Arduino Weld Quality Monitoring Project

Handover Document

Description: Document detailing the preparation and handling of the Arduino system developed by Sava Arsenijevic during his honours project.

Project Sponsors: Dr. Matthew Doolan, Mr. Cameron Summerville.

Author: Mr. Sava Arsenijevic.

Date: **09/11/2018**

1 Introduction

This document details the procedure to set up the Arduino Weld Quality Monitoring system. Information regarding the overall function, troubleshooting methods, and areas for further work are also provided.

2 Project Details

Information regarding the strengths and limitations of the Arduino Weld Quality Monitoring system is detailed below. Whilst the system has been upgraded since it was last worked on during the honours project, there are still some limitations. These limitations are regarding the environment it can work in and as well as some reliability issues. However, by following the setup procedure accurately and maintaining a consistent welding environment, the system will work adequately.

2.1 Deliverables

Most of the deliverables outlined at the start of the project have been met and are displayed in Table 1 below.

Deliverable	**Completed?**
Working lights	Yes
Define welding scenario	Yes
Define training the Arduino system / streamline	Yes
Make the Arduino system presentable	Partially
Handover manual	Yes
Works with at least 1 reproducible fault	Yes

Table 1 - Project Deliverables

2.2 Working Lights

A new LED has been installed which emits a green or red light depending on whether the system determines a good or bad weld occurring.

2.3 Define Welding Scenario

Steps have been taking to further define and restrict the scenario which the system can function under. The programs to be uploaded to the Arduino have been streamlined so that variables related to the welding environment can be changed easily.

An ideal welding environment has also been defined. Although the system is able to function in differing conditions (MFDC welder) with minor changes to the program code, most of the testing has been conducted under the following conditions:

2.3.1 Welder Parameters

The following parameters were set on the AC-DN 50 welder to test the Arduino system. Key information includes a welding current of 225, based on a scale of 1-450 used, as well as 12 weld cycles. The Arduino system should be able to function under different weld conditions, but these have not been tested.

Parameter	Number	Setting
Pre-press	1	50
Squeeze	2	25
Preheat current	3	0
Preheat time	4	0
Cooling time	5	0
Slow rising	6	0
Welding current	7	225
Welding time	8	12
Cooling time	9	0
Slow falling	10	0
Temper current	11	0
Temper time	12	0
Hold time	13	25
Off time	14	0

Table 2 - Welding Parameters.

2.3.2 Metal Parameters

Zincanneal strips of 150mmx24mmx1.2mm dimensions were used to test this system. Welds should be conducted at intervals of 15mm at the minimum during the testing procedure, with the strips to be changed if there is no room left on the sample. These numbers have been determined empirically but seem to work well enough. If welds are made too close to one another, incorrect classifications are made due to weld shunting.

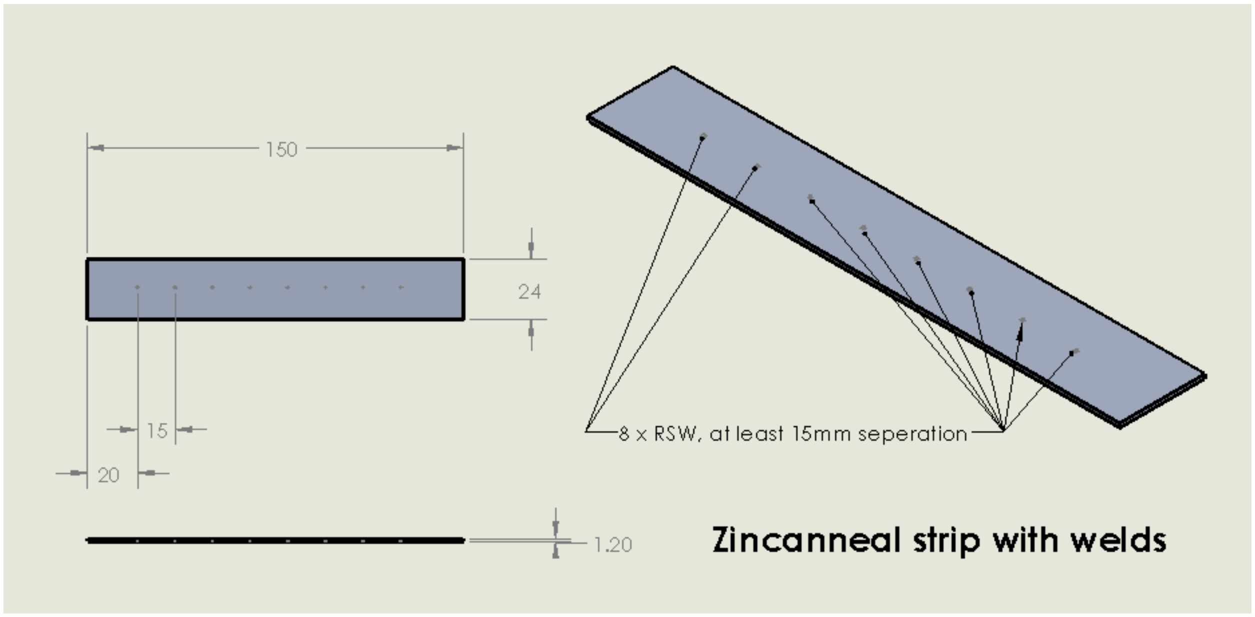

150
24
15
20
1.20
8 x RSW, at least 15mm seperation
Zincanneal strip with welds

Figure 1 - Specifications of Zincanneal Strip with weld spacing.

To simulate a "good" weld, the samples should be placed at an angle perpendicular to the electrodes. To simulate a "bad" weld, the metal sample should be placed at an angle of ±15 degrees with respect to the flat sample. Figure 2 and Figure 3 show the orientations for a misaligned sample and a flat sample respectively.

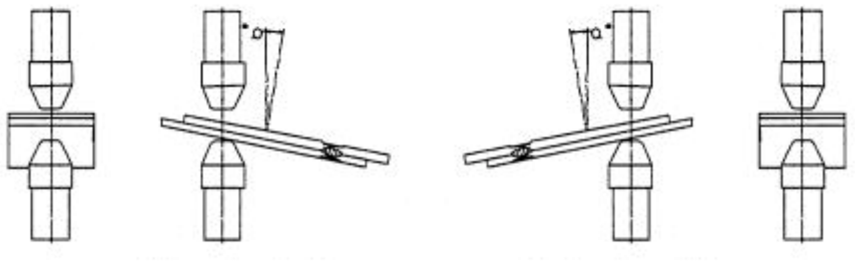


Figure 2 - Misaligned Sample Orientation at +15 degrees (left) and -15 degrees (right). Source: (Li et al., 2000).

