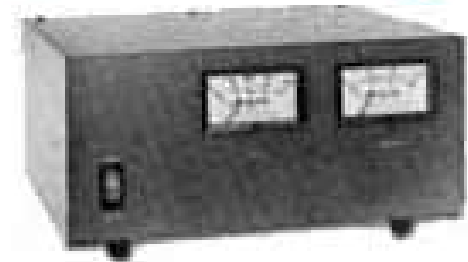


Rig Power Supplies



- Many rigs require external source of Power
- Primary power 115VAC / 60 Hz
- Rig Specs for Voltage & Current ?
- What to look for in a power supply?



Rig Power Requirements



- **Operating Voltage**

- ◆ typically 13.8VDC (derived from nominal car battery voltage)

- **Allowable variation in DC voltage**

- ◆ typically +/- 1 volt (will have to be a regulated supply)

- **Maximum DC Current**

- ◆ typically 25 amp for 100W on Transmit
- ◆ transmit, key down, means continuous (use this to determine current)
- ◆ Receive will be much less

- **Connectorization**

- ◆ Need special connectors or cable from manufacturer ?

Rig Supplies - AC to DC

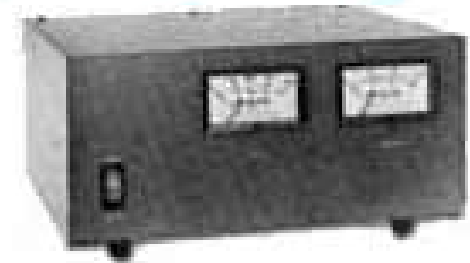


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- Two basic types ...

- Linear Supplies

- ◆ Least expensive / Simple circuitry
- ◆ Big & heavy
- ◆ Runs hot



Astron Linear

- Switching Supplies

- ◆ More expensive / Complex circuitry
- ◆ Small and light
- ◆ Runs cool



Alinco Switcher

- Which is best ?

Specifications



— • — • — • — • • • — • — • • • — • • • • — •

■ Input Voltage

- ◆ Input voltage nominally 120 VAC
- ◆ Range of input voltage typically 105 to 135 VAC
- ◆ PS may be selectable to run off 220 VAC

■ Output Voltage

- ◆ Fixed (13.8VDC) or if Adjustable (5 to 15 VDC), what range?
- ◆ Spec'd at nominal input voltage and rated output current?

■ Output Current

- ◆ Maximum continuous current rating in Amps
- ◆ Intermittent maximum current rating (SSB or CW peaks)

Regulation



- Requirement to hold output voltage to better than $\pm 1\%$ under all conditions (something like $13.8V \pm \sim 100 \text{ mV}$)
- Line Regulation
 - ◆ How much does the output voltage change when the AC input voltage changes ?
 - ◆ Input voltage can vary from 105 to 130 VAC, or $\sim \pm 10\%$
- Load Regulation
 - ◆ How much does the output voltage change when the load current goes from zero to maximum?
 - ◆ Output voltage will vary due to circuit resistances within the power supply

Protection



■ Fuses

- ◆ Input fuse is a safety must (generally Yes)
- ◆ Output may be electronically “fused” (generally Yes)

■ Short Circuit

- ◆ if the output overloaded or is accidentally shorted does the power supply automatically limit the current to a safe level? (generally Yes)

■ Over Voltage

- ◆ Internal failure of PS may cause output voltage to go high, is there over-voltage protection? (generally No)
 - ▶ Rig damage

Output Ripple & Noise



■ Ripple

- ◆ Rectify 60 Hz line to convert AC to DC
- ◆ Ripple freq is the 120 Hz + harmonics (full wave rectification)
- ◆ DC Output filter circuits reduce ripple content
- ◆ Excessive ripple shows up as audio hum (filter caps died)

■ Noise

- ◆ AC voltages other than 60 Hz harmonics
- ◆ Linears are very quiet; no noise sources.
- ◆ Switchers are very “noisy” due to switching action (more later)
- ◆ Switchers can produce harmonics at RF and may be heard on receiver.

