Chapter- 4

Hardware

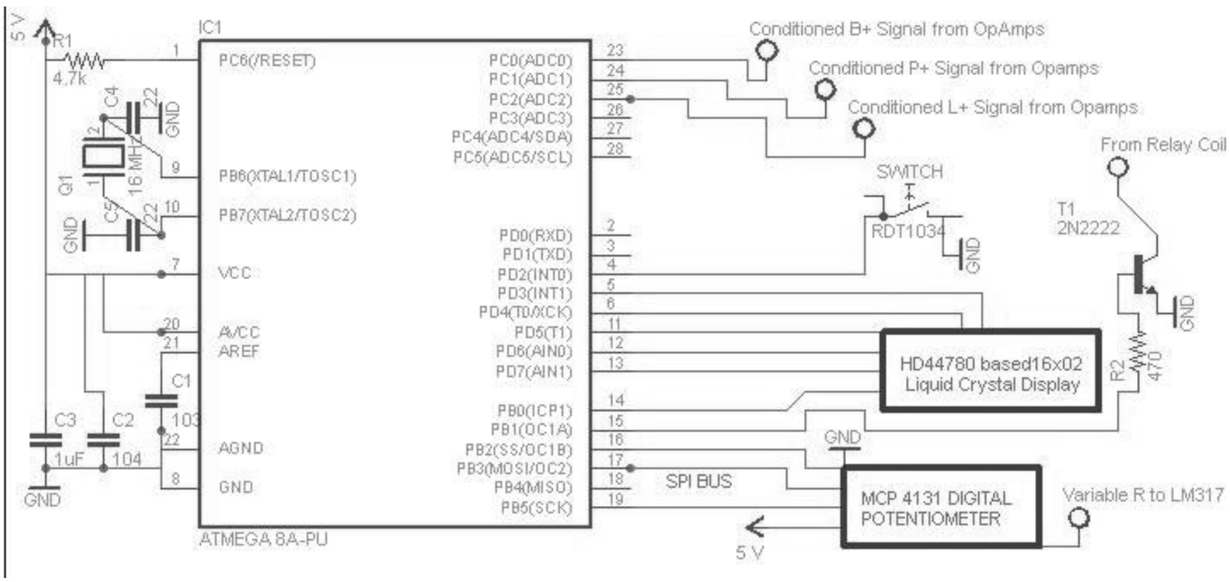

Figure 4.1 Circuit Diagram part I

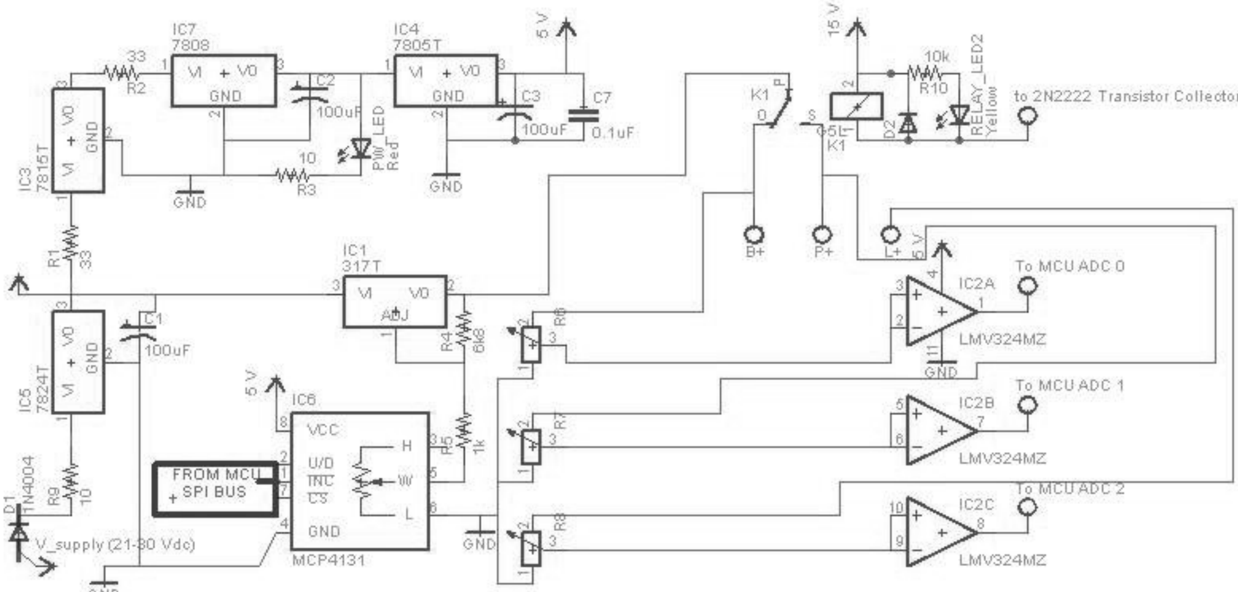

Figure 4.2 Circuit diagram part II

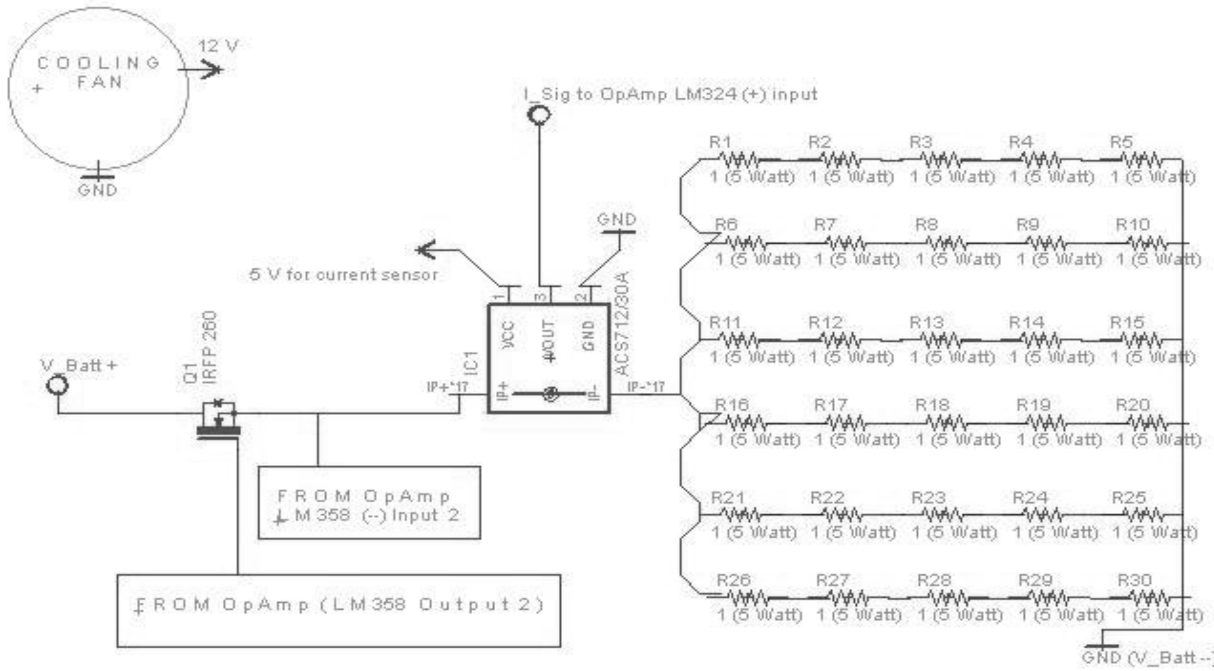

Figure 4.3 Load circuit diagram

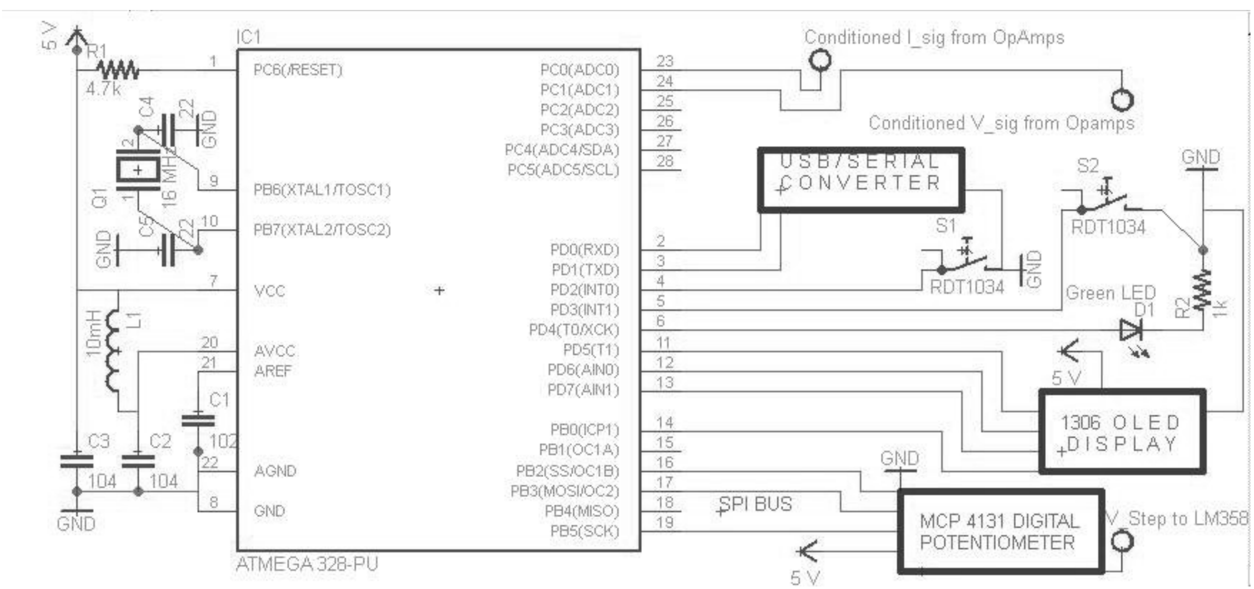

Figure 4.4 MCU digital circuit

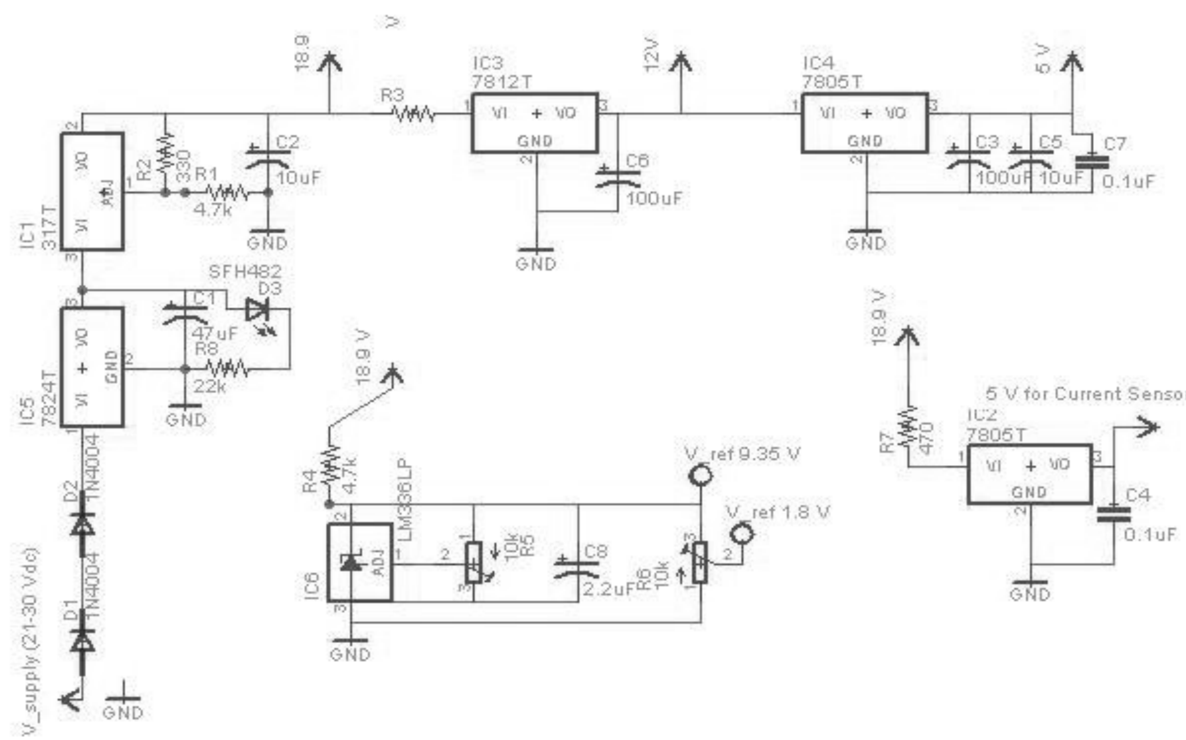

Figure 4.5 Power Circuit

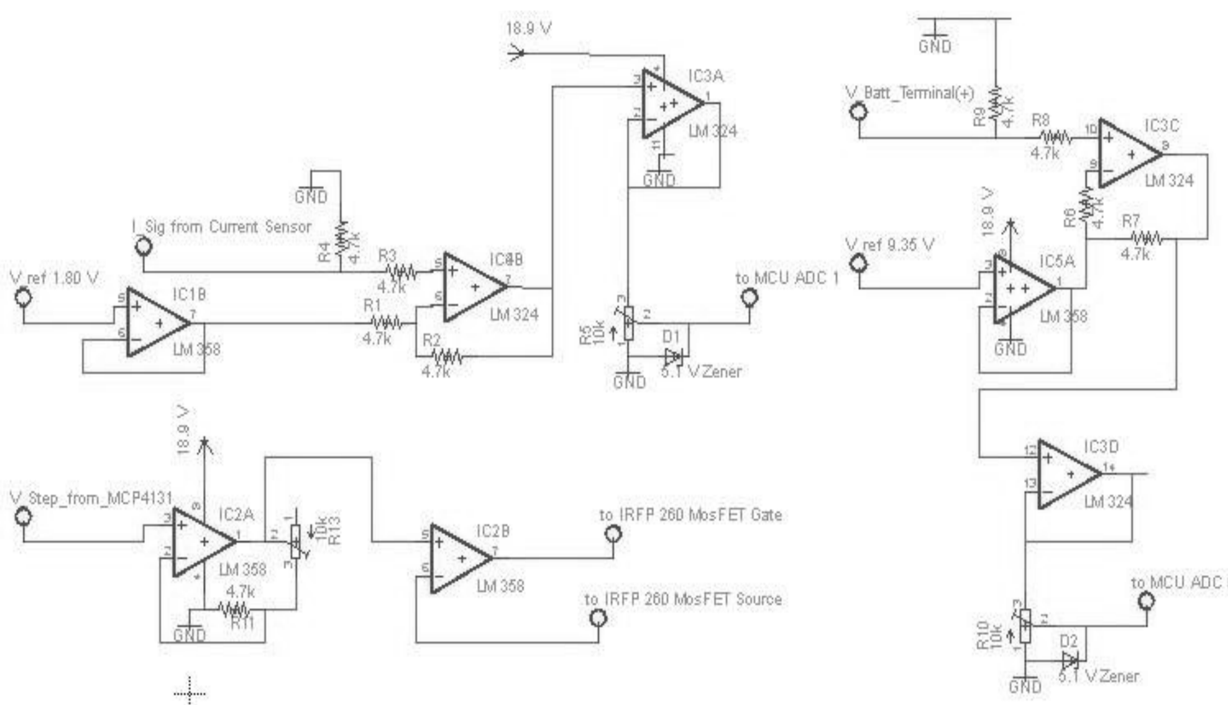

