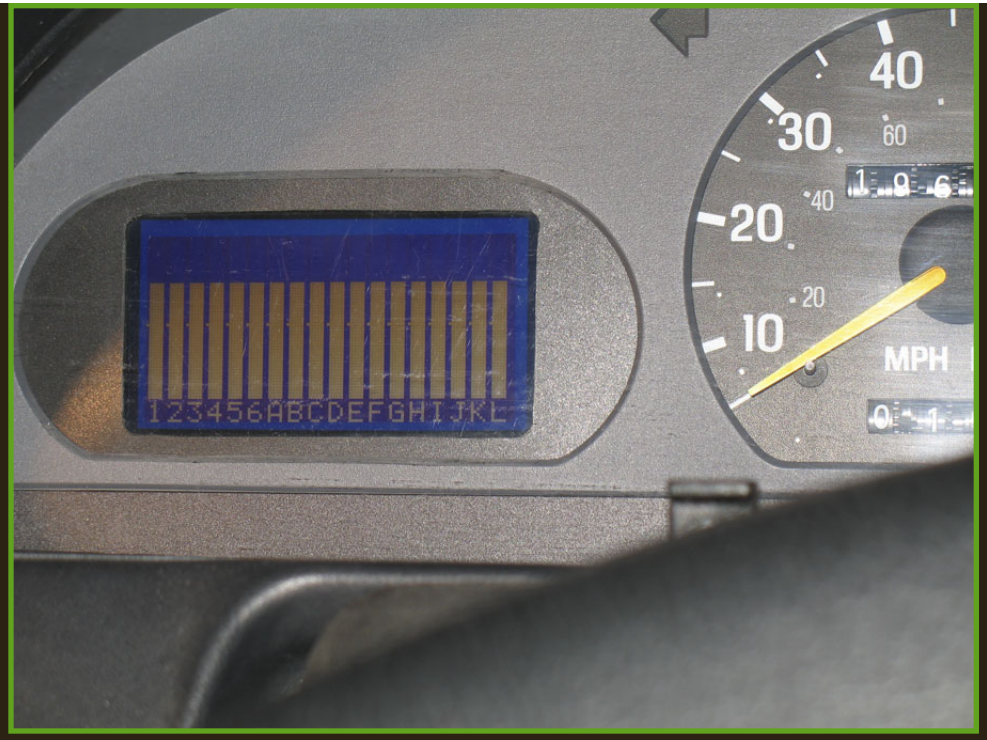
How I Made An Electric Vehicle Battery Monitoring System

By Tim Wong

I had been happily driving my electric car, a Soleq Evcort, for a few months when I found that my vehicle range had dropped based on the voltage sag under acceleration current load. After some investigation, I found that I had two batteries that was reversing so that its voltage was dropping from a nominal 6+V to 2.5V! This is, of course, not good for the battery (it never recovered). In retrospect, I should have broken the car in - it had been sitting for a long time. Anyway, the following is a record of my battery monitoring system.

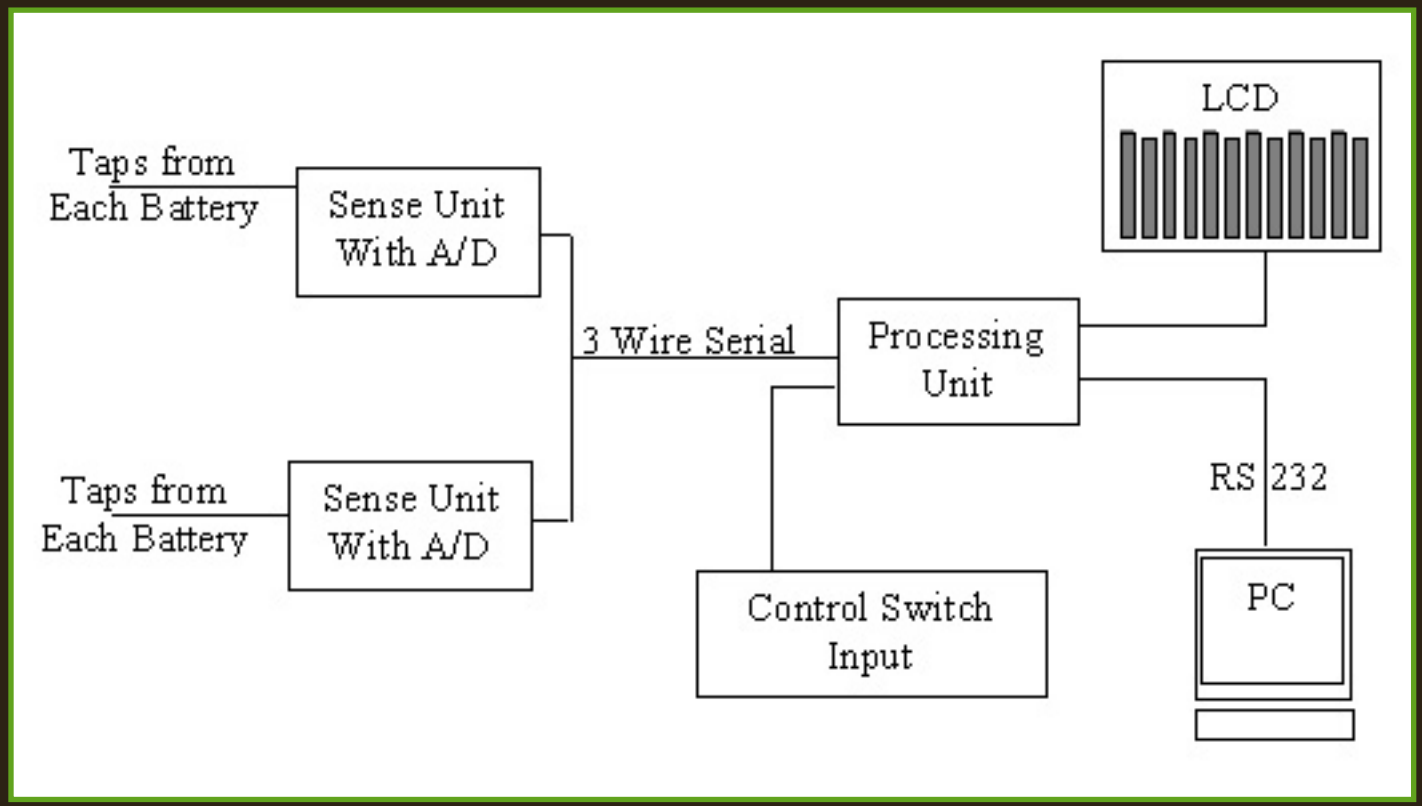


I decided I wanted a system to measure and display each batteries voltage. I found that nobody made a production system, so I decide to build my own. I found Gordon Stalling's outstanding system, which I used as a starting point for my system. Superficially mine is very simmilar to his. Gordon's system is extremely well isolated by using opto isolators on the input. If I didn't want decimal voltage measurement, his would have been the way to go! See his system here:

- Gordon Stallings Battery Monitor

I decided to make a system that would be able to accurately measure the voltage of each battery

individually, send each batteries voltage to a PC, and have a graphical display to use while driving (to prevent battery damage). Like Gordon Stalling's system, I used a small sensing box in each of my two battery compartments which measures the voltage of the batteries in the boxes, converts analog to digital, and sends the voltage number to a processing unit inside the instrument cluster. The processing unit has a Basic Stamp module which sequentially requests the battery voltages from the sense boxes. The battery voltages are sent to an LCD as a bar graph, voltage number, or sent via RS232 to a PC.



The system operates in three modes; bar graph, voltage, and data collection. In bar graph mode, the voltage of all batteries is plotted in a continuously updating bar graph. In voltage mode, the voltage of one battery is displayed to two decimal places, and each battery can be selected using a switch mounted on the dash. In data mode, the voltage of each battery can be sent to a PC via RS232. To switch modes, another switch is used. An on/off switch is used to turn on the system when the ignition is off - I use this to collect data while charging.

The sense boxes measure voltage using a differential amplifier that can measure a common mode voltage up to +/-250V. Voltages are measured between each positive tap. The analog voltage is converted to digital with a 10bit ADC. The processor box, containing a Basic Stamp processor, requests the voltages from each ADC (my system has three eight channel ADCs) with 3 wire serial, then, depending on what mode the system is in, presents the voltage to the LCD mounted inside the instrument panel or sends the data over RS232 to a PC.

Here is a picture of my system in the bar graph mode. It updates in less than .5 sec, so I can watch and monitor the weakest battery. When driving long range, I keep the weakest battery above the line indicating 5.25V.

- LCD Display in Bar Graph Mode

Here is a picture of the system in voltage mode - the selector switch scrolls through all the batteries. In very high or low temperatures, the accuracy is not good enough to have the second decimal place, but it always agrees exactly with my Fluke meter, even to .01V. From the specifications of the parts, it is good to around .05V.

- LCD Display in Voltage Mode

  Here is a picture of the system in data collection mode - it can run in high speed or low speed. In low speed, the data comes every 23 sec, and high speed it is something like every .8 sec. I guess I should know exactly, but I don't use the high speed much - the bar graph is fine. If I had a laptop (which I don't) I could use high speed mode to monitor battery voltages while driving.

- LCD Display in Data Collection Mode

  Here is a picture of some data collected during charging - I added all the battery voltages up to see the charge profile.

- Battery Pack Voltage during charging

  I used expresspcb.com to make my boards - I don't know if they are great, but the boards were fast to arrive and worked well. My layouts were made in their free design

program, which must be downloaded to view it. The process of having the boards made was very easy - the whole thing is done online, including file transfer, and the boards showed up in a few days. Here is the layout file for the processor board and the sense boards.

- Processor Board Layout File
- Sense Board Layout File

Here is the schematic for my processing unit. It is consists of a Basic Stamp with the drive circuitry for the Optrex LCD.

- Processing Unit Schematic

Here is the diagram for the sense box. The main input chip is the Linear Technologies LT1990 - use the LT1990A for higher resolution. Analog Devices chip AD629 is similar with less error, but is more expensive and also is not a direct replacement.

- Sense Box Schematic

Here is the diagram for my switch input to change menus and turn on the monitor when there is no key power and the connection to the 12V accessory battery:

- **Power and Input Wiring Schematic**

  Here is the diagram for the cable connecting the control box to the sense box and the switch inputs:

- **Control Box Wiring Harness Schematic**

  Here is the internal wiring for the sense box from the connector to the PCB:

- **Sense Board to Connector Wiring Schematic**

  Here are the cables connecting the sense box to the batteries - one front and one rear box. The rear box has two sense boards that measure 6 batteries each, and the front box has one sense board. I have 18 batteries, obviously. The system is somewhat modular, so more boxes could be added by changing the software and making up a new cable - the serial communication between the Basic Stamp and the different ADC is controlled by a chip select, allowing for a modular system.

