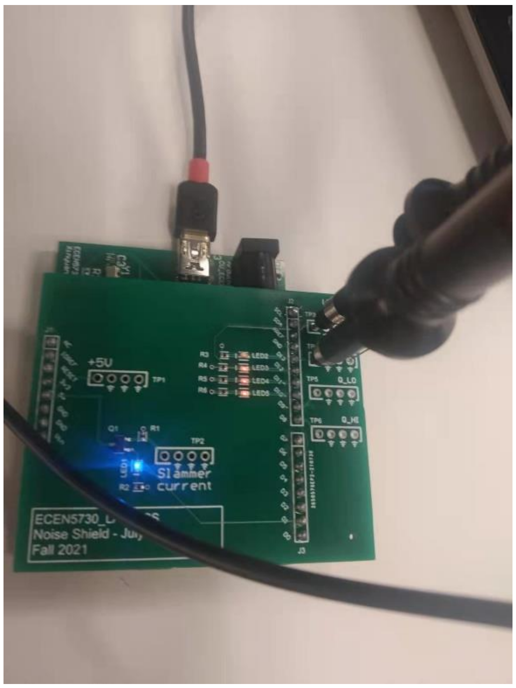
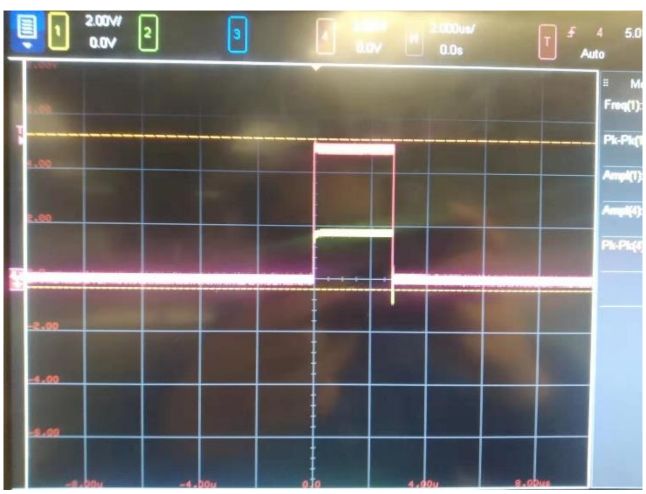
Noise Measurements

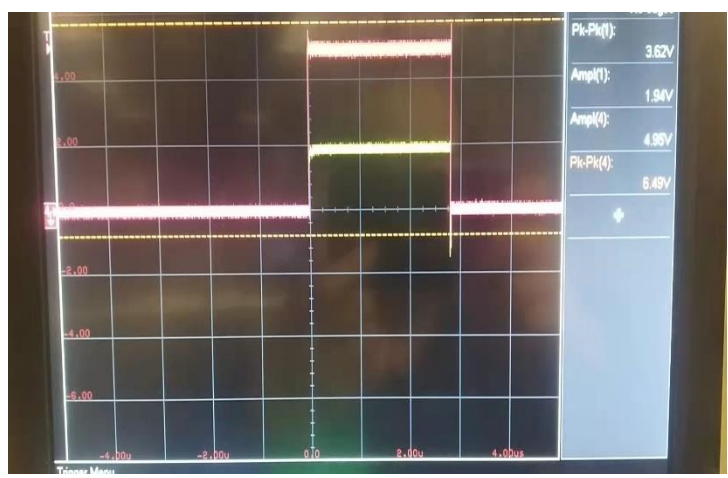
1. When the three I/O were switching, what was the total current switching, the duration, and the rise time? (left column is my board, the right is commercial Arduino).
   Use a plot of the measured current to justify your analysis.

   Measurement setup: Measure TP4 the trigger pin, TP3 the current.



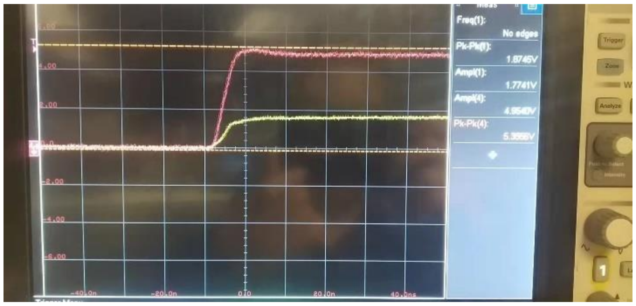
The scope trace of duration, current through 63ohm.

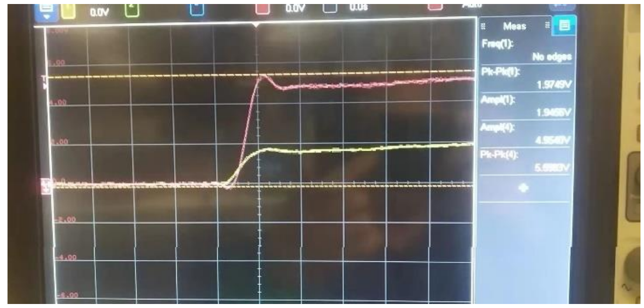




The duration is about 3us, the current through 63ohm is about I = 2V/63ohm = 30mA.

Scope trace of rise time.

