# Lab Power Supply Manual

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$\mathbf{C}$	ont	ents		Colophon
1	Ack	knowledgments	1	The schematic diagram and printed circuit board
2	Mot	tivation	1	layout were both created with KiCAD. This manual was compiled using LATEX. Relatively fine
3	Safe	ety Notice (Grounding)	2	(0.51 mm) lead-based solder and mildly activated rosin flux were required to solder the components
4	Usa	ge Instructions	2	to the PCB.
	4.1	Setting the output voltage	2	
	4.2	Setting the current limit	2	1 A alemanda dama araka
	4.3	Indicator LEDs	2	1 Acknowledgments
	4.4	Monitoring the output current	3	The exection of this lab never supply was goner
	4.5	Monitoring the internal temperature	3	The creation of this lab power supply was gener- ously funded by the Reed College Physics Depart-
	4.6	Calibrating the current limit	3	ment. I would like to thank Edgar Perez for his
	4.7	Calibrating the output error indicator	3	kind advice, as well as Lucas Illing for supporting
<b>5</b>	Pri	nciples of Operation	5	this project.
	5.1	The LT3081 linear regulator	5	
	5.2	The internal load	5	0.75.4
	5.3	The $V_{ m out}$ error indicator circuit	5	2 Motivation
6	Sch	ematic Diagram	6	Often when working in electronics, several volt-
7	Date	nted Cinquit Pound I arrang	7	age sources are needed. In addition to a main
7	7.1	nted Circuit Board Layers Front Copper	7	power rail, one may need a complementary nega-
	7.1	Back Copper	8	tive power rail for analog circuitry, or a different
	7.3	Front Solder Mask	9	logic power supply at 3.3 V instead of 5 V. Low-
	7.4		10	impedance bias voltages are also a frequent re-
	7.5		11	quirement, needed for biasing BJTs, comparator
	7.6		$\overline{12}$	inputs, and more.
	7.7		13	For most applications, a power supply fulfilling
	7.8	-	14	the requirements of these applications need not be
	7.9	User Comments	15	capable of supplying much more than 1 A of current, must have a stable voltage output (requiring
	7.10	Edge Cuts (Board Outline)	16	a linear regulator), and must have a current lim-
				iting function. Additionally, it would be nice if the
T	iet d	of Tables		power supply was much smaller than a conven-
L	191 (	ui ianies		tional 30 V, 3 A output bench power supply with
	1	Electrical Characteristics	4	a large transformer, being conveniently powered
	$\overline{2}$		17	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. is active, but internal protection circuitry or a set You may use either the binding posts or the test voltage that is too high may also cause an output points labeled on the board to achieve this. Turn error.

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  $10\,\mathrm{k}\Omega$  (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  $100\,^{\circ}\mathrm{C}$  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  $125\,^{\circ}\mathrm{C}$ ), 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 ?? and 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 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.

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 5.3. 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 5.3 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  $500\,k\Omega$  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.

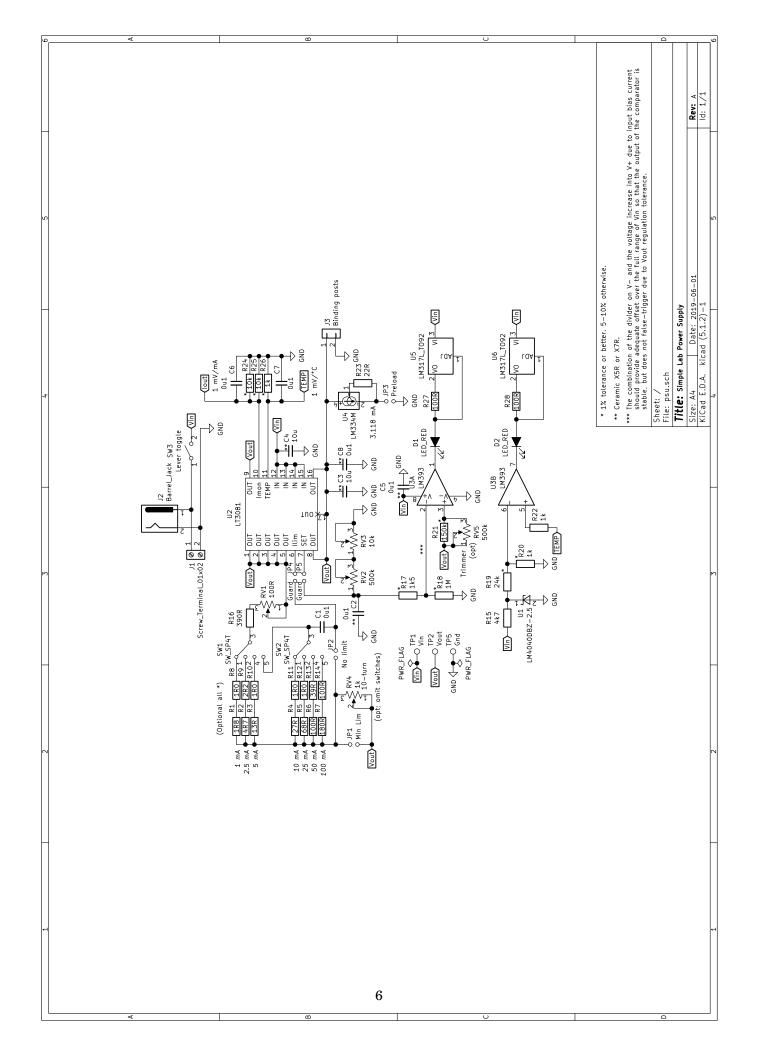
With the potentiometer RV5 and the default resistor R21 soldered on the board or not depending on your needs, adjust the external load potentiometer until the output is  $2-10\,\mathrm{mV}$  below the set voltage. If you intend to use the supply only above about 5 V, the lower the better (you may even 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.

