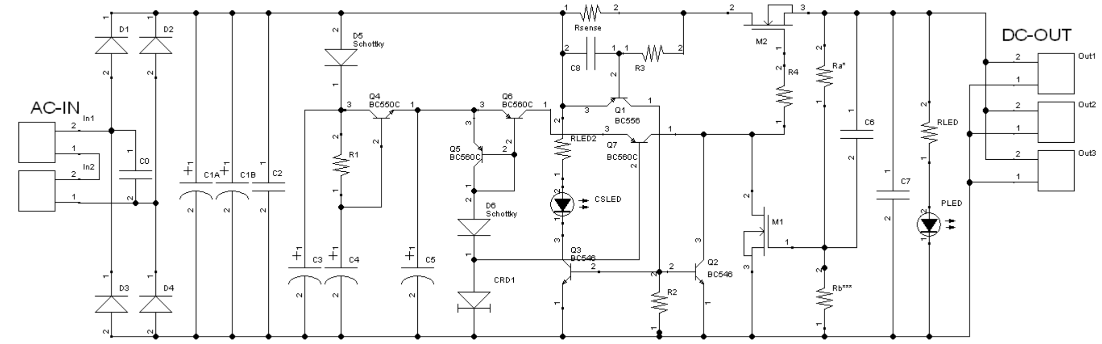
ToliRegV3 Guide, BOM, and Notes – TolisDIY.com



D1-D4 are simply a full-wave rectifier. This is filtered by C1/C2 and goes into C3 through D5. D5 is there to make sure high voltage fluctuations on C1 due to high currents at the output won't make the capacitance multiplier misbehave. This results in better regulation under moderate to heavy loads. The combination of R1 and C4 forms a LPF which is buffered by Q4 (capacitance multiplier), filtered further by C5. Q5/Q6 are used as a current mirror to mirror the current of constant-current-source (CRD1) to the regulating transistor with lower dropout voltage. D6/Q7 improve line regulation. M2 is the pass transistor, and M1 is the feedback transistor in charge of regulating the output voltage.

R_{sense} is the current sensing resistor. Transistor Q1 is used to sense the voltage over R_{sense} and once its high enough Q1 starts conducting current. This current goes through R2 and creates a voltage to drive Q2 which is used to discharge M2's gate node and reduce its voltage. This in turn limits the output current to I_{MAX}. Transistor Q3 is used to turn on CSLED. CSLED (Current Sense LED) is used to inform the user the current limit has been reached. The user can choose to ignore this issue (if it's a single current rush at start up for example), increase the maximum allowed current if it limits the performance of the circuit powered by the regulator, or turn the power off if there's a short circuit/fault at the output. Keep in mind this scheme of current limiting (at the drain of M2 instead of the source, and with no source degeneration resistor) has its drawbacks. While keeping output impedance to a minimum which is desirable, it will easily oscillate when a direct short circuit is placed at the output (due to very high loop gain). The DC current at the output will be limited, but the instantaneous current will fluctuate around this DC value. Therefore, this scheme isn't appropriate for use as a current source, only to limit power dissipation of the pass transistor.

If you don't want to have CSLED in the circuit, you can simply omit Q3, CSLED, and RLED2.

BOM:

Part	No.	Description
D1-D4	4	MBR10100 or MUR820 (note 8)
D5, D6	2	BAT46 or 1N400x (Schottky like the BAT46 is preferred)
C0	1	10n-100nF MLCC 50V (100V recommended)
C1A,C1B	2	2200uF 63V electrolytic capacitor (note 2,6)
C2,C7	2	1uF metalized polyester capacitor (note 2)
C3,C4,C5	3	220uF 63V electrolytic capacitor (note 2)
C6, C8	2	MLCC 100nF (note 2)
RLED,RLED2	2	Your choice (10Kohm recommended value)
R1, Rb	2	1/4W metal film resistor 1% 1K
R2,R4	1	1/4W metal film resistor 1% 120R
R3	1	1/4W metal film resistor 1% 10K
Ra	1	1/4W metal film resistor 1% (note 1 for value)
Rsense	1	2W-3W metal oxide resistor (note 3 for values)
Q1	1	BC556 PNP
Q5,Q6,Q7	3	BC560C PNP (note 4)
Q2,Q3	2	BC546 NPN (note 4)
Q4	1	BC550C NPN (note 4)
CRD11	1	E452 CRD(note 7)
M1	1	IRFZ34N MOSFET
M2	1	IRLZ24N/IRL520N MOSFET
PLED,CLED	2	LED of your choice, can be of different type/color
Heat Sink	1	657-1XABPN/657-2XABPN/other HS (where X is 0 or 5)
Input Terminals	1	0.2” (200mil/5.08mm) spacing terminals
Output Terminals	1	0.2” (200mil/5.08mm) spacing terminals

