SPX Ultra High Performance
Voltage Regulator

Low Noise High Current
Bootstrap Powered
Low Dropout Regulator

FEATURES

- 1µV rms noise 20 to 20kHz
- Exceptionally fast transient response
- Ripple rejection > 120dB to 20kHz
- Vout range 3.3V to 30V
- Max output current 3A
- Low 8mΩ output impedance
- Low drop-out voltage <1.5V @3A
- Positive and negative versions
- LM78xx, LM79xx, LM1117, LM1084 pin outs
- No thermal pad needed for heat sink attachment

APPLICATIONS

- Integrated or Phono preamps
- Power amps
- Microphone preamps
- High resolution D/A and A/D converters
- Mixer consoles
- Precision high power sources
- Precision measurement systems
- Transducer or sensor power supply
- Turntable motors
- Any system that needs clean, quiet, fast power!

DESCRIPTION

The Superpower regulator is a high performance voltage regulator with a novel circuit design (U.S. Patent 8,294,440) to internally power its reference circuit with its own regulated output. A floating reference allows fixed or variable output voltage from 3.3V to 30V, with low noise, low output impedance, high current and fast transient response, in a compact circuit that fits a standard TO-220 footprint.

Superpower delivers current to a load with a clean fast waveform with no ringing or overshoot, settles quickly, with mere millivolts of output voltage change.

With a footprint to match industry standard TO-220 monolithic regulators, Superpower can be easily retrofit into existing systems or designed into new systems for maximum performance.

Contact Belleson for more information.

SPX17

SPX78

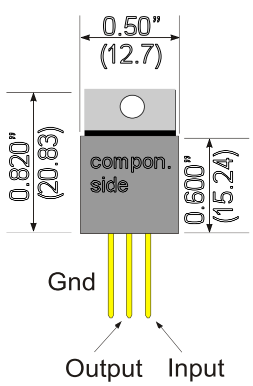
SPX79

Absolute Maximum Ratings

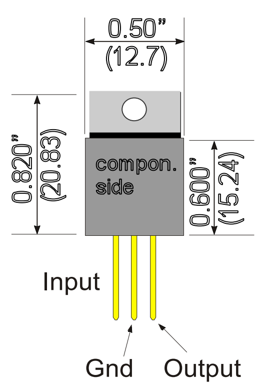
Parameter	Conditions	Value	Units
Input voltage maximum		40	V
Input→Output maximum	Within power dissipation limits	30	V
Peak current	Transient current from output	8.0	A
Total power dissipation	T_A = 25°C (requires heat sink) Derate above 25°C	36 288	W mW/°C
Thermal Resistance	$R_{\theta JA}$, Junction−to−Ambient no heat sink	63	°C/W

Operation at these limits is not guaranteed. Operation beyond these limits may result in irreversible damage.

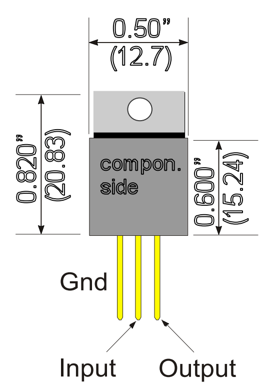
Pin Connections



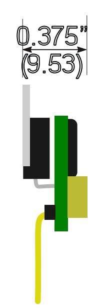
SPX17



SPX78



SPX79



Side View/Dimension

Typical Performance Characteristics

Parameter	Conditions	MIN	TYPICAL	MAX	Units
Input voltage range	(Note 1)	Vout + 0.5	Vout + 1	40	V
Output voltage range	Fixed output from 3.3V to 30V, or variable (Note 2)		+3.3 to +30		V
Output Noise	RMS 20Hz – 24KHz, no load 3.3V <= Vout <= 15V		1		μV
Output voltage accuracy		-1.5	0	1.5	%Vout
SET pin current	(Note 3)	2.48	2.5	2.52	mA
SPX17,SPX78 Ripple Rejection (Note 4)	Vin=Vout+4Vdc with 1Vpp ripple 60Hz 20kHz		 126 120		dB
SPX79 Ripple Rejection (Note 4)	Vin=Vout-4Vdc with 1Vpp ripple 60Hz 20kHz		 110 108		dB
Maximum continuous output current (Note 5)				3	A
Maximum power dissipation	no heat sink sufficient heat sink (Note 6)		1 36		W
Drop–out voltage	Load Current 0.5A 1A 2A 3A		 0.6 0.8 1 1.5		V
Output Impedance	20Hz – 50KHz		8		mΩ
Idle current	Current used by the regulator (no-load current from GND pin)		11		mA

