Lab Power Supply Manual
Rev. B

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July 8, 2019

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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.

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 5.1) 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 Table 1 and Section 5.2). 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 5.1) 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 Disabling the internal load

The internal load may be disabled by *opening* the *Internal Load* jumper. Note that this will increase the current limit by at most 4 mA above the current limit displayed on the switches or that previously set by `RV4`, if installed. For most purposes, the *Internal Load* jumper should be in its normal, *shorted* position (see Section 5.2).

4.7 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 5.2), but this offsets the effective current limit on the output. A trimmer potentiometer is provided to compensate for this offset.

First, choose which current limit range you most value precision on, say the 10 mA range. Set the supply to a relatively low voltage, like 1 V, and place the appropriate load on the output of the supply with a potentiometer. In this case, we would adjust a potentiometer until it drew 10 mA through itself. The V_{out} *Error (I lim)* indicator LED should be off. Measuring I_{out} should show about 13 mV, corresponding the 10 mA external load and the (fixed) 3 mA internal load. 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 4.8. If using a voltmeter (the more precise method), aim for a limit situation where the output is about 10 mV below the set (stable) voltage.

4.8 Calibrating the output error indicator

The issues associated with creating a reliable output error indicator are discussed in Section 5.4. 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 5.4 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 Principles of Operation

5.1 The LT3081 linear regulator

All of the regulation that the power supply provides is done by the LT3081, a rugged linear regulator IC. The regulation circuitry is depicted in Figure 1. An internal current source of 50 µA allows the set voltage to be configured with a single resistor R_{set}. In the power supply, R_{set} is determined by the two potentiometers RV2 and RV3.

If $V_{\text{out}} < V_{\text{set}}$, then the error amplifier will increase the base voltage of the NPN transistor until the entire Sziklai pair has V_{set} at its emitter. Similarly, the base voltage will be suitably reduced if $V_{\text{out}} > V_{\text{set}}$. In this way, the output voltage is regulated by a negative feedback loop.

In practice, it may be difficult to stabilize such a circuit constructed of discrete components against oscillation. Using an integrated circuit solution such as the LT3081 allows us to have matched transistors at close to the same temperature, as well as to take advantage of the work done by previous engineers to make the output voltage stable. We simply add on some additional capacitances (C1 to C4 and C8) to improve noise characteristics, transcient performance, and stability a bit more.

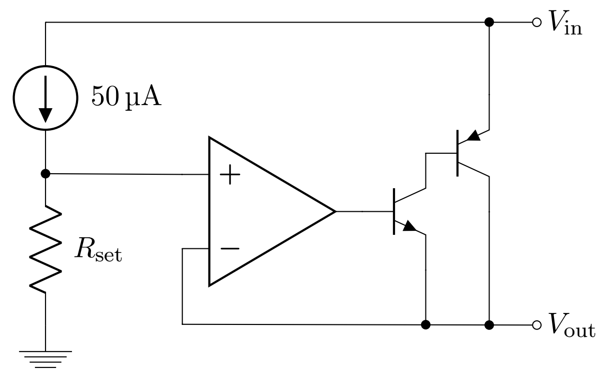


Figure 1: The equivalent voltage regulation circuitry inside the LT3081. The equivalent current regulation circuitry is not depicted here or in the LT3081 datasheet.

5.2 The internal load

Given the requirement that any circuitry used in the power supply must function consistently over the entire range of V_{in}, a simple resistor (as in the LT3081 datasheet) *cannot* be used as a means of meeting the minimum load requirement of the LT3081. Instead, the LM334 current source (U4) was used. With R23 set to 22 Ω, we expect about 3.1 mA to be sunk from the output of the power supply, which is well above the minimum load requirement of the LM3081, over temperature. Since we are manually nulling the offset due to this current, it is allowable to use a common through-hole 5 % tolerance resistor for R23, but if your application requires precise current limiting over a wide and changing range of temperatures, a 1 % or better tolerance resistor should be used for added thermal stability.

5.3 The *Hot* indicator circuit

To establish a precise voltage of 100 mV over the entire range of V_{in}, corresponding to a junction temperature of 100 °C, a 2.5 V LM4040 voltage reference (U1) and a voltage divider were used. The LM393 comparator (U3B) compares the *Temp* output to this reference temperature, and is configured to pull the open collector output of the comparator low if the *Temp* output goes above the reference. This connects the indicator LED to ground. A LM317 (U6) configured as a cur-

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. Note that application of negative input voltages may damage the supply. Specifically, such damage tends to disable any current limiting functionality, while maintaining the capability for voltage regulation.

