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Switching Power Supplies

Chuck Clark

AF8Z

Regulated Power Supply Basics

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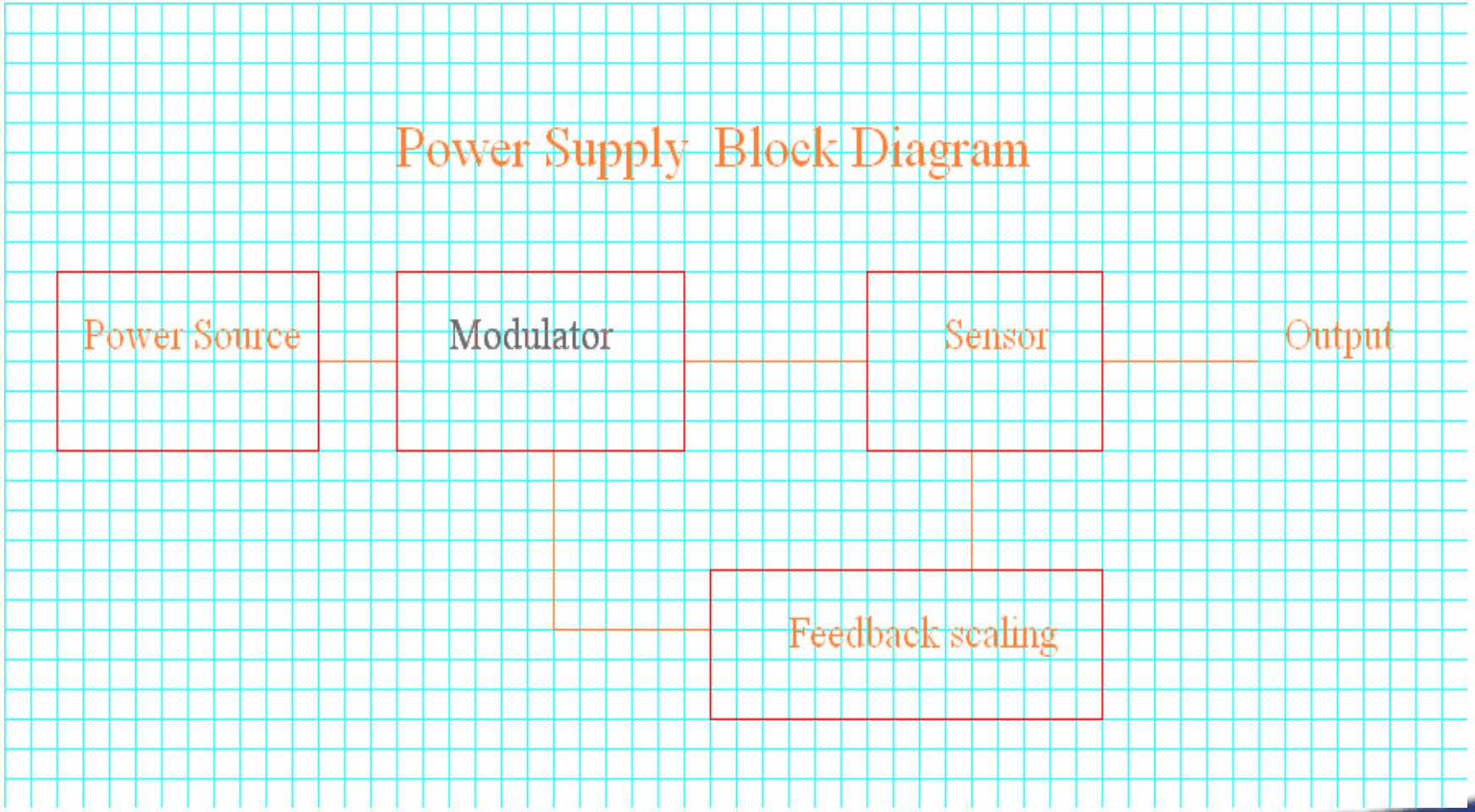

Topics

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- Linear Supplies
- Switching Supplies
- Components

Why switching supplies

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- Smaller
- Lighter
- More Efficient
- CHEAPER

Why Not

- Noise
- Appears more complex well it is…
  - Complex is cheap
  - Weight is not cheap

Classic Linear Supply

- Has large expensive Power transformer
- Has huge filter capacitors

Heathkit HP 1144

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- Needs a line filter on input
- Has high capacitor current, they get warm
- Has high diode current
- Really is a 60 Hz switching supply
- Slow frequency response

