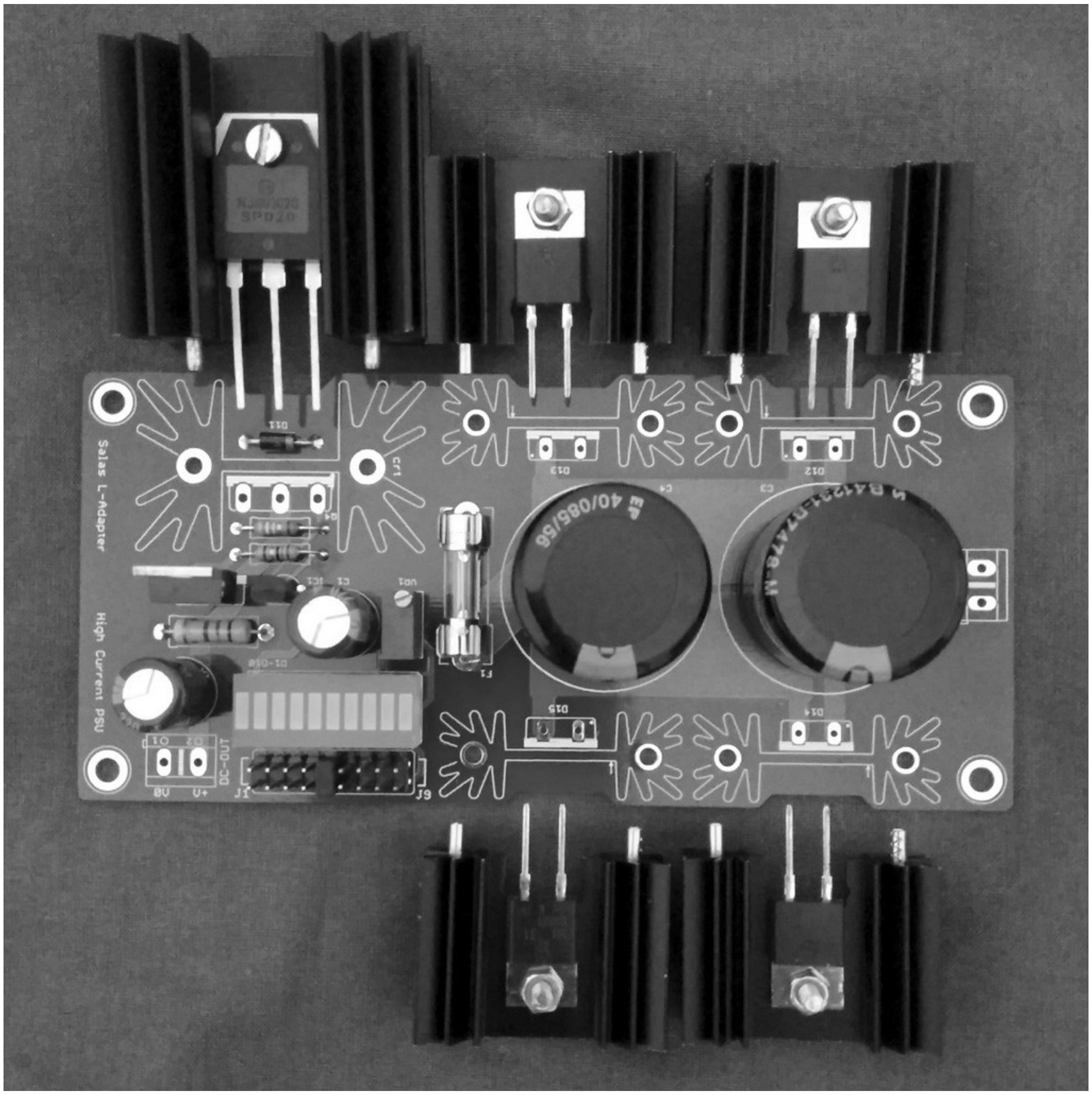
L-Adapter Guide



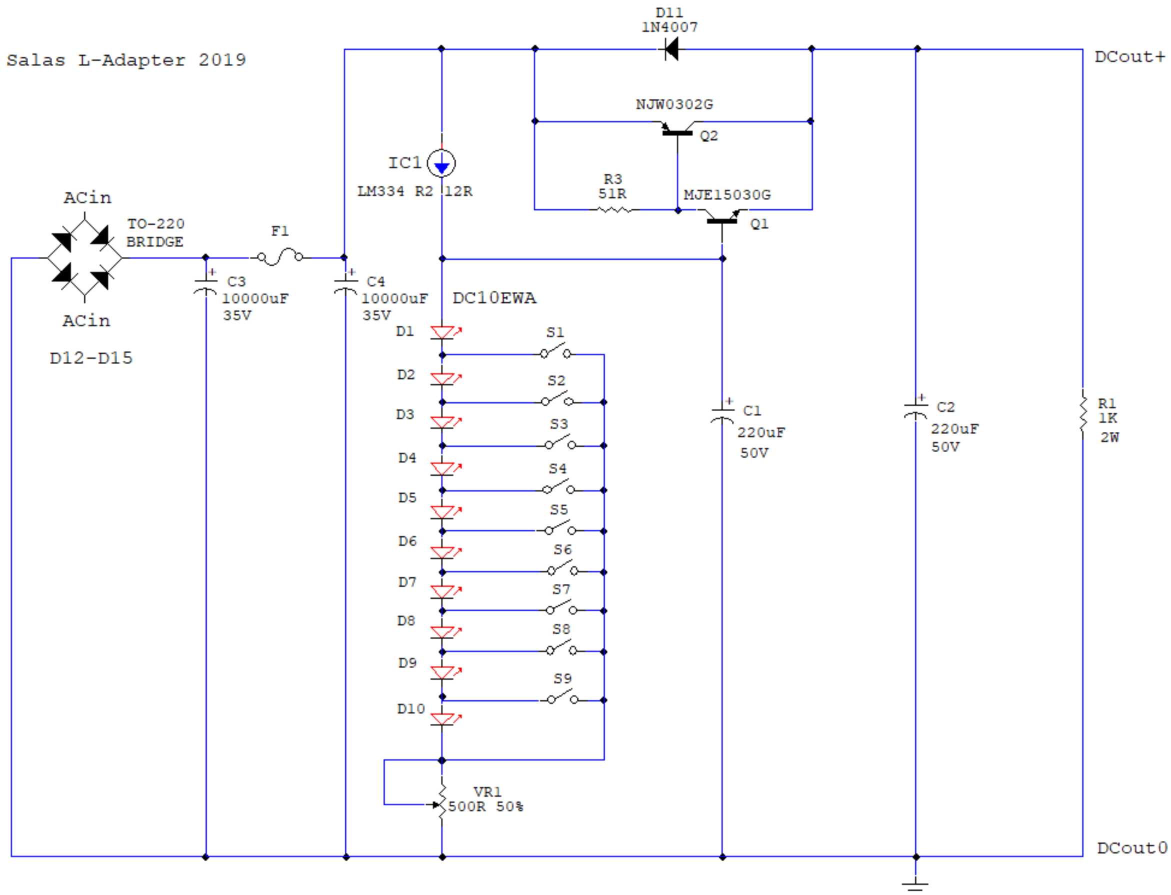
What is it

Its a simple low noise linear PSU of considerable power capability. Mainly aimed to replace SMPS adapters for various gear like mini PC, DSP, DAC, small Class D amps etc. Applications are many. Extending to vacuum tubes heating for instance. Lower consumption apps are of course not excluded.

Spec

1.3V to 20V positive polarity, adjustable
100W max output (with external sinking)
PSRR -70dB or less 10Hz to 100kHz
35,25,20mΩ Zo at 1,2,3A load & 2.5V Q2 Vce
Turn on time to 5V output: 200mSec
Turn on voltage peaking: None
PCB size 136mmX63mmX2mm
Black, 2oz copper, gold surface pads

Schematic



How it works

Transformer's AC enters a rectification bridge and reservoir capacitors stage converting it to raw DC. In other words DC+ripple voltage. IC1 is a constant current chip driving low noise voltage elements. These are LEDs which make the bulk of the PSU's voltage reference. R2 (Rset in LM334 datasheet) programs the bias current to an amount where their IF/VF curve is steep. The LEDs bar form ensures same factory batch for all ten. So to avoid sorting them out for individual characteristics.

