A Report on the 350 Watt Motor Controller

Model FC350BJ/110V

Made by

The Shanghai SIEG Industrial Company

and Used in Their Line of Mini-Mills

March 2009

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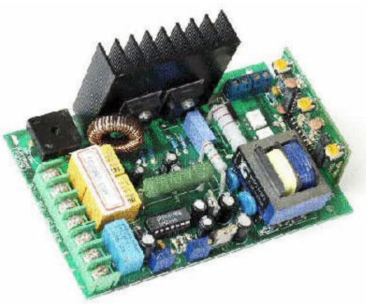
The SIEG 350 Watt Motor Controller

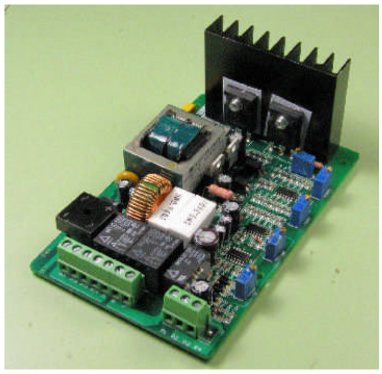
Introduction - When the motor controller failed in my Grizzly G8689 mini-mill I decided I would put my engineering background to work and try to fix it myself.

This started me on an odyssey of discovery and effort that resulted in my being able to fix my controller and left me with a ton of information I decided was worth sharing. Hence this paper.

I am indebted to Anvio Media for their information on the 1st generation (http://anivo.com/reed/G8689_cont/g8689_cont.htm) and to Chris Wood of the LittleMachineShop.com (http://littlemachineshop.com) who was kind enough to lend me a current model so that I could incorporate that version into this discussion.

Controllers Being Reviewed – There are three models discussed which I refer to as the 1st generation, 2nd generation and current – i.e. the model now being sold.





The 1st generation had the low level circuit on a "daughter board' mounted perpendicular to the main board. It was construction with standard components.

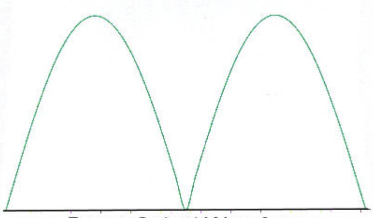
The 2nd generation was redesigned to permit putting all of the circuits on the main board without increasing the size of the board. Unfortunately, this meant going to surface mount components which makes the board almost impossible to repair if there is a failure in a low level circuit. From a schematic standpoint, it is virtually identical to the 1st generation. There are a few component changes and relocation, but nothing substantial. This is my controller.

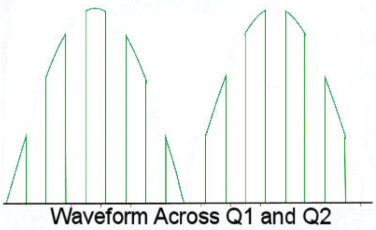
The current model is almost identical to the 2nd from a schematic standpoint. Even the part numbers are the same. The are a number of component changes (single turn trim pots to 10 turn pots e.g.). A major change is the substitution of a 4 pin optocoupler for the 6 pin version. An important change for the user is the change to a wire insertion terminal board from a spade lug type board. This makes replacement in a mill with spade lug terminated wires somewhat difficult. (more about this later)

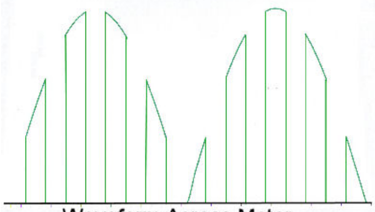
Through all of this, SIEG kept the same part number – FC350BJ/110V.

Theory of Operation – The following discussion is based on tests and observations of my controller – the 2nd generation. The schematics were carefully checked against the actual circuit. I believe that this information applies to the current model.