HP1144 Schematic

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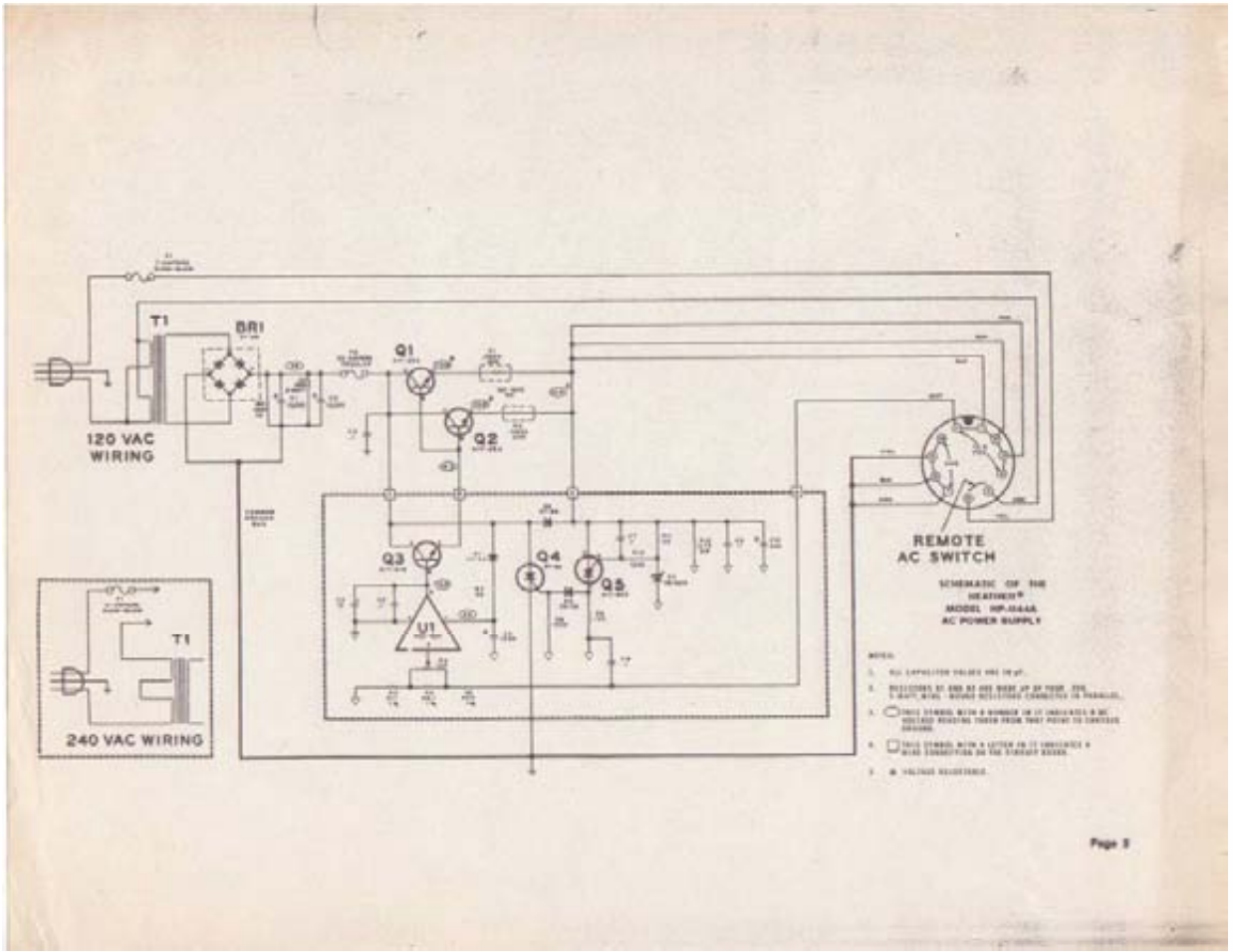

Currents

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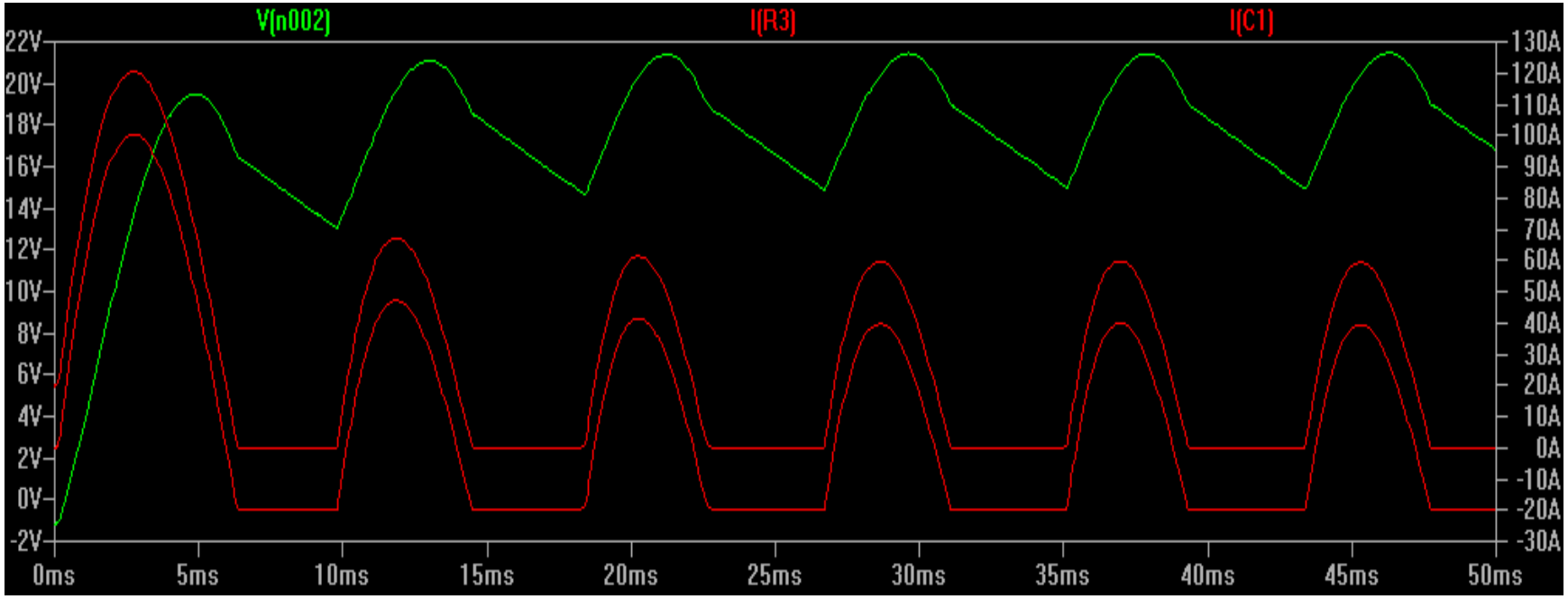

Peak diode currents 60+amps, 100 amps turn on….
Limited by Resistance of Capacitors.

