Board 3 Report
ECEN 3730 - PCB Design and Manufacturing

Completed by:
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Introduction

Board 3 centers on a custom Arduino Uno compatible PCB, nicknamed the "Golden Arduino." This project aims to refine the board's layout to significantly cut down electromagnetic interference and improve overall noise behavior beyond that of standard commercial Arduinos. In doing so, it emphasizes applying robust PCB design principles and gives practical experience in emission reducing layout techniques.

What does it mean to work?

For Board 3, the Golden Arduino, "working" means it behaves like a standard Arduino while delivering cleaner performance. A functional board must power up reliably, accept a bootloader, be programmable over USB, and successfully run example sketches. The header pins need to be properly positioned so Arduino shields can plug in for noise and emission testing. Key circuitry must also operate correctly, including the voltage regulator stepping 5 V down to 3.3 V, the CH340 USB to serial interface, and the microcontroller itself. Well-placed test points support measurement and troubleshooting, and isolation switches make it possible to disconnect and evaluate different sections of the circuit. When these conditions are met, with lower noise and reduced far-field emissions, the board satisfies the POR criteria.

Board 3 Plan of Record (POR)

1. A power plug to use an external 5V AC to DC charger to power board.
2. Convert 5V to 3.3V
3. USB mini support to program and power the board.
4. A power selector switch to select the source of supply USB of 5V power supply.
5. LDO to convert 5V to 3.3V
6. Indicator LED for 5V and 3.3V
7. Power isolator switch to isolate power to microcontroller and to CH340 chip
8. Reset switch to reset the microcontroller in case of any undesirable behaviour
9. ICSP compatibility to boot-load the microcontroller and also an additional way to program the microcontroller
10. Functionality to measure the in-rush current
11. Additional headers for GND connection to ease the process of connecting sensors or take any other measurements

12.Plan test points for these signals:

a. 5V input

b. 3.3V input

c. To measure the in-rush current

d. The D+ and D- of USB

e. VBUS of the USB

f. RX and TX of the microcontroller

g. SDA and SCL of the microcontroller

13.Placing decoupling capacitor closer to all the ICs to reduce the switching noise

14.Copper poured return plane(ground)