- **6 Front Battery Tap Cable Schematic**
- **12 Rear Battery Tap Cable Schematic**

I had originally wanted to add one more LT1990 chip for current sensing - just tap off of the existing current measuring resistor (AKA shunt - this exists in most all electric vehicles). This would have been easy to do, and I am extremely annoyed now that I didn't do it. Just add another LT1990 to the layout of the sense board, add another voltage divider to match the Shunt, and reconfigure the LT1900 for 10x gain if needed, and then add the software to convert the Voltage reading to current. This reletively simple hardware change allows for all kinds of very useful additional functions including current sensing (obviously), real time power, energy or KWh meter, fuel gage, and probably other things I have forgotten. I feel stupid for, after putting in all this work to make the system, got lazy at the last 1% of work and left out this feature which cut the usefulness of my system monstrously.

Additionally, there are several unused outputs from the basic stamp which could have be used to shut off or control a charger or whatever, and the program memory is only 25% full.

I used a Basic Stamp to avoid buying a development system - it uses RS232 from a PC with free development software to program the chip. The programming language is simple but proprietary. Here are the program files from my system, one for the main program and one variable file.

- Main Basic Stamp Program Code File
- Basic Stamp Character Definitions File

Here is the parts list for the system that I made. It is a bit messy, and may have errors, but it gives an idea of what parts I used.

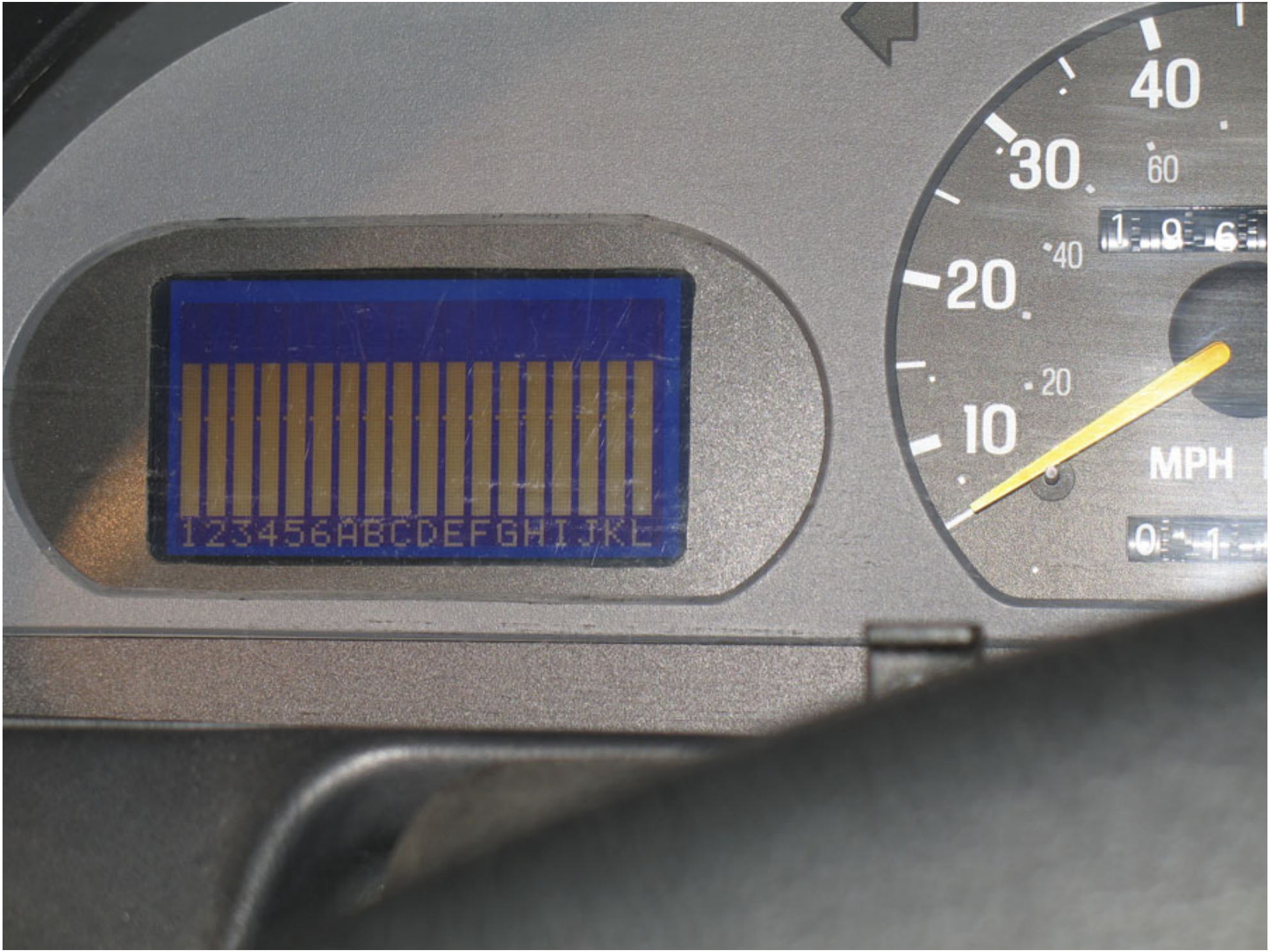
- Battery Monitor Parts List

In the end I have been happy with the results of this system. On paper it is reliable within about .05V, but it always matches my Digital Fluke Voltmeter to .01V. It is a bit expensive, but I think it was worth it. The system is relativeley modular - by adding more modules and changing the software, more batteries can be used. My system is set up for 6V batteries, but it could be adjusted with different resistors to be a 12V system. The main change I would make would be to add the current measurement and additional functions it affords.

If you ever use this information I would ask that you send me an email to tell me what you did, and also don't use it for financial gain. If you find a horrible flaw in the system or just have questions about it, I would also like to hear from you. My email is:

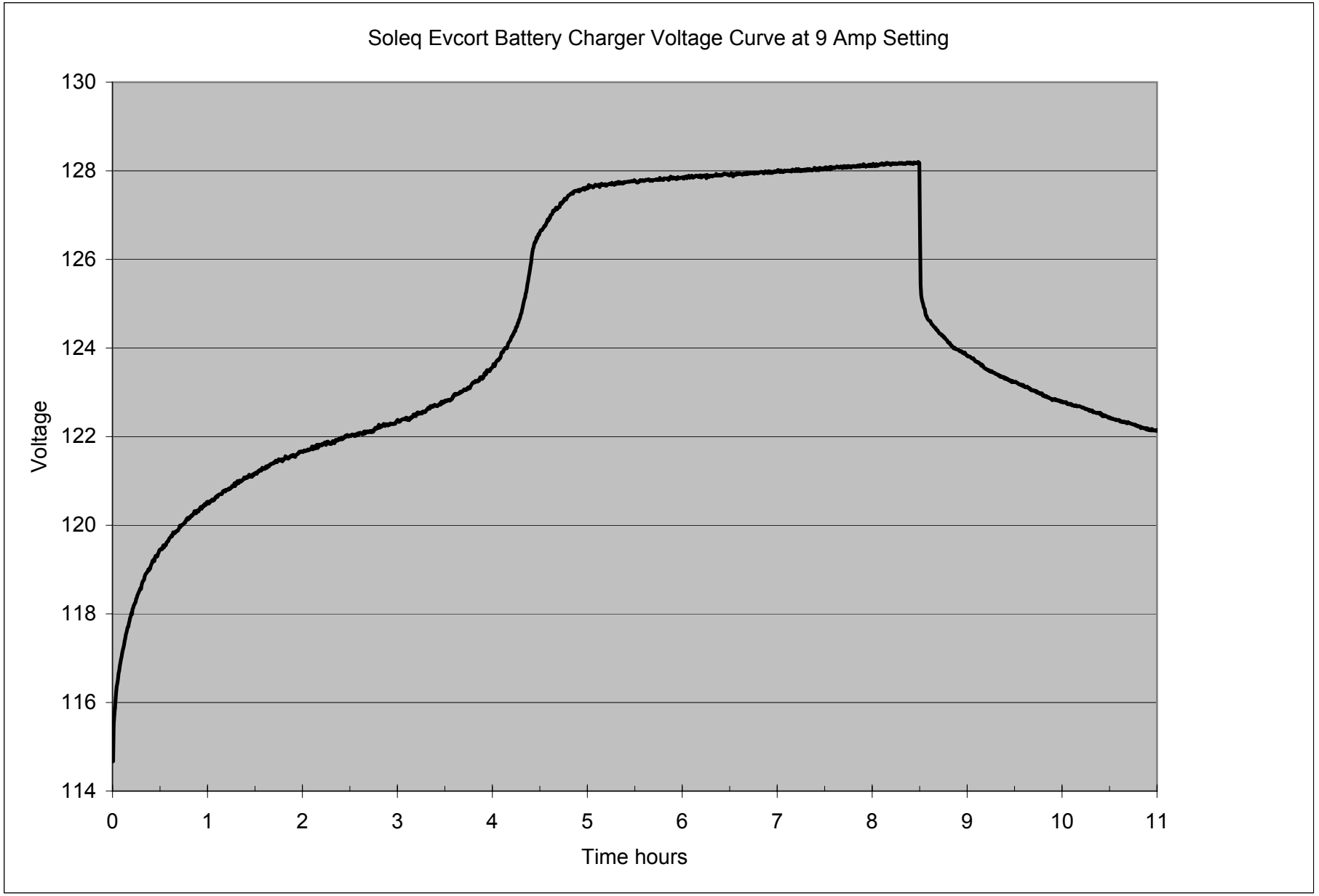
mailto:evtkw@earthlink.net

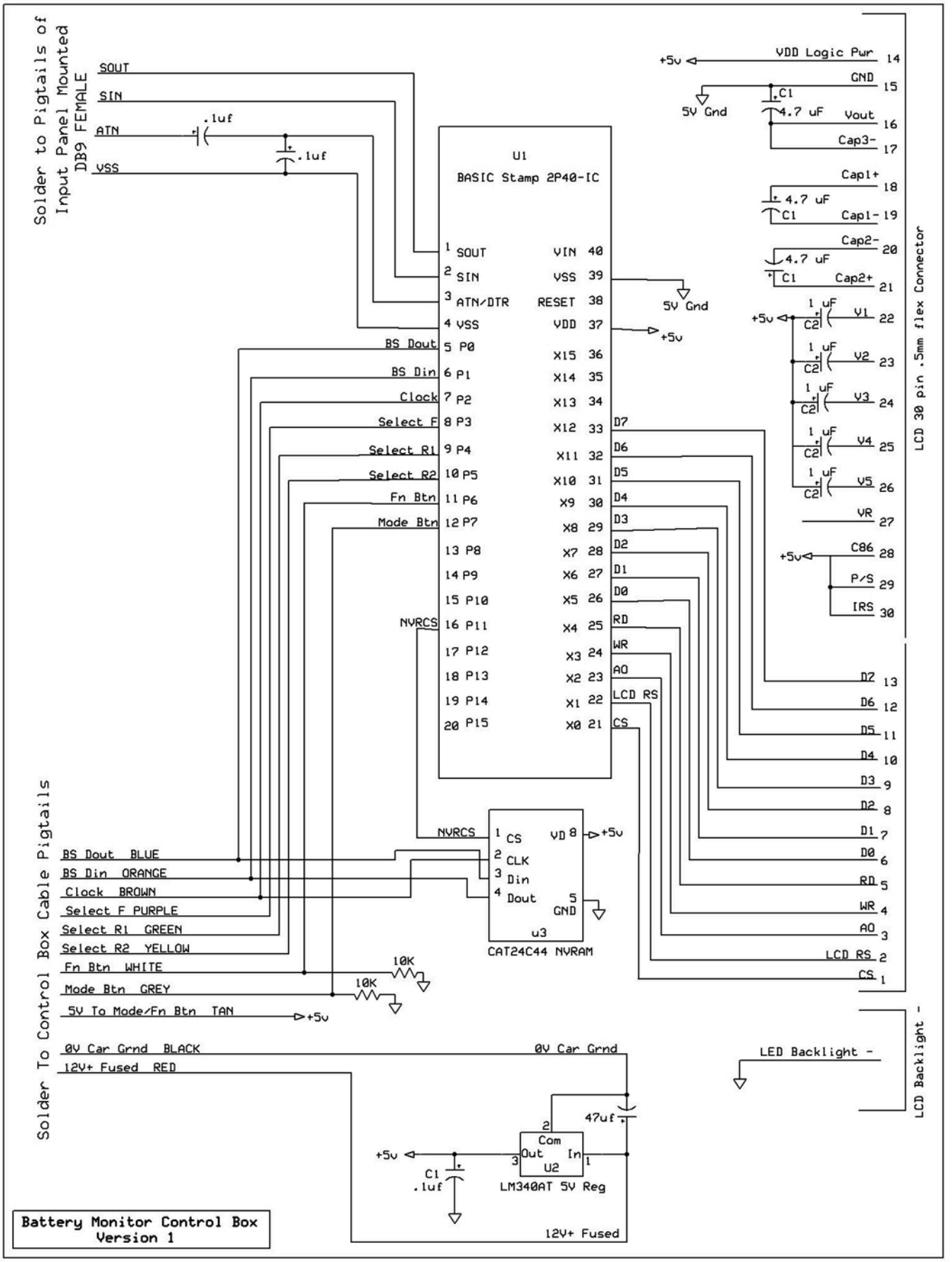
Put "EV BATTERY MONITOR" in the subject so I don't miss it.