Figure 4.6 Signal circuit

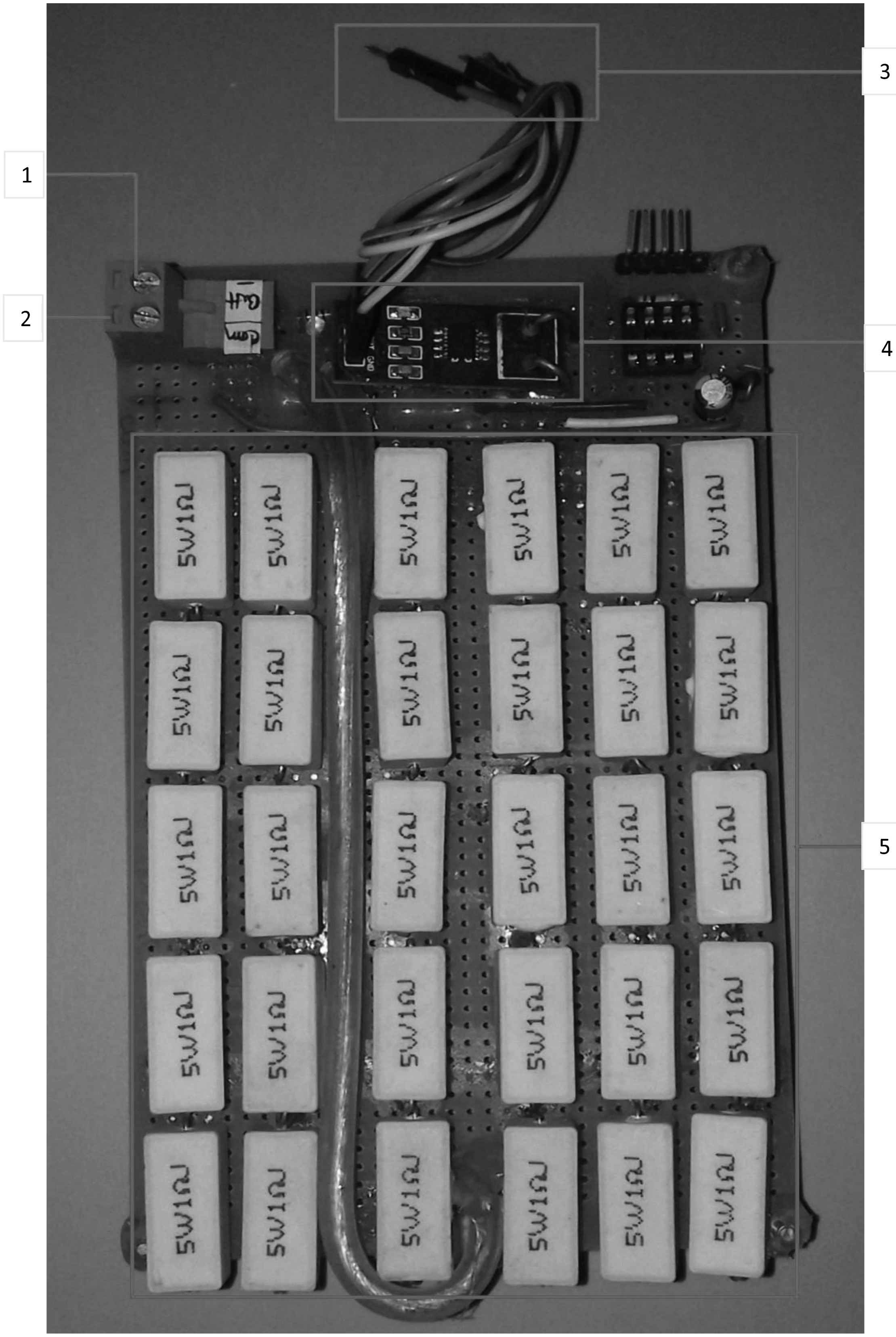

Figure 4.7 Load resistor network Unit

4.1 Load resistor network Unit

1. Load resistor network Unit From MOSFET source: the battery tester MOSFET is connected here
2. To common ground.
3. Power to current sensor: red wire – 5V
   Yellow wire – Ground
   Green wire – transmit the measured current signal to Analog signal conditioning unit
4. 30A (up to) hall effect current: : ACS712. 30A is used to sense current. It's a Hall effect current sensor.
5. Load resistor network: per resistor is of 5W, 1 ohm. There are 50 resistors in total. Per line 5 resistor is in series connection, and 6 such lines are in parallel with each other. Equivalent resistance is .870 ohm and total load is of 150W. Current sensor is connected in series with this network.