Notes

(*1) Input voltage must be above Vout+drop-out voltage, which depends on regulator output current
(*2) -3.3V not available. Variable output is set with an added resistor at Rset pin 1, see Application Information on page 6.
(*3) Current is fixed and independent of Vin, Vout or load current. If fixed output, SET pin current flows out GND pin
(*4) See graph page 5
(*5) Within power dissipation limit. Transient current can exceed 3A
(*6) Maximum *regulator* (not load) dissipation at 25°C ambient air temperature

Maximum Load Current vs. (Vin-Vout)

no heat sink

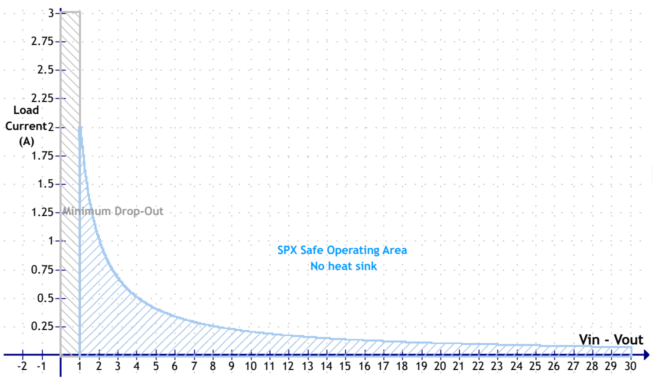


Figure 1: Blue hashed area is safe operating condition

with heat sink

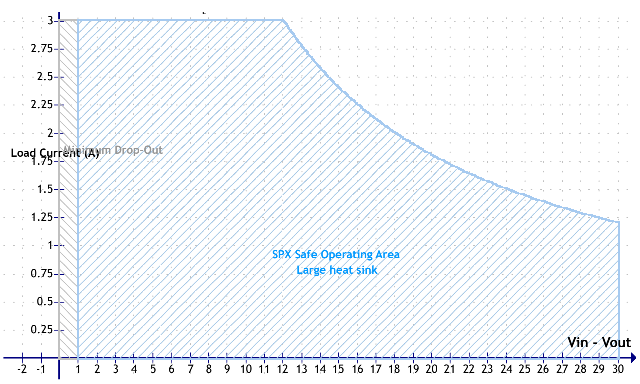


Figure 2: Blue hashed area is safe operating condition

Start up response

Figure 3: SPX78 start up response, V_{out}=5V

Output Noise

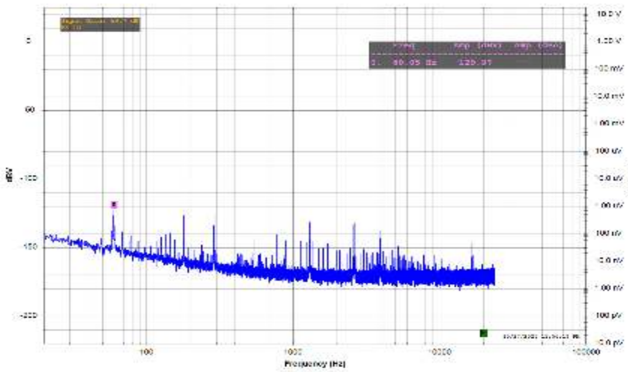


Figure 4: SPX78 noise, Vout=15V,
$V_{noise(rms)}$=-120dBV (1μV)

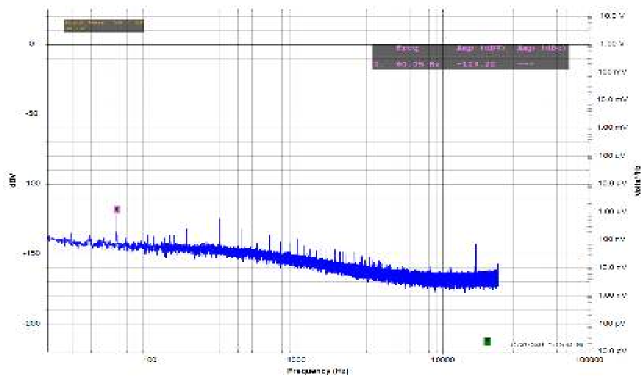


Figure 5: SPX79 noise, Vout=-15V
$V_{noise(rms)}$=-113dBV (2.2μV)