Power Generation and Control – refer to the main schematic page 6 and the following idealized waveforms:


Power Output Waveform
Measured Between + and - of B1


Waveform Across Q1 and Q2
Measured Motor Neg to PE


Waveform Across Motor
Measured Motor Pos to Motor Neg

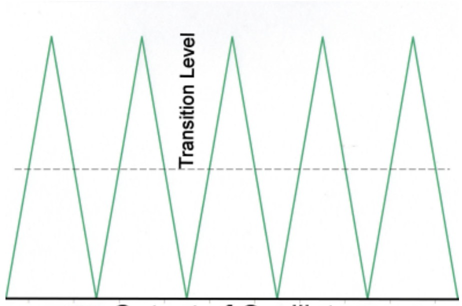
Line voltage is delivered to the bridge rectifier B1. The + DC output of B1 (left waveform) goes to motor pos, through the motor, returns to motor neg and is delivered to the drain of the power mosfets Q1 and Q2.

The power mosfet is a switch. A plus voltage at the gate turns it on and a zero voltage turns it off. Assume that a pulse with a repetition rate of 1080 pulses per second and a 50% duty cycle is delivered to the gates of Q1 and Q2. They will turn on (conduct) when the pulse is present and the waveform across the mosfets will be as shown in the middle waveform.

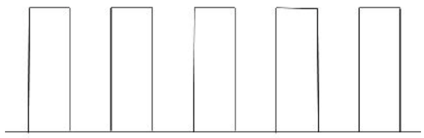
When they conduct, current is drawn through the motor and the voltage now appears across the motor. This waveform is shown on the right. Note that it is the inverse of the mosfet waveform.

As the duty cycle (pulse width) of the gate pulse varies, so does the power to the motor. A wider pulse means more power to the motor.

Gate Pulse Generation – Refer the schematic of the low level components, page 7 . The 1 KHz oscillator is a triangular waveform generator, the output of which is feed into the negative of opamp comparator IC2D. An opamp turns on when the + terminal is higher than the – terminal and vise-versa. Assume that the speed control is set to +6 volts at the plus input of the opamp and that the output of the oscillator goes from 0 to +12 volts. Consider the following idealized wave forms:



Output of Oscillator



Pulse Output at IC2-14

The transition level is the same as the voltage on the + input. When the triangle rises above the transition, the opamp turns off and when it falls below the transition level it turns on. The output of the opamp at pin 14 is as shown.

When the speed control is turned up, the transition point is raised and the pulse width is increased.

The remainder of the circuitry on this schematic is involved with buffers and the insertion of voltage and current feedback signals.

Now refer back to the main schematic. The PWM signal is delivered to the inputs of the optocouplers OK1 and OK2. The optocoupler is required because of the voltage differences between the ground of the low level circuits and power earth (PE). This device isolates the two by using an LED to photocouple to a light sensitive diode. The output of the optocoupler is delivered to the gates of the mosfets.

Overload and Interlock Circuits - Refer to the main schematic and to the schematic of the operator controls on pages 6 and 8.

Consider the state of the circuits before power is applied. Relays 1,2 and 3 are open and in the state shown. Assume the motor switch is on and that the speed control pot is at zero and the pot switch is closed..

When power is applied, The voltage is applied first through the pot switch. This applies power to the bridge rectifier and to the low voltage supply. This cause relay 1 and 2 to close, bypassing the pot switch and delivering power to the motor. Because the power voltage of a sufficient level is delivered to IC3A, relay 3 stays open. The power pot can now be advanced and power delivered to the motor.

If an overload occurs, the voltage at IC3A drops and relay R3 is energized removing the coil voltage to relays 1 and 2 causing them to open. This removes power from B1 and TR1 and causes the yellow overload lamp to go on.

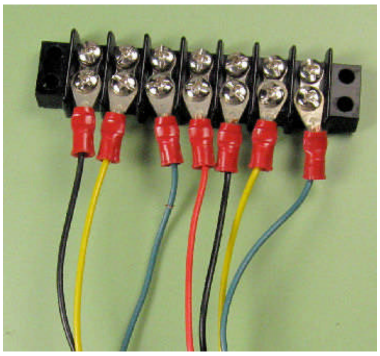
The system is reset when the power pot is turned to zero and the switch closed.

