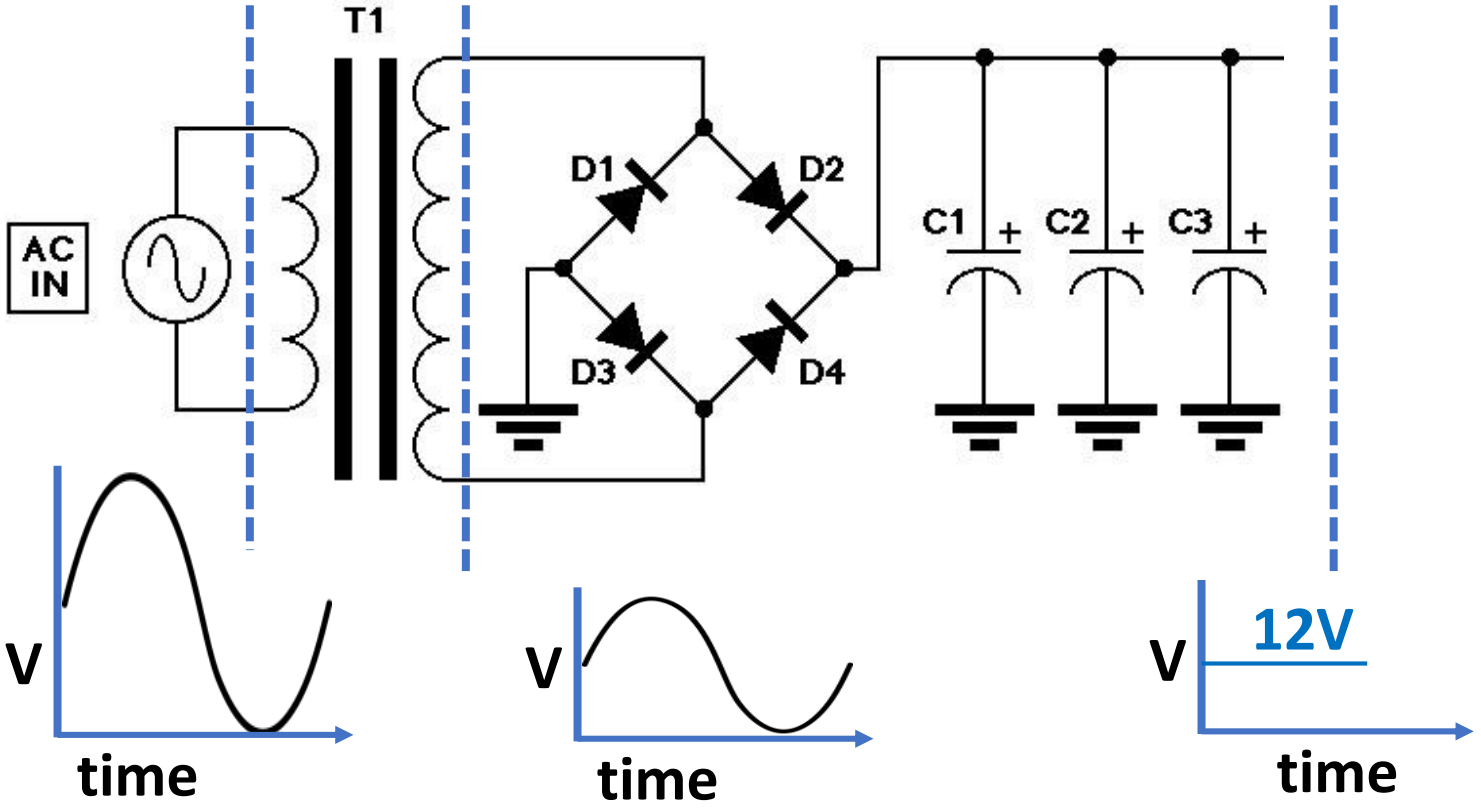


# Classic AC to DC Linear Supply




- ***An unregulated linear AC-DC supply is fairly efficient, 75%***
- ***An unregulated linear AC-DC supply might be a fast off-the-shelf option***
- ***A regulated linear AC-DC supply is typically 40-60% efficient***