**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.

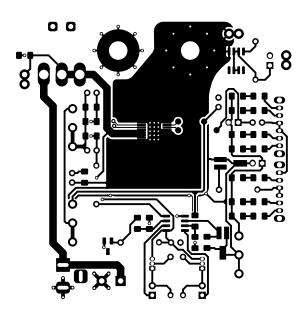
Parameter		Conditions		Min	Тур	Max	Units
Input Voltage	$V_{ m in}$		<b>♦</b>	5.0		32.0	V
Output Voltage	$V_{ m out}$	$I_{ m load}$ $<$ $I_{ m lim}$	<b>♦</b>	0.0		$V_{ m in}$ – $V_{ m do}$	V
Dropout Voltage	$V_{ m do}$	$I_{\rm load} = 100  \rm mA$			1.21		V
		$I_{ m load} = 1.5 A$	<b>♦</b>		1.23	1.5	V
Internal Current Limit	$I_{ m max}$	$V_{\rm in} = 5  \text{V},  V_{\rm set} = 0  \text{V},  V_{\rm out} = -0.1  \text{V}$	•	1.5	2.0		Α
$I_{ m out}$ Relative Error		$I_{ m load} = 1.5 A$		0	6	11	%
$I_{ m out}$ Operating Range			<b>♦</b>	$V_{ m out}$ – 40 V		$V_{ m out}$ + 0.4 V	V
Temp Absolute Error		$0^{\circ}\text{C} \le T_J \le 125^{\circ}\text{C}$		-10		10	μA
		$125^{\circ}\mathrm{C} < T_{J} \leq 150^{\circ}\mathrm{C}$		-15		15	μA
Ripple Rejection	PSRR	$f = 120 \mathrm{Hz}$		75	90		dB
$V_{\text{ripple}} = 0.5  \text{V}_{\text{pp}},  I_{\text{load}} = 0.1  \text{A},$		$f = 10 \mathrm{kHz}$			75		dB
$V_{\rm in} = V_{\rm out(nom)} + 3  \rm V$		$f = 1 \mathrm{MHz}$			20		dB

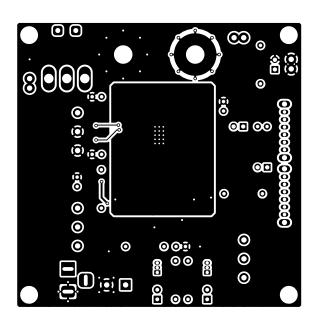
## 5 Principles of Operation

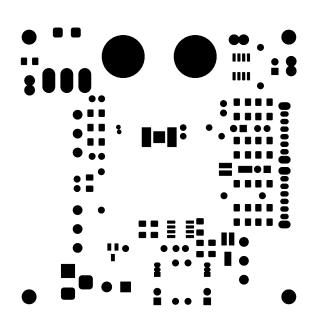
- 5.1 The LT3081 linear regulator
- 5.2 The internal load
- 5.3 The  $V_{\mathrm{out}}$  error indicator circuit