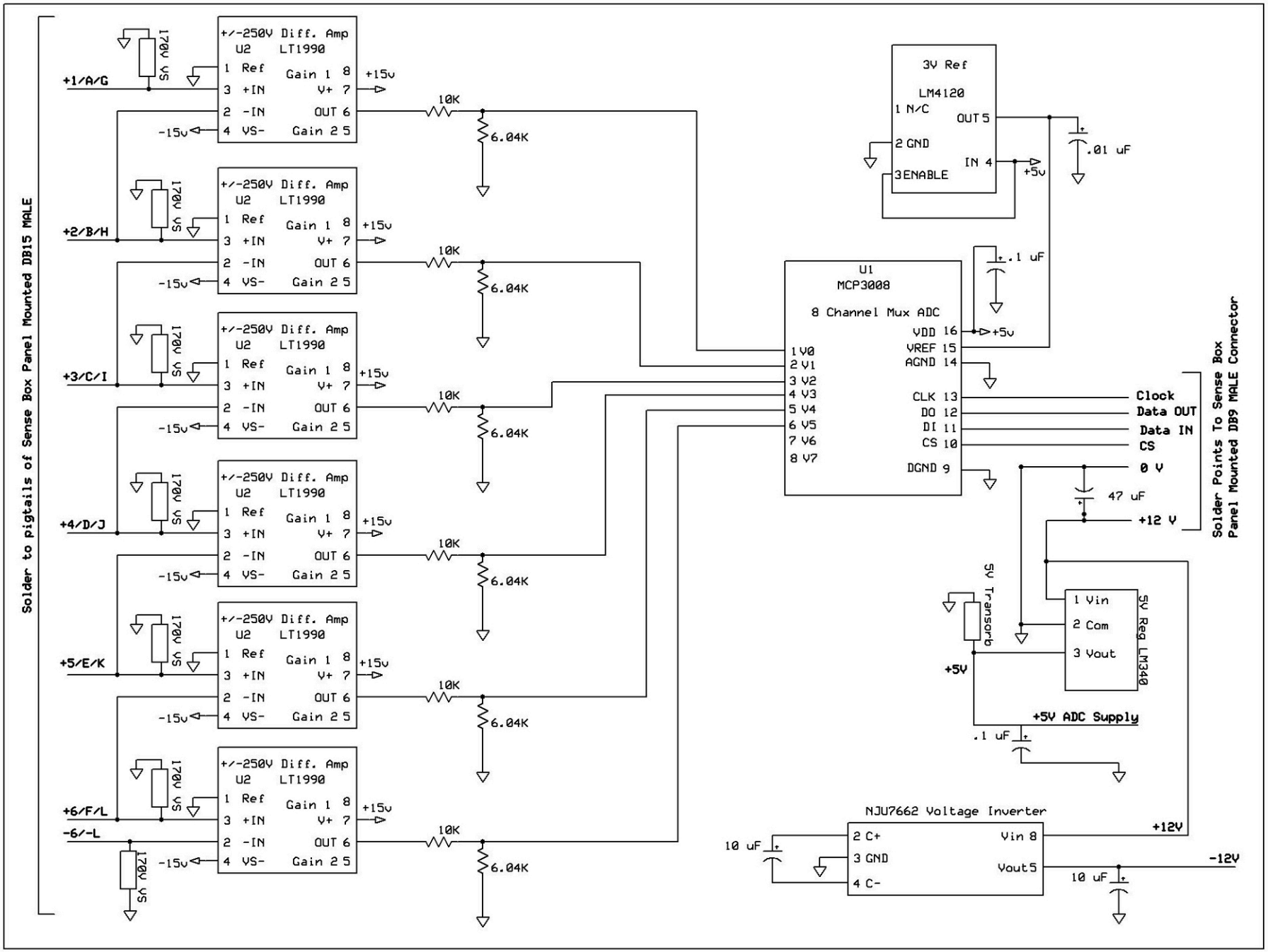

123456ABCDEFGHIJKL
40
30
60
20
40
20
10
MPH
0
1

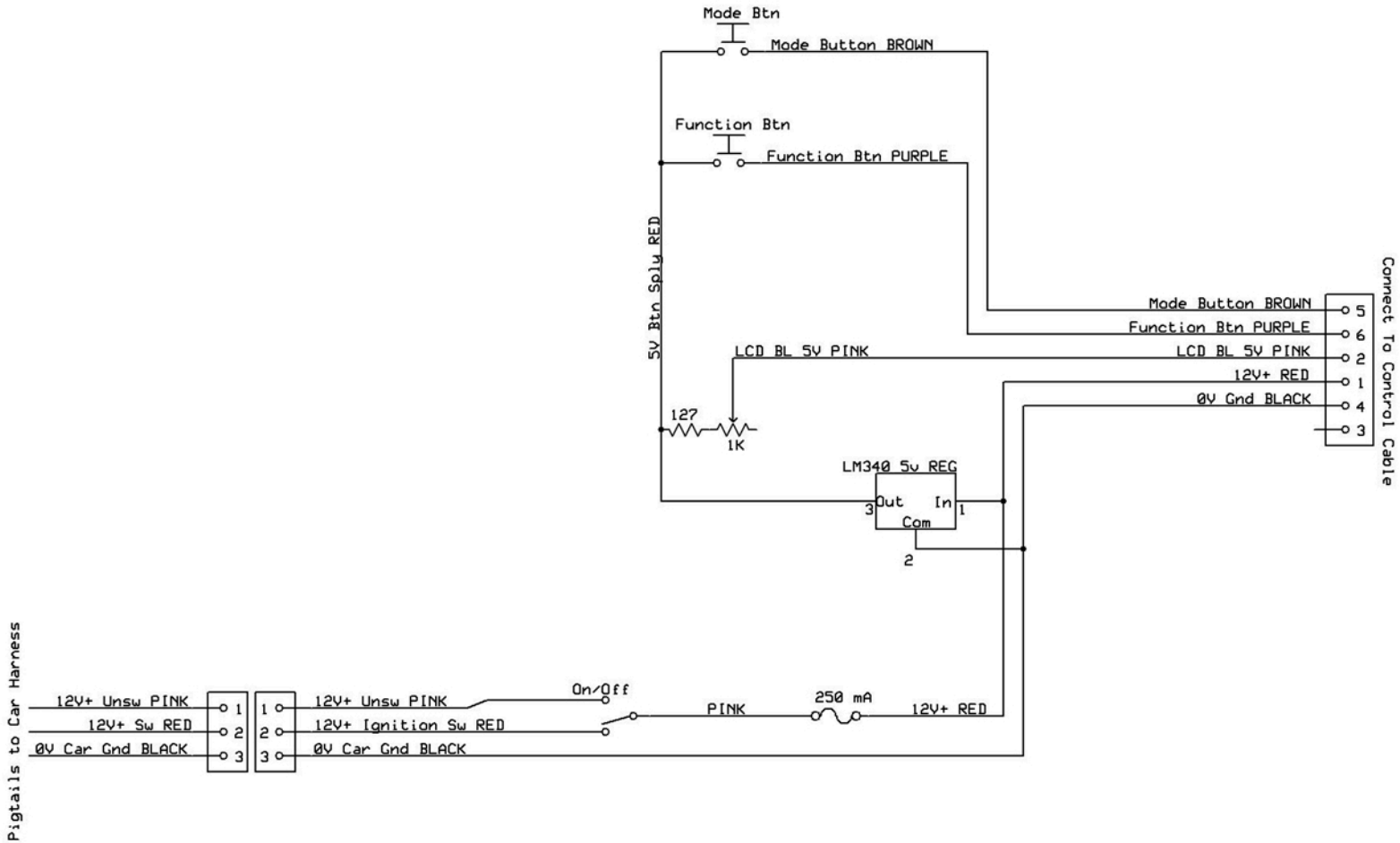

BATTERY 6
6.59 V
40
30
60
20
40
10
20
UNLEAD

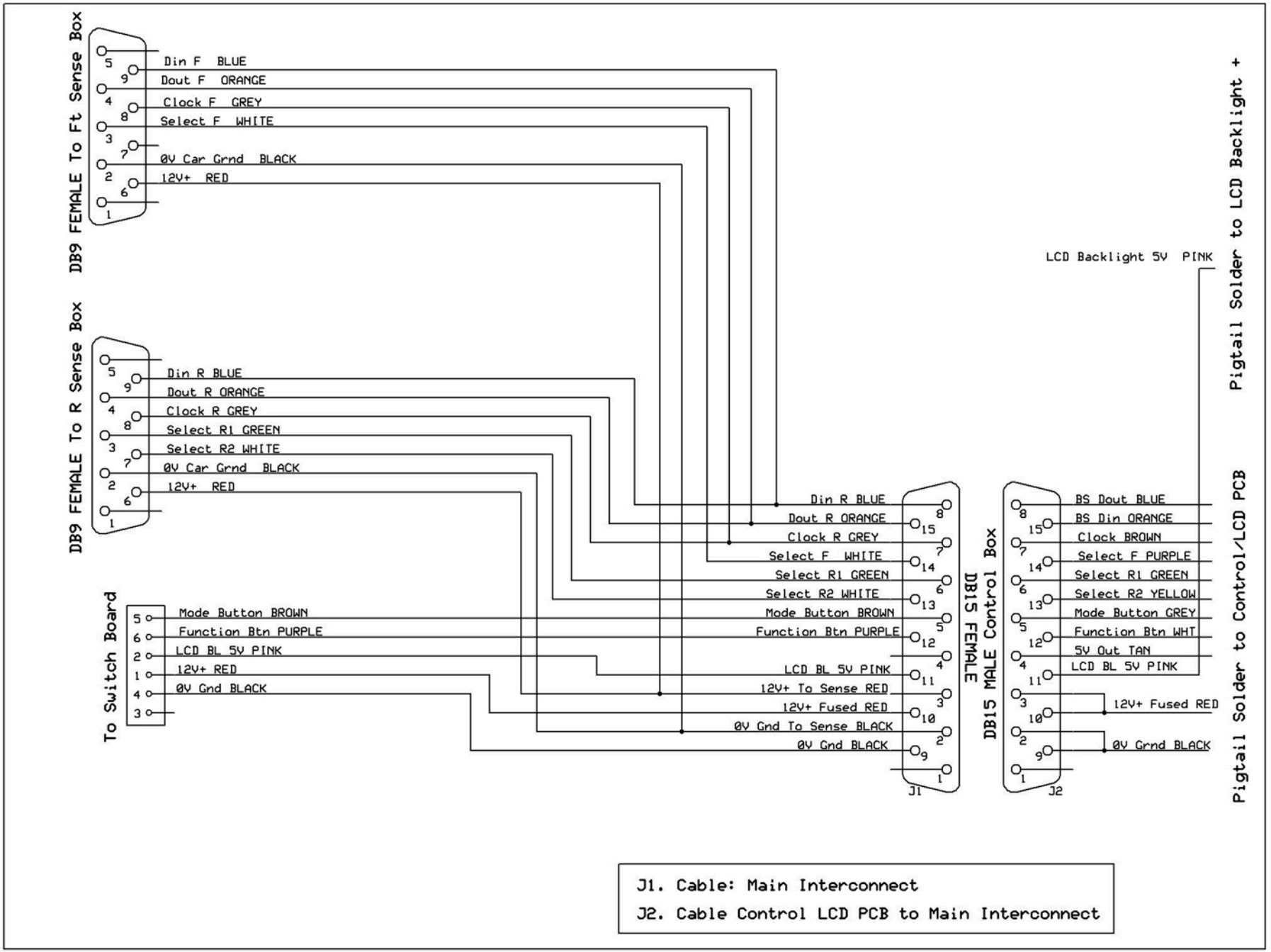

DATA
ON LO
FUEL
DOOR
20
10


Soleq Evcort Battery Charger Voltage Curve at 9 Amp Setting
Voltage
130
128
126
124
122
120
118
116
114
0
1
2
3
4
5
6
7
8
9
10
11
Time hours


Solder to Pigtails of Input Panel Mounted DB9 FEMALE
SOUT
SIN
ATN
VSS
.1uf
.1uf
U1
BASIC Stamp 2P40-IC
1 SOUT
2 SIN
3 ATN/DTR
4 VSS
5 P0
6 P1
7 P2
8 P3
9 P4
10 P5
11 P6
12 P7
13 P8
14 P9
15 P10
16 P11
17 P12
18 P13
19 P14
20 P15
VIN 40
VSS 39
RESET 38
VDD 37
X15 36
X14 35
X13 34
X12 33
X11 32
X10 31
X9 30
X8 29
X7 28
X6 27
X5 26
X4 25
X3 24
X2 23
X1 22
X0 21
BS Dout
BS Din
Clock
Select F
Select R1
Select R2
Fn Btn
Mode Btn
NVRCS
D7
D6
D5
D4
D3
D2
D1
D0
RD
WR
A0
LCD RS
CS
+5v
5V Gnd
VDD Logic Pwr 14
GND 15
C1
4.7 uF
Vout 16
Cap3- 17
Cap1+ 18
Cap1- 19
Cap2- 20
Cap2+ 21
1 uF
C2
V1 22
V2 23
V3 24
V4 25
V5 26
VR 27
C86 28
P/S 29
IRS 30
LCD 30 pin .5mm flex Connector
D7 13
D6 12
D5 11
D4 10
D3 9
D2 8
D1 7
D0 6
RD 5
WR 4
A0 3
LCD RS 2
CS 1
LCD Backlight -
LED Backlight -
CS
CLK
Din
Dout
VD 8
GND 5
u3
CAT24C44 NVRAM
BS Dout BLUE
BS Din ORANGE
Clock BROWN
Select F PURPLE
Select R1 GREEN
Select R2 YELLOW
Fn Btn WHITE
Mode Btn GREY
5V To Mode/Fn Btn TAN
10K
10K
Solder To Control Box Cable Pigtails
0V Car Grnd BLACK
12V+ Fused RED
0V Car Grnd
47uf
Com
Out
In
U2
LM340AT 5V Reg
C1
.1uf
12V+ Fused
Battery Monitor Control Box
Version 1


Solder to pigtails of Sense Box Panel Mounted DB15 MALE
+/-250V Diff. Amp
U2 LT1990
1 Ref
3 +IN
2 -IN
4 VS-
Gain 1 8
V+ 7
OUT 6
Gain 2 5
+15v
-15v
120V VS
+1/A/G
+2/B/H
+3/C/I
+4/D/J
+5/E/K
+6/F/L
-6/-L
10K
6.04K
3V Ref
LM4120
1 N/C
2 GND
3 ENABLE
OUT 5
IN 4
+5v
.01 uF
.1 uF
U1
MCP3008
8 Channel Mux ADC
VDD 16
VREF 15
AGND 14
CLK 13
DO 12
DI 11
CS 10
DGND 9
1 V0
2 V1
3 V2
4 V3
5 V4
6 V5
7 V6
8 V7
Clock
Data OUT
Data IN
CS
0 V
47 uF
+12 V
Solder Points To Sense Box
Panel Mounted DB9 MALE Connector
5V Transorb
5V Reg LM340
1 Vin
2 Com
3 Vout
+5V ADC Supply
NJU7662 Voltage Inverter
2 C+
3 GND
4 C-
Vin 8
Vout 5
10 uF
+12V
-12V


Mode Btn
Mode Button BROWN
Function Btn
Function Btn PURPLE
5V Btn Sply RED
LCD BL 5V PINK
127
1K
LM340 5v REG
Out
In
Com
3
1
2
Connect To Control Cable
Mode Button BROWN
Function Btn PURPLE
LCD BL 5V PINK
12V+ RED
0V Gnd BLACK
5
6
2
1
4
3
Pigtails to Car Harness
12V+ Unsw PINK
12V+ Sw RED
0V Car Gnd BLACK
1
2
3
12V+ Unsw PINK
12V+ Ignition Sw RED
0V Car Gnd BLACK
On/Off
PINK
250 mA
12V+ RED