# How does an unregulated linear work?

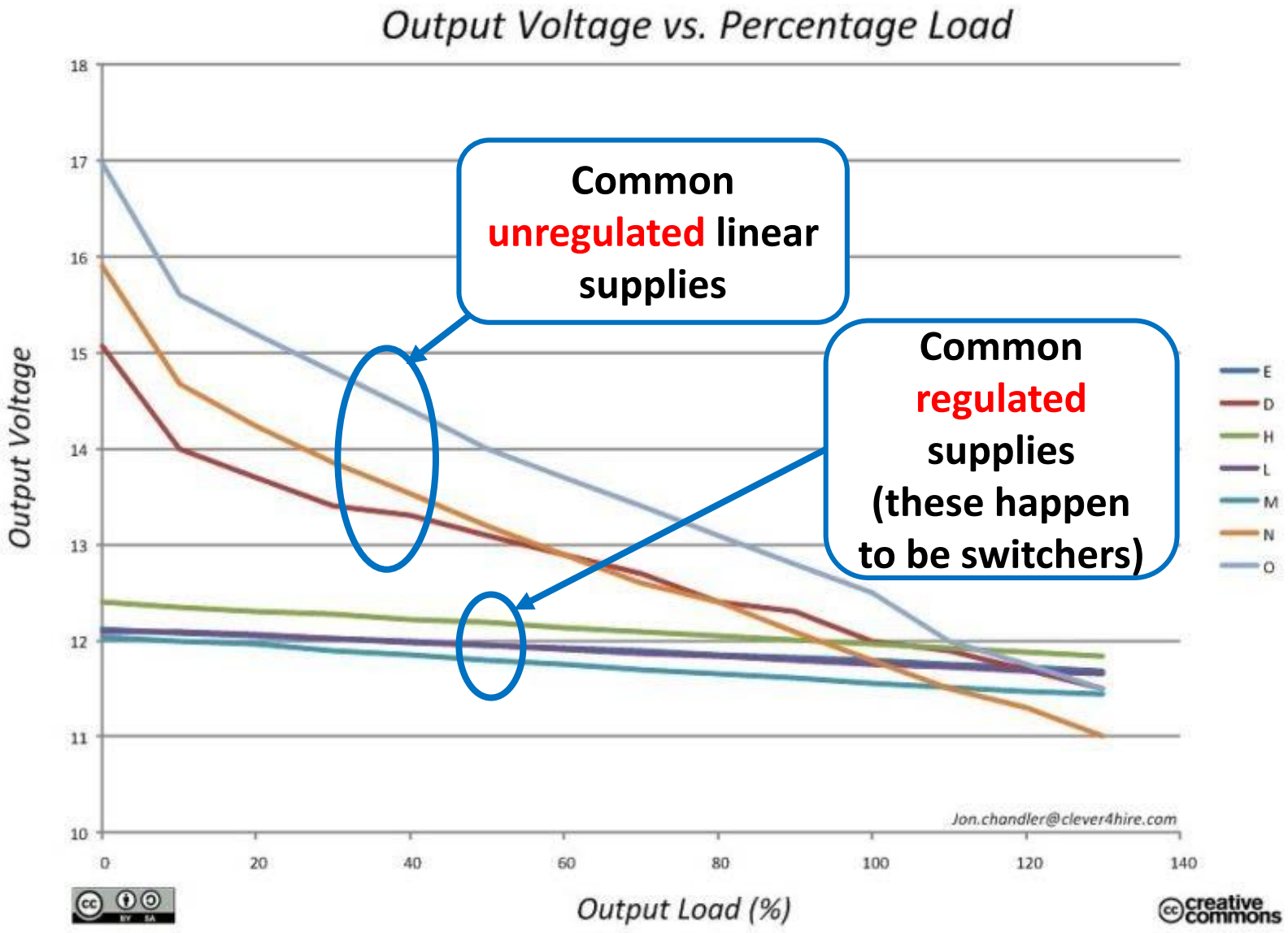



120VAC RMS
170V peak
340V peak-peak

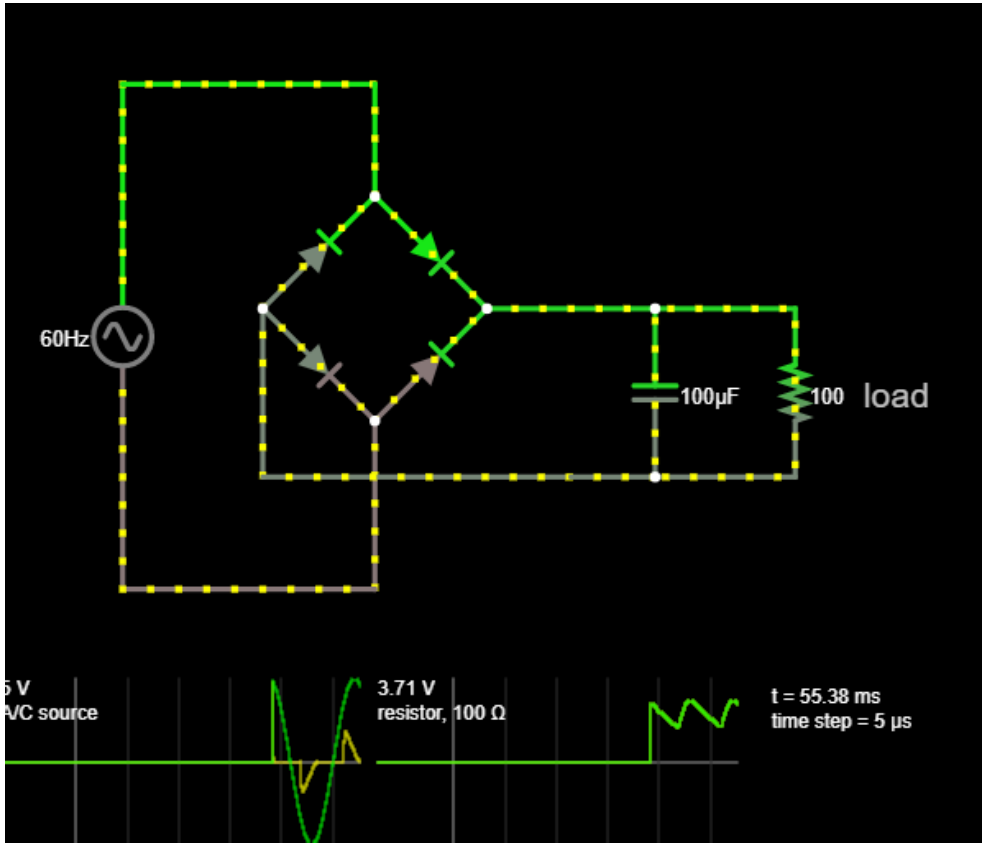
12VAC RMS
17V peak
34V peak-peak

~16VDC no load
~11V full load
~30% drop is typical

# Unregulated vs regulated behavior



# Bypass/Decoupling Capacitors




See simulations

# Component Selection

Transformer:

- Primary voltage = Wall voltage
- Secondary voltage = $V_{DC}$ x 1.1 + 5.2
- Secondary current = $I_{DC}$ x 1.8
- Volt Amp rating = $V_{DC}$ x $I_{DC}$

Rectifier diodes:

- Peak Inverse Voltage > 2.5x transformer's rated secondary
- Maximum average current rating > 2x the DC current required

Filter capacitors

- C ~= $I_{DC}/(60xV_{RIPPLE})$
- or C ~ $I_{DC}$ / 100 for 1.6V ripple

120VAC to 5V 1A DC supply:

Transformer:

- 120V
- 5V x 1.1 + 5.2 = 10.9V -> 12V
- 1A x 1.8 = 1.8A
- 10.9V x 1.8A = 19.6VA

Rectifier diodes:

- 12V x 2.5 = 30V
- 1A x 2 = 2A

Filter capacitors:

- 1A / 100 = 0.01F or 10,000µF

# Workhorse Components

Transformers:

- Scavenge from old electronics, wall warts, ebay
- Tend to be expensive to buy new.

