Golden Arduino Board **(04/10/2022)** **Rishab Shah**

Project Overview/Definition of work:

The Golden arduino should be able to boot after burning the bootloader should be able to execute a test blinky program and have lower switching and ground bounce noise compared to the commercial arduino board.

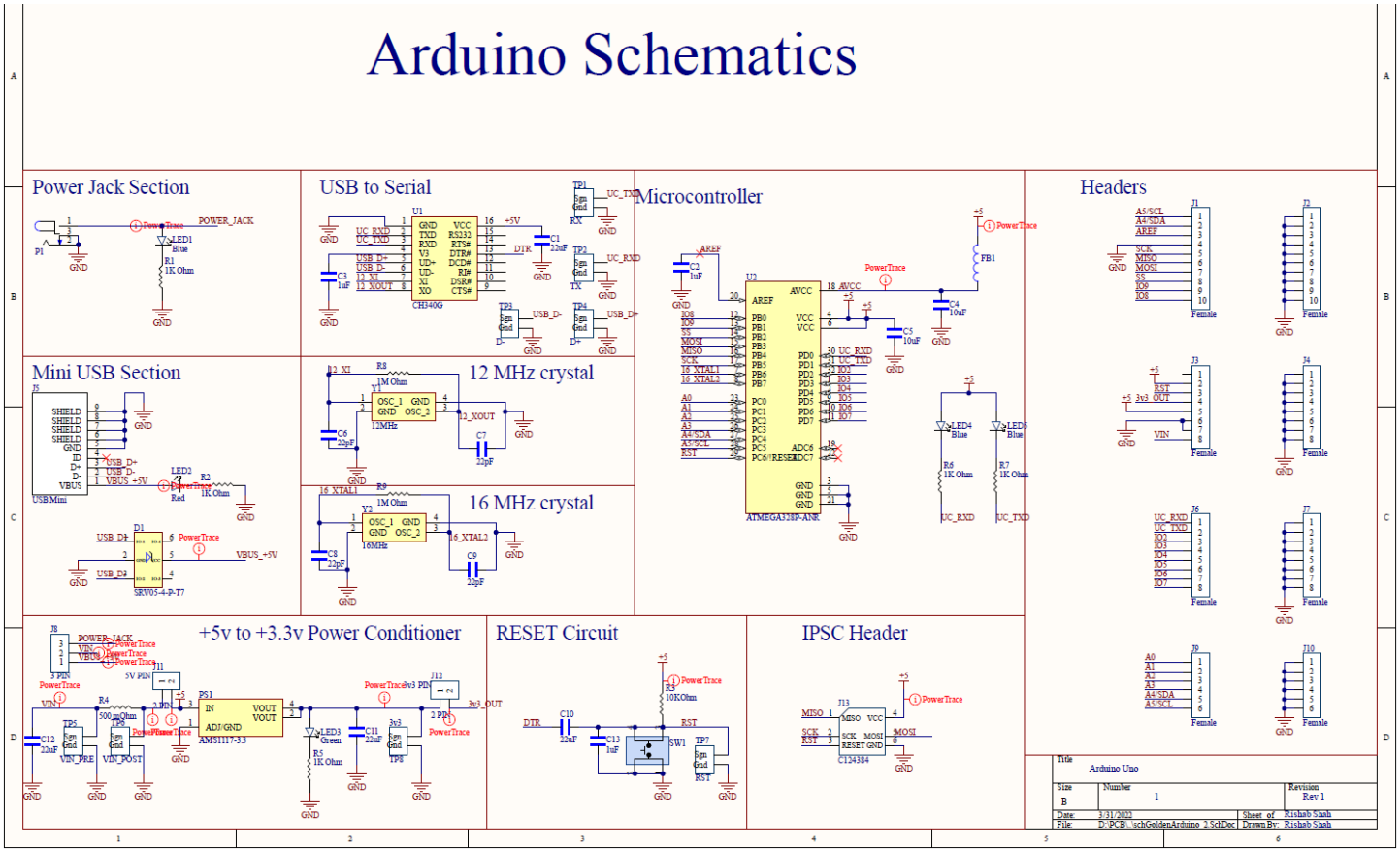
POR:

To facilitate testing and debug there are power indicator LEDs added as well as test points. TO reduce noise at every location a decoupling capacitor is added, and the value chosen is 22uf to act as a bulk capacitor as well for a better stable local power supply source. An attempt is made to chose less unique parts to have a better chance if assembly is required in case of missing parts. From experience, it is easier to desolder than to solder the parts especially small parts. (0603, 0402). Hence, parts where it required to remove 1208 package is chosen. The crystal oscillator's resistor is 1208 and 1 M Ohm in value. To endure mechanical stress, not component is chosen which has a height higher than the female headers that will be soldered on the board. For physical considerations, the USB and power port should be aligned at the edge of the board for ease in access. Some of the existing problems in existing commercial arduino are Decoupling capacitor is not placed in proximity to Vcc Pin, Absence of a ferrite filter to suppress then noise at Analog Vcc pin to have almost or no noise when using ADC., Absence of ground across each pin for ease in measurement as well as to remove the ground bounce when many signals are switching simultaneously. Some of the common aspects to pay attention in terms of routing were Tx, Rx pin of UC routed properly, Place crystal closer to the IC, Having the LED connected to power supply so that they lit up only when there is communication over UART, 20 mil width of power lines, Proper naming of all the designators, test and debug points, addition of switcher jumper circuit to alternate between power sources, Usage of proper net naming to make routing life easy, alignment of test points as far as possible in the same direction for easy operations, addition of a capacitor and proper resistor to the reset circuit to have a better stable signal to trigger RESET, Addition of ESD protection diode for safety on push buttons and USB input. These are to be incorporated in design apart from the drawbacks identified in the design. The reference design chosen should be critically evaluated and ownership must be taken for the parts which are added and wherever modifications are required it should be incorporated into the design.