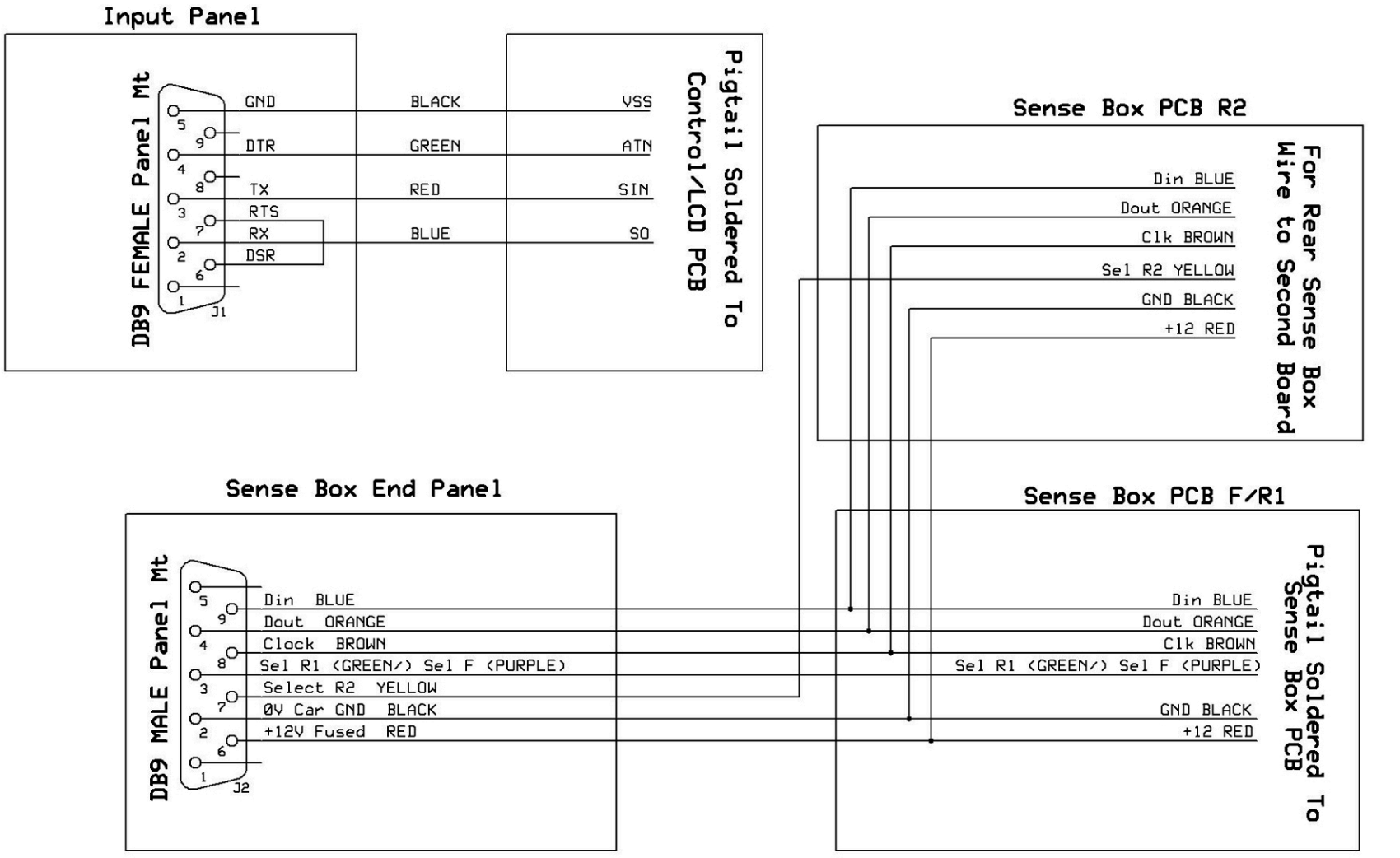


J1. Cable: Main Interconnect

J2. Cable Control LCD PCB to Main Interconnect

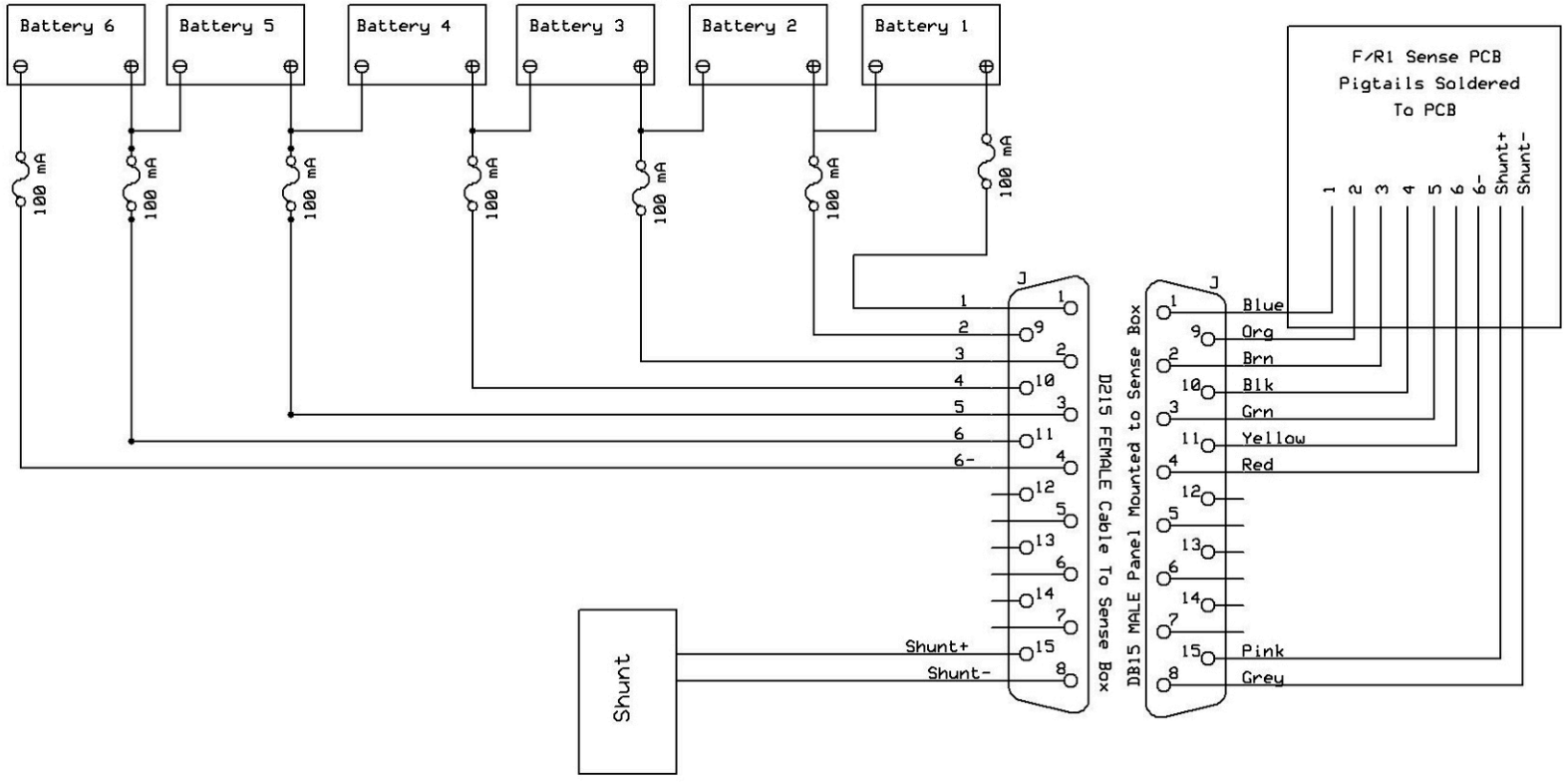
J1. Cable: Control LCD PCB to Input Panel Prog/Data

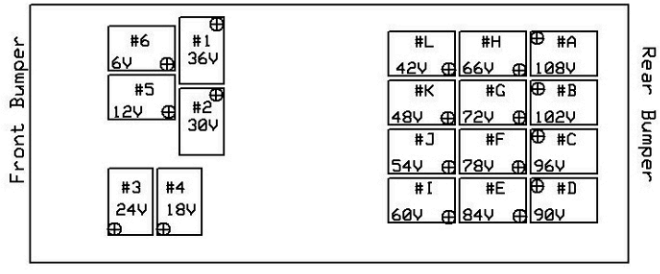
J2. Cable: Battery sense PCB to Box (Main Interconnect Side)



J1: Cable: Batteries to Battery Sense Box

J2: Cable: Battery Sense PCB to Box (Battery Side)