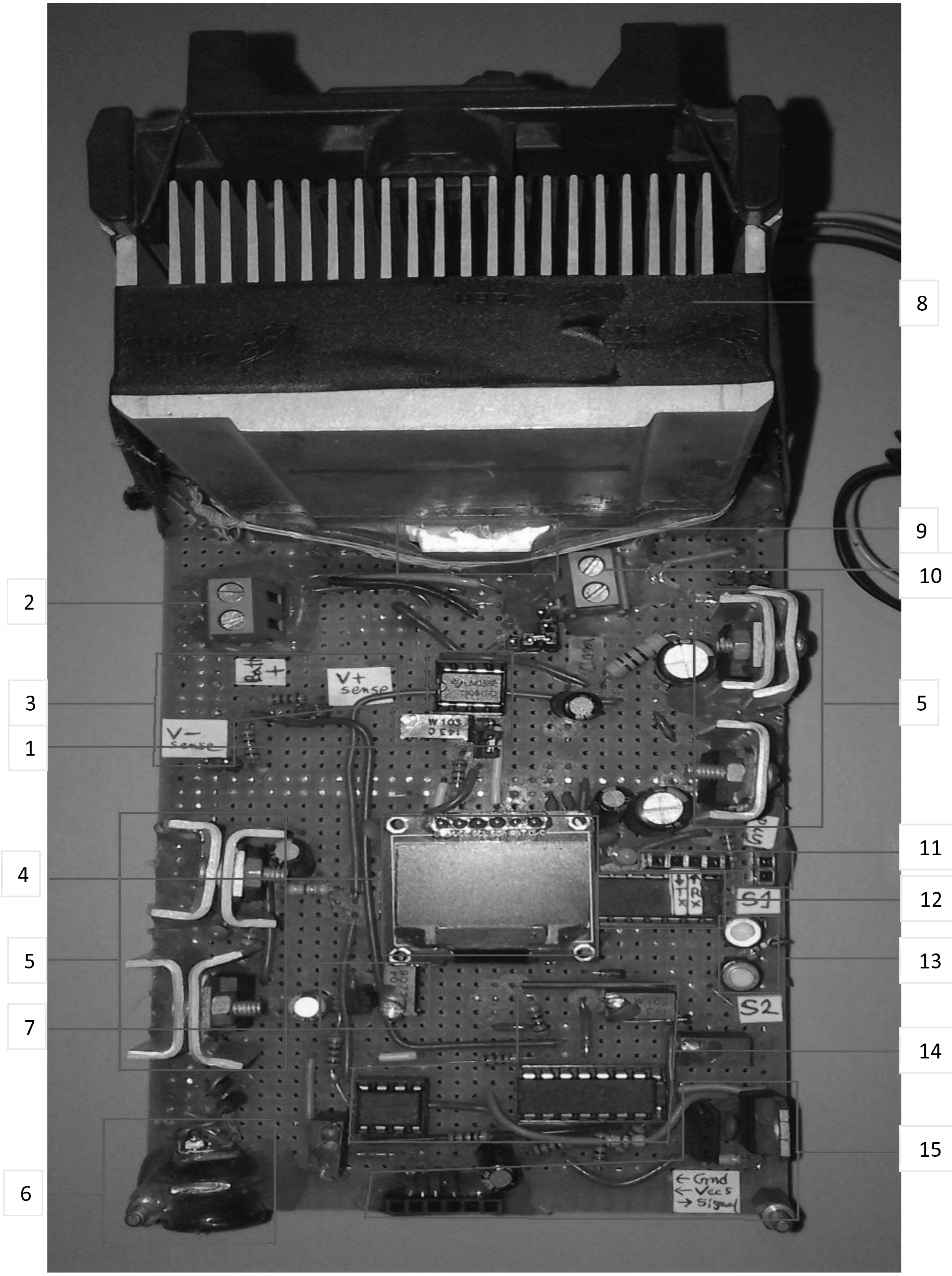

Figure 4.8 battery testing Unit

4.2 battery testing Unit

1. MOSFET linear region driver: this unit consist of 1 Digipot and 2 Op-amp. The resistance of the Digipot is variable with the programming of micro-controller. By varying this resistance the voltage is also varied. This variable voltage is gained 2.5 by an Opamp at first Opamp then it is used as an input in the non-inverting channel of the 2nd Opamp. The inverting channel of the 2nd Opamp is connected with the source of the MOSFET, the output of the 2nd Opamp is connected with the gate of the MOSFET.

   Opamp will try to do anything with in their capability to keep their both (+) Input and (-) Input at same voltage level.

   No Current Flows In or Out of the Opamp Input pins.

   So, Opamp U2 will try to keep its both (+) Input and (-) Input at 2.5 Volt. The (-)Input of U2 is directly wired to 1 Ohms Resistance R1. According to Ohms Law V=IR, 2.5 Amp current must flow through the Resistor R1. There is now way the Opamp's Input will deliver this current.

   This is where the Opamp U2 will Output a Suitable Gate Driving Voltage Such-A-Way that the MOSFET Q1 turns on partially operates like a voltage controlled current source.

2. From battery: the positive of battery is connected here with a thick wire. The battery discharging current pass through here. It is also connected with the Drain of the MOSFET.