Output Connections



- **Polarity Markings - positive and negative**

- **Binding Posts**

- **Screw Terminals**

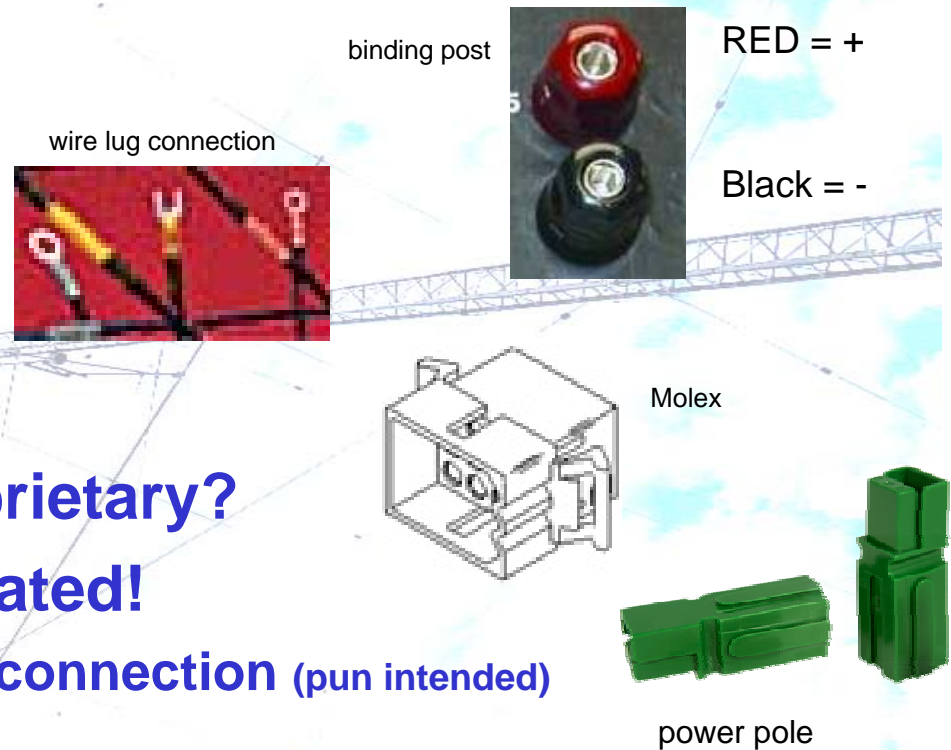
- **Molex Style**

- **Power Pole Style**

- **Manufacturer's proprietary?**

- **High Current - 30A rated!**

 - ◆ **need a very positive connection (pun intended)**



Safety



- **Three Prong Plug – very least requirement**
 - ◆ Provides shock (**electrocution**) protection
- **Electrical Safety**
 - ◆ CSA (Canadian) & UL (American) approval sticker?
 - ◆ Agencies are harmonized – tested for same parameters
 - ◆ Tested for hazards; fire, insulation, shock etc.
 - ◆ Do not determine how well PS performs.
 - ◆ Every electrical appliance sold in Canada must be CSA approved.
 - ◆ Ham power supplies often not approved.