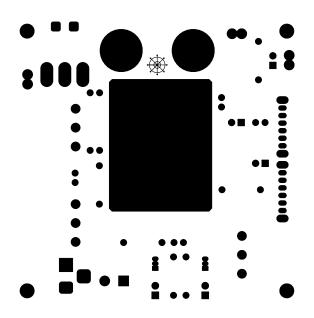


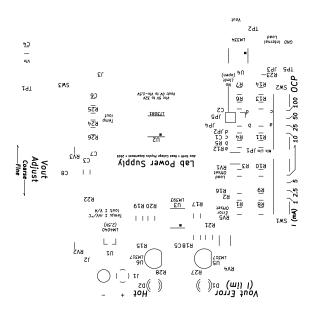
## 7 Printed Circuit Board Layers

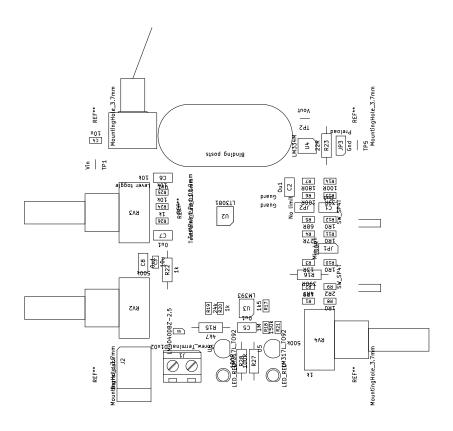


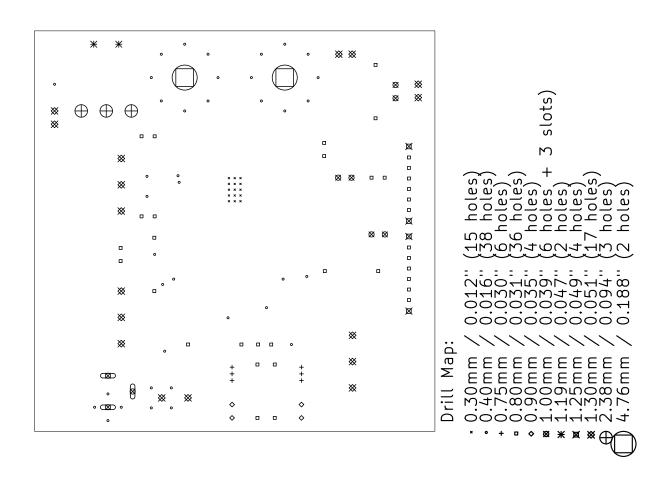


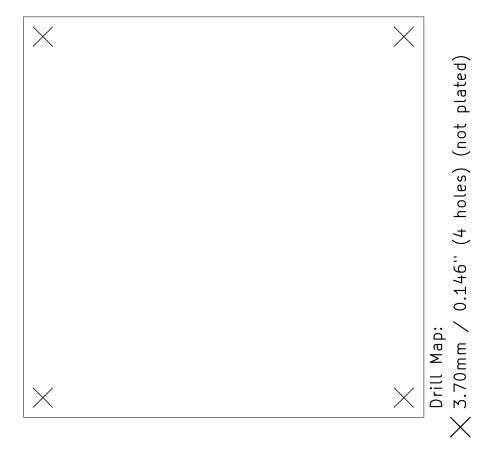












Material: 1.6 mm FR4 (standard); 1 oz copper; 2 layers. Board dimensions: 3 in x 3 in. Colors: White solder mask, black silk screen (front). Surface finish: HASL (with lead) (standard). NO gold fingers NO panelization NO castellated holes NO tented vias NO stencil

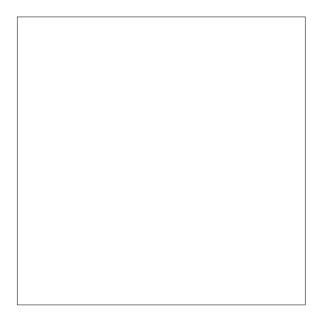


 Table 2: Bill of materials with collated items. There are 60 components total.