Their population can be selected with a jumper. VR1 trimmer follows. With its extra voltage drop we can adjust the total voltage reference level finer. C1 shunts for AC the LEDS+trimmer Vref system to ground. Thus the active elements noise finds an easier path to ground through it and filtering happens.

Because the current source chip is high impedance and the voltage source elements are low impedance, the high division ratio rejects raw DC's ripple better. By now we have a very simple but useful voltage reference. It has unity gain i.e. it self spans the whole voltage level we set. As it requires no DC level amplification to Vout, its self noise residual stays non amplified too.

The voltage drift of the chip is positive while the voltage drift of the LEDS is negative, lending an amount of balance. With synergistic arrangement of their placement on the PCB regarding relative distances from main heat sources, benign enough drift against ambient temperature differentials has been achieved. Much better than expected from simulations.

Q1 stands on the voltage reference and drives the main current pass transistor Q2. They form a compound feedback pair system of a type called Sziklai. Q1 is biased with high enough collector current trying to stay indifferent of output load current changes as reflected to Q2's base node. Being an audio amplification grade type, Q2 has enough beta (current gain) for its size to already reflect relatively little. The Q1 & Q2 pairing did not show oscillation tendencies as applied here.

This collaboration has lower output impedance than a single emitter follower would have. Nice and steady up to 100kHz or so. There is still only one base to emitter voltage drop between the reference and the output though, thus minimal temperature change effect on Vout which equals Vref – Q1 Vbe.

The two transistors beta multiplication product guards IC1+C1 base reference node's AC filtering capacity to very good effect.

There is no error correction amplifier, thus no loop feedback between output and Vref. Feedback exists only within the transistors pair. So this PSU is not a classic regulator by proper terminology. Lets call it a voltage stabilized ripple eater. Dynamic performance is very good and extended in frequency for such a type, while its voltage output is well fixed.

D11 protects the transistors from reverse biasing in case of mishaps like connecting a charged load that stands at higher voltage than Vout. C2 is the output decoupling capacitor. R1 slowly discharges the system after power off not to stay high if unloaded and also helps it go lower faster when setting Vout unloaded.

How to plan it

The circuit is standard for active section but the range of power delivery it can cover asks for scaling its transformer, reservoir capacitors, and sinking accordingly.

Transformer: What we look for is high enough secondary voltage so Q2 will not see less than 2.5VDC across it at max load peaks. But not too high creating unnecessary dissipation when the loading cruises. The losses due to bridge diodes forward voltage drop and the storage capacitors ripple voltage combine to eat the raw DC to Vout voltage margin dynamically. Diodes have curves in datasheets and there is a formula (read post #149) to predict ripple voltage vs capacitors and load too but I will also try to give you few rough guidelines for this particular PSU:

1. For 2.5V-3.3V output rail use 7V transformer. For 5V-6.3V rail 9V Tx. For 7.5-10V rail 12V Tx. For 12-14V rail 15V Tx. For 15-18V rail 18V Tx. For 19-20V rail 20V Tx.
2. 2. Select 2 times more VA transformer spec than the load Watts when for below 14V rail. For example a 5V 2.5A RPi rail is 12.5W peak capable. Thus don't use smaller than 25VA transformer. In higher than 14V rail voltage cases use 1.5 times more VA than load Watts.

Storage capacitors: For up to 50W peaking loads 6800uF C3 C4 should suffice. 10000uF for higher.

Sinking strategy: There are two ways to sink this PSU. Board level sinking or external sinking. It accepts 25.4mm pitch on-board sinks. It also has side slots for easy underside mounting of Q2 and bridge diodes to chassis or to a back sink. In the second case full insulation must be used for those semiconductors.

How much sinking depends on each application's average current level. For example 2A peak loading if with low average current pull like mini computers do could only ask for a 38mm height board level sink on Q2 and 25mm height on the diodes. Even no diodes sinking. Then again if its a 2A constant load like tube heaters are, much more heat would be building up. Dissipated power is DC voltage across diodes and Q2 times average load current. Low VF diodes should be used. Voltage drop across Q2 should be >2.5V in all cases but not much higher, at least during peak power consumption phases by the load.