3. Battery voltage sensor: through this the battery voltage is provided to the Analog Signal conditioning. Both battery terminals are connected here with 2 different wire to measure the voltage.
4. User display: this Display is used as a output for the user. User can configure setting or obtain data from this display.
5. Regulated power rails: there are 4 voltage rails of 18.9V, 12V, 5V, 24V.
   a. 18.9V – is supplied to Op-amp
   b. 12V - Supplied to fan
   c. 5V – supplied to Micro-controller, Display, Current sensor, Digipot.
   d. 24V - voltage is reduced from 32V
6. Power input to device: input voltage is 21V-32V Vdc, it is reverse voltage protected.
7. Precision voltage reference: 9.35V and 1.8V are generated here in the purpose of Analog signal conditioning.
8. Heat sink cooling fan: It is used to cool the MOSFET down. There is a 12 V fan in the heat sink.
9. Active load (MOSFET): the MOSFET is operated in linear region as a variable resistor. Here the Drain to Source voltage depends on the Gate to Source voltage.(shown in figure below)

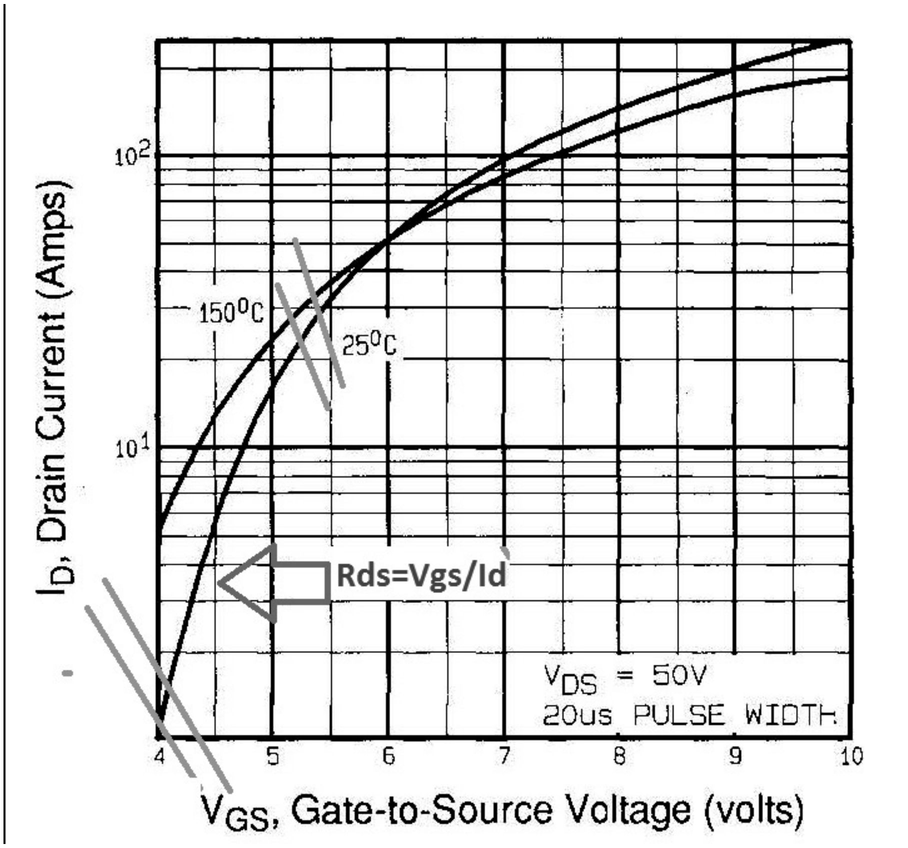

Figure 4.9 MOSFET characteristics

10. To resistor network: the source of MOSFET is connected to the load resistor network through here.
11. Serial data port: there are 5 ports in here. The ports are used as
    a. 2 ports are used as ground
    b. Reset
    c. Receive
    d. Transmit

    After the test the result can be transferred to PC through this serial port by using USB 2.0 from the EEProm.