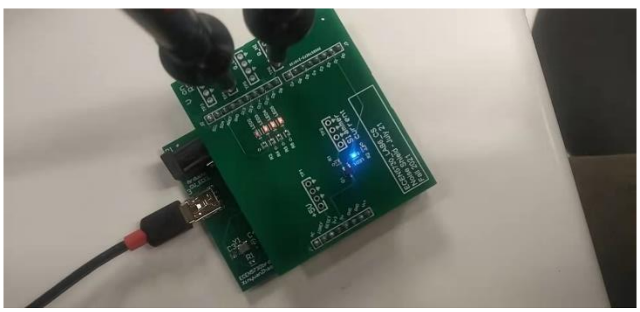


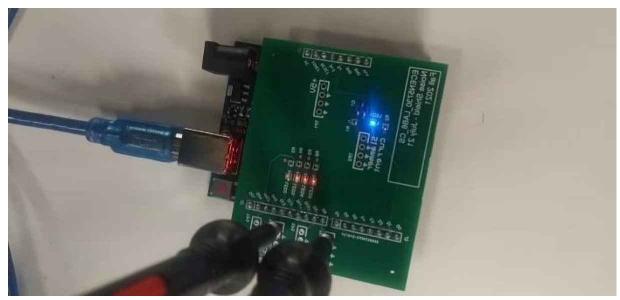


The rise time is about 10ns.

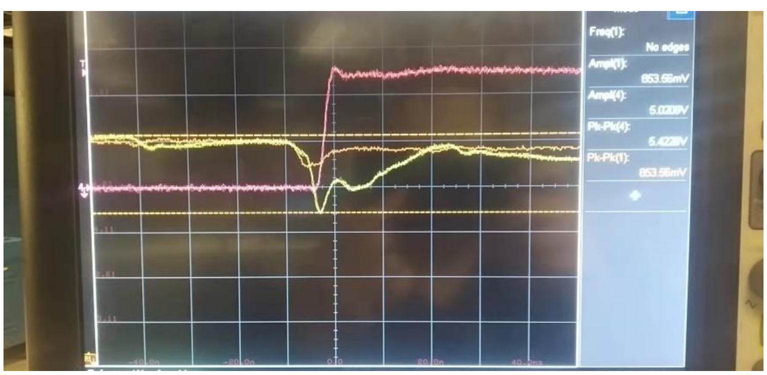
2. What was the quiet HIGH and quiet LOW noise on the die for the rising edge? Compare these on the same plot.

   Measurement setup: (An example of measuring quiet high and trigger)



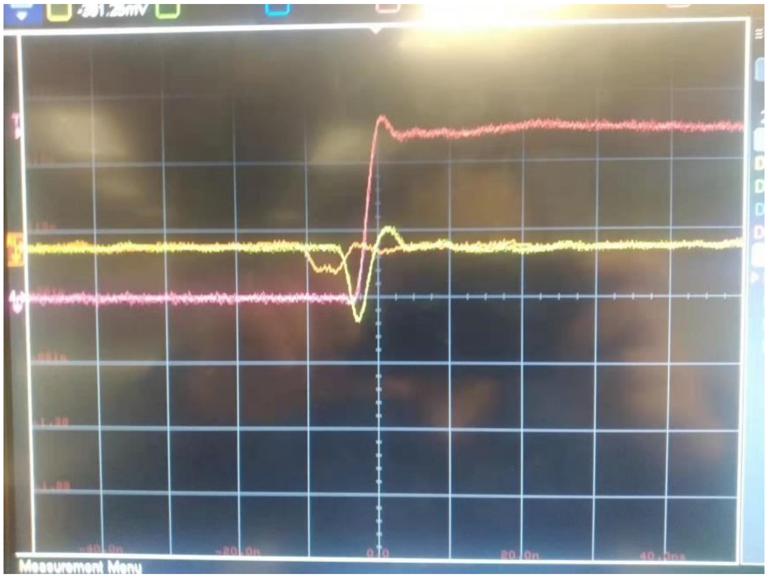


   Scope of quiet high noise on same plot. (Rising edge)



The orange trace is quiet high noise on my board, its pk to pk about 300mV, the yellow trace is the commercial board, the noise pk to pk is about 850mV.

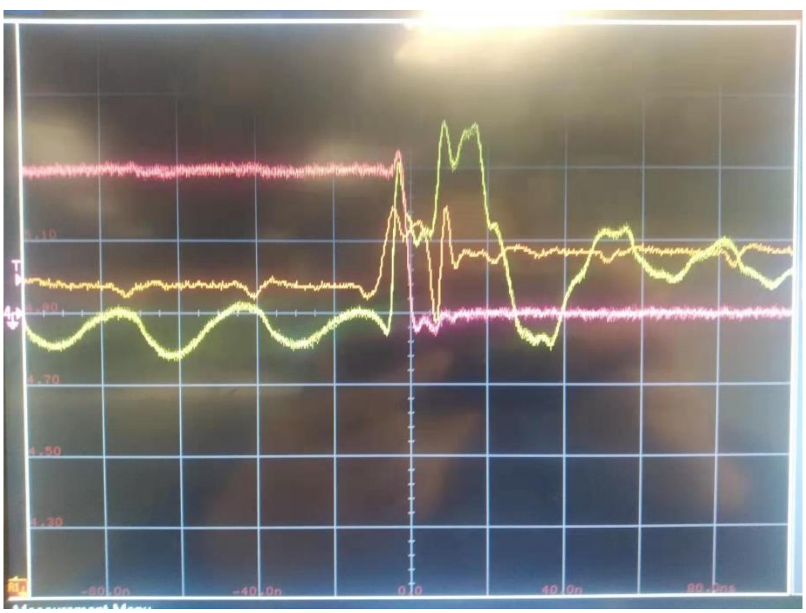
Scope of quiet low noise on same plot. (Rising edge)



The orange trace is quiet low noise on my board, its pk to pk about 250mV, the yellow trace is the commercial board, the noise pk to pk is about 680mV.