Diodes:

- 1N400x family

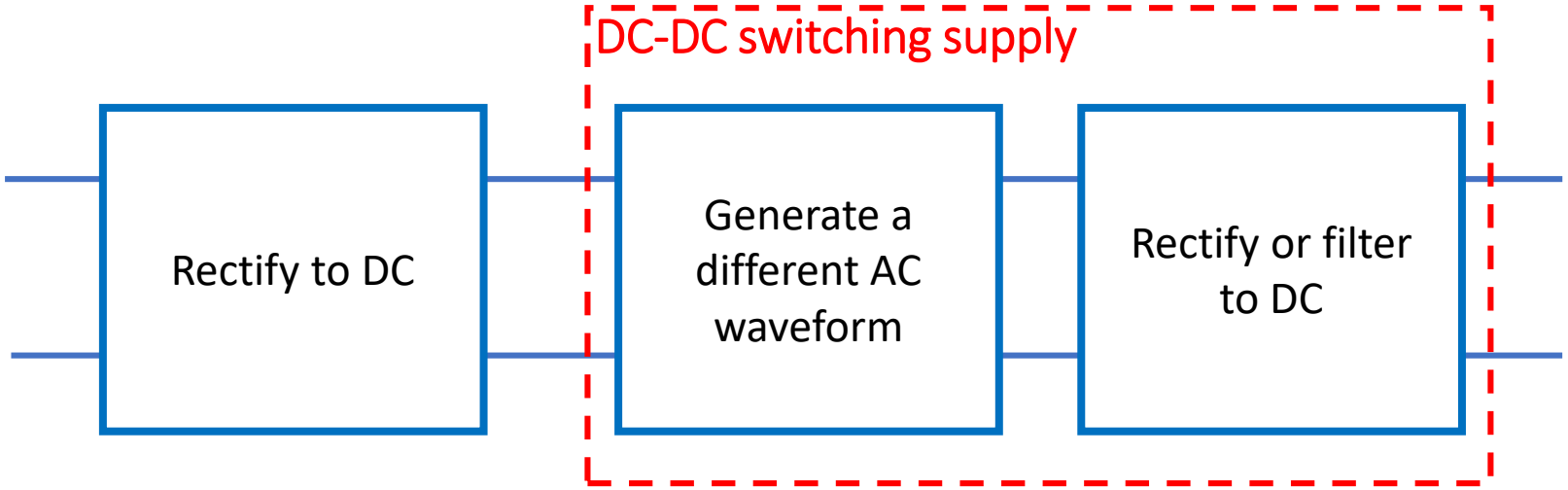
**MAXIMUM RATINGS** ($T_A$ = 25 °C unless otherwise noted)

| PARAMETER | | SYMBOL | 1N4001 | 1N4002 | 1N4003 | 1N4004 | 1N4005 | 1N4006 | 1N4007 | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum repetitive peak reverse voltage | | $V_{RRM}$ | 50 | 100 | 200 | 400 | 600 | 800 | 1000 | V |
| Maximum RMS voltage | | $V_{RMS}$ | 35 | 70 | 140 | 280 | 420 | 560 | 700 | V |
| Maximum DC blocking voltage | | $V_{DC}$ | 50 | 100 | 200 | 400 | 600 | 800 | 1000 | V |
| Maximum average forward rectified current 0.375" (9.5 mm) lead length at $T_A$ = 75 °C | | $I_{F(AV)}$ | 1.0 | | | | | | | A |
| Peak forward surge current 8.3 ms single half sine-wave superimposed on rated load | | $I_{FSM}$ | 30 | | | | | | | A |
| Non-repetitive peak forward surge current square waveform $T_A$ = 25 °C (fig. 3) | $t_p$ = 1 ms | $I_{FSM}$ | 45 | | | | | | | A |
| | $t_p$ = 2 ms | | 35 | | | | | | | |
| | $t_p$ = 5 ms | | 30 | | | | | | | |