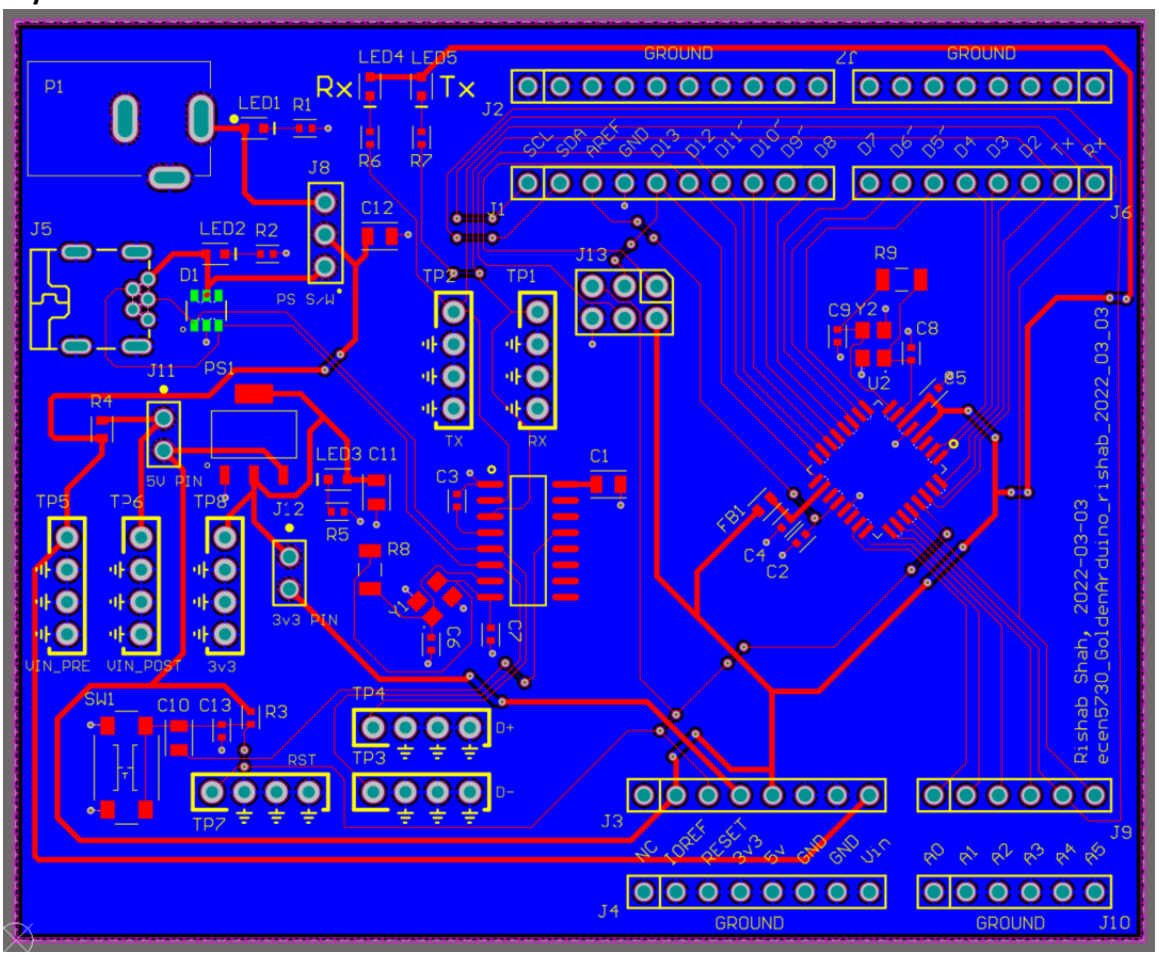
Reference Design link:

http://cdn.sparkfun.com/datasheets/Dev/Arduino/Boards/RedBoard-V22.pdf
https://forum.kicad.info/t/arduino-uno-r3-female-pin-headers-spacing/12551/5
Lecture notes

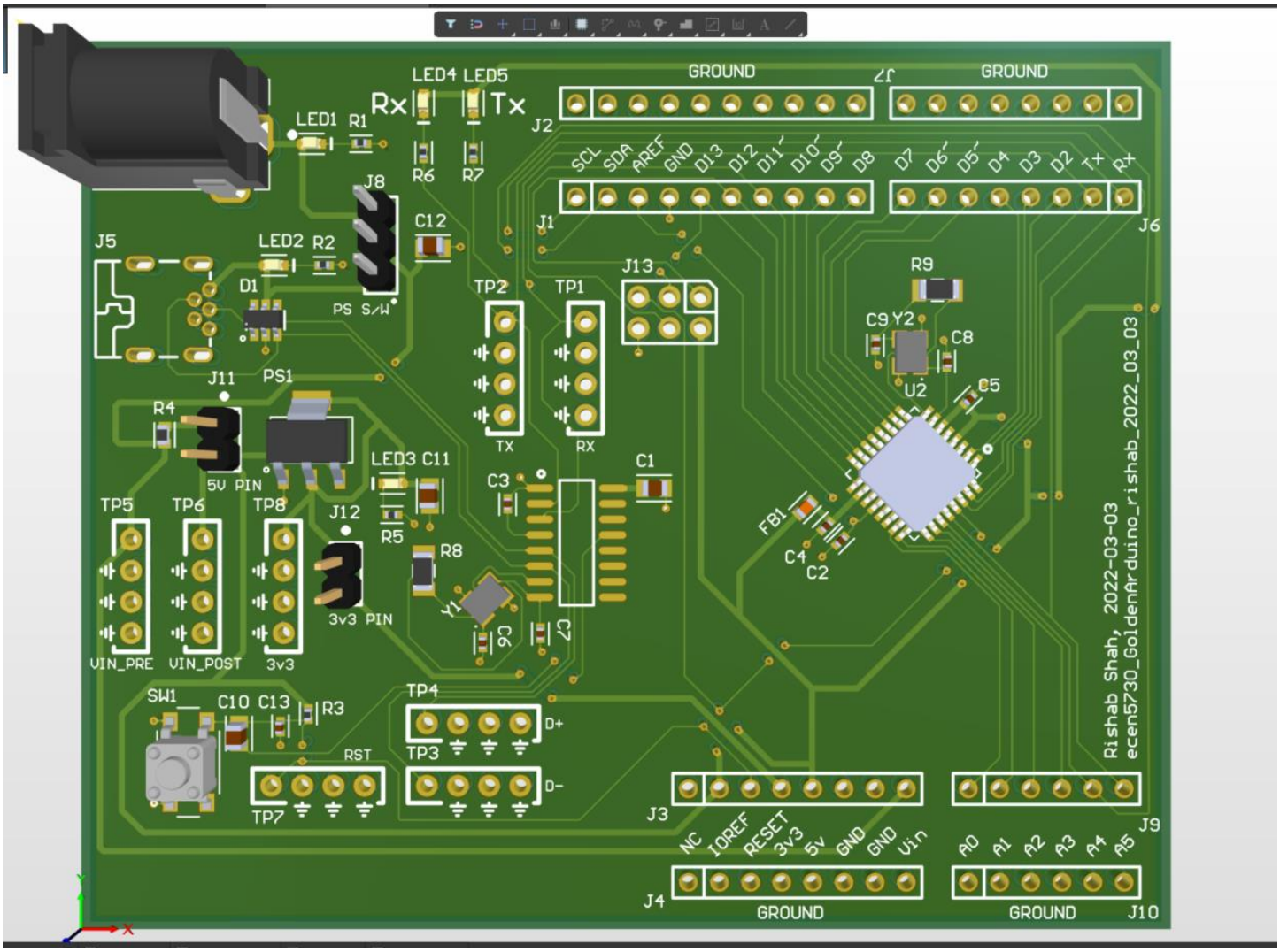
Schematic of Golden Arduino:

