

Increasing Efficiency in the GRACE Line at CERN's Antimatter Factory using Arduino Interface

Robby Finan

AEgIS

- Weak Equivalence Principle – does it apply to antimatter?
- AEgIS' ultimate goal is measuring the acceleration due to gravity on antimatter.
 - Is it 9.8 m/s^2 ?
- Anti-hydrogen enters the AD and its vertical deflection is used to measure its a_g

GRACE.. AEgIS.. What's the difference?

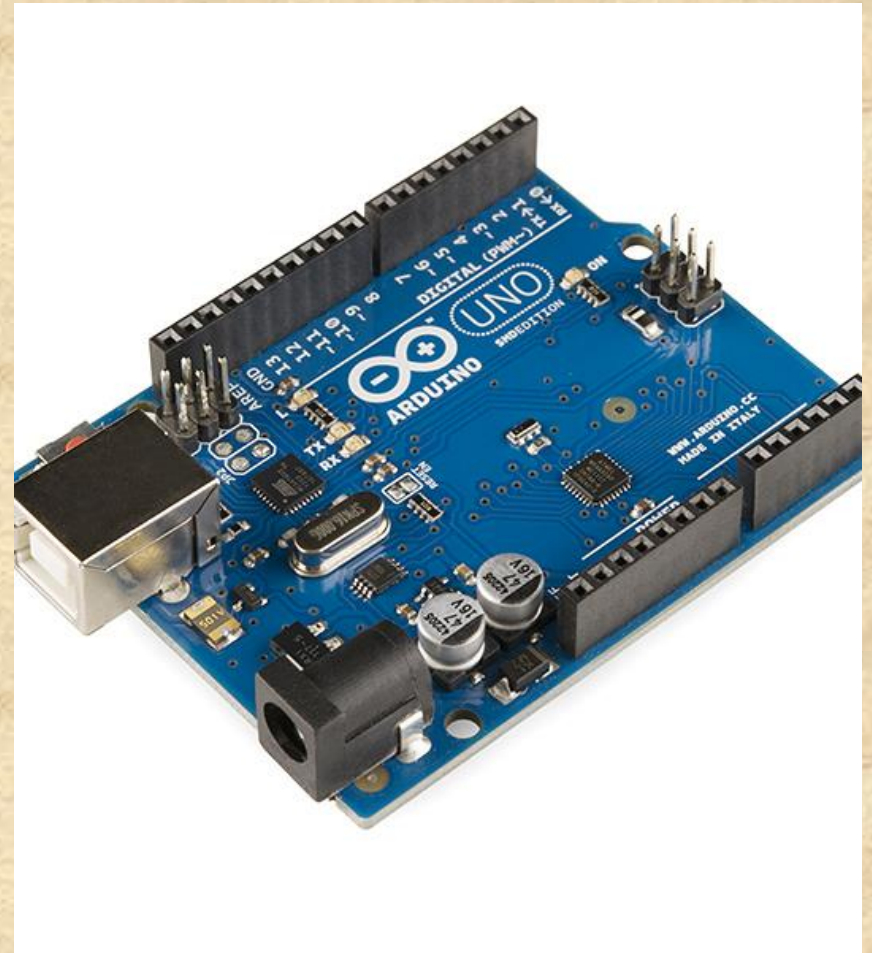
- GRACE: separate beam line symbiotic to AEgIS
- General purpose beam line to do whatever future anti-proton experiments may need
- Currently: producing low energy anti protons to learn about antimatter annihilations in detectors
 - Detectors could be used in AEgIS in the future
 - Annihilations = background noise of detector

Problem

- Efficiency: AD delivers bunches of 3×10^7 particles at 5.3 MeV at a time.. 10's of particles mark it to the detector.
- Trajectories of low energy (<1 KeV) anti-protons are effected by stray magnetic fields.
- Measuring and removing stray magnetic fields in the beam line could dramatically increase the efficiency.
- Here's where I come in...