My Problem – My problem, after being found, turned out to very simple and easy to repair at no cost.

The two white resistors, R1A and R1B, roughly in the center of the board, are each 0.37 ohm 5 watt resistors and are wired in parallel. Current to the motor passes through these resistors and the voltage across them is used in the current feedback loop. (This explains why +12V is tied to the output of B1)

These resistors were mounted on long leads to remove the heat source from the circuit board. When the mill vibrates, these resistors vibrate, and after a while a lead breaks off at the board. Both of my resistors had broken leads but they were hidden and I never found the break until I got to that part of the circuit while measuring each component. I pulled the resistors, trimmed the leads, resoldered them in place, reinstalled the controller and got 100% performance.

I note that the leads are much shorter on the current model and I do not anticipate this problem reoccurring.



Before I found the problem, I was prepared to buy a new controller and had one delivered. It is the one described above as the current model. One of my problems was trying to get the spade lug terminated wires into the wire insertion board on the controller. One option is the remove the lugs, strip the wires and insert them. Unfortunately terminal 5 takes three wires and the hole is not big enough. My solution would have been to use an intermediary terminal block with connection leads as shown in the photo.

Service Considerations – To assist in servicing efforts on the 2nd generation controller, I have prepared two views of the controller, top and bottom, each with component locations and IDs These are found on pages 9 and 10.

There are a few considerations that must be made when doing test and repair.

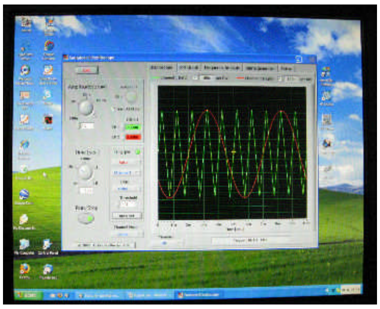
1. This board is not line isolated – be careful of electrical hazards.

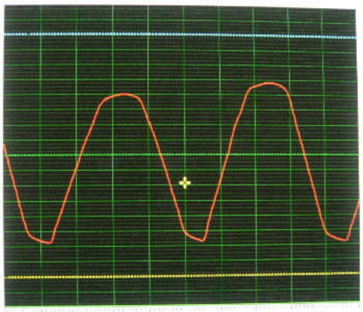
2. The low voltage ground is different that the power earth ground. Do not confuse them or you will wipe out components.

3. Use battery operated test meters.

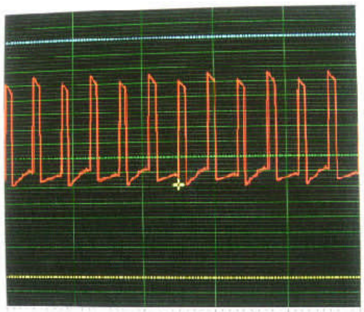
4. If you are going to test it on the bench, use a good load in place of the motor. I used 3 each 100 ohm 100 watt resistors wired in parallel and got good performance.

5. If you want to look at waveforms, you must use an isolated oscilloscope. I solved the problem by turning my laptop PC into an oscilloscope using some very sophisticated software from Germany. www.zeitnitz.de/Christian/Scope/Scope_en.html . The pictures show the laptop screen and two of the waveforms I recorded. I was not able to get good power output shots because the gate pulse frequency was not synchronized with the line frequency.