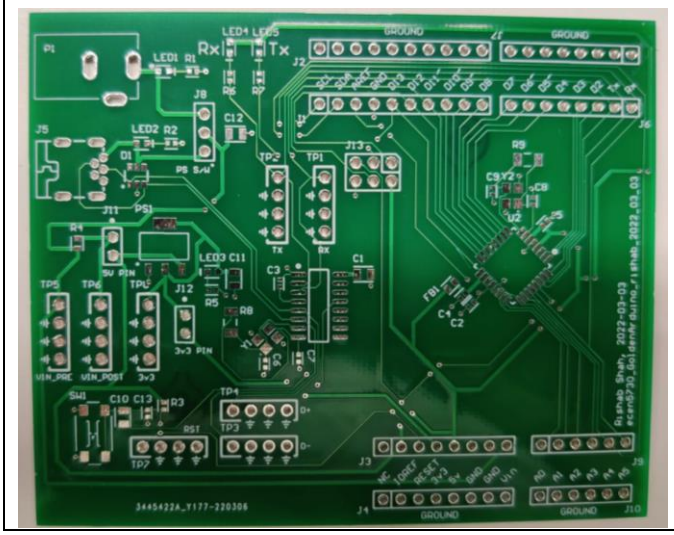
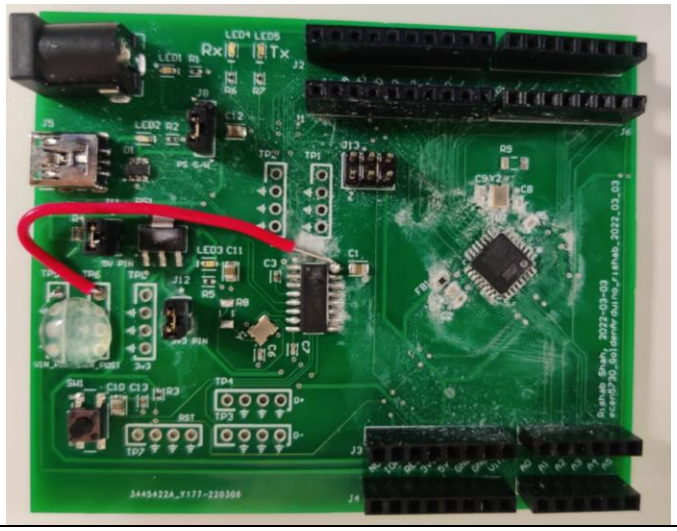


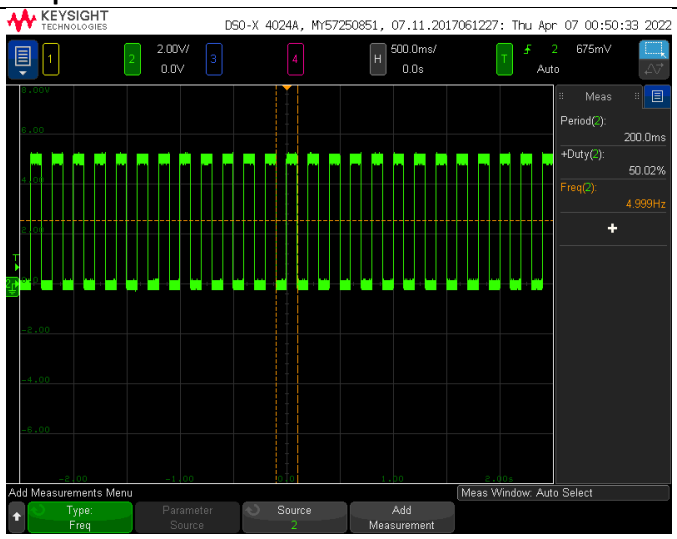
Layout of Golden Arduino:



3D View of Layout:



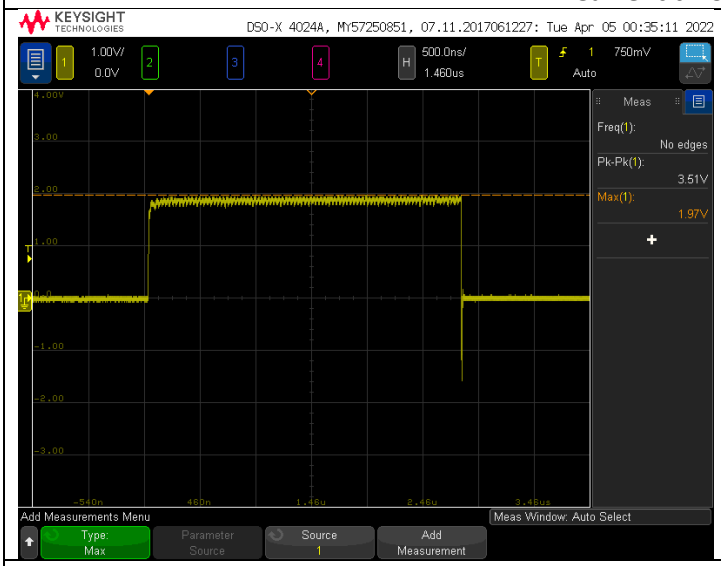
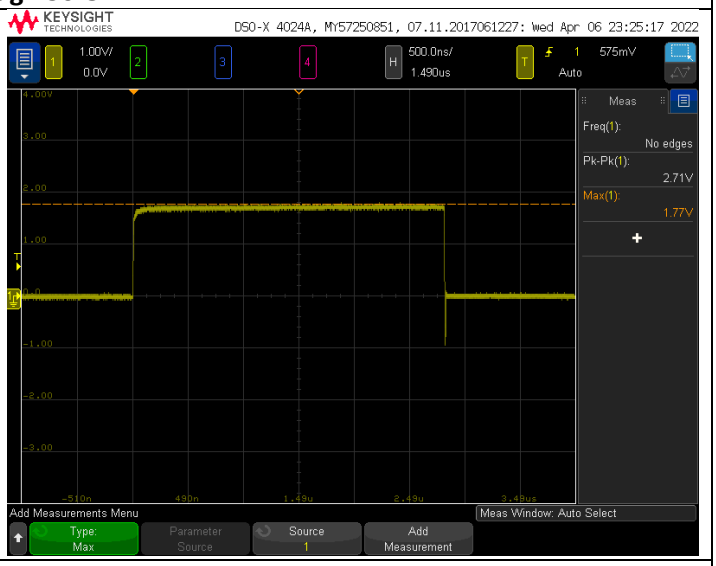
Bare Board Picture	Assembled Board Picture
	

Working Board	Output
	 Frequency is 5Hz. Digital Pin 13 used to generate the waveform.