12. Micro controller: this microcontroller controls this whole unit. It also control the display. It take the input from the user. Also controls the active load. The voltage and current signal is saved in EEProm by converting through ADC.
13. User input switch: by this user can configure the parameters of the test. User can stop the test and collect data from EEProm.

14. Analog signal conditioning block: voltage and current signal is buffered here. Then it is differentiated by Opamp and scaled down by using voltage divider rule. Then it is sent to the ADC of microcontroller.
15. 5v supply for current sensor and data from current sensor: it is a dedicated 5V supply for current sensor for better power rejection ratio.

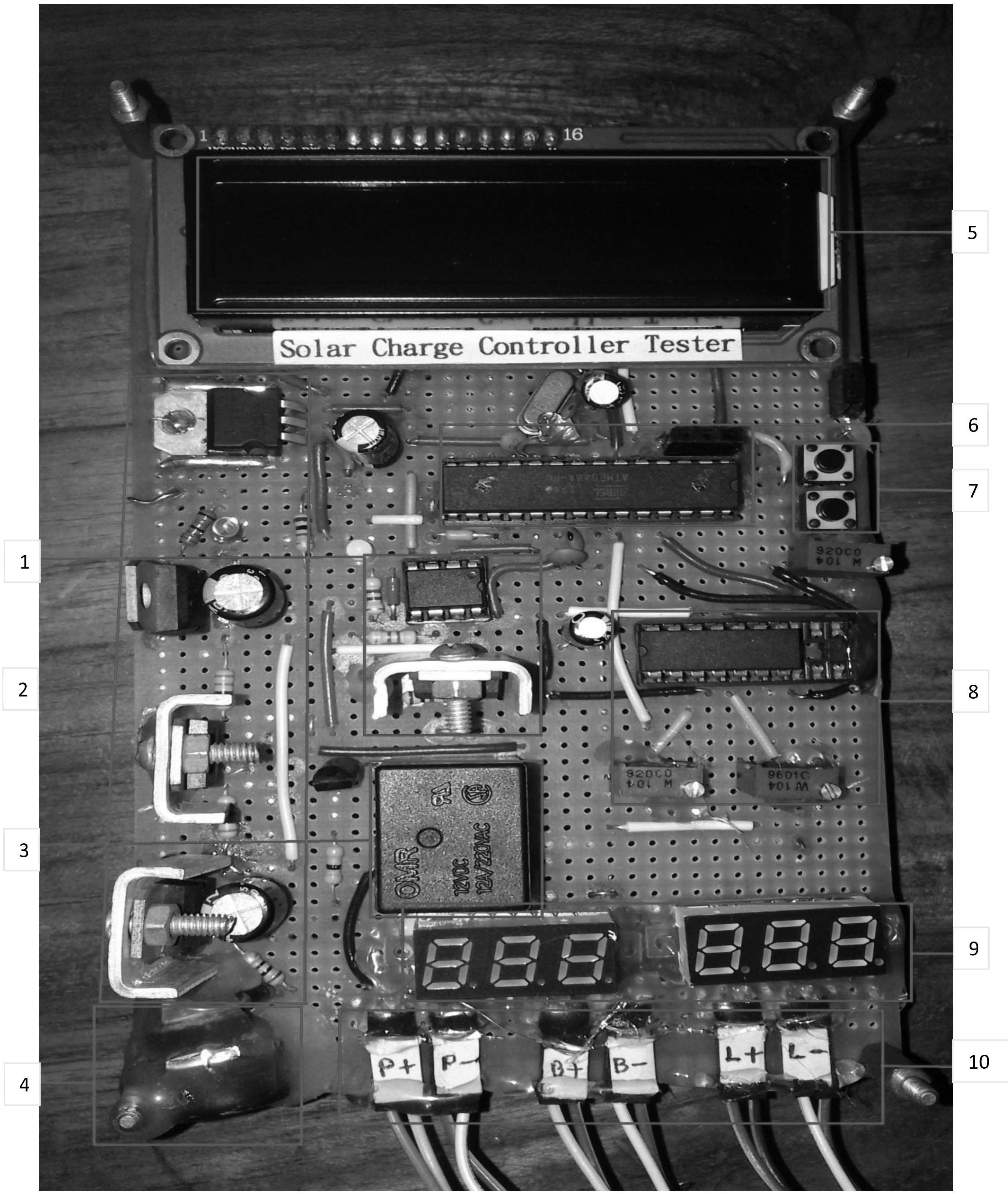

Figure 4.10 Charge Controller testing Unit

4.3 Charge Controller testing Unit

1. Variable test voltage generator: It is consisting of Digipot and adjustable voltage regulator. By varying the resistance of the Digipot variable voltage is generated. Voltage can be varied from 10V to 15.5V with per step of being 0.1V.
2. Regulated power supply: there are 4 voltage rails of 24V, 15V, 8V, 5V.
    a. 24V – power to variable voltage generation unit.
    b. 15V – to power relay.
    c. 8V – to power Op-amp
    d. 5V– to power micro-controller, Display, Digipot.
3. Test voltage switching relay: the job of this relay is to switch the connection of the ‘variable test voltage generator’ to the positive of battery or panel.
4. Device power input (21-32 Vdc): input voltage is 21V-32V Vdc, it is reverse voltage protected.
5. User input display: after turning on the tester, user operating instruction s Displayed here and after the test is competed the result is shown here also.
6. Microcontroller: this micro-controller suns this whole system. It senses the voltage of ADC. Generates variable voltage by varying the resistance. Takes input the from user and shows the test on the display as output.
7. User input switch: by these 2 switches user can start the test and after the rest user can redo the test again.
8. Analog signal conditioning/buffering block: to measure 3 voltages of the 3 terminals of charge controller those voltages are scaled down and sent to the ADC of the micro-controller after being buffered by the Opamp.
9. Voltmeter: to show the panel and load reconnect and disconnect voltages.
10. Test probes to ‘charge controller under test’: these test probes are connected to the charge controller’s battery, load and panels terminals.