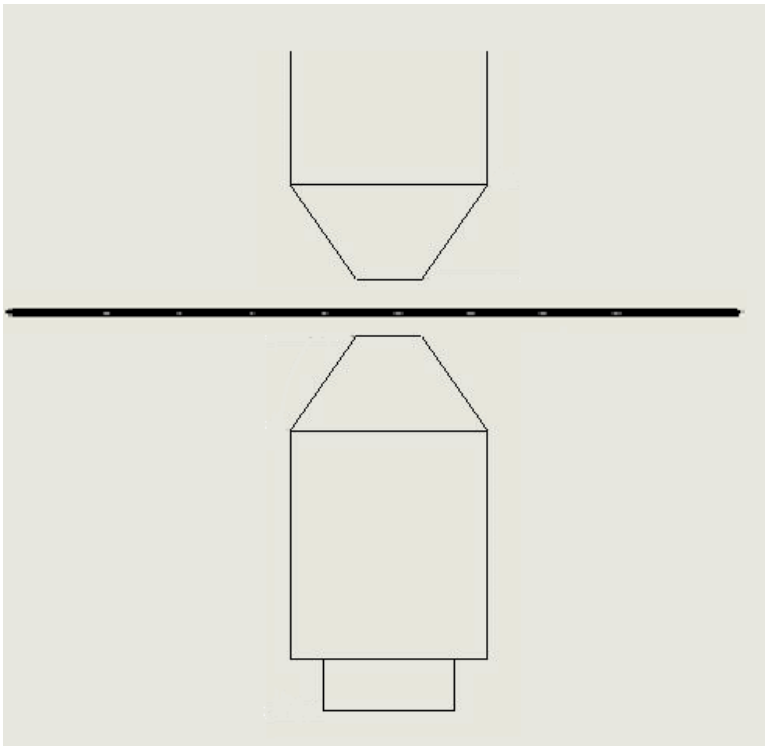


Figure 3 - Flat Sample Orientation.

2.4 Define training the Arduino system / streamline

Defining and streamlining the Arduino system has been fulfilled by creating a Setup process seen on Page 8. Precise instructions to follow have been tested to provide accurate results. A troubleshooting section on Page 20 has also been provided to assist with common errors that might occur.

2.5 Make the Arduino system presentable

This deliverable has only been partially achieved. There were some issues regarding the reliability of the system that caused this deliverable to not be finished. Some planned changes to the presentability of the system, such as a transparent box to view the system, were not able to be installed due to a fear of comprising the overall function of the system. Some efforts have been made to minimise unnecessary wiring and components.

2.6 Works with at least 1 reproducible fault

This deliverable has been met. The system can determine between a flawed and a normal weld if the setup procedure has been followed. Sometimes the system will not make a correct weld classification, but 100% correct classification is not to be expected. If incorrect classification occurs too regularly, this can be fixed by checking the troubleshooting section on Page 20.

2.7 Included Extra Parts

1. Some extra 3 prong LEDs and associated 100ohm resistors.
2. Extra wires.
3. Approx. 2m long lead from the breadboard to the welder ground.
4. 4x 1N5408 capacitors.
5. A box

2.8 Not included

1. SD card reader adapter for computers lacking an SD card slot.

3 Setup

3.1 Glossary

This section contains a glossary of relevant variables that are used in the Arduino Weld Quality Monitoring System.

3.1.1 General terms

3.1.1.1 Trigger

"trigger" refers to the voltage at which the Arduino should start recording a weld as occurring. This point depends on the characteristics of the background noise as well as the weld signal characteristics. The first value recorded of the weld signature will be below this value (see Figure 4 below). Heuristically, when this value is set between 100-250 (490mV-~1250mV), the start of the weld is seen, and the weld signal is captured properly.

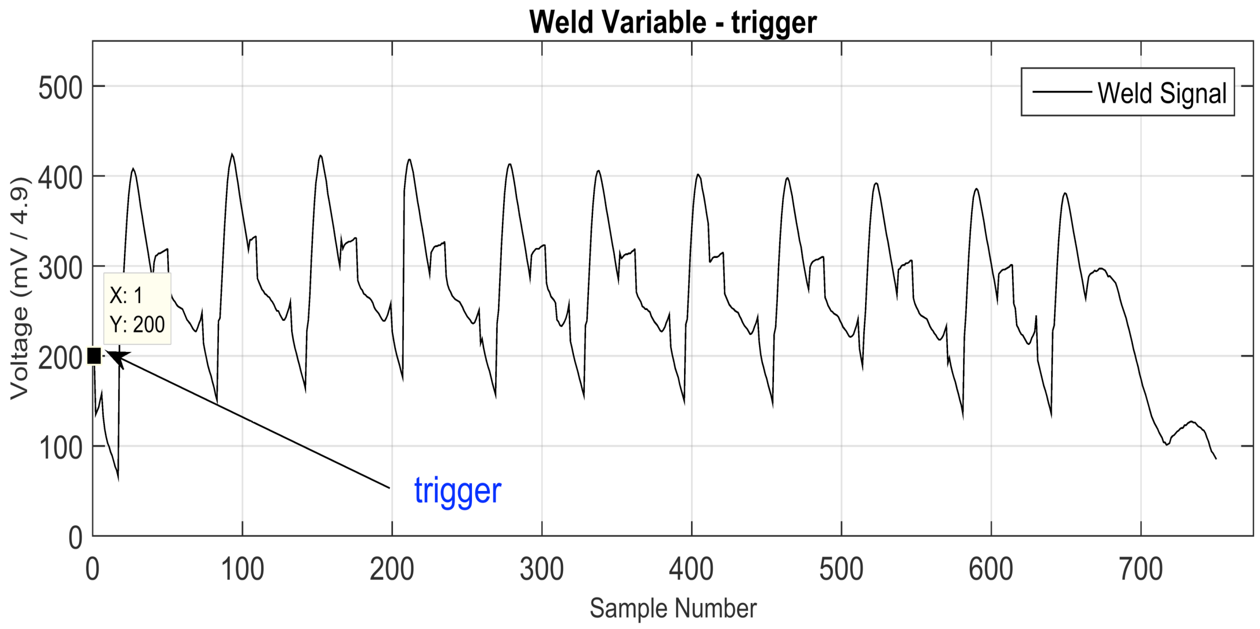


Figure 4 – "trigger" example

3.1.1.2 peaktrigger

“peaktrigger” refers to the voltage value just above the values of the false peaks shown in Figure 5 below. This value is determined from the “threshold” value on the PCA MATLAB program and should work as long as it is above the “false” improperly rectified weld peaks.