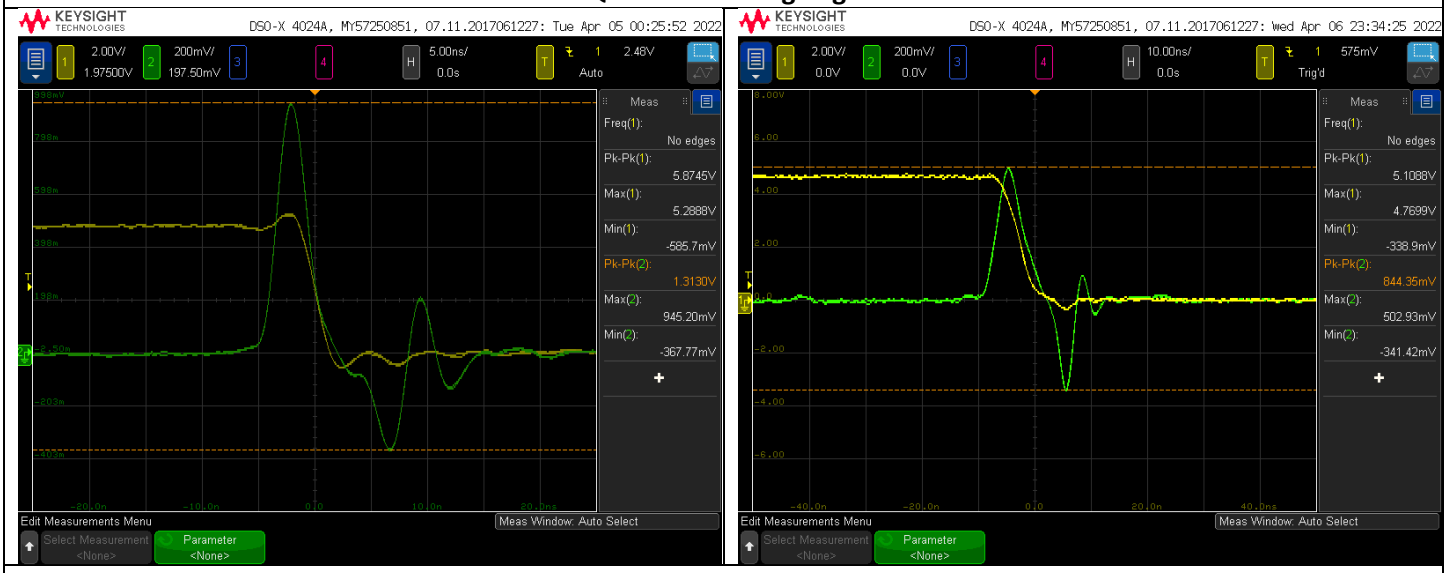
Board bring-up:

1. Power ground shorting was checked. There was no short. Then the voltage delivered was checked by bringing one power circuit at a time.
2. The 16 MHz crystal had noise. The resistor was removed. 12 MHz crystal oscillations were not visible. From layout analysis, it was determined. There was no connection to the Vcc of CH340G. A red colored wire was used to make the connection from a nearby test point.
3. For measurement of inrush current, one header pin and a wire were used and to ensure no short, the back pads were put on the nearby ground pins.

Measurements:

Commercial Arduino Uno Board	**Golden Arduino (GA) Board**
Following are the measurements taken when 3 signals are switching simultaneously. Pin 13 runs at 0.25 Mhz frequency comparable to board frequency range.	
Current through 50 Ohm	
	
I = V/R = 1.97/50 = 0.0394 = 39.4 mA	I = V/R = 1.7/50 = 0.0354 = 35.4 mA
Conclusion: The Golden Arduino (GA) can provide the same behavior as the commercial board in terms of current drive capacity but with reduced noise on the rail.	
Ground bounce noise: Following measurement helps to analyze the impact on a nearby ground signal (Quiet Low) due to high frequency switching signals on both the boards	
Quiet Low Rising Edge	
	
Yellow: Pin 13, Green: Quiet Low	
The commercial has a bad impact of about 550 mv noise compared to 211 mV of the GA. Reduction to 1/3rd.	

Quiet Low Falling Edge

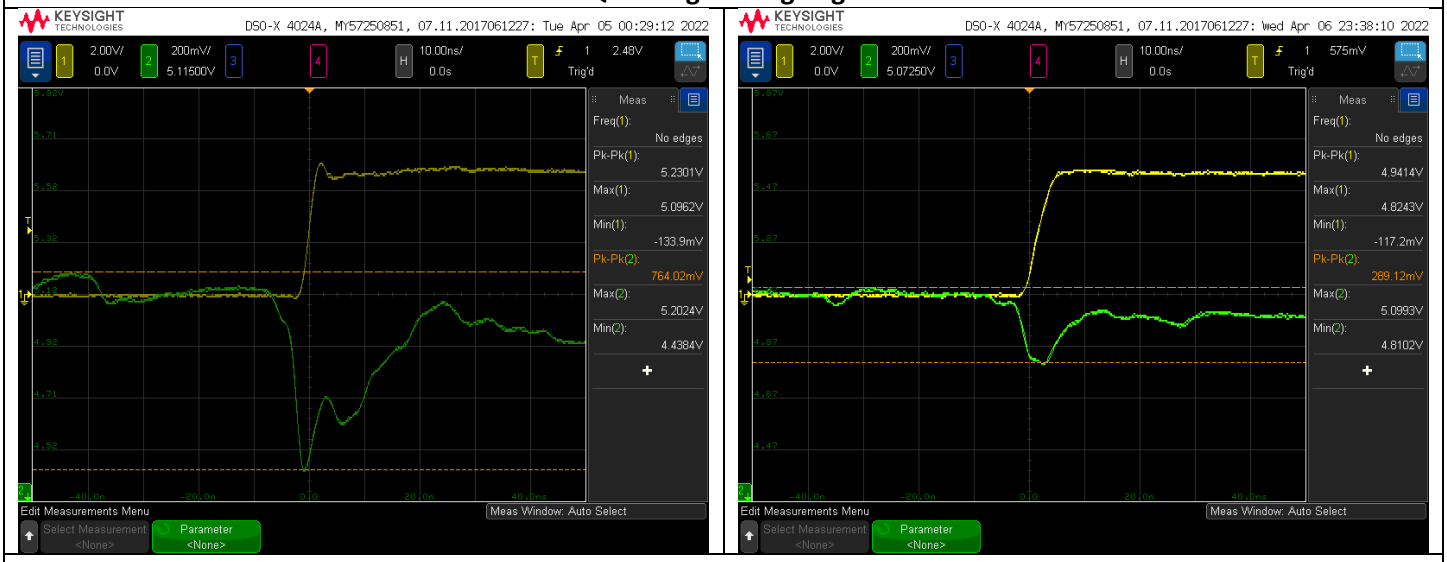


Yellow: Pin 13, Green: Quiet Low

The commercial has a bad impact of about 1.3V noise compared to 844 mV of the GA. Reduction to ½.

Conclusion: The GA performed better due to presence of ground pins near to the digital I/O pins thus providing a signal return path to each signal.