Spec Summary



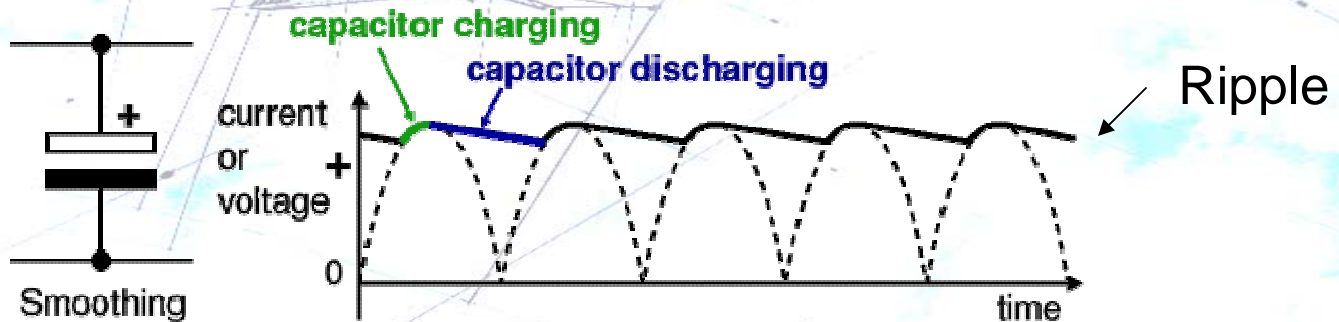
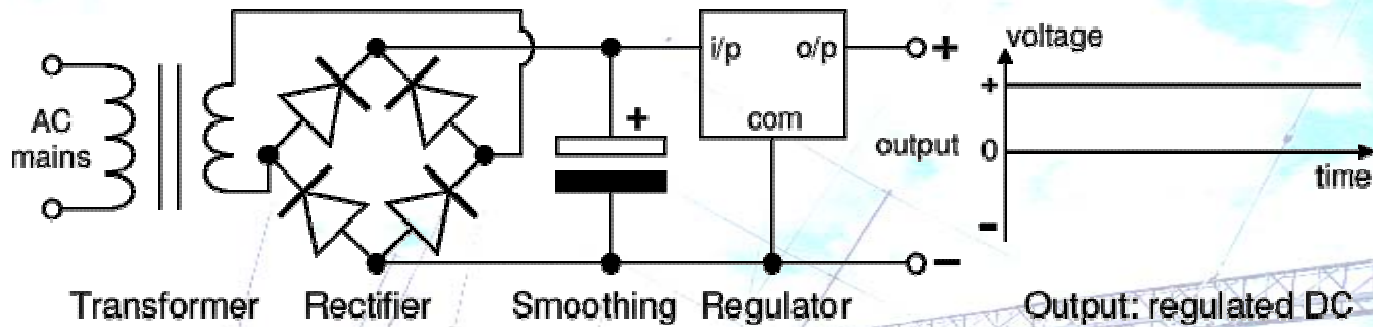
- **Linear or Switcher – all considerations apply**
 - ◆ **Input Voltage, and Range**
 - ◆ **Output Voltage, and Range**
 - ◆ **Output Current, and Range**
 - ◆ **Regulation of output voltage, Line and Load (a must)**
 - ◆ **Ripple and Noise (get lowest you can)**
 - ◆ **Protection against Over Current & Short Circuit.**
 - ◆ **Protection against Over Voltage (rarely, bonus)**
 - ◆ **Safety CSA / UL (you take your chances with Ham stuff)**

