ECEN 3730-5730-001 **Practical PCB Design Manufacture** **Fall 2023**

Board3 Report

Rajesh Srirangam

Objective

The objective of this lab is to create a board which is Golden Arduino board which has less switching and noise than the commercial Arduino uno.

Plan of Record

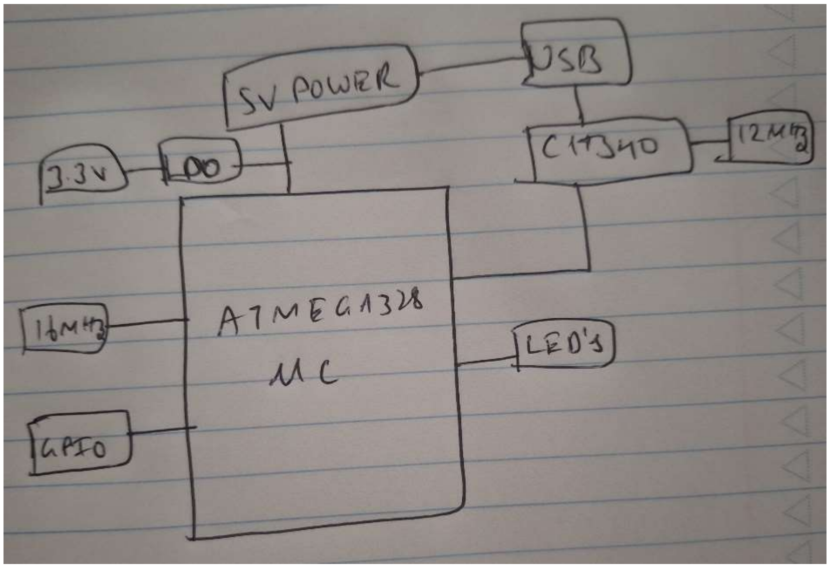
In the POR we will articulate what the purpose of your board is, what it means to "work" and any special features you expect to implement.
In the POR, we will sketch out the board design and the risk reduction steps.
We will demonstrate the following features:
Boot load your Atmega 328 to turn it into an Arduino
Run the Arduino IDE on your board and any standard sketch
You must use the same header pin footprint for the pins so any shield will fit on your board
Using a special switching noise shield we will give you, you will measure the noise on a commercial board and on your board under identical conditions. Your noise should be 20% to 50% of the noise on the commercial board.
You will measure the near field emissions from your board, compared to an identical commercial version and find your near field emissions are << 10% that of the commercial Arduino board.
As a stretch goal, add test points to the digital buses and sniff the digital signals with a scope. For example, add a test point to the D+ and to the D- lines and to the TX and RX of the UART. This way, you will be able to see the actual bus traffic on these lines.

Some of the features we will use in your design are:

1. An Atmega 328 microcontroller
2. A CH340g USB to UART interface chip
3. A 16 MHz resonator for generating a clock. A 12 MHz resonator for the CH340g.
4. Appropriate decoupling capacitors
5. A connector for the SPI and boot loading pins
6. A TVS chip to protect the data pins from ESD
7. Power from the power plug or the USB connector, but not at the same time
8. A reset switch
9. A 3.3 V LDO, not used by a component on the board, but available on one of the header pins.
10. Header sockets that match the location of the standard Arduino board so that you can plug a shield into your Uno board.
11. Maximum board size 3.9 inches x 3.9 inches
12. Add a second row of header pins 300 mils center to center spaced on the outside of your digital I/O pins all connected to the ground plane. These will be used to demonstrate the lower switching noise when
connections are made off your board.
13. Add a 22 uF decoupling capacitor close to the header pin locations on your board for the 5 V and 3.3 V rails. This will decouple connections from your golden Arduino board to any shields you will add.
14. Consider adding an isolation switch in the power path to your CH340g. (NOT between the VCC pin and decoupling capacitor!). This way you can turn the CH340g off and isolate it if you need to, in the debug process. Consider doing the same for your 328 uC.

Risk Identification
To facilitate easy access, verification, and testing of components, switches, and test points on the PCB, the following naming conventions will be employed:
1. Component Naming: Each component, including Surface Mount Technology (SMT) and Through-Hole (TH) components, will be labeled with clear and distinct reference designators. These designators will ensure efficient tracking for testing and verification purposes.
2. Switch Labeling: Switches will be clearly labeled to indicate their function and purpose within the circuit. This labeling simplifies circuit isolation for testing and debugging and swift identification of the section being tested.
3. Test Point Identification: Test points will be strategically placed within the circuit and labeled appropriately to mark specific measurement locations. These labels will ensure that measurements can be taken at the desired points, streamlining the debugging process.
Best Design Practices
1. Trace Thickness: Use power traces with a thickness of 20 mils to support the required current flow without significant voltage drops. Employ thinner 6 mil traces for low-current signal lines to enhance overall PCB performance and reliability.
2. Component Integration: Include indicator LEDs, test points, and isolation switches in the circuit diagram. This simplifies troubleshooting and maintenance, enabling quick identification of specific points
for evaluation or isolation during diagnostics.
3. Minimize Cross-Under Connections: Reduce the use of cross-under connections and, when necessary, keep them as short as possible. This minimization mitigates signal interference and crosstalk, preserving signal integrity and reducing the risk of electrical noise.
4.Decoupling Capacitor Placement: When you position decoupling capacitors close to the integrated circuits (ICs), it helps in reducing electrical noise .
5.Limiting Cross-Under: Using a smaller number of cross-under, and ensuring they are short, helps in decreasing interference and noise in the circuit.
6)Adding LDO: Employing a filter capacitor at the output of the Low Dropout Regulator (LDO) aids in reducing fluctuations in the voltage output, enhancing stability.
Expectations for what it means to "work"
To confirm the operational status of the PCB, we must verify that it functions as intended and aligns with its design specifications:
1)Power Source: The board can be powered through a USB connection or a 5V power supply we have given a switch to alter the power between USB and 5V Power Supply
Indicator LED: By giving supply LED will glow which indicates that both 5V and 3.3V circuit is working
2)Voltage Regulation: The voltage regulator used for stepping down voltage from 5V to 3.3V.
Inrush Current Measurement: Calculate the inrush current using a 10x scope.
3)LDO Stability: Low Dropout Regulator (LDO) output should give us constant 3.3V or else it leads to instability.
4)Reduced Emissions: Reduce Noise in Near Field Emissions.
5)Indicators and Switches: Use of LEDs and switches will ease the process of debugging
6)ATmega328 Reset: Reset signal should be observed when we are triggering the reset signal
7)Boot loading via ISP: Boot loading via ISP with SPI Protocol should function as it is the main source for boot loading the Arduino Board.