3. Do the same analysis for the falling edge. Any comments amount this noise?

Scope of high noise on same plot (falling edge)



The orange trace is quiet high noise on my board, its pk to pk about 300mV, the yellow trace is the commercial board, the noise pk to pk is about 700mV.

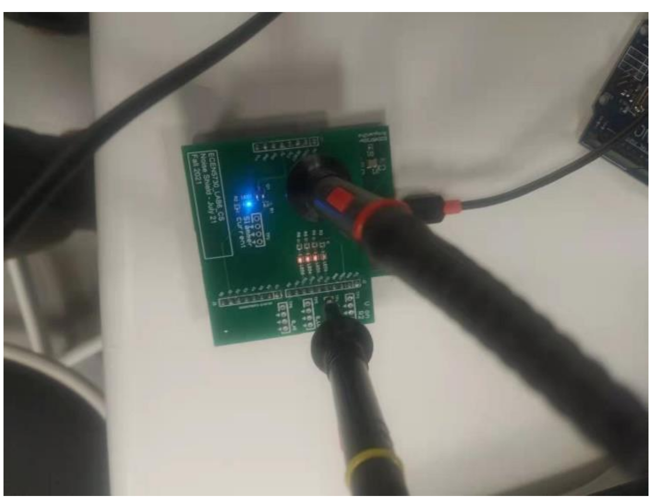
Scope of low noise on same plot (falling edge)

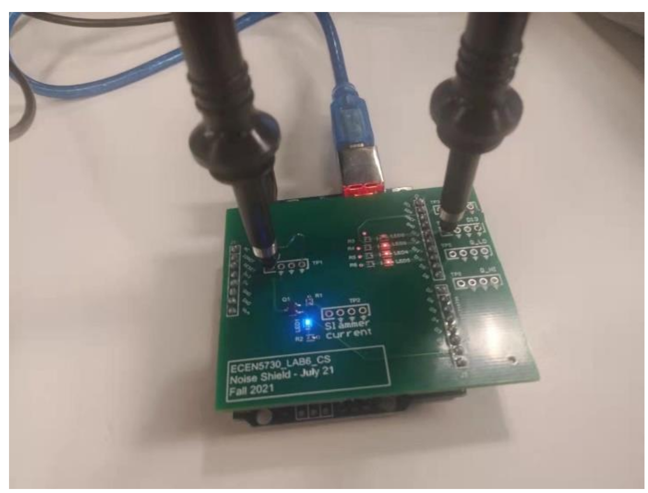
The orange trace is quiet high noise on my board, its pk to pk about 850mV, the yellow trace is the commercial board, the noise pk to pk is about 1.45V.

Comment on this noise: The quiet low noise and high noise on my board is a lot lower than the quiet low noise and high noise on the commercial board on both rising edge and falling edge.

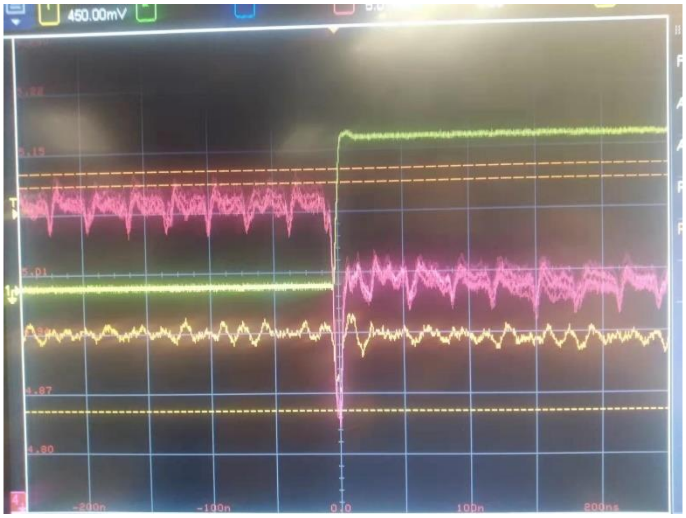
4. When the I/O current was switching, what was the difference in switching noise on the 5 V rail on the die and on the board? Compare the two measurements on the same plot.

   Measurement setup: Measure the 5v rail on board and on die





Scope of 5v on the die and on the board, rising edge on my board.



The orange trace is the noise on board, its pk to pk is about 80mV.