Schematics and Design

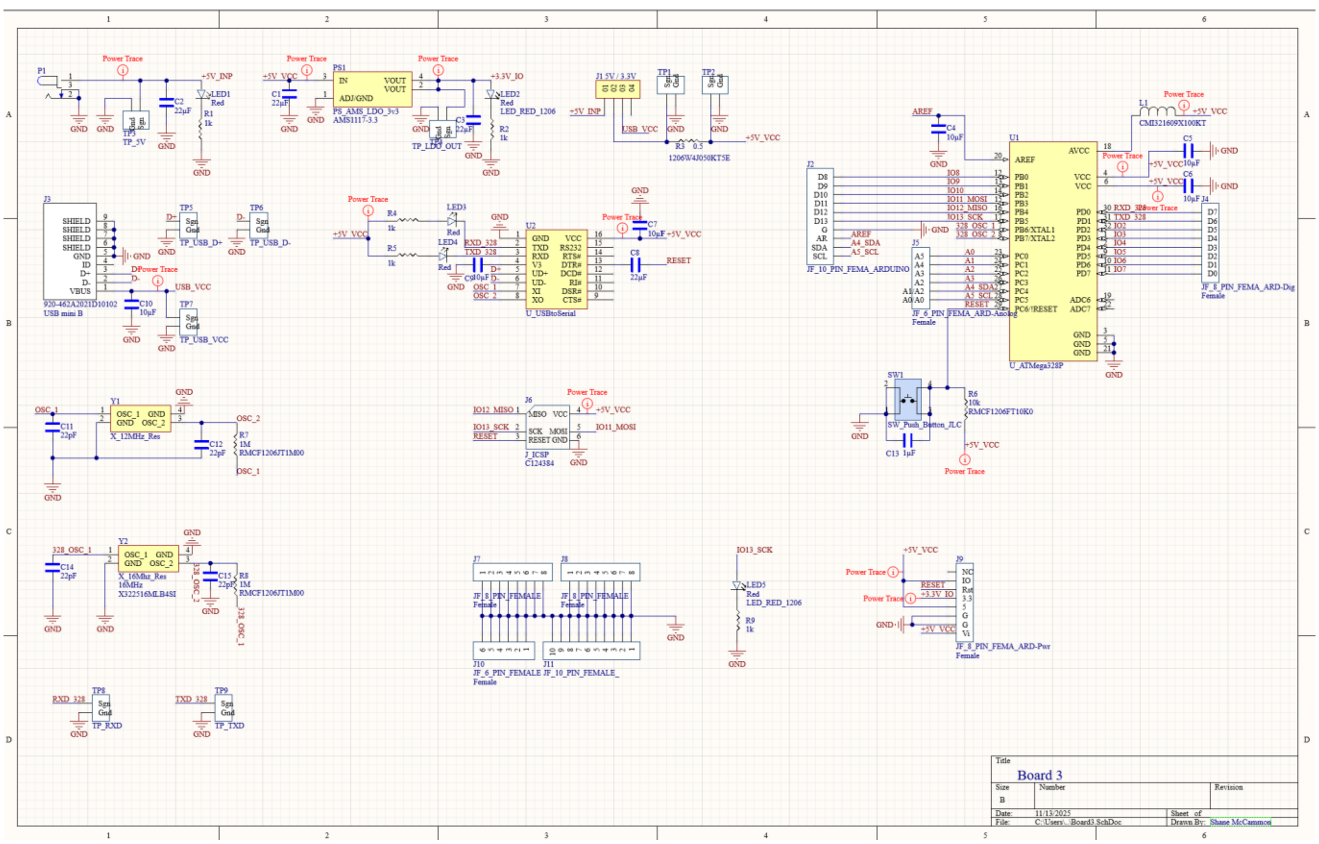

Figure 1: Altium schematic of Board 3

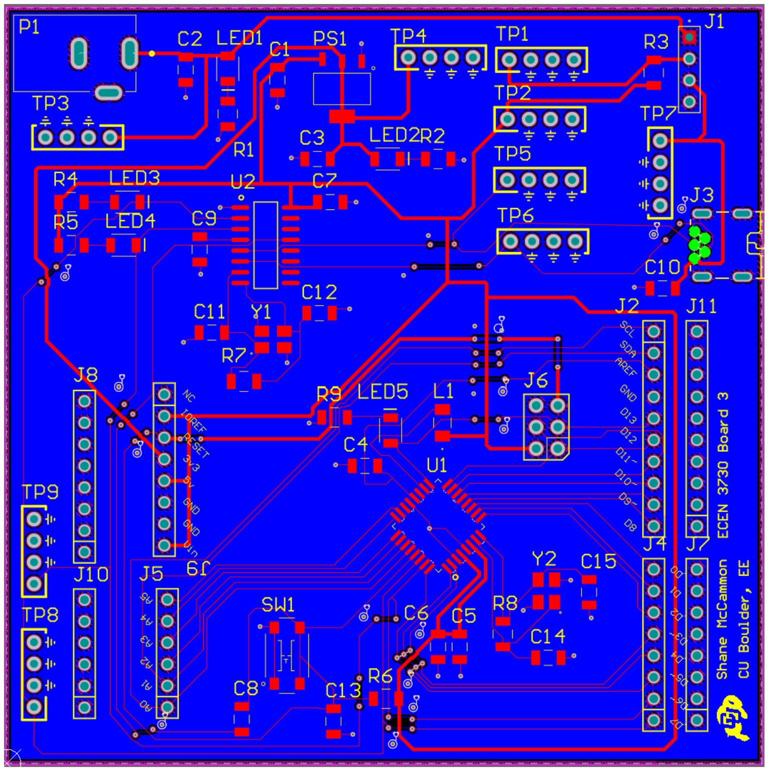

Figure 2: Altium board assembly

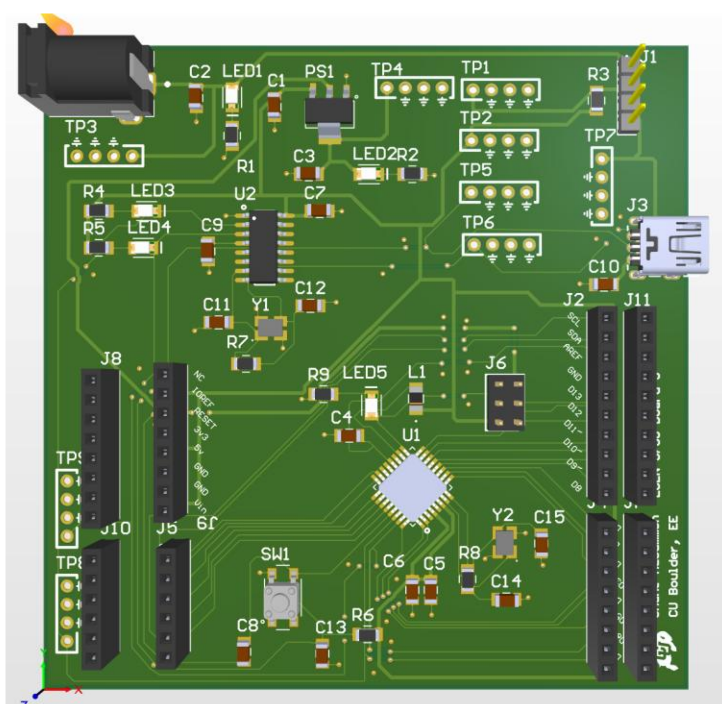

Figure 3: Printed and Assembled Board 3

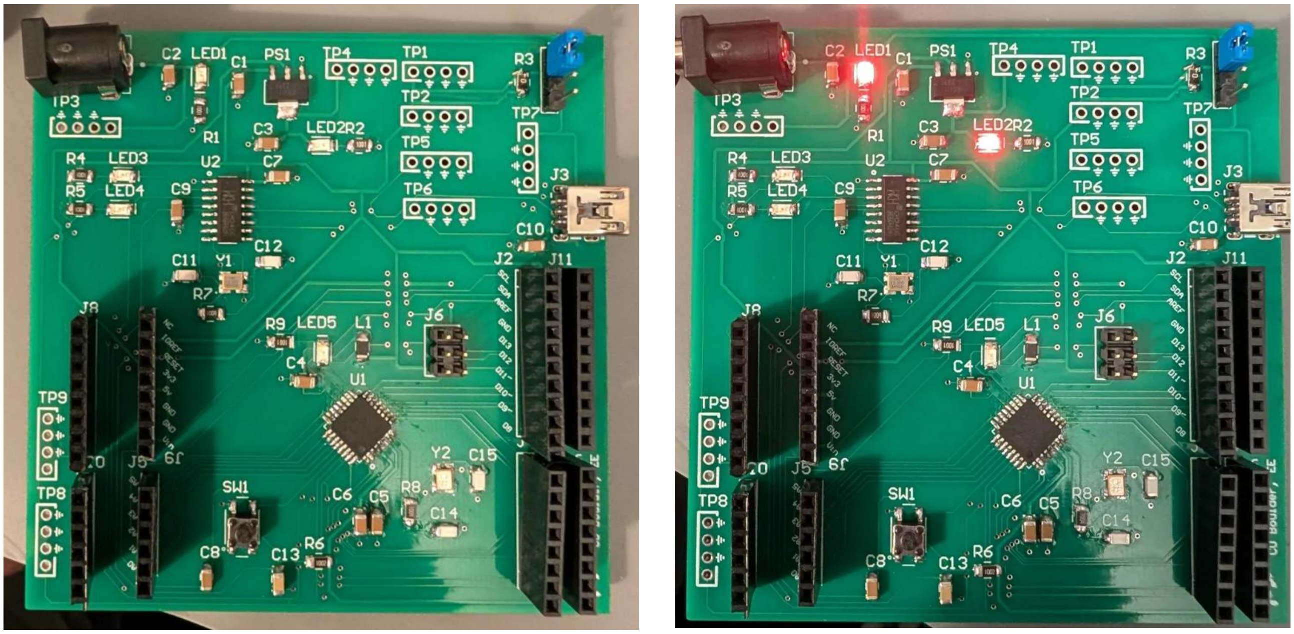

Figure 4: Completed & Boot-loaded Board 3

Output Waveforms

To obtain measurements from both the commercial Arduino and my Arduino, I uploaded the sample code in Figure 5 to both while also using a noise shield circuit to measure and compare noise in both Arduinos.

```
void setup() {
  DDRB = B00111111;
  pinMode(7, OUTPUT);
  digitalWrite(7, LOW);
}

void loop() {
  PORTB = B00111101;
  delayMicroseconds(4);
  PORTB = B00000001;
  delay(1);
  digitalWrite(7, HIGH);
  delayMicroseconds(400);
  digitalWrite(7, LOW);
  delay(10);
}
```

Figure 5: Sample Code for Noise Measurements

Commercial Arduino Measurements:

Figure 6: Trigger output (yellow) compared to 5V rail noise (green)

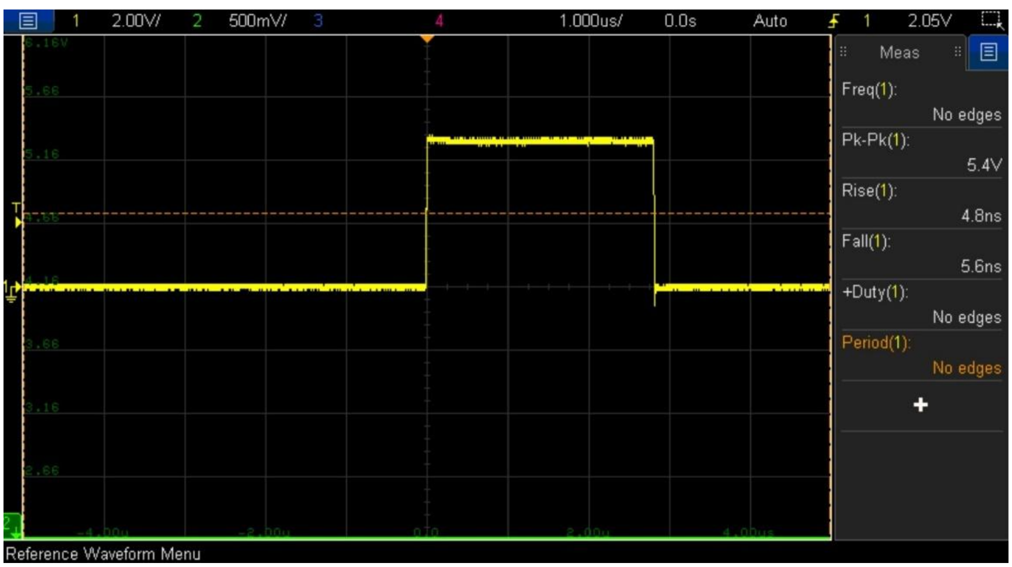

Figure 7: Trigger Output

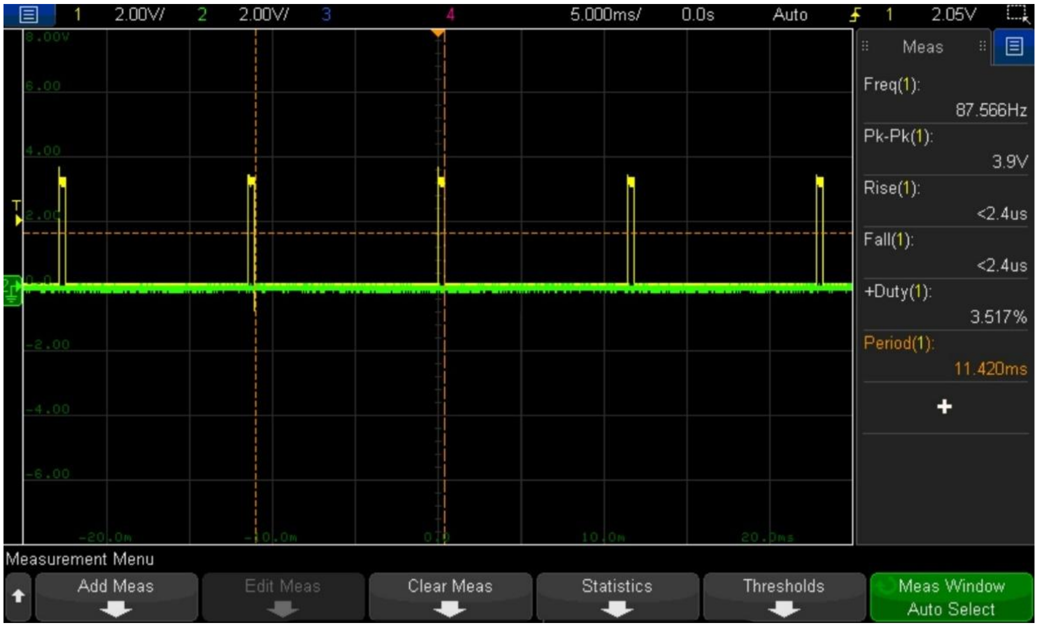

Figure 8: Slammer circuit current

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Figure 9: Voltage drop across 47 Ohm resistor