Parameter		Conditions		Min	Typ	Max	Units
Input Voltage	V_{in}		⧫	5.0		32.0	V
Output Voltage	V_{out}	$I_{load} < I_{lim}$, $V_{in} < 16\,V$	⧫	0.7		$V_{in} - V_{do}$	V
		$I_{load} < I_{lim}$, $V_{in} \geq 16\,V$	⧫	0.7		16	V
		No internal load	⧫	0.0			V
Dropout Voltage	V_{do}	$I_{load} = 100\,mA$			1.21		V
		$I_{load} = 1.5\,A$	⧫		1.23	1.5	V
Internal Current Limit	I_{max}	$V_{in} = 5\,V$, $V_{set} = 0\,V$, $V_{out} = -0.1\,V$	⧫	1.5	2.0		A
I_{out} Relative Error		$I_{load} = 1.5\,A$		0	6	11	%
I_{out} Operating Range			⧫	$V_{out} - 40\,V$		$V_{out} + 0.4\,V$	V
Temp Absolute Error		$0\,°C \leq T_J \leq 125\,°C$		-10		10	µA
		$125\,°C < T_J \leq 150\,°C$		-15		15	µA
Ripple Rejection	PSRR	$f = 120\,Hz$		75	90		dB
$V_{ripple} = 0.5\,V_{pp}$, $I_{load} = 0.1\,A$,		$f = 10\,kHz$			75		dB
$V_{in} = V_{out(nom)} + 3\,V$		$f = 1\,MHz$			20		dB
Internal Load	I_{int}		⧫	2	3	4	mA

rent source supplies a stable current to the LED over the full range of V_{in}. Inspection of the circuit shows that errors introduced by resistor tolerances and comparator input offset currents and voltages will result in an absolute error of at most 5 °C. Furthermore, the comparator operates without hysteresis, so the LED may flicker when the actual and reference temperatures coincide. For the purpose of a coarse temperature indication, these undesirable characteristics are inconsequential.

5.4 The V_{out} error indicator circuit

The general configuration of the V_{out} error indicator circuit is similar to that of the *Hot* indicator circuit, described in Section 5.3. However, the error introduced by that circuit is unacceptable for the purpose of displaying the current status of regulation. Additionally, we *expect* the output voltage to coincide *precisely* (to within a few millivolts) with the set voltage. Without any correction, the LED may reasonably indicate an error indefinitely, or at least flicker, when the output voltage is actually well-regulated.

The standard solution that one may propose is to add hysteresis (in the form of a Schmitt trigger) to the comparator. This will not work. A Schmitt trigger must have an upper trigger threshold that lies *above* the set voltage, but in the course of recovering from current limiting, the output voltage may never overshoot the set voltage. Thus the threshold will never be crossed, and the error indicator may remain on indefinitely. What is needed instead, is a small offset.

If the comparator recieved a set voltage that was, say, 10 mV below V_{set}, then the problem is solved. Hysteresis is not even needed, since most all causes for a failure in regulation will not manifest as a steady offset of 10 mV. But how can we create such a small offset over the entire range of V_{out}, especially when the offset is comparable in size to all of the sources of error involved? The main barriers to control that must be addressed include

- Resistor tolerances,
- Loading of input sources,
- Comparator input offset voltage,
- Comparator input bias current,
- Comparator input offset current, and
- Noise.

Since the entire point of adding the offset is to allow for errors, we can deal with the comparator input offset voltage and current by lumping in the

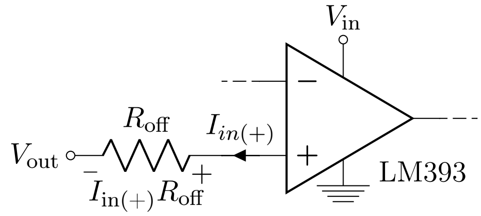


Figure 2: Introducing a small voltage offset by exploiting the input bias current of the LM393 comparator.

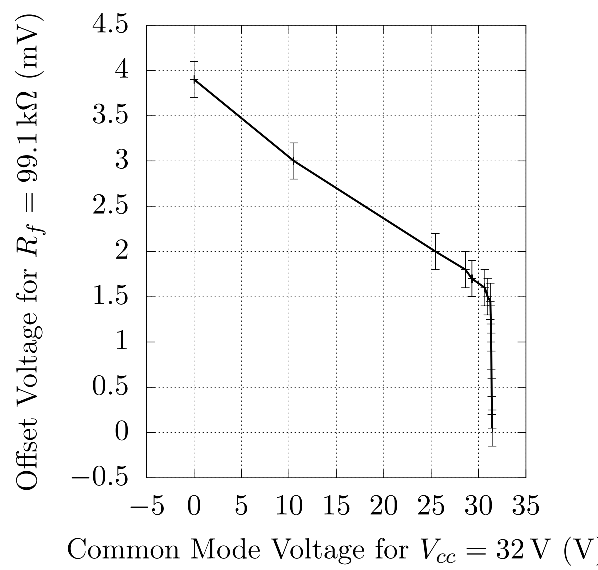


Figure 3: In the configuration of Figure 2, the offset voltage due to the input bias current of the LM358 decreases with increasing common mode voltage.