Notes:

1 – This resistor and Rb set the output voltage. Because the output voltage will depend on M1 as well, this voltage divider should be adjusted to the V_{TH} of M1 you are using. However, since $Vout = Vgs(1 + \frac{Ra}{Rb})$ and Vgs is about 3.3V (this is only a rough estimate and can change between transistors) a good rule of thumb is to choose Ra=Vout*305-1000(ohm). So for 24V output voltage you'll choose 24*305-1000=6.3Kohm (a 6.2Kohm resistor is close enough and easily sourced).

2- It is possible to use capacitors with other voltage ratings/other capacitance values as long as they physically fit. Make sure the voltage rating of the capacitor you select is sufficiently high so it won't be damaged by the expected voltage across it.

3 – This resistor is used for current limiting. If you don't want it you can simply short its pads (and leave out Q1-Q3, R2, RLED2, CSLED), but I recommend you use a resistor even if current limiting is not required, it'll offer some protection against high current transients. Its value should be about 0.55/Imax (the actual current limit will be about 25% higher than Imax). Its power rating should be higher than the maximum power dissipated over it which is $Imax^2 * Rsense$. For example if you'd like 2.5A max current you'll choose Rsense=0.22ohm with a power rating greater than 1.375W (2W should be sufficient in this case). If there's a need for a higher wattage resistor that doesn't fit the board an external resistor could be used. It's recommended to mount this resistor with some space between it and the board to allow better air circulation around it.

4 – These transistors can only operate with V_{CE} of up to 45V. Therefore if you are feeding the regulator with an AC source of over 30VAC you should replace some of these transistors with a type that can operate under these elevated voltages. Q4 will have the entire supply voltage across it at start-up; Q7 will have the entire supply voltage across it when the current limiting is active. Q5-Q6 should be safe due to CRD and Q7 that take bare the entire voltage. Q1-Q3 are good for somewhat higher voltages, therefore should be ok with input up to about 40VAC. However, I recommend not pushing this to the limits, as the output of the transformer can change depending on line voltage variations and load current.

5 – These terminal blocks are optional; you can solder wires directly to the board. It's also possible to use a combination of 2 contacts terminal blocks of the same series instead of a single 4/6 contacts terminal blocks.

6 – C1 must be large enough to guarantee the input voltage to the regulator won't drop below the minimum required voltage for regulation. This must take into account line voltage variation and sufficient headroom for best performance. This voltage should be at least 5V higher than the output voltage the regulator is set for, and must be maintained under full load. A rule of thumb is ~3000uF per 1A of continuous load current (that's 2X1500uF). So a load of 150mA will only require ~470uF. Obviously, more capacitance will result in better regulation and higher values are recommended.

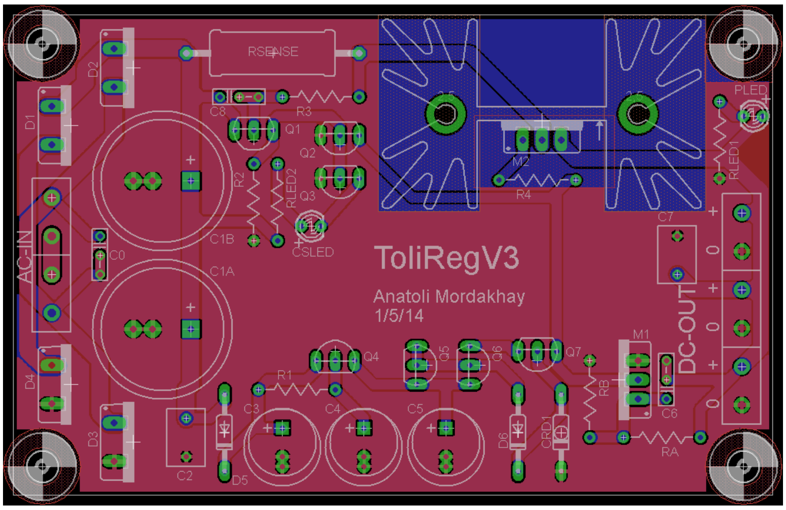
7 – The JFET/CRD should be able to withstand the voltage you expect your circuit will have at the input. For low output voltages (up to ~15V) there's no issue with any of the common JFET's. However, the 2N5457 can only withstand 25V of VDG. Therefore for higher input voltages it shouldn't be used. 2SK170 is good for 40V, 2SK117 is good for 50V. Keep in mind this is the input voltage we are talking about, so it would be ~ 10V higher than the output at its peak. If you are using a different part verify it'll work with your expected voltage. There's also quite a large variation in the current of the JFET's, so if you are indeed using a JFET and not a CRD, you can check its IDSS (short gate to source, put 5-10V across VDS an measure the current through it) to see if it's close to the 4.7mA recommended value. You can use different values as well (anything in about ~3-7mA will work just fine, but if you use higher IDSS devices you should increase C3 as well). The E452 is 4.5mA CRD with up to 100V maximum voltage so it is a great device for this application.