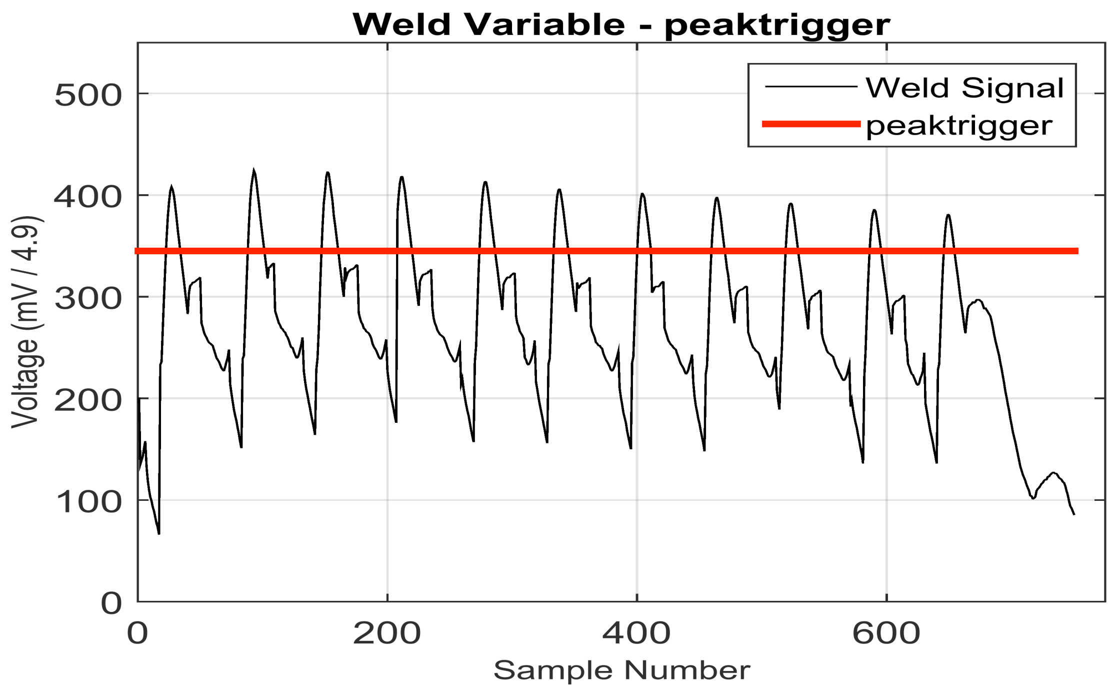


Figure 5 – “peaktrigger” example

3.1.1.3 maxvoltage

“maxvoltage” refers to the maximum voltage indicative of a weld. This value is here to remove the effect of voltage spikes tricking the system into thinking a weld has occurred. As seen in Figure 6 below, this value should be about 150 units (~750mV) above the “good” weld peak values.

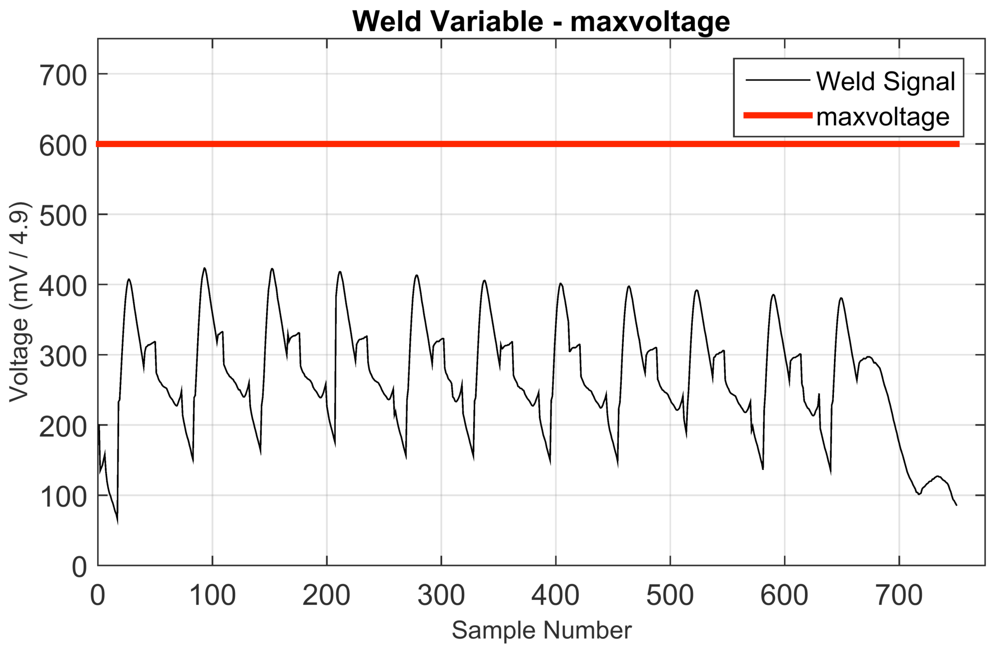
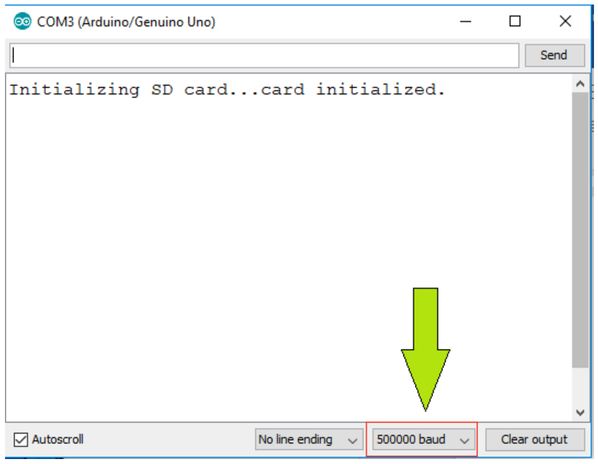


Figure 6 – “maxvoltage” example

3.1.1.4 baudrate

baudrate refers to the rate at which information is sent through the Arduino. When the baudrate is too slow, the data sampling rate of the system is too low and information about the weld is lost. The creator of this system doesn’t really understand how this works. Just keep it at 500000 for training_set_gatherer.ino and weld_classifier.ino. 230400 for ground_tester.ino as 500000 is too fast.



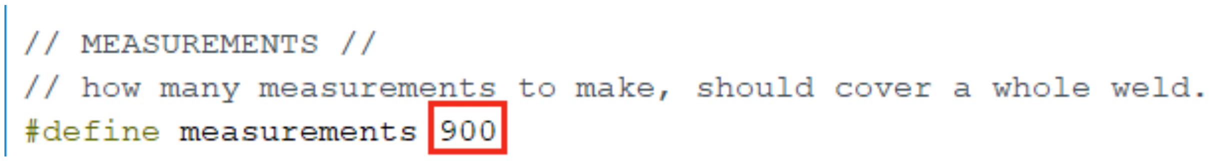
```
Initializing SD card...card initialized.
```

