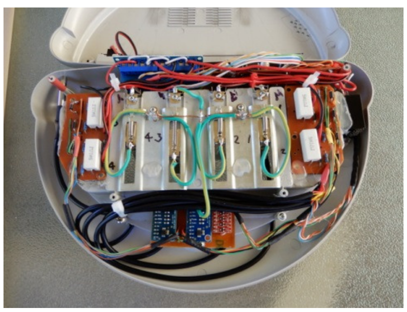
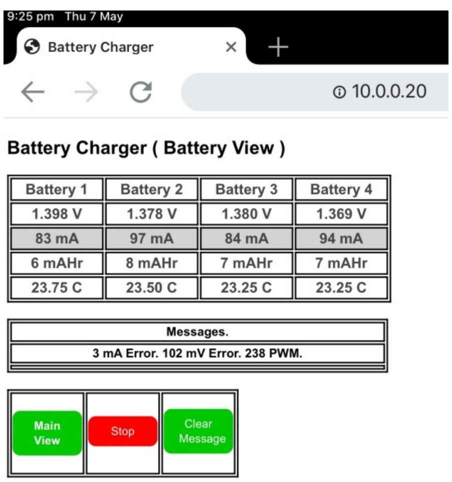
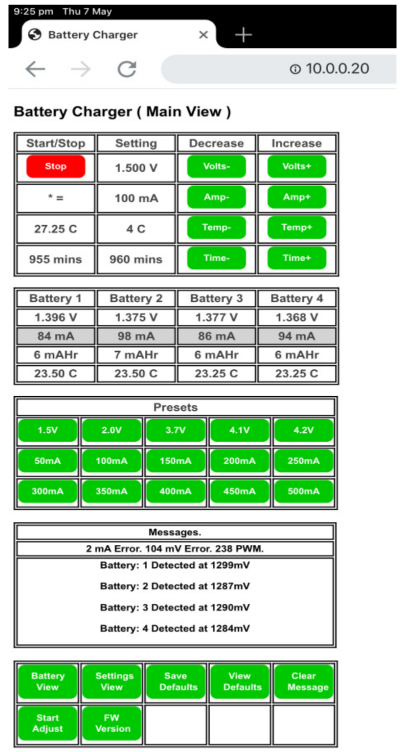
Flexible, Efficient 4 bay Battery Charger with Browser Interface.

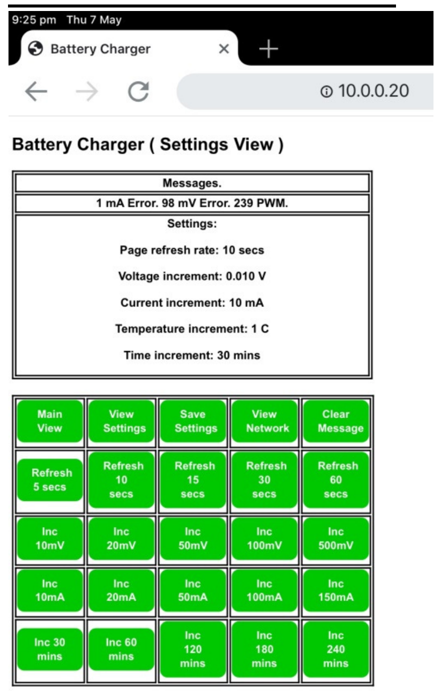
By P J Webb Hope Valley SA 5090

8/5/2020









Contents

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1 Disclaimer

Although the author has made every effort to ensure that the information in this manual is correct, the author does not assume and hereby disclaims any liability to any party for any loss, damage, or disruption caused by errors or omissions, whether such errors or omissions result from negligence, accident, or any other cause. This design is produced for personal use only and is not guaranteed to be fit for purpose. It is presented for information and experimentation as a circuit concept. Further use is conditional on acceptance of these conditions.