effect of their worst-case absolute errors with the error in regulation. This increases the minimum offset needed from that due to regulation, but only to about the 10 mV stated before. However, we cannot increase the offset too much: at an output voltage of 1.00 V, an offset of 10 mV already represents a 1 % error in indication. The aim is to keep this level of precision for set voltages from 1.00 V to 30.0 V. If better precision than about 10 % is needed below about 100 mV, the calibration procedure detailed in Section 4.8 may be done at the necessary low voltage, at the cost of less realiable indication at higher voltages of 10 V to 30 V, depending on the configuration.

So how are we to obtain the offset? Since the input bias current of the comparator may introduce errors comparable to the offset, we can change perspective. The "error" that it introduces can in fact be *used* as the offset. The LM393 and many other common differential-input analog devices such as the LM358 have PNP darlington pair input stages. This means that any input bias current will flow *out* of the input terminals, conveniently allowing us to place a resistor on the *noninverting* input of the comparator to achieve an offset in the correct direction. Since the noninverting input is connected to the low-impedance V_{out}, the offset voltage introduced may be reliably predicted as $I_{\text{in}(+)}R_{\text{off}}$ (see Figure 2). For the typical $I_{\text{in}(+)} = 25\,\text{nA}$ and $R_{\text{off}} = 150\,\text{k}\Omega$ (`R21`), we obtain an offset of 3.8 mV. This should handle possible offsets due to comparator input offset voltage and regulation of up to 3 mV, and more offset may be provided with a potentiometer as described in Section 4.8.

But there is a problem with this circuit. Let's take a closer look at the input bias current. While datasheets like that for the LM393 give the input bias current at 0 V common mode voltage, we must know it for all common mode voltages up to V_{in}. The LM358 has a simpler input stage than the LM393, so let's look at it instead to understand what is going on. Some quick measurements reveal that the offset voltage we are after *decreases* with increasing common mode voltage (Figure 3). For simplicity, we may treat this decrease as linear, as we will only be operating in the approximately linear region.

Thus our solution does not work well at high common mode voltages. We fix this by adding a high-ratio voltage divider on the other input to the comparator. Note that for a voltage divider with gain close to unity ($R_1 \ll R_2$),

$$A_V = \frac{R_b}{R_a + R_b} = \frac{1}{1 + R_a/R_b} \approx 1 - R_a/R_b\,.$$

Thus with 1 % resistors, we expect a relative error of about 1.4 % in R_a/R_b. For the values actually used (`R17` and `R18`), we then obtain an absolute error of 21 µV per volt in, giving a worst case 0.6 mV error for a 30 V input. Not bad.

