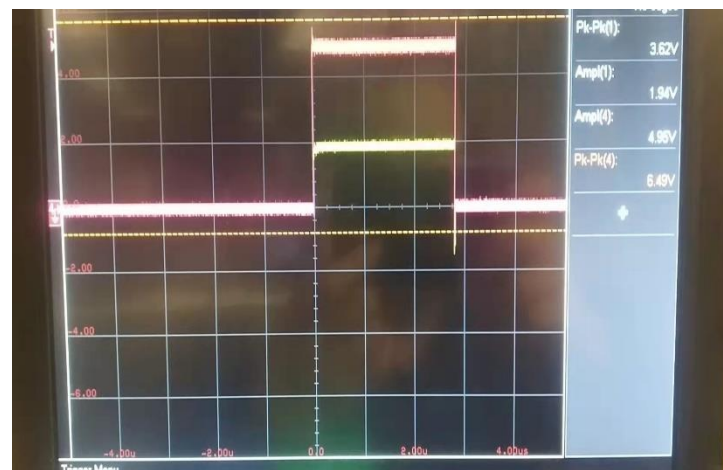


1. When the three I/O were switching, what was the total current switching, the duration, and the rise time? (left column is my board, the right is commercial Arduino).
Use a plot of the measured current to justify your analysis.

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

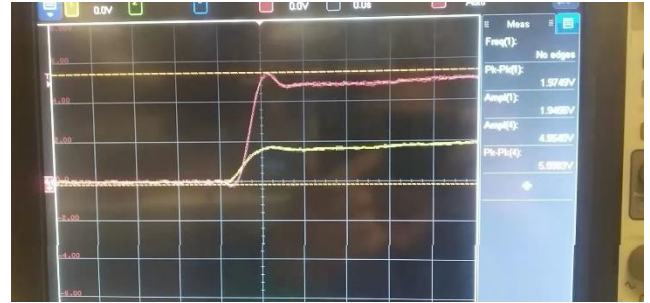
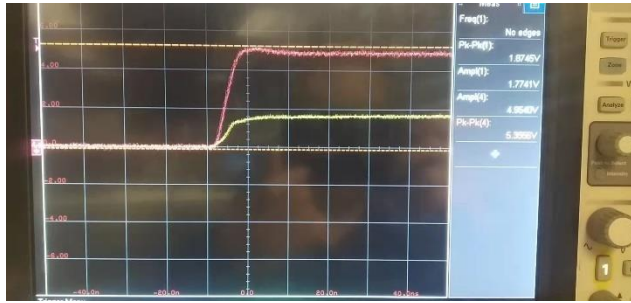


The scope trace of duration, current through 63ohm.



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

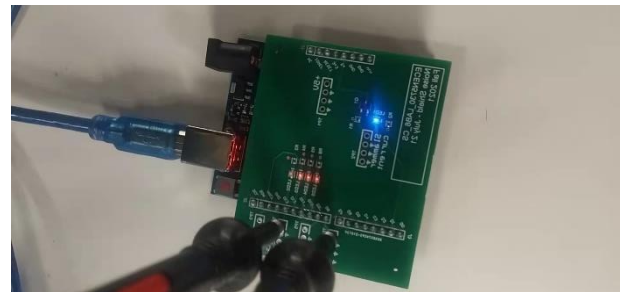
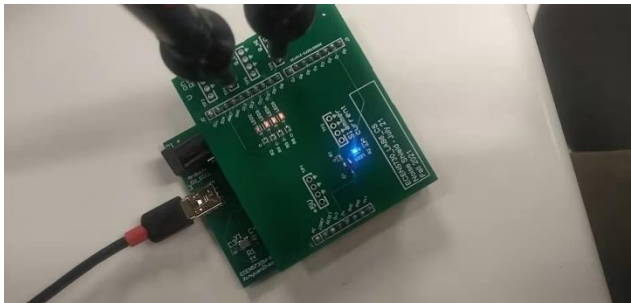
Scope trace of rise time.



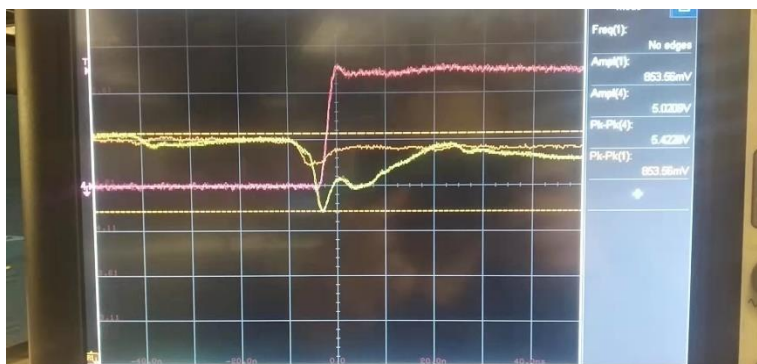
The rise time is about 10ns.