2 Overview.

The charger can charge re-chargeable AA, AAA, 14500 and 18650 size single cell NiCad, NiMh or Li-Ion cells. 1, 2, 3 or 4 cells can be charged at a time. The control and monitoring interfaces are web pages that are accessed locally only using the browser on your smart phone, tablet or PC. The unit serves the web pages via your usual home WiFi network so that network switching of your device is not needed to access the charger controls. The novel and very useful feature of this design is that the cumulative mAHr capacity of each battery is shown as well as charge Current and Voltage.

The system operates using a proportional controller that controls current or voltage to user set limits with regulation of around +-5mA current error when under constant current control and about 10mV voltage error when under constant voltage control. Error is set point minus actual. Battery temperature and charge time are also monitored and controlled. A 12 volt 2 ampere regulated plug pack will charge 4 Li batteries at currents up to 500mA. A 12V 1 ampere regulated plug pack will charge 4 Ni batteries at currents up to 500mA.

3 Hardware.

A WeMos D1 mini ESP8266 provides WiFi communication and control and monitoring using one PWM output for charge control, one digital input for the five DS18B20 temperature sensors, I2C connection for the ADC voltage monitoring and one digital output for on/off control of the switching regulator buck LM2596 module and LED.

Two four input ADS1115 ADC modules monitor each battery voltage and their current sensing resistor. A simple DAC circuit converts the PWM output to Analog to drive the feedback control pin of the LM2596 buck converter module to control the charge voltage and hence current.

A power on LED is included as well as PWM level indication LED connected between the PWM output pin and 3.3 V. Five temperature sensors are used, one for ambient and the others for battery temperature.

4 Control Panel.

The control panel is provided by web pages with the ESP 8266 running a web server in Station mode. This means that it connects to your usual home WiFi network (2.4GHz only) and is accessible using any web browser in a device connected to your home WiFi network. The WiFi credentials need to be set up in the Arduino sketch to match your router and a fixed IP for the web server is set to ensure that you will be always able to access the control panel using a consistent IP address and DHCP cannot re-allocate the IP address.

External internet access could be set up using DDNS and port forwarding but this is not recommended as there is no security with the simple html interface and your WiFi credentials would be exposed to a hacker who may scan your internet connection for open ports.

5 How does it work

The charger features a closed loop proportional control system that monitors each battery voltage, current, temperature and charge time. The control loops are current and voltage. Limits are set for Voltage, Current, Charge Time and Temperature rise above ambient in the Control Panel. The controller measures the actual voltage and current of each battery, takes the highest reading and compares it to the limits set to provide a proportional error signal to correct the pulse width modulated output at the WeMos digital output.

The lowest error (current or voltage) determines the control mode. Proportional means that the output change is higher if the error is high and smaller changes are made if the error is low. Initially the unit will operate in constant current mode and as the battery voltage rises and depending on the voltage limit set, it will switch to constant voltage.

The 10kHz PWM signal drives a low pass filter comprising r2 and c4. This filter effectively creates a simple Digital to Analog converter (DAC) that biases the feedback pin of the buck module along with the on board output voltage feedback setting pot. Thus the buck module output analogue voltage is varied by the PWM digital output. Variable Resistors 1 and 2 set the maximum and minimum output voltage of the buck module corresponding to the range of the PWM output. Due to the DAC circuit configuration, the PWM signal is inverted but for ease of understanding, high PWM means high battery charger output.