If you have in mind to use an ideal rectifier Mosfets bridge with microchip controller, don't populate D12,14,14,15 and feed that device's raw DC output to C1's pins under the board. Watch the polarity.

More demanding applications for peak current and/or high average consumption will need chunkiest board level sinks or moving to external sinking. To gauge the situation good information of the load's behavior is needed. How much current for how long on average. Then see about various sinking solutions temperature rise above ambient. It takes calculations work. There are articles on the web.

Empirical way would be, when with more than 65C on Q2 or bridge diodes with what sinking you got, better upgrade it.

How to build it

Populate and solder the parts in groups progressively from the lowest profile ones to the highest. What is to be on sinks secure it on them first, then install on the PCB as a whole. The LEDS bar has one side with beveled edge. Make sure its the one neighboring VR1. All other parts shapes are very obvious for orientation against the solder mask symbols. Its a very simple build, it should take short time to finish.

How to set it

Power on without a load. Select enough LEDS with the jumper to take Vout nearest to your voltage target at the output connector. Turn VR1 until meeting your target. Turning clockwise increases Vout when anticlockwise decreases it. Power down.
Connect the gear to be powered. Turn on again. Let the system work for few minutes. Some loading loss should have taken place due to output impedance and some thermal drift deviation should have settled by now. Still near. Readjust VR1 to target. If the application works as expected you are done.

When there are bad working signs, the load maybe sees less voltage than targeted. Measure at the end of the output wires. For voltage loss because of wire resistance, carefully compensate with VR1 as you watch the meter. Don't overcompensate for large voltage losses due to thin cable when strong ups and downs in current consumption happen like computers do. Use thicker/shorter cable. You don't want to overshoot digital chips max rail spec when their load current goes to minimum and the loss disappears.

When the bar LEDS dim or blink at load peaks, voltage drop across the PSU went too low. Measure no less than 2.5VDC across D11 or between F1's mounting clips and +Vout connector screw in worst case. If its less, use higher secondary voltage and/or bigger storage capacitors for the particular application.

> The jumper should only be moved in parallel to the LEDS across the two rows of pins.
> Not vertically on single row. No jumper at all allows for all the LEDS to operate when the transformer has enough output. Each added LED contributes about 1.75V extra. 17.5V total + 2.5V from VR1 maximum. For >20V needs, using 2kΩ VR1 can extend Vout to 27.5V max.

Bill of materials

Main section

R1 = 1K 2W non critical
R2 =12R 1/4W 100ppm
R3 = 51R 1/2W 100ppm
VR1 = 500R mutli-turn 3296Y Bourns style
C1,C2 = 220uF/35V 105C 10mm diam max
D1-D10 = Bar graph Kingbright DC10EAW
D11 = 1N4007G DO-41
Q1 = MJE15030G TO-220 50W NPN
Q2 = NJW0302G TO-3P 150W PNP
IC1 = LM334Z TO-92 adj current source

Rectification section

D12,13,14,15 = TO-220 12-30A fast diodes
C3,C4 = 10mF 35V 105C 30mm d max (typical)
F1 = 8A Slow Blow 5mm X 20mm glass fuse

Miscellaneous

5mm pitch Molex style two screw terminals x2
5mm fuse clips x2
2.54 mm pitch 2 row 9 pin long male header (or cut from longer)
2.54mm pitch jumper socket
When for board level sinks:
25.4mm pitch models like Wakefield 647-15ABPE or higher x1
25.4mm pitch models like Wakefield 637-10ABPE or higher x4
When for external sinking:
TO-220 thermal pads x4
TO-247 thermal pad x1 (same as TO-3P)
Insulating grommets (shoulder washers) x5

Notes

35V rating for all capacitors in this guide is for better quality. If having lower voltage caps that suffice vs the rectified level voltage and the output level voltage in your application you could still use them.

When externally sinking, TO-264 big Q2 transistor can also fit. I successfully tested with 2SA1943. MJL1302A could work as well. Such types would require a larger 30x20mm thermal pad of course.

There is also a medium power BOM with Mouser number references in the GB thread: GB thread
For more tech discussion and seeing / showing builds visit the main L-Adapter's thread: L-Adapter

Thanks for your attention & happy building!