Lab Power Supply Manual

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1 Acknowledgments

The creation of this lab power supply was generously funded by the Reed College Physics Department. I would like to thank Edgar Perez for his kind advice, as well as Lucas Illing for supporting this project.

2 Motivation

Often when working in electronics, several voltage sources are needed. In addition to a main power rail, one may need a complementary negative power rail for analog circuitry, or a different logic power supply at 3.3 V instead of 5 V. Low-impedance bias voltages are also a frequent requirement, needed for biasing BJTs, comparator inputs, and more.

For most applications, a power supply fulfilling the requirements of these applications need not be capable of supplying much more than 1 A of current, must have a stable voltage output (requiring a linear regulator), and must have a current limiting function. Additionally, it would be nice if the power supply was much smaller than a conventional 30 V, 3 A output bench power supply with a large transformer, being conveniently powered from a common wall plug, batteries, or any other DC power source at hand. I have attempted to construct such a power supply.

3 Safety Notice (Grounding)

Please note that the negative voltage output of the supply is directly connected to the negative voltage input to the supply. That is, the output voltage of the supply floating relative to earth ground if and only if the input voltage is floating.

If you are uncertain if the supply (or any other piece of equipment) is floating, it is quick and simple to check if this is the case. Set a digital multimeter to its resistance measurement or continuity check mode. Connect one probe to the negative output of the PSU (the black five-way binding post) or to the other terminal in question, and then connect the other probe to earth ground.

This can be done either by insertion in to the *earth* socket of a wall outlet, or by touching the outside of a BNC connector on any nearby oscilloscopes, as these are almost always earth grounded. If inserting into a wall outlet, be certain that you know which hole is which, and that you are using a multimeter approved for wall testing (most are).

If the output is not floating (earth-referenced), then one must be careful to only connect oscilloscope ground leads to the negative output of the supply. Whatever the ground lead is connected to will be shorted to earth ground. If an incorrect connection is made, then connected circuit components, oscilloscopes, or computers (*e.g.* through USB) may be damaged. If you are uncertain, connect probes as if the circuit is not floating.

If the output is floating (or if you know which terminals are earthed and which are not), then the supply may be safely connected to other voltage sources in whatever configurations are convenient, such as in a dual-rail setup.

4 Usage Instructions

4.1 Setting the output voltage

Connect a voltmeter to the output of the supply. You may use either the binding posts or the test points labeled on the board to achieve this. Turn the PSU on and adjust the voltage using the *coarse* and *fine* adjustment knobs as needed. Note that the maximum output voltage is about 1.5 V below the input voltage.

4.2 Setting the current limit

To set the current limit to its minimum value, *short* the minimum limit jumper (labeled *Min Lim*, `JP1`). To set the current limit to higher than this value, the jumper must be *open*.

The current limit is set to fixed values by moving the switches on the board. The default values are 1, 2.5, 5, 10, 25, 50, and 100 mA. To set the limit to any of the upper four values, the switch for the lower values must be in its rightmost position, as indicated on the board.

Alternatively, the switch section on the board may not be populated, and a 10 kΩ (preferably 10-turn) potentiometer (`RV4`) may be soldered in to provide a continuously variable current limit.

To set the current limit to its maximum value, *open* the no limit jumper (labeled *No Limit*, `JP2`). To set the current limit to lower than this value, the jumper must be *shorted*. The maximum value is about 2.0 A in normal operation, and less when the device shuts down to prevent overheating.

4.3 Indicator LEDs

The power supply includes two indicator LEDs for when output voltage regulation is not guaranteed.

The *Hot* indicator LED (`D2`) lights when the main regulation IC (see Section 6.1) starts to get hot (when the junction temperature is about 100 °C or above). This light is a warning, and the output should continue to be regulated as normal. If the IC continues to heat up (to a junction temperature of 125 °C), then internal protection circuitry will prevent damage and reduce the output voltage.