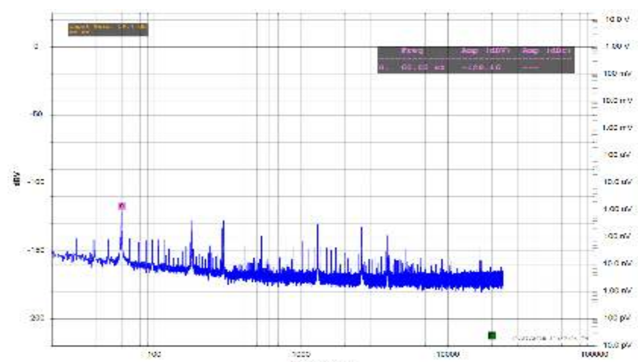


Figure 6: SPX78 noise, Vout=5V
$V_{noise(rms)}$=-120dBV (1μV)

Transient Step Response

50mA to 1A

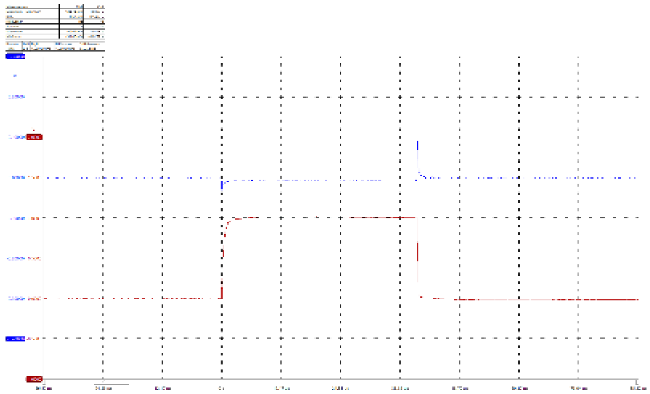


Figure 7: SPX17 step response, 50mA to 1A
Top: ΔVout, 0.1V/div
Bottom: ΔOutput current, 0.5A/div

50mA to 3A

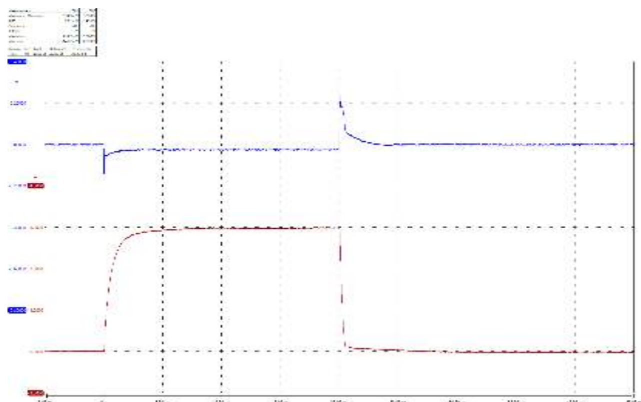


Figure 8: SPX17 step response 50mA to 3A
Top: ΔVout, 0.2V/div
Bottom: ΔOutput current, 1A/div

Output Impedance vs. Frequency

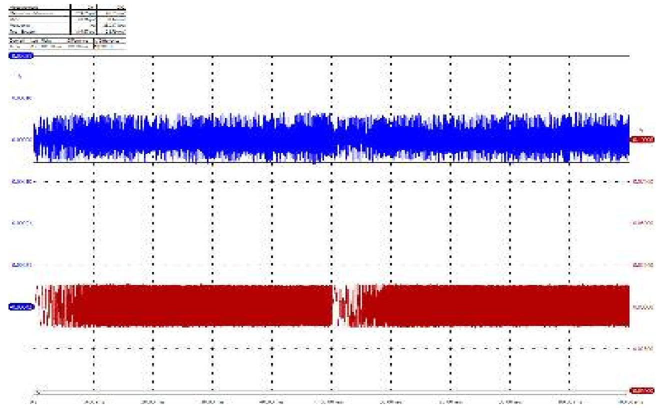


Figure 9: SPX78 12V out, z_{out}<8mΩ
Horizontal axis: 50Hz-50kHz sweep (10kHz/div)
Top: ΔVout 0.1mV/div
Bottom: 25mA/div