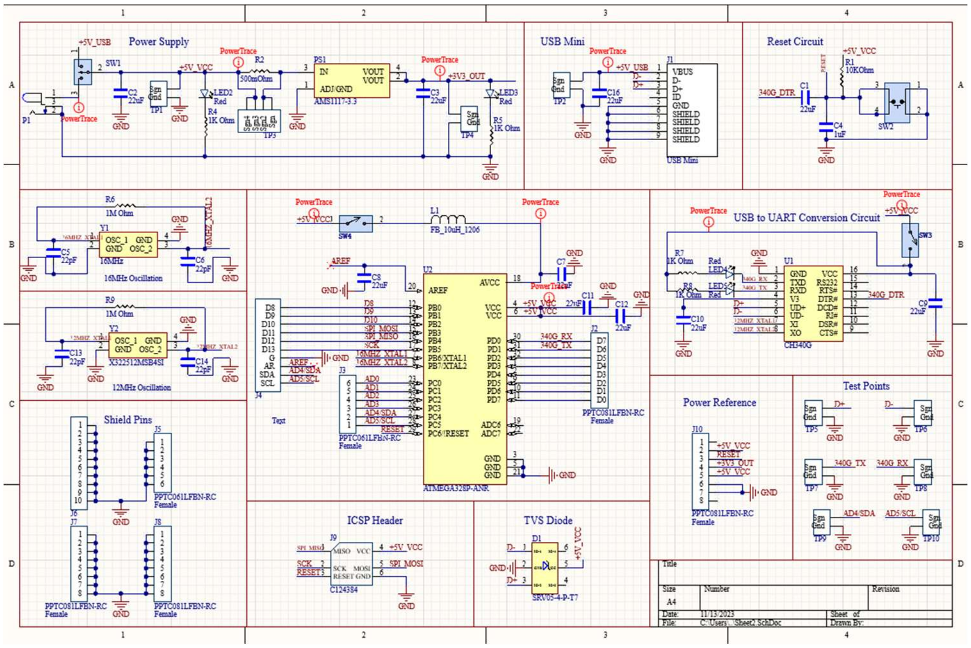
Circuit Sketch



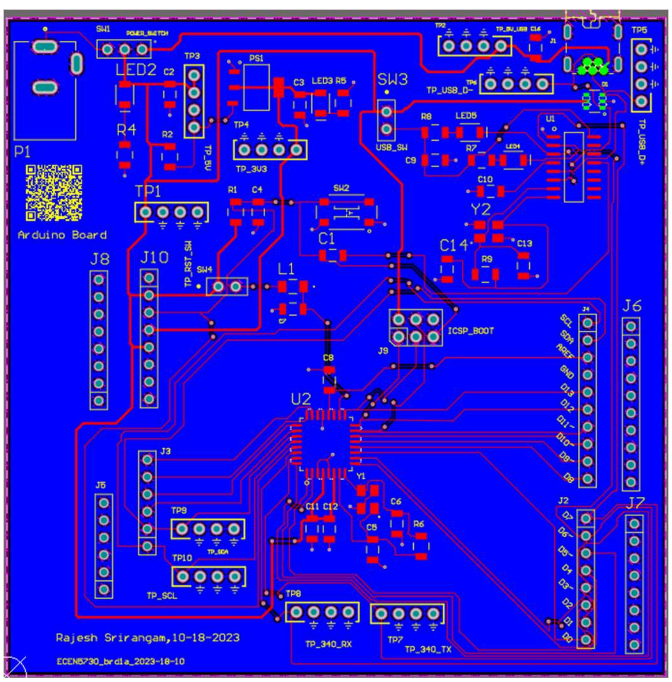
BOM

A	B	C	D	E	F	G
Comment	Description	Designator	Footprint	LibRef	Quantity	LCSC Part#
22uF	22uF ±10% 25V X5R 120	C1	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C2	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C3	1206_Passive_Capacito	C_22uF_1206	1	C12891
1uF	MULTILAYER CERAMIC	C4	1206_Passive_Capacito	C_1uF_1206	1	C1848
22pF	22pF ±5% 1kV C0G 1206	C5	1206_Passive_Capacito	C_22pF_1206	1	C107174
22pF	22pF ±5% 1kV C0G 1206	C6	1206_Passive_Capacito	C_22pF_1206	1	C107174
22uF	22uF ±10% 25V X5R 120	C7	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C8	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C9	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C10	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C11	1206_Passive_Capacito	C_22uF_1206	1	C12891
22uF	22uF ±10% 25V X5R 120	C12	1206_Passive_Capacito	C_22uF_1206	1	C12891
22pF	22pF ±5% 1kV C0G 1206	C13	1206_Passive_Capacito	C_22pF_1206	1	C107174
22pF	22pF ±5% 1kV C0G 1206	C14	1206_Passive_Capacito	C_22pF_1206	1	C107174
22uF	22uF ±10% 25V X5R 120	C16	1206_Passive_Capacito	C_22uF_1206	1	C12891
SRV05-4-P-T7	TVS SOT-23-6 ROHS	D1	TVS	D_TVS_Diode	1	C85364
USB Mini	Through Hole USB Conn	J1	USB_MINI_B	J_USB_B_Mini	1	C46398
PPTC081LFBN-RC	8 Position Header Conn	J2	8_PIN_ARD-DIG_100MI	JF_8_PIN_FEMA_ARD-D	1	C27438
PPTC061LFBN-RC	6 Position Header Conn	J3	6_PIN_100MIL -Female	JF_6_PIN_FEMALE	1	C40877
PPTC101LFBN-RC	10 Position Header Con	J4	10_PIN_ARDUINO_100	JF_10_PIN_FEMA_ARDU	1	C225507
PPTC061LFBN-RC	6 Position Header Conn	J5	6_PIN_100MIL -Female	JF_6_PIN_FEMALE	1	C40877
PPTC101LFBN-RC	10 Position Header Con	J6	10_PIN_100MIL - Fema	JF_10_PIN_FEMALE_	1	C225507
PPTC081LFBN-RC	8 Position Header Conn	J7	8_PIN_100MIL - Female	JF_8_PIN_FEMALE	1	C27438
PPTC081LFBN-RC	8 Position Header Conn	J8	8_PIN_100MIL - Female	JF_8_PIN_FEMALE	1	C27438
NRPN032PAEN-RC	Connector Header Thro	J9	ICSP	J_ICSP	1	C124384
PPTC081LFBN-RC	8 Position Header Conn	J10	8_PIN_100MIL - Female	JF_8_PIN_FEMALE	1	C27438
FB_10uH_1206	25mA 10uH ±10% 800m	L1	AIML-1206_ABR-M	FB_10uH_1206	1	C1051
Red	Red 621~631nm 1206 Li	LED2	LED_1206	LED_RED_1206	1	C93133