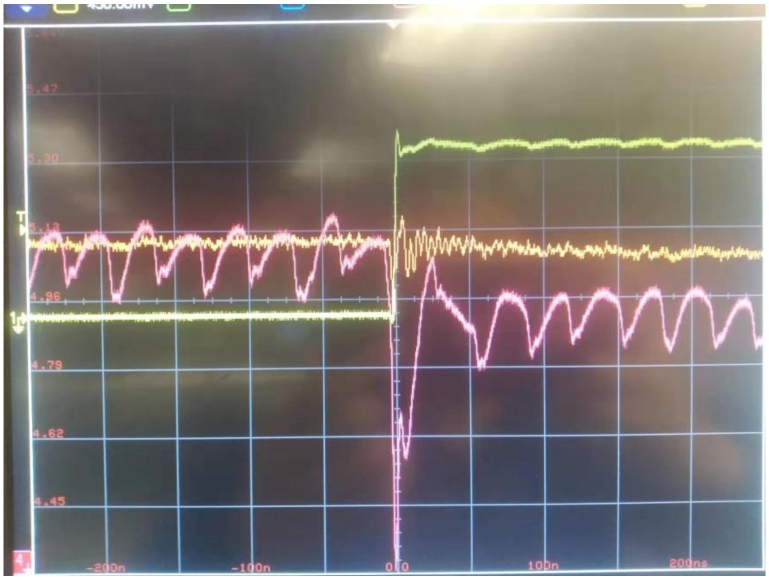
The red trace is the noise on die, its pk to pk is about 280mV.

Scope of 5v on the die and on the board, falling edge on my board.

The orange trace is the noise on board, its pk to pk is about 100mV.

The red trace is the noise on die, its pk to pk is about 300mV.

Scope of 5v on the die and on the board, rising edge on commercial Arduino.



The orange trace is the noise on board, its pk to pk is about 100mV.

The red trace is the noise on die, its pk to pk is about 850mV.

Scope of 5v on the die and on the board, falling edge on commercial Arduino.

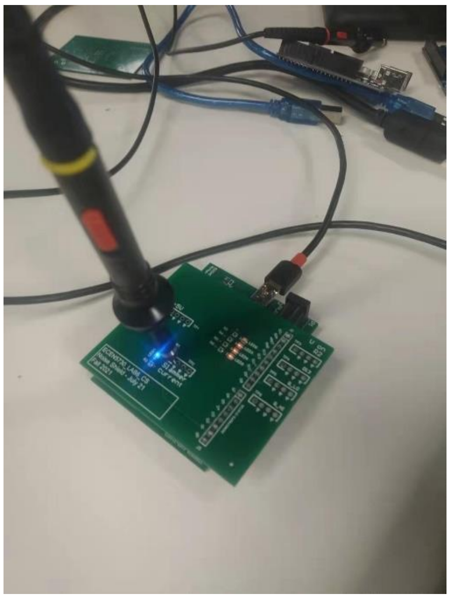
The orange trace is the noise on board, its pk to pk is about 200mV.

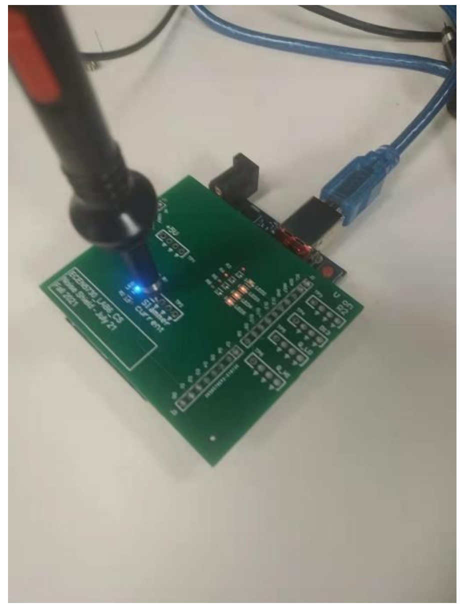
The red trace is the noise on die, its pk to pk is about 1V.

Analysis: the noise on the board is significantly lower than the noise on the die when the IO pins are switching.

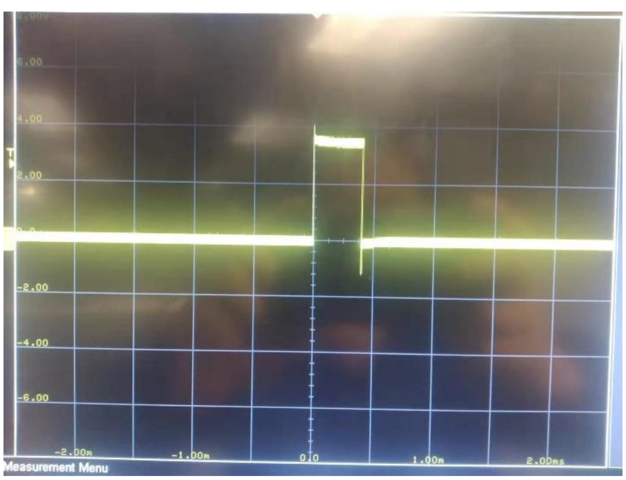
5. When the slammer circuit triggered, what the was current flowing through the 5 V rail on the die? What was the duration and the rise time?