Quiet High Rising Edge



Yellow: Pin 13, Green: Quiet High

The commercial has a bad impact of about 764.02 mv noise compared to 289 mV of the GA. Reduction to 1/3rd.

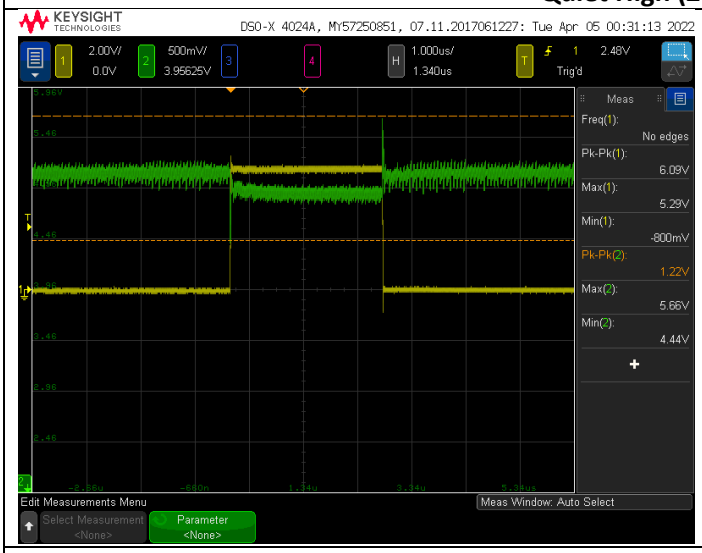
Quiet High Falling Edge

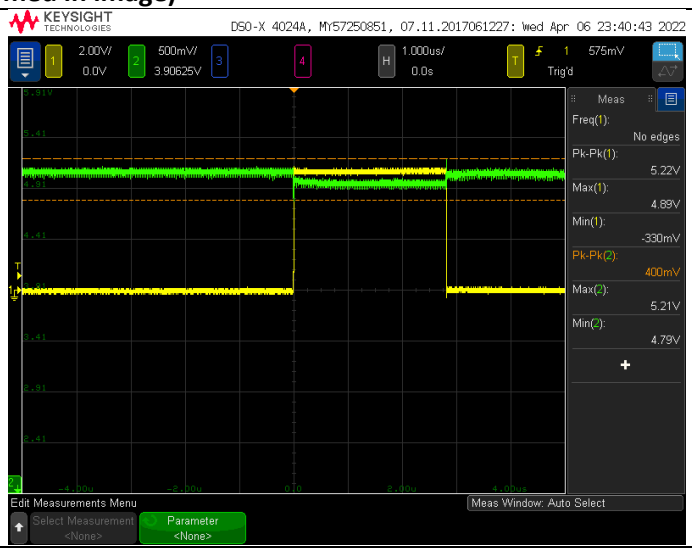
Yellow: Pin 13, Green: Quiet High

The commercial has a bad impact of about 809.21 mV mv noise compared to 259 mV of the GA. Reduction to 1/3rd.

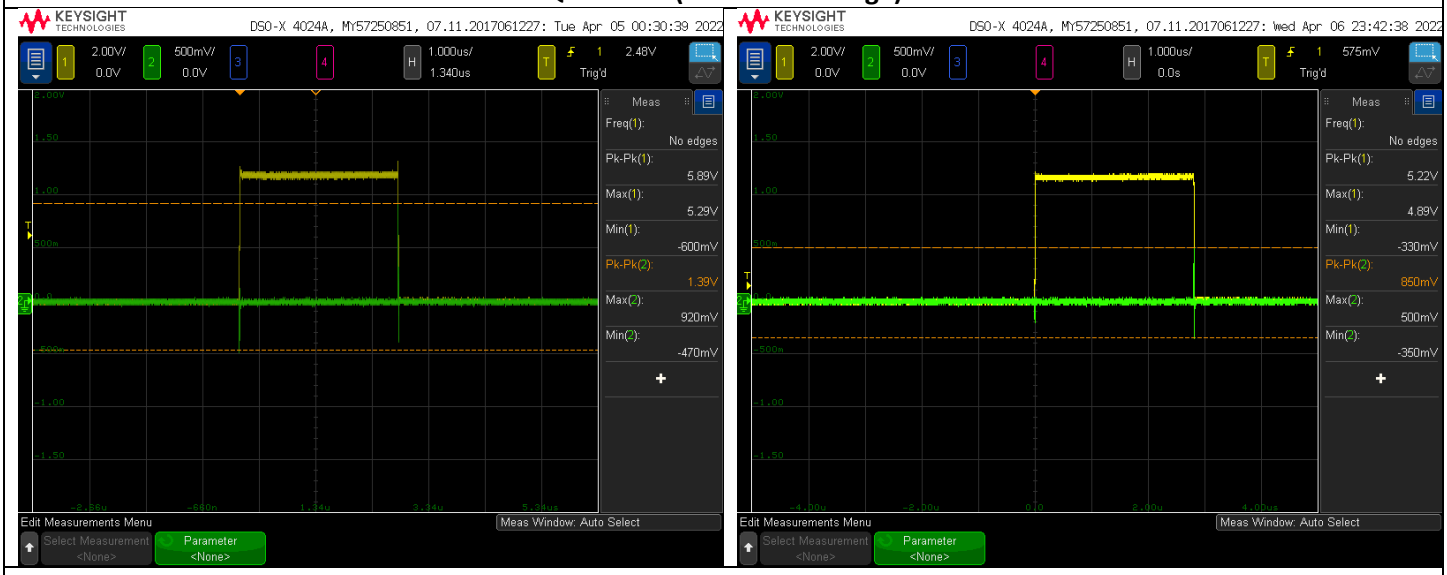
Conclusion: The GA performed better due to presence of ground pins near to the digital I/O pins thus providing a signal return path to each signal.

Quiet High (Zoomed in image)