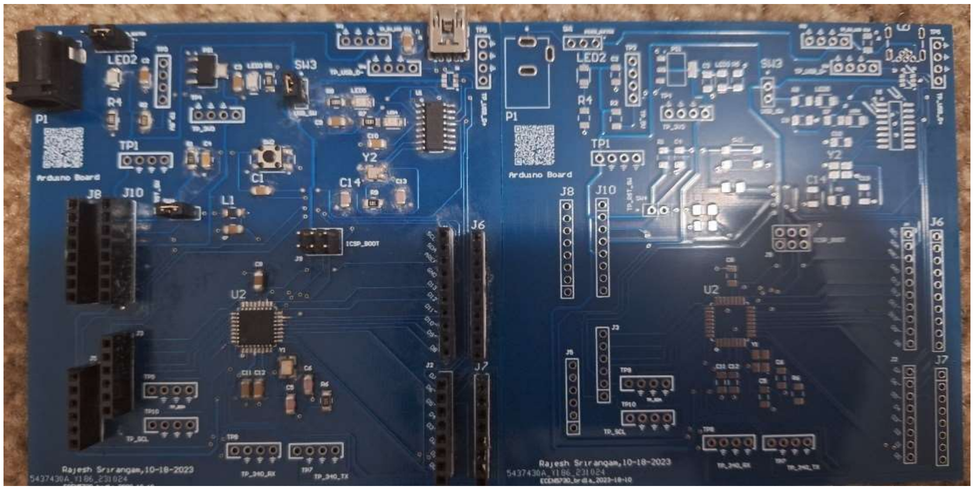
Schematic



Layout



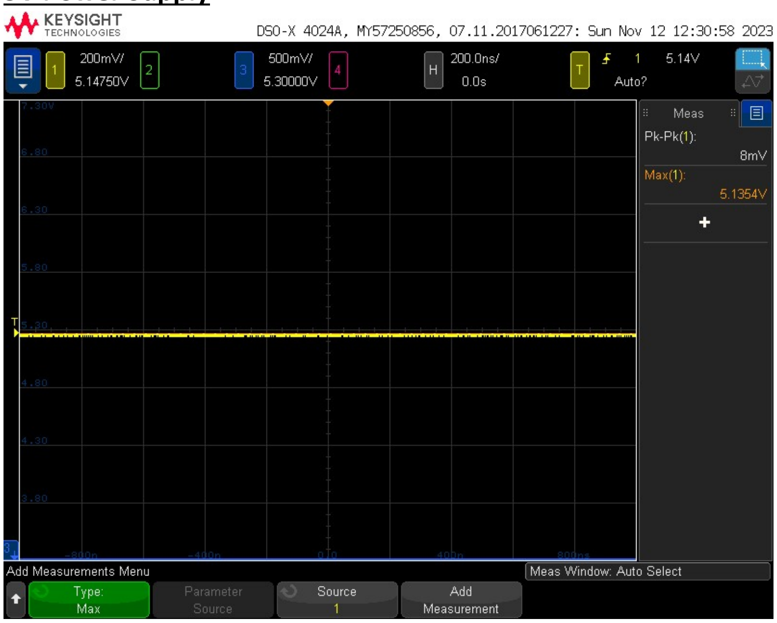
Assembly



In this Pic ,Left Side is Assembled Board and Right Side is the Bare Board

Board Bring Up, Analysis and Calculations

5V Power Supply



Fig(1) Yellow Trace-5V Power Supply

In this Fig(1) we can say that the golden Arduino is receiving the 5V Power Supply when placed under the 5V test point

3.3V Power Supply

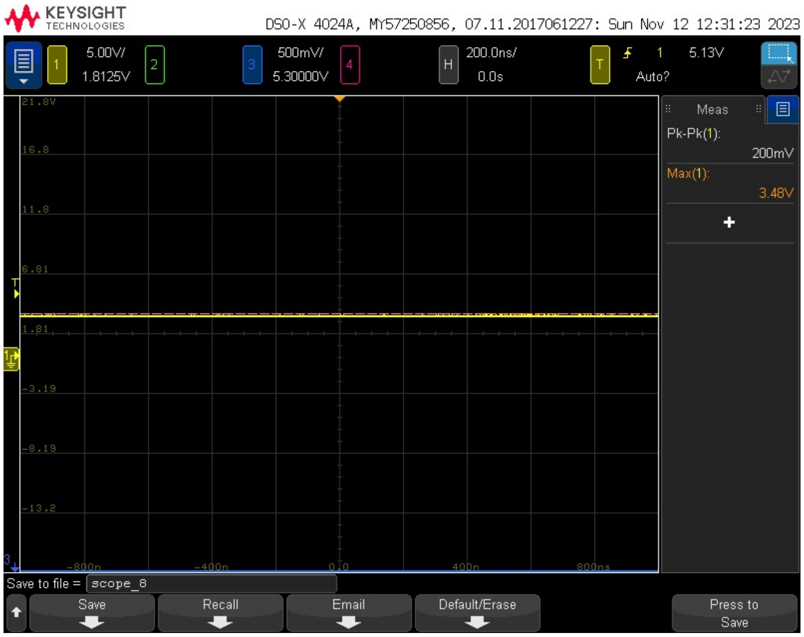
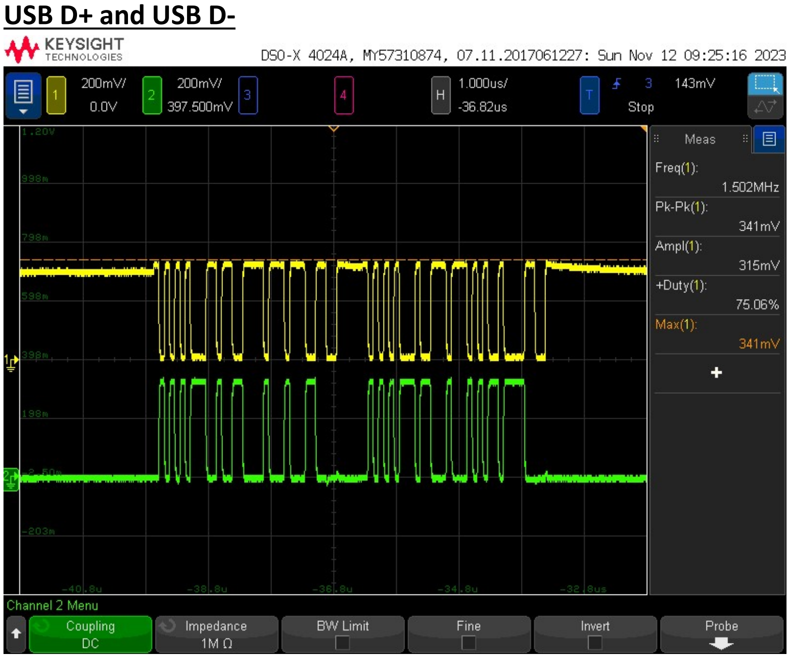