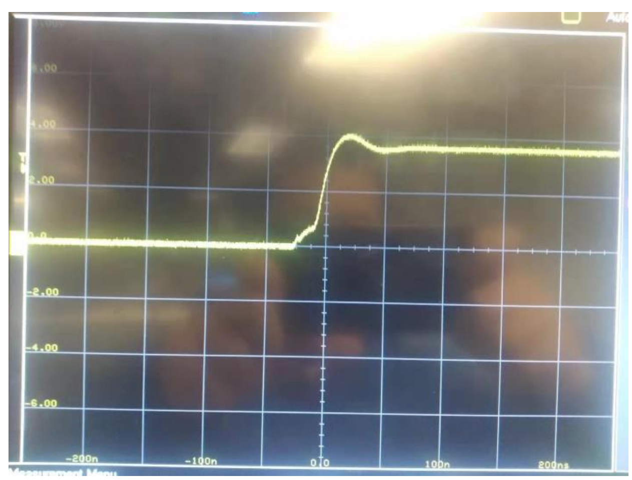
Measurement setup: Measure the slammer current.





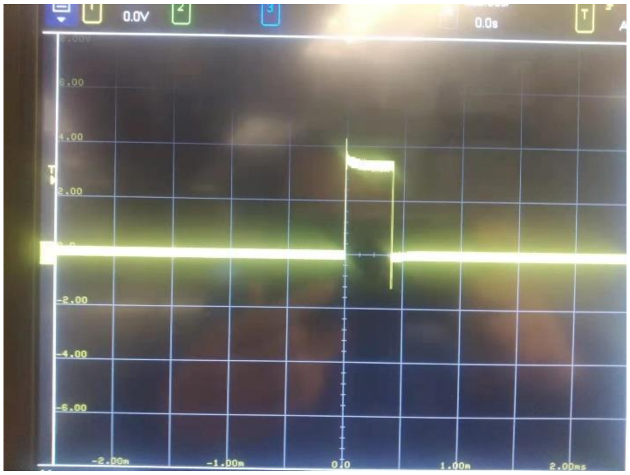
Scope of current through 5v on the die, duration and rise time on my board.





The voltage is about 3.6v, The current I = 3.6v/10ohm = 360mA. The duration is 400milsec. The rise time is about 23ns

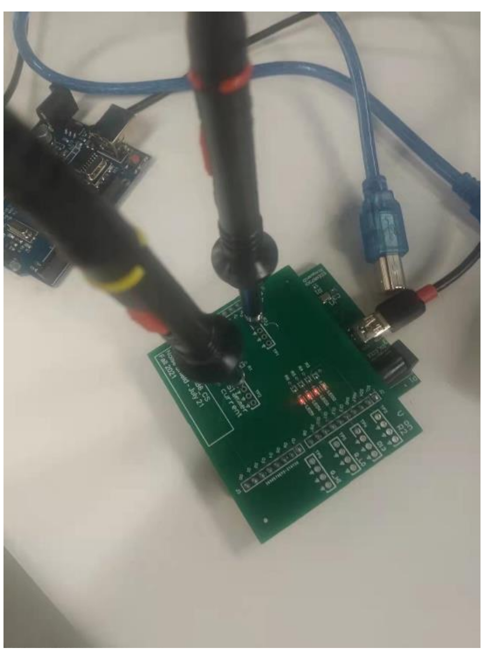
Scope of current through 5v on the die, duration and rise time on commercial arduino.

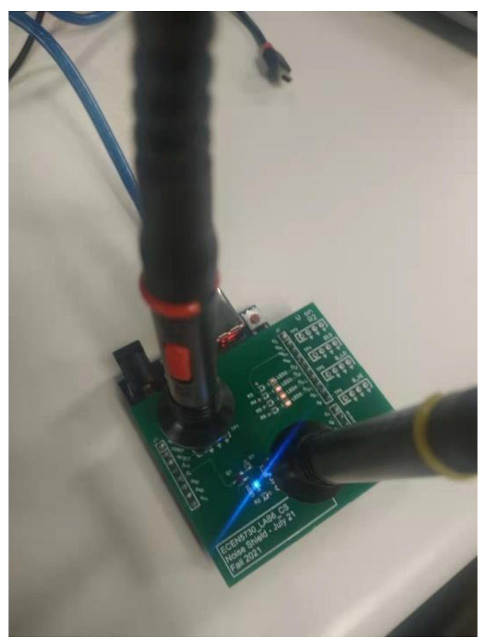


The voltage is about 3.6v, The current I = 3.6v/10ohm = 360mA. The duration is 400milsec. The rise time is about 17ns

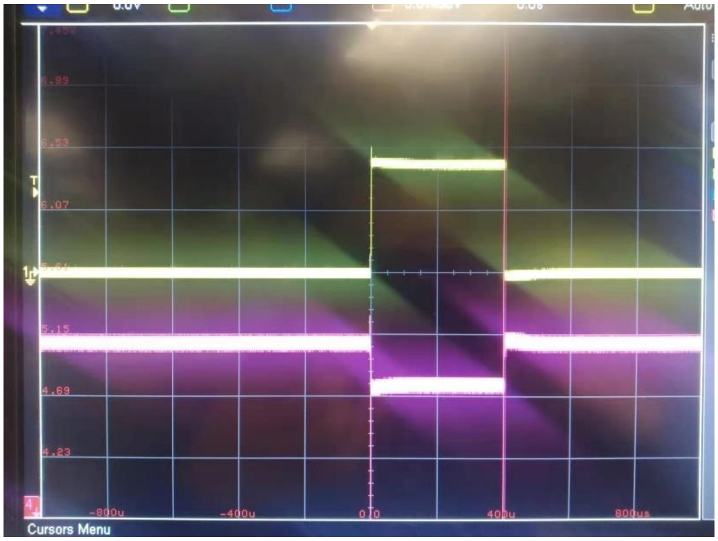
6. What was the voltage drop on the 5 V rail at steady state and the current flow? What does this suggest as the output Thevenin source resistance of the 5 V power rail?