Power Factor

- Non sinusoidal current limits the power available from magnetics and even receptacles….

Parameter	No PFC	Passive PFC	Active PFC
Line VA	1440	1440	1440
PF	0.65	0.90	0.98
Output watts	936	1257	1340

120 V, 15-A circuit, I_{rms}<= 12A to comply with UL limits for circuit breaker

Linear Supply Fixes

- Add line Filter
- Speed up supply by removing shunt caps internal to loop.
- Speed up loop with feed forward network around Darlington
- Add bypass across bridge output

Linear Problems

- Not a very fast response
- Lots of energy storage
- Lots of heat

Switching Supply

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- Switching Frequency 450 kHz
- Energy storage down by 60/450,000
- Inductor core size down by 60/450,000
- Transformer core size down by 7500
- Heat down by almost 100 watts peak!

Switching Supply

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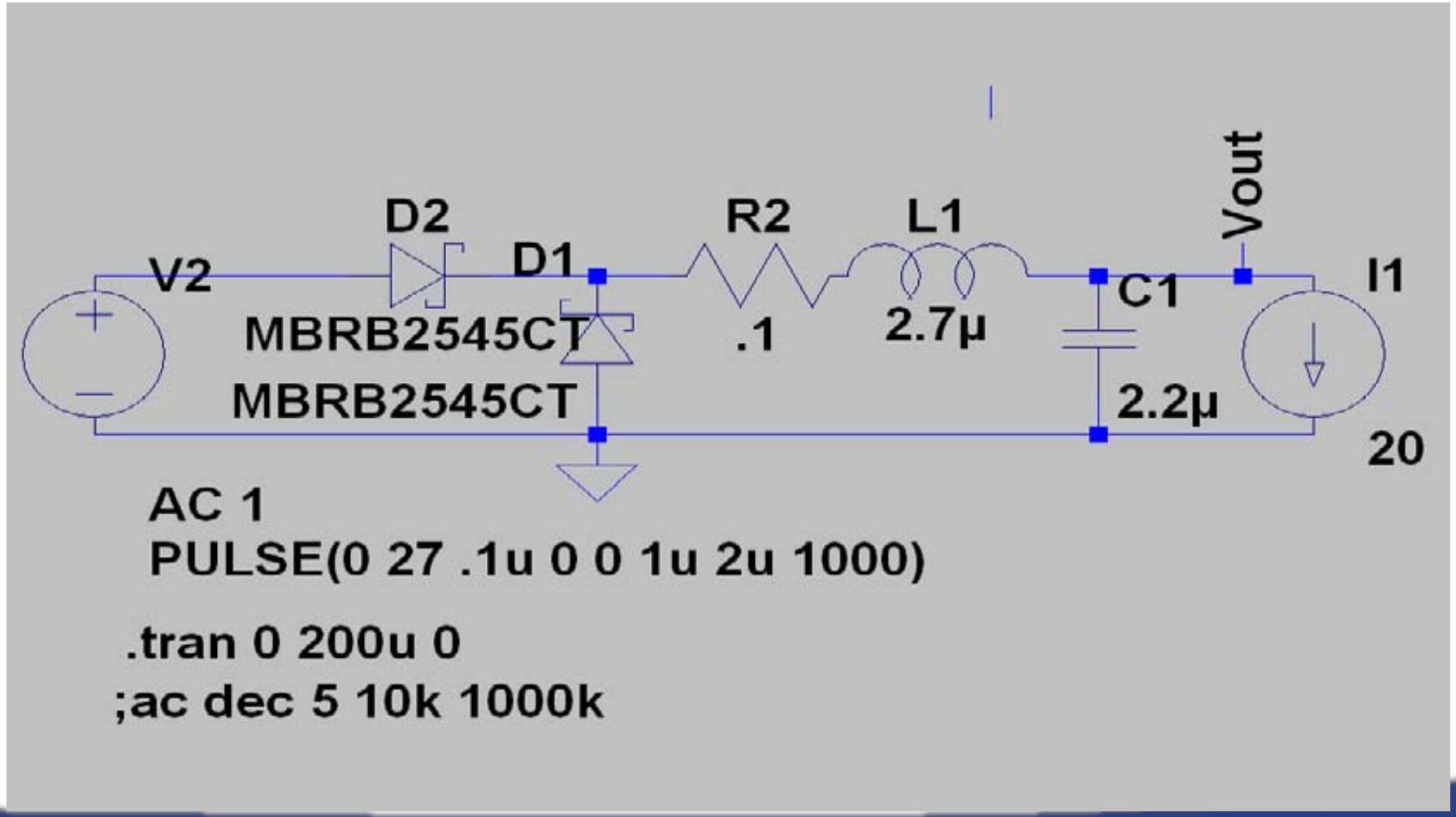