Fig (2) Yellow Trace-3.3V Power Supply

In this Fig(2) we can say that the golden Arduino is receiving the 3.3V Power Supply when placed under the 3.3V test point

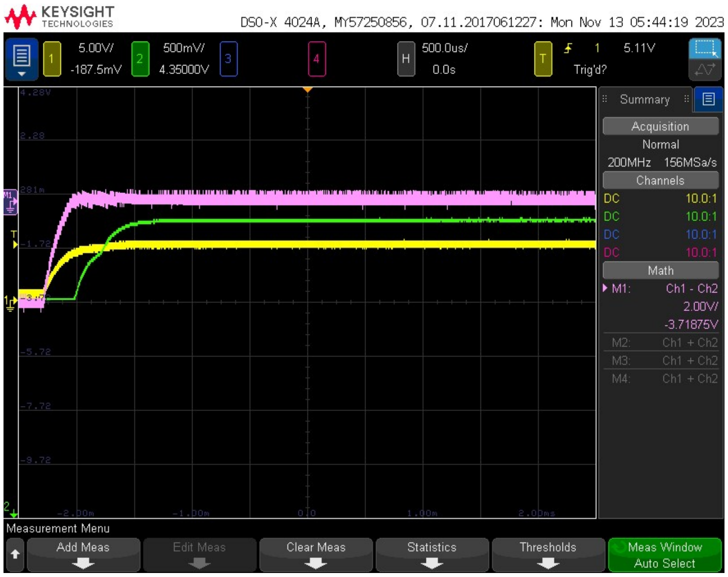
USB D+ and USB D-



Fig(3)-Yellow Trace-USB D+ Signal and USB D- Signal

Here, The signals D+ and D- transmit the data signal and its polarities are inverted. These signal patterns are evident in the scope images only when the board is powered via a mini-USB cable and is connected to a USB port. The presence of a functional USB port confirms the correct connection of D+ and D- and validates the proper functioning of CH340G.

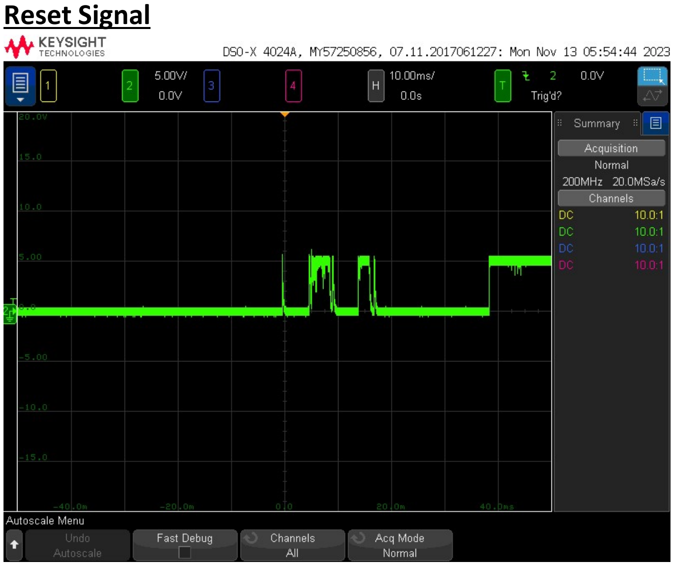
In Rush Current



Fig(4)-Yellow Trace -Low Side of 0.5ohms,Green Trace-High Side of 0.5ohms,Pink Trace-Math Function

We can observe the circuit's inrush current is 8A (4 V/500 mOhm) and this high current consumption is caused by the decoupling capacitors as the power is initially applied, the decoupling capacitors when they charge up, they draw significant current from the power supply which leads to lower the equivalent series resistance and the higher inrush current is observed.

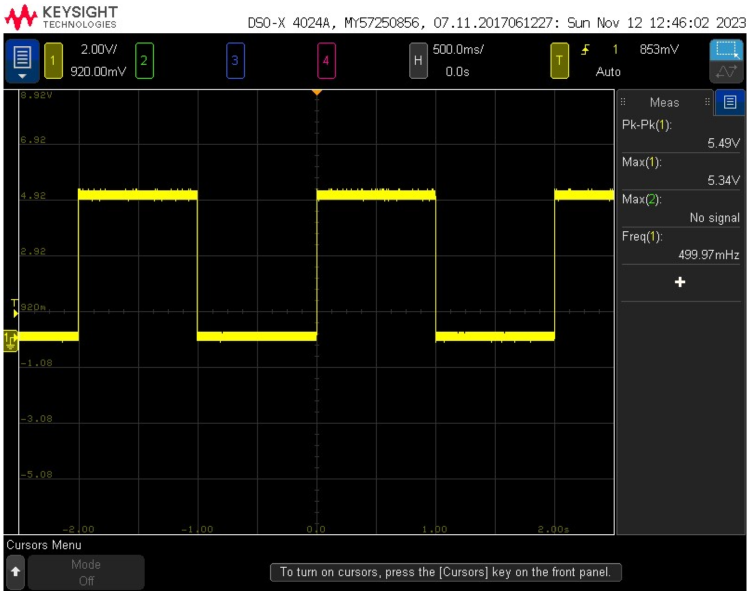
Reset Signal



Fig(5) Green Trace – Reset Signal

When the reset button is pressed, the Reset signal, which is in high state will switch to to low state before shifting to high state.