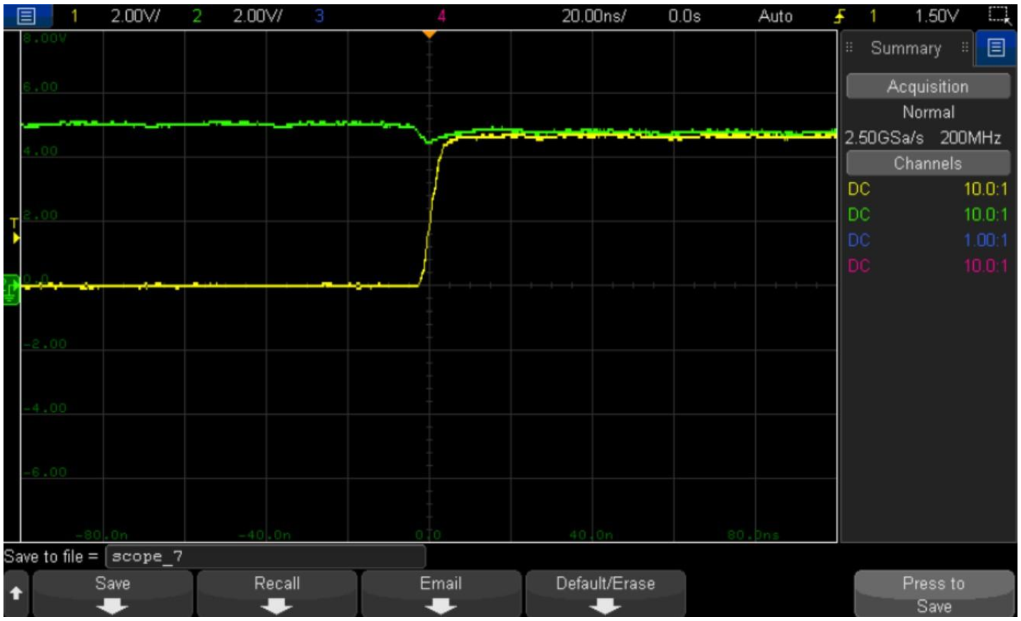

Figure 10: Quiet high noise vs Trigger rising edge

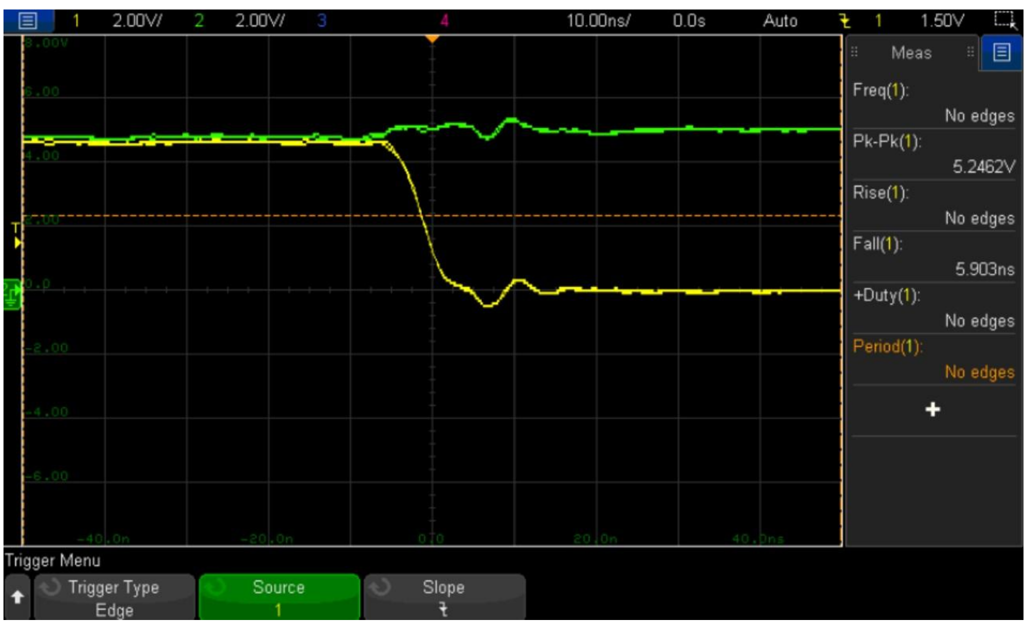

Figure 11: Quiet high noise vs Trigger falling edge

(CH1) Rise Time: 5ns / **Fall Time:** 5.902ns / **Peak-to-Peak:** 5.247V
(CH2) Rise Time: 11ns / **Fall Time:** 5ns / **Peak-to-Peak:** 0.5V

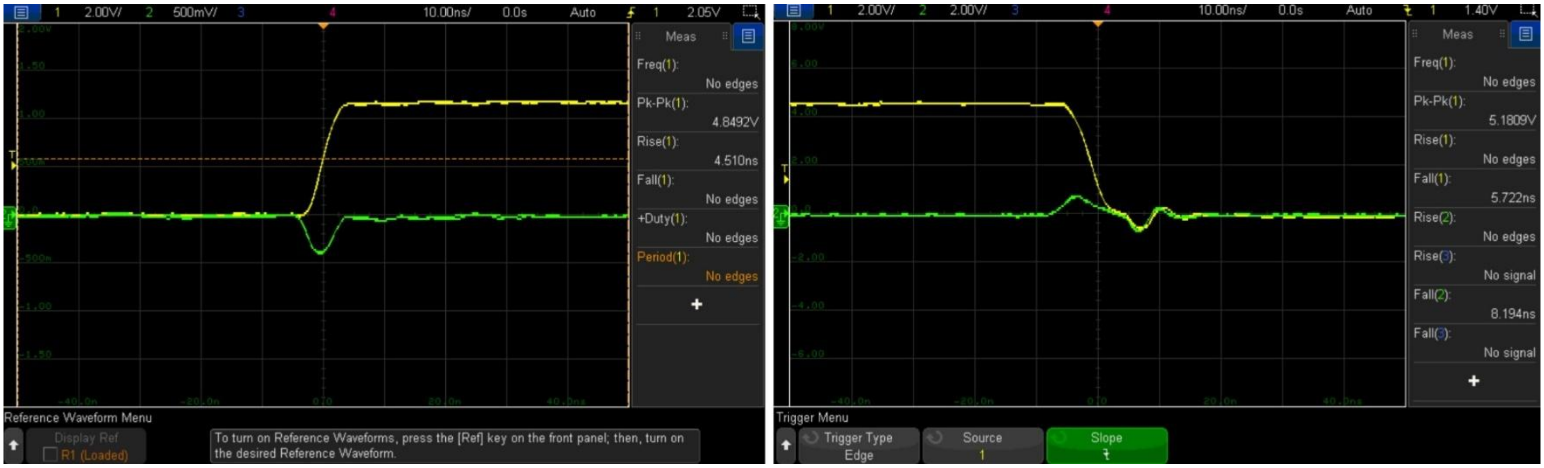

Figure 12: Quiet low noise vs Trigger rising and falling edges

(CH1) Rise Time: 4.51ns / **Fall Time:** 5.722ns / **Peak-to-Peak:** 5.015V
(CH2) Rise Time: 7ns / **Fall Time:** 8.192ns / **Peak-to-Peak:** 0.75V