500000 baud

Figure 7 - baudrate location

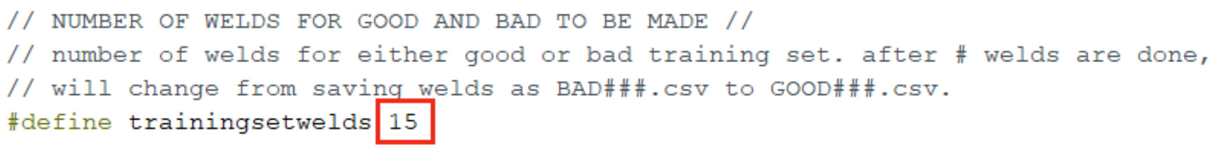
3.1.2 training_set_gatherer.ino

3.1.2.1 measurements



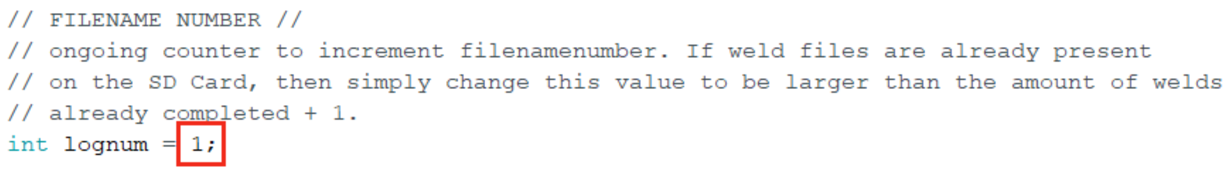
```
// MEASUREMENTS //
// how many measurements to make, should cover a whole weld.
#define measurements 900
```

3.1.2.2 trainingsetwelds



```
// NUMBER OF WELDS FOR GOOD AND BAD TO BE MADE //
// number of welds for either good or bad training set. after # welds are done,
// will change from saving welds as BAD###.csv to GOOD###.csv.
#define trainingsetwelds 15
```

3.1.2.3 lognum

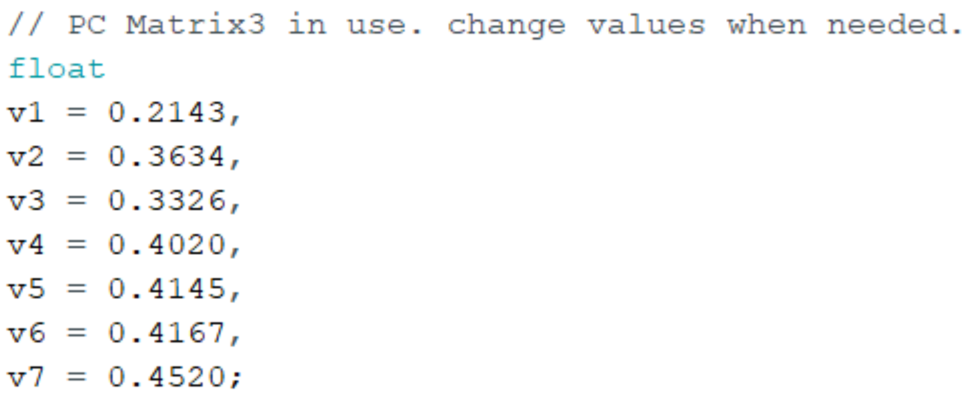


```
// FILENAME NUMBER //
// ongoing counter to increment filenamenumber. If weld files are already present
// on the SD Card, then simply change this value to be larger than the amount of welds
// already completed + 1.
int lognum = 1;
```

3.1.3 weld_classifier.ino

3.1.3.1 v1, v2…

First Principal Component values. Gathered from Principal Component Analysis. Insert new 1st PC values when a new training set has been gathered. Depending on the data provided, should be a 1x7 matrix.



```
// PC Matrix3 in use. change values when needed.
float
v1 = 0.2143,
v2 = 0.3634,
v3 = 0.3326,
v4 = 0.4020,
v5 = 0.4145,
v6 = 0.4167,
v7 = 0.4520;
```

Figure 8 - v1, v2.... location of first PC matrix

3.1.3.2 Av1, Av2…

Mean values of each of the first seven peaks from the training set data. Shown as ‘mean’ curve in Figure 9 below.

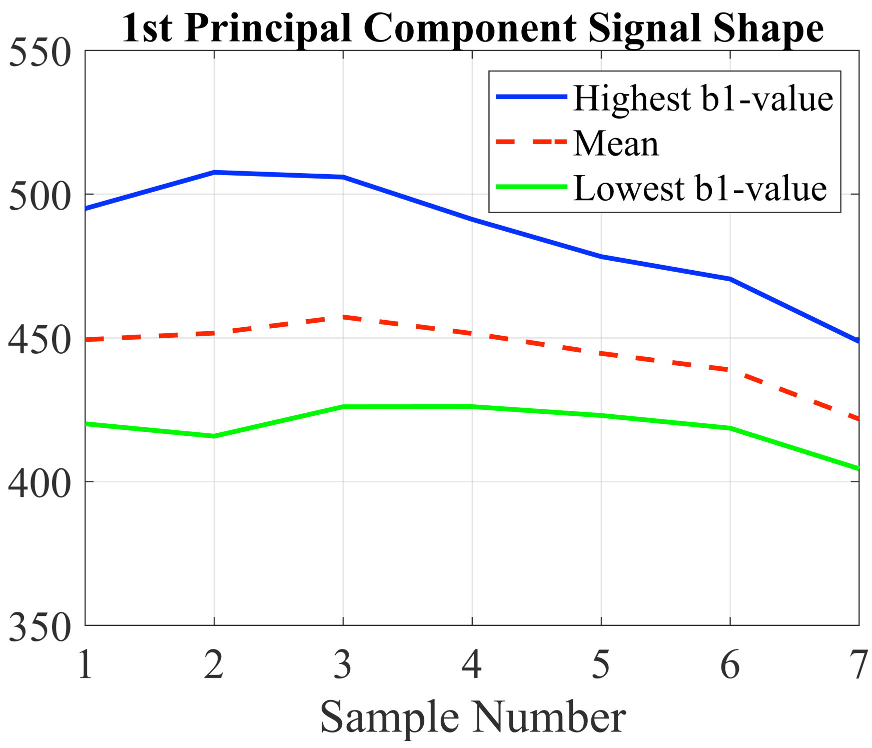


Figure 9 - Av1, Av2 ... data. shown as 'mean' curve. Source: (Summerville, 2018).

3.2 Laptop Setup

(ONLY DO 3.2 LAPTOP SETUP IF THE COMPUTER USED TO UPLOAD FILES TO THE ARDUINO HASN'T BEEN USED WITH THIS SYSTEM BEFORE.)

a. Download and Install Arduino IDE https://www.arduino.cc/en/Main/Software.
b. Connect Arduino to laptop via blue USB cable and check the following.
    i. Tools > Board > Arduino/Genuino Uno.
    ii. Tools > Port > COM# (Arduino/Genuino Uno.).
c. Download and Save (Clone or download -> Download ZIP) Arduino Programs on Laptop Drive from https://github.com/savdogmillionaire/RSW-Arduino-Files-Sava (or wherever else the RSW-Arduino-Files-Sava folder is kept).
    i. training_set_gatherer.ino.
    ii. weld_classifier.ino.
    iii. ground_tester.ino.
d. Extract files from ZIP.
e. Open training_set_gatherer.ino on Arduino IDE.
    i. Sketch > Include Library > Manage Libraries.
    ii. Install CircularBuffer by AgileWare.
    iii. Install SdFat by Bill Greiman.
    iv. Save training_set_gatherer.ino.
    v. Close training_set_gatherer.ino.
f. Open weld_classifier.ino on Arduino IDE.
    i. Sketch > Include Library > Manage Libraries.
    ii. Install CircularBuffer by AgileWare.
    iii. Install SdFat by Bill Greiman.
    iv. Install BasicLinearAlgebra by Tom Stewart.
    v. Save weld_classifier.ino.
    vi. Close weld_classifier.ino.
g. Open ground_test.ino on Arduino IDE.
    i. Sketch > Include Library > Manage Libraries.
    ii. Install CircularBuffer by AgileWare.
    iii. Install SdFat by Bill Greiman.
    iv. Save ground_test.ino.
    v. Close ground_test.ino.
h. Close and reopen Arduino IDE. Check each program is compiling (ctrl+r).