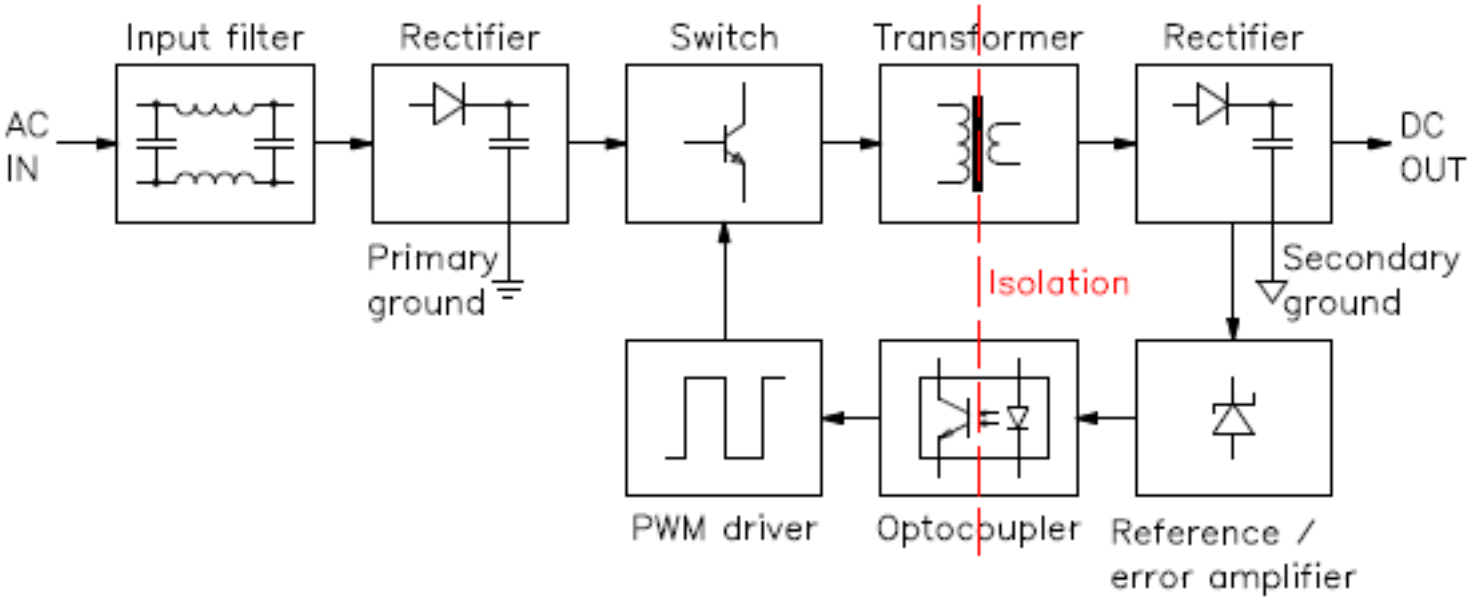
Capacitors

- Will be electrolytic type to achieve required large value of capacitance
- Can scavenge but be wary of older parts, electrolytics degrade over time
- A small cap, 0.1uF or so is sometimes used to filter high frequency noise