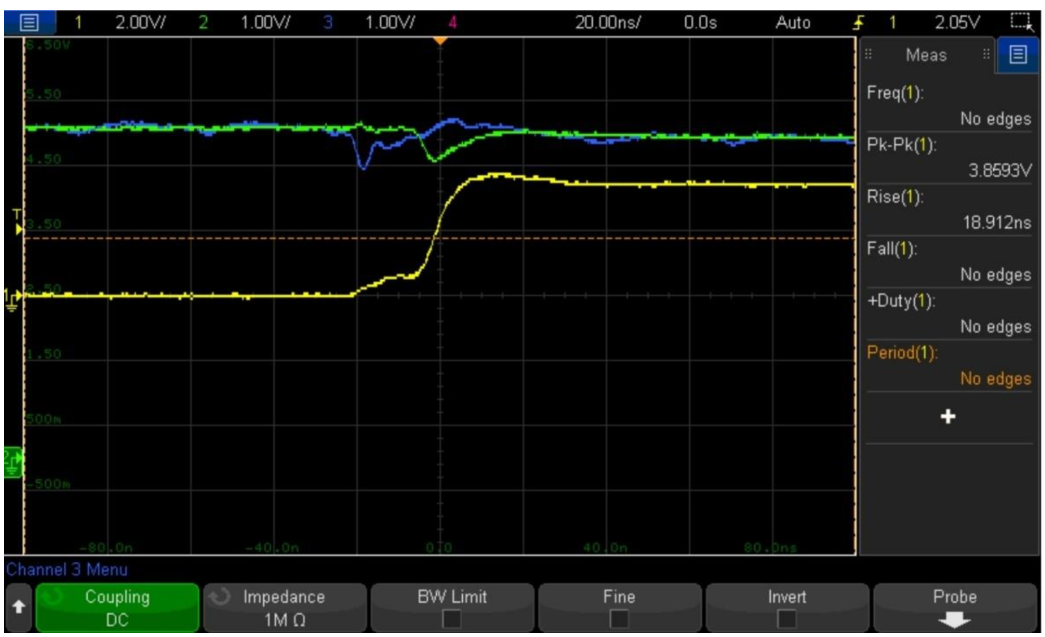

Figure 13: Power rail noise (microcontroller aggressor)

(CH1) – slammer current rise time, **(CH2) –** 5V Power rail noise , **(CH3) –** Quiet High

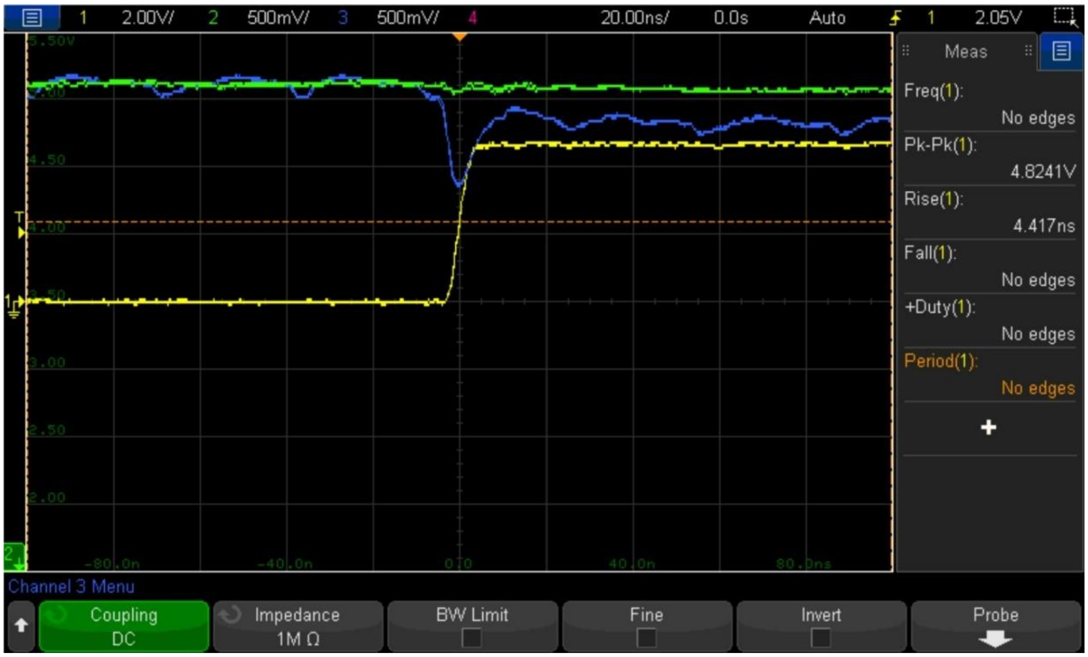

Figure 14: Power rail noise (board as aggressor)

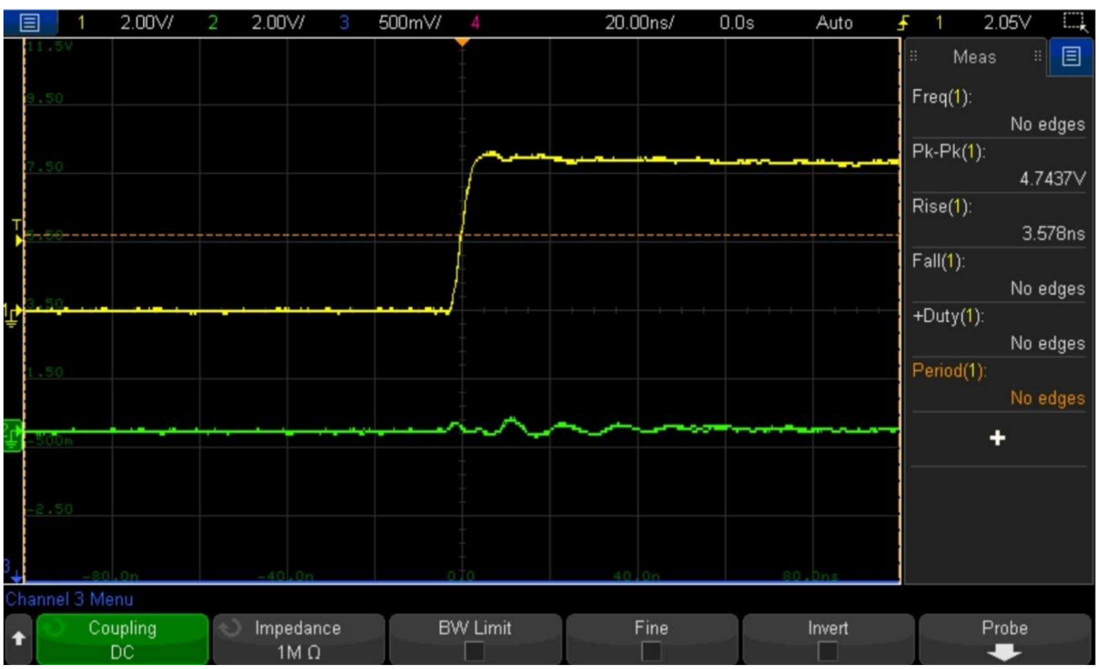

Figure 15: Trigger output compared to Near field emission

Board 3 Measurements:

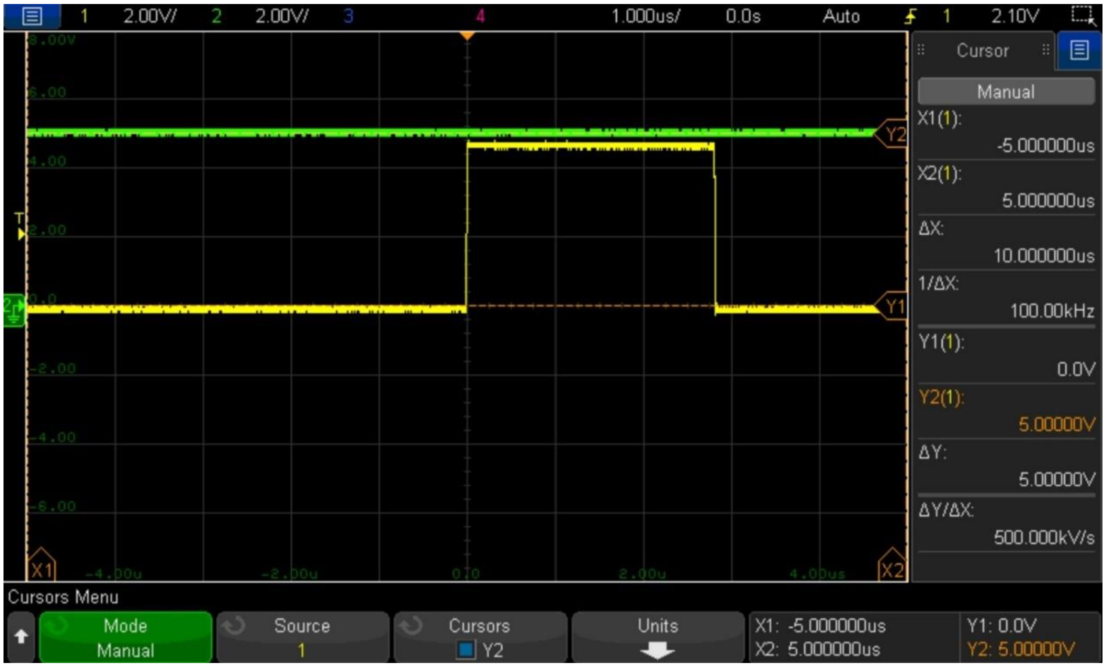

Figure 16: Trigger output (yellow) vs 5V rail noise (green)