Ripple Rejection vs. Frequency

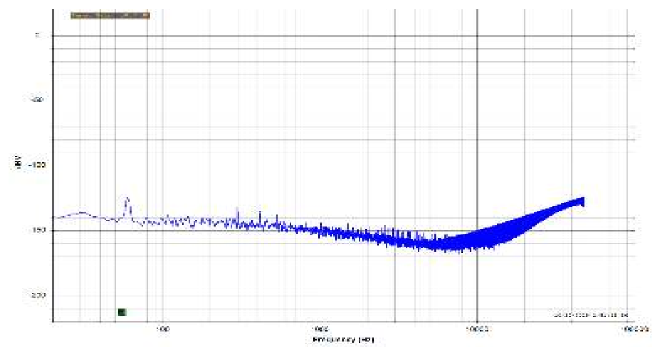


Figure 10: Ripple rejection of SPX 78
Vin:16VDC ±0.5VppAC
Vout: 12VDC, no load
Horizontal: Log frequency
Vertical: 10dBV/div

Application Information

Superpower provides a breakthrough combination of dynamics and low noise. This provides information to allow you to get the best use from your Superpower.

No Output Short Circuit Protection

SPX has a patented internal control circuit which is powered from the output voltage. Thus when the output is shorted to ground, the control circuit fails to function due to its loss of power, making an internal current limit circuit ineffective. Any output short circuit to ground will likely damage the regulator. We recommend using a low cost monolithic regulator in your power supply design and debug stages, then replacing it with Belleson SPX after all is working.

Dynamics and Capacitance

Good dynamic response means supplying a lot of current very quickly. A large capacitor (100+µF) located near the input pins of Superpower provides reserve storage so Superpower can deliver that current. An input capacitor can also decrease output noise. See the discussion of **Line Rejection and Drop Out Voltage** on page 8 for minimum input capacitance requirements for a transformer-rectifier-filter raw supply.

SPX has a 10µF output capacitor on board, but adding a 100µF external capacitor near the load may improve dynamic response.

If low level multi-MHz oscillation is observed at Vout, a 0.22µF film capacitor soldered directly across the IN to GND pins may cure it.

Load Current, Stability and Output Impedance

SPX has special internal loop compensation to provide the low output impedance seen in figure 9. (Also see the above section on Dynamics and Capacitance.) Like other linear regulators, it can have a high frequency low level oscillation at some values of load current. Typically the recommended 100µF capacitor at OUT will prevent this, but it's good to check Vout with a multi-MHz bandwidth oscilloscope to be sure it's stable with whatever load current your application requires. Adding capacitance to the regulator output will usually quiet any oscillation. With the exception of in-rush current at power-up, there is no maximum value of additional capacitance.

Output impedance is conceptualized as an ideal regulator with zero output impedance followed by a non-zero impedance Z_{out}, followed by a load impedance Z_{load}. The voltage across the load is set by the regulator output current and the voltage drop across Zout, as these two impedances form a voltage divider between the ideal output point and ground. Ideally, load voltage is fixed, constant and stable under any load current demands across all frequencies. Real situations are, of course, less than ideal.

z_{out} *can* vary over frequency, so output transient response depends on the nature of current demand from the load and can become a complex response of ringing or even oscillation depending on the regulator, the load and even the circuit layout. In fact, a flat z_{out} versus frequency may be more important than the actual impedance value.

A look at z_{out} of a standard "jelly bean" LM7812 compared to SPX78 in figure 9 illustrates how z_{out} can affect regulation of a linear circuit.