The output of the LM2596 supplies each battery via a normally open relay contact, a blocking diode and a 1 ohm resistor. The relay provides isolation and individual disconnection when a battery is charged. The blocking diode prevents one battery from discharging into another if there is a significant difference in battery voltages at start up. The voltages at each side of the 1 ohm resistors are fed to the ADCs to calculate battery current and voltage. The 1k resistors and Schottky diodes at the ADC inputs protect the ADC in the event that a battery is inserted with incorrect polarity or if the voltages exceed the ADC limits

This design charges the batteries in parallel compared to the more traditional series arrangement where each battery receives the same charge irrespective of initial state of charge. The basic Ni chargers also tend to continue charging until the current tapers off at some high battery voltage resulting in very hot batteries and no doubt lower than optimum service life. With this parallel arrangement, the battery with the lowest charge receives a higher initial current than the others until its voltage rises and catches up with the others. As the voltages equalise, each battery starts receiving a similar charge current. Faulty batteries are easily identified as their voltage rises to a high level with much smaller charge currents compared to good batteries. The mAHr capacity reading is another useful battery condition indicator.

For Li-Ion cells, temperature monitoring is not used and the controller switches from current control to voltage control when the cell approaches the applicable voltage limit typically 4.2 for 3.7 volt Li cells or about 0.5 V above the nominal cell voltage for 3.2 and 3.6 volt cells.

For Li-Ion cells, charge is terminated for each battery when its voltage is at the voltage limit and the current falls to less than 50% of the set limit or the time limit is reached.

With Ni batteries, a charge current is set and the voltage allowed to float by setting the voltage limit at a high level The temperature sensors are used and a temperature rise limit above ambient is also set. Delta V end of charge is not enabled as this method works best at high charge currents that are not realistic for this design. As the batteries approach full charge the charge energy cannot be stored and is converted to heat. The parallel charge arrangement tends to equalise the charge because the least charged voltage is lower and charges at the current limit with the initially higher charged batteries receiving a proportionally lower current.   This means that each battery tends to have a similar temperature rise when approaching end of charge.   The charge for each battery is terminated when it reaches the temperature or time limit.

6 The Web Control and Monitoring Pages

The web control panel includes three pages or views. The first is the Main View containing all the controls and monitored quantities, options and message panel. The second page is a simplified Battery View and the third a Settings View. A button on each page either selects the required View or returns to the Main View. Defaults and Settings can be viewed and saved to EEPROM.

The current and voltage settings can be selected from a range of presets and increased or decreased using the relevant buttons.

An end of charge temperature control can be set in integers to represent the temperature rise limit above ambient. A cautious approach would be to set this at a low value to ensure long battery life at the expense of a small reduction in capacity.

A time limit on operation set in minutes provides a countdown timer.

End of charge occurs when:

- A battery has been on voltage control and its current has reduced to 50% of the setting or;
- A battery reaches its temperature rise limit or;
- The time limit is reached.

7 Optional Builds.

If Li batteries are not required to be charged, then the maximum PWM voltage output can be reduced to say 2.5V as this will extend the PWM operating range and provide finer current control.

If higher currents are required such as for Pb or Li batteries, the 5.5 V limit can be increased but only after installing voltage dividers on the ADC inputs to keep the AD1115 inputs within limits and ensure that they are not damaged by the higher voltage. A calibration factor will then be needed in software to make the analogue accurate.

8 Software.

8.1 Install Arduino IDE on Your Computer

I you haven't already, you will need to install the Arduino Integrated Design Environment (IDE. Design or Development) so that you can flash the WeMos D1 Mini -ESP8266 as follows:

- Do a web search for Arduino Download. Click on the arduino.cc link and find the installer for your computer.
- Download the installer, run it to install the Arduino IDE.
- Click on the Arduino desktop icon to run the IDE.

8.2 ESP8266 Boards Library Installation

- Click on the Arduino desktop icon to run the IDE.
- In the IDE, Open the File Menu then Preferences.
- In the Additional Boards manager URLs, add the following line including the quotes "http://arduinoesp8266.com/stable/package_esp8266.com_index.json" and then click OK and then OK again to close the file Menu window.