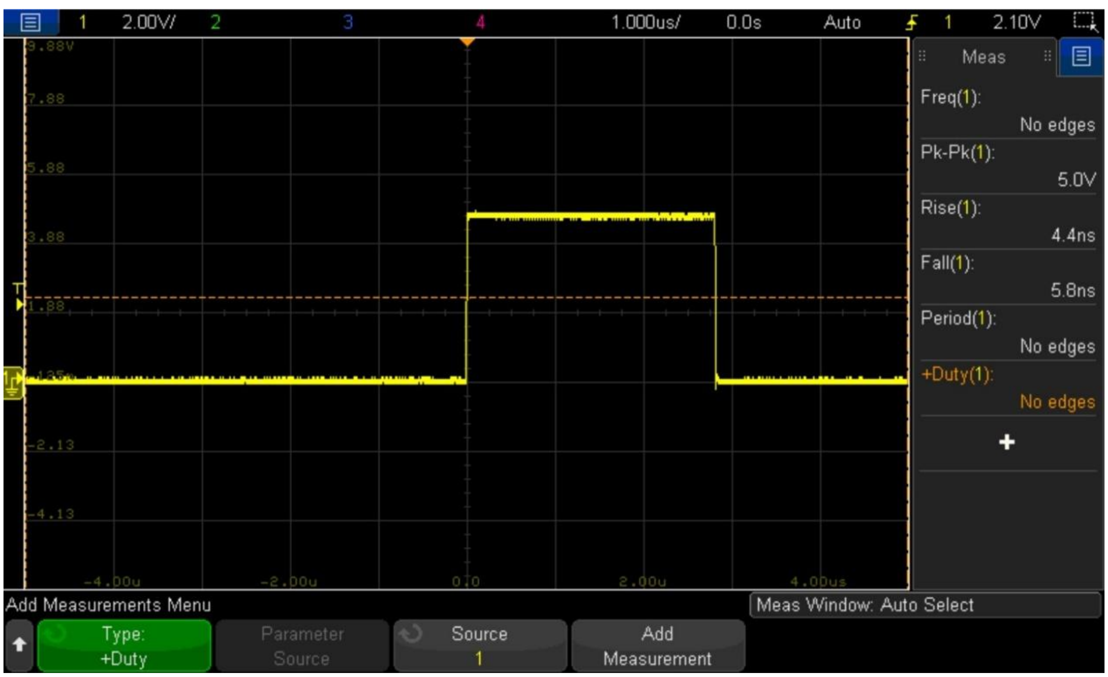

Figure 17: Trigger output

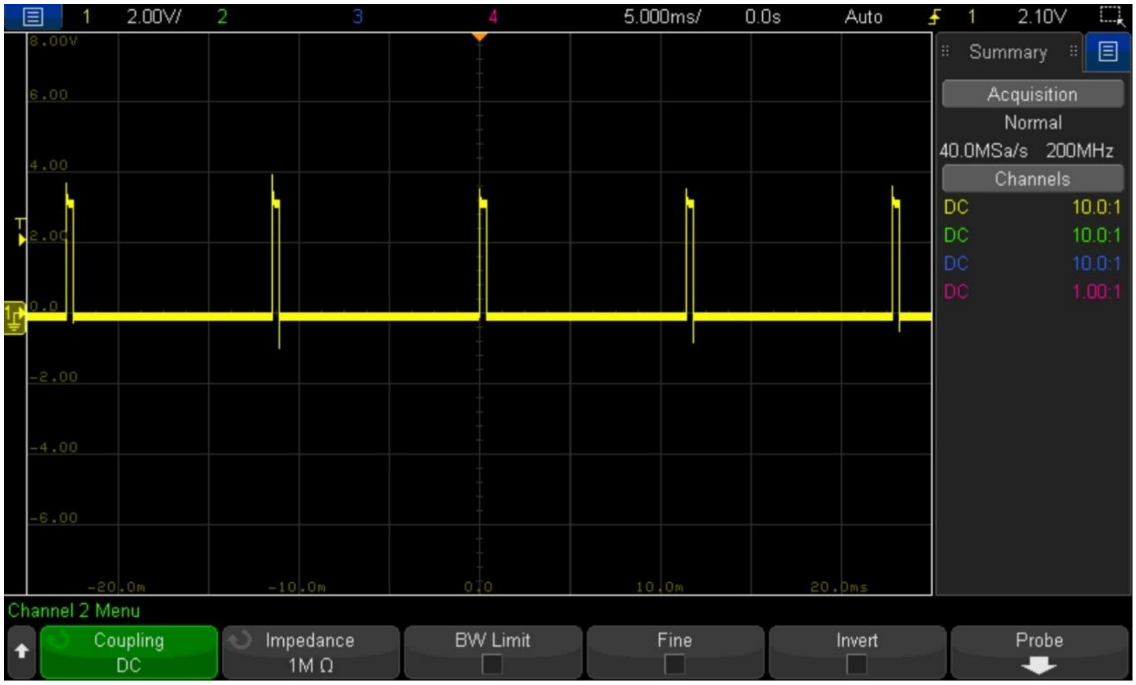

Figure 18: Slammer circuit current

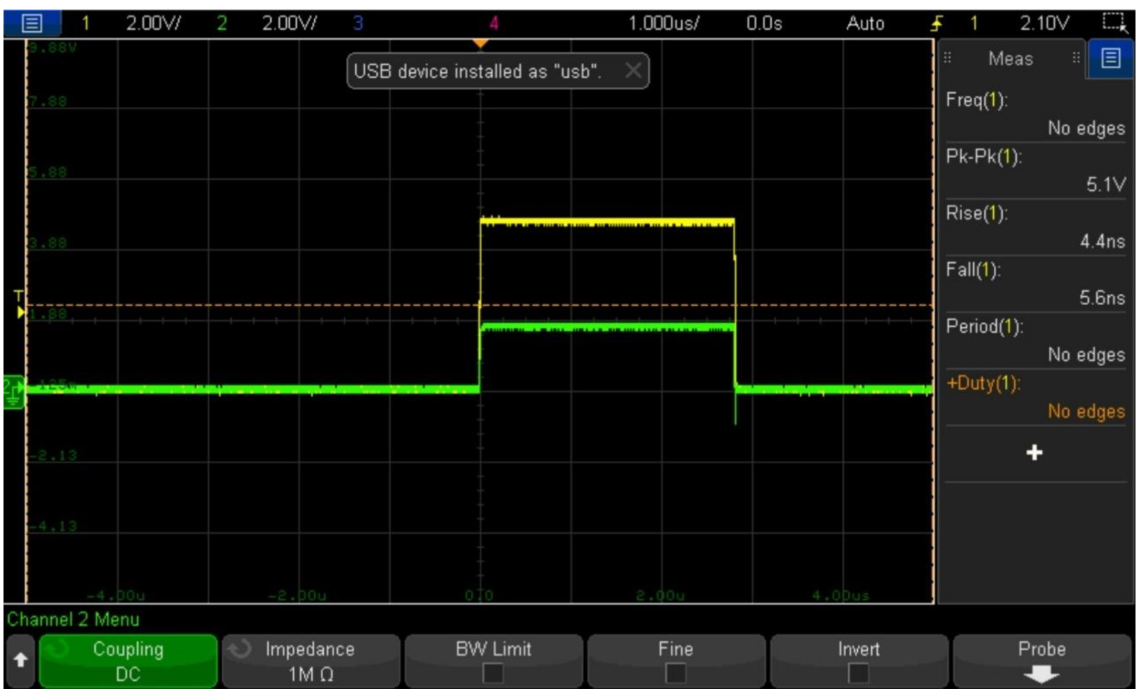

Figure 19: Voltage drop across 47 Ohm resistor

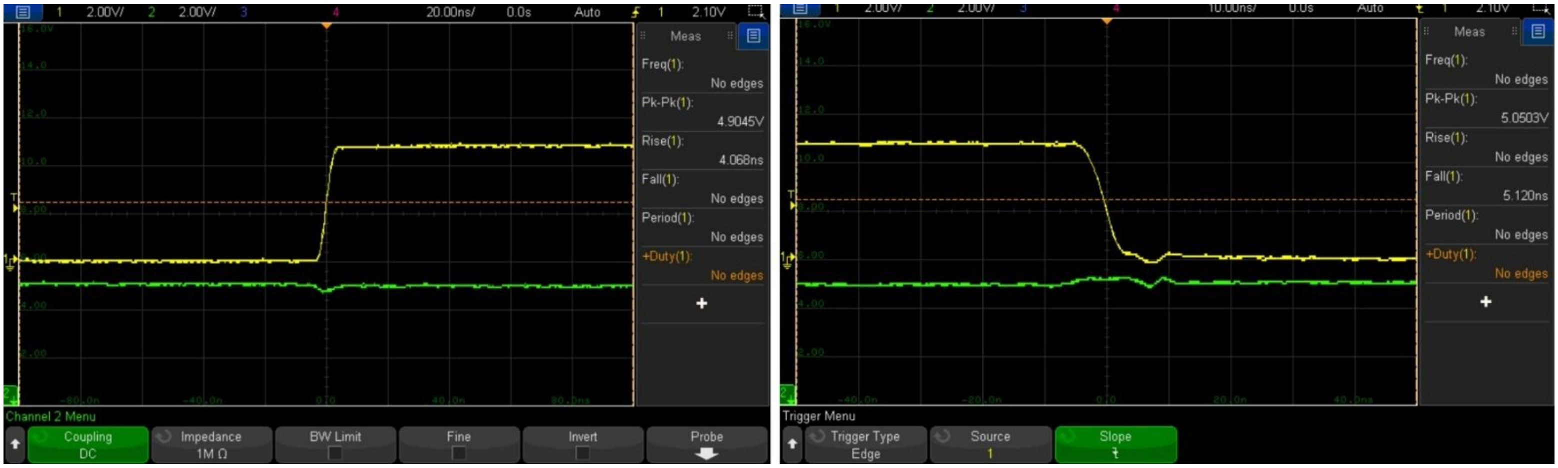

Figure 20: Quiet high noise on rising and falling edges

(CH1) Rise Time: 4.068ns / **Fall Time:** 5.12ns / **Peak-to-Peak:** 5.051V