Switcher Currents

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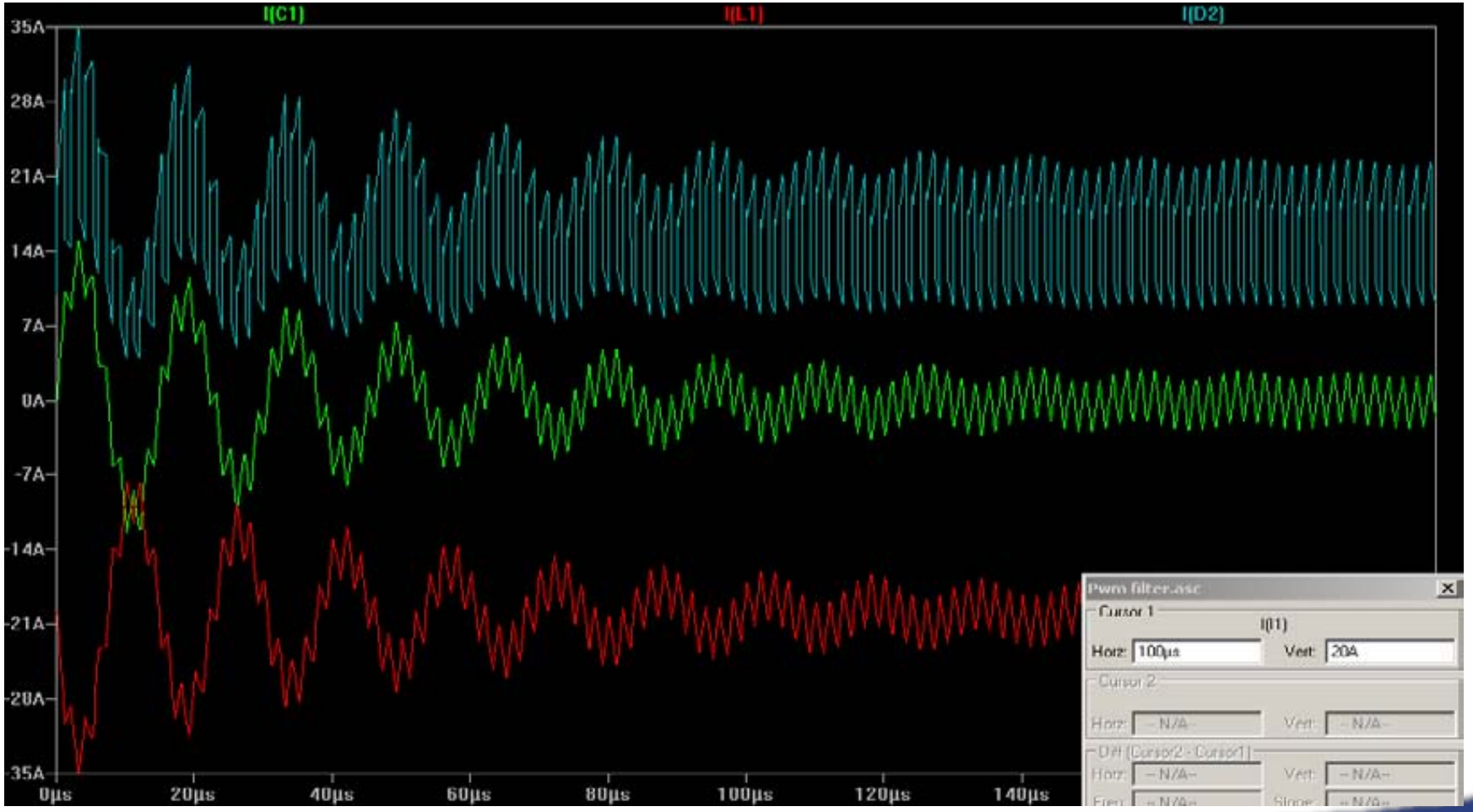

Switching Supply AC Input

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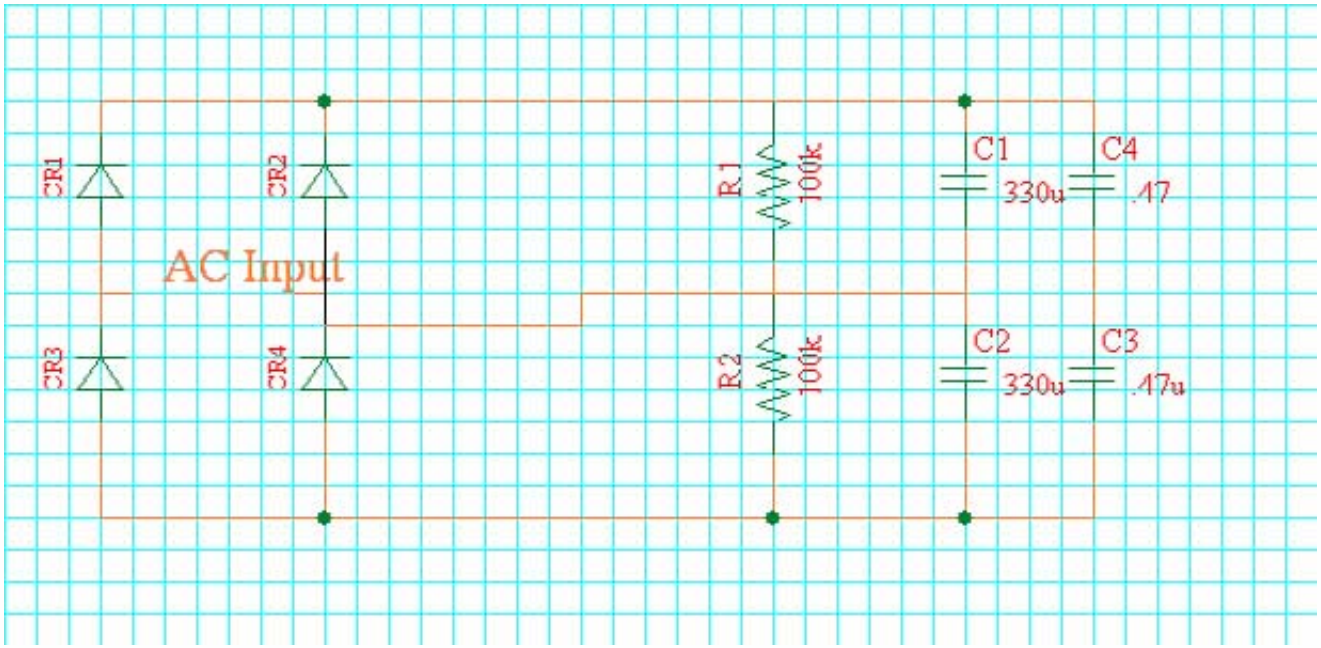

