Documentation for Power Supply Project

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1 Requirements

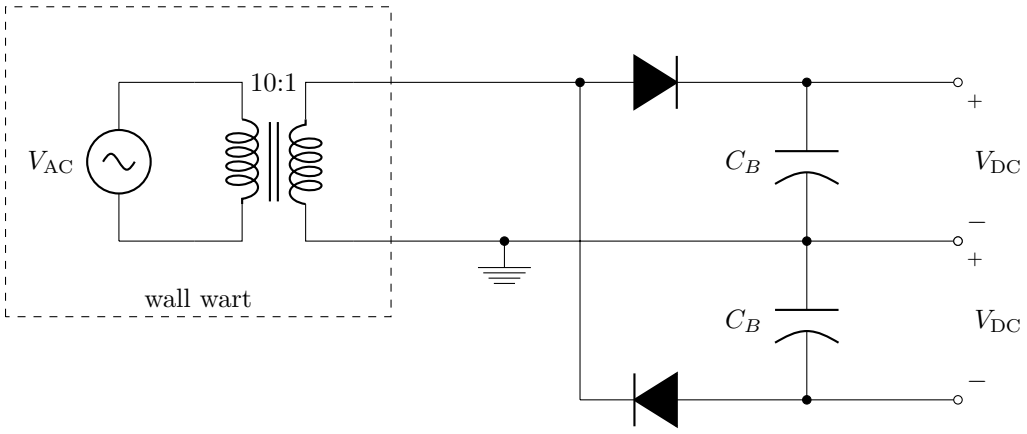
- one dual-polarity output channel; i.e. one positive and one negative output equidistant from ground
- output voltage range: up to 12 V
- current limit adjustable from 0 mA to 300 mA
- seven-segment displays for current and voltage setpoints
- knob to set current and voltage limits
- output on/off switch
- indicator light for constant current or constant voltage. Perhaps this could be an LED indicating the output is on with a separate LED for constant current mode.

2 Components

- voltage regulation is accomplished using an LM317 for the positive rail and an LM337 for the negative rail
- power input to the module is through a 15 V, 1 A AC-to-AC power adapter

3 AC Input and Rectification

3.1 Schematic



	LM317	LM337	Unit
$R_{\theta JA}$	23.3	22.9	°C/W
$R_{\theta JC(\text{top})}$	16.2	15.7	°C/W
$R_{\theta JB}$	4.9	4.1	°C/W
$R_{\theta JC(\text{bot})}$	1.1	1.0	°C/W

Table 1: Thermal parameters for LM317-N and LM337-N linear regulators in the T0-220 package.

3.2 Peak Input Voltage

Using a 12 V RMS AC input, the peak input voltage will be

$$12\,\text{V RMS} \times \sqrt{2} \approx 17\,\text{V}$$

3.3 Ripple Voltage

In a half-wave rectifier, peak-to-peak ripple voltage is given by Equation (1) for a given line frequency f, bulk capacitance C_B, and load current I.

$$V_{\text{ripple}} = \frac{I}{f\,C_B} \tag{1}$$

When unloaded, the output of the rectifier has no ripple. The ripple voltage increases linearly with load current. The LM317 and LM337 regulators require a minimum load current of 10 mA. At this minimum load current, and with a bulk capacitance of 3300 µF, the ripple voltage will be

$$\frac{0.01\,\text{A}}{(60\,\text{Hz})(3300\,\mu\text{F})} \approx 51\,\text{mV}$$

At the supply's maximum load current of 300 mA, the ripple voltage will be

$$\frac{0.3\,\text{A}}{(60\,\text{Hz})(3300\,\mu\text{F})} \approx 1.5\,\text{V}$$

3.4 Rectified Output Voltage

The maximum voltage at the output of the rectification is given by

$$V_{\text{DC max}} = V_{\text{peak}} - V_{\text{diode min}} = 17\,\text{V} - 0.8\,\text{V} = 16.2\,\text{V}$$

The minimum voltage at the output of the rectification circuit, is given by

$$V_{\text{DC min}} = V_{\text{peak}} - V_{\text{diode max}} - V_{\text{ripple}} = 17\,\text{V} - 1.1\,\text{V} - 1.5\,\text{V} = 14.4\,\text{V}$$

The 7812 and 7912 fixed ±12 V regulators each have a dropout voltage of 2 V, and therefore will operate correctly off of a 14.4 V supply. The LM317-N and LM337-N regulators have a dropout voltage of less than 2 V, and therefore will also operate correctly at least up to the supply's maximum rated output of 12 V.

4 Power Dissipation

Maximum power dissipation is with V_{out} minimized, i.e. $V_{\text{out}} = 1.25\,\text{V}$.

$$P_{\text{max}} = I_{\text{max}}(V_{\text{DC max}} - V_{o\ \text{min}}) = 300\,\text{mA} \times (16.2\,\text{V} - 1.25\,\text{V}) = 4.49\,\text{W}$$

The LM317-N and LM337-N thermal parameters (for T0-220 packages) are given in Table 1. Both parts have a maximum operating temperature of 125 °C. A maximum design temperature of 100 °C was selected to give plenty of margin to the datasheet maximum temperature. With heatsinks installed, the overall thermal

resistance from junction to ambient is the sum of the thermal resistances from junction to the bottom of the case, the bottom of the case to the heatsink, and the heatsink to ambient:

$$R_{\theta\text{overall}} = R_{\theta JC(\text{bot})} + R_{\theta C(\text{bot})S} + R_{\theta SA}$$

The junction temperature is:

$$T_J = T_A + R_{\theta\text{overall}} \times P_{\max}$$

At an ambient temperature T_A of 50 °C, the maximum $R_{\theta\text{overall}}$ that gives a junction temperature lower than the design maximum temperature is 11.15 °C/W.

Using $R_{\theta C(\text{bot})S} = 0.5\,°\text{C/W}$ (typical for a heat conducting pad on a TO-220 package, according to *The Art of Electronics*), gives $R_{\theta SA\ \max} = 9.55\,°\text{C/W}$ for the LM317 and 9.65 °C/W for the LM337.

5 Control

Options

- PID loop in software: encoder sets setpoint, DAC/amp generates adj voltage, ADC measures actual output voltage, PID loop corrects
- hardware feedback loop: DAC/amp generates desired output voltage, opamp feedback loop compares output to desired output voltage

6 Ideas for a future version with more features

- two mutually isolated primary voltage channels
- each channel has a variable voltage from 0 V to 15 V
- each channel has a variable current limit from 0 A to 1 A
- third output channel for logic? Perhaps with voltage and current limits selectable from certain presets, i.e. 1.8 V, 2.5 V, 3.3 V, 5 V, and 12 V, and 0.1 A, 0.25 A, 0.5 A, 1.0 A, and 2.0 A.
- selectable voltage tracking between two primary channels
- seven-segment displays for set voltage and current limits for primary channels (i.e. four separate displays
- output enable/disable toggles for each channel
- output enable LED for each channel
- current-limit warning LED for each channel
- separate 10-turn control knobs for each channel's current and voltage controls