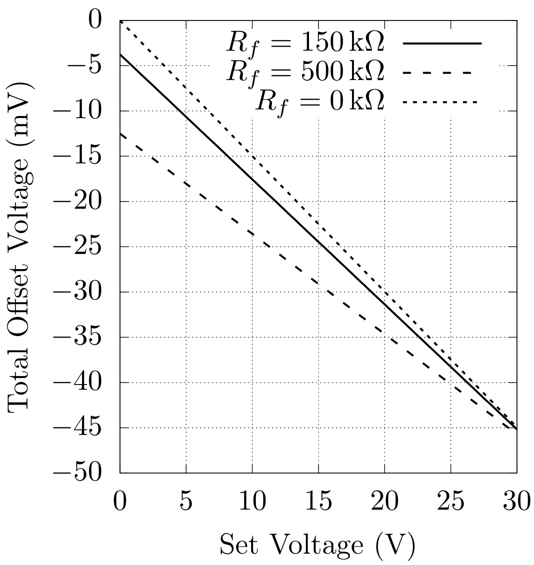
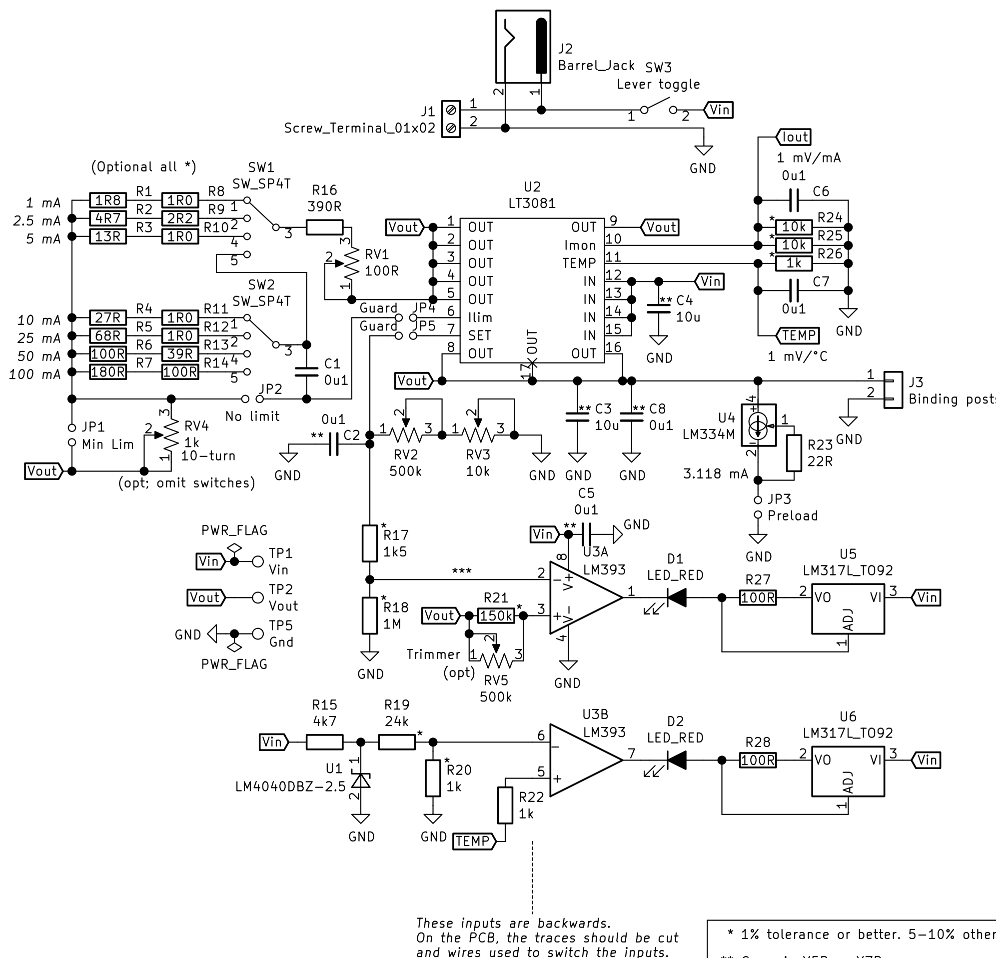


Figure 4: The expected offsets from the full offset circuit for varying values of R_f.

Now that we know why, a quick analysis of the actual offset circuit, where we have both offset methods acting together, gives the characteristic plot of Figure 4. Values were chosen to give an increasing offset with common mode, rather than the constant offset originally discussed, for additional margin and a more understandable relative-drop trigger, rather than an offset trigger. This way, the higher voltage ranges do not seem more sensitive to loading than the lower ranges.



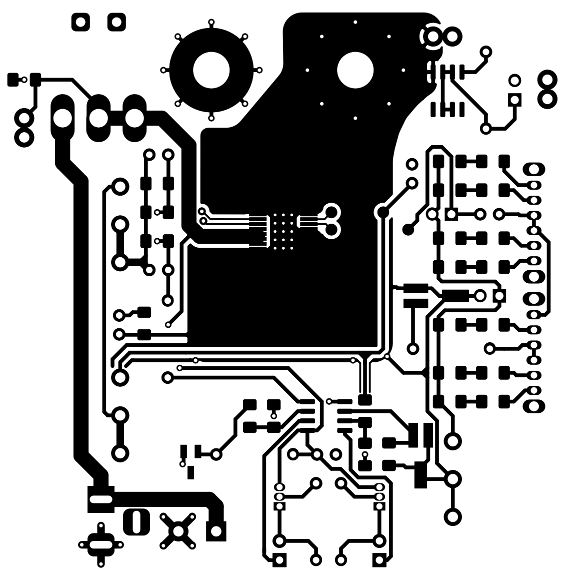
* 1% tolerance or better. 5–10% otherwise.