- TIP: to the right of the text box is a window button. Click it to open a larger text entry box. Make sure that the URL is on a line of its own.
- Got to Tools, Board, Boards: Boards Manager, type ESP8266 if its installed then OK if not install it when it appears (ESP8266 by ESP Community..). See Tip Below.
- When finished click OK. Go to Tools, Board, scroll down and select your ESP module (eg WeMos D1 Mini)

TIP: You must use the correct board to match your ESP8266 hardware. I used a WeMos D1 Mini that would not compile with the later versions of the board library that has a Lolin WeMos D1 Mini board listed.
Ver 2.0.0 of the ESP8266 by ESP Community… has the original WeMos D1 Mini and that worked fine for me. If you have problems compiling, then you may have to experiment with board selection.

TIP: To change the version of the installed boards file, go to Tools, Boards: Boards Manager and search for ESP8266. You will see the version installed. Click on the more info link and you will get a drop down list to select previous version. Select the version and click install. Click close after completion.

8.3 Dallas DS18B20 Temperature Sensor Library Installation

- Do a www search for Arduino Dallas Temperature Library.
- Usually there is a GitHub link, click on it and when in the Git hub page check that the title is for the Dallas DS18B20 temperature sensors then look for the Clone or Download (Green) button on the right side.
- Click on the button and select “Download ZIP”
- The file will be downloaded to your downloads folder. Don’t run it or unzip it.
- Click on the Arduino desktop icon to run the IDE.
- In the IDE, Open the Sketch Menu – Include Library- Add Zip Library. Then navigate to the download location and select the Dallas temperature library previously downloaded.
- The library should be installed and a message to that effect should be displayed in the Arduino IDE.

8.4 Arduino Sketch Files Installation

Download the software from Silicon Chip.

- Open siliconchip.com.au website or the link in the article or;
- Open the Menu: Shop, Software

- In the search text box, Search for Battery Charger or similar
- Scroll to the Project entry it should be identified with the Month of the magazine and Click on the .Zip file link to download.
- Save the file to the down loads folder or favourite downloads location so that you can find it later.
- Create a new folder in your Arduino Folder (Usually User\Documents\Arduino) called "Battery_Charger_Web_Server" or in the location where you keep your Arduino sketches such as Drop Box.
  If you are not sure where this location is then you are indeed new to Arduino and need to keep on researching and learning about Arduino. Don't give up, keep researching and reading. It's easy once you know how! To short cut your learning you can find this location by opening/running the Arduino IDE then select File Menu, Preferences and look for the text box "Sketchbook Location:"

- Got to your downloads folder and copy the downloaded sketch Zip file into the newly created Arduino folder and then unzip it (open the Zip file and check that the destination folder is the newly created Arduino folder).
- Open the Arduino IDE: Select Menu: File, Open and Navigate to your "Battery_Charger_Web_Server "folder location.
- Open the folder it and select "Battery_Charger_Web_Server.ino"
- All the files should open. I have used the IDE tabs for most of the functions and you will see them listed across the top of the IDE. To edit any one just select the tab or if the one you want is not shown then click on the down arrow icon to the right of the screen at the top and just below the Serial Monito Icon.
- Edit the WiFi credentials in the Sketch where indicated to match your Home WiFi. You will need the Router WiFi IP Range, The Subnet Mask and the Router (GateWay Address)

  For a Windows machine: Click the network icon in the task bar bottom right (or if not shown, click on the up arrow to show the icon and click on it) then click "Network and internet Settings" then scroll down and click on "Change adapter options", then double click on your active network connection (It will be highlighted), then click on the details button and you will see all the settings needed. (Use the IPV4 ones) the IPAddress for your battery charger needs to have a unique last number.

  If you can assess your routers web page setup then you will find the details under a LAN tab. If this is not possible then;

For an Apple Machine: Tap on Settings Icon, Tap Wi-Fi, look for the currently connected WiFi network and tap on the information icon (i) to the right of the network name. The Router IP credentials, Range and SNM are shown (use the IpV4 numbers if there are also IPV6.

For Android Machines, do a www search for instructions on finding the Network parameters. Best of British luck in finding all the parameters.