1         C CL	Item 6	Qty	Reference(s)	Value	LibPart	Footprint
2         C3, C4         10u         Device:C_Small           2         D1, D2         LED_RED         Device:C_Small           1         J1         Sevew Terminal_O1x02         Connector:ED_AIT           1         J2         Barrel_Jack         Connector:Generic.Com. 01x02           1         J2         Barrel_Jack         Connector:Barrel_Jack           1         JP2         Binding posts         Connector:Barrel_Jack           1         JP2         Binding posts         Connector:Barrel_Jack           1         JP2         Binding posts         Connector:Barrel_Jack           1         JP3         Binding posts         Connector:Barrel_Jack           1         JP3         Binding posts         Connector:Barrel_Jack           2         JP4, JP5         Guard         Device:Marrel_Jack           3         RR         Ak7         Device:R           4         RR         RR         Ak7         Borice:R           5         RG         Bevice:R         Bevice:R           6         RR         RR         Borice:R           1         RR         Br         Bevice:R           1         RR         Br         Br <tr< td=""><td>-</td><td>9</td><td>C1. C2. C5. C6. C7. C8</td><td>0u1</td><td>Device: C Small</td><td>Canacitor THT:C Disc D5 0mm W2.5mm P2.50mm</td></tr<>	-	9	C1. C2. C5. C6. C7. C8	0u1	Device: C Small	Canacitor THT:C Disc D5 0mm W2.5mm P2.50mm
2         Di, D2         LED_RED         Device:LED_ALT           1         J1         Screw Terminal_O1x02         Connector:Screw_Terminal_O1x02           1         J2         Barrel_Jack         Connector:Tercaw_Terminal_O1x02           1         JP1         Barrel_Jack         Connector:Tercaw_Terminal_O1x02           1         JP2         Binding posts         Connector:Tercaw_Terminal_O1x02           1         JP3         Binding posts         Connector:Tercaw_Terminal_O1x02           1         JP3         Min Lim         Devices/Immper_NO_Small           1         R1         R2         ART         Devices/Immper_NO_Small           1         R3         TR         Devices         Rall           1         R4         R5         Guard         Devices         Devices           1         R4         R5         Book         Devices         Devices           2         R6, R14         100R         Devices         Devices         Regulator_Lika           3         R7         Book         Devices         Devices         Regulator_Likaer_LA00BBC_25           4         R8, R10, R11, R12         10         Devices         Devices         Regulator_Likaer_LA00_US	6	8	C3. C4	101	Device: C Small	Canacitor SMD:C 1206 3216Metric Pad 142x1 75mm HandSolder
1         J1         Serew_Theminal_O1x02         Connector:Serew_Terminal_O1x02           1         J2         Barrel_Jack         Connector:Barrel_Jack           1         JPP         Binding posts         Connector:Generic Connector.Osmall           1         JPP         Min Lim         Devices/Immper_NO_Small           1         R1         R2         AR7         Devices/Immper_NO_Small           1         R2         AR7         Devices         Devices           1         R4         27R         Devices         Devices           1         R4         27R         Devices         Devices           2         R6, R14         100R         Devices         Devices           3         R8         10R         Devices         Devices           4         R8, R10, R11, R12         1180         Devices         Devices           5         R6, R14         100R         Devices         Devices           6         R8, R10, R11, R12         1180         Devices         Devices           7         R8         R1         A47         Devices         Devices           8         R16         B4         Devices         Revices	1 00		D1. D2	LED RED	Device:LED ALT	CED THT:LED D30mm
1         J2         Barrel_Jack         Connector.Barrel_Jack           1         J3         Binding posts         Connector.GenericCom_01x02           1         JP2         Min Lim         Device-Jumper_NO_Small           1         JP3         No limit         Device-Jumper_NO_Small           2         JP4, JP5         Grand         Device-Jumper_NO_Small           1         R2         4R7         Device-R           1         R3         13R         Device-R           1         R3         13R         Device-R           1         R5         68R         Device-R           2         R6, R14         100R         Device-R           3         BR         Bevice-R           4         R8, R10, R11, R12         1R0         Device-R           1         R3         390R         Device-R           2         R6, R16         1M         Device-R           4         R8         100R         Device-R           5         R20         Bevice-R         Device-R           6         R20         Device-R         Device-R           1         R16         Device-R         Device-R <td< td=""><td>4</td><td></td><td>J1</td><td>Screw Terminal 01x02</td><td>Connector:Screw Terminal 01x02</td><td>TerminalBlock Metz Connect: TerminalBlock Metz Connect Tvpe 094 RT03502HBLU 1x02 P5.00mm Horizontal</td></td<>	4		J1	Screw Terminal 01x02	Connector:Screw Terminal 01x02	TerminalBlock Metz Connect: TerminalBlock Metz Connect Tvpe 094 RT03502HBLU 1x02 P5.00mm Horizontal
1         J3         Binding posts         Connector_Generic Conn_O1x02           1         JP1         Min Lim         Device-Jumper_NO_Small           1         JP2         No limit         Device-Jumper_NO_Small           2         JP4, JP5         Guard         Device-Jumper_NO_Small           1         R2         R8         RD         Device-Bumper_NO_Small           1         R3         TR         Device-R         Device-R           1         R4         TR         Device-R         Device-R           2         R6, R14         100R         Device-R         Device-R           4         R8, R10, R11, R12         180R         Device-R         Device-R           1         R3         39R         Device-R         Device-R           1         R13         39R         Device-R         Device-R           1         R14         14         Device-R         Device-R           1         R15         447         Device-R         Device-R           1         R15         487         Device-R         Device-R           1         R15         14         Device-R         Device-R           2         R24         D	2	Н	J2	Barrel_Jack	Connector: Barrel_Jack	Connector_BarrelJack:BarrelJack Horizontal
1         JP1         Min Lim         Device-Jumper_NO_Small           1         JP2         No limit         Device-Jumper_NO_Small           2         JP4, JP5         Guand         Device-Jumper_NO_Small           1         R1         R2         HR         Devicer           1         R2         4R7         Devicer           1         R3         13R         Devicer           2         R6, R14         100R         Devicer           3         R6, R14         100R         Devicer           4         R8, R10, R11, R12         180R         Devicer           1         R1         R9         20R         Devicer           1         R1         B0         Devicer         Devicer           1         R1         B0         Devicer         Devicer           1         R1         B0         Devicer         Devicer           2         R20, R26         14K         Devicer         Devicer           3         R20         Devicer         Devicer         Devicer           4         R21         14K         Devicer         Devicer           5         R24         Devicer         Devi	9	1	J3	Binding posts	Connector Generic:Conn_01x02	psu-foot:Binding Posts