Linear Supplies

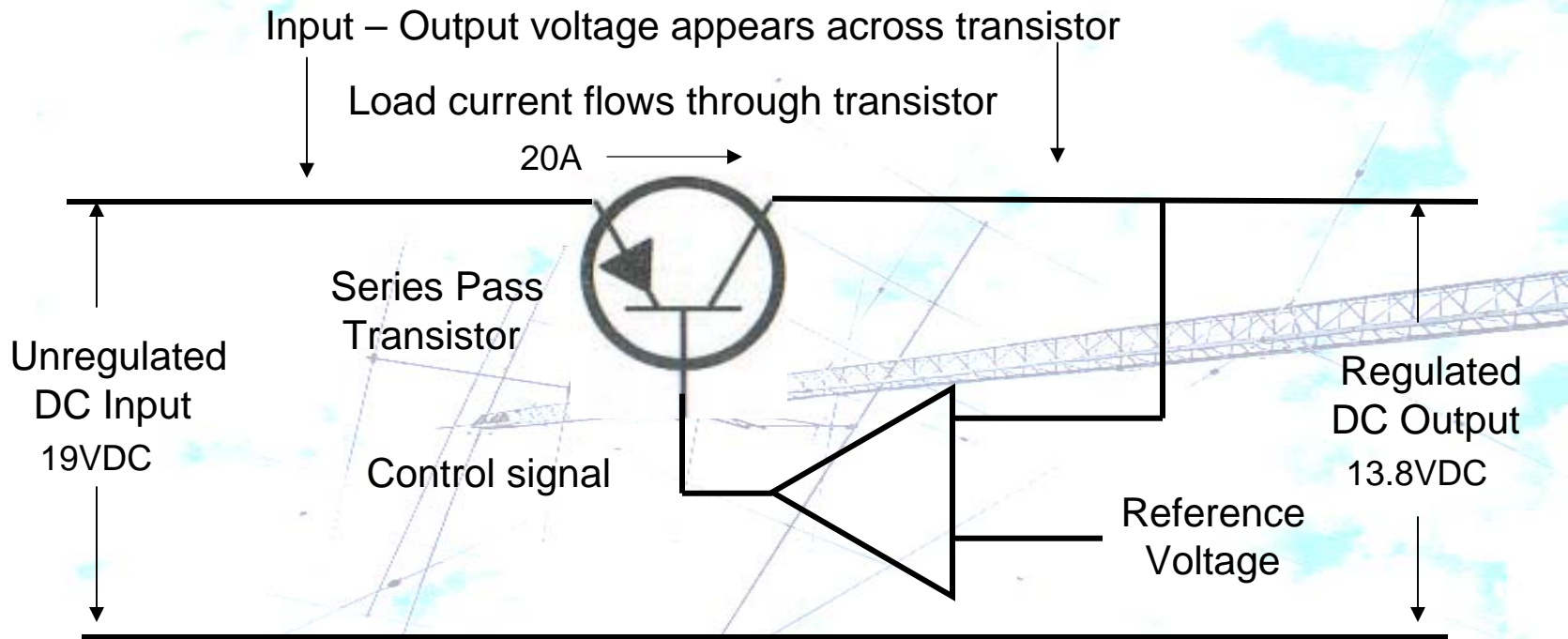


- Transform 120 VAC to ~ 12VAC
- Rectify AC to DC
- Filter the rectified DC
- Regulate the DC Output

Linear Circuit



Regulator

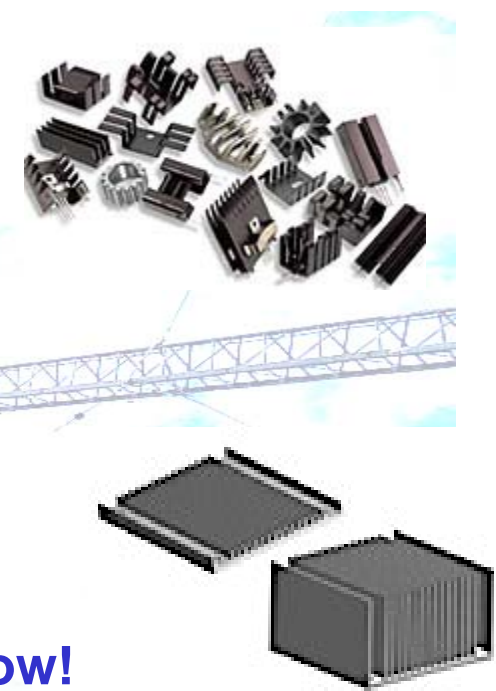


$$\text{Power} = (\text{Voltage across transistor}) \times (\text{current through transistor})$$

Heat & Heat Sinks



- Power dissipation = Heat
 - 5 volts x 20 amps = 100 watts !
 - Transistor will incinerate
 - Need a Heat Sink
-
- Heat sink removes heat from the transistor and dissipates to ambient air
 - Heat Sink devices have large surface area to contact air for cooling
 - Ensure there room around HS to allow airflow!
 - **KEEP IT COOL**



Large Components

— • — • — • — • • • — • — • • • — • • • • — •

- **Linear supplies characterized by:**

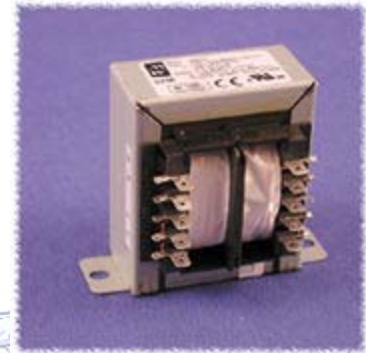
- **Large transformers**

- ◆ 25 lbs or more
- ◆ Run hot
 - ▶ Copper loss (wire resistance)
 - ▶ Core loss (magnetic losses)

- **Large filter capacitors**

- ◆ Typically > 1000 uF

- **Large heat sinks**



Output Ripple

- • — • — • — • • • — • — • • • — • • • • — •
- Rectification ripple can be improved by using larger or more filter caps.