Make your Battery Charger last number of the IP Address unique. If your gateway is 192.168.0.1 then choose 192.168.0.150 for your Battery Charger IP Address. Or if it is say 10.0.0.138 then use 10.0.0.20. The number is not critical along as it is not the gateway number or the IP Address of your PC or Smart Device and is significantly different to the gateway number so that there is not going to be an IP conflict with an already allocated IP existing on your network.

- Connect the Battery Charger to the WeMos D1 Mini to your computer with a USB cable. Make sure you have the correct board selected in Tools as well as the correct Port (Port must be open and ticked in Tools: Port).
- Compile and download it to the WeMos D1 Mini.

TIP: Sometimes the Sketch compiles, but will not download with an ESP Comms error. Pressing and releasing the reset button on the WeMos D1 Mini usually fixes it. Sometimes it is necessary to hold the reset button <u>down until</u> the compiling progress bar (Bottom Right of the IDE) reaches the right hand side and the Uploading prompt is seen.

9 Case Details.

I modified an old commercial battery charger case that included the spring loaded battery holders. The fit was tight but all the components and circuit boards fitted well. Another alternative is to use a smaller battery charger case that has battery holders and then build the electronics in a separate Jiffy box with an umbilical cord between (Only 4 wires would be needed)

10 Construction Details.

The relay module should have 12V relay coils. Don't use 5V relays supplied from the 7805 regulator as the dissipation will increase and a large heatsink will be required. Alternatively you could use 5V relays if you swap the 7805 with a switched mode 5V regulator module that is so much more efficient than the linear unit.

I used the temperature sensor types that are fitted into stainless steel tubes and have a flexible 3 core cable. Each sensor must be identified before final assembly. To do this I connected them all together in parallel temporarily (3.3V to 3.3V - Red, Data to Data - Yellow and Ground to ground- Black) and then held a tube one at a time in my fingers and observed which one gave a temperature rise for a specific battery and also for ambient. I then marked them B1 to B4 and ambient before final assembly in their correct battery locations.

A small finned heatsink should be fixed (I used Jaycar heat sink thermal glue) to the LM2596 chip to assist with heat dissipation if output current summation exceeds about 1.5 amps. The LM2596 can output about 3A in open air and with a large PCB but not in the small module that is usually available.

A small finned heatsink is needed for the 7805 regulator that dissipates about 0.7W or alternatively replace it with a 5V switched mode regulator module.

The on/off pin 5 of the LM2596 integrated circuit must be unsoldered and lifted from the PCB and wired to pin x of the WeMos D1 mini.

The resistor between the Feed Back Pin and ground on the LM2596 module must be replaced with a 2k7 resistor to reduce the loading on the PWM DAC circuit and to reduce the usual output range which can be up to 30V. The resistor to be replaced is usually about 330 ohm. This is a bit fiddly. I found it easier to remove the Pot from the board first to gain access to the resistor for de-soldering and replacement. I used a through hole 1/4W resistor mounted vertically. Be careful with soldering and position so as to not create any shorts.

Construct the circuit so that the LM2596 module setting pot and the PWM pot are easily accessible.

11 Initial setup.

Important. Do not start charging before this procedure is complete.

To achieve the most sensitive current control and optimum voltage ranges, the two potentiometers must be adjusted prior to using the charger. Both pots are connected to the feedback pin of the LM2596 module.

Setup for RV1 and RV2 (Pot 1 and Pot 2).

The objective is to adjust the pots so that the output voltage range of the LM2596 module is between 5.5 volts and 1.3 volts. This provides the greatest sensitivity for mA or mV per PWM step. A control button labelled “Adjust On” and then “Adjust Off” is included in the Main View to semi-automate this procedure. The PWM output is 9 bits or 1024 steps.

The setting of each pot affects the other so that a few iterations will be required to achieve the correct range.

The 5.5 volt maximum is required for a 4.2V battery charged at about 500 mA. If you do not want to charge Li-Ion cells then this range can be reduced to provide finer current control.