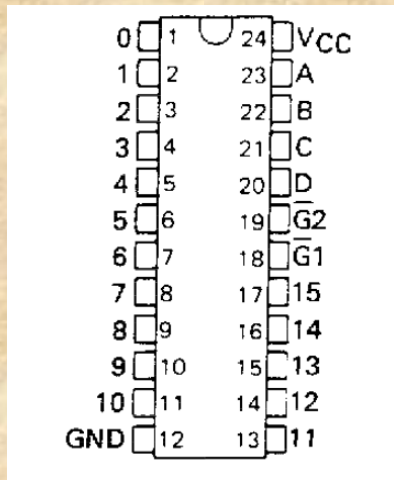
Arduino

- Microcontroller using the SPI interface.
- Master/Slave setup
- Master = Arduino
- Slave = Magnetometer



Arduino/Demultiplexer Combo

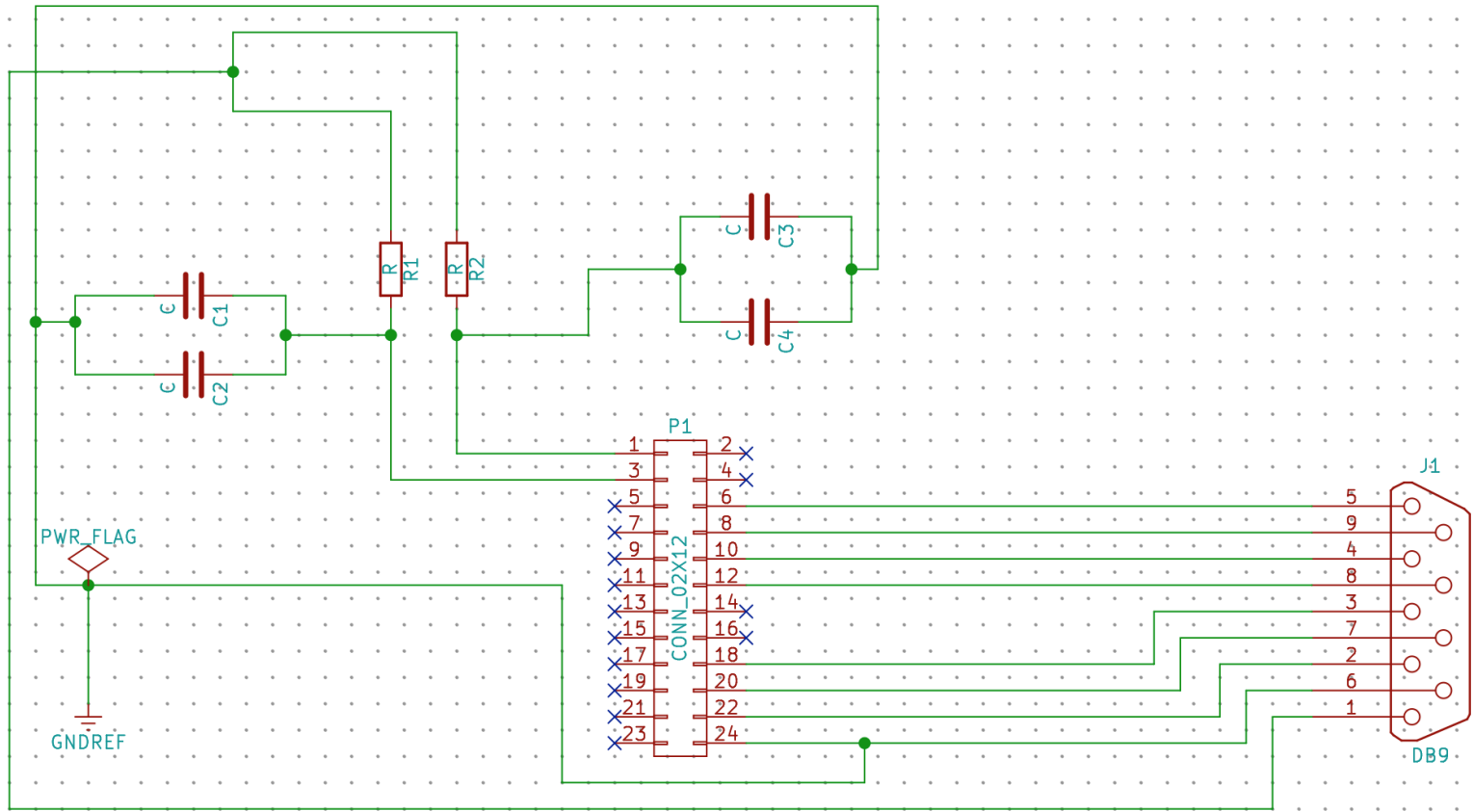
- Using a 4 to 16 line demultiplexer, 4 slave lines on one Arduino can be used to control 6 slaves (magnetometers)!