1         JP2         No limit         Device-Jumper_NO_Small           1         JP3         Preload         Device-Jumper_NO_Small           1         R1         R1         R8           1         R2         4R7         Device:R           1         R3         3R         Device:R           1         R3         27R         Device:R           2         R6, R14         100R         Device:R           4         R7         100R         Device:R           5         R6, R14         100R         Device:R           1         R7         Device:R         Device:R           1         R7         Device:R         Device:R           1         R13         39R         Device:R           1         R15         Device:R         Device:R           2         R20, R26         1k         Device:R           39R         1k         Device:R         Device:R           1         R15         1k         Device:R         Device:R           2         R20, R26         1k         Device:R         Device:R           3         R21         1k         Device:R         Device:R <td>7</td> <td>-</td> <td>JP1</td> <td>Min Lim</td> <td>Device:Jumper_NO_Small</td> <td>Connector_PinHeader_2.54mm.PinHeader_1x02_P2.54mm_Vertical</td>	7	-	JP1	Min Lim	Device:Jumper_NO_Small	Connector_PinHeader_2.54mm.PinHeader_1x02_P2.54mm_Vertical
1         JP3         Preload         Devices.Jumper_NO_Small           1         R3         Guard         Devices.Jumper_NO_Small           1         R3         4R7         Devices.R           1         R3         13R         Devices.R           1         R4         27R         Devices.R           2         R6,R14         100R         Devices.R           3         R6,R14         100R         Devices.R           4         R8,R10,R11,R12         1R0         Devices.R           1         R7         180R         Devices.R           1         R13         390R         Devices.R           1         R13         390R         Devices.R           2         R20,R26         1k         Devices.R           390R         100rices.R         Devices.R           4         R22         1k         Devices.R           5         R20,R26         1k         Devices.R           6         1k         Devices.R         Devices.R           7         1k22         1k         Devices.R           8         1k23         1k         Devices.R           8         1k24         Device	80	1	JP2	No limit	Device:Jumper_NO_Small	Connector PinHeader 2.54mm:PinHeader 1x02 P2.54mm Vertical
2         JP4, JP5         Guard         Devices/Iumper_NO_Small           1         R1         R8         HR         Devices R           1         R3         13R         Devices R           1         R4         27R         Devices R           2         R6, R14         100R         Devices R           4         R8, R10, R11, R12         1R0         Devices R           1         R13         39R         Devices R           1         R13         39R         Devices R           1         R13         39R         Devices R           1         R14         Devices R         Devices R           1         R15         Devices R         Devices R           2         R20, R26         1K         Devices R           390R         Devices R         Devices R           4         R22         1K         Devices R           5         R20, R26         1K         Devices R           6         R21         16         Devices R           7         R22         100R         Devices R           8         100R         Devices R           9         R24, R25         100R	6	_	JP3	Preload	Device:Jumper_NO_Small	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical
1         R1         IR8         Device:R           1         R2         4R7         Device:R           1         R3         13R         Device:R           1         R4         27R         Device:R           2         R6, R14         100R         Device:R           4         R8, R10, R11, R12         180R         Device:R           1         R7         Device:R         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R15         390R         Device:R           1         R16         390R         Device:R           2         R20, R26         1k         Device:R           3         1k5         Device:R         Device:R           4         R21         1k5         Device:R           5         R24, R25         1k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           3         1k2         Device:R           4         R22         10k         Device:R	10	2	JP4, JP5	Guard	Device:Jumper_NO_Small	psu-foot:Guard Jumper
1         R2         4R7         Device:R           1         R3         13R         Device:R           1         R4         27R         Device:R           2         R6, R14         100R         Device:R           4         R8, R10, R11, R12         180R         Device:R           1         R7         180R         Device:R           1         R13         390R         Device:R           1         R13         390R         Device:R           1         R15         390R         Device:R           1         R15         Device:R         Device:R           1         R2         14K         Device:R           2         R2, R2         14K         Device:R           3         130R         Device:R         Device:R           4         R2         14K         Device:R           5         R2, R2         14K         Device:R           6         R2         150K         Device:R         Device:R           7         R2         100R         Device:R         Device:R           8         R2         100R         Device:R         Device:R           1<	11	П	R1	1R8	Device:R.	Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder
1         R3         13R         Device:R           1         R4         27R         Device:R           2         R6, R14         100R         Device:R           3         R7         Device:R           4         R8, R10, R11, R12         1R0         Device:R           1         R3         39R         Device:R           1         R15         390R         Device:R           1         R15         390R         Device:R           1         R15         390R         Device:R           1         R15         Device:R         Device:R           2         R20, R26         1k         Device:R           1         R21         1k         Device:R           2         R24, R25         100R         Device:R           3         R27         Device:R         Device:R           4         R7, R28         100R         Device:R           5         R24, R25         100R         Device:R           1         R2         100R         Device:R           2         R24, R25         100R         Device:R           3         R24         100R         Device:R </td <td>12</td> <td>1</td> <td>R2</td> <td>4R7</td> <td>Device:R</td> <td>Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder</td>	12	1	R2	4R7	Device:R	Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder
1         R4         27R         Device:R           1         R5         68R         Device:R           2         R6,R14         100R         Device:R           4         R, R14         100R         Device:R           1         R9         2R2         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R17         1k5         Device:R           2         R20, R26         1k         Device:R           3         R22         1k         Device:R           4         R22         1k         Device:R           5         R24, R25         10k         Device:R           6         R24, R25         10k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           3         R24         Device:R         POT_US           4         R71         100R         Device:R           5         R24, R25         10k         Device:R	13	1	R3	13R	Device:R	Resistor, SMD:R, 1206, 3216Metric, Pad1,42x1,75mm, HandSolder
1         R5         68R         Device:R           2         R6,R14         100R         Device:R           4         R7         180R         Device:R           4         R8,R10,R11,R12         1R0         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R15         4k7         Device:R           1         R17         1k5         Device:R           1         R17         1k5         Device:R           2         R20,R26         1k         Device:R           3         R22         1k         Device:R           4         R22         1k         Device:R           5         R24,R25         10k         Device:R           6         R24,R25         10k         Device:R           1         R22         10k         Device:R           2         R24,R25         10k         Device:R           3         R24         R25         10k         Device:R           4         R7         500k         Device:R         POT_US           5         S24,R25 <td< td=""><td>14</td><td>_</td><td>R4</td><td>27R</td><td>Device:R</td><td>Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder</td></td<>	14	_	R4	27R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
2         R6,R14         100R         Device:R           1         R7         180R         Device:R           4         R8,R10,R11,R12         1R0         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R18         1M         Device:R           2         R20,R26         1k         Device:R           1         R21         15k         Device:R           2         R24,R25         10k         Device:R           3         10k         Device:R           4         10k         Device:R           5         R24,R25         10k         Device:R           1         R23         22R         Device:R           2         R24,R25         10k         Device:R           3         R24         Device:R         Porice:R           4         1         R23         22R         Device:R           5         R24,R25         10k         Device:R         Porice:R           6         R24         R25         10k	15	1	R5	68R	Device:R	Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder
1         R7         180R         Device:R           4         R8, R10, R11, R12         1R0         Device:R           1         R9         2R2         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R15         24k         Device:R           2         R20, R26         1k         Device:R           3         R21         150k         Device:R           1         R21         150k         Device:R           2         R24, R25         10k         Device:R           3         R24k         Device:R         Device:R           4         R21         Device:R         Device:R           5         R24, R25         10k         Device:R           6         R24, R25         10k         Device:R           1         R23         22R         Device:R           2         R24, R25         10k         Device:R           3         R24         Device:R         Porice:R           4         R7         500k         Device:R           5         SW, SP4T         SW, SP4T	16	2	R6, R14	100R	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
4         R8,R10,R11,R12         1R0         Device:R           1         R9         2R2         Device:R           1         R15         4k7         Device:R           1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R18         1M         Device:R           1         R19         24k         Device:R           2         R20, R26         1k         Device:R           1         R21         150k         Device:R           2         R24, R25         10k         Device:R           3         R22         10k         Device:R           4         R71         Device:R         Porice:R           5         R24, R25         10k         Device:R           6         R27, R28         100R         Device:R           1         RV1         100R         Device:R           2         R24, R25         10k         Device:R           3         R24         Bevice:R         Porice:R           4         R7         500k         Device:R         Porice:R           5         SW1, SW2         <	17	1	R7	180R	Device:R	Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder
1         R99         2R2         Device:R           1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R17         1k5         Device:R           1         R19         24k         Device:R           2         R20, R26         1k         Device:R           1         R22         1k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           3         R22         10k         Device:R           4         R71         100R         Device:R           5         R24, R25         10k         Device:R           6         R27, R28         100R         Device:R           1         RV3         100R         Device:R           2         R27, R28         100R         Device:R           3         R04         Device:R         POT_US           4         RV3         10K         Device:R           5         SW1, SW2         SW_SP4T         SW_SP4T	18	4	R8, R10, R11, R12	1R0	Device:R	Resistor, SMD:R, 1206, 3216Metric, Pad1,42x1,75mm, HandSolder
1         R13         39R         Device:R           1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R17         1k5         Device:R           1         R19         24k         Device:R           2         R20, R26         1k         Device:R           1         R21         150k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           3         R24, R25         10k         Device:R           4         RV1         Device:R         POT_US           5         R27, R28         100k         Device:R           1         RV2         500k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         Sw1-Sw2-T           3         SW2         SW_SP4T         Sw1-sch:SW_SP4T           4         SW3         Lever toggle         Switch:SW SP4T           5         SW1, SW2	19	1	R9	2R2	Device:R	Resistor SMD:R 1206 3216Metric Pad1.42x1.75mm HandSolder