   Measurement setup: connect the slammer current as trigger and 5v rail.





Scope of voltage drop on 5V rail on my board



The voltage drop is about 360mV, the current is about 360mA, The output Thevenin source resistance is 360mV/360mA = 1ohm

Scope of voltage drop on 5V rail on Arduino commercial board

The voltage drop is about 280mV, the current is about 360mA, The output Thevenin source resistance is 280mV/360mA = 0.78ohm

7. What was the switching noise on the 5 V rail during the rising edge? On the quiet HIGH rail on the die?

   The measurement setup is the same as question 6.

   Scope of switching noise on the 5V rail on board and on the die (rising edge on commercial Arduino).

The orange trace is the noise on the 5V rail on the board, the red trace is the noise on the die, they are almost the same.

   Scope of switching noise on the 5V rail on board and on the die (rising edge on my board).

The orange trace is the noise on the 5V rail on the board with 1.7v pk to pk noise, the red trace is the noise on the die, it is almost clean with about 300mV pk to pk noise.

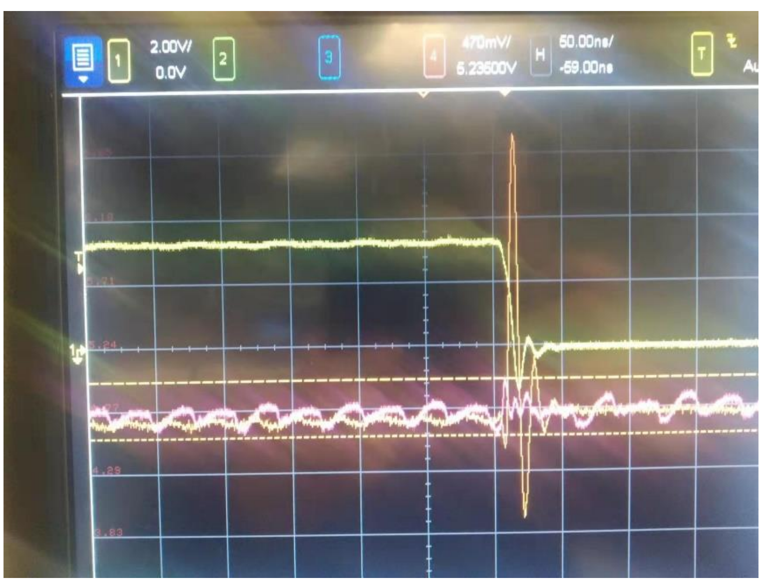
8. What was the switching noise on the 5 V rail during the falling edge? On the quiet HIGH rail on the die?

The measurement setup is the same as question 6.

Scope of switching noise on the 5V rail on board and on the die (falling edge on commercial Arduino).

The orange trace is the noise on the 5V rail on the board, the red trace is the noise on the die, the noise on the die is much smaller on the board.

Scope of switching noise on the 5V rail on board and on the die (falling edge on my board).



The orange trace is the noise on the 5V rail on the board with pk to pk of 4V, the red trace is the noise on the die, the noise on the die is clean with pk to pk of 280mV.

9. What do you conclude about noise on the die getting onto the board and noise on the board getting on the die?

    Decoupling capacitor can act as a very good filter regarding the noise on the die getting to the board, but not the noise on the board getting on the die.

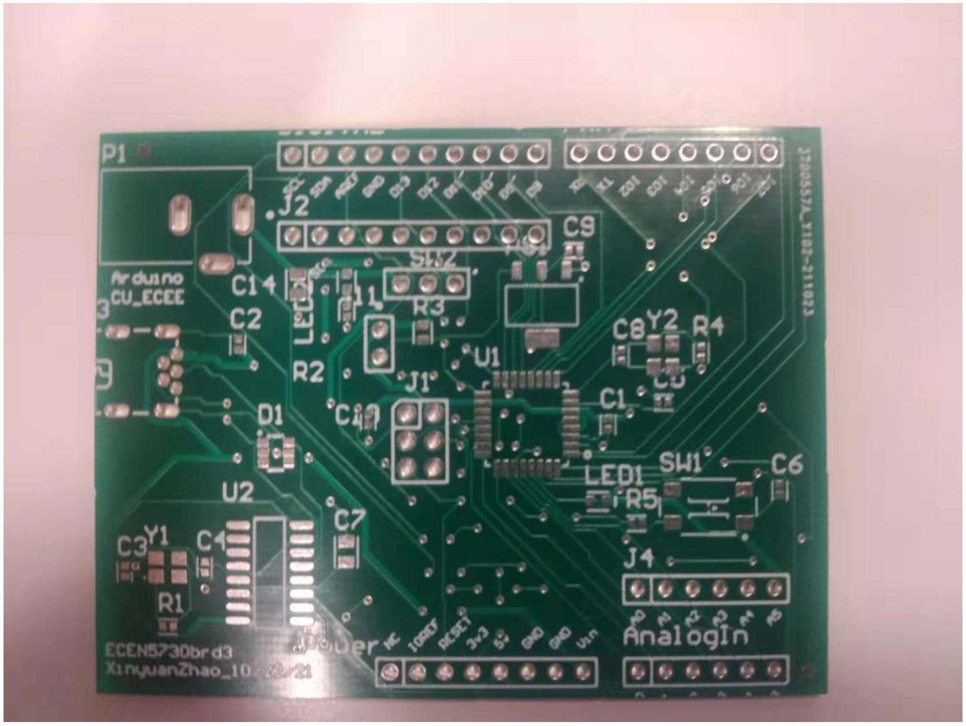
    Continuous return plane can act as a good filter regarding the noise on the board getting to the noise on the board.