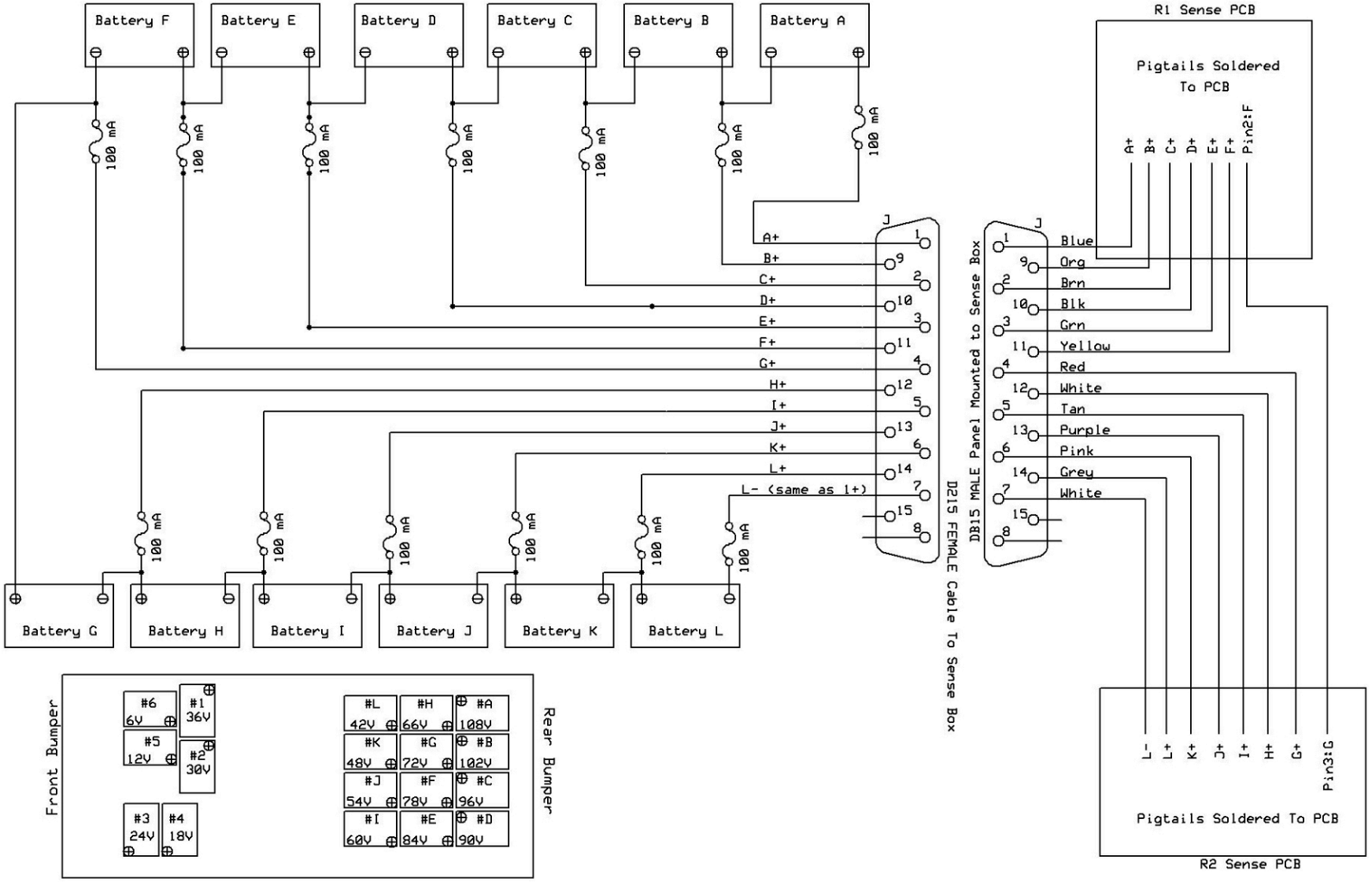




R2 Sense PCB

J1: Cable: Batteries to Battery Sense Box

J2: Cable: Battery Sense PCB to Box (Battery Side)



```
' {$STAMP BS2p}  ', Char Definitions.bsp}
' {$PBASIC 2.5}
'Char Definitions.bsp
'*****************************************************************************
' This is a program used with a Parallax Basic Stamp 2sx
' module.  The BS2sx is the control computer for an electric vehicle
' battery monitoring system.  This systems function is to read battery voltage
' and display it to the vehicle driver.  The system supports 18 6Volt batteries.
'*****************************************************************************
'  CHANGES
' version 4
' * added 5x averaging to voltage display
'
' version 5
' * make bargraph scale adjustable: 2v-8v,3v-8v,4v-8v,5v-8v
'
'
'*****************************************************************************
' Variable definition and Constants
'*****************************************************************************
' some counters
i VAR Byte
k VAR Byte
p VAR Byte
l VAR Byte
' global state constants
BARGRAPHSTATE CON 1
BATTVOLTSTATE CON 2
DATAAQSTATE CON 3
' data aquisition state
DATAAQOFF CON 0
DATAAQONLOW CON 2
DATAAQONHIGH CON 3
' DATa aquisition mode/state
dataaqmode VAR Nib
' data collection freq vars
dataaqcout VAR Byte
' global state variable
globalstate VAR Byte
' battery selected for display in battvoltstate
BattSelected VAR Byte
' variables used by read ADC function - used as arguments (set before running func)
voltage VAR Word
channel VAR Byte
chipselection VAR Byte
' EPROM position of character for argument to DrawItem
itemmempos VAR Byte
' temp vars
```

```
temp1 VAR Word
temp2 VAR Word
colmnpos VAR Byte
temp VAR Byte
nblow VAR Word
nbhigh VAR Word
' variables used internally by Stamp for Button command
btnwork1 VAR Byte
btnwork2 VAR Byte
' var to indicate battery voltage scale
bargraphscale VAR Byte

'****************************************************************
'******* initialize variables ********************************
' initialize vars used internally by Button comand - don't use otherwise
btnwork1 = 0
btnwork2 = 0
' init the selected batter to battery 0
BattSelected = 0
' init global state to bar graph mode
globalstate = BARGRAPHSTATE
' set bar graph scale to 5 volts to 8 volts scale
bargraphscale = 4

'****************************************************************
' main program function
'****************************************************************
Main:
  ' set main io to 1 or 0 as needed - io layout is: 1111111100111101 = 0xFF3D
  MAINIO
  DIRS = $FF3D
  ' set all aux io to outputs - 1 corrosponds to output in DIRS
  AUXIO
  DIRS = $FFFF
  ' first initialize the LCD
  ' initialize the LCD -  first set lcd reset low, wait 100ms, then go high
  LOW 1
  PAUSE 100
  HIGH 1
  ' reset display - ao_rd_wr_d7_d6..._d0
  LOW 0
  OUTS = $1C52
  HIGH 0
  ' set LCD bias
  LOW 0
  OUTS = $1452
  HIGH 0
  ' set ADC to reverse
```

```
    LOW 0
    OUTS = $1432
    HIGH 0
    ' set to normal common output
    LOW 0
    OUTS = $1812
    HIGH 0
    ' set built in resistance - values 0x20 to 0x27.  it sets contrast ratio base value
    LOW 0
    OUTS = $492
    HIGH 0
    ' set LCD contrast. this is a two command operation - first send Volume Mode Set Cmd
    LOW 0
    OUTS = $1032
    HIGH 0
    ' now send contrast value, the second part of the LCD contrast operation
    LOW 0
    ' original, medium contrast
  '  OUTS = $592
    ' higher contrast
    OUTS = $592
    ' maximum contrast
  '  OUTS = $592
    HIGH 0
    ' set power mode - turn on internal pwr supply features -
    ' Volt Regulator, Volt follower,booster circuit
    LOW 0
    OUTS = $5F2
    HIGH 0
    ' turn on display
    LOW 0
    OUTS = $15F2
    HIGH 0
    ' initialize first state
    GOSUB InitBargraphLCD


    ' **** MAIN PROGRAM LOOP: Loop forever! ******
    DO WHILE 1
      ' case statement to select and run current program state
      SELECT globalstate
        CASE BARGRAPHSTATE
          ' run bar graph "funcitonality"
          ' read each voltage then display to LCD
          FOR chipselection = 3 TO 5
            FOR channel = 0 TO 5
              ' run function to get one battery voltage, with channel and chipselection as arguments
              GOSUB Read_ADC
```

```
            'display current battery voltage bar on LCD, with channel and chip selection as input
            GOSUB LCD_Bargraph
          NEXT
          ' check mode button and call function to change state if button pressed
          MAINIO
          BUTTON 7, 1, 100, 50, btnwork1, 1, ModeButtonFn
          BUTTON 6, 1, 100, 50, btnwork2, 1, FunctionButtonFn
        NEXT
      CASE BATTVOLTSTATE
        ' single battery voltage state - read and display selected battery voltage
        ' read selected batteries voltage then display to LCD
        ' select ACD chip and channel
        chipselection = (BattSelected / 6) + 3
        channel = BattSelected // 6
        ' average 4 readings for noise rejection - good electronics design?!
        temp1 = 0
        FOR l = 0 TO 4
            ' run function to get one battery voltage, with channel and chipselection as arguments
            GOSUB Read_ADC
            temp1 = voltage + temp1
        NEXT
        ' divid to get average
        voltage = temp1 / 5
        'display current battery voltage numerically on LCD
        ' send one batteries voltage to LCD in decimal format
        ' change voltage to decimal and send out serial port
        ' this is a decimal approximation but accruate for 0-1024 to two decimal places
        ' I have to convert back to voltages based on a 10 bit 1024 count ADC, 3V voltage span,
        ' 10K / 6.04K resistor voltage divider .3765586x gain.
        ' Instrument amp gain = 100,000ohm/6040ohm + 1.
        ' formula is
        '     Display V = (Counts * 3)*(10,000 + 6040) / (1024 * 6040)
        ' simplified:
        '      Display V = Counts * 30 / 3856
        ' To get voltage in a fixed point system do in this order
        '     V = Counts * 30
        ' then go
        '     V = V / 3856
        ' first get the integer part of the number
        temp1 = voltage * 30
        ' draw - battery voltage, first set draw location page
        AUXIO
        LOW 0
        OUTS = $1692
        HIGH 0
        ' set high column nib
        LOW 0
        OUTS = $252
```

```
          HIGH 0
          ' set low column nib
          LOW 0
          OUTS = $1B2
          HIGH 0
          ' print the whole part of voltage left of decimal point
          itemmempos = (temp1 / 3856)
          GOSUB DrawItem
          ' print decimal point
          itemmempos = 30
          GOSUB DrawItem
          ' drwa numbers after decimal point. this is done by taking the number you want
          ' to devide, temp1, and taking the modulus of it with the dividor, 3856, then
          ' multiplying by 10.  this number, call it X is saved for the next digit.  the current digit
          ' is X / 3856.
          ' So IF I wanted TO GET the first digit of 2/3, Go:
          '    2 // 3 = 2
          '    2 * 10 = 20
          '    20 / 3 = 6 (.66667, but this isn't here in fixed point)
          '    since 2/3 = .6666666667, the first digit is, correctly, 6
          FOR p = 0 TO 1
            ' first digit remainder of desired dividor * 10
            temp1 = (temp1 // 3856) * 10
            ' display just created digit on LCD of this value:
            itemmempos = (temp1 / 3856)
            GOSUB DrawItem
          NEXT

        CASE DATAAQSTATE
          ' run data aquisition setup fun
          GOSUB DataAquisionSetup
        CASE ELSE
          ' unrecognized state - set to default
          globalstate = BARGRAPHSTATE
      ENDSELECT
      ' switch to main io
      MAINIO
      ' check mode button and call function to change state if button pressed
      BUTTON 7, 1, 100, 50, btnwork1, 1, ModeButtonFn
      ' check function button and call function to change data if button pressed
      BUTTON 6, 1, 100, 50, btnwork2, 1, FunctionButtonFn
      ' put a "label" marker to allow for returning from functions called by Button
      return_to_main_label:
      ' continue main loop
    LOOP
    ' end of main - program done.  don't get here ever...
  END
  '*****************************************************************
```

```
'*****************************************************************
' funciton update state when mode button pressed
' ONLY FOR USE FROM MODE BUTTON INSTRUCTION FROM MAIN
'*****************************************************************
ModeButtonFn:
  ' mode button pressed - clear lcd
  GOSUB ClearLCD
  ' now update state TO NEXT state
  IF (globalstate = BARGRAPHSTATE) THEN
    ' set flag to go to new state
    globalstate = BATTVOLTSTATE
    ' init new state
    GOSUB InitBattVolt
  ELSEIF (globalstate = BATTVOLTSTATE) THEN
    globalstate = DATAAQSTATE
    ' set data aquisition mode to off
    dataaqmode = DATAAQOFF
    ' ****update LCD for this state/function change
    GOSUB LCD_Datasetup
    ' reset the counter for high or low frequency data collection
    nblow = 0
  ELSE
    ' in dataaq state - set state flag to bargraph
    globalstate = BARGRAPHSTATE
    ' initialze new state
    GOSUB InitBargraphLCD
  ENDIF
  ' return to maain - Return command doesn't work when called from button...