The V_{out} *Error (I lim)* indicator LED (`D1`) lights when the actual output voltage is not sufficiently close to the set output voltage. The most common cause for this is if the current limiting function is active, but internal protection circuitry or a set voltage that is too high may also cause an output error.

4.4 Monitoring the output current

If it is not preferred to use an ammeter to measure the output current, the I_{out} test point is provided for convenient measurement or external control of the load current. The signal at I_{out} is one volt for every ampere of output current, *including the internal load* (see Sections 5 and 6.2). For example, if the supply is outputting 25 mA total, then I_{out} should read 25 mV.

4.5 Monitoring the internal temperature

For more quantitative information about the temperature of the main regulation IC (see Section 6.1) than is provided by the *Hot* indicator LED, the *Temp* test point is provided. The signal at *Temp* is one millivolt for every degree Celsius of junction temperature. For example, if the junction temperature of the IC is about 73 °C (subject to variation inside the IC), then *Temp* should read 73 mV.

4.6 Calibrating the current limit

The power supply requires a minimum load in order to regulate the output voltage properly. An internal load usually supplies this minimum load (see Section 6.2), but this offsets the effective current limit on the output. A trimmer potentiometer is provided to compensate for this offset.

Set the supply to the minimum limit as described in Section 4.2. Using a screwdriver, adjust the potentiometer (labeled *Load Offset*, `RV1`) until the output voltage is stable (no current limiting), and then carefully reverse direction and adjust until the current limit just starts to activate. This may be judged by checking the output voltage with a voltmeter, or by using the built-in indicator if it is calibrated as described in Section 4.7

4.7 Calibrating the output error indicator

The issues associated with creating a reliable output error indicator are discussed in Section 6.3. If necessary, a trimmer potentiometer (`RV5`) may be populated to correct the default setting by the resistor `R21`.

Attach a voltmeter to the PSU and set the output voltage to 1 V. Attach an external potentiometer to the output of the supply, valued to draw a typical current for your application. Set the PSU current limit so that increasing the load current will trigger the limit function. If the 1 V output does not demand enough current, it may be increased, but try to keep it as low as possible (see 6.3 for why). Wait until the temperature of the circuit has stabilized. Error on the side of drawing a slightly lower current than needed, depending on the sensitivity required (see below). Increase the load gradually, and watch the error indicator LED (`D1`).

If the default indication threshold set by `R21` is not sensitive enough for your needs, solder in the 500 kΩ `RV5` and try the adjustment procedure below.

If this does not work, or if the default indication did not work at all, solder in `RV5` and *remove* `R21`. This provides a wider range of variation for the indication threshold, at the cost of a coarser adjustment rate.

With the potentiometer `RV5` and the default resistor `R21` soldered on the board or not depending on your needs, adjust the external load potentiometer until the output is 2 – 10 mV below the set voltage. If you intend to use the supply *only* above about 5 V, the lower the better (you may even be able to remove `RV5` and wire a short across `R21` for a bit more sensitivity). To complete the calibration, adjust `RV5` to the barrier where `D1` just barely lights, or perhaps flickers.

5 Electrical Characteristics

6 Principles of Operation

6.1 The LT3081 linear regulator

6.2 The internal load

6.3 The V_{out} error indicator circuit

7 Schematic Diagram

8 Printed Circuit Board Footprints

9 Bill of Materials

10 Colophon

The schematic diagram and printed circuit board layout were both created with KiCAD. This manual was compiled using LaTeX. Relatively fine (0.51 mm) lead-based solder and mildly activated rosin flux were required to solder the components to the PCB.

Table 1: Electrical Characteristics. The ⧫ mark indicates specifications which apply over the full operating temperature range. Otherwise, specifications are at (junction) temperatures of 25 °C.

Parameter		Conditions	Min	Typ	Max	Units
Input Voltage	V_{in}	⧫	5		32	V
Input Voltage	V_{in}	⧫	5		32	V
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