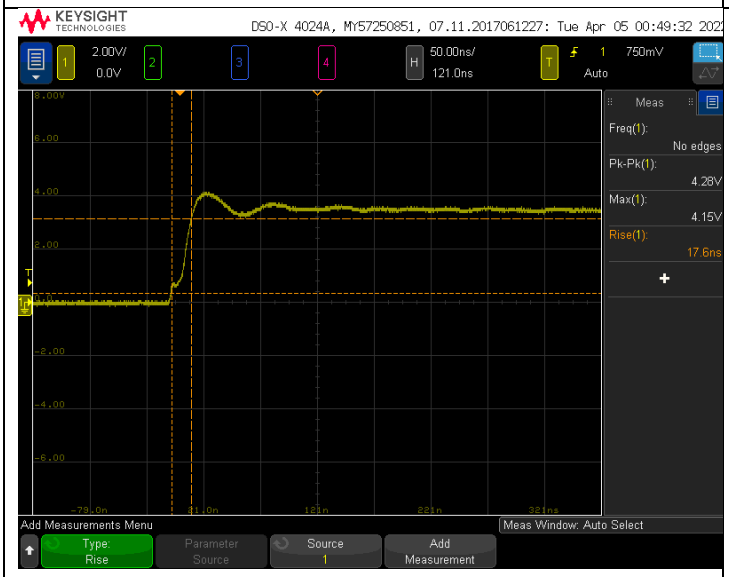


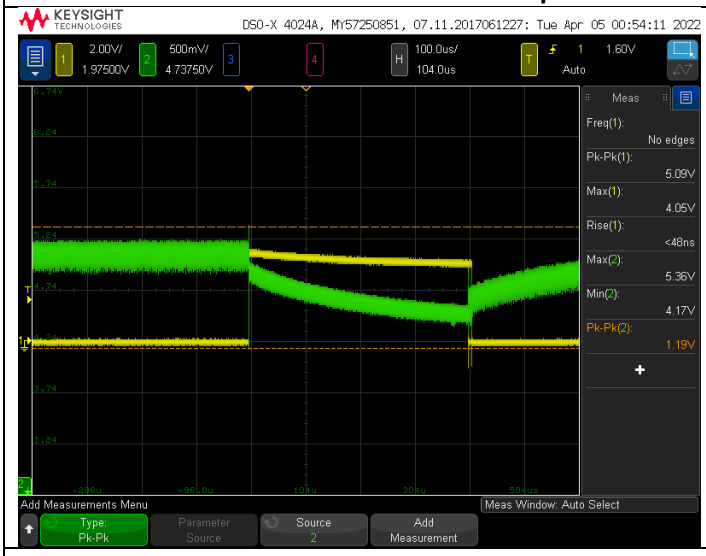
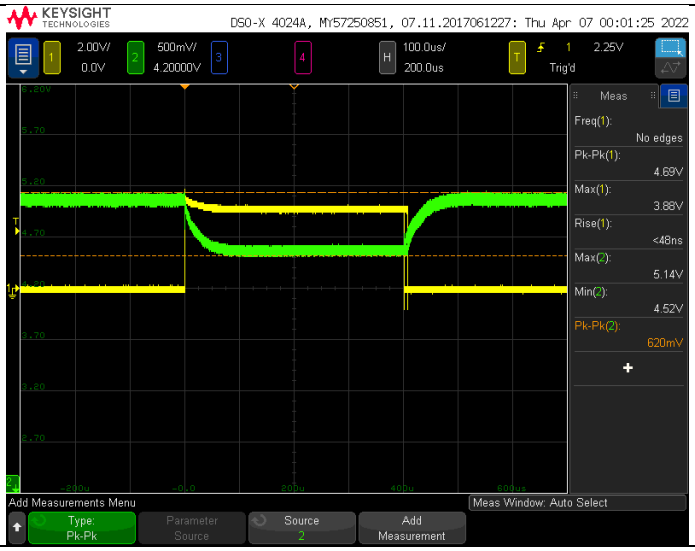
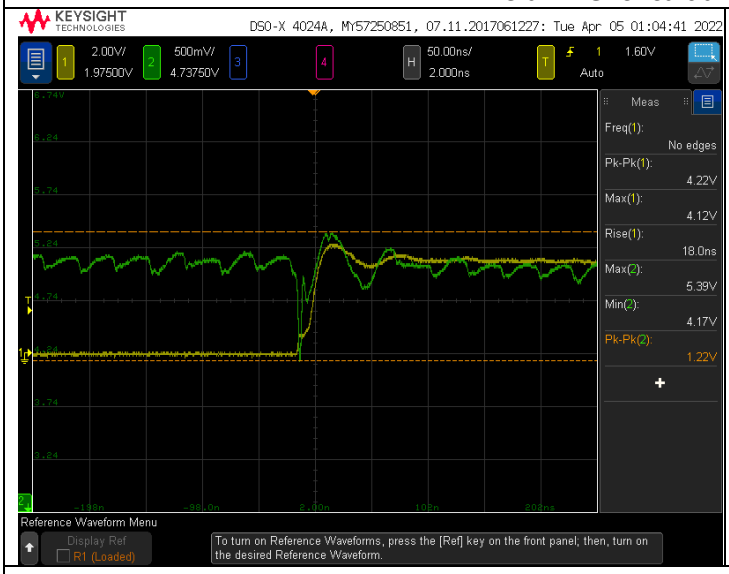
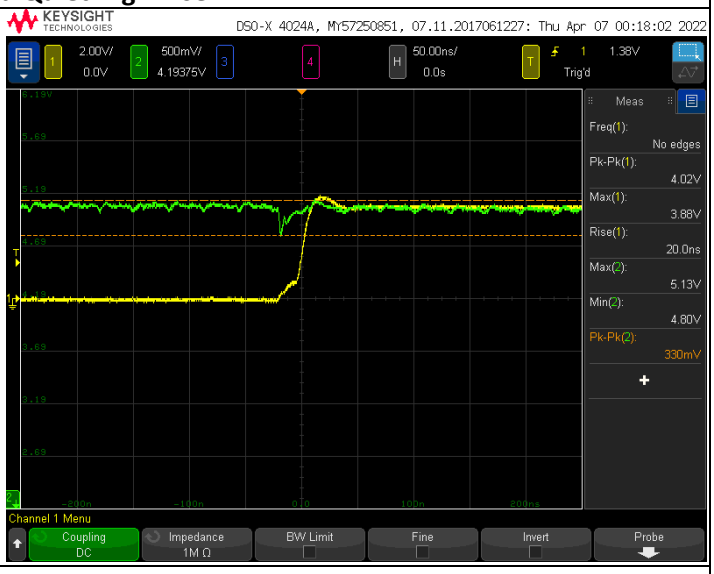


Yellow: Pin 13, Green: Quiet High

Quiet Low (Zoomed in image)

Yellow: Pin 13, Green: Quiet High
Conclusion: From above images, the impact of noise over a region can be observed. GA has les noise compared to commercial board.

In Following circuit, the impact of a slammer circuit driven by a digital Pin is observed. A slammer circuit is a basic MOSFET used as a switch driven by a pulsating digital I/O. The high switching frequency introduces a noise at the rising and falling edge.

Commercial Arduino Uno Board	Golden Arduino (GA) Board
	
There is no line capacitance or decoupling capacitors in the commercial arduino. I = V/R = 4.15/10 = 415 mA.	GA has higher rise time due to addition of all the line capacitance. I = V/R = 3.88/10 = 388 mA.
The rise time of slammer circuit driven by GA is slower compared to the rise time of a commercial board. The GA has less ripple voltage compared to commercial Arduino board. Also, the noise is less. Hence, does not reach a higher voltage at the transition edges due to addition of noise.	