    GOTO return_to_main_label
RETURN
'*****************************************************************

'*****************************************************************
' function updatae variables accordingly when fucntion button pressed
' ONLY FOR USE FROM FUNCTION BUTTON INSTRUCTION FROM MAIN
'*****************************************************************
FunctionButtonFn:
  ' function button pressed- change data according to mode
  IF (globalstate = BARGRAPHSTATE) THEN
    ' increment scale counter
    bargraphscale = bargraphscale + 1
    IF (bargraphscale >= 6) THEN
      bargraphscale = 3
    ENDIF
  ELSEIF (globalstate = BATTVOLTSTATE) THEN
    ' in battery monitor state - increment the battery selected for display
    BattSelected = Battselected + 1
```

```
      ' roll over the number when at max battery
      IF (BattSelected > 17) THEN
         BattSelected = 0
      ENDIF
      ' functio button hit and data updated
      ' redraw - Battery Label (or 1-6 or A-L)
      AUXIO
      LOW 0
      OUTS = $1652
      HIGH 0
      ' set high column nib
      LOW 0
      OUTS = $2B2
      HIGH 0
      ' set low column nib
      LOW 0
      OUTS = $152
      HIGH 0
      ' draw selected battery label 1-6 A-L
      IF (BattSelected < 6) THEN
        itemmempos = BattSelected + 1
      ELSE
        itemmempos = Battselected + 4
      ENDIF
      GOSUB DrawItem
    ELSEIF (globalstate = DATAAQSTATE) THEN
      ' in data aquistiion state - increment data aquisition mode
      IF (dataaqmode = DATAAQOFF) THEN
           ' switch to low data aquisition rate
          dataaqmode = DATAAQONLOW
          ' set the frequency counter to low freq data collection
          nbhigh = 10000 'LOWDATAOUTPUTLOOPS
      ELSEIF (dataaqmode = DATAAQONLOW) THEN
          ' switch to high data aquisitoin rate
          dataaqmode = DATAAQONHIGH
          ' set the frequency counter to high freq data collection
          nbhigh = 0'HIGHDATAOUTPUTLOOPS
      ELSEIF (dataaqmode = DATAAQONHIGH) THEN
        dataaqmode = DATAAQOFF
        ' reset the counter for high or low frequency data collection
        nblow = 0
      ENDIF
      ' update lcd
      GOSUB LCD_Datasetup
    ENDIF
    ' RETurn to maain - Return command doesn't work when called from button...
    GOTO return_to_main_label
  RETURN
```

```
'*****************************************************************

'*****************************************************************
' INitialize Bar Graph LCD
'*****************************************************************
' this function will initialize the bar graph display by drawing hte
' battery labels, scale markers, and over/under voltage lines
InitBargraphLCD:
    ' clear LCD
    GOSUB ClearLCD
    ' draw dotted "range" lines at
    ' 5.25V (675 counts) AND 7.45V (958 counts)--- or 4.8V (617) like Mr. Oba of Soleq said?
    ' should I also draw voltage scale?  or both?  scale may take up too much space...
    AUXIO
    'page
    LOW 0
    OUTS = $16F2
    HIGH 0
    ' set high column nib
    LOW 0
    OUTS = $212
    HIGH 0
    ' set low column nib
    LOW 0
    OUTS = $12
    HIGH 0
    ' print the battery labels along bottom 1-6
    FOR p = 1 TO 6
      itemmempos = p
      GOSUB DrawItem
    NEXT
    ' BATTS A-L
    FOR p = 10 TO 21
      itemmempos = p
      GOSUB DrawItem
    NEXT
RETURN

'*****************************************************************
' function/state initlization of Batteries Voltage state
'*****************************************************************
InitBattVolt:
  ' draw - battery label (or 1-6 or A-L)
  LOW 0
  OUTS = $1652
  HIGH 0
  ' set high column nib
  LOW 0
```

```
    OUTS = $252
    HIGH 0
    ' set low column nib
    LOW 0
    OUTS = $52
    HIGH 0
    ' print "BATTERY" in middle of screen
    itemmempos = 11 'B
    GOSUB DrawItem
    itemmempos = 10 'A
    GOSUB DrawItem
    itemmempos = 26 'T
    GOSUB DrawItem
    itemmempos = 26 'T
    GOSUB DrawItem
    itemmempos = 14 'E
    GOSUB DrawItem
    itemmempos = 25 'R
    GOSUB DrawItem
    itemmempos = 28 'Y
    GOSUB DrawItem
    itemmempos = 29 'BLANK SPACE
    GOSUB DrawItem
    IF (BattSelected < 6) THEN
      itemmempos = BattSelected + 1
      GOSUB DrawItem
    ELSE
      itemmempos = Battselected + 4
      GOSUB DrawItem
    ENDIF
    ' draw "V" for voltage after numbers to be printed later
    ' draw - battery label (or 1-6 or A-L)
    LOW 0
    OUTS = $1692
    HIGH 0
    ' set high column nib
    LOW 0
    OUTS = $2B2
    HIGH 0
    ' set low column nib
    LOW 0
    OUTS = $12
    HIGH 0
    itemmempos = 27 'V char
    GOSUB DrawItem
    ' draw decimal point
  RETURN
  '*****************************************************************
```

```
'*****************************************************************
' subroutine to read ADC
'*****************************************************************
Read_ADC:
    ' this function has arguments - chipselection, for the ADC to select,
    ' and channel, for the channel on the selected ADC to be slected
    ' the args are set outside, so care has to be take when calling this funciton
    ' set to use main IO
    MAINIO
    ' set chip select output to enable Front, Rear1 or Rear2 ADC
    LOW chipselection
    ' create command - 11000 binary 0x18, setting start bit and the single ended bit
    ' channel is the channel that is to be converted and muxed - it is zero based
    ' write to select channel and convert
    SHIFTOUT 0, 2, MSBFIRST, [($18 | channel) \6]
    ' read channel 1 voltage: pins - 2=clock,0=dout, 1=din
    SHIFTIN 1, 2, MSBPOST, [voltage \11]
    ' set chip select back high
    HIGH chipselection
'   RANDOM voltage
'    voltage = voltage / 64
    ' return to call fucntion
 RETURN

'*****************************************************************
' Clear LCD
'*****************************************************************
ClearLCD:
  FOR p = 7 TO 0
    AUXIO
    ' set to page
    LOW 0
    OUTS = $1612 + (p << 5)
    HIGH 0
    ' set column back to zero
    ' set high column nib
    LOW 0
    OUTS = $212
    HIGH 0
    ' set low column nib
    LOW 0
    OUTS = $12
    HIGH 0
    FOR i = 0 TO 127
      LOW 0
      OUTS = $16
      HIGH 0
```

```
      NEXT
    NEXT
  RETURN

  '*****************************************************************
  ' Display current voltages in a bar graph on LCD
  '*****************************************************************

  LCD_Bargraph:
    ' display this many pixels: voltage count * (full scale #pixels) / 1024
    AUXIO
    ' subtract off the equivalent of 3 volts from adc counts read to
    ' set scale to 3 volt minimum instead of 0 volt minimum - also set to 0 if
    ' it will be negative. 3 volts is 385 counts
    ' **if you want to use 2 volts instead use 257 counts.
    ' ** also could just cut off at 5.25 volts?!
    ' subtract off the desired scale positoin - the scale count bargrpahscale
    ' ranges from 3 to 5, and is user selectable with the fucnction switch.
    ' 128 counts is about 1 volt, so go bargraphscale x 128 and rescale based on
    ' that.
    ' first make sure i don't geT A negative number (it rolls over to 65535)
    IF (voltage > (bargraphscale * 128)) THEN
'     IF (voltage > 385) THEN
     ' voltage not less than min scale, subtract off scale
      temp1 = voltage - (bargraphscale * 128)
'     temp1 = voltage - 385
    ELSE
      temp1 = 0
    ENDIF
    ' calc pixels (temp1) = voltage in counts * full scale pixels / full scale ADC counts
    ' full scale adc counts varies based on bargraphscale
    temp1 = (temp1 * 56) / (1024 - (bargraphscale * 128))
'   temp1 = temp1 * 56 / (1024 - 385)

    '*************************************************************************************
    ' ******* should I round pixels based on the first decimal place...? TAKES TIME:
    ' see function LCD_OneBattery comments for rounding/decimal place calculation explination
''  IF ((((voltage * 56) // 1024) * 10 / 1024) >= 5) THEN
'   IF ((((voltage * 56) // (1024 - (128 * bargraphscale))) * 10 / (1024 - (128 * bargraphscale))) >= 5) THEN
'     IF (temp1 < 55) THEN
        ' round pixel up one
'       temp1 = temp1 + 1
'     ENDIF
'   ENDIF
    '*************************************************************************************

    ' calculate column for this battery
    colmnpos = ((((chipselection - 3) * 6) + channel) * 7)
```

```
    ' calculate the solid page incmrent
    i = 7 - (temp1 / 8)
    ' make the high and low nib column addres to write to display - which requires two cmds for this
    nblow = $12 + (colmnpos.LOWNIB << 5)
    nbhigh = $212 + (colmnpos.HIGHNIB << 5)
    IF (i <> 7) THEN
      ' write solid pages
      FOR p = 6 TO i
        ' set page, column to start
        LOW 0
        OUTS = $1612 | (p << 5)
        ' set high column nib based on the battery currently printing
        HIGH 0
        LOW 0
        OUTS = nbhigh
        HIGH 0
        LOW 0
        ' set low column nib
        OUTS = nblow
        HIGH 0
        'write $00
        LOW 0
        OUTS = $16
        HIGH 0
        ' write column
        FOR k = 0 TO 4
          LOW 0
          OUTS = $1FF6
          HIGH 0
        NEXT
        'write $00
        LOW 0
        OUTS = $16
        HIGH 0
      NEXT
    ENDIF

    ' draw partial page that isn't whole solid page - it will be the last one on top