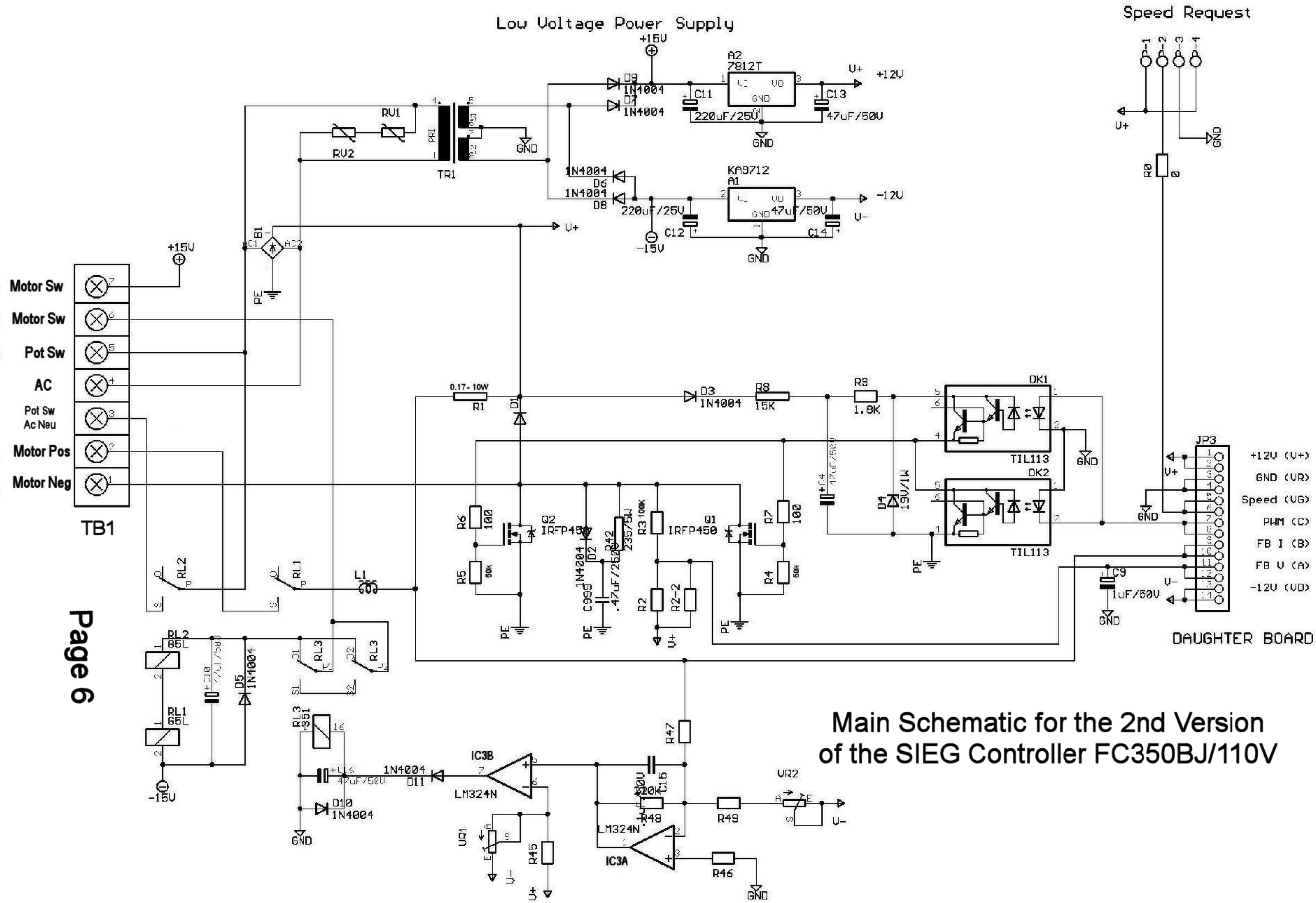


DC Output of B1

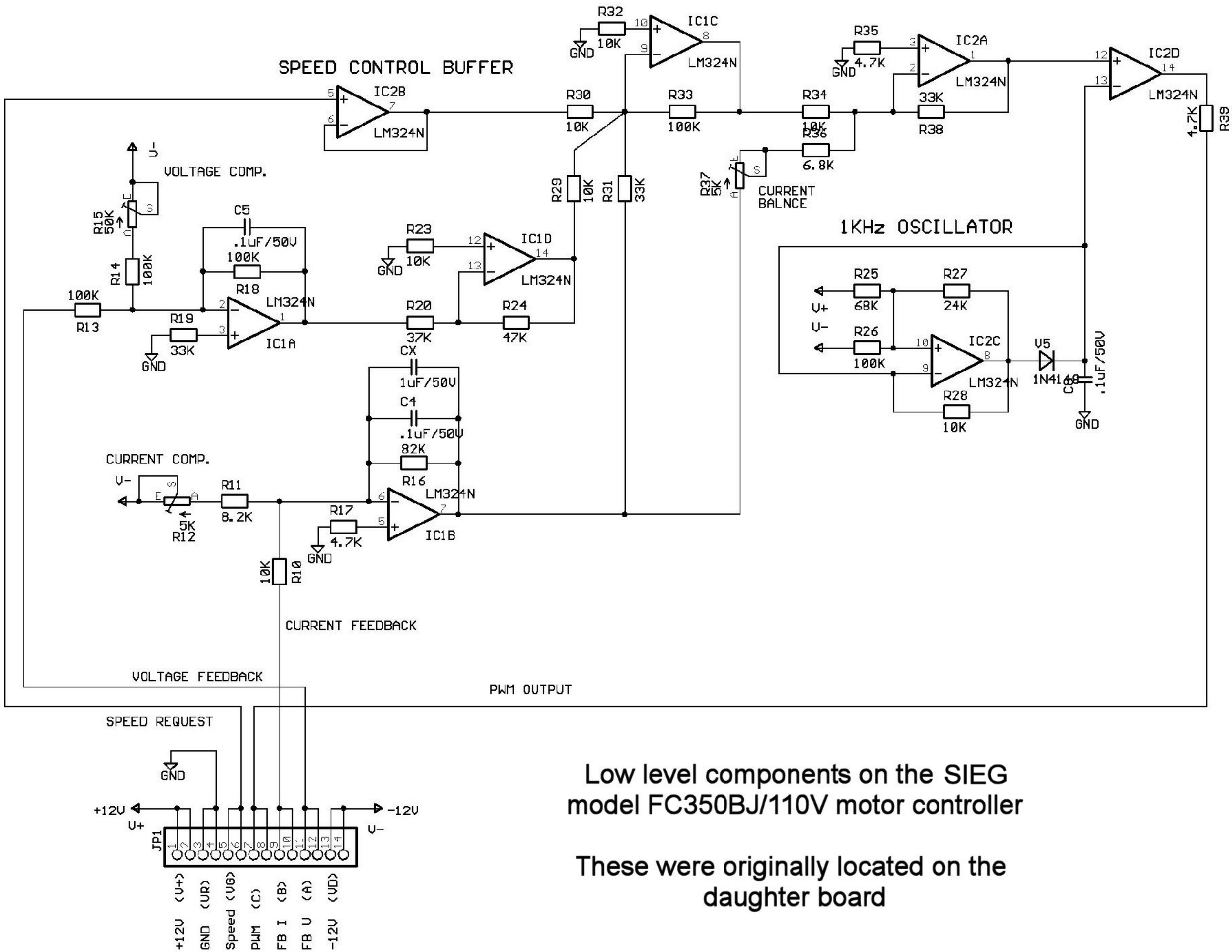


Pulse at the Gate of Q1

6. If you are going to do board repair, make sure that you have a constant temperature (700 F) soldering iron and use solder wick to remove excess solder from the repair point. The board is easily damaged.