Setting the Pots

After completion of wiring and uploading of the sketch, power up the unit and wait until it connects to your WiFi network indicated by the PWM LED flashing 5 times.

Connect a voltmeter between the LM2596 module positive output and ground and set to a 20V range.

- Press the button “Start Adjust” in the Main View.
- Instructions will be seen in the message panel
- Firstly adjust the LM2596 module pot to set the output voltage close to 5.5V
- After a short delay of about a minute, the unit will switch to low output for adjusting the PWM pot.
- Instructions will be seen in the message panel.
- Adjust the DAC pot to set a minimum voltage of 1.35V
- After a short delay of about a minute, the unit will switch back to high output to repeat the setting process.

When the voltages are as specified, reset the unit to normal by either:

- Pressing the “Stop Adjust” button or;
- Re-setting the WeMos using its reset button or;
- Cycling the power.

Disconnect the voltmeter.

12 Using the charger.

Connect the Charger to power and observe that power LED is lit and the PWM indicator flashes 5 times to indicate a connection to WiFi.

Open up a browser window on your PC or smart device and type the Battery Charger’s IP address into the Address text box. Press Enter. (You may have to type the IP Address followed by the port number in the following format such as 192.168.0.120:80 (Not these numbers but the IP address you have selected earlier.

If all is well, the Main View should magically appear on your browser.

Tip: If this fails, check that your smart device WiFi is connected and is on the same Network as the Battery Charger.

Insert battery(s) with correct polarity into the battery holders.

If Nickel based, attach a temperature sensor using a short length of plastic tubing or rubber band to each battery.

Select the required voltage and current using the Preset buttons and adjust if required using the increase or decrease buttons. Change the Temperature rise and Charge time limit to suit from the options tab or set the limit parameters manually by using the + or - buttons on the controls.

The optimum current setting is about 0.1C. Where C is the mAHr rating. For example a 2500 mAHr AA battery, the setting should be 250 mA.

The optimum voltage setting limit is 4.2V for 3.7V Li-Ion and for Ni based batteries of nominal 1.2V it is set high such as 2.0V and the temperature sensors installed in contact with each battery using a rubber band or a suitably sized short length of plastic tubing.

The temperature probes and setting need only be used with Ni based batteries.

When ready, press the start button to start charging. The start button turns red and its text turns to Stop. The details of batteries detected will be shown in the message panel.

After a short delay, battery voltages and currents should now be shown. The voltage and currents of empty bays should read zero.

The PWM indicator LED should gradually increase in brightness.

Most batteries will have a different state of charge. The flatter batteries having a lower voltage should have the highest initial charge current (Unless they are Kaput and then the voltage will rise very quickly). The charge current will tend to equalise as the batteries charge.

The charge capacity in mA H is indicated. The flatter batteries should indicate a higher charge over time than others. As the charge progresses, significant differences in voltage or charge current of nominally identical batteries may indicate a faulty or low capacity battery.

There is a heart-beat indicator (*) as well as symbols indicating current or voltage change (V+, V-, A+, A-, or = for no change) that will appear in the table cell below the Start (Stop) button.

13 End of charge

End of Charge is determined for a battery:

- When reaching the Voltage limit and Current has reduced to 50% of current limit.
- When reaching the Temperature limit.
- When reaching the Time limit.

14 Charging Information.

Li cells must have a voltage limit set. Temperature sensing is not used.

3.7 V Li cells should have a voltage limit of 4.2V or alternatively 4.15V to be conservative with life at the expense of a small reduction in charge capacity.

Charge current should be about 0.1 Capacity. Thus a 2500 mAHr battery should charge at 250 mA. If it is fully flat then full charge would take about 12 hours (allowing about 20% extra due to charging inefficiency in the battery.)