Input Currents

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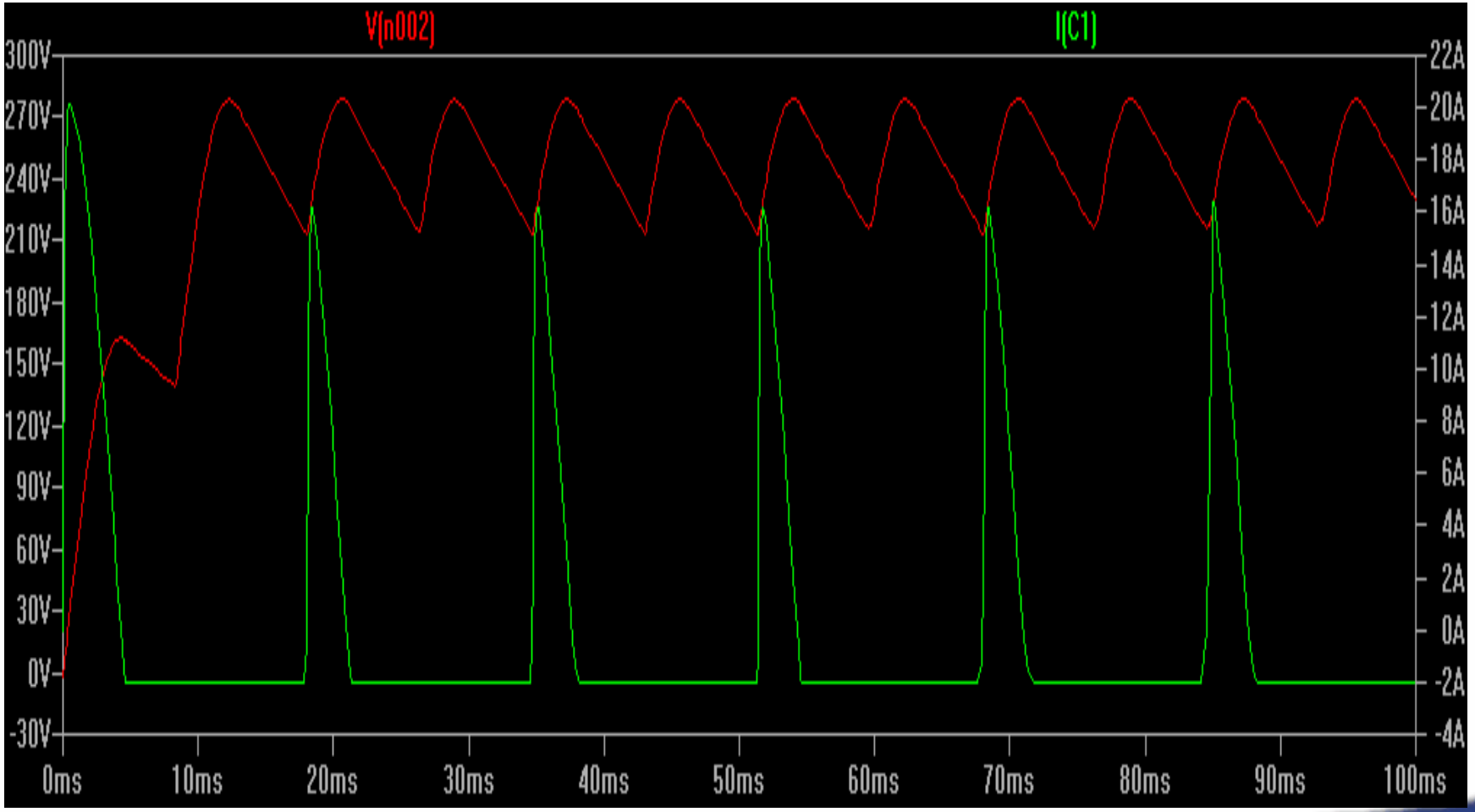