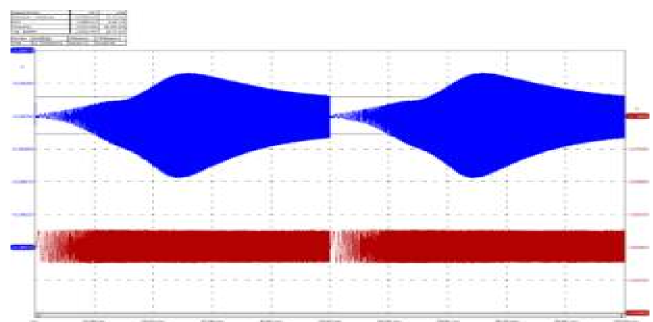
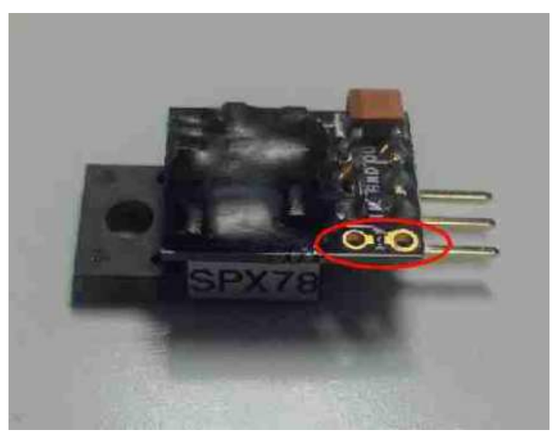


Figure 11: LM7812 z_{out} with 10µF output capacitor
Impedance peaks near 250mΩ near 25kHz
Horizontal: frequency sweep, 50Hz-50kHz, 10kHz/div
Top: ~2mV/div
Bottom: 25mA/div

Output Voltage Set

SPX is available as variable Vout. As shipped, Vout is set at 30V and decreased by soldering a ¼ Watt



resistor between the two PCB holes near the pins. We suggest soldering on the rear side of the PCB.

Calculate Rset in kΩ as

$$Rset(kOhms)=\frac{(10\times Vout)-50}{30-Vout}$$

Typical values are

Vout	Rset	Nearest 1% value (Ohms)	Nominal Vout
5	0	0	5
6.3	548.52	549	6.3
7	869.57	866	6.99
8	1363.64	1370	8.01
9	1904.76	1910	9.01
10	2500	2490	9.98
12	3888.89	3900	12.01
12.6	4367.82	4320	12.54
15	6666.67	6650	14.98
16	7857.14	7870	16.01
18	10833.33	10700	17.92
20	15000	15000	20
24	31666.67	31600	23.99
30	none	none	30

Heat Sinks and Power Dissipation

This discussion pertains to the power dissipation in the regulator itself, not power delivered from a regulator to a load. This is calculated as

$$\frac{V_{in}-V_{out}}{I_{load}+5\,mA}$$

Superpower can dissipate 1 or 2 Watts without heat sinking depending on ambient temperature and air flow. You can minimize regulator power dissipation by taking advantage of the low drop–out voltage, i. e. setting input voltage slightly higher than output voltage + drop-out.

Heat sink attachment

To dissipate more than 1W, attach Superpower to a heat sink or a heat conductive chassis. A thermal pad or mica insulator is not required because the power transistor is electrically insulated. Use of thermal paste may improve heat conduction away from the regulator.

Other Thermal Considerations

When building a regulated power supply there are two origins of power dissipation. The power you *want* to dissipate is in the load, which is calculated as load current times voltage across the load. The power you *don't want* to dissipate is power in the regulator, which is wasted power. The whole reason for complicated switched mode power supplies is to provide as much power to the load as it needs while wasting as little power in the supply as possible.

Linear regulators, however, require a minimum voltage between input and output to allow regulation to happen. This is known as drop-out voltage. Typically the difference between input and output voltage is more than the minimum to ensure regulation continues in cases like AC mains fluctuations. Thus the input to output voltage difference times the current delivered to the load is the power dissipated by a linear regulator. The lower the dropout voltage on a linear regulator, the lower the wasted power can be, which is why LDO regulators are popular. There is also additional power consumption due to regulator internal current, which is typically a small fraction of load current (11mA for SPX) and we will ignore that in this discussion.

The heat generated by a linear regulator is a direct result of regulator power dissipation. To complicate things, a transformer-based linear power supply has ripple that must be kept above the drop-out threshold. Thus the RMS value of the input voltage to the regulator is the basis for power dissipation calculation. The Belleson website has a transformer calculator to help simplify this task of how much power the regulator will dissipate. Another, a heat sink calculator, uses that information to calculate how much heat sink is needed for a given set of supply parameters.