Note that there are very few batteries that are true to label in regard to capacity. Only expensive brand names come close to label capacity when new. Typically cheaper no name batteries can be expected to have capacity less than 50% of rating even when new. (My experience – not gospel.)

Ni cells end of charge can be determined either by temperature rising at end of charge or by a fall in voltage. Fall in voltage is not easy to detect unless the charge rate is high. This charger uses temperature rise above ambient to detect end of charge with Ni batteries. For long life, a low Temperature rise of about 3 or 4 degrees should be suitable.

You can confirm that the batteries are being detected and charged correctly by:

- Listening to the relays clicking in, as each are slightly delayed from one another.
- Checking the message to show which batteries are detected.
- Checking that a voltage and current other than zero is displayed on the main screen.
- Confirm the charge is started by observing the PWM LED increasing in brightness.
- Checking that the message panel displays the current error, the voltage error and the PWM output.

At low current settings there will be a small delay before charging begins while the PWM output ramps up compared to high current settings. This is due to the proportional control where lower errors between set point and actual result in lower step changes to the PWM output.

P Webb

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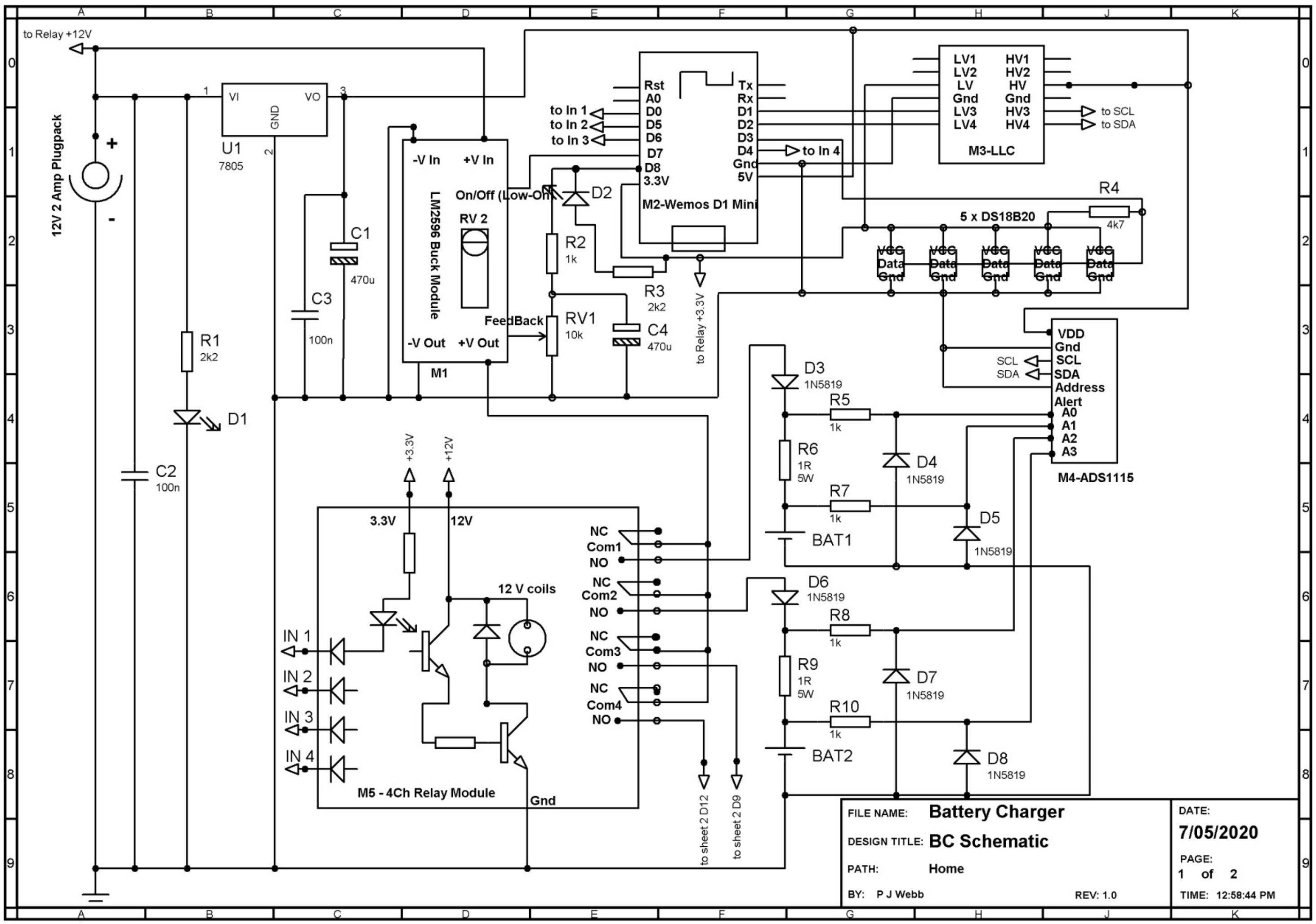
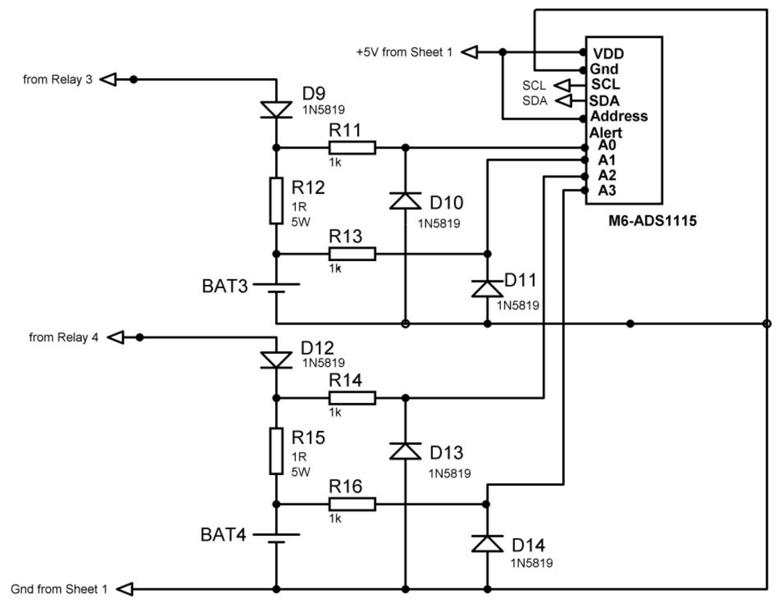
15 Schematics (2 sheets)