Commercial Arduino Uno Board	Golden Arduino (GA) Board
Impact of slammer circuit on 5v rail	
	
Yellow: Pin 7, Green: 5V rail	
The negative impact of noise can be seen at the power rail. The power rail dips to 4.17V whereas the power rail in GA is stable at 4.5V. Also, the amount of noise is very large in commercial compared to Golden Arduino as seen in the above images.	
Slammer circuit and Quiet High Rise	
	
Yellow: Pin 7, Green: 5V rail	
The commercial has a bad impact of about 1.22 V noise compared to 330 mV of the GA. Reduction to 1/4th.	

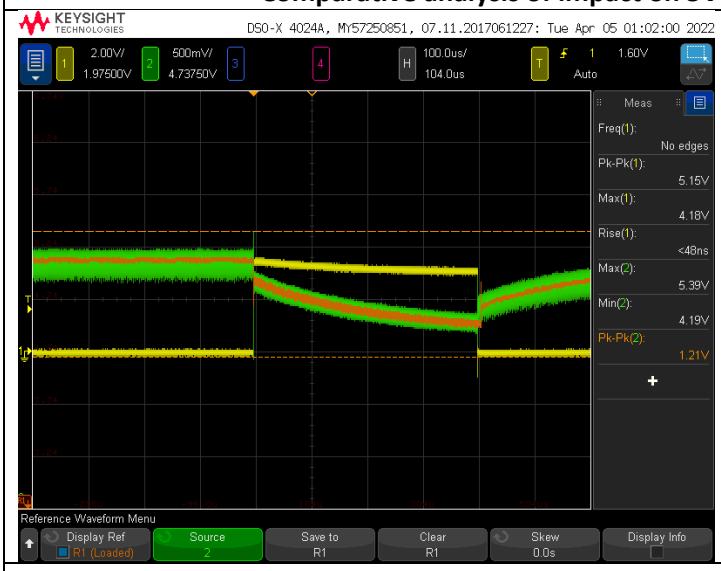
Slammer circuit and Quiet High Fall

Yellow: Pin 7, Green: 5V rail

The commercial has a bad impact of about 652 mV noise compared to 200 mV of the GA. Reduction to 1/3rd.

Conclusion: The noise is significantly reduced in GA due to usage of sufficient capacitors which acted as a local charge storage as well removed any high frequency noise associate d by usage as a decoupling capacitor.

Comparative analysis of impact on 5V and Quiet high due to slammer circuit



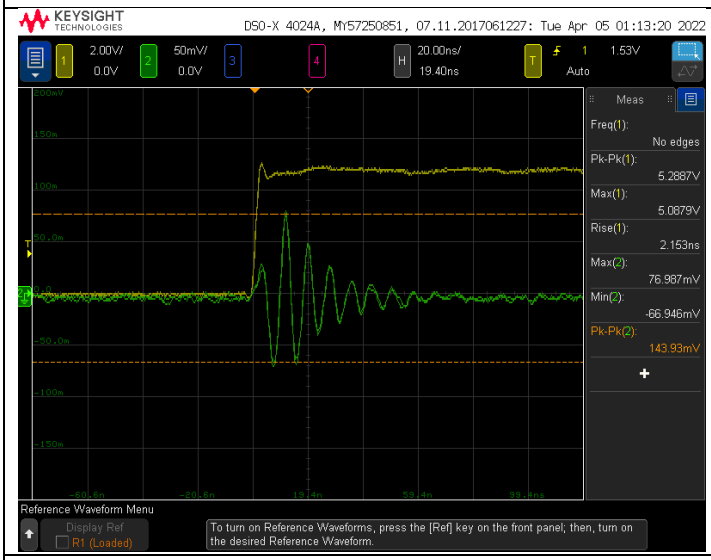
Yellow = Pin 7, Green = 5v Rail, Orange = Quiet High

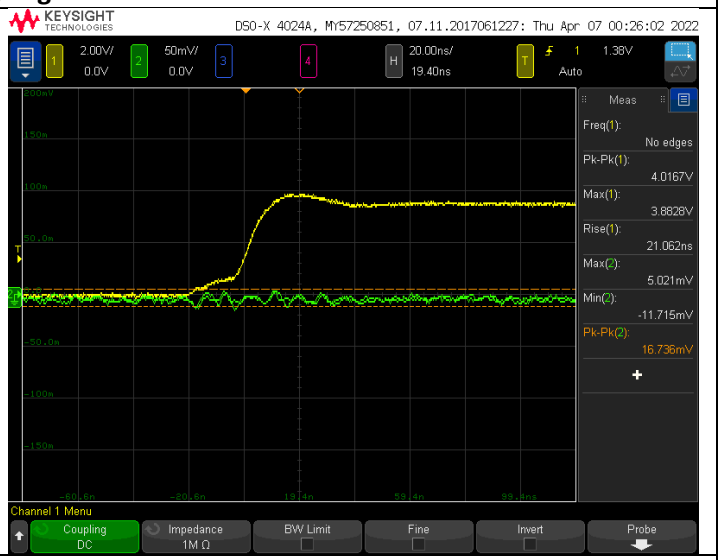
From the above images, Golden Arduino due to its better design has better noise immunity.

EMI Analysis: Analysis was carried out to see the radiation generated by the board due to (dI/dt). This measurement was performed by using the other scope probe as a loop antenna to capture the near field radiation.

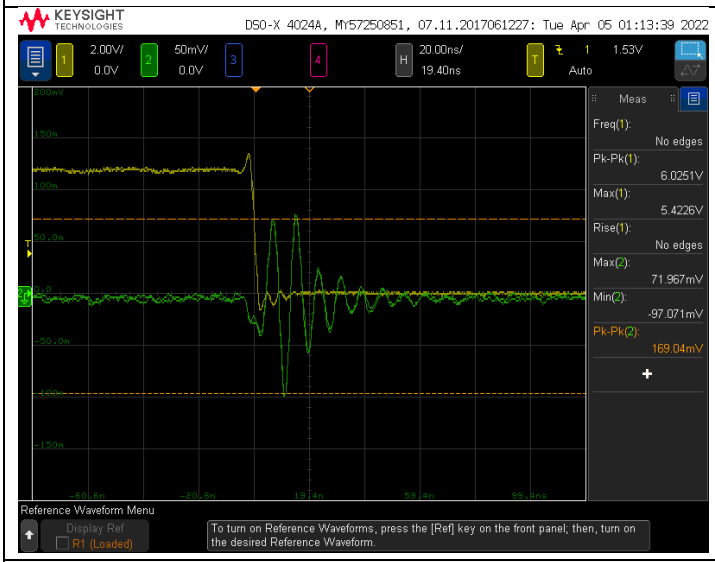
Commercial Arduino Uno Board	**Golden Arduino (GA) Board**