(CH1) Rise Time: 5ns / **Fall Time:** 6ns / **Peak-to-Peak:** 0.25V

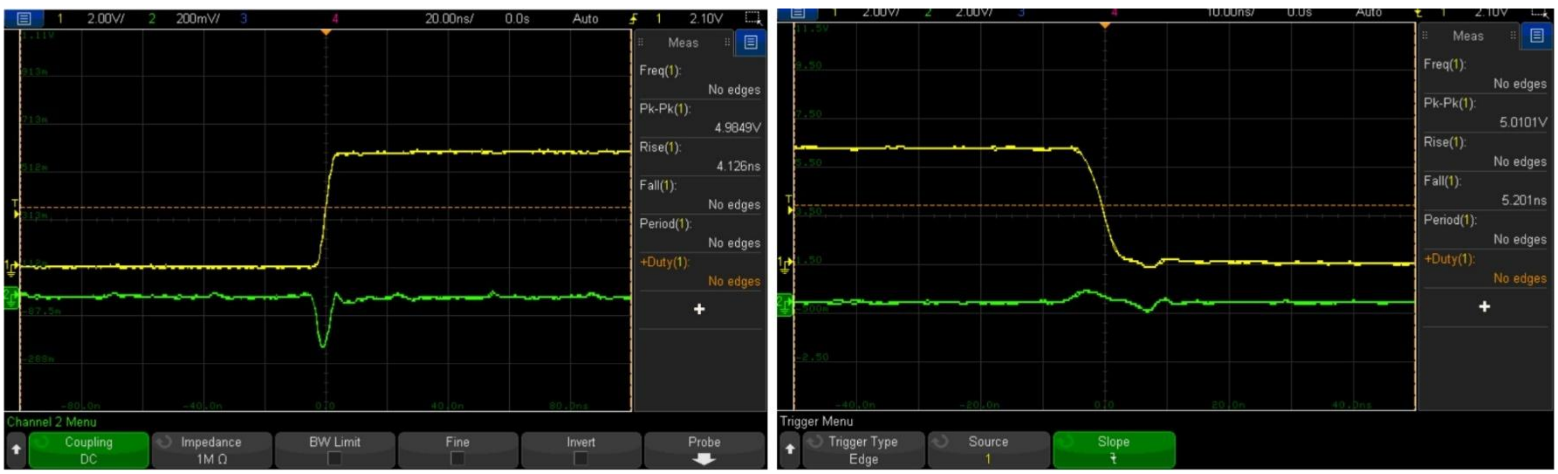

Figure 21: Quiet low noise on rising and falling edges

(CH1) Rise Time: 4.128ns / **Fall Time:** 5.2ns / **Peak-to-Peak:** 5.01V
(CH1) Rise Time: 3ns / **Fall Time:** 6ns / **Peak-to-Peak:** 0.5V

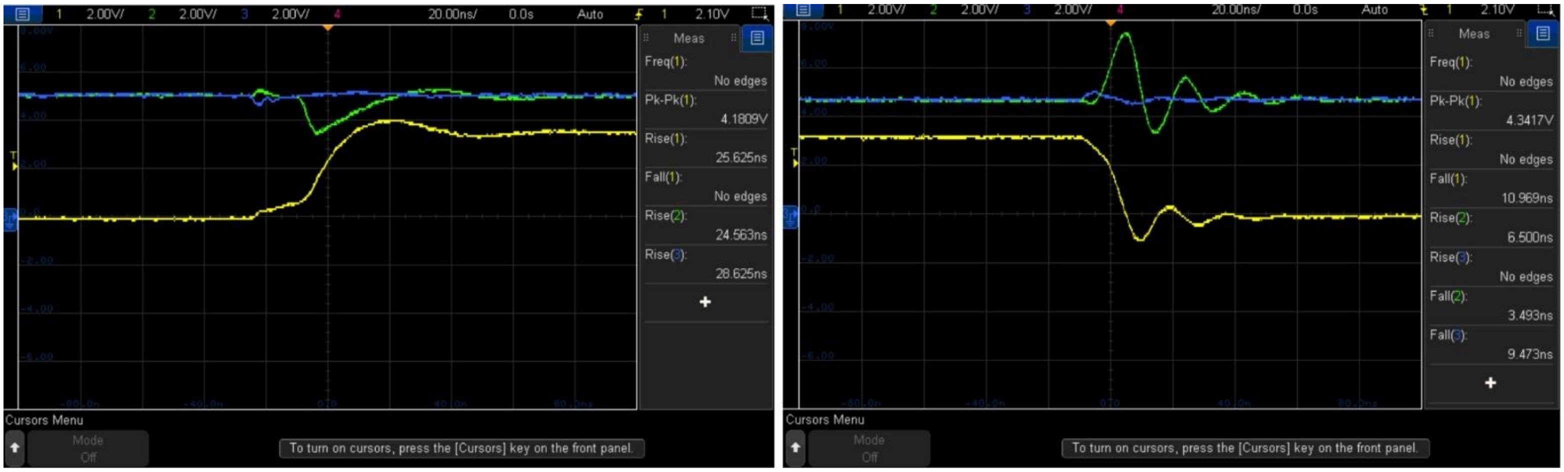

Figure 22: Rise/fall time of power rail noise (microcontroller as aggressor)