Diode Voltages

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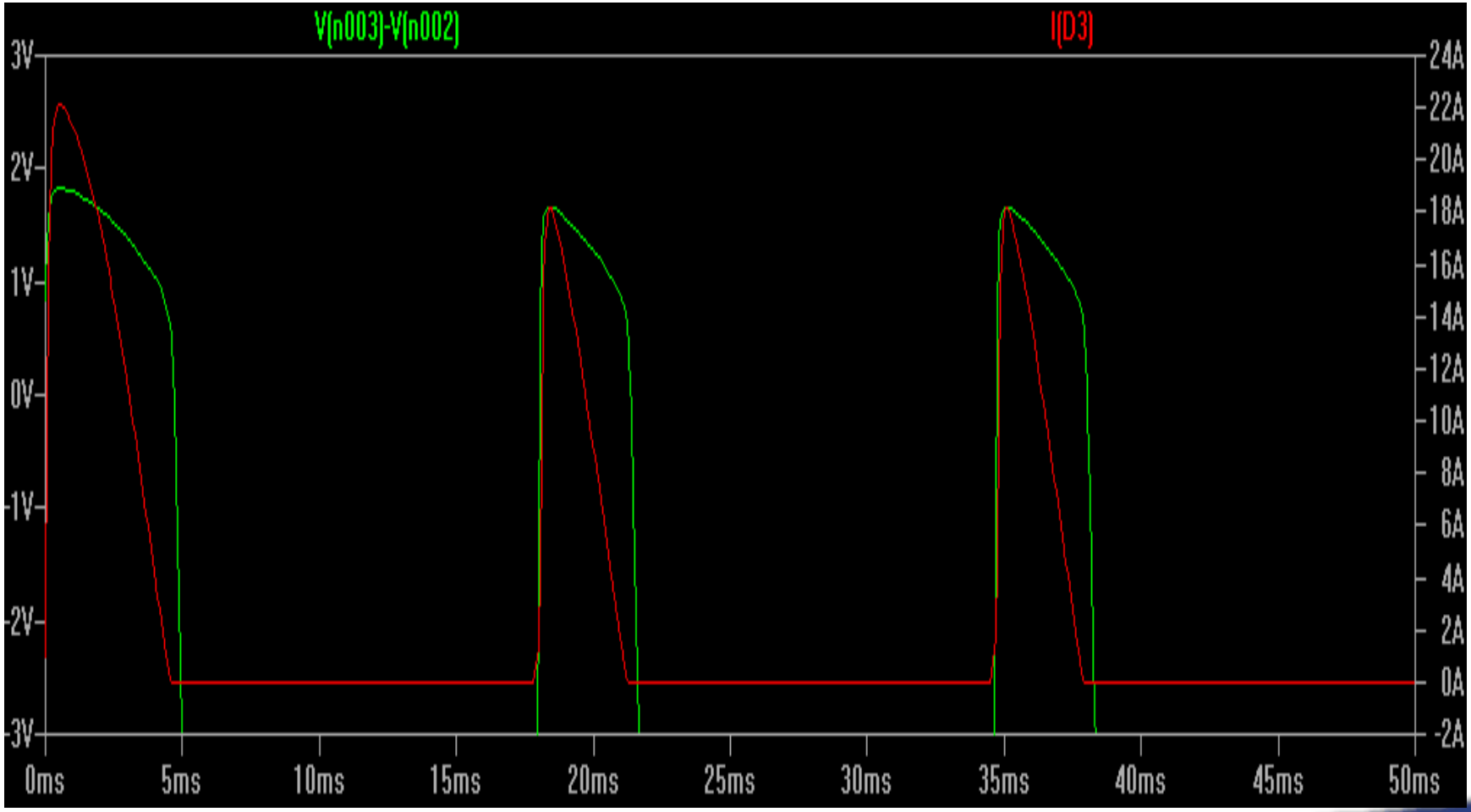

Diodes

- Diodes Current ratings
  - IAV Average repetitive current x
  - IFRM Peak repetitive surge current 2x
  - IFSM Non repetitive surge current 12x

Diode Types

- Standard Recovery
  - 60 Hz
- Snap Action Recovery
  - May have EMI issues
  - Less dissipation than Fast Recovery
- Fast Recovery
  - Soft recovery. Higher dissipation.
- Schottky and Ultrafast Recovery

Inductor Design

- One of biggest issues with switching supplies is Inductor Design
- Core materials are nonlinear, with exception of one…..guess which?
- Nonlinear material means the permeability of the material decreases with increasing flux.

Inductor Design

- Need to avoid core saturation, that's when the reluctance of the inductor goes away.
- An air gap will prevent saturation but the inductance goes down.
- Solution, larger core or higher flux saturation material.

Cores

- EI cores may be most common
- Pot cores are EI cores rotated around the center. The are self shielding.
- Toroids 4/7ths of an EI core. Some shielding, no gap
- Bars, they radiate, but are inexpensive to wind.

Materials

- Low Frequency---silicon steels
  - » Nickel Iron
  - » Cobalt Iron
- Higher Frequency –Ferrites
  - » Permalloy
  - » Powered Iron
- Ferrites and Powered iron useful to microwave frequency range.

Core Losses

- Eddy Currents…Currents induced in the core by the varying magnetic flux.
- Copper losses, the resistance of the winding.
- Hysteresis is a form of magnetic friction.
  - Affected by dc saturation and other frequencies.