D13 Signal

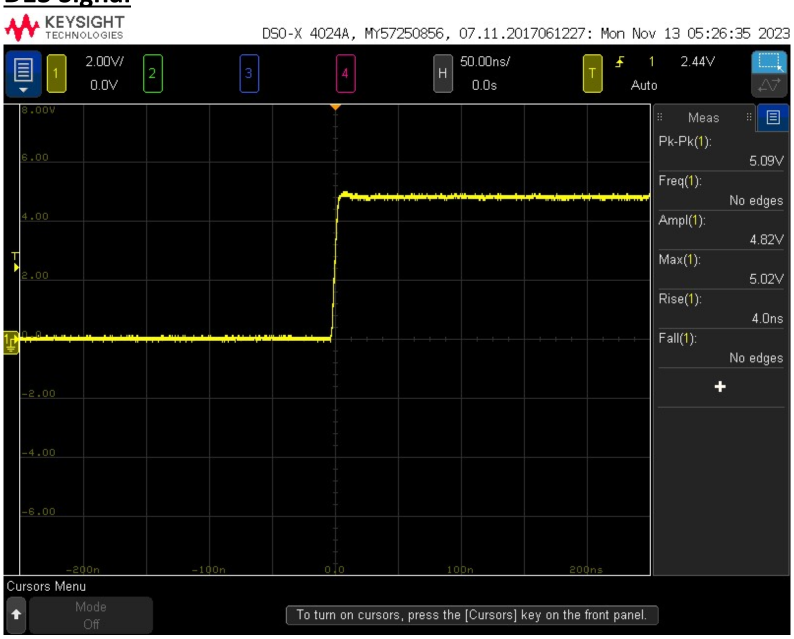


Fig(6) Yellow Trace – D13 Signal

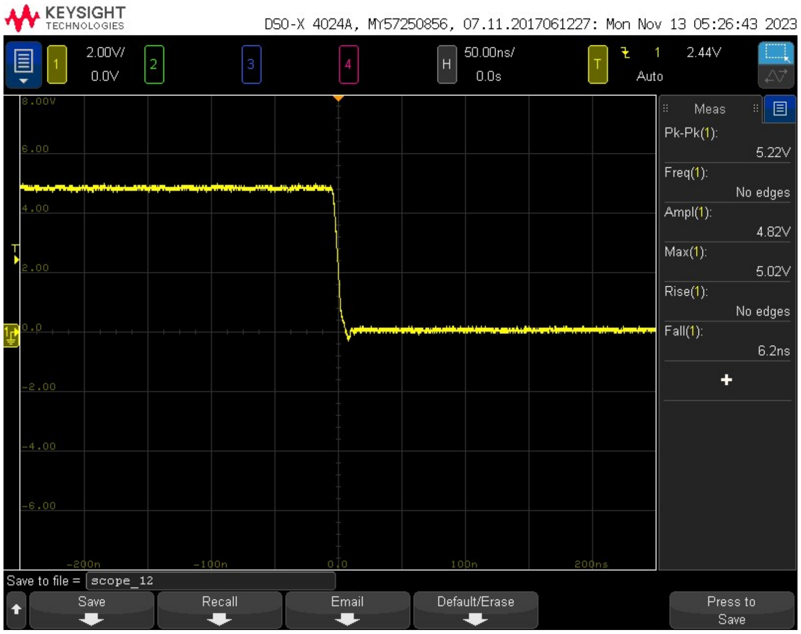
In this Fig(6) we can observe that for the D13 Signal we are observing a frequency of 0.5Hz and also the amplitude of 5V.

Comparison between Golden Arduino and Commercial Arduino

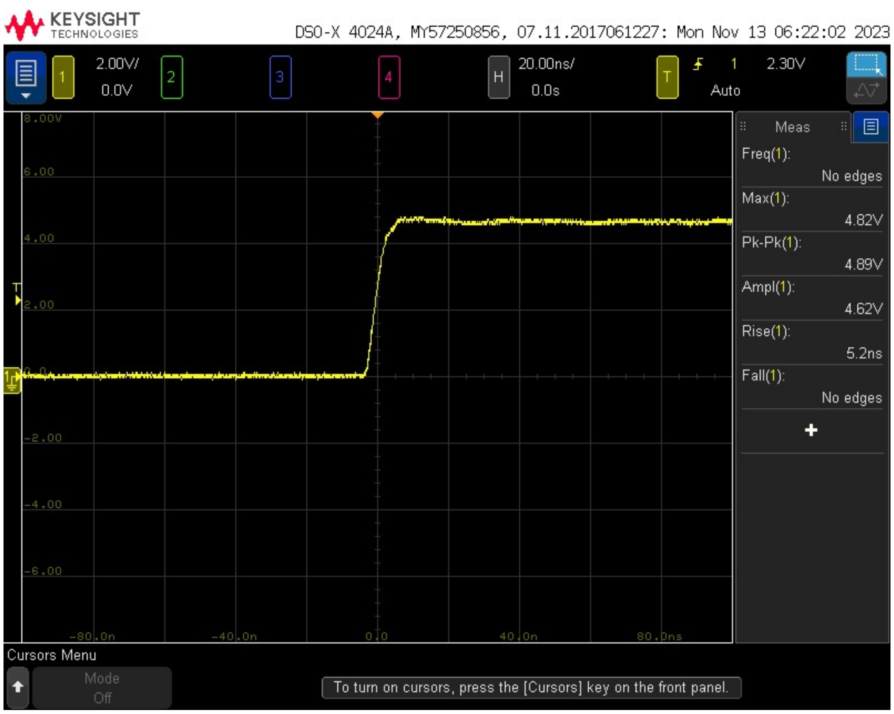
D13 Signal



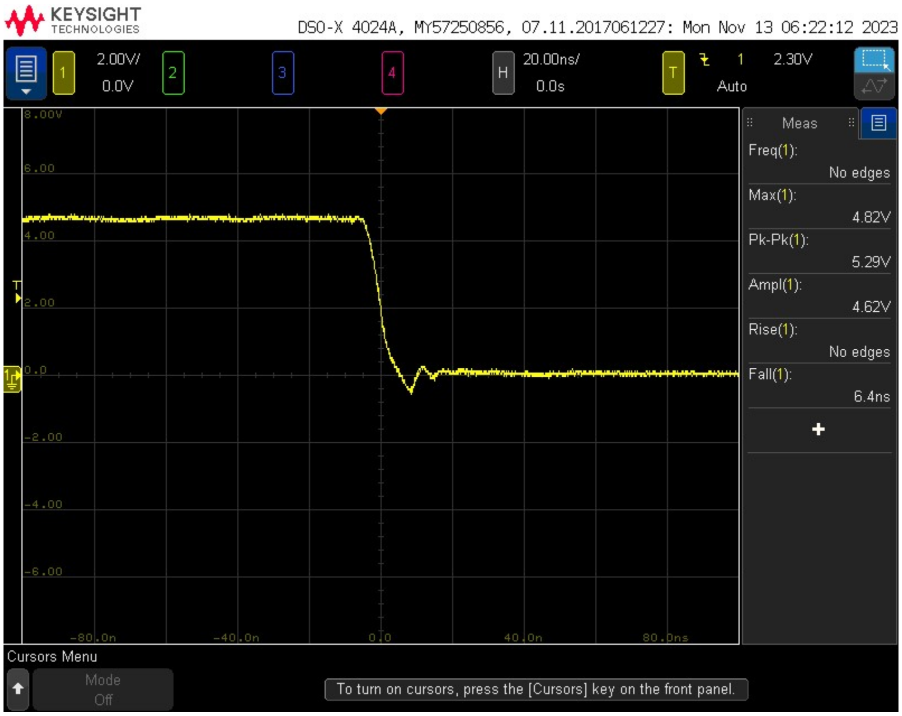
Fig(7) Yellow Trace – D13 Signal Rise time (Golden Arduino)