Chapter -5

Operation

5.1 Operating Principle of the Battery Capacity Tester

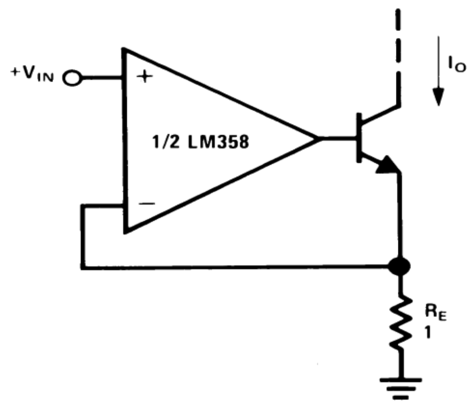

Figure 5.1 Current Sink

The high compliance Current Sink (picture above) is the part that of the device consists of a MOSFET (attached with the big Heat sink), a high wattage Resistors Network, an Opamp which can maintain a constant current through the MOSFET by adjusting its output such a way that the MOSFET is operated in the linear region.

The amount of current through the active load is directly proportional to the Vin applied to the non-inverting terminal of this Opamp.

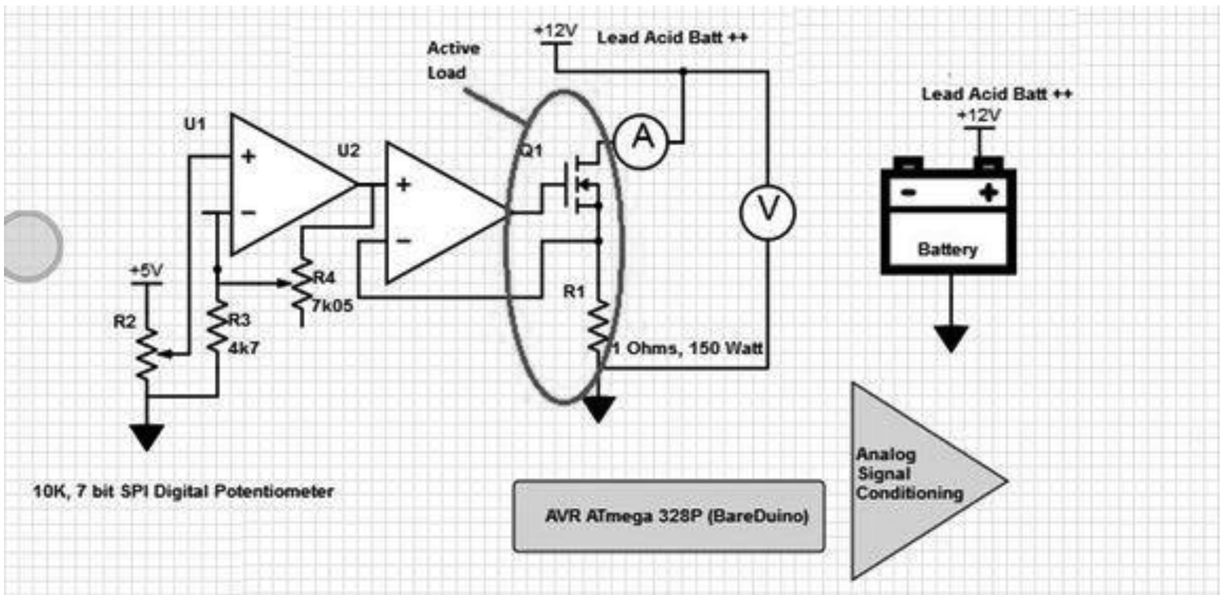

Figure 5.2 Battery Capacity Tester Core Block

This Vin is generated based on the User Input Setting to the Microcontroller during initialization. A 7 bit 10k Ohms Digital Potentiometer is connected to the Microcontroller through SPI Bus and 5 volt is applied across it's 10k resistor, so voltages in step of about 40mV (e.g. 0mV, 40mV, 80mV, ….. up to 5V) can be made from the sweep output of the Digital Potentiometer by controlling from the Microcontroller. Then this voltage is fed to another Opamp to Gain 2.5 times, so steps of 100mV, 200mV, 300mV …… upto 12.5 Volts can be produced. This Step Voltages are applied to the Vin of the MOSFET Driving Opamp, this Opamp will produce a Gate Voltage to operate the MOSFET such a way the current steps of 100 mA, 200 mA, 300 mA …. Up to 12500 mA can be sinking through the active load.

5.2 Experimental Procedure with the Battery Capacity Tester

The Battery Capacity Tester Device has two parts: the "Resistor Network & Current Sensor" is part(A) and the "Active Load, Control & I/O" is part(B). Before starting test and even before powering up the device, two parts must be interconnected.

Here is how it should be connected:

"Com" terminal (Green Connector) of part(A) should be connected to "Com" terminal of part (B) with a thick wire (22/7). Com terminal does not represent system common ground but it is the common point of MOSFET Source and Resistor Network. Alternatively, a Ammeter can be connected between "Com"s of part(A) and part(B) to manually measure the discharge current instead of connecting a wire, which should be connected for the whole period of the test.