Core Saturation

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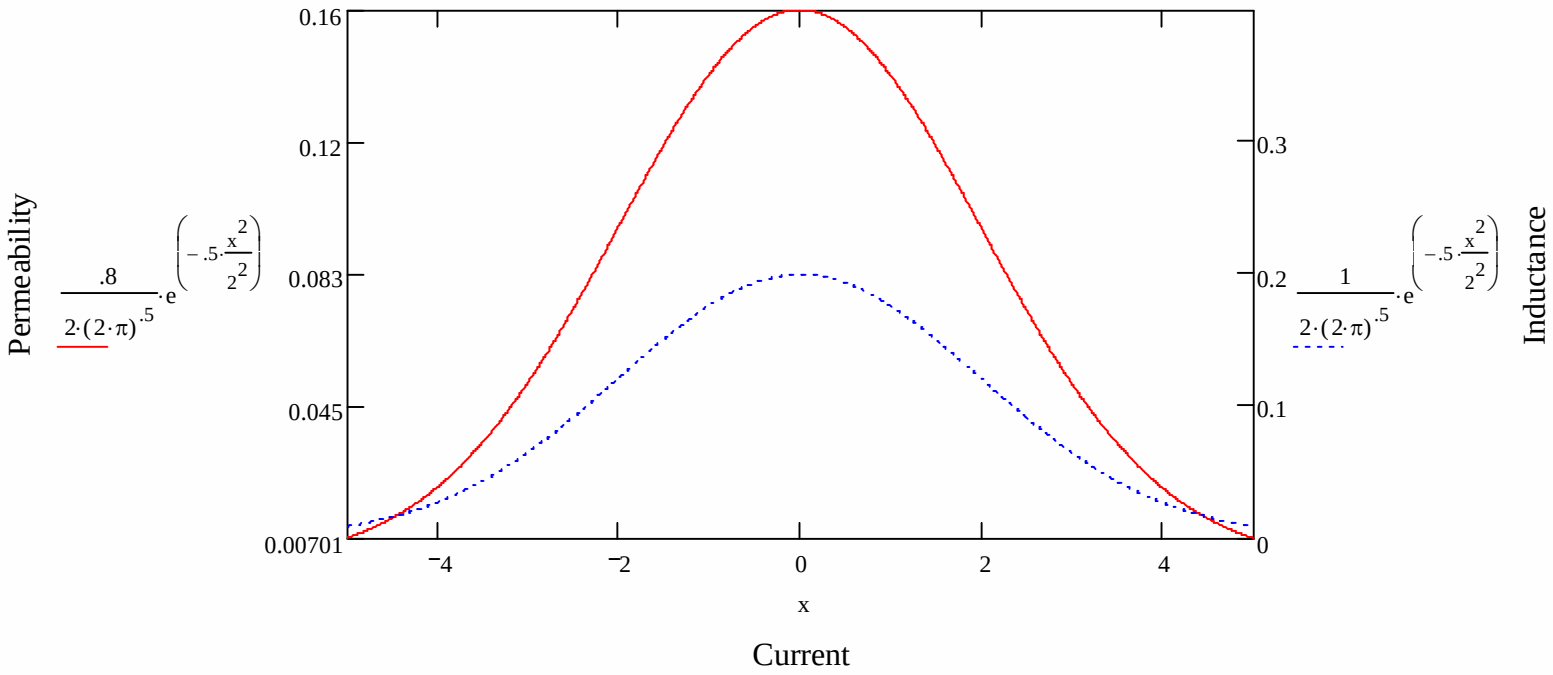