1         R15         4k7         Device:R           1         R16         390R         Device:R           1         R17         1k5         Device:R           1         R18         1M         Device:R           2         R20, R26         1k         Device:R           1         R21         1k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           2         R24, R25         10k         Device:R           3         R23         22R         Device:R           4         R23         10k         Device:R           5         R27, R28         100R         Device:R           1         RV1         100R         Device:R           2         R27         10k         Device:R-POT_US           3         10k         Device:R-POT_US           4         10k         Device:R-POT_US           5         500k         Device:R-POT_US           6         500k         Device:R-POT_US           7         500k         Device:R-POT_US           8W3         Lever toggle <td< td=""><td>20</td><td>1</td><td>R13</td><td>39R</td><td>Device:R</td><td>Resistor, SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder</td></td<>	20	1	R13	39R	Device:R	Resistor, SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         R16         390R         Device:R           1         R17         1k5         Device:R           1         R18         1M         Device:R           2         R20, R26         1k         Device:R           1         R21         150k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           2         R24, R25         10k         Device:R           3         R23         22R         Device:R           4         R23         10k         Device:R           5         R27, R28         100R         Device:R           1         RV1         100R         Device:R           1         RV2         500k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           1         RV5         500k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW SP4T         Switch:SW SP4T           3         SW3         SW S	21	1	R15	4k7	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
1         R17         lk5         Device:R           1         R18         lM         Device:R           1         R18         lM         Device:R           2         R20, R26         lk         Device:R           1         R21         l50k         Device:R           1         R23         22R         Device:R           2         R24, R25         l0k         Device:R           2         R24, R25         l0k         Device:R           3         R27         Device:R         POT_US           4         R7         bevice:R         POT_US           5         R27, R28         l00R         Device:R         POT_US           1         RVJ         bowice:R-POT_US         Povice:R-POT_US           1         RVJ         l0         Device:R-POT_US         Povice:R-POT_US           1         RVJ         lk         Device:R-POT_US         Povice:R-POT_US           2         SWJ, SW2         lk         Device:R-POT_US         Povice:R-POT_US           3         SW3         Lever toggle         Switch:SW_SP4T         Switch:SW_SP4T           4         LA3040DBZ-2.5         psu-sch:L7308         Comparato:	22	1	R16	390R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
1         R18         1M         Device:R           1         R19         24k         Device:R           2         R20, R26         1k         Device:R           1         R21         150k         Device:R           1         R22         22R         Device:R           2         R24, R25         10k         Device:R           2         R24, R25         10k         Device:R           3         R27, R28         100R         Device:R           4         RV1         100R         Device:R-POT_US           5         R24, R25         10k         Device:R-POT_US           1         RV2         500k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         Device:R-POT_US           3         SW2         500k         Device:R-POT_US           4         LANS         SW_SP4T         psu-s-ch:SW_SP4T           5         SW1, SW2         SW_SP4T         psu-s-ch:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SP5T           1         U1         LA4040DBZ-2.5         psu-s-ch:SW_SP5T </td <td>23</td> <td>1</td> <td>R17</td> <td>1k5</td> <td>Device:R</td> <td>Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder</td>	23	1	R17	1k5	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         R19         24k         Device:R           2         R20, R26         1k         Device:R           1         R22         1k         Device:R           1         R22         1k         Device:R           2         R24, R25         10k         Device:R           2         R24, R25         10k         Device:R           3         R27, R28         100R         Device:R           4         R71         100R         Device:R           5         R24         1k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         Success.POT_US           3         SW2SP4T         Success.POT_US           4         LAV4040DBZ-2.5         Switch:SW_SP4T           5         SW1, SW2         SW_SP4T           1         U1         LAM4040DBZ-2.5           1         U3         LAM4040DBZ-2.5           1         U3         LAM393           1         U4         LM334M           1         U4         LM334M <tr< td=""><td>24</td><td>1</td><td>R18</td><td>1M</td><td>Device:R</td><td>Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder</td></tr<>	24	1	R18	1M	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
2         R20, R26         1k         Device:R           1         R21         150k         Device:R           1         R22         1k         Device:R           1         R22         22R         Device:R           2         R24, R25         10k         Device:R           2         R27, R28         100R         Device:R-POT_US           1         RV1         500k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         Device:R-POT_US           3         SW_SP4T         psu-sch:SW_SP4T           4         SW_SP4T         psu-sch:SW_SP4T           5         SW1, SW2         SW_SP4T         psu-sch:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SP4T           1         U1         LM4400DBZ-2.5         Reference_Cutaer:LM393           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Cutrent:LM334M	25	1	R19	24k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         R21         150k         Device:R           1         R22         1k         Device:R           1         R22         1k         Device:R           2         R24, R25         100k         Device:R           2         R27, R28         100R         Device:R           1         RV1         500k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         psu-sch:RPOT_US           3         SW_SP4T         psu-sch:SW_SP4T         psu-sch:SW_SP4T           4         Lever toggle         Switch:SW_SP8T         psu-sch:GW_SP8T           5         SW1, SW2         SW_SP4T         psu-sch:GW_SP8T           1         U1         IM4040DBZ-2.5         Reference_Voltage:IM4040DBZ-2.5           1         U2         LT3081         Comparator:LM393           1         U3         LM393         Comparator:LM394           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	26	2	R20, R26	1k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         R22         1k         Device:R           1         R23         22R         Device:R           2         R24, R25         10k         Device:R           2         R27, R28         100R         Device:R           1         RV1         100R         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW_SP4T         Device:R-POT_US           3         SW_SP4T         Device:R-POT_US           4         Lever toggle         Switch:SW_SP4T           5         SW1, SW2         SW_SP4T           1         SW3         Lever toggle           1         U1         LA4040DBZ-2.5           1         U2         LA3983           1         U3         LM393           1         U4         LM334M           1         U5, U6         LM317L_T092           2         U5, U6         LM317L_T092	27	1	R21	150k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         R23         22R         Device:R           2         R24, R25         10k         Device:R           2         R27, R28         100R         Device:R           1         RV1         100R         Device:R-POT_US           1         RV3         500k         Device:R-POT_US           1         RV3         10k         Device:R-POT_US           1         RV4         1k         Device:R-POT_US           2         SW1, SW2         SW SP4T         Device:R-POT_US           3         SW3         Lever toggle         Switch:SW SP4T           4         LW393         Reference_Voltage:IM4040DBZ-2.5           5         LM398         Comparator:LM393           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	28	1	R22	1k	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