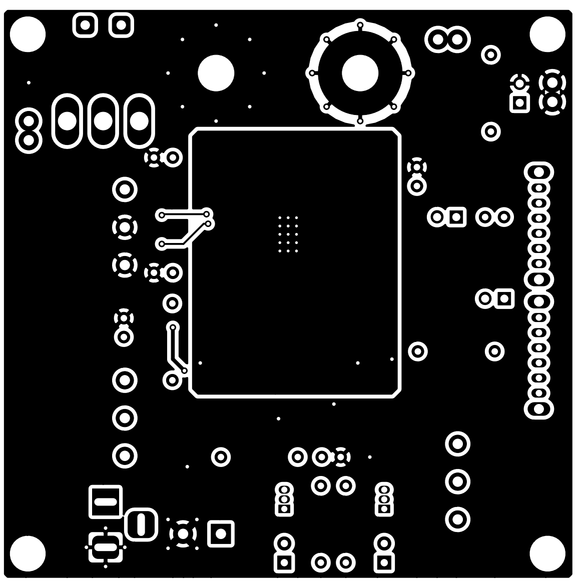
** Ceramic X5R or X7R.

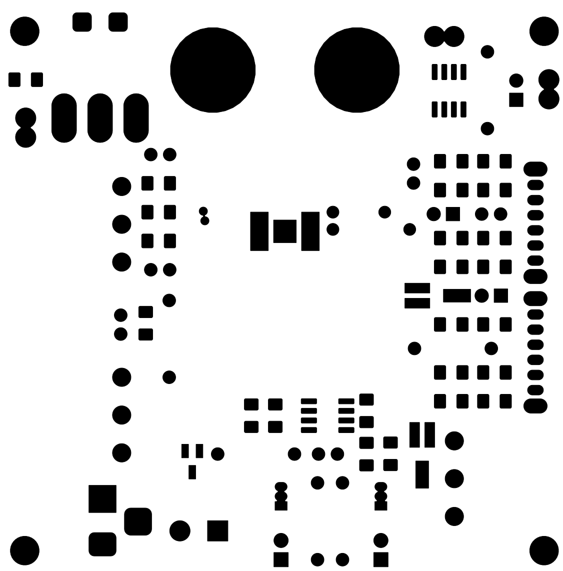
*** The combination of the divider on V− and the voltage increase into V+ due to input bias current should provide adequate offset over the full range of Vin so that the output of the comparator is stable, but does not false-trigger due to Vout regulation tolerance.

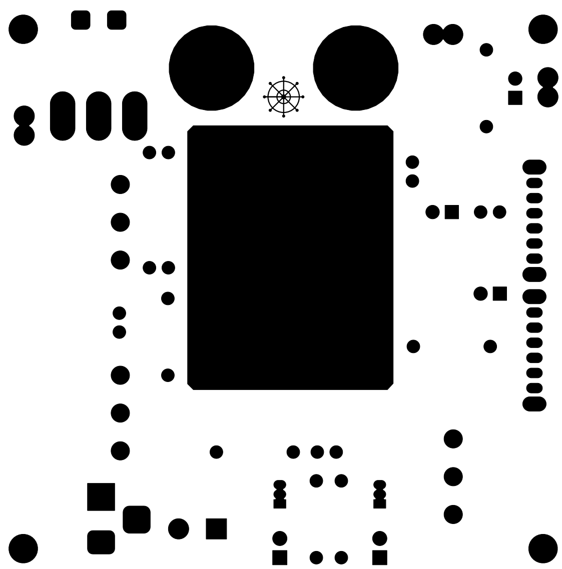
Sheet: /	
File: psu.sch	
Title: Simple Lab Power Supply	Alex Striff <striffa@reed.edu> <https://github.com/jfjhh/lab-psu>
Size: A4 Date: 2019-06-01	**Rev:** B
KiCad E.D.A. kicad 5.1.0	Id: 1/1

