Power Supplies and Overcurrent Protection (fuses)
Key Points

Power Supplies & Overcurrent Protection:

- know the 5 steps in a linear power supply
- know what the waveform is at each stage
- be familiar with common voltage regulator ICs
- know the 4 steps in a switching power supply
- know what the waveform is at each stage
- be prepared to identify ICs in different physical packages
- understand advantages and disadvantages of both types of P/S
- know about Apparent Power; when does VA = Watts?
- be able to specify a plug-in power supply
- know what functions a Power Entry module can provide
- know some families of fuses (1 1/4", 20mm)
- troubleshooting; Check, in order:
  > Line cords
  > Power entry
  > Fuses / Breakers
  > Capacitors
  > IC’s, transistors
Linear power supply

1. 120 VAC Input
2. Step-up/Step-down AC Voltage
3. Convert AC Voltage To DC Voltage
4. Filtering
5. Linear IC Voltage Regulation

Regulated DC Voltage Output
Linear power supply

- Line in
- Transformer
- Rectifier
- Filter
- Regulation

AC input to Rectifier

‘Lumpy DC’ output from Rectifier

+ peak
0 volts
- peak
+ peak
0 volts
Linear power supply

1) Line in (not shown here)
2) Transform (only the output is shown here)
3) Rectify (usually a 4-diode bridge)
4) Filter (usually a big cap & a small cap)
5) Regulate (often with 78xx & 79xx ICs on heat sinks)
National Semiconductor voltage regulators:

78xx series:  \( xx \) = + regulated voltage
79xx series:  \( xx \) = - regulated voltage

(May be an 8-pin DIP chip, a TO-220, or TO-3 package)

learn more: https://en.wikipedia.org/wiki/Linear_regulator
Shunt Transistor Voltage Regulator

120 V/60 Hz/0 Deg

Chassis Ground

BYM10-200

V_IN

Q1

Rs 100 Ω

Feedback

Q2

100 Ω

Offset Voltage

Zd

R1 1 kΩ

Load 1 kΩ

R1 and R2 create a voltage divider.
Typical Linear Power Supplies:

Advantages:
- Electronically simple
- Relatively inexpensive
- Fewer components to fail
- Can tolerate transients & spikes

Disadvantages:
- Inefficient
- Heavy
- Hot
IC Packages

8-pin DIP: Dual In-line Planer

SOT-223 (Surface Mount Devices)

TO-220

TO-263

TO-3
The Switching Power Supply

1) Input AC is rectified to DC and filtered.

2) DC is fed to switching transistors that chop it into a hi-freq square-wave.

3) The hi-freq square wave is then fed to a transformer that steps it down.

4) This low voltage output is then rectified and filtered as the output.
Why is this better?

- High freq transformers can carry more power than those at 60 Hz.
- High freq transformers can be much smaller.
- The filter caps can be much smaller at high freqs than at low freqs.
- The ON and OFF times (Duty Cycle) of the switching transistors automatically adjust according to the load.
- Very little power is wasted.
Simple Switching Power Supply

Diagram showing the components of a simple switching power supply:
- Bridge Rectifier
- Filter Capacitor
- Series Transistor Transformer
- Bridge Rectifier
- Filter Capacitor
- Bleeder Resistor

Graphs illustrating the voltage and time relationships:
- AC Voltage
- Unregulated DC
- Chopped DC
- High Frequency AC Voltage
- Regulated DC
Simple Switching Power Supply

Block Diagram of Basic Flyback Switchmode Power Supply
Feedback loop for regulation

Switching Transistor

Monostable Multivibrator

Voltage-Controlled Oscillator

Error amp

Voltage Reference

Unregulated DC Input

Regulated DC Output

A = B = C = D
(Constant Width/Duty Cycle)
Feedback loop for regulation

Switching Transistor

Free-Wheeling Diode (protects transistor from back-EMF coming from coil)

Unregulated DC Input

Error amp, Comparator and pulse-width modulator

Oscillator

Voltage Reference

Regulated DC Output

A = B = C
( Constant Rate/Frequency )
Switching Power Supplies:

**Advantages:**
- Very efficient - draw only the current needed
- Small and Light weight
- Run cool

**Disadvantages:**
- May be more expensive
- Less tolerant of overloads
- Potentially higher failure rate
‘Apparent power’ vs ‘True (or Real) Power’
or
VA vs Watts

Watts is Real Power - the power (V x A) that does work.
VA is Apparent Power - the vector sum (S) of real power (P) and reactive power (Q).

Reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they actually do dissipate power. This “phantom power” is called reactive power.


Apparent Power is used when sizing wiring and components.

Real Power is what accomplishes useful work in the device.

Apparent Power is always > Real Power if there is any reactive factor.

Power Factor = \( W / VA \) (0.60 is typical)
see the Condor supply in this Valleylab ESU?
The capacitor plague was a problem related to a higher-than-expected failure rate of non-solid aluminum electrolytic capacitors, between 1999 and 2007, especially those from some Taiwanese manufacturers, due to faulty electrolyte composition that caused corrosion accompanied by gas generation, often rupturing the case of the capacitor from the build-up of pressure.

High failure rates occurred in many well-known brands of electronics, and was particularly evident in motherboards, video cards, and power supplies of personal computers, leading to premature failure of these devices.

Industrial espionage was implicated in the capacitor plague, in connection with the theft of an electrolyte formula.

https://en.wikipedia.org/wiki/Capacitor_plague
Better than new:
## Onboard monitoring of power supply:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-28-09</td>
<td>16:36</td>
<td>M003</td>
<td>02 DIFF HIGH%</td>
</tr>
<tr>
<td>01-28-09</td>
<td>07:04</td>
<td>V050</td>
<td>LT SYS FAIL &gt;350</td>
</tr>
<tr>
<td>01-28-09</td>
<td>07:01</td>
<td>V050</td>
<td>LT SYS FAIL &gt;350</td>
</tr>
<tr>
<td>01-27-09</td>
<td>17:26</td>
<td>PS06</td>
<td>+28V SUPPLY FAILURE</td>
</tr>
<tr>
<td>01-27-09</td>
<td>07:44</td>
<td>V050</td>
<td>LT SYS FAIL &gt;350</td>
</tr>
<tr>
<td>01-23-09</td>
<td>14:07</td>
<td>PS02</td>
<td>-2.5V SUPPLY FAILURE</td>
</tr>
<tr>
<td>01-23-09</td>
<td>07:03</td>
<td>M003</td>
<td>02 DIFF HIGH%</td>
</tr>
</tbody>
</table>
Major Market Players in OEM Power Supplies:

> Sola
  > Condor
    > Lambda
    > Power One
Plug-in power supplies
Plug-in power supplies
- Allow manufacturers to internationalize easily.
- Requirements for meeting NRTL certification of the product is reduced by isolating the line-level circuitry.
- Lets the power supply manufacturer deal with the expense and liability of certification.
- Makes repair by the customer possible.

Choosing (or replacing) a plug-in supply "only" requires attention to these details:
1. input voltage and frequency (your national standard)
2. input connector (NEMA, IEC, or 17 other national standard plugs)
3. output voltage
4. output current (maximum available)
5. whether the output is DC or AC
6. for DC, whether the supply is:
   - linear un-regulated (must match load)
   - linear regulated
   - switching
7. if the power supply will fit physically where it needs to go

