Purpose and Function

The original power supply used a resistance line cord for the filament voltage, and used the household mains directly into the rectifier for the plate power supply.

The line cord, rectifier, RI and the electrolytic condenser form the "power supply". It is the function of all these parts to supply the proper voltages for the tube. The power supply will be found in all the circuits you will build.

The line cord provided with the "Edu-Kit" is a special type, known as a "Resistance Line COTd". This line cord contains two wires (known as "conductors") and a resistance wire. You will notice that a standard 2-prong plug is used. However, the line cord terminates in three wires.

The line cord has the function of supplying the 105-120 Volt AC or DC to the radio which you build. In addition, the resistance wire of the line cord reduces the 105-120 Volt AC or DC to a lower voltage suitable for the filaments of the tubes. It is normal for the line cord to become quite warm during operation. This is due to the fact that heavy current flows through the resistance wire.

The line cord uses a color code for the three wires. These wires are identified by number on the schematics. Wire 3 is always connected to the chassis. It's purpose is to act as the return path for the electricity. Wire 2 supplies the 105-120 Volt AC or DC to the rectifier. Wire 1 is the resistance wire, which reduces the 105-120 Volt AC or DC to the proper voltage required by the filaments of the tubes.

Selenium Rectifier: used to convert the 60 cycles AC (common home electric supply) to the proper amount of DC required by Tube 1. If the home electric supply happens to be DC, the selenium rectifier does not change it; the DC passes through the rectifier, and is used by Tube 1. In this manner, Tube 1 receives a DC voltage regardless of whether the home electric supply is AC or DC.
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Plate Power Supply

Line Cord: has the double function of supplying the 105-120 Volt AC or DC home electric supply to the selenium rectifier, and also of supplying the filament of the tube with the proper voltage. Since the filament of the tube requires a low voltage (approximately 6 volts), this line cord has a built-in resistor, which reduces the incoming 105-120 volts to approximately 6 volts for the filament. The filament can use either AC or DC. Therefore the power for the filament does not have to be rectified. The home electric supply is reduced to a lower voltage, but is not changed to DC. If the available supply is 105-120 volts AC, the filament will receive approximately 6 volts AC; if the available supply is 105-120 volts DC, the filament will receive approximately 6 volts DC. During operation, the line cord will feel very warm. This is due to the built-in resistance, and is normal. Since only a very small voltage is required by the filament of the tube, the rest of the voltage must be removed. This is done by changing the excess voltage to heat.

For safety I have modified the power supply by adding an isolation transformer for the plate voltage, and a step down transformer for the filament supply. In addition I have added a 47K bleeder resistor to ground from lead 1 of the Electrolytic Capacitor.

The plate power supply uses an isolation transformer(s) followed by a simple half wave rectifier followed by a low pass filter. The original design of the plate power supply used the AC mains directly into the rectifier circuit with no isolation transformer. The Plate power supply supplies about 116 Vdc.

The Filament power supply uses a step down transformer. The original design used a resistance of about 300 ohms to drop the line voltage directly. The Filament supply is about 6.3Vac.
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Theory and Design
Rectified Voltage (no load)
- The rectified voltage approaches the peak voltage of the input from the transformer.
- $V_{\text{rectified}} \approx \sqrt{2} \cdot V_{\text{rms}}^{\text{peak}}$

Rectified Ripple Voltage
- $C \cdot V_{p-p_{\text{ripple}}} = I \cdot t$
- Dividing both sides by $C$ we get
  - $V_{p-p_{\text{ripple}}} = \frac{I \cdot T}{C}$

Filtered Voltage
- The output voltage is determined by the Rectified voltage and a simple voltage divider consisting of $R_1$ and $R_{\text{load}}$
  - $V_{\text{out}} = V_{\text{Rectified average}} \left( \frac{R_{\text{load}}}{R_1 + R_{\text{load}}} \right)$
- The total resistance of $R_1$ and $R_{\text{load}}$ is determined by
  - $R_1 + R_{\text{load}} \approx \frac{V_{\text{peak}}}{I_{\text{max}}}$
  - $I_{\text{max}}$ is determined by the sum from the data sheets for the three tubes
  - $R_{\text{load}} = \frac{V_{\text{peak}}}{I_{\text{max}}} - R_1$

Filtered Ripple Voltage
- The Cutoff frequency for an RC Filter is given by
  - $F_c = \frac{1}{2\pi RC}$

Diode Current Requirements
- If we assume that the power switch may be thrown at its peak voltage level and that the electrolytic capacitor(s) are at 0 volts then the Diode will have an (inrush) current constrained only by the input resistance of the transformer.
- $I_{\text{max}} = \frac{V_{\text{peak}}}{R_{\text{transformer}}}$

Diode Voltage Requirements
- The peak inverse voltage occurs when the Rectifier Capacitor is fully charged and $V_{\text{in}}$ is at the peak negative voltage. This is $\approx 2 \cdot V_{\text{rectified}}$. 
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Plate Power Supply

Calculated

Rectified Voltage (no load)
- $V_{\text{rectified}} \sim V_{\text{peak}} = \sqrt{2} * V_{\text{rms}}$  
  - $V_{\text{rectified}} \sim V_{\text{peak}} = \sqrt{2} * 120$
  - $V_{\text{rectified}} \sim 170 \text{ Volts}$