Fig(8) Yellow Trace – D13 Signal Fall time (Golden Arduino)



Fig(9) Yellow Trace – D13 Signal Rise time (Commercial Arduino)



Fig(10) Yellow Trace – D13 Signal Fall time (Commercial Arduino)

Analysis of D13 Signal Between Golden board and Commercial Board

Boards	Rise Time (ns)	Fall Time(ns)
Golden Board	4	6.2
Commercial Board	5.2	6.4

Observation

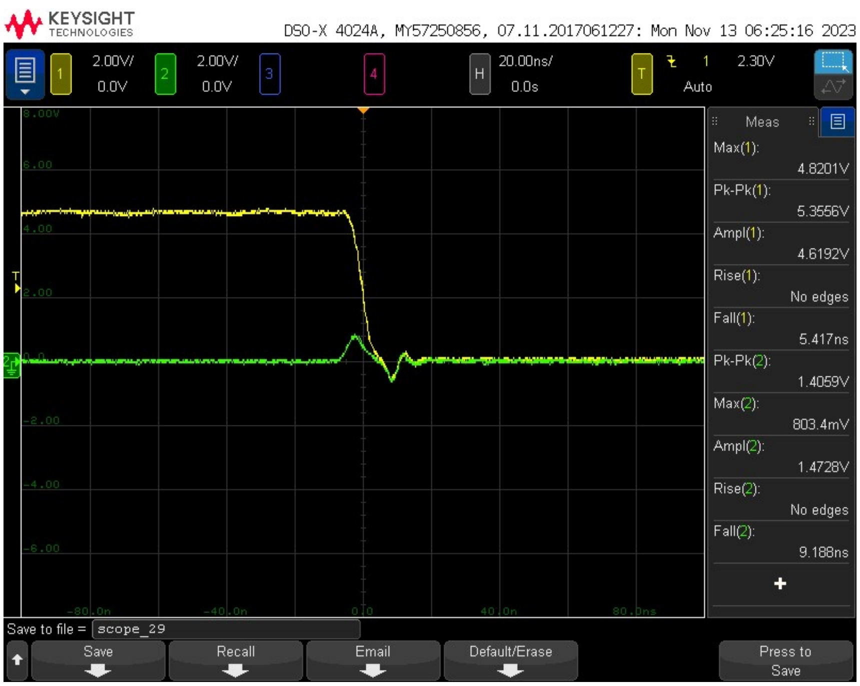
From this table we can say that Golden board has less switching noise with the comparison of Commercial Arduino Board as the high-rise time will lead to high switching noise.

Quiet Low Measurement

Fig(11) Yellow Trace – D13 Signal Rise time ,Green Trace – Quiet Low Signal (Golden Arduino)

Fig(12) Yellow Trace – D13 Signal Fall time ,Green Trace – Quiet Low Signal (Golden Arduino)

Fig(13) Yellow Trace – D13 Signal Rise time ,Green Trace – Quiet Low Signal (Commercial Arduino)



Fig(14) Yellow Trace – D13 Signal Fall time ,Green Trace – Quiet Low Signal (Commercial Arduino)

Analysis of Quiet Low Signal Between Golden board and Commercial Board

Boards	Peak to peak voltage observed at Rise time	Peak to Peak Voltage observed at fall time
Golden Arduino	220mV	903mV
Commercial Arduino	535mv	1.4V
Noise Reduction Percentage	38%	46%

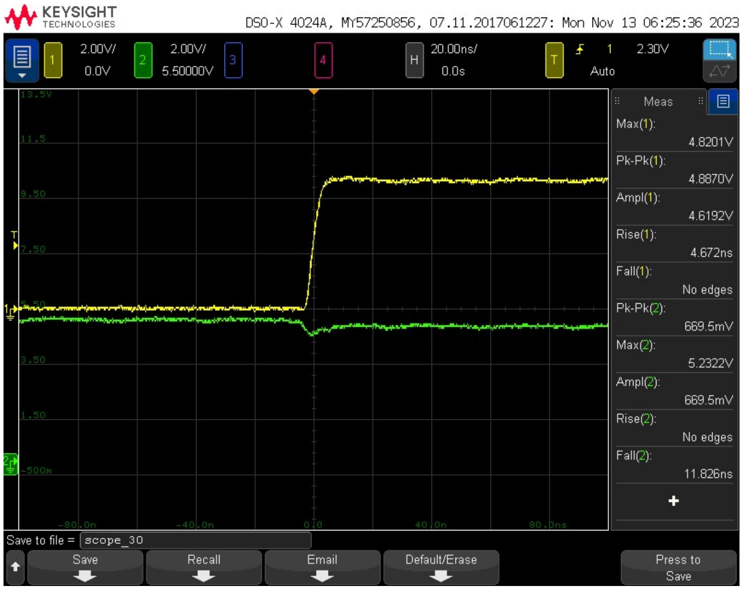
Observation

From this table we can say that Golden board has less switching noise on Quiet Low with the comparison of Commercial Arduino Board as we reduce the switching noise on the rise time like 38 % and Fall time by 46%.

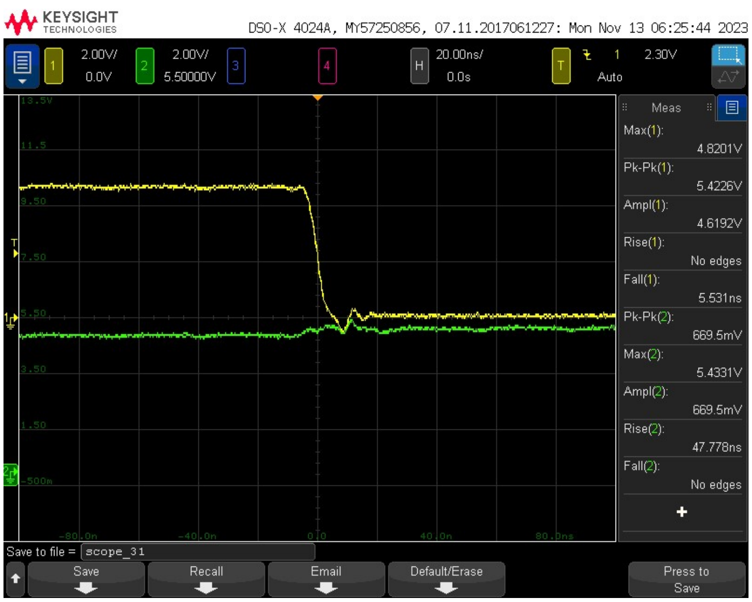
Quiet High Measurement

Fig(15) Yellow Trace – D13 Signal Fall time ,Green Trace – Quiet High Signal(Golden Arduino)

