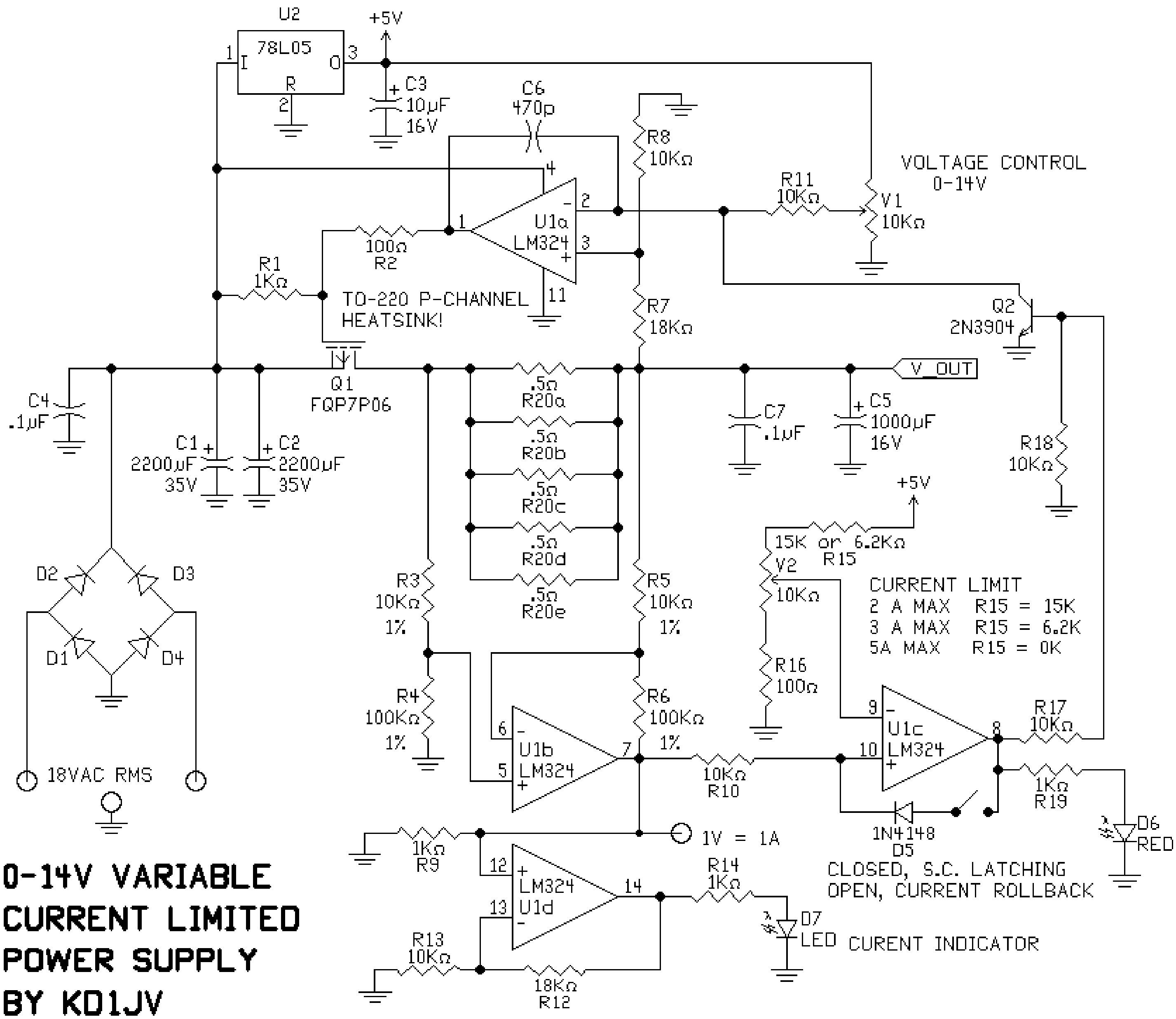
0-14V variable power supply with current limiting, Version 2.

For the experimenter and homebrewer, a variable power supply with current limiting can be very handy. There are not too many of these commercially available and those which are, are fairly expensive. However, it does not cost much to build your own.

Version 2 of the variable power supply fixes a problem with the original design which was designed a number of years ago. The problem is the current sense resistor is outside the voltage regulation feedback loop, which causes the output voltage to vary a little with current. The voltage drop is only 200 mv for a 2A current and that generally isn't a problem, but it would be nice if that drop was not there. This new circuit puts the current sense resistors on the supply side, rather then the ground return, so that the current sense resistors are inside the voltage regulation loop.

Additional changes to the original design are using a P-Channel MOSFET for the pass transistor instead of a NPN and the ability to select current fold back or latching shut down of the output when the current limit is reached.

The circuit:



How it works:

U2, a 78L05, 5 volt regulator is used as the voltage reference. U1a and Q1 form the basic regulator circuit. The U1a op amp compares the voltage on the negative input as set by the voltage output control pot V1 to the voltage on the positive (non-inverting) input which is derived by a voltage divider network, R7 and R8. If the voltage at the positive input to U1 a is too low, the output of the U1a goes negative, which turns Q1 on which brings the output up to the point at which the two inputs of U1a are in balance.

C6 provides some negative feedback to reduce noise and prevent oscillations. Because power MOSFETs have large gate capacitances, resistor R1 between the source and gate helps speed up the response time so that the output of U1a doesn't have to "overshoot" in an attempt to adjust the output voltage quickly.