8 – The 1N400x series is a cheap and easily sourced part, but its current handling capability is very limited. It must withstand short pulses of high currents in this use as a rectifier diode; therefore it should only be used with light load up to ~400mA average load current. The MBR10100 and MUR820 diodes can withstand much higher current (X8-X10 compared with the 1N400x series), so for high current loads these are an excellent option. While the new board revision only accommodates TO220 packages, 1N400X diodes can still be used by bending the leads. It is still recommended to use one of the two diode models listed in the BOM above (MBR10100, MUR820).

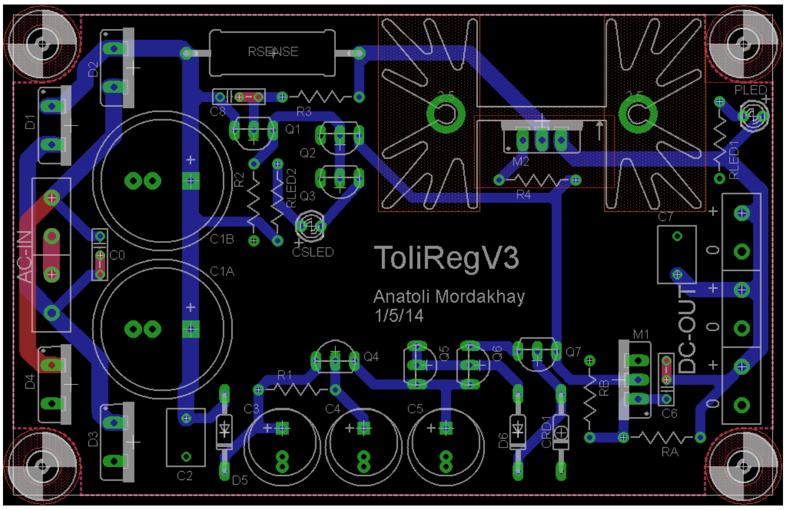
PCB:

The PCB is a 2-layer design. It can accommodate an on-board heat-sink for M2, with variable heat-sink height only limited by the height of the case you are using. The transistor can be mounted to the case instead of a heat-sink; in that case it should be soldered underneath the board with no additional wiring. If you are using the case as a heat-sink use a TO-220 insulation kit (washer and pad) to keep the case electrically insulated from the transistor package.

Board Layout:

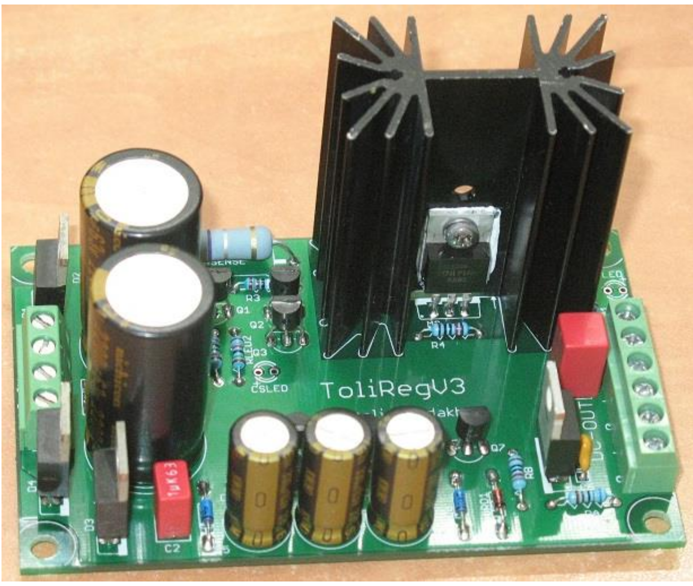


With ground plane hidden:



Assembled board:

Here are some images and measurement data for the assembled regulator:



The board was set to 32VDC, with a current limit of ~1.5A (0.47ohm Rsense), with an input capacitance of 4400uF (2x2200uF).

Actual output voltage is measured at 31.9VDC, and actual current limit is measured at 1.58A.