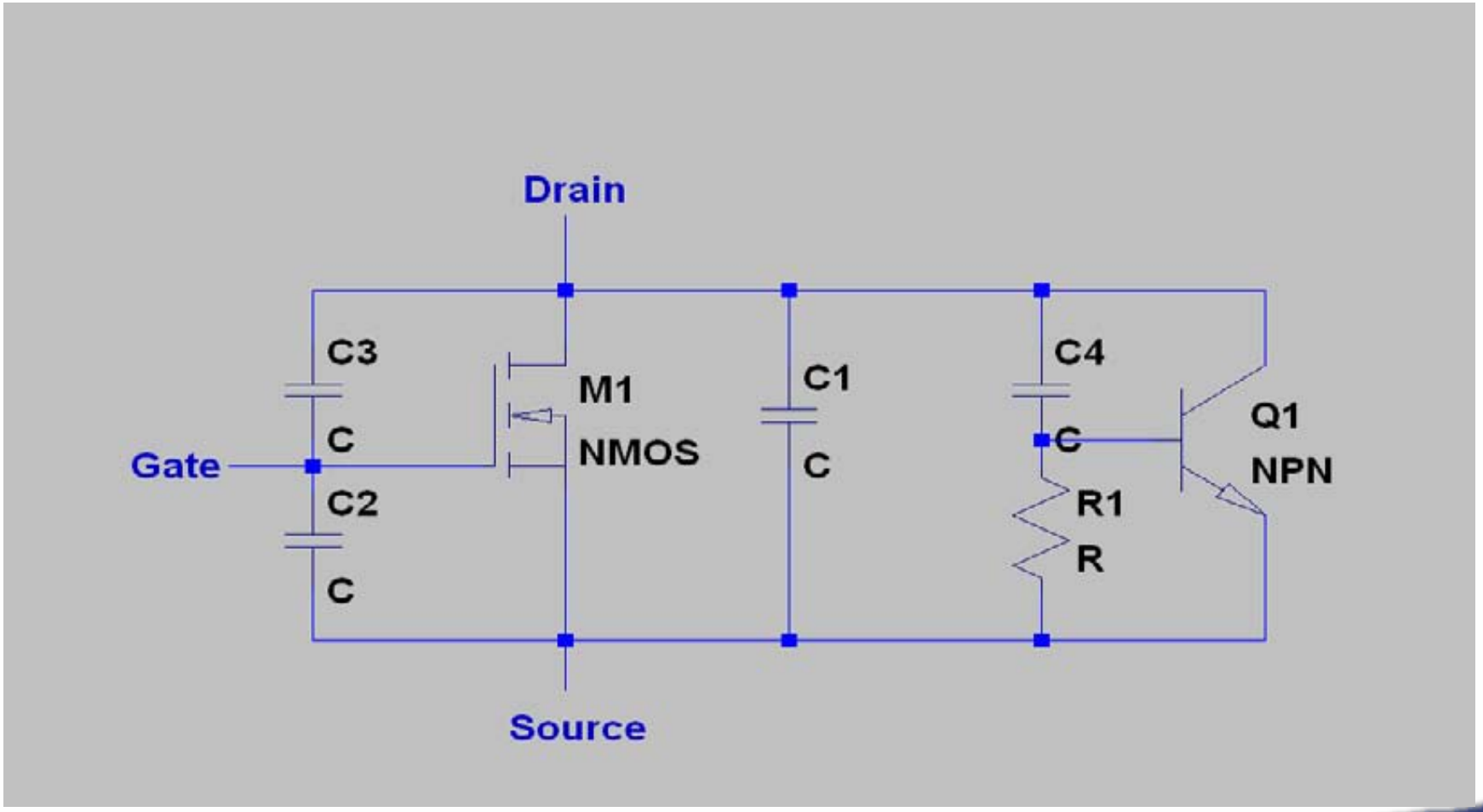
Leakage inductance

- That inductance that is not coupled to the secondary.
- Causes high L di/dt to appear across switches or diodes.
- Use dissipative or reactive snubbers to prevent distruction of the transistors or diodes.

Switching Transistors

- Fets superior
  - Majority Carrier, fast switching without storage time effects.
  - Positive temperature coefficient of resistance eliminates localized hot spotting.
  - Freedom from secondary breakdown.
  - On state forward voltage drop higher than bipolar transistor

Fet Model



Fet Model

- The bipolar transistor is intrinsic.
- Never turn on BJT, or supply will break.
- BJT acts as poor(slow) diode.
  - Replace with actual diode for better performance.

Control

- Many regulators are voltage control loops.
  - The output voltage is compared to a reference and the pulse width or output voltage is increased.
  - Poorer line regulation
- Switching Supplies can have an inner control loop based on current.
  - Advantages Faster loop response
    - Allows pulse by pulse current limiting.
- Control Loop Design is a course by itself

Line Filters

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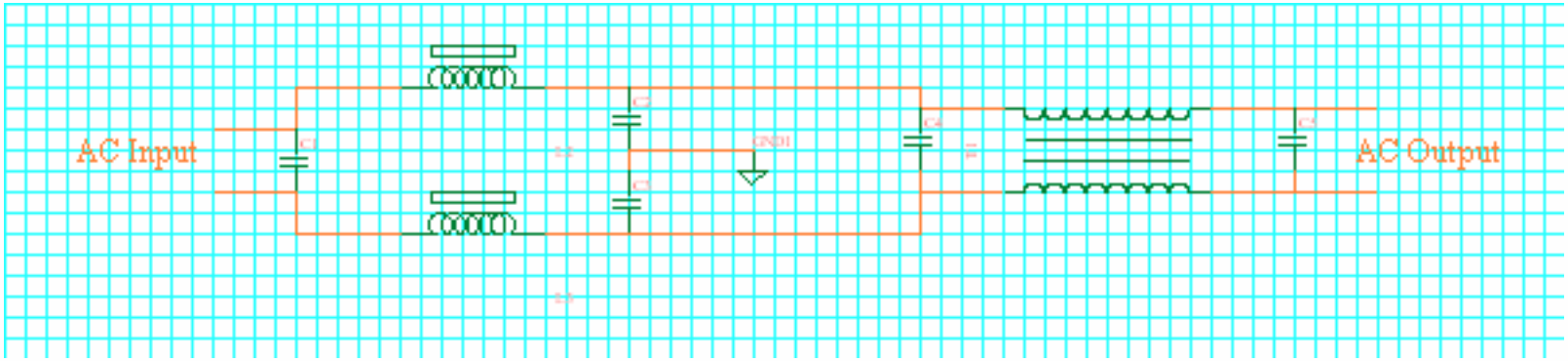
- Brute force L & C's
- Limit C to ground to protect user from ground current.



AC Caps

- Need to be Class X or Class Y for safety.
- Class X Used where damage to the capacitor will not lead to shock.
- Class Y Have greater mechanical and electrical security, which exclude short circuits within the capacitor. Capacitances are limited to reduce currents to a safe level.

Safety Capacitors

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Class	Rated Voltage	Test Voltage
X2	275	3 kV
Y2	250	1.5 kV

Software

- www.linear.com for Switchercad
- www.national

- Note….component limits are not checked!

References

- R. Tarter Solid-State Power Conversion Handbook, 1993, Wiley
- Terman, Radio Engineers Handbook, 1943, McGrawHill.
- ARRL Handbook, 2005
- Van Valkenburg, Network Analysis, 1974
- Reference Data for Radio Engineers, Howard Sams & Co. 1975

WSJT works on 20M!

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- Try 14.075-14.077