... not necessary as

- Regulators act fast enough to regulate out the ripple variations
- Linear supplies are VERY “quiet” electrically

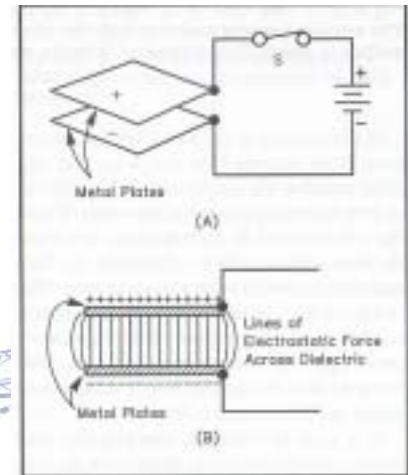
Switching Supplies



- Rectify AC to DC directly off line (~ 150 VDC)
- Filter the raw rectified DC
- Switch the DC on and off at a 60 kHz to make an AC waveform
- Apply to a high frequency, voltage step down, transformer
- Rectify the 60 kHz to DC
- Filter the DC
- Regulate the DC output
- But first, a “new” look at basic components

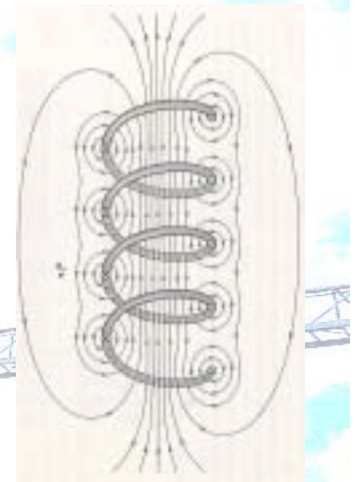
Capacitors

- Acting as Energy storage device
- Energy stored in Electric Field
- Voltage storage device
- Put energy in
- Take energy out
- Capacitor runs cool (non-dissipative)



Inductors

- Acting as an Energy storage device
- Energy stored in Magnetic Field
- Current storage device
- Put energy in
- Take energy out
- Inductor runs cool (non-dissipative)



Transistor as a Switch



■ Think of a light switch ..

- ◆ When closed – current flows / no voltage drop across switch
- ◆ Power = Volts x Amps and $V = 0$, therefore power = 0
- ◆ When open – current = zero, voltage = 120V
- ◆ Power = Volts x Amps and $I = 0$, therefore power = 0

■ Transistor as a switch

- ◆ Drive transistor on hard, $V \sim 0$ as current flows. \sim no power
- ◆ Turn transistor off, $I = 0$ as no current flows, \sim no power
- ◆ Power dissipated in a switched transistor is small
- ◆ **Transistor runs cool** (unlike the series pass regulator)

Diode as a Switch

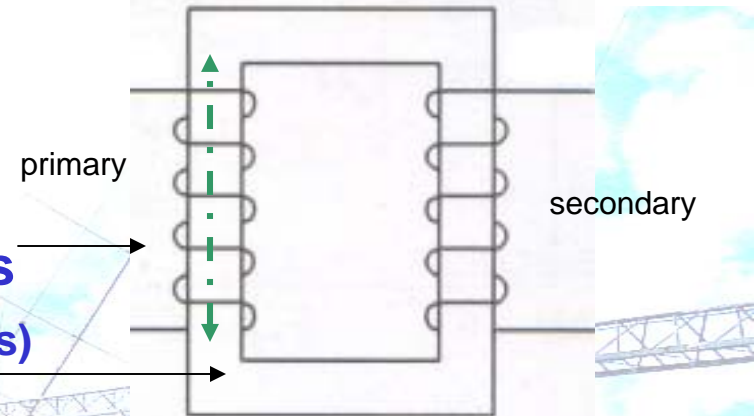


- Rectifier diode acts like a switch
- Conducts in “forward” direction, $V \sim 0$ (actual 0.3 to 0.6V)
- Does not conduct in “reverse” direction, $I = 0$
- Power dissipated in a Diode is small
- Diode runs cool

Transformer Equation

■ $V_{\text{primary}} = k \times f \times N \times A \times B$

- ◆ k is a constant
- ◆ f is frequency
- ◆ N = number of primary turns
- ◆ B = flux density (magnetic lines)
- ◆ A = area of core



- Applying the primary voltage at 60 kHz instead of 60 Hz, the area A [= size of core] can be reduced by a factor of 1000, all else staying the same!
- The higher the transformer frequency, the smaller the transformer becomes.