Heat is primarily from the output transistor, and can be "wicked" to a heat sink. With no heat sink, it can dissipate one watt indefinitely in 25°C ambient air. Under these conditions, the power transistor temperature will rise about 65°C and the control circuit PCB will have a temperature increase.

If the regulator is in an enclosure with little or no airflow, the ambient temperature will rise and so will the regulator temperature. We suggest at minimum to have air vents that allow air to circulate from the bottom to top of an enclosure.

Using a heat sink will allow much higher regulator power dissipation. As already noted, this is wasted power so do whatever you can in the circuit design to keep drop out voltage across the regulator low.

Line Rejection and Drop Out Voltage

(This section does not apply when Vin is supplied by a switched mode power supply, only to a linear rectified power supply.)

As current increases, the minimum value of input ripple goes down and the regulator drop-out voltage goes up. If they meet or overlap, line regulation degrades rapidly. Ripple on the output of a full wave rectifier is calculated as

$$Vr = \frac{Idc}{2\,fC}$$

where Vr is the peak to peak ripple voltage.

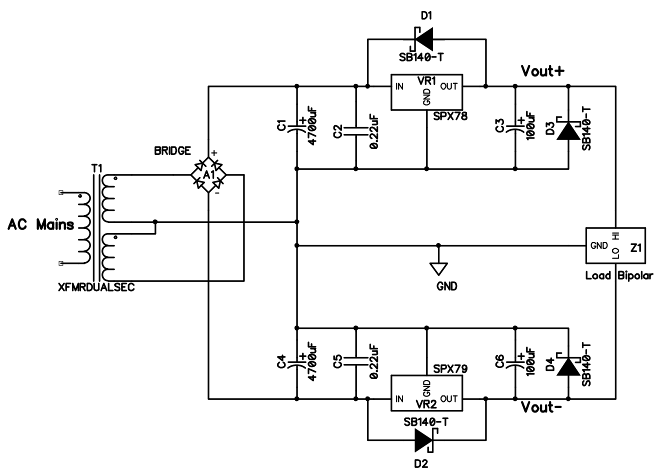


Figure 12: Typical regulated power supply with recommended input and output capacitors and reverse current protection diodes

For example, consider a 5V regulator circuit as seen in figure 12 using a 100uF input filter capacitor C1. At 400mA, the ripple for a 60Hz AC input =

$$\frac{0.4}{2\times 60\times(100\times 10^{-6})} = 33\,V\,(!)$$

Clearly 100µF is not enough input capacitance for this circuit.

The same calculation with 4700µF results in a more tolerable 0.7V ripple. If the minimum point of the rectified voltage must be 5V, the DC + ripple at C1 must have a minimum low peak of 5.7V or higher to deliver 5V out.

To calculate the capacitance required for a given ripple voltage and output current, use

$$C = \frac{Idc}{2\,fVr}\ .$$

However, this does not consider the regulator drop out voltage—the voltage to operate SPX is 0.6V of drop out "head-room" at 400mA. The minimum point of ripple must then be 5V + 0.6V drop out and Vin must peak at least 0.7V above that. So the absolute minimum voltage supplied by the rectifier at full load must be 6.3V to reliably get 5V out and meet the SPX specification for line regulation. It is best to allow for other factors such as transformer secondary output deviation, line voltage sag, etc., and supply something higher than minimum, for example 7V for this circuit.

Reverse Current Protection

When input power is cut from a circuit such as figure 12, capacitors C1-C6 will discharge through the path of least resistance. Diodes D1-D4 provide a low resistance path for transient capacitor currents to discharge, by-passing the regulators. This protects the regulators from immediate and long term damage. DO NOT OMIT THESE, it will be more expensive to fix a system than to pay their extra cost.

Replacing Existing Regulators

Superpower regulators are designed to make it easy to replace lesser regulators in your equipment. They are built as a direct replacement for some pin outs or can be externally mounted or chassis mounted and wired into PC boards where there is not enough space or where you are replacing a surface mount regulator.