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.

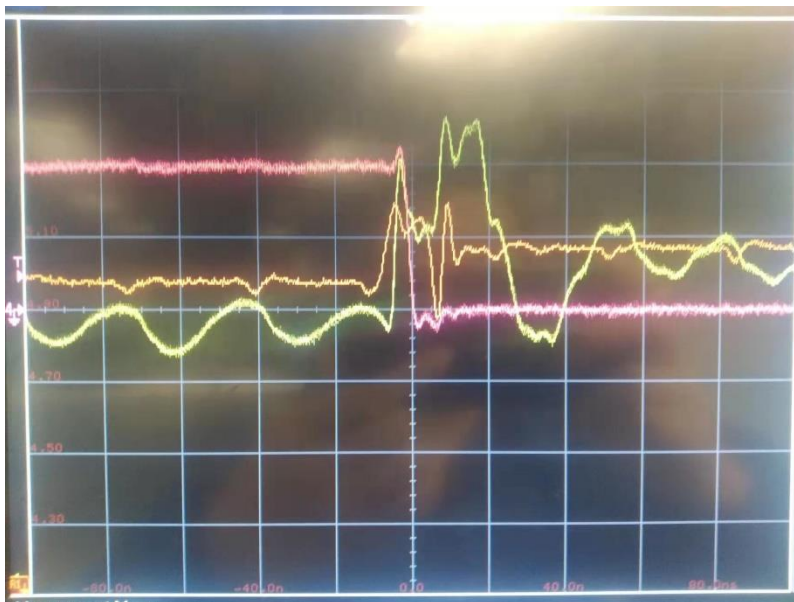
Scope of quiet low noise on same plot. (Rising edge)



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)

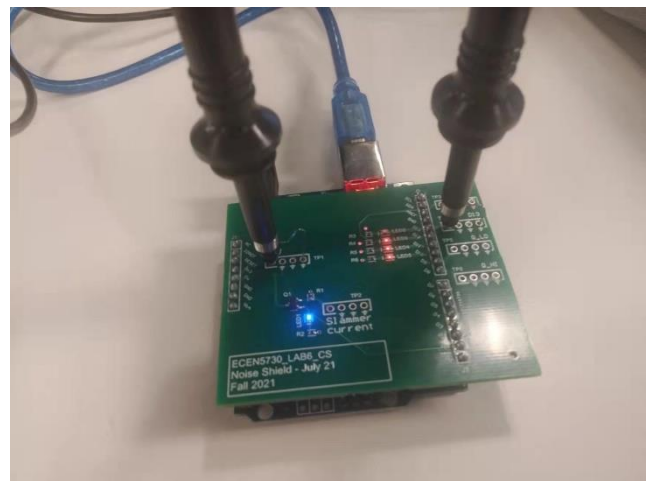
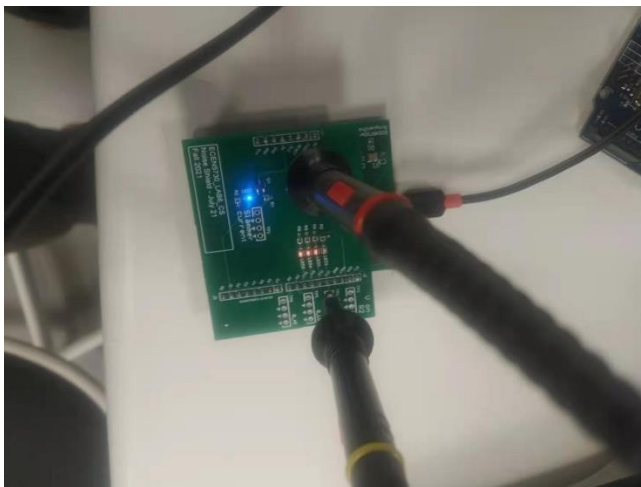


The orange trace is quiet high noise on my board, its pk to pk about 850mV, the yellow trace is the commercial board, the noise pk to pk is about 1.45V.

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.



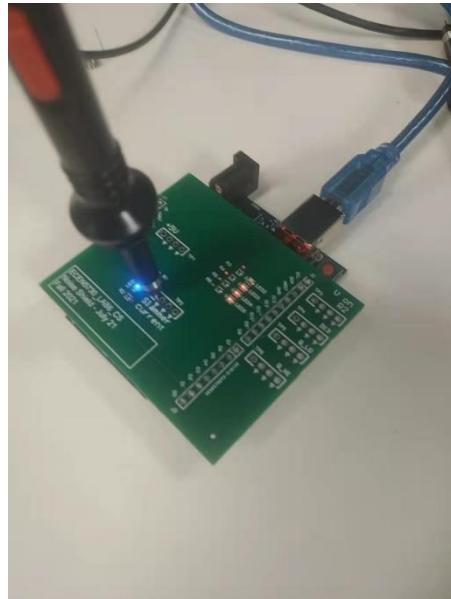