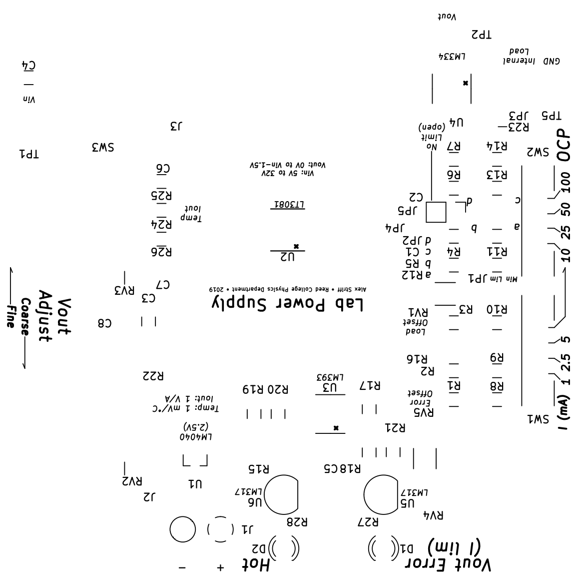
7 Printed Circuit Board Layers

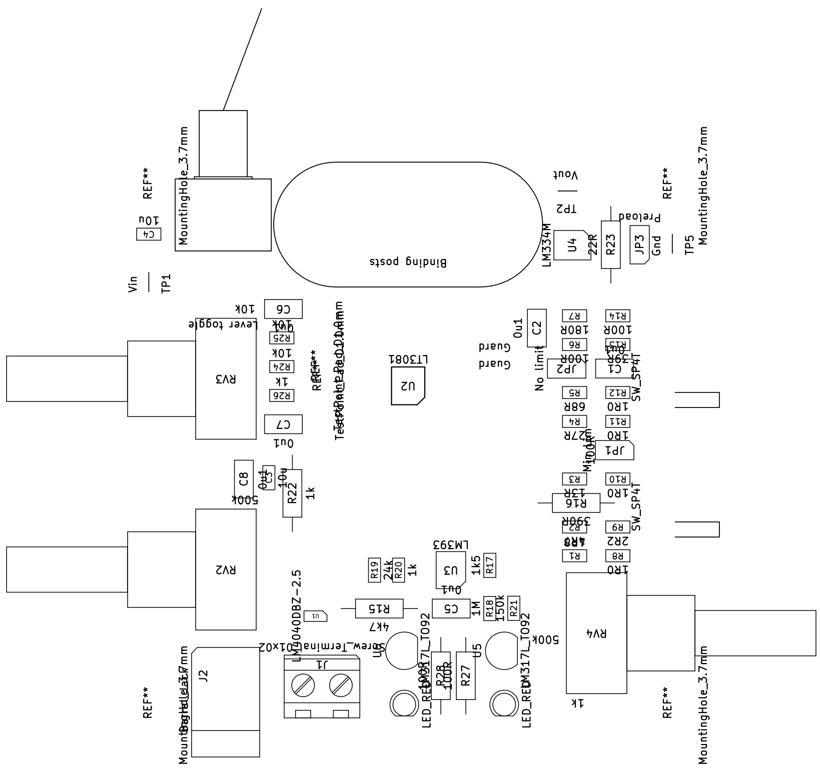


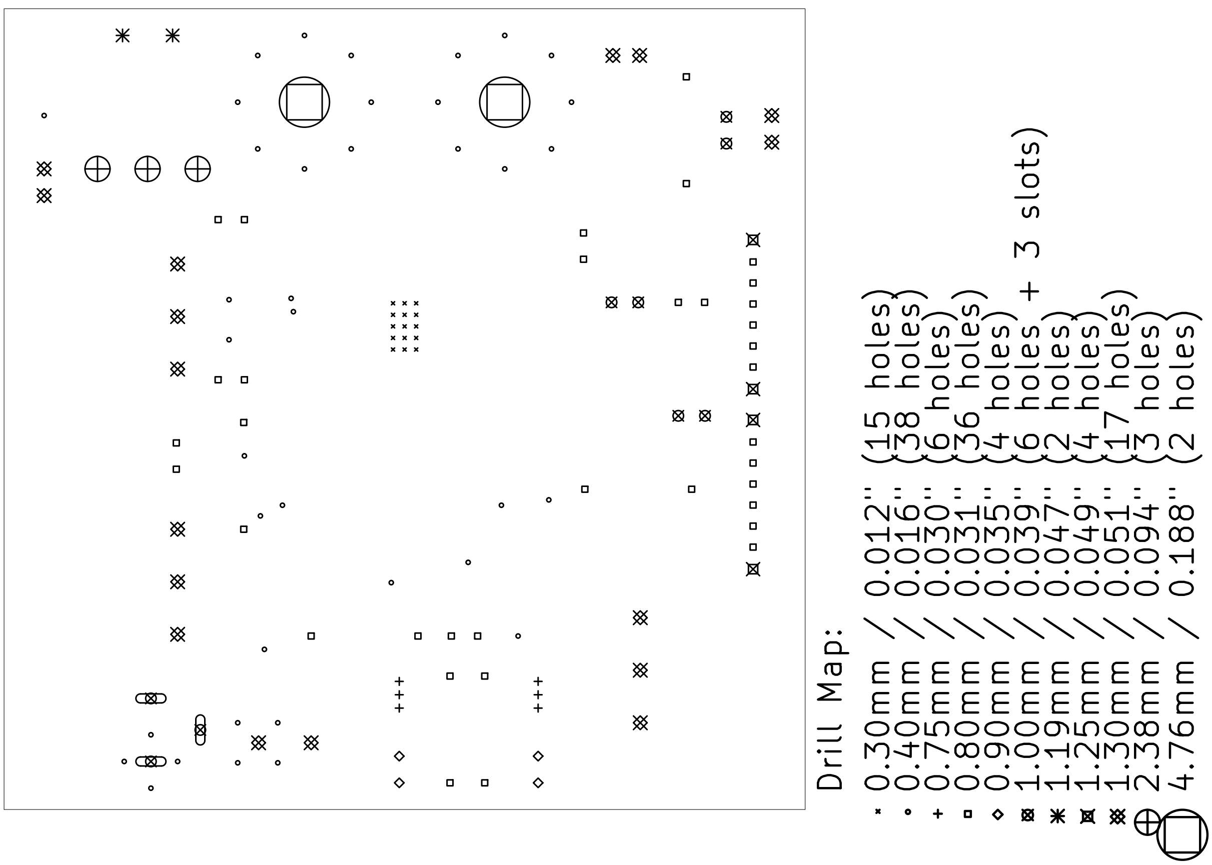


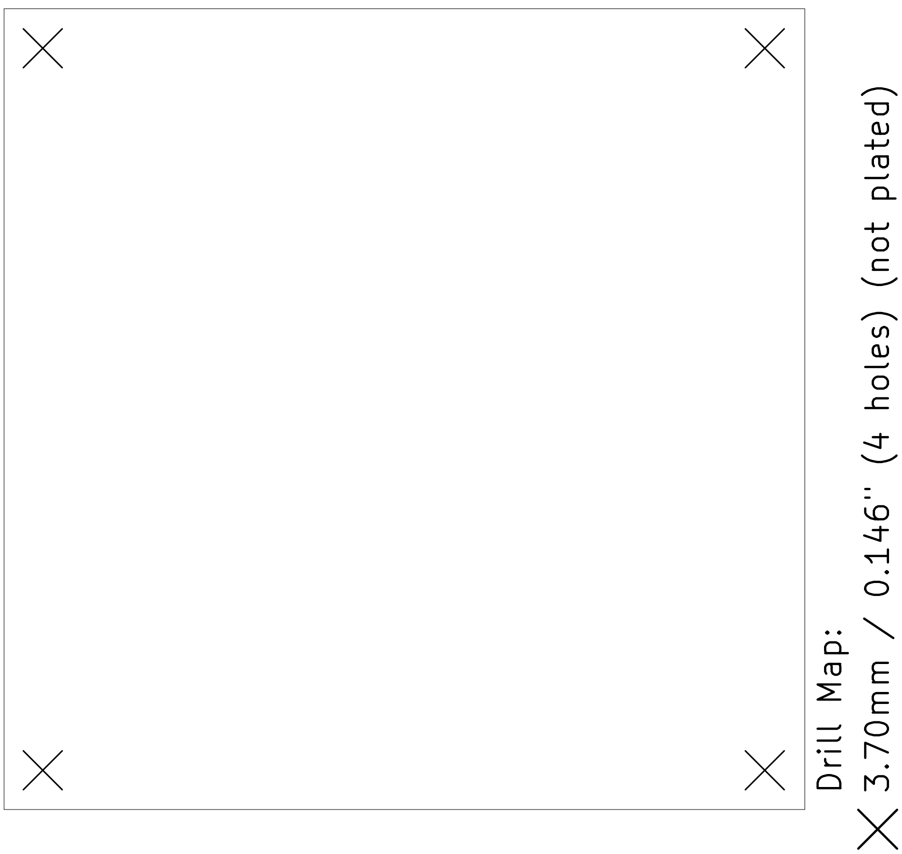





Lab Power Supply
Vout Adjust
Coarse
Fine
OCP
I (mA)
Hot
Vout Error
(I lim)




Drill Map:
0.30mm / 0.012'' (15 holes)
0.40mm / 0.016'' (38 holes)
0.75mm / 0.030'' (6 holes)
0.80mm / 0.031'' (36 holes)
0.90mm / 0.035'' (4 holes)
1.00mm / 0.039'' (6 holes + 3 slots)
1.19mm / 0.047'' (2 holes)
1.25mm / 0.049'' (4 holes)
1.30mm / 0.051'' (17 holes)
2.38mm / 0.094'' (3 holes)
4.76mm / 0.188'' (2 holes)


Drill Map:
3.70mm / 0.146" (4 holes) (not plated)

NOTES

Material: 1.6 mm FR4 (standard); 1 oz copper; 2 layers.
Board dimensions: 3 in x 3 in.
Colors: White solder mask, black silk screen (front).
Surface finish: HASL (with lead) (standard).
NO gold fingers
NO panelization
NO castellated holes
NO tented vias
NO stencil