LM78x and LM79x and similar regulators

SPX78 and SPX79 regulators are drop–in replacements for TO-220 packaged LM78x and LM79x type regulators. Unsolder and remove the existing regulator, insert and resolder the same voltage Superpower. You can keep or remove any existing input and/or output capacitors. For best performance, use a 100µF capacitor directly at the Superpower input to ground and another at the load.

LM317, LM1117, LM337 type adjustable regulators

Refer to figures 13 and Error: Reference source not found for this discussion. Superpower regulators are fixed output, whereas LM317 and LM337 regulators are adjustable. To replace the adjustable regulators, circuit modifications must be made. To replace LM317/LM337/LM1117 (variable), etc., make the following circuit changes:

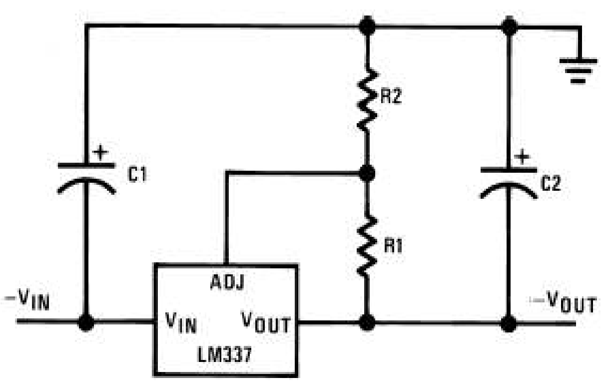


Figure 13: Standard LM337 connections. Remove R1, replace R2 with wire.

1. Replace R2 (goes from ADJ to ground) with a wire or short R2 to ground.
2. Remove R1 (goes from Vout to ADJ) because now it has the full Vout across it (instead of 1.2V) and will overheat.

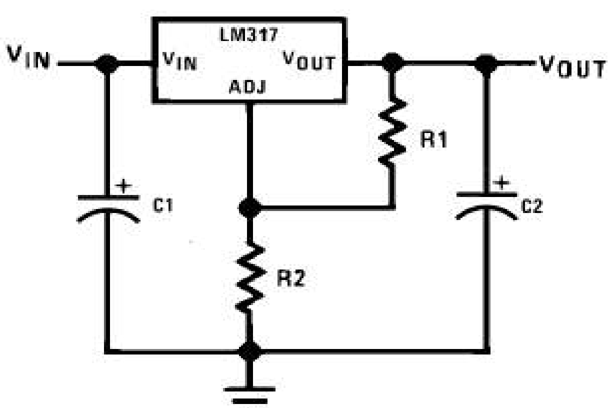
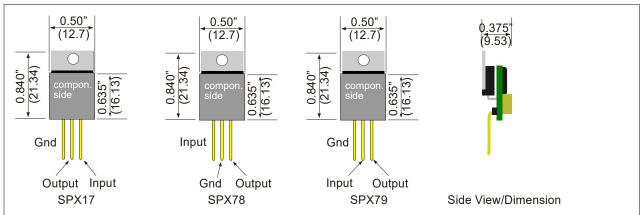


Figure 14: Standard LM317 connections. Remove R1, replace R2 with wire.

3. If there is a capacitor at the ADJ adjustment pin, it can stay or be removed as it now has both ends grounded.
4. See **Line Rejection and Drop Out Voltage** section on page 8 for capacitor C1 value. C2 should be a high quality 100uF capacitor such as Nichicon UVR1H101MPD.

Mechanical Specifications



SPX pinout and dimensions
inches” and (mm)
Pins extend 0.21” (5.3mm) from PCB bottom.

External dimensions may vary by ±2%, mounting hole dimensions by ±0.5%.

Legal Information

By using Belleson Superpower regulators, you acknowledge that for SPLV, SPHV, SPX, SPHP and any Belleson products with no output protection, a short circuit of the output to ground can damage or destroy the regulator. All devices are tested prior to shipment and damaged devices will not be replaced.

You also agree that misuse or misapplication of Belleson products may cause damage where attempted use or application occurs and you as user of the product(s) accept all responsibility for all consequences of use or application of Belleson product(s) and will not hold Belleson responsible for any damage nor injury as a result of use or attempted use of Belleson products.

Belleson products are not authorized for use as critical components in life support devices or systems.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.