The current sense resistor is make up of five, 0.5 ohm,1/4 watt resistors in parallel to create a 0.1 ohm, 2.25 W resistor. U1b is used to amplify and level shift the voltage drop across the these current sense resistors so that it can be used for the current limiting/ short circuit protection. The amplifier has a gain of 10, so the output is 1 volt per 1 amp. 1% resistors are use to ensure the output is at about ground. 5% resistors could be used if they are matched to be close in value first. R9, a 1K resistor from the output of U1b is needed to ensure the output does go to ground, as it will not quite get there on it's own.

The output of the current detector amplifier U1b is then additionally amplified by U1d and is used to drive a

LED to provide a relative current output indicator based on the brightness of the LED.

The output of U1b is also sent to U1c, which is used for the current limiting and short circuit protection. The output current, represented as a voltage at the output of U1b is compared to the voltage set by the current limiting control, V2. Depending on the value of R15, the maximum current can be selected to be 2, 3 or 5 amps depending on the rating of the input voltage source.

The current limiting can be selected to be either a fold back type or a latching type. This is determined by if the switch in series with D5 is open or closed. With the switch open, fold back limiting will be enabled. Fold back limiting will limit the current to the value set by V2 and effectively turns the supply into a constant current source if the load desires more current then what the supply is set for. Q2 will reduce the output voltage to a level which results in the limited current as set by the V2.

Latching limiting is enabled when the switch in series with D5 is closed. Now if the current exceeds the set point as set by V2, the output voltage will be shut down until the load is removed and the switch opened. This mode provides the best protection against short circuits.

Construction, parts selection:

The P-Channel MOSFET can be pretty much any type in a TO-220 package. The Fairchild FQP7P06 shown on the schematic is rated at 6.7 A and 45 watts of dissipation and has one of the smaller capacities typical for a medium power MOSFET.

The diodes in the bridge rectifier need to have a rating of at least that of the design output current and some over kill is recommended. 5A diodes should be the minimum used, which rules out the common 1N4001 types, which are only good for 1A.

The raw supply voltage can come from center tapped or non-center tapped transformer. If a center tapped transformer is used, D1 and D4 need to be eliminated. Because this regulator is effectively a low drop out type, the supply voltage less ripple can come very close to the maximum output voltage. This makes it possible to use a common 12.6 volt filament transformer, which despite the fact that tubes are rarely used these days, this voltage transformer is still commonly available. However, a large value filter capacitor is required to keep the ripple voltage low.

12.6 V rms x 1.414 = 17.8 V - 1.6 V (rectifier diode drop) = 16.2 V which leaves about 2 volts of acceptable ripple if full regulation at 14V output is desired. At 2A maximum output current, this requires a minimum of 8,800 ufd of filter capacitance. (use 2X 4700 ufd caps) For 5 amp output, 20,800 ufd is required which could be made up of five, 4700 ufd caps.

Using a 18V rms transformer as shown on the schematic allows for much greater ripple voltage so the 2X 2200 ufd caps will be sufficient for 2-3 amp output currents.

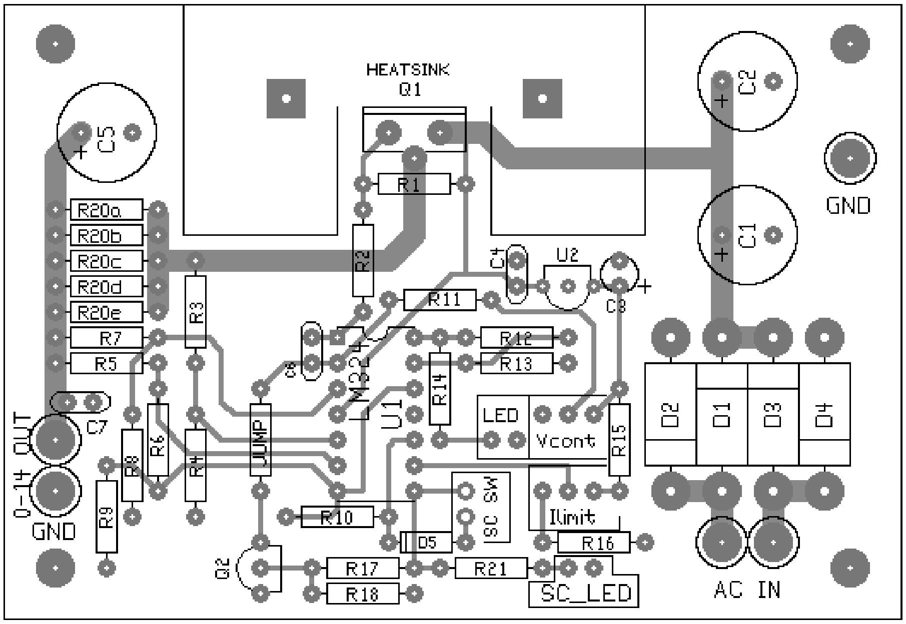
It would also be possible to use a DC supply, such as a Laptop power supply with typically has a 16 to 18V output. A large "wall wart" could also be used.

Be sure to use a suitably large heat sink on the pass transistor. The circuit board is laid out for a Wakefield 657-25ABP heatsink, which is suitable if maximum current is not being used for long periods of time.

Circuit board layout:

A X1, thru board view layout is available here. The pads only have small pilot holes on the plot, actual drill size will have to be determined by the parts you use, which will be typically 0.032" for most of the parts.

Here are the component placement diagram. For clarity, the ground plane is not shown.


HEATSINK
Q1
C5
C2
C1
GND
R1
R20a
R20b
R20c
R20d
R20e
R2
R3
R7
R5
C4
U2
C3
R11
R12
R13
R14
LM324
U1
LED
Vcont
R15
D2
D1
D3
D4
C7
0-14 OUT
GND
R8
R6
R4
JUMP
R9
R10
SC SW
Ilimit
D5
R16
Q2
R17
R21
R18
SC_LED
AC IN