Next, three wires coming form part(A) current sensor needs to be connected to the female header on part(B) marked as (Gnd, Vcc, Signal) on the bottom right corner of part(B). The Red wire goes to Vcc, the Yellow wire goes to Gnd and the Green wire is the current signal goes to signal.

Then, another separate cable pair (Red-Blue) needs to be connected to "V+ Sense" and "V- Sense" male header pins on part(B). The alligator clips on the other end will be connected later to the Battery Positive (+) and Negative (-) terminals.

Next, one Red thick wire is connected to Batt+ (Green Terminal) on part(B) and one Black thick wire is connected to Batt- (Green Terminal) on part(A) firmly so they don't get detached during test.

Now the device is powered up with a 24-32 VDC power supply. Using the instructions on display and S1/S2 input buttons, New Test, Discharge Current, C –Rates are configured. When the display will show "Now Connect Batt+ & Batt - ….." message, then the other end of the thick Black wire is connected to the Battery Negative terminal, also the black alligator clip attached to V-Sense wire is connected to the Battery Negative terminal.

Similarly the thick Red wire is connected to the Battery Positive terminal, also the red alligator clip attached to V+Sense wire is connected to the Battery Positive terminal.

Finally, pressing S1/S2 switch the test begins to discharge the battery.

The test will end if one of the 3 conditions are met :

If user aborts test using S1/S2 switches

If battery voltage reaches 10.5 volts

If C hours of time elapsed during test

The test should never be aborted by pulling out the wires, sudden change of current may damage MOSFET. Instead using S1/S2 switches along with instructions displayed to abort the test, the software will slowly Ramp Down the current to zero avoiding any possibilities of damage.

The device should never be connected to battery without powering it up first and before initialization. Otherwise high currents will flow for a short duration of time and may damage the system.

Battery should never be connected to the device in Reverse Polarity to avoid serious damage.

At the end of each test all the voltage data points are saves on the EEPROM of the microcontroller, which can be copied to a PC using a USB-Serial converter. There is a serial port available on part(B) marked as (RX/TX/Gnd). By connecting a Serial-USB converter here and following the instructions on the display along with pressing S1/S2 switching and opening a Serial Terminal (like Putty, Serial Monitor) data can be copied to PC. Each time new test data is Overwritten on the Old Test data. Serial baud rate is 9600 for this system.

5.3 Operating Principle of the Charge Controller Tester

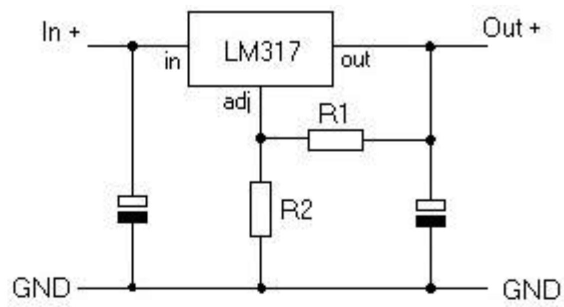

Figure 5.3 Adjustable Voltage Regulator

The Adjustable Voltage Regulator is the part of this device which will simulate a variable voltage from 10 volts to 15.5 volts on the charge controller's Panel and Battery terminals to get the set points. Similar like the battery capacity tester, here a 10k digital potentiometer and a fixed value resistor is used as R2 (see picture above). So, the resistance of R2 is varied from the microcontroller. This is how voltage steps of 10.1V, 10.2V, 10.3V ….. up to 15.5 volts can be generated to test the charge controller.

Because different manufacturers make charge controllers differently, many charge controller's Battery (--), Panel (--), Load (--) terminals are not system common ground. So measuring voltages on these terminals with single ended ADC is difficult.

To avoid this issue, two separate LED Voltmeters are used to measure voltages on Battery and Load Terminals, while the Panel terminal voltage is measured using ADC and shown on the LCD display.

5.4 Experimental Procedure with the Charge Controller Tester

The Charge Controller Tester Device needs to be connected to a Charge Controller under test. The Connection are relatively simple as following :

The P+ and P- marked cables are connected to the Panel+ and Panel – terminals of the charge controller, the B+ and B- marked cables are connected to the Battery+ and Battery – terminals of the charge controller, similarly L+ and L- marked cables are connected to the Load+ and Load– terminals of the charge controller.

The tester is powered up from a 24-32 VDC power supply. The LCD display will show a message how to connect the tester to a charge controller, then ask user to press switch to start test.

The test will begin once the user presses any of the switches, panel terminal voltage will rise with a step of 0.1 volts starting from 10 volts, the battery terminal voltage will rise along with panel voltage, which will be shown on the Greee LED Voltmeter Display. At the beginning of test run, the load terminal voltage will be absent for a while, because the load is disconnected due to low battery terminal voltage. As the voltage rises, around 12+ some voltage the load will connect and the load terminal voltage will appear on the Red LED Voltmeter Display. The first value on Red LED Voltmeter Display is the Load Reconnect voltage.

Now as the Panel terminal voltage rises, so does the Battery terminal. But around some 14+ voltage, with the rise of Panel terminal voltage, the Battery terminal voltage won't rise. The maximum voltage on the Green LED Voltmeter is the Panel Disconnect voltage. During this time the Green Voltmeter voltage will fluctuate between 13 something to 14 volts. The minimum voltage during this on Green Voltmeter is the Panel Reconnect Voltage.

Once the Panel terminal voltage (on LCD display) reaches 15.5 volts, it will start to fall. Now the Battery/Load voltages will follow it. At some voltage between 10 something to 11 something volts the voltage on Red LED voltmeter will disappear. The last value on Red LED volt is the Low Voltage Load Disconnect voltage.

The whole test will run again, just in case user failed to capture the set points.