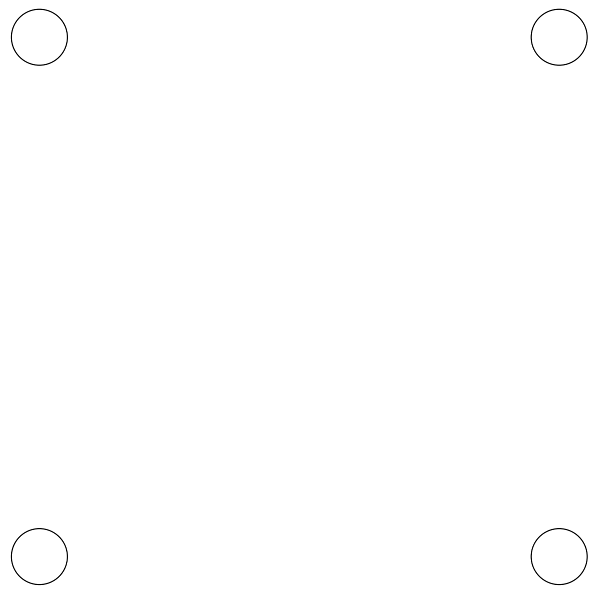


Table 2: Bill of materials with collated items. There are 60 components total.

Item	Qty	Reference(s)	Value	LibPart	Footprint
1	6	C1, C2, C5, C6, C7, C8	0u1	Device:C_Small	Capacitor_THT:C_Disc_D5.0mm_W2.5mm_P2.50mm
2	2	C3, C4	10u	Device:C_Small	Capacitor_SMD:C_1206_3216Metric_Pad1.42x1.75mm_HandSolder
3	2	D1, D2	LED_RED	Device:LED_ALT	LED_THT:LED_D3.0mm
4	1	J1	Screw_Terminal_01x02	Connector:Screw_Terminal_01x02	TerminalBlock_MetzConnect:TerminalBlock_MetzConnect_Type094_RT03502HBLU_1x02_P5.00mm_Horizontal
5	1	J2	Barrel_Jack	Connector:Barrel_Jack	Connector_BarrelJack:BarrelJack_Horizontal
6	1	J3	Binding posts	Connector_Generic:Conn_01x02	psu-foot:Binding Posts
7	1	JP1	Min Lim	Device:Jumper_NO_Small	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical
8	1	JP2	No limit	Device:Jumper_NO_Small	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical
9	1	JP3	Preload	Device:Jumper_NO_Small	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical
10	2	JP4, JP5	Guard	Device:Jumper_NO_Small	psu-foot:Guard_Jumper
11	1	R1	1R8	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
12	1	R2	4R7	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
13	1	R3	13R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
14	1	R4	27R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
15	1	R5	68R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
16	2	R6, R14	100R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
17	1	R7	180R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
18	4	R8, R10, R11, R12	1R0	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
19	1	R9	2R2	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
20	1	R13	39R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
21	1	R15	4k7	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
22	1	R16	390R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
23	1	R17	1k5	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
24	1	R18	1M	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
25	1	R19	24k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
26	2	R20, R26	1k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
27	1	R21	150k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
28	1	R22	1k	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
29	1	R23	22R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
30	2	R24, R25	10k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
31	2	R27, R28	100R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
32	1	RV1	100R	Device:R_POT_US	psu-foot:Trim_pot_Bourns_TC33X-2-101E
33	1	RV2	500k	Device:R_POT_US	Potentiometer_THT:Potentiometer_Piher_PC-16_Single_Horizontal
34	1	RV3	10k	Device:R_POT_US	Potentiometer_THT:Potentiometer_Piher_PC-16_Single_Horizontal
35	1	RV4	1k	Device:R_POT_US	Potentiometer_THT:Potentiometer_Piher_PC-16_Single_Horizontal
36	1	RV5	500k	Device:R_POT_US	psu-foot:Trim_pot_Bourns_TC33X-2-101E
37	2	SW1, SW2	SW_SP4T	psu-sch:SW_SP4T	psu-foot:SP4T_CK_SK-14D01-G-6
38	1	SW3	Lever toggle	Switch:SW_SPST	psu-foot:SW_SPST_Lever_Rubber
39	1	U1	LM4040DBZ-2.5	Reference_Voltage:LM4040DBZ-2.5	Package_TO_SOT_SMD:SOT-23
40	1	U2	LT3081	psu-sch:LT3081	Package_SO:HTSSOP-16-1EP_4.4x5mm_P0.65mm_EP3.4x5mm_Mask3x3mm_ThermalVias
41	1	U3	LM393	Comparator:LM393	Package_SO:SOIC-8_3.9x4.9mm_P1.27mm
42	1	U4	LM334M	Reference_Current:LM334M	Package_SO:SOIC-8_3.9x4.9mm_P1.27mm
43	2	U5, U6	LM317L_TO92	Regulator_Linear:LM317L_TO92	Package_TO_SOT_THT:TO-92_Inline