Conclusion: The noise on my board is generally much smaller the noise on the commercial Arduino board. It is due to the low inductance of the decoupling from the IC and using a continuous return plane for all signals.

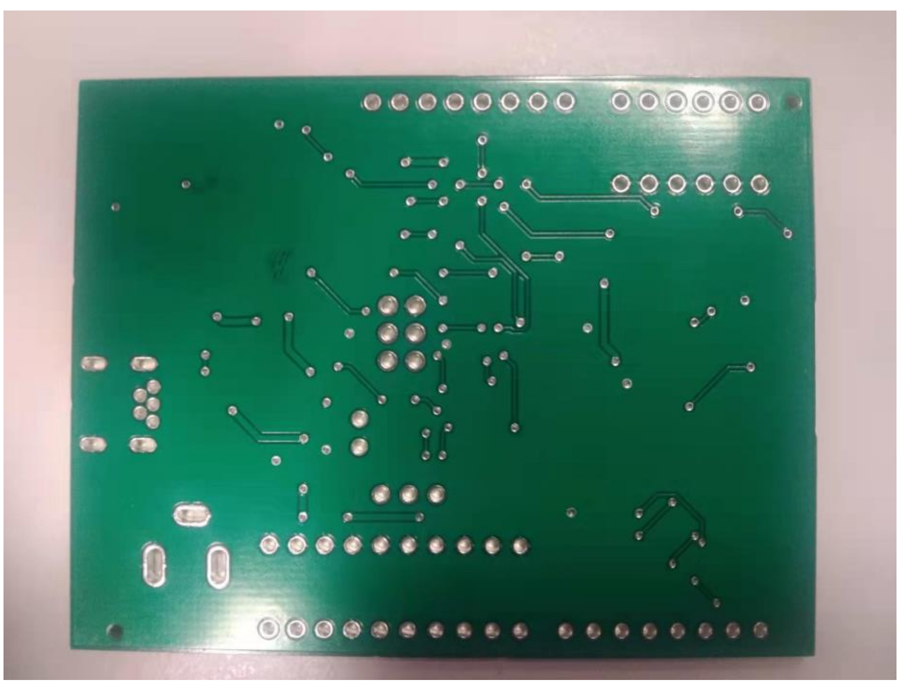
Bring Up and Test

1. Layout and design

Here is the layout of my board:

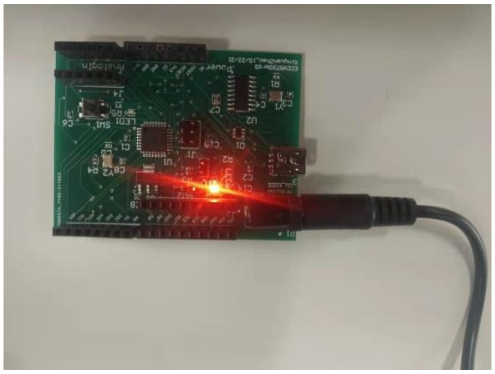
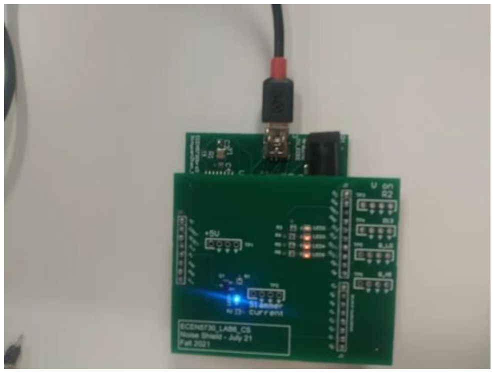


Here is the ground plane:

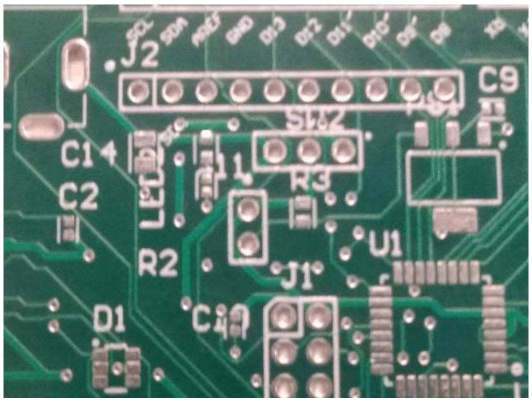


It meets basic requirements of no copper fill on top layer, has a ground plane on bottom, no long gaps in ground plane, low inductance routing with decoupling caps, has name on the board, no lacking labels for pins, correct header sockets and has indicator LEDs.