AND...
8. the output connector!
<table>
<thead>
<tr>
<th>Adaptaplug O.D.</th>
<th>I.D</th>
<th>Pin dia.</th>
<th>Standard Voltage range</th>
<th>Voltage range</th>
<th>Ring color</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.3 mm</td>
<td>0.7 mm</td>
<td>EIAJ-01</td>
<td>&lt; 3.15 V</td>
<td>Yellow</td>
</tr>
<tr>
<td>B</td>
<td>4.0 mm</td>
<td>1.7 mm</td>
<td>EIAJ-02</td>
<td>3.15 - 6.3 V</td>
<td>Yellow</td>
</tr>
<tr>
<td>C</td>
<td>4.7 mm</td>
<td>1.7 mm</td>
<td>EIAJ-03</td>
<td>6.3 - 10.5 V</td>
<td>Yellow</td>
</tr>
<tr>
<td>D</td>
<td>5.5 mm</td>
<td>3.3 mm</td>
<td>EIAJ-04</td>
<td>10.5 - 13.5 V</td>
<td>Yellow</td>
</tr>
<tr>
<td>E</td>
<td>2.5 mm</td>
<td>(3/32&quot; submini plug, no ID)</td>
<td></td>
<td></td>
<td>Black</td>
</tr>
<tr>
<td>F</td>
<td>3.5 mm</td>
<td>(1/8&quot; mini plug, no ID)</td>
<td></td>
<td></td>
<td>Black</td>
</tr>
<tr>
<td>G</td>
<td>3.0 mm</td>
<td>1.1 mm</td>
<td></td>
<td></td>
<td>Turquoise</td>
</tr>
<tr>
<td>H</td>
<td>3.4 mm</td>
<td>1.3 mm</td>
<td>IEC 60130-10 Type E</td>
<td></td>
<td>Orange</td>
</tr>
<tr>
<td>I</td>
<td>3.8 mm</td>
<td>1.1 mm</td>
<td>IEC 60130-10 Type C</td>
<td></td>
<td>Pink</td>
</tr>
<tr>
<td>J</td>
<td>5.0 mm</td>
<td>1.5 mm</td>
<td></td>
<td></td>
<td>Red</td>
</tr>
<tr>
<td>K</td>
<td>5.0 mm</td>
<td>2.1 mm</td>
<td></td>
<td></td>
<td>Purple</td>
</tr>
<tr>
<td>L</td>
<td>5.0 mm</td>
<td>2.5 mm</td>
<td></td>
<td></td>
<td>Dark Green</td>
</tr>
<tr>
<td>M</td>
<td>5.5 mm</td>
<td>2.1 mm</td>
<td>IEC 60130-10 Type A</td>
<td></td>
<td>Navy</td>
</tr>
<tr>
<td>N</td>
<td>5.5 mm</td>
<td>2.5 mm</td>
<td>IEC 60130-10 Type A</td>
<td></td>
<td>White</td>
</tr>
<tr>
<td>O</td>
<td>5.5 mm</td>
<td>2.8 mm</td>
<td></td>
<td></td>
<td>Brown</td>
</tr>
<tr>
<td>P</td>
<td>5.5 mm</td>
<td>3.8 mm</td>
<td></td>
<td></td>
<td>Not Specified</td>
</tr>
<tr>
<td>Q</td>
<td>6.3 mm</td>
<td>3.0 mm</td>
<td></td>
<td></td>
<td>Yellow-Green</td>
</tr>
<tr>
<td>R</td>
<td>6.9 mm</td>
<td>4.2 mm</td>
<td></td>
<td></td>
<td>Not Specified</td>
</tr>
<tr>
<td>S</td>
<td>5.5 mm</td>
<td>1.5 mm</td>
<td></td>
<td></td>
<td>Gray</td>
</tr>
<tr>
<td>T</td>
<td>6.5 mm</td>
<td>4.3 mm</td>
<td></td>
<td>EIAJ-05</td>
<td>13.5 - 18.0 V</td>
</tr>
<tr>
<td>U</td>
<td>6.5 mm</td>
<td>4.1 mm / 3.10 mm</td>
<td>1.0 mm</td>
<td>IEC 60130-10 Type D</td>
<td>Light Yellow</td>
</tr>
</tbody>
</table>
**Coaxial Power Connector (barrel connector)**

IEC 60130-10:1971 defines five DC power connectors.
- **Type A**: 5.5 mm OD, 2.1 mm ID (with optional screw lock)
- **Type A**: 5.5 mm OD, 2.5 mm ID (with optional screw lock)
- **Type B**: 6.0 mm OD, 2.1 mm ID
- **Type B**: 6.0 mm OD, 2.5 mm ID
- **Type C**: 3.8 mm OD, 1.4 mm ID
- **Type D**: 6.3 mm OD, 3.1 mm ID
- **Type E**: 3.4 mm OD, 1.3 mm ID

**EIAJ standard RC-5320A (JEITA RC-5320A)**

<table>
<thead>
<tr>
<th>O.D.(mm)</th>
<th>I.D.(mm)</th>
<th>Most manufacturers use a yellow insulating material.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIAJ-01 for 0–3.15 V</td>
<td>2.35</td>
<td>0.70</td>
</tr>
<tr>
<td>EIAJ-02 for 3.15–6.3 V</td>
<td>4.00</td>
<td>1.70</td>
</tr>
<tr>
<td>EIAJ-03 for 6.3–10.5 V</td>
<td>4.00</td>
<td>1.70</td>
</tr>
<tr>
<td>EIAJ-04 for 10.5–13.5 V (also called JSBP 4)</td>
<td>5.50</td>
<td>3.30</td>
</tr>
<tr>
<td>EIAJ-05 for 13.5–18 V (also called JSBP 5)</td>
<td>6.50</td>
<td>4.30</td>
</tr>
</tbody>
</table>

**DIN 45323**

- 5.00 mm OD, 2.00 mm ID, 14 mm long
- 6.00 mm OD, 1.98 mm ID

at least 45 sizes listed: https://en.wikipedia.org/wiki/Coaxial_power_connector#Listing_of_DC_coaxial_connectors

**Determining which size you need requires measurement with a caliper, inside and out.**

https://en.wikipedia.org/wiki/Coaxial_power_connector
Power Entry modules –

combine:
- cord connection (usually IEC C-14)
- fuses
- (sometimes) voltage selection (115 / 230 VAC)
- (sometimes) power switch
- (sometimes) filter / line conditioner
Interior fuse-holding module *may be reversible for 115 or 230 VAC* note: power conditioner built-in
Power entry module separate from power conditioner
Power Entry with power conditioner built-in:
Watch for interlock switches…
Fuses
Rated by:
- normal operating current
- speed of action
- maximum voltage
- overload current point
- physical dimensions & mounting options

confusing nomenclature?

164 pages of detail from Australia!

Fuses most commonly found in medical devices:

- 3AG style: $\frac{1}{4}'' \phi \times 1\frac{3}{4}''$ long
- Metric standard: $5 \text{ mm} \phi \times 20 \text{ mm} \text{ long}$
- Pico-fuses: axial-lead for board mounting
- Blade type ‘automotive-style’ fuses

Can be:

Fast acting or

Delayed Opening: Slow Blow (‘Slo-Blo’)

(absorbs brief current surges on start-up)
typical \( \frac{1}{4}'' \) by \( 1 \frac{1}{4}'' \) types

“3AG” style

(3 refers to size; AG originally stood for ‘All Glass’

)
"AGC" might stand for "automotive glass cartridge"
"MDL" might stand for "method detection limit"

It is generally understood that an "AGC" fuse is fast blow whereas an "MDL" fuse is slow blow
“M205” metric standard  5 mm by 20 mm fuses
PC board mounted fuses
(often called “automotive blade fuses”)

- micro2, micro3, low-profile mini (APS)
- mini (APM / ATM)
- regular (APR / ATC / ATO)
- maxi (APX) heavy-duty

https://en.wikipedia.org/wiki/Fuse_(electrical)
typical cartridge fuses
Sometimes the fuse doesn’t fail first

failure inside a Corcom Power Entry module
Fuses are **protective** devices.

When a fuse opens-up, it has protected a part of a device.

But always ask: **Why did it open-up?**

- natural failure of the fuse?
- a transient current spike?
- high current draw due to a circuit failure downstream?
Fuses are always placed on the hot (Line) side of the power input. Often on the neutral leg as well.
Major players in fuses and breakers:

- **Cooper / Bussman**
  - use letters for their models
  - *eg* AGC, MDL, GMC

- **Littelfuse Corp**
  - use numbers and letters
  - *eg* 312xxx, 313xxx, 235.xxx
Troubleshooting Power Supply Issues

Check, in order:

> Line cords

> Power entry

> Fuses / Breakers

> Capacitors

> IC’s, transistors