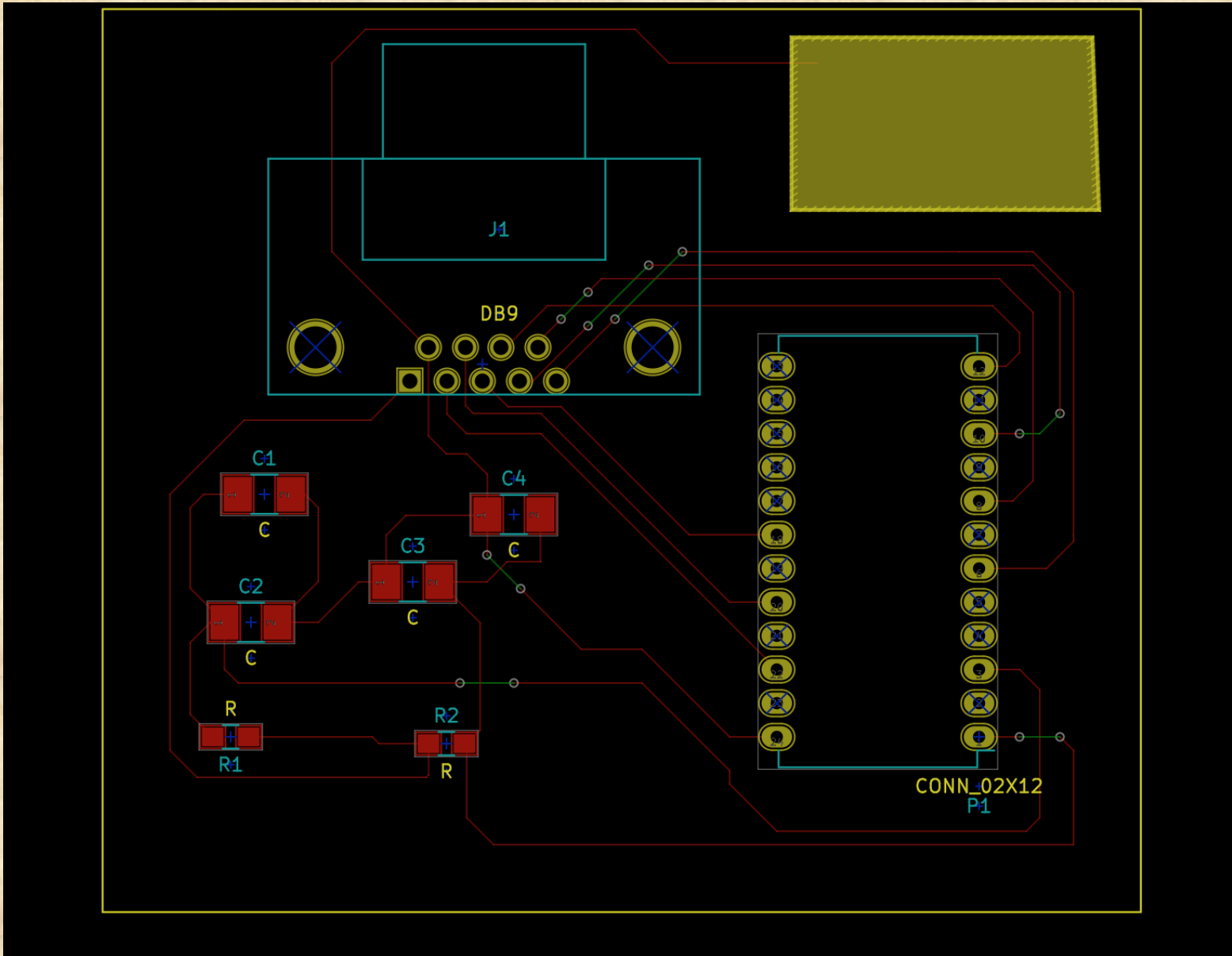


FUNCTION TABLE

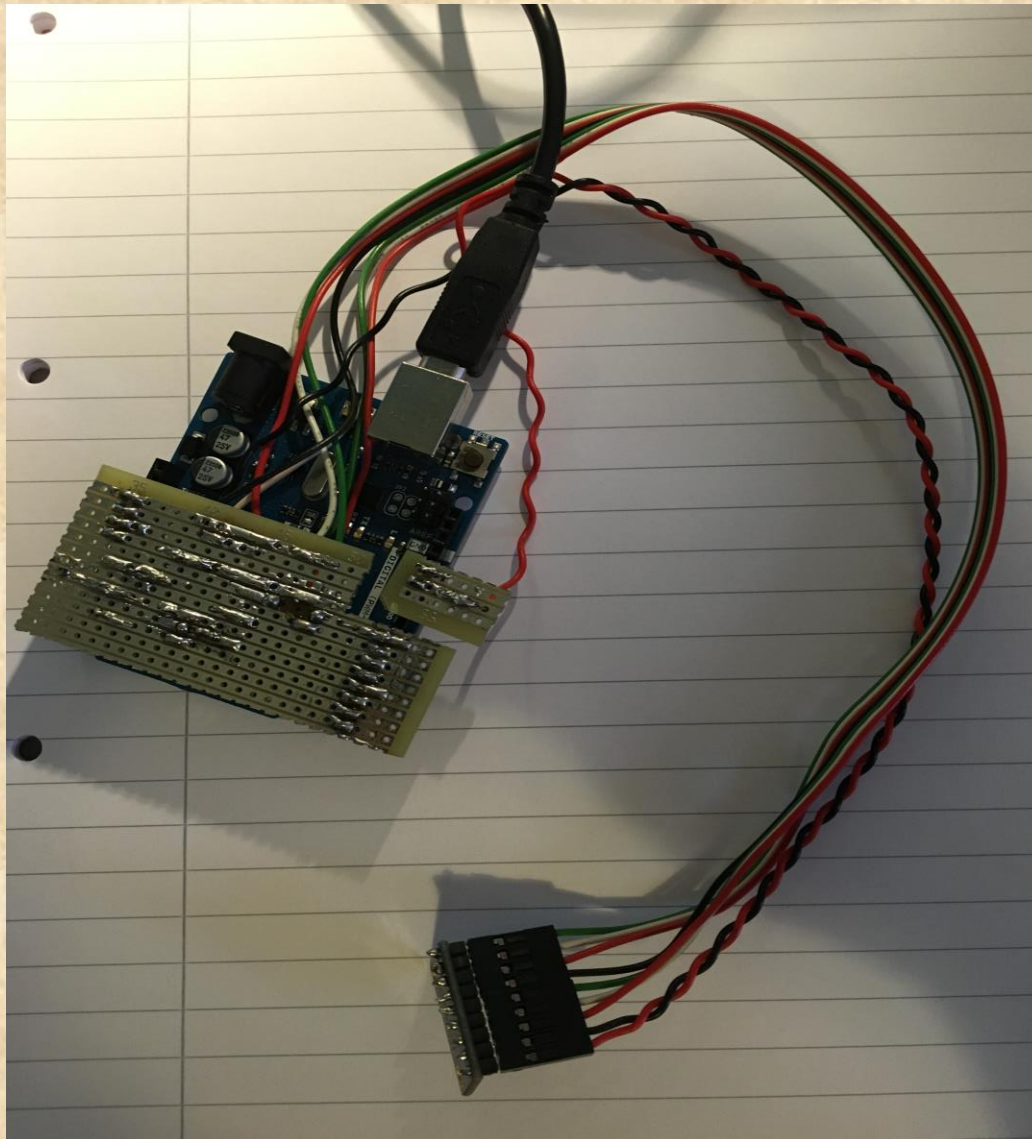
INPUTS		OUTPUTS																				
G ₁	G ₂	D	C	B	A	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	H	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	H	L	L	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	H	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H
L	L	L	H	H	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H
L	L	L	H	H	H	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H
L	L	L	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H
L	L	H	L	L	L	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H
L	L	H	L	H	L	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H
L	L	H	L	H	H	L	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H
L	L	H	H	L	L	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H
L	L	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H
L	L	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H
L	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
H	L	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
H	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