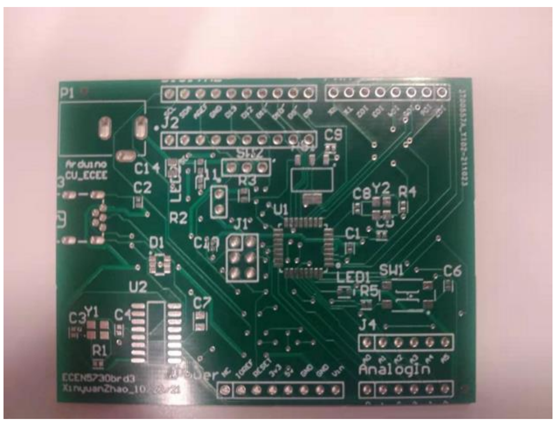
Addition features: It can be powered with USB and power jack with indicator LED.

R3 with header pins connected to it is the Current sense resistor

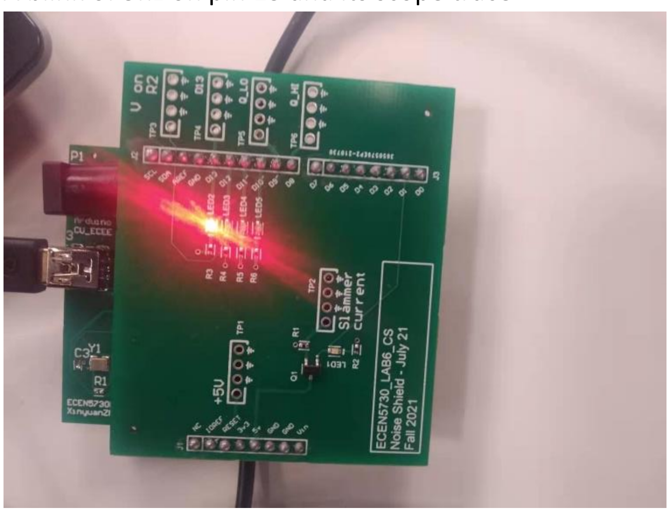


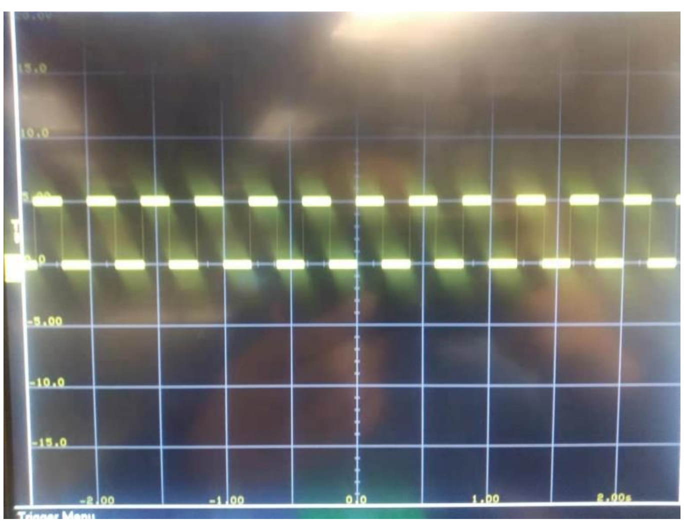
Additional unique feature added: Additional ground headers pins are added near the header socket



2. Function of the board.
   Picture of the board with all parts assembled.

A blink of 5hz on pin 13 and its scope trace





3. Each step of the project, what I did right, What I did wrong.

(1): The POR

During the plan of the record. I start out planning this board early, I referenced other's reference design and take responsibility for it. I most utilized the sparkfun design, it has a lot of things I don't need it.

What I shouldn't do is to spend a lot of time look at the reference manual for each module. I should instead figure out the important circuit quickly referencing others' design.

(2): The BOM

Installed the latest integrated library is crucial. Which I did correctly.

And when comes to the part that maybe need revising, use the 1206 parts, which I should pay attention to next time.

(3): The Schematic

Using netlabels when connecting chips which has a lot of wires to connect to it, using wires to connect directly when there is a few wires. At first, I didn't use netlabels which causes a little trouble.

(4): The layout

Pay attention to specific requirement for the layout, I didn't notice I should use exactly pinout as the commercial Arduino at first. I would pay attention to these details. Follow the correct order of routing and don't use auto route, which will end up long traces at the back of the ground plane. I first use it, then re-route my board manually and patiently

(5): Assembly

The JLC does the assembly, when it comes to important ready to change parts, it's better off to use large parts.

(6): Bring up and test

The oscillator at first is not oscillating, after removing the 10k resistors connected to it, the board works. Next time, first test the important location such as power, oscillator, to debug the work when it's not working at expected.

(7): Your report is the documentation- be sure to include pictures

Included the picture and analysis as detailed as possible when writing the report.

(8): Measurements of the Quiet hi, quiet low noise on your board when I/Os are switching, and your analysis! (9): Compare your noise on your board with the same measurement on a commercial Uno board

It is done at the noise section above. Measurement of my board are given at question4.

Switching noises are much smaller with my board compared to the commercial Arduino. And with my board, the noise on the board and the noise on the die are completely decoupled, but with commercial Arduino, it can only prevent the noise on the die getting to the board, not the other way around. It is because it has not used a continuous return plane.

(10): What features in your board contributed to the difference in measured noise.

The features added contribute to this difference includes short decoupling cap near IC, short ground traces, a continuous return plane, additional ground rows near the header sockets.