3.3 Train Arduino System

i. Connect Arduino to computer through blue USB lead.
    i. Connect grounding lead to earth at the base of the welder.
    ii. Connect voltage lead from welder into Arduino jack.
    iii. Insert empty FAT32 SD Card into Arduino.
    iv. Check wires are all connected (refer to Figure 10 and Figure 11 below).

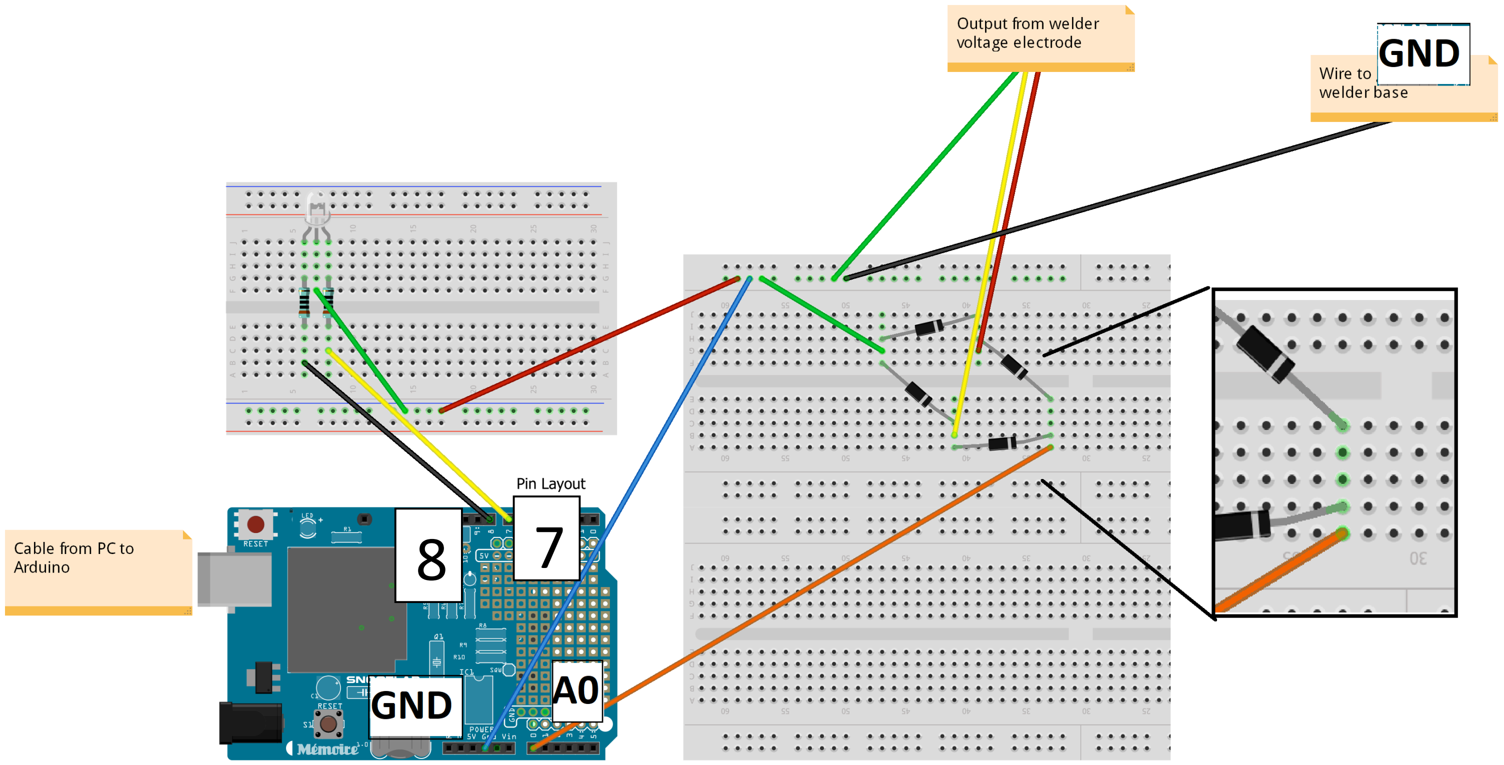


Figure 10 - Arduino Circuit Layout.