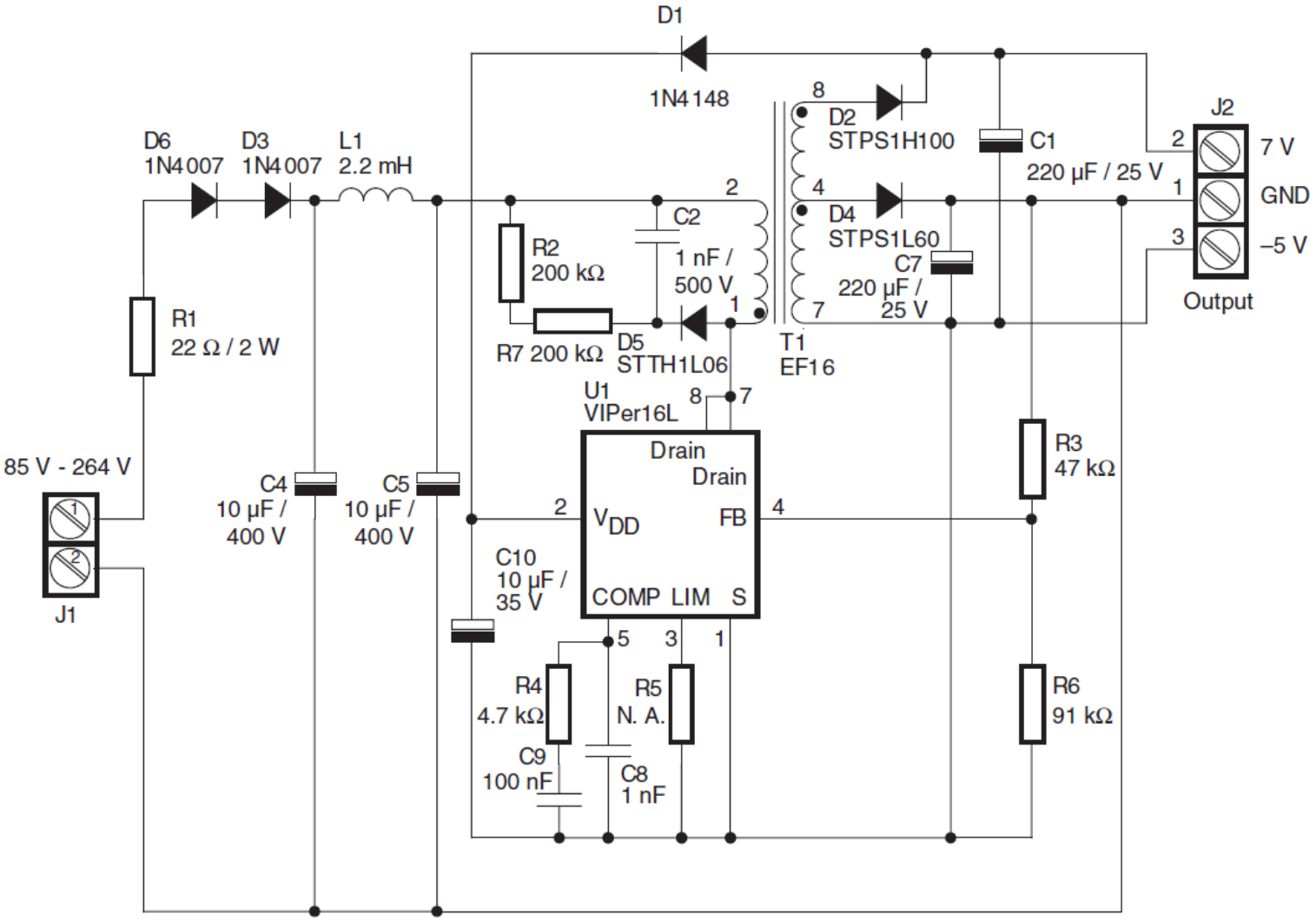
# AC-DC Switch Mode Supply



# A little more detailed view



# The real deal



# AC-DC type, 2.5A class linear vs switching supplies

| | Why Build | Why Use Off the Shelf |
|---|---|---|
| Switching (Regulated) | • "I want to learn about AC-DC switching supplies"<br>• A big project in its own right<br>• >$20 | • "I just want power"<br>• Small<br>• Easy<br>• Efficient<br>• $10 |
| Linear Regulated | • "I want to learn about AC-DC linear supplies"<br>• "I have the parts laying around"<br>• Free to $20 | • "I already have one"<br>• "Switchers are noisy"<br>• Hard to find<br>• Free - $50? |
| Linear Unregulated | • "I want to learn about AC-DC supplies"<br>• "I have the parts laying around"<br>• Don't care that output voltage varies a lot (e.g. 11-17V)<br>• Free to $20 | • "I already have one"<br>• "Switchers are noisy"<br>• Some wall warts<br>• Free - $10 |