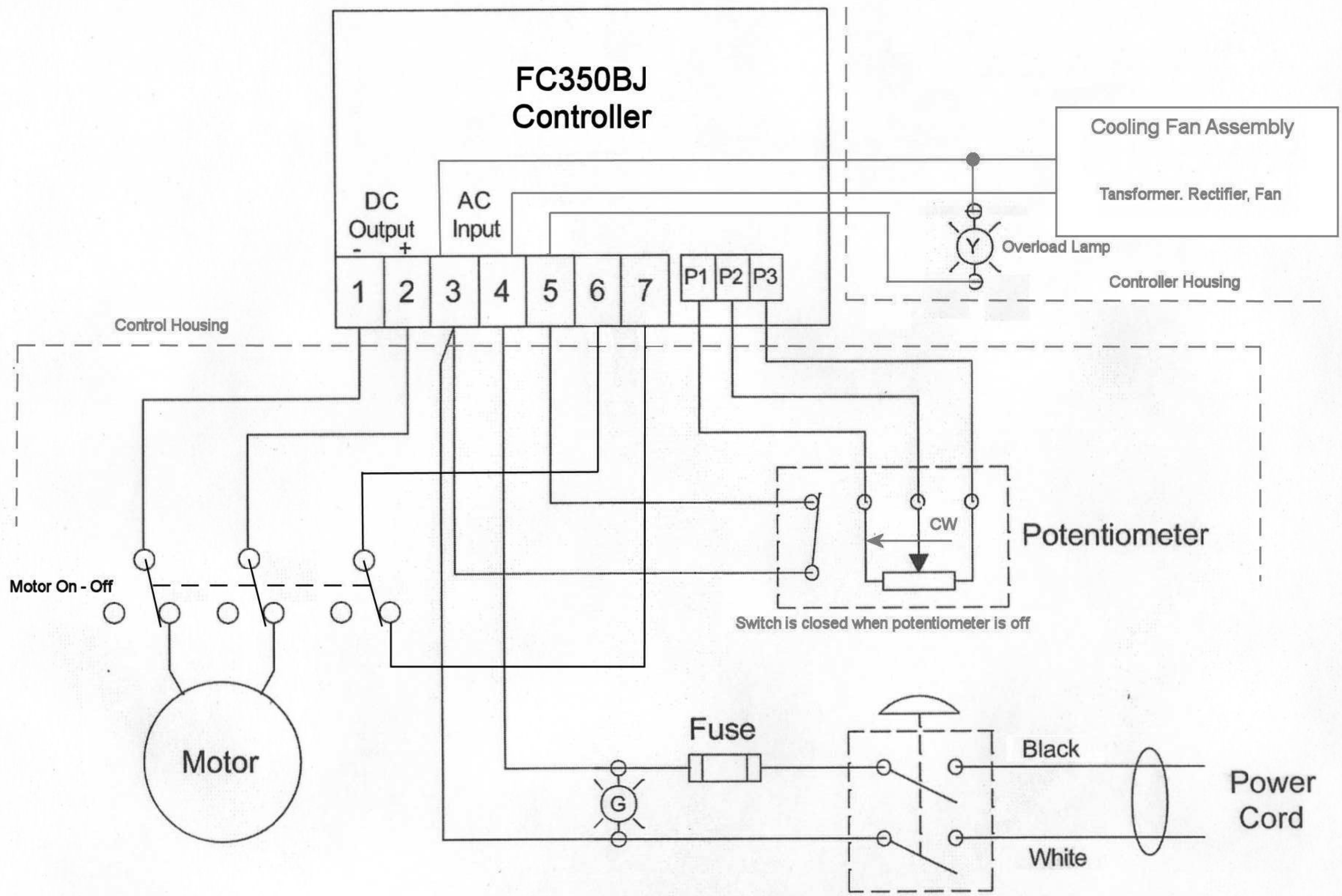


Main Schematic for the 2nd Version of the SIEG Controller FC350BJ/110V

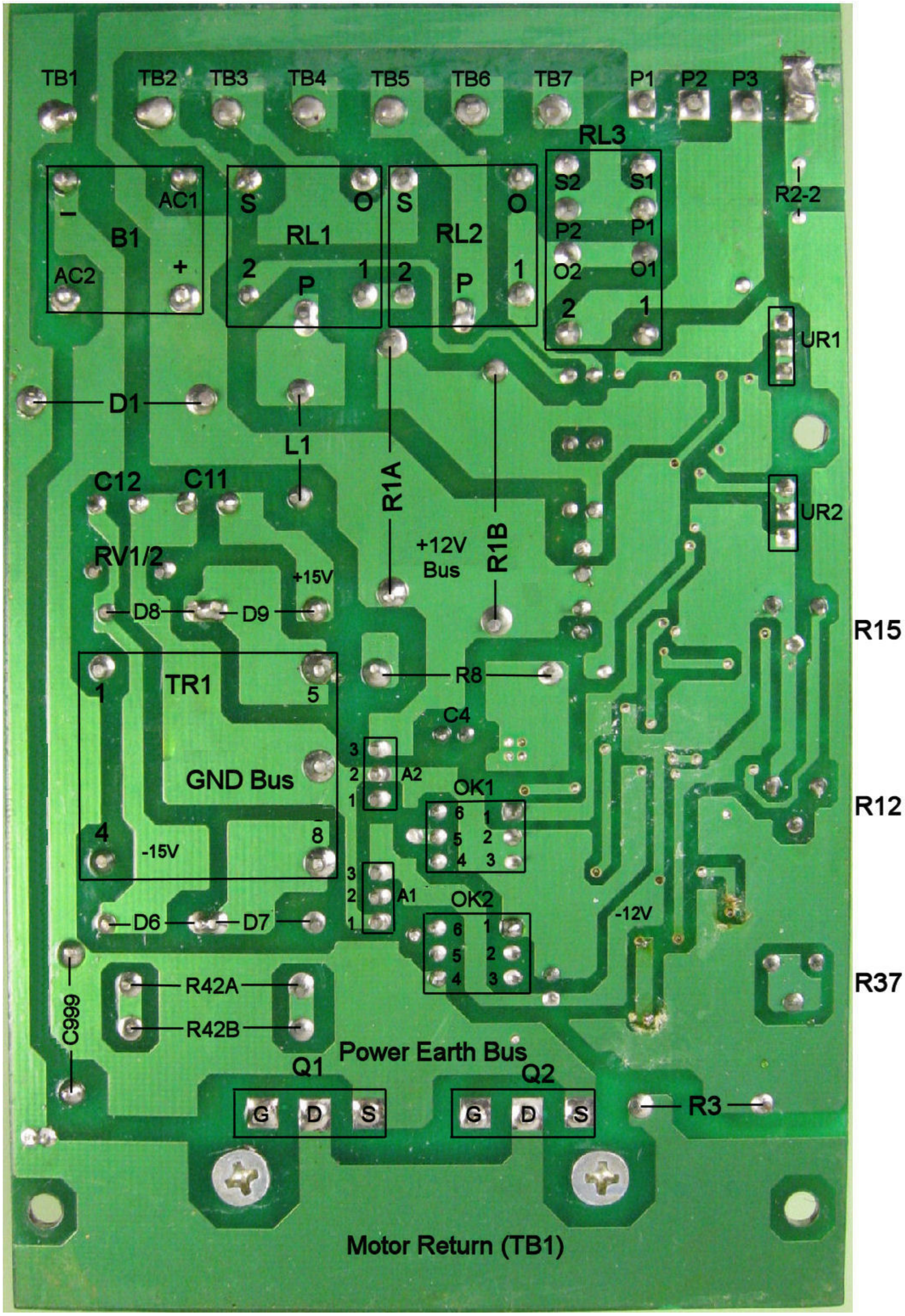


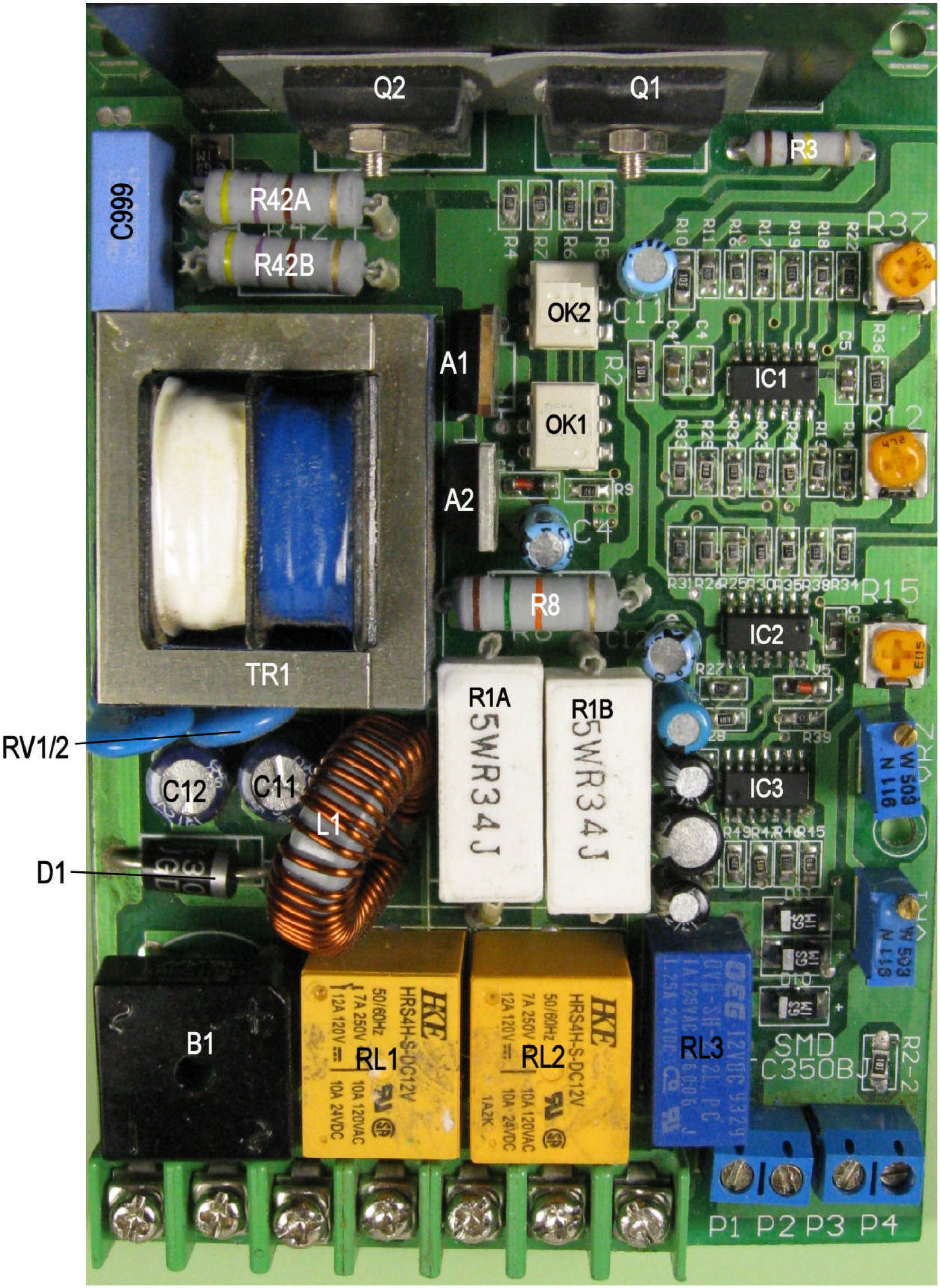
Low level components on the SIEG model FC350BJ/110V motor controller

These were originally located on the daughter board



Schematic drawing of the operator controls
on the Grizzly model G8689 mini-mill


TB1
TB2
TB3
TB4
TB5
TB6
TB7
P1
P2
P3
RL3
S2
S1
R2-2
P2
P1
O2
O1
2
1
–
AC1
B1
AC2
+
S
O
RL1
2
P
1
S
O
RL2
2
P
1
UR1
D1
L1
R1A
R1B
C12
C11
+12V
Bus
UR2
RV1/2
+15V
D8
D9
R15
TR1
1
5
R8
C4
3
2
1
A2
GND Bus
OK1
6
5
4
1
2
3
R12
4
-15V
8
3
2
1
A1
OK2
6
5
4
1
2
3
-12V
D6
D7
R37
R42A
R42B
C999
Power Earth Bus
Q1
G
D
S
Q2
G
D
S
R3
Motor Return (TB1)


Q2
Q1
R3
C999
R42A
R42B
R37
OK2
A1
OK1
IC1
R12
A2
R8
R15
IC2
TR1
R1A
R1B
5WR34J
5WR34J
RV1/2
C12
C11
L1
IC3
D1
B1
RL1
RL2
RL3
SMD
P1 P2 P3 P4