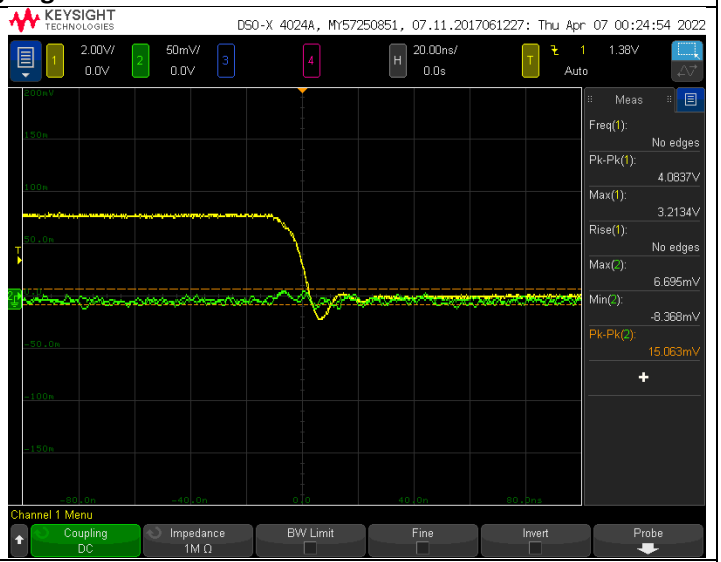
Rising Edge





Falling Edge

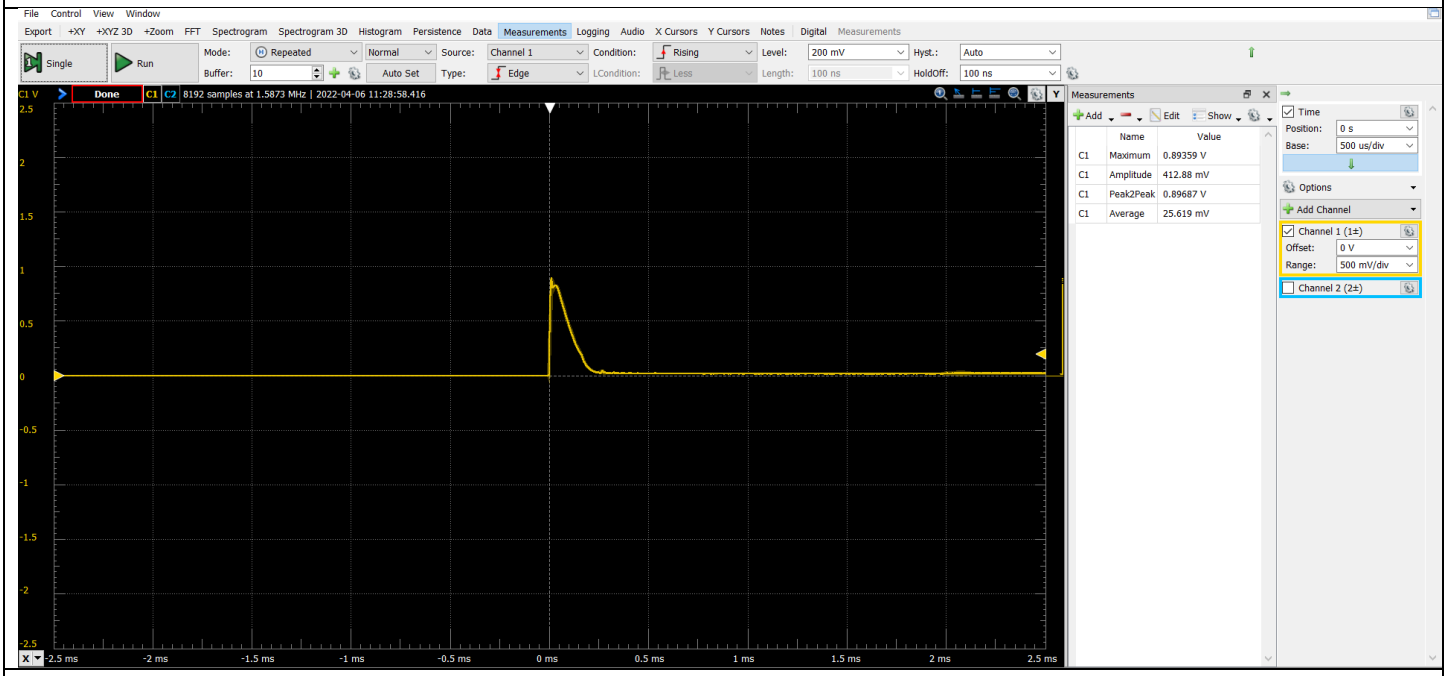




Yellow is the D7 signal whereas the green signal is the usage of another oscilloscope as an antenna probe. The EMI in GA is significantly less compared to commercial Golden Arduino.

Conclusion: A better board was developed majorly due to proper usage of decoupling caps in proximity, small cross under and reduced cross under as well as attempt for 1:1 signal:return path. These design considerations significantly reduced noise.

Inrush Current



Using AD2 scope the inrush current was measured using differential probes. The maximum voltage reached is 0.89359V. R= 0.5 Ohm. I= V/R = 0.89359/0.5 = 1.7A . Hence, even if our board does not make use of large current. It is always better to use a thick trace of 20 mils to handle such surged current at the switch ON condition.

Conclusion:

A better design with good noise immunity was possible to develop due to usage of a continuous common ground plane, placement of decoupling capacitors near to the Vcc of IC, reduced cross under as well as short cross under, and usage of 1:1 signal:return path

Improvement/Care for next time:

Not to rely completely on Altium layout designer even if the schematic shows connectivity between points. The issue occurred due to usage of multiple netlabels which were not necessary. Care must be taken to look for power connections more closely for 1:1 connection with the main power source. This is to reduce a hard-error.

Analysis of your project:

Q. What worked and you did well and want to do in future design

- Labelling every component and division of the blocks beforehand helped to visualize and breakdown tasks. Usage of LED helped to identify from which power selector is the power received as well as the extent to which power is received.
- Getting the schematic reviewed from multiple eyes helped eliminate hard-errors and get a better final product.

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

- Altium did not give a DRC error for connection of Vcc of CR340G to 5V power lane. Due to this, the programming functionality was not active and could not be programmed. A jumper wire from 5V rail was soldered to the CH340G Vcc.
- The 16MHz crystal oscillator oscillations were noisy. 1M Ohm 1208 resistor was removed.
- The 12 MHz crystal was faulty. It required to be replaced from another board to get the oscillations.

Q. Were there any hard errors- why did they go wrong

- Hard error was a missing of voltage connection between CH340G Vcc and 5V rail. It was solved by using a jumper.

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

- CH340G IC was missing as well as AtMega Chi and 10 pin female headers. It was solved by soldering the required pins. The components could be placed properly. CH340G was present in the BOM. It was not on board because the part might be out of stock as was the case with 10 pin female header and AtMega 328.
- Starting earlier can help with component routing and placement planning to reduce further cross under.
- Addition of more indicators would be very helpful to debug with ease for the issue faced with CH340G Vcc.
- Make a better placement of the test points and ICSP header from Arduino shield perspective.
- Addition of a DEBUG LED to test using blinky program and profiling.