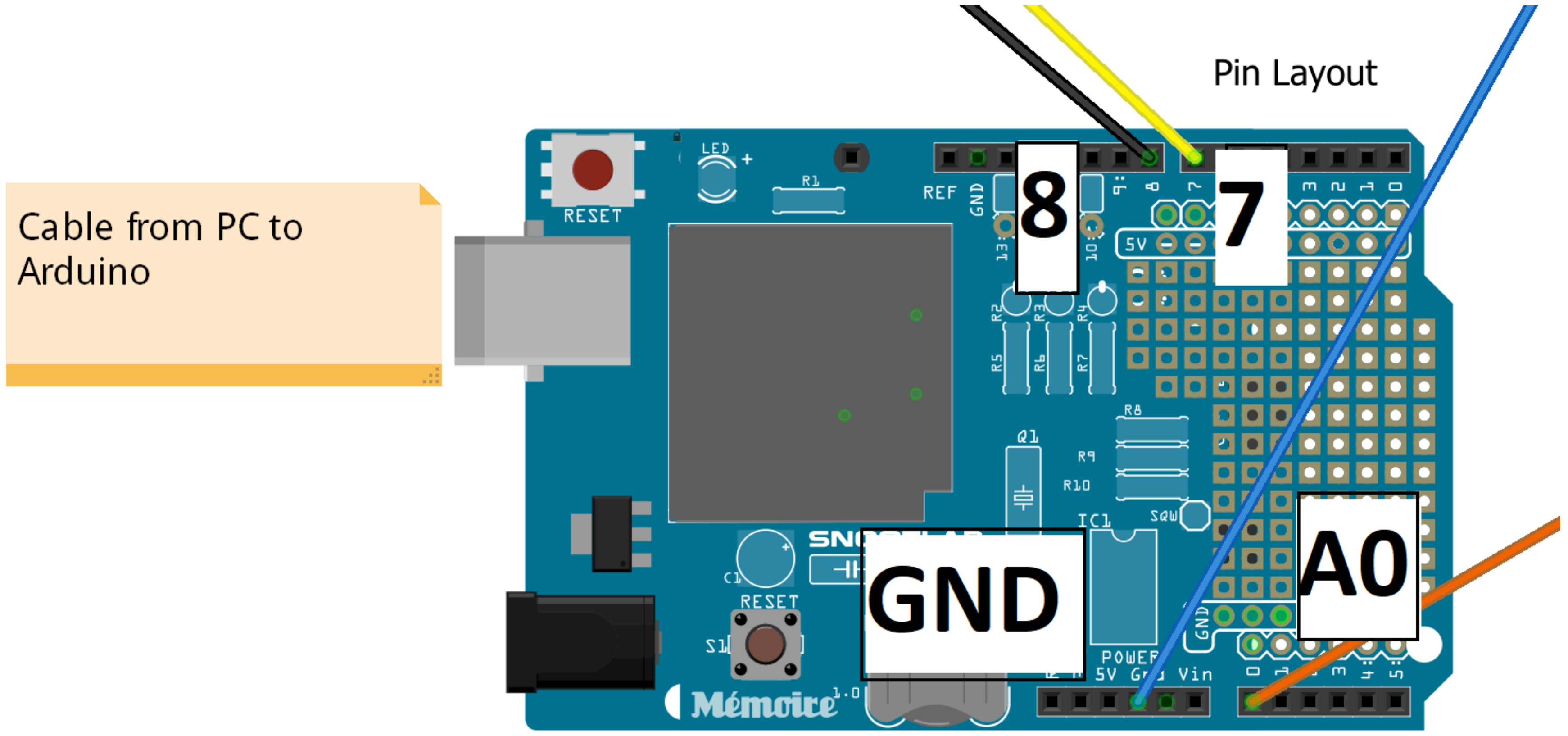


Figure 11 – Closeup of pin connections on Arduino.

j. Open ground_test.ino and Upload to Arduino (ctrl+u).

k. Open Serial Plotter (ctrl+Shift+L) and set baud rate to 230400 in bottom right of window.

l. Inspect incoming signal from welder. Should be the background noise of the system. Visually estimate the peak value of the background noise (see Figure 12 below), and note this value down.

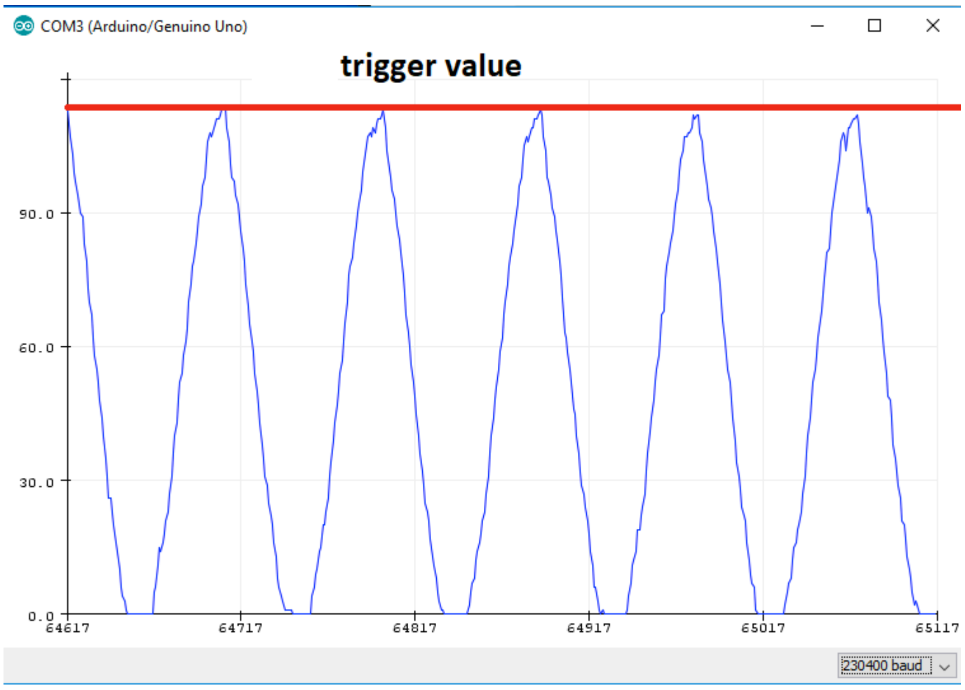
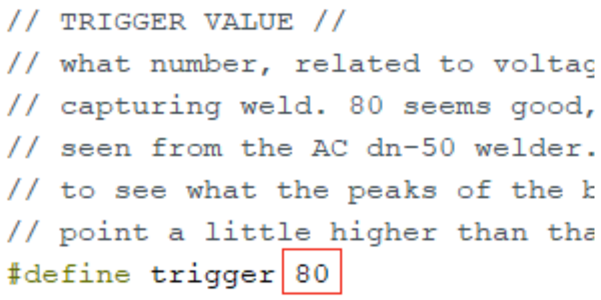


Figure 12 - Example of background noise.

m. Close ground_test.ino.

n. Open training_set_gatherer.ino.

o. Insert visually inspected peak background noise value + 30 under // TRIGGER VALUE // (see Figure 13 below).



```
// TRIGGER VALUE //
// what number, related to voltag
// capturing weld. 80 seems good,
// seen from the AC dn-50 welder.
// to see what the peaks of the b
// point a little higher than tha
#define trigger 80
```

Figure 13 - Trigger Value.

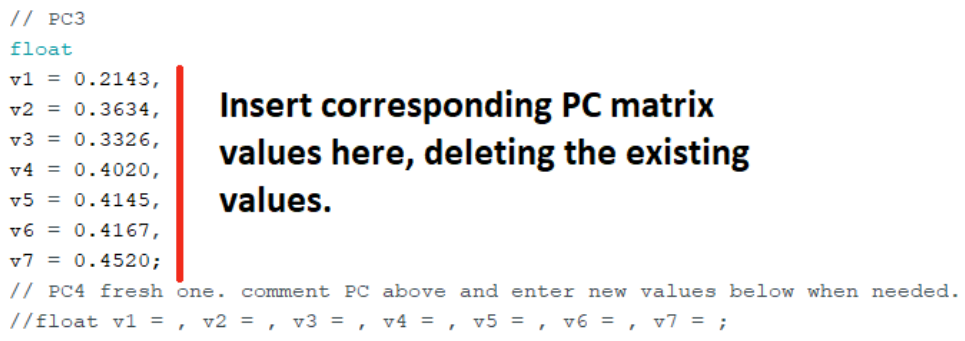
p. Save and upload to Arduino (ctrl + s), (ctrl + u).

q. Open Serial Monitor (Ctrl + Shift + m).
r. Set baud rate to 500000 in bottom right of window.
   i. Dress Electrode tips and conduct 15 Good Welds (repeat steps 1-5 below 15 times).
      1. Place flat sample holder on bottom electrode.
      2. Insert 2x Zincanneal strips.
      3. Conduct weld.
      4. Verify weld has been saved (look at serial monitor for Saved and Weld number).
      5. Prepare Zincanneal strip for next weld by moving at least 15mm along.
   ii. Dress Electrode tips and conduct 15 Bad Welds, alternating between a +15 degree orientation and -15 degree orientation (Figure 2). (repeat steps 1-5 below 15 times).
      1. Place Misaligned sample holder.
      2. Insert 2x Zincanneal strips.
      3. Conduct weld.
      4. Verify weld has been saved (look at serial monitor for Saved and Weld number).
      5. Prepare Zincanneal strip for next weld by moving at least 15mm along strip.
   iii. Close Serial Monitor.
   iv. Remove SD card from Arduino.
   v. Conduct PCA on SD card files to calculate a new PC matrix and average peak values of training set.
   vi. Also need to find the maximum peak voltage value reached, as well as peak threshold for the weld classifier program.