(CH1 – slammer current) Rise Time: 25.625ns / **Fall Time:** 10.967ns
(CH2 – 5V rail noise) Rise Time: 24.564ns / **Fall Time:** 3.491ns
(CH3 – quiet high) Rise Time: 28.625ns / **Fall Time:** 9.473ns

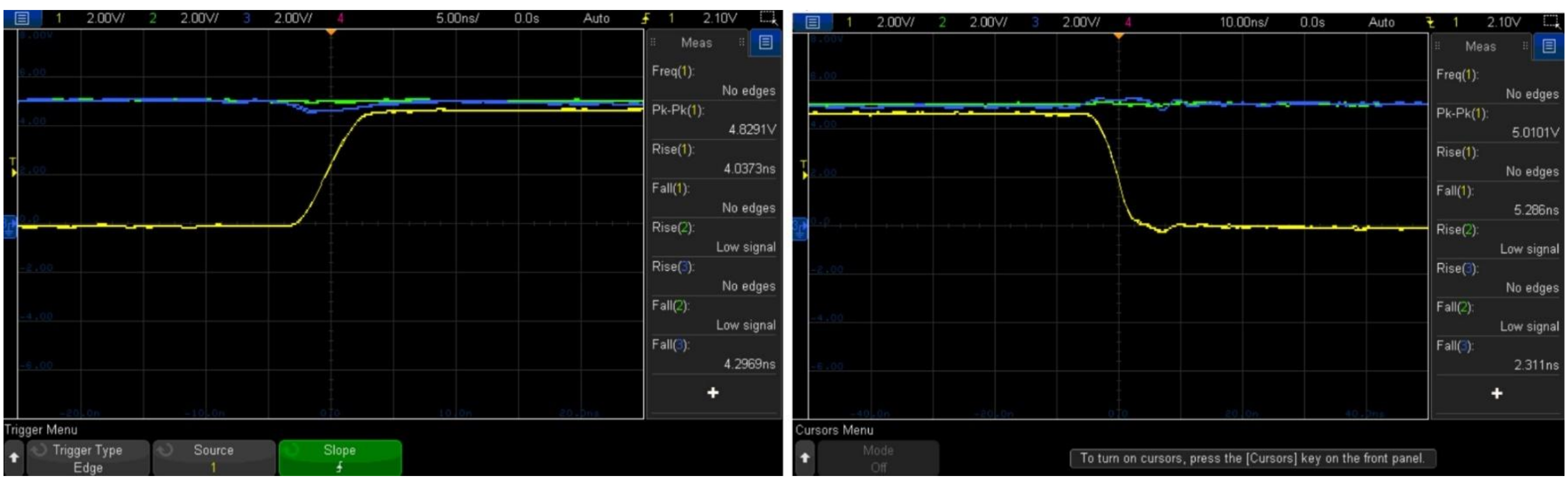

Figure 23: Rise/fall time of power rail noise (board as aggressor)

(CH1 – Trigger) Rise Time: 4.027ns / **Fall Time:** 5.286ns
(CH2 – 5V rail noise) Rise Time: - / **Fall Time:** -
(CH3 – quiet high) Rise Time: - / **Fall Time:** 2.311ns