    ' set page, column to start
    LOW 0
    OUTS = $1612 | ((i - 1) << 5)
    ' set high column nib based on the battery currently printing
    HIGH 0
    LOW 0
    OUTS = nbhigh
    HIGH 0
    LOW 0
    ' set low column nib
```

```
OUTS = nblow
HIGH 0
' first column is always blank
LOW 0
OUTS = $16
HIGH 0
' figure out how many pixels to write on top of full pages just written
' pixels extra are remainder of temp1/8 pages. temp1 is total pixels.
' since we are unfortunately drawing from bottom of lcd, do flip bits
' by taking FF and shifting it by the ammount of hte remainder. since
' storing in p, a byte, it should shift off end
p = $FF << (8 - (temp1 // 8))
' p is data, so shift to data section of IO, then use temp2 to send to io in for loop
temp2 = $16 + (p << 5)
FOR k = 0 TO 4
  LOW 0
  OUTS = temp2
  HIGH 0
NEXT
'write $00
LOW 0
OUTS = $16
HIGH 0
' now clear the pages above the pages written with a bar.
IF (i <> 1) THEN
  i = i - 2
  FOR p = i TO 0
    ' set page, column to start
    LOW 0
    OUTS = $1612 | (p << 5)
    ' set high column nib based on the battery currently printing
    HIGH 0
    LOW 0
    OUTS = nbhigh
    HIGH 0
    LOW 0
    ' set low column nib
    OUTS = nblow
    HIGH 0
    ' draw spaces to blank out if column gets smaller
    FOR k = 0 TO 7
      LOW 0
      OUTS = $16
      HIGH 0
    NEXT
  NEXT
ENDIF
' draw 5.25 low voltage line. 5.25V is 674.8 counts, so I will use
```

```
    ' 675 counts as the cutoff. also must subtract offset (128 counts x bargraphscale)
    ' set page, column to start
    ' if page is 5.25v page, write $xx, for 675 - (128 * bargraphscale) count line
    ' calculate page of 5.25v low limit line
    ' first get total pixels
    temp1 = ( (675 - (128 * bargraphscale)) * 56) / (1024 - (128 * bargraphscale))
    ' get page #: page zero is on top, so have to invert number accordingly
    temp2 = 6 - (temp1 / 7)
    ' get extra pixels. pixel 7 is at bottom, so have to convert
    temp1 = 8 - (temp1 // 8)
    ' go to desired page just calculated
    LOW 0
    OUTS = ($1612 | (temp2 << 5))
    ' set column in var nbhigh
    ' set high column nib based on the battery currently printing
    HIGH 0
    LOW 0
    OUTS = nbhigh
    HIGH 0
    LOW 0
    ' set low column nib
    OUTS = nblow
    HIGH 0
    ' write line
    LOW 0
    ' this is a potential bug if changed - shift 4 will overwrite data if temp1 is 0
    ' however, a "1" will be overwriten with a "1", and temp1 is, coicedentally, 0
    OUTS = ($16 | (1 << (temp1 + 4)))
    ' done writing LCD - set the chip select to on, disabled
    HIGH 0
    ' return to main loop
  RETURN
  '*****************************************************************

  '*****************************************************************
  ' Draw an item on dislpay:
  '       0-6,A-L,N,O,P,R,S,T,U,V,W,Y,:,5x8 fill
  ' this information will be written into the eprom with the DATA command
  ' in the consecutive order above, and is in the file "Char Definitions.bsp"
  '*****************************************************************
  DrawItem:
    FOR k = 0 TO 6
      AUXIO
      LOW 0
      READ ((itemmempos * 7) + k), temp
      OUTS = $16 + (temp << 5)
      HIGH 0
    NEXT
```

```
  RETURN

  '*****************************************************************
  ' function/state that selects data collection state
  '*****************************************************************
  DataAquisionSetup:
    IF (dataaqmode = DATAAQOFF) THEN
      ' data aquision is off - do nothing
    ELSE
      ' in data aquisition state
      ' read adcs and send data out serial port if frequency count is reached
      IF (nblow >= nbhigh) THEN
        nblow = 0
        ' read each voltage then send out the serial port for data collection
        ' for each ADC, 6 batteries per ADC - chip selects are on IO points 3-5
        FOR chipselection = 3 TO 5
          ' for each batter measured by each adc
          FOR channel = 0 TO 5
            ' run function to get one battery voltage, with channel and chipselection as arguments
            GOSUB Read_ADC
            ' send voltage to serial port 115200 baud rate
            ' for 155200 use 16385. Formula is int(2,500,00/baud) - 20 +16384
            ' for 19200 use 16494
            ' this will just send out the current battery number to the serial port...

            ' change voltage to decimal and send out serial port
            ' this is a decimal approximation but accruate for 0-1024 to two decimal places
            ' ** check function LCD_OneBattery comments for more info
            ' first get the integer part of the number
            temp1 = voltage * 30
            SEROUT 16, 16494, [DEC (temp1 / 3856), "."]
            FOR k = 0 TO 1
              ' remainder * 10
              temp1 = (temp1 // 3856) * 10
              ' display just created digit
              SEROUT 16, 16494, [DEC1 (temp1 / 3856)]
            NEXT
            SEROUT 16, 16494, [" "]
          NEXT
        NEXT
        ' done sending 18 batteries - send carriage return to serial port
        SEROUT 16, 16494, [CR]
      ENDIF
      ' we are in data collection mode - increment data count for low/high freq control
      nblow = nblow + 1
    ENDIF

  RETURN
```

```
'*********************************************************************

'*********************************************************************
' Display data aquisition setup on LCD
'*********************************************************************
LCD_Datasetup:
  ' send new title to LCD
  ' draw - battery label (or 1-6 or A-L)
  AUXIO
  LOW 0
  OUTS = $1652
  HIGH 0
  ' set high column nib
  LOW 0
  OUTS = $272
  HIGH 0
  ' set LOW column Nib
  LOW 0
  OUTS = $92
  HIGH 0
  ' print "DATA SETUP" in middle of screen
  itemmempos = 13 'D
  GOSUB DrawItem
  itemmempos = 10 'A
  GOSUB DrawItem
  itemmempos = 26 'T
  GOSUB DrawItem
  itemmempos = 10 'A
  GOSUB DrawItem

  SELECT dataaqmode
    CASE DATAAQOFF
      LOW 0
      OUTS = $1692
      HIGH 0
     ' set high column nib
      LOW 0
      OUTS = $272
      HIGH 0
      ' set LOW column Nib
      LOW 0
      OUTS = $12
      HIGH 0

      itemmempos = 29 '__
      GOSUB DrawItem
      itemmempos = 23 'o
      GOSUB DrawItem
```

```
        itemmempos = 15 'f
        GOSUB DrawItem
        itemmempos = 15 'f
        GOSUB DrawItem
        itemmempos = 29 '__
        GOSUB DrawItem
      CASE DATAAQONLOW
        ' set page
        LOW 0
        OUTS = $1692
        HIGH 0
       ' set high column nib
        LOW 0
        OUTS = $272
        HIGH 0
        ' set LOW column Nib
        LOW 0
        OUTS = $12
        HIGH 0

        itemmempos = 23 'o
        GOSUB DrawItem
        itemmempos = 22 'n
        GOSUB DrawItem
        itemmempos = 29 '__
        GOSUB DrawItem
        itemmempos = 21 'L
        GOSUB DrawItem
        itemmempos = 23 'o
        GOSUB DrawItem
      CASE DATAAQONHIGH
        ' page
        LOW 0
        OUTS = $1692
        HIGH 0
        ' set high column nib
        LOW 0
        OUTS = $272
        HIGH 0
        ' set LOW column Nib
        LOW 0
        OUTS = $12
        HIGH 0

        itemmempos = 23 'o
        GOSUB DrawItem
        itemmempos = 22 'n
        GOSUB DrawItem
```

```
        itemmempos = 29 '__
        GOSUB DrawItem
        itemmempos = 17 'H
        GOSUB DrawItem
        itemmempos = 18 'I
        GOSUB DrawItem
    ENDSELECT
  RETURN
```

```
' {$STAMP BS2p}
' {$PBASIC 2.5}

' this file defines the LCD characters needed in the program,
' and stores them into EPROM
' characters are:
'  0-9,A-L,N,O,P,R,S,T,U,V,W,Y,:,5x8 fill,"dashed line segment"
Zchar DATA $00,$7C,$A2,$92,$8A,$7C,$00            '0
Onechar DATA $00,$00,$84,$FE,$80,$00,$00
Twochar DATA $00,$84,$C2,$A2,$92,$8C,$00
Threechar DATA $00,$42,$82,$8A,$96,$62,$00
Fourchar DATA $00,$30,$28,$24,$FE,$20,$00
Fivechar DATA $00,$4E,$8A,$8A,$8A,$72,$00         '5
Sixchar DATA $00,$78,$94,$92,$92,$60,$00
Sevnchar DATA $00,$02,$E2,$12,$0A,$06,$00
Eightchar DATA $00,$6C,$92,$92,$92,$6C,$00
Ninechar DATA $00,$0C,$92,$92,$52,$3C,$00
Achar DATA $00,$FC,$22,$22,$22,$FC,$00            '10
Bchar DATA $00,$FE,$92,$92,$92,$6C,$00
Cchar DATA $00,$7C,$82,$82,$82,$44,$00
Dchar DATA $00,$FE,$82,$82,$44,$38,$00
Echar DATA $00,$FE,$92,$92,$92,$82,$00
Fchar DATA $00,$FE,$12,$12,$12,$02,$00            '15
Gchar DATA $00,$7C,$82,$92,$92,$F4,$00
Hchar DATA $00,$FE,$10,$10,$10,$FE,$00
Ichar DATA $00,$00,$82,$FE,$82,$00,$00
Jchar DATA $00,$40,$80,$82,$7E,$02,$00
Kchar DATA $00,$FE,$10,$28,$44,$82,$00            '20
Lchar DATA $00,$FE,$80,$80,$80,$80,$00
Nchar DATA $00,$FE,$08,$10,$20,$FE,$00
Ochar DATA $00,$7C,$82,$82,$82,$7C,$00
Pchar DATA $00,$FE,$12,$12,$12,$0C,$00
Rchar DATA $00,$FE,$12,$32,$52,$8C,$00            '25
Schar DATA $00,$8C,$92,$92,$92,$62,$00 '**
Tchar DATA $00,$02,$02,$FE,$02,$02,$00
Uchar DATA $00,$7E,$80,$80,$80,$7E,$00 '**
Vchar DATA $00,$3E,$40,$80,$40,$3E,$00
Wchar DATA $00,$7E,$80,$70,$80,$7E,$00  '**          '30
Ychar DATA $00,$0E,$10,$E0,$10,$0E,$00
Fillchar DATA $FF,$FF,$FF,$FF,$FF,$FF,$FF '**
Emptychar DATA $00,$00,$00,$00,$00,$00,$00
Decpt DATA $00,$00,$00,$C0,$C0,$00,$00
Bargraph DATA $00,$FF,$FF,$FF,$FF,$FF,$00  '**       '35
'low dash char at 5.25V (675 counts, 37 pixels on 56 pix scale) OR 4.8V (617, 34pix) like Mr. Oba of Soleq said?
' high dash char 7.45V (958 counts, 52 pix on 56 pix full scale)
```