3.4 Test Arduino System

s. Connect and Prepare System.
   i. Connect Arduino to computer through blue USB lead.
   ii. Connect grounding lead to earth, at the base of the welder.
   iii. Connect voltage lead from welder into Arduino jack.
   iv. Insert empty FAT32 SD Card.
   v. Check wires are all in. refer to Figure 10 and Figure 11.

t. Open weld_classifier.ino. **(see 3.1 Glossary for definitions).**
   i. insert new first PC matrix values under // PRINCIPAL COMPONENT MATRICES // - // PC3 (Figure 14).

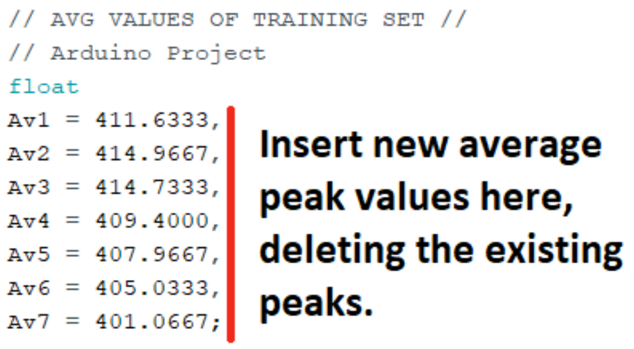


```
// PC3
float
v1 = 0.2143,
v2 = 0.3634,
v3 = 0.3326,
v4 = 0.4020,
v5 = 0.4145,
v6 = 0.4167,
v7 = 0.4520;
// PC4 fresh one. comment PC above and enter new values below when needed.
//float v1 = , v2 = , v3 = , v4 = , v5 = , v6 = , v7 = ;
```

Insert corresponding PC matrix values here, deleting the existing values.

Figure 14 - PC Matrix Values.

   ii. Insert new Average peak values under // AVG VALUES OF TRAINING SET // (Figure 15).

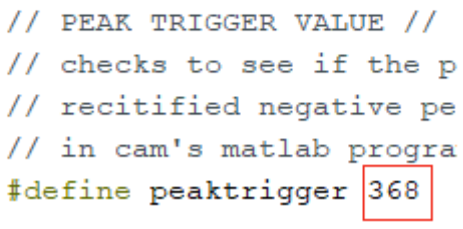


```
// AVG VALUES OF TRAINING SET //
// Arduino Project
float
Av1 = 411.6333,
Av2 = 414.9667,
Av3 = 414.7333,
Av4 = 409.4000,
Av5 = 407.9667,
Av6 = 405.0333,
Av7 = 401.0667;
```

Insert new average peak values here, deleting the existing peaks.

Figure 15 - Average Peak Values.

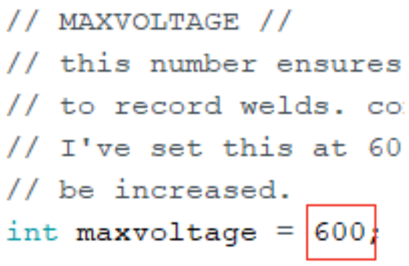
   iii. Insert new peak threshold value under // PEAK TRIGGER VALUE // (Figure 16).



```
// PEAK TRIGGER VALUE //
// checks to see if the p
// recitified negative pe
// in cam's matlab progra
#define peaktrigger 368
```

Figure 16 - Peak Trigger Value.

iv. Insert new maximum voltage value, which should be about 150 units above the maximum weld peaks under // MAXVOLTAGE // (Figure 17).



```
// MAXVOLTAGE //
// this number ensures
// to record welds. co
// I've set this at 60
// be increased.
int maxvoltage = 600;
```

Figure 17 - Max Voltage Value.

u. Save and upload weld_classifier.ino to Arduino (ctrl+U).
v. Open the serial monitor (ctrl+shift+m), check baud rate is set to 500k.
w. Randomly select and place a flat or misaligned sample holder.
x. Insert 2x Zincanneal sheet.
y. Conduct weld.
z. If Flat sample holder is placed and LED is Green
OR
misaligned sample holder is placed, and LED is Red,
then test is considered a success. Can visually inspect the b value produced by looking at serial monitor display.
aa. Repeat however many times.

4 Troubleshooting

1. *I open Serial Monitor or Serial Plotter and gibberish characters appear?*

A. Remember to change baud rate to necessary value. 230400 for ground_tester.ino and 500000 for other programs.

2. *I have attempted to save a weld, but nothing appears on the Serial Monitor?*

A. Sometimes the program has difficulty saving the first weld conducted on a new sample. Check everything is connected properly (see Figure 10). Could also either be a small glitch from the welder or the trigger values aren't being set appropriately.

3. *Weld files are being saved but they appear to be corrupted.*

A. Probably the SD card module has failed after of time. Can attach a new one. (https://www.jaycar.com.au/sd-card-shield-for-arduino/p/XC4552) CAT NO, XC4552.

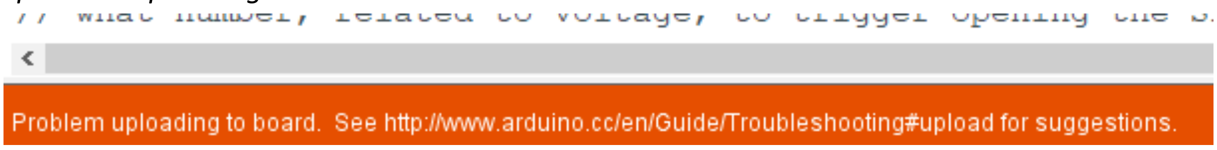
4. *Welder cannot classify weld correctly an appropriate amount of the time.*

A. This is a tough one. First thing to do is to ensure that the all the conditions from when the training set was collected are identical to the conditions when testing the weld.

Inspect the peak values shown on the serial monitor screen. If they seem to be too low or too high from the values collected in the training set, then something about the welding conditions may have changed.

If the system doesn't classify a weld when it has occurred, then more than likely the system isn't being triggered to collect peak data (peak trigger value too high) OR the peak trigger value is too low and captures false peaks within the data.

5. *"problem uploading to board."*



```
// what number, related to voltage, to trigger opening the S
```

Problem uploading to board. See http://www.arduino.cc/en/Guide/Troubleshooting#upload for suggestions.