Transformer - Inductor



- **Transformer can act as an inductor**

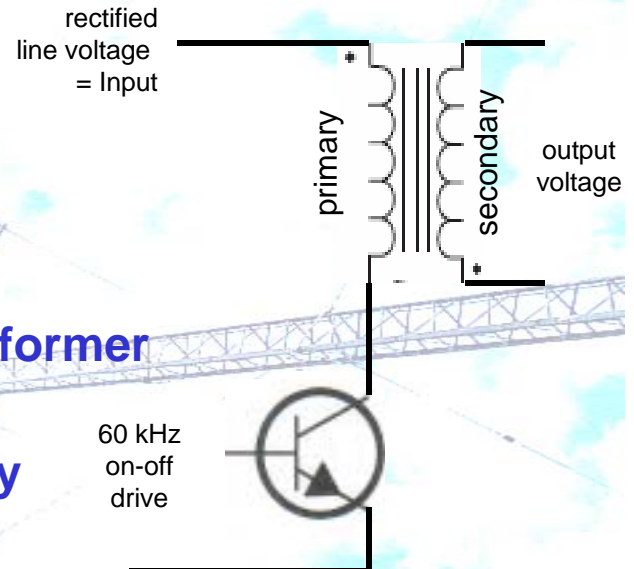
- ◆ Primary winding is an inductor
- ◆ Store energy in its magnetic field

- **Put a switch in the primary,**

- ◆ turn switch on, store energy in transformer
- ◆ turn off switch
- ◆ stored energy flows out of secondary

- **Transformer also isolates “line side” from “load side”**

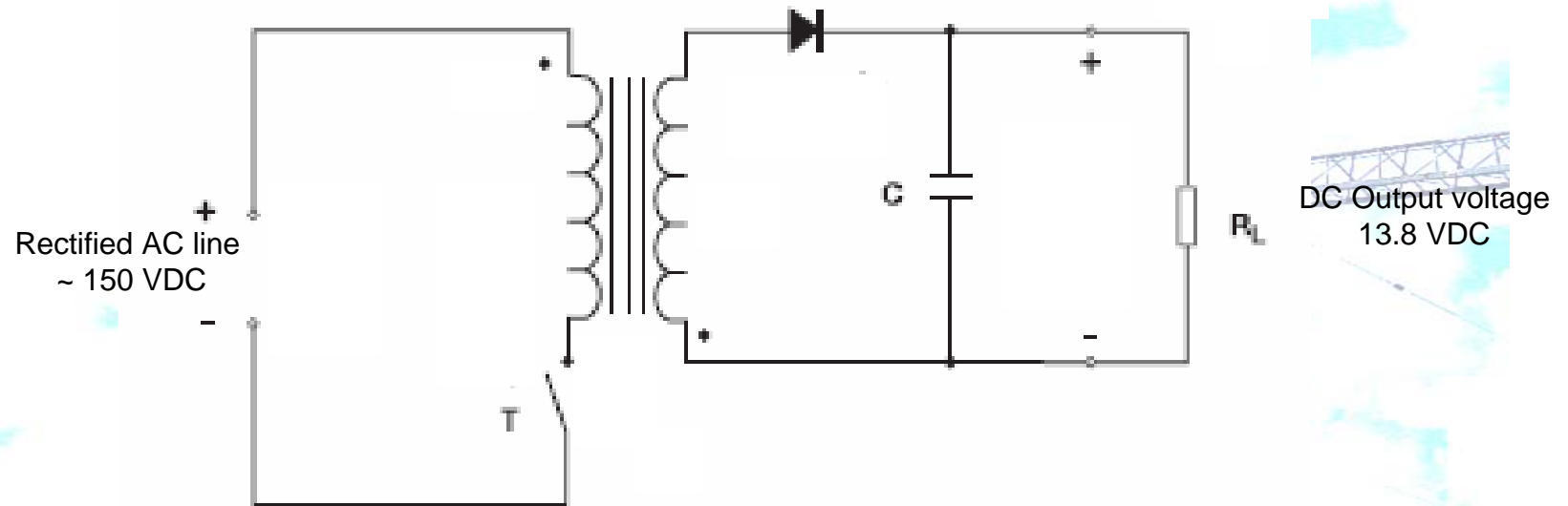
- ◆ Safety requirement; prevents load (you and equipment) from becoming connected to the AC mains in case of insulation failure