Fig(16) Yellow Trace – D13 Signal Fall time ,Green Trace – Quiet High Signal(Golden Arduino)



Fig(17) Yellow Trace – D13 Signal Rise time ,Green Trace – Quiet High Signal(Commercial Arduino)



Fig(18) Yellow Trace – D13 Signal Fall time ,Green Trace – Quiet High Signal(Commercial Arduino)

Analysis of Quiet High Signal Between Golden board and Commercial Board

Boards	Peak to peak voltage observed at Rise time	Peak to Peak Voltage observed at fall time
Golden Arduino	334mV	294mV
Commercial Arduino	669mv	669mV
Noise Reduction Percentage	47%	36%

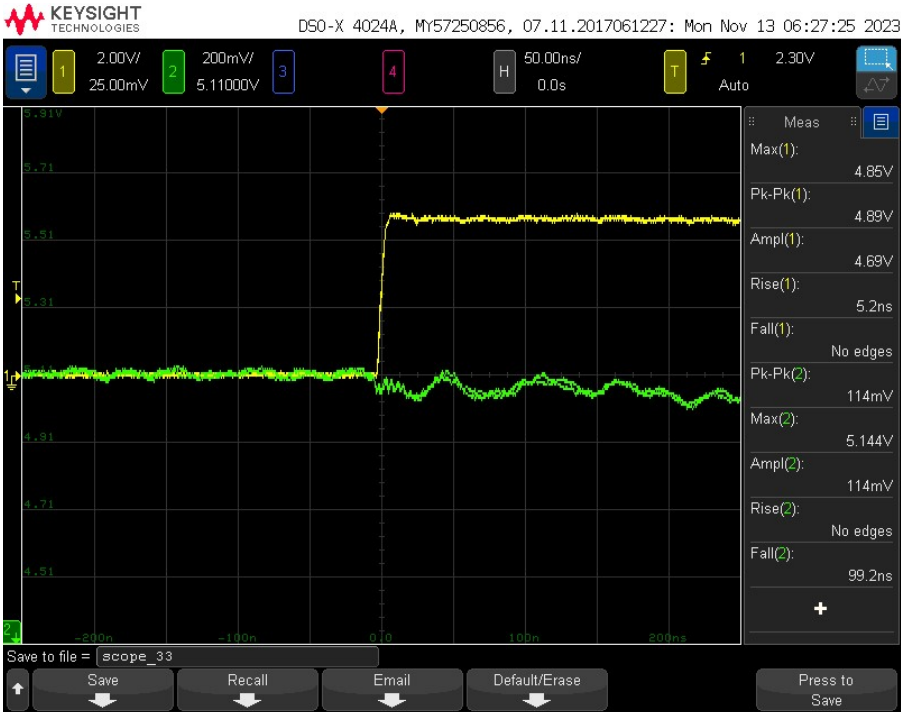
Observation

From this table we can say that Golden board has less switching noise on Quiet High with the comparison of Commercial Arduino Board as we reduce the switching noise on the rise time like 47 % and Fall time by 36%.

Switching Noise Measurement for 5V Power Rail (Slammer Circuit On)

Fig(18) Yellow Trace – 5V Power Rail, Green Trace – D13 Signal(Golden Arduino)

Fig(19) Yellow Trace –5V Power Rail, Green Trace – D13 Signal(Golden Arduino)



Fig(20) Yellow Trace –5V Power Rail, Green Trace – D13 Signal(Commercial Arduino)

Fig(21) Yellow Trace –5V Power Rail, Green Trace – D13 Signal(Commercial Arduino)

Analysis of 5V Power Rail Switching Noise Between Golden board and Commercial Board

Boards	Peak to peak voltage observed at Rise time	Peak to Peak Voltage observed at fall time
Golden Arduino	50mV	47mV
Commercial Arduino	114mV	114mV
Noise Reduction Percentage	44%	51%

Observation

From this table we can say that Golden board has less switching noise on 5V Power Rail with the comparison of Commercial Arduino Board as we reduce the 5V Power Rail switching noise on the rise time like 44 % and Fall time by 51%.

Slammer Circuit trigger for Quiet High Rail Switching Noise Measurement

Fig(22) Yellow Trace –Slammer Trigger Rail, Green Trace – Quiet high(Golden Arduino)

Fig(23) Yellow Trace –Slammer Trigger Rail, Green Trace – Quiet High(Golden Arduino)

Fig(24) Green Trace –Slammer Trigger Rail, Yellow Trace – Quiet High(Commercial Arduino)

Fig(25) Green Trace –Slammer Trigger Rail, Yellow Trace – Quiet High(Commercial Arduino)

Analysis of 5V Power Rail Switching Noise Between Golden board and Commercial Board

Boards	Peak to peak voltage observed at Rise time	Peak to Peak Voltage observed at fall time
Golden Arduino	328mV	221mV
Commercial Arduino	570mV	420mV
Noise Reduction Percentage	38%	47%

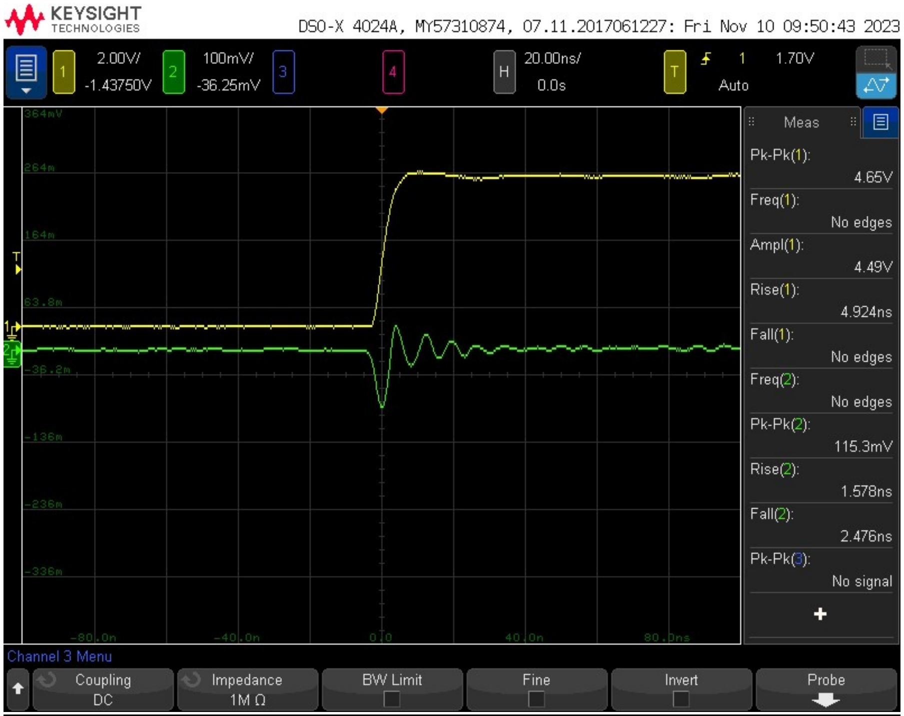
From this table we can say that Golden board has less switching noise on 5V Power Rail with the comparison of Commercial Arduino Board as we reduce the Quiet High switching noise on the rise time like 38 % and Fall time by 47%.Here the D7 Pin is Responsible for the Slammer Circuit Trigger as it is connected to the MOSFET.