A. Most often I would get this problem because I didn't have the correct board or port selected. To fix this, check:

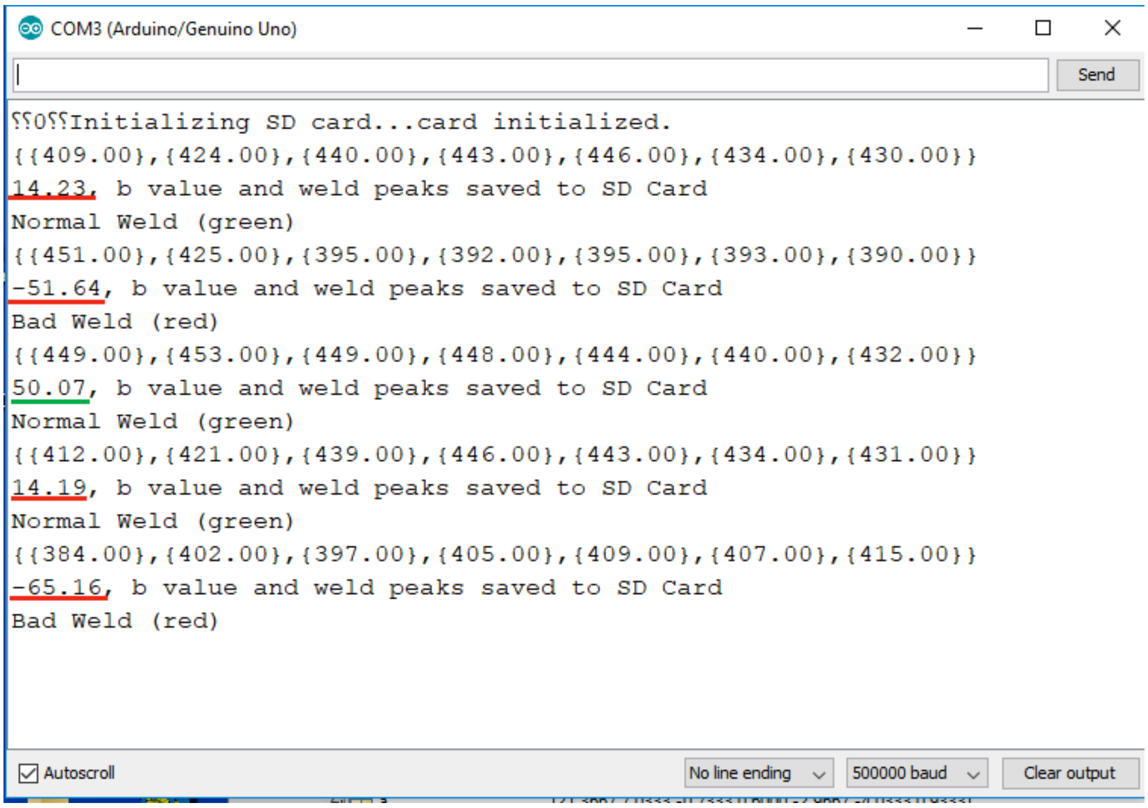
i. Tools > Board > Arduino/Genuino Uno.

ii.Tools > Port > COM# (Arduino/Genuino Uno.).

Sometimes I would get this problem because I inserted the Arduino cable into the faulty USB port on my laptop. Just put the cable into another USB port.

Another problem is that the lead to the "GND" pin on the Arduino may be accidentally inserted into the "VIN" pin next to it. Make sure the blue lead in Figure 11 goes from the ground on the breadboard to the "GND" pin on Arduino. '

6. *The b value calculated from a "bad weld" is less than a "good weld" but it is still positive?*
   An example of this occurring:



```
؟؟0؟؟Initializing SD card...card initialized.
{{409.00},{424.00},{440.00},{443.00},{446.00},{434.00},{430.00}}
14.23, b value and weld peaks saved to SD Card
Normal Weld (green)
{{451.00},{425.00},{395.00},{392.00},{395.00},{393.00},{390.00}}
-51.64, b value and weld peaks saved to SD Card
Bad Weld (red)
{{449.00},{453.00},{449.00},{448.00},{444.00},{440.00},{432.00}}
50.07, b value and weld peaks saved to SD Card
Normal Weld (green)
{{412.00},{421.00},{439.00},{446.00},{443.00},{434.00},{431.00}}
14.19, b value and weld peaks saved to SD Card
Normal Weld (green)
{{384.00},{402.00},{397.00},{405.00},{409.00},{407.00},{415.00}}
-65.16, b value and weld peaks saved to SD Card
Bad Weld (red)
```

Figure 18 - some example welds

There are five welds shown in Figure 18. The first two welds are misaligned, the third weld is flat, and the last two are misaligned. Two of the misaligned samples are positive, but lower than the "good" weld. What's happening here is the sample for welds 1 and 4 are misaligned 15 degrees with respect to the flat sample, but 30 degrees with respect to the configuration shown in Figure 2. The reason for this discrepancy is that I believe the training set was taken with a misaligned weld measurement only taken at -15 degrees with respect to the flat sample, and not +15 degrees with respect to the flat sample.

Another big cause for incorrect classifications from high b values is that the electrode tips are clean. Once the electrode wears a bit, the b values tend to decrease to normal.

You can also try commenting the currently used 1st PC matrix and avg. values, and uncomment the other ones. The currently commented 1st PC matrix and avg. values tend to provide slightly higher b values in my experience.

7. *What are these MATLAB files for?*

A. These MATLAB files are predominantly what I used for my own troubleshooting. I would save a weld to the SD card using the Arduino and then inspect the files using the MATLAB programs. I haven't been able to comment them at all but if you are familiar with MATLAB, you should be able to use these if you require. Pc1tester checks what b value is being calculated from a set of saved welds. Peakfunctest tests the peak finding function I have created on the Arduino to the inbuilt MATLAB one. Sdcardplotter displays collected weld signals from the training set.

8. *When collecting welds for the training set, why are files created that do not contain a weld?*

A. This happens sometimes when the training set collector is triggered for unknown reasons. Usually this would happen when working with the small AC welder, and not the automated MFDC welder. I believe this has to do with electrical interference tricking the system into believing a weld has occurred. To fix this, ensure that there are as few objects possible in the vicinity of the weld location. It would also help to test parts of the system separately to check that everything is working as expected.

5 Further Work

The code used to collect training sets may need some refinement. It appears to trigger sometimes even though welds have not occurred. I would look at making the code able to ignore voltage spikes due to background noise. System seems to work quite well in the more controlled environment found at the MFDC welder.

Further work is probably required on the overall presentability of the system. Difficult to achieve during the limited time in the project without causing delays due to altering the way the system is able to collect data.

6 References

LI, W., CHENG, S., HU, S. J. & SHRIVER, J. 2000. Statistical Investigation on Resistance Spot Welding Quality Using a Two-State, Sliding-Level Experiment. *Journal of Manufacturing Science and Engineering,* 123**,** 513-520.

LING, S.-F., WAN, L.-X., WONG, Y.-R. & LI, D.-N. 2010. Input electrical impedance as quality monitoring signature for characterizing resistance spot welding. *NDT & E International,* 43**,** 200-205.