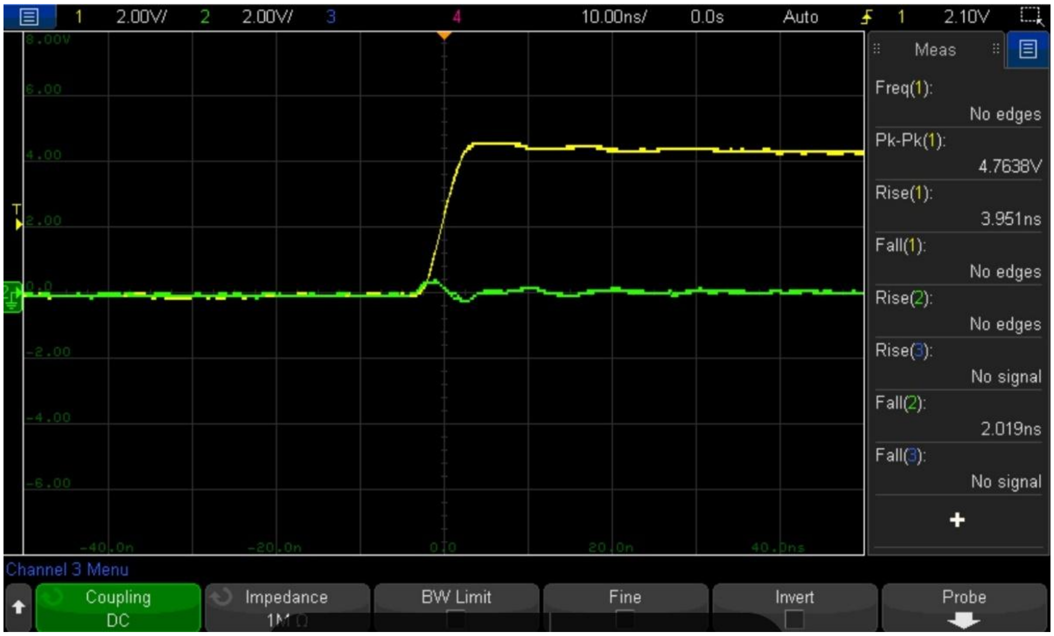

Figure 24: Near field emission of Board 3 compared to Trigger

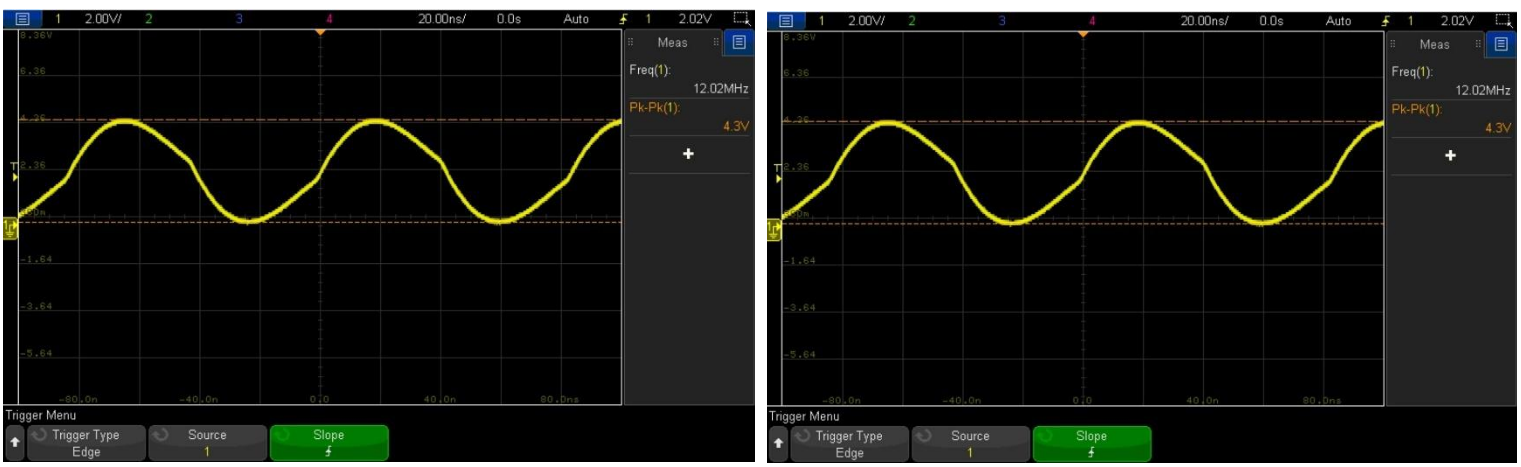

Figure 25: 12MHz (left) & 16MHz (right) crystal oscillator outputs

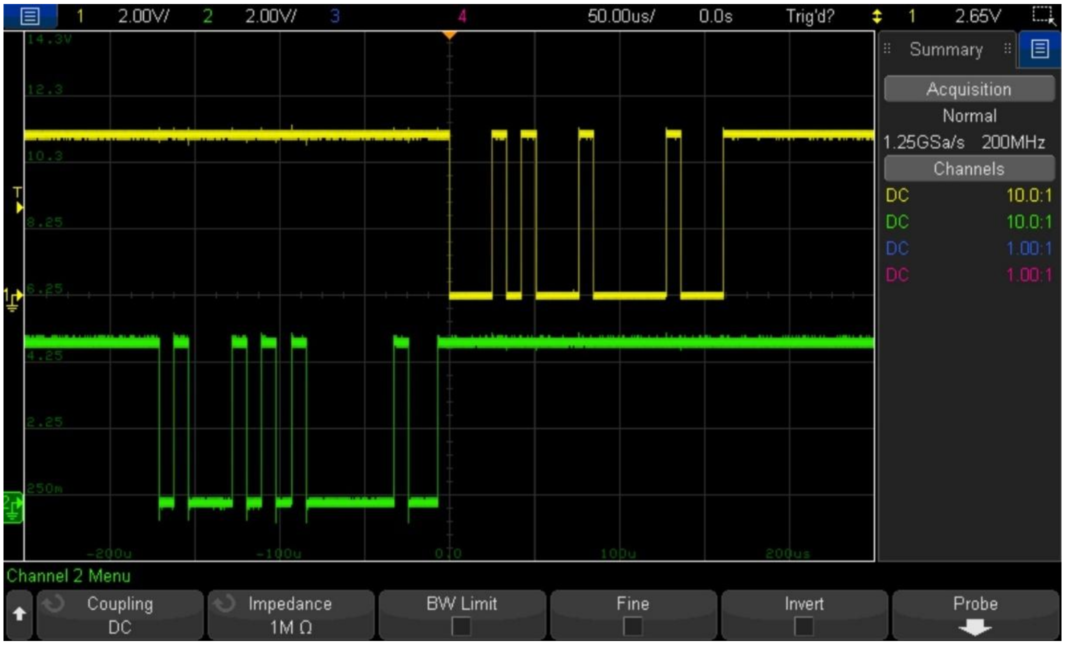

Figure 26: Board 3 TX and RX outputs

Figure 27: Board 3 mini USB D+ and D- signals

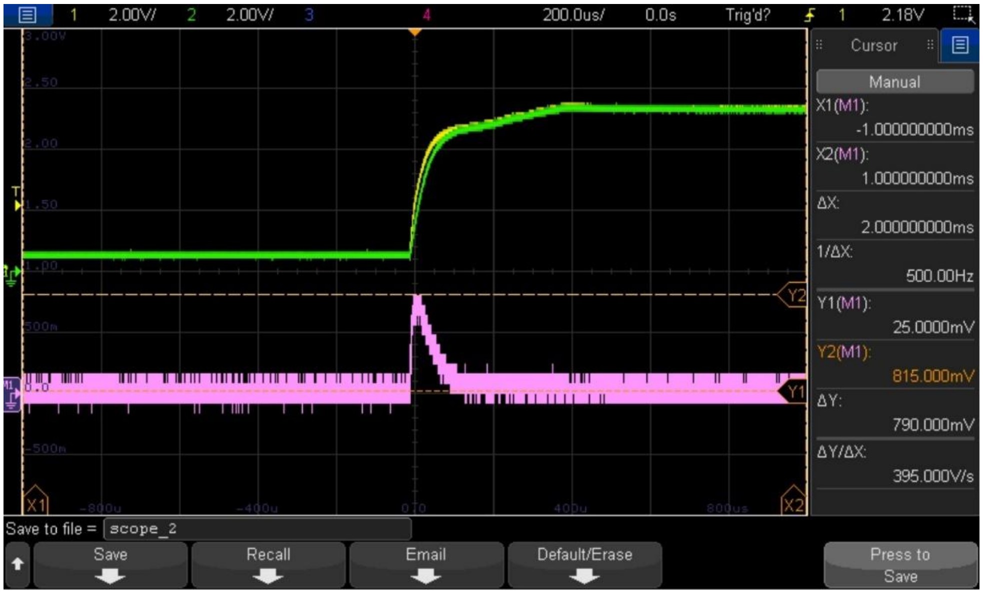

Figure 28: 5V Barrel jack in-rush current

Figure 29: 5V USB in-rush current

Barrel Jack In-Rush Current: 790mV/0.1 = **7.9A**

USB In-Rush Current: 920mV/0.1 = **9.2A**

Analysis

The Golden Arduino PCB incorporates several targeted upgrades over a standard Arduino Uno to lower noise, improve supply stability, and reduce electromagnetic interference (EMI). This section summarizes how the board performs, based on lab measurements and testing.

Voltage Drop Across R2

To estimate current consumption, a 47 Ω sense resistor (R2) was used and the voltage across it was measured. On the Golden Arduino, the drop across R2 was 1.879 V, corresponding to about 40 mA of current. Under the same conditions, the commercial Arduino showed a 1.6 V drop, or roughly 34 mA. The slightly higher current on the Golden Arduino indicates it is capable of supporting a bit more load, which is consistent with a design focused on robust performance during signal activity.

Noise Reduction

A major design priority was cleaning up the 5 V power rail, since its quality directly impacts how stable the entire board is. Decoupling capacitors were placed very close to the power pins of sensitive devices such as the microcontroller and the CH340G USB-to-serial interface to filter out switching transients. Oscilloscope comparisons between the commercial board and the Golden Arduino showed that the custom board exhibited roughly 50% less noise on the 5 V line. In practice, this means fewer unwanted disturbances riding on the supply.

Near-Field Emissions

Near-field emissions describe how much localized electromagnetic energy the board generates, which can couple into nearby electronics. To characterize this, a 10× probe was used as the trigger, while a second probe configured as a small loop was moved underneath the PCB to scan for field emissions. To reduce these emissions, the Golden Arduino design incorporates a solid ground plane in the power path. These changes reduced the measured near-field noise relative to a standard Arduino Uno, meaning the Golden Arduino is less likely to interfere with surrounding devices.

Power-Rail Stability During Switching

The steadiness of the 5 V rail, especially during rapid signal transitions, was another key focus. Power-rail noise was evaluated under two scenarios: one where the microcontroller generated the switching activity and another where the board's own circuitry acted as the primary aggressor.

Microcontroller as Aggressor: In this setup, measurements were taken at the trigger, 5 V, and "quiet high" test points while the microcontroller rapidly toggled its outputs. This kind of activity normally injects noticeable noise onto the supply. Oscilloscope traces showed that the Golden Arduino maintained lower noise levels on the 5 V rail compared to the commercial Arduino, demonstrating better suppression of switching-induced disturbances.

Board as Aggressor: Here, a dedicated slammer circuit on the board was used to stress the power rail. Probes were placed on the 5 V and quiet high test points to see how much the voltage fluctuated during these events. The Golden Arduino showed smaller voltage excursions during these transitions, indicating a more stable supply. Design choices such as a continuous ground plane and routing that avoids unnecessary trace overlap helped to reduce spikes and improve overall power integrity.

Inrush Current

Inrush current—the surge that occurs when the board is first powered—was also examined, because overly high inrush can stress components. Initially, a 0.5 Ω current-sense resistor was used, but this configuration led to a higher startup surge than desired. Replacing it with a 0.1 Ω resistor significantly reduced the initial current spike, resulting in a smoother and safer power-on behavior. It was also observed that powering the board from a bench power supply produced lower inrush current than powering it over USB, making the bench supply the gentler option for startup conditions.

Conclusion

Design Improvements:

I initially had a hidden short on my ATMEGA chip that caused a lot of issues getting it started and working. I also messed up the spacing of my headers, so the slammer circuit did not initially fit onto my board. I built a small adapter to connect it to my board 3 and it worked great. Moving forward, I would definitely use solder paste to connect smaller components and chips as well as triple checking my layout measurements when they are critical. I also would've liked to have an indicator LED for the USB line as I found that would be helpful when troubleshooting. You may also notice that I used a 0.5Ohm resistor as the in-rush current sense resistor but later changed it to 0.1Ohm to improve in-rush current measurements.

Knowledge Obtained:

1. Good Via Placement: Conserves board space and can also be used to lower emi in cross-unders of multi-layer PCBs
2. Near-Field Emission Design: Helps reduce far-field emissions staying within EMC compliance
3. Crystal Oscillator Placement: Place oscillators as closely to IC as possible for proper voltages and timing