H = high level, L = low level, X = irrelevant

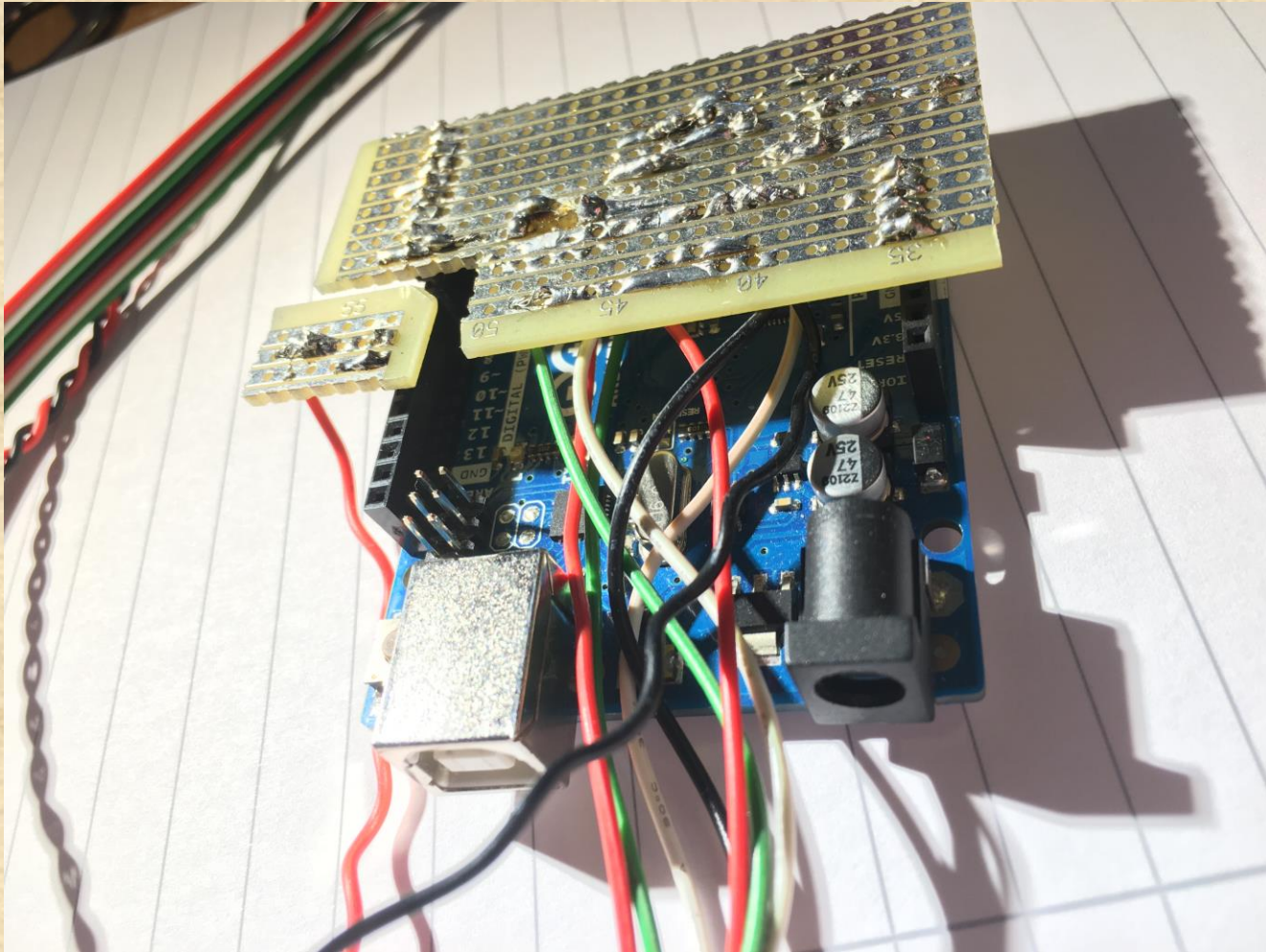




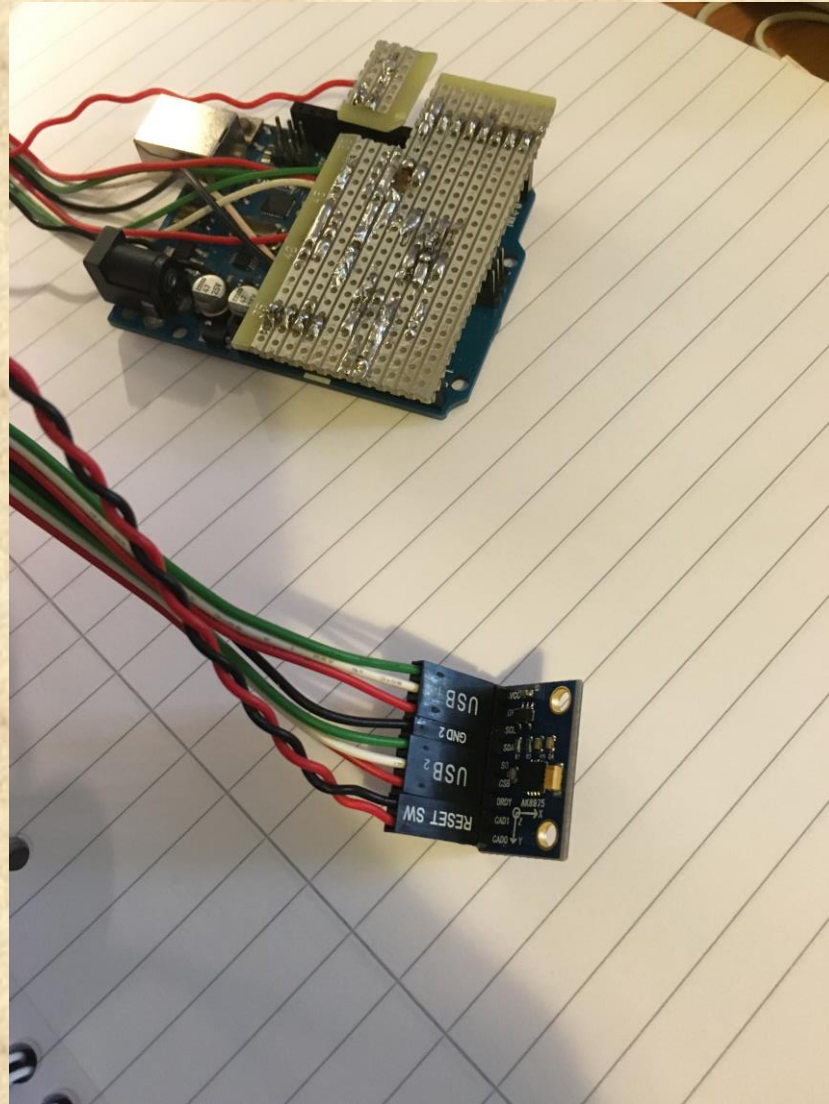
My Current Setup



My Current Setup



My Current Setup



```
Magnetometer_WriteInSetup | Ar  
Magnetometer_WriteInSetup  
int S0 = 5;  
int CAD1 = 2;  
int CAD0 = 11;  
int CSB = 4;  
int DRDY = 3;  
  
void myDelay(int Iterations){  
  for(int i=1; i<Iterations; i++);  
}  
void setup() {  
  
  Serial.begin(9600);  
  
  while (!Serial) {}  
  
  pinMode(SI, OUTPUT);  
  pinMode(CLK, OUTPUT);  
  pinMode(CAD1, OUTPUT);  
  pinMode(CAD0, OUTPUT);  
  pinMode(CSB, OUTPUT);  
  
  digitalWrite(CAD1,LOW); // sets CAD1 to ground, requirement for SPI interface  
  digitalWrite(CAD0,LOW); // sets CAD0 to ground, requirement for SPI interface  
  
  digitalWrite(CSB,HIGH);  
  delay(1);  
  digitalWrite(CLK,HIGH); // sets the clock to low  
  delay(1);  
  digitalWrite(CSB,LOW); // activates slave select line to alert magnetometer  
  
}
```

```
/dev/cu.usbmodem1421 (Arduino/Genuino Uno)  
Magnetic Flux Density X axis (binary): 111111111110101  
Magnetic Flux Density Y axis (binary): 0001111100011111  
Magnetic Flux Density Z axis (binary): 00110111100110111  
  
Autoscroll  
Newline 9600 baud
```

Done uploading.
Sketch uses 6,294 bytes (19%) of program storage space. Maximum is 32,256 bytes.
Memory, leaving 1,576 bytes for local variables. Maximum is 2,048 bytes.

Update available for some of your [boards](#) and [libraries](#)

Desktop environment showing files: IMG_3602.JPG, IMG_3599.JPG, IMG_3603.JPG, IMG_3601.JPG, Arduino_Uno_R3.jpg, seconds compli...e ideas, IMG_3604.JPG, Screen Shot 2016-0...1.21 AM, Screen Shot 2016-0...0.37 AM, Screen Shot 2016-0...1.26 PM, HSTD10_Pacific o.pdf, cern presentation

Moving Forward

- Make binary readings in units of Tesla
- Combine system with the Demultiplexer
- Measure the GRACE line B field
- Build electromagnetic coils to cancel out the B field
- Increased efficiency!