Switch Mode Circuit

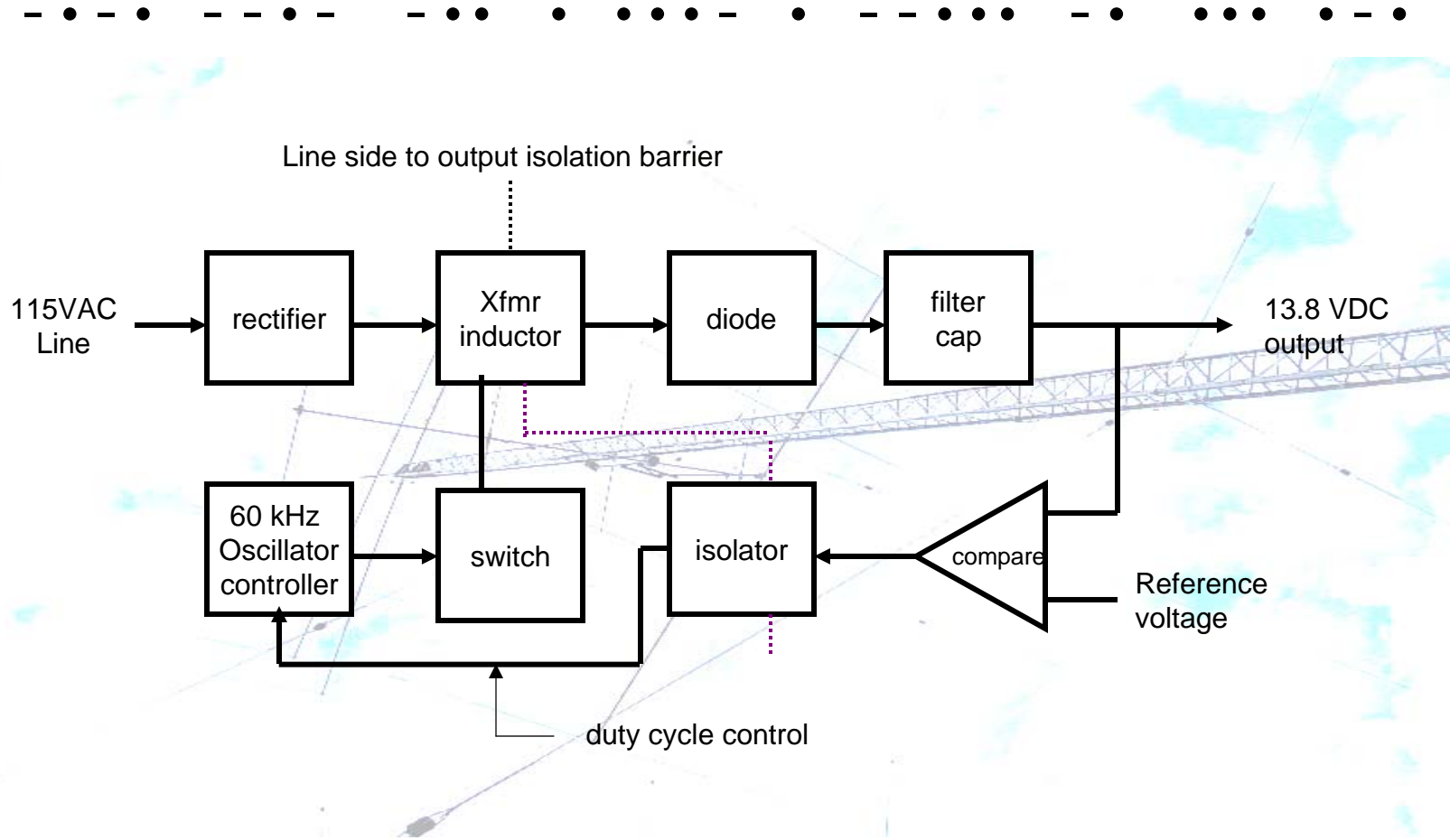


- Flyback converter



At 60kHz, energy is being transferred every 17 microseconds

Switch Mode Diagram



Duty Cycle Control



- Regulation achieved by varying the on – off time (duty cycle) of the 60kHz signal
- More “on” time (higher duty cycle) more energy is transferred, resulting in higher output voltage
- More “off” time, (lower duty cycle) less time, less energy, resulting in lower output voltage
- Regulator adjusts duty cycle such that output voltage remains constant as input voltage or output current changes