Note 1: LM2596 module chip pin 5 (On/Off) lifted from PCB to connect to Pin D7 of WeMos D1

Note 2: LM2596 module - Glue small finned heat sink to Chip body - Use Jaycar thermal adhesive NM2014

Note 3: LM2596 module. Replace 330R FB pin to ground resistor with 2k7 resistor.

Note 4: 7805 with Heatsink. Jaycar HH8514

FILE NAME:	**Battery Charger**	DATE: **7/05/2020**
DESIGN TITLE:	**BC Schematic**	PAGE: 2 of 2
PATH:	**Home**	
BY: P J Webb	REV: 1.0	TIME: 12:58:44 PM

R1, R3 2k2
R4 4k7
R2, R5, R7, R8, R10, R11, R13, R16, R14 1k
R6, R9, R12, R15 1R 5W
D3 – D14 IN5819 Schottky 1A
C1, C3 0.1uF
C2, C4 470uF
LED D1 Green

LED D2 White
VR1, VR2 10k Lin (2k7 FB to Gnd)
U1 LM 7805
U2 – U6 DS18B20 in SS tubes
M1 LM2596 Module
M2 WeMos D1 Mini Module
M3 Logic Level Converter Module
M5 4Ch 12V Relay Module
M4, M6 ADS1115 ADC Module