Near Field Emission

Here we will use 10x probe with ground tip as a small loop where this probe produce an Electromagnetic wave which is the source for near-field emissions. We will place loop probe below the board and we will see the Near Field Emision Noise effected on the board.

Fig(26) Green Trace –Near Field Emission, Yellow Trace –D13 Signal(Golden Arduino)

Fig(27) Green Trace –Near Field Emission, Yellow Trace –D13 Signal(Golden Arduino)



Fig(28) Green Trace –Near Field Emission, Yellow Trace –D13 Signal(Commercial Arduino)

Fig(29) Green Trace –Near Field Emission, Yellow Trace –D13 Signal(Commercial Arduino)

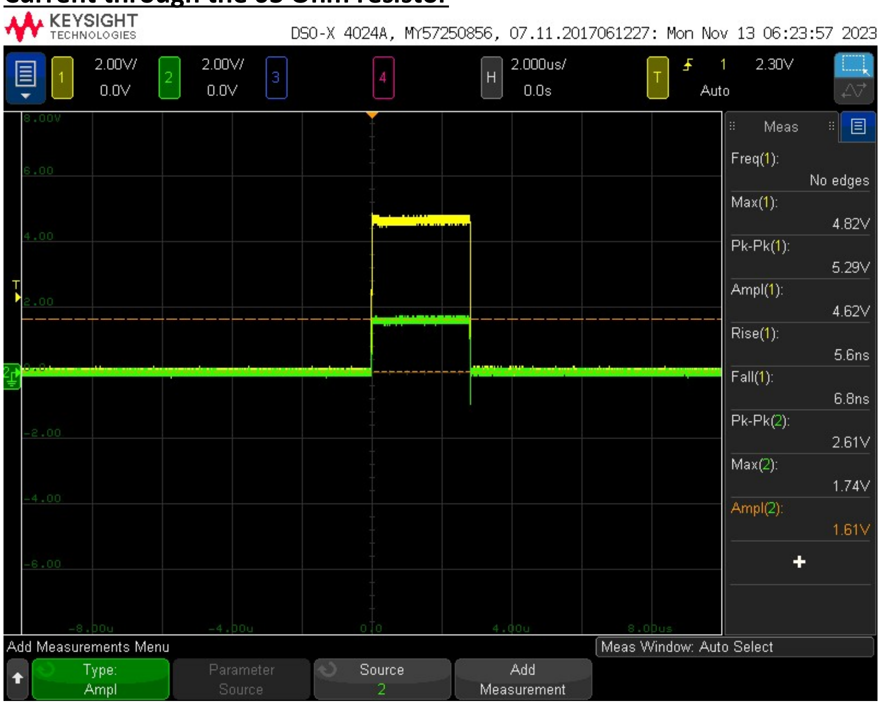
Analysis of Near Field Emission Noise Between Golden board and Commercial Board

Boards	Peak to peak voltage observed at Rise time	Peak to Peak Voltage observed at fall time
Golden Arduino	37mV	72mV
Commercial Arduino	115mV	122mV
Noise Reduction Percentage	64%	48%

Observation

From this table we can say that Golden board has less switching noise on 5V Power Rail with the comparison of Commercial Arduino Board as we reduce the Near Field Emission noise on the rise time like 64 % and Fall time by 48%.

Current through the 63 Ohm resistor



Here the voltage across the 63 Ohm resistor is 1.61 V and the current across the 63Ohm resistor is (1.74/63)=26mA

What Worked

Your definition of what it means to work

I can see the power voltages such as 5V and 3.3V on the test points.
I am getting the expected frequency of 12 MHz and 16MHz on the Arduino Board
I bring up the board and lit up all the LEDs to ensure that my core signals are working, which can be observed through naked-eye LED visualization.
Able to load the blink code and successfully boot loaded the board.

What you actually measured to verify your board "worked"?

We are able to calculate 63Ohm resistor current, able to get the related the power to Board like 5V and 3.3V when placed test point, measuring the switching noise and Near Field Emission Noise on the board by placing the shield on to the board.

Your expectations for any performance features

Here our expectations was to observe the switching noise in 20-50% switching noise range and we are able to see that switching noise range in comparison with the commercial Arduino that what end goal of this lab.

Demonstration of Best Measurement Practices?

The use of spring tips, as they reduce noise on the probe, is beneficial.
Opt for the 10x test point instead of the 1x test point.
For signals, employ a 6 mils trace width, and for power rails, use 20 mils.
Utilize test points and switches for debugging and testing purposes.
Ensure that you check circuit continuity via a DMM for self-verification.

Summary for the Analysis done for the Quiet High, Quiet Low,5V Power Rail, Slammer Trigger, Near Field Emission,D13 Signal

Here I have observed that our commercial Arduino board is providing us with a lot of switching noise in comparison with the Golden Arduino Board as we are going with best design practices for the Golden Arduino Board we are able to see less switching noise .

What did not work

There are no hard errors on my PCB.

What worked and you did well and want to do in future designs

By including test points for all the related signals, I can obtain the expected voltages or outputs.
The switch has helped me isolate the circuit, and the naming convention for the test points has been extremely beneficial.
Maintaining modularity in the test points for my easy reference is essential for future designs.

What did not work, and you will want to do differently in future designs.

Everything worked for me and may be trying to get less in rush current for my future design.

Were there any hard errors- why did they go wrong

No hard errors observed

Were there any soft errors that you would like to do differently next time?

There is a dimension issue when placing the shield on one side of the connector. On the other side, everything is fine. Small wires were used on the side where it was not fitting correctly, mainly related to the power section of the shield. TAs has been very helpful in providing suggestions for resolving this issue. For the next time I want to give priority to dimension placing for shield and will go for the routing.

<u>Key Takeaways and Learning</u>

1)Use of decoupling capacitor near the IC to reduce switching noise
2)Implementing the ferrite bead to filter the noise present on the AVCC pin
3)Use less cross under and also maintain the cross under distance short to reduce the noise
4)Avoid the crosstalk and also reduce the cross talk by implementing continuous return path

5) Signal pathways are placed further apart, as it reduces electromagnetic interference
6)Addition of test points and switches are helpful for debugging and troubleshooting