Low duty cycle – more off time



High duty cycle – more on time

Efficiency

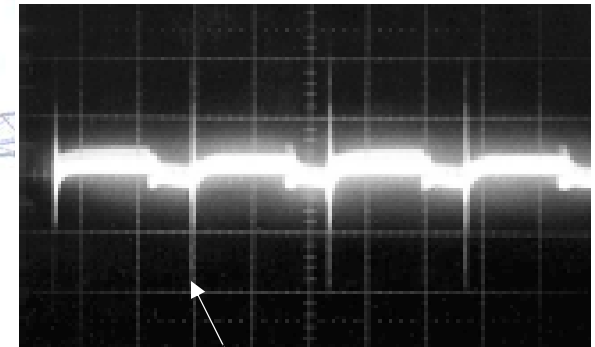


- **Switcher is highly efficient, typically 85 to 90%**
- **Cool parts**
- **Linear supplies are inefficient, typically < 40%**
- **Hot parts**

Switcher Noise



- Turning a transistor on and off at a 60 kHz rate, when passing amps of current, at 100's of volts generates harmonics well into RF spectrum
- “Egads, my switcher is S7 on 20m”
- Choose switcher that is QUIET



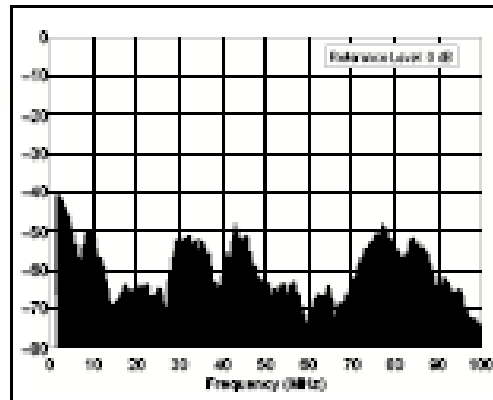
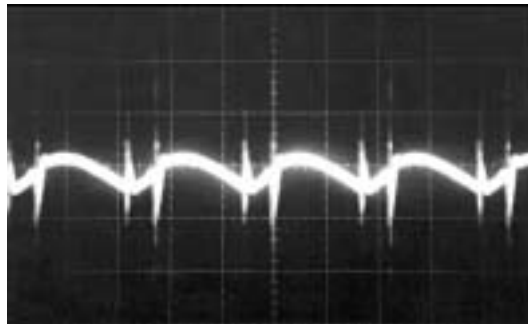
Jiggers & Gizzies
technically known as switching transients
Bob Widler / National Semiconductor / SK

Switcher Comparison

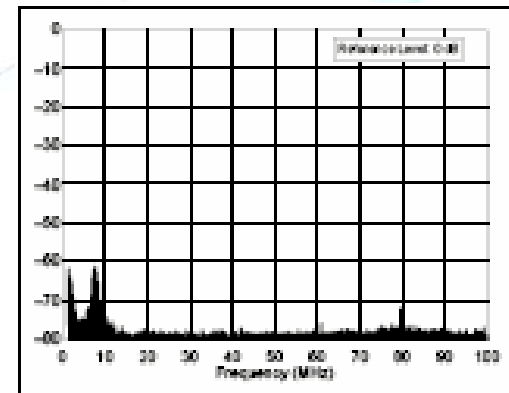
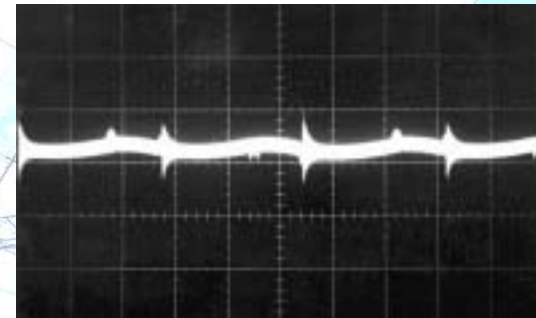


- **January 200 QST – Product review SMPS** (switch mode power supplies)

Icom IC-85
> 200 mV pk -pk



MFJ -4225
<10 mV pk to pk



The End

- Buy switcher for size and efficiency
- Buy linear for low noise and reliability



- Questions