2         R24, R25         10k         Device:R           2         R27, R28         100R         Device:R           1         RV1         100R         Device:R_POT_US           1         RV2         500k         Device:R_POT_US           1         RV3         10k         Device:R_POT_US           1         RV4         1k         Device:R_POT_US           2         SW1, SW2         SW_SP4T         Device:R_POT_US           3         SW2         SW_SP4T         Device:R_POT_US           4         LANS         SW-SP4T         Device:R_POT_US           5         SW1, SW2         SW_SP4T         Device:R_POT_US           6         SW2         SW-SP4T         Device:R_POT_US           7         LANS         SW-SP4T         Device:R_POT_US           8         SW1, SW2         SW2         SW1           1         U1         LANGAODBZ-2.5         Reference_Voltage:LA4040DBZ-2.5           1         U2         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	29	1	R23	22R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
2         R27, R28         100R         Device:R           1         RV1         100R         Device:R-POT_US           1         RV2         500k         Device:R_POT_US           1         RV3         10k         Device:R_POT_US           1         RV4         1k         Device:R_POT_US           2         SW1, SW2         SW_SP4T         Device:R_POT_US           3         SW2 SW4T         Device:R_POT_US           4         SW3         Lever toggle         Switch:SW_SP4T           5         SW1, SW2         SW_SP4T         Switch:SW_SP4T           1         U1         LA4040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         IT3081         Comparator:LM393           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	30	2	R24, R25	10k	Device:R	Resistor_SMD:R_1206_3216Metric_Pad1.42x1.75mm_HandSolder
1         RV1         100R         Device:R_POT_US           1         RV2         500k         Device:R_POT_US           1         RV3         10k         Device:R_POT_US           1         RV4         1k         Device:R_POT_US           2         SW1, SW2         SW_SP4T         Device:R_POT_US           2         SW1, SW2         SW_SP4T         Device:R_POT_US           1         SW3         Lever toggle         Switch:SW_SP4T           1         U1         LA4040DBZ-2.5         Reference_Uotlage:LM4040DBZ-2.5           1         U2         LT3081         Comparator:LM393           1         U4         LM393         Comparator:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	31	7	R27, R28	100R	Device:R	Resistor_THT:R_Axial_DIN0207_L6.3mm_D2.5mm_P10.16mm_Horizontal
1         RV2         500k         Device:R_POT_US           1         RV3         10k         Device:R_POT_US           1         RV4         1k         Device:R_POT_US           2         SW1, SW2         SV         SV           1         SW3         Lever toggle         Switch:SW_SP4T           1         U1         LM4040BBZ-2.5         Reference Voltage:LM4040BBZ-2.5           1         U2         LM393         Comparator:LM393           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	32	Н	RV1	100R	Device:R_POT_US	psu-foot:Trim_pot_Bourns_TC33X-2-101E
1         RV3         10k         Device:R_POT_US           1         RV4         1k         Device:R_POT_US           1         RV5         500k         Device:R_POT_US           2         SW1, SW2         SW_SP4T         Swich:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SP8T           1         U1         IAM040DBZ-2.5         Reference_Voltage:IM4040DBZ-2.5           1         U2         LM3981         Comparator:LM3981           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	33	1	RV2	500k	Device:R_POT_US	${f Potentiometer\_THT:} {f Potentiometer\_Piher\_PC-16\_Single\_Horizontal}$
1         RV4         1k         Device:R_POT_US           1         RV5         500k         Device:R_POT_US           2         SW1, SW2         SW_SR4T         psu-edn:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SPST           1         U1         LAM040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         LM3981         Comparator:LM3981           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	34	н	RV3	10k	Device:R_POT_US	$Potentiometer\_THT: Potentiometer\_Piher\_PC-16\_Single\_Horizontal$
1         RV5         500k         Device:R_POT_US           2         SW1, SW2         SW_SP4T         psu-sch:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SPST           1         U1         LM4040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         LT3081         Comparator:LM3981           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	35	1	RV4	1k	Device:R_POT_US	${f Potentiometer\_THT:} {f Potentiometer\_Piher\_PC-16\_Single\_Horizontal}$
2         SW1, SW2         SW_SP4T         psu-sch:SW_SP4T           1         SW3         Lever toggle         Switch:SW_SPST           1         U1         LM4040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         LT3081         psu-sch:LT3081           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_TO92         Regulator_Linear:LM317L_TO92	36	_	RV5	500k	Device:R_POT_US	psu-foot:Trim_pot_Bourns_TC33X-2-101E
1         SW3         Lever toggle         Switch:SW_SPST           1         U1         LM4040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         LT3081         psu-sch:LT3081           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	37	2	SW1, SW2	$SW_SP4T$	psu-sch:SW_SP4T	psu-foot:SP4T_CK_SK-14D01-G-6
1         U1         LM4040DBZ-2.5         Reference_Voltage:LM4040DBZ-2.5           1         U2         LT3081         psu-sch:LT3081           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_T092         Regulator_Linear:LM317L_T092	38	1	SW3	Lever toggle	Switch:SW_SPST	psu-foot:SW_SPST_Lever_Rubber
1         U2         LT3081         psu-sch:LT3081           1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_TO92         Regulator_Linear:LM317L_TO92	39	_	U1	LM4040DBZ-2.5	Reference_Voltage:LM4040DBZ-2.5	Package_TO_SOT_SMD:SOT-23
1         U3         LM393         Comparator:LM393           1         U4         LM334M         Reference_Current:LM334M           2         U5, U6         LM317L_TO92         Regulator_Linear:LM317L_TO92	40	-	U2	LT3081	psu-sch:LT3081	Package_SO:HTSSOP-16-1EP_4.4x5mm_P0.65mm_EP3.4x5mm_Mask3x3mm_ThermalVias
1 U4 LM334M Reference_Current:LM334M 2 U5, U6 LM317L_TO92 Regulator_Linear:LM317L_TO92	41	-	U3	LM393	Comparator:LM393	Package_SO:SOIC-8_3.9x4.9mm_P1.27mm
2 U5, U6 LM317L_T092 Regulator_Linear:LM317L_T092	42	-	U4	LM334M	Reference_Current:LM334M	Package_SO:SOIC-8_3.9x4.9mm_P1.27mm
	43	2	U5, U6	$LM317L\_T092$	Regulator_Linear:LM317L_TO92	Package_TO_SOT_THT:TO-92_Inline