Rectified Ripple Voltage
- $C * V_{\text{p-p ripple}} = I * T$  
  - $V_{\text{p-p ripple}} = \frac{I * T}{C}$
  - $I$ is determined by the load
    - The worst case $I$ would be the max plate current of all three tubes in the kit
    - $I_{\text{plate max}} 6C5GT = 8 \text{ mA}$
    - $I_{\text{plate max}} 6SD7GT = 6 \text{ mA}$
  - $I_{\text{max}} = 8 + 2 * 6 \text{ mA} = 20 \text{ mA}$
  - $C_{1a} = 33 \text{ uF}$ (Note book calls for 20 uF but the available part is 33 uF)
  - $T$ is 1/60 Hz
  - $V_{\text{p-p ripple}} = \frac{20mA * 1/60}{33\mu F}$
  - $V_{\text{p-p ripple}} = 10 \text{ Vp-p}$

Filtered Voltage
- $R1 + R_{\text{load}} \sim V_{\text{peak}}/I_{\text{max}}$
  - $R1 + R_{\text{load}} = 170V/20 \text{ Ma}$
  - $R1 + R_{\text{load}} = 8.5K$
  - $R_{\text{load}} = 8.5K - 3.9K$
  - $R_{\text{load}} = 4.6K$
  - $V_{\text{out}} = V_{\text{Rectified average}} \left( \frac{R_{\text{load}}}{R1 + R_{\text{load}}} \right)$
  - $V_{\text{out}} = V_{\text{Rectified average}} \left( \frac{V_{\text{ripple}}}{2} * \left( \frac{R_{\text{load}}}{R1 + R_{\text{load}}} \right) \right)$
  - $V_{\text{out}} = 170 - \frac{10}{2} * \left( \frac{4.6K}{3.9K + 4.6K} \right)$
  - $V_{\text{out}} = 89.3 \text{ Volts}$

Filtered Ripple Voltage
- The Cutoff frequency for an RC Filter is given by
  - $F_c = \frac{1}{2\pi RC}$
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Plate Power Supply

- \( F_c = \frac{1}{2\pi \times 3.9K \times 47uF} \) (Note book calls for 20 uF but the available part is 47 uF)
- \( F_c = 0.868 \text{ Hz!} \)
  - This almost 2 orders of magnitude lower than the ripple frequency of 60 Hz so the output will have little or no ripple
- \( V_{out\_ripple} \approx 0 \text{ Volts} \)

**Diode Current Requirements**
- The input resistance of the line transformer was measured at 11.25 ohms
  - \( I_{\_\text{max}} = \frac{V_{\text{peak}}}{R_{\text{transformer}}} \)
  - \( I_{\_\text{max}} = \frac{170}{11.25\text{Ohms}} \)
  - \( I_{\text{max}} = 15.1 \text{ Amps} \)
- The 1N5406 diode that I used has an Ifsm of 200 Amps
  - Simulations show that with 11.25 ohms and 33 uF that we will be below the max Average rectified current in less that ½ cycle (~1 msec)

**Diode Voltage Requirements**
- The peak inverse voltage occurs when the Rectifier Capacitor is fully charged and Vin is at the peak negative voltage. This is \( \approx 2*V_{\text{rectified}} \).
  - \( V_{\text{rev}} = 2*170 \)
  - \( V_{\text{rev}} = 340 \text{ Volts} \)
Simulation

R\text{load} was calculated as the worst load the Circuit will see. Imax = 20\text{ma} (see calculated Filter Voltage above)

- R\text{load} = 4.6\text{K}

\begin{align*}
\text{V1 is} & \text{ 170 Vpeak at 60 Hz} \\
\text{Rectified Voltage (no load)} & \\
\text{• Vrectified} & = 169.1 \text{ Volts} \\
\text{Rectified Ripple Voltage} & 
\end{align*}
• \( V_{p-p\_ripple} = V_{max} - V_{min} \)
• \( V_{p-p\_ripple} = 169.2 - 160.0 \)
• \( V_{p-p\_ripple} = 9.2 \text{ Vp-p} \)

Filtered Voltage
• \( V_{out} = 89.1 \text{ Volts} \)

Filtered Ripple Voltage
• \( V_{out\_ripple} = 89.14 - 89.04 \)
• \( V_{out\_ripple} = 0.1 \text{ Volts} \)
Real Circuit

- Note the line voltage was a little low 113 Vrms compared to 120Vrms used for calculations and simulation.

- The initial measurements were without a load as I could not find 4.6K resistor that could take over 5 watts

Rectified Voltage

- \( V_{\text{rectified}} = 154.1 \text{ Volts (no load)} \)
- \( V_{\text{rectified}} = 148.6 \text{ Volts (1 tube Triode Grid Leak Detector)} \)

Rectified Ripple Voltage

- \( V_{\text{p-p ripple}} = 59\text{mVp-p (no load)} \)
- \( V_{\text{p-p ripple}} = 3.32\text{Vp-p (1 tube Triode Grid Leak Detector)} \)

- See section below for scope trace
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Filtered Voltage (no load)

- Vout = 154.1 Volts (no load)
- Vout = 117.9 Volts (1 tube Triode Grid Leak Detector)

Filtered Ripple Voltage

- Vout_ripple = 4 mVp-p (no load)

- Vout_ripple = 75 mVp-p (1 tube Triode Grid Leak Detector)
  - Upper trace is 1 tube Triode Grid Leak Detector rectified ripple voltage
  - Lower trace is 1 tube Triode Grid Leak Detector filtered ripple voltage
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Comparison

- The difference in ripple between calculated and simulation is probably due to the real verses calculated minimum Rload.
- The table below compares the results

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<th>Real-Measured</th>
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<th>Calculated</th>
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<td>Filtered Ripple Voltage Vp-p</td>
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<td>0.1</td>
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Plate Power Supply

References

2. UNKNOWN, The ARRL Handbook For Radio Communications, (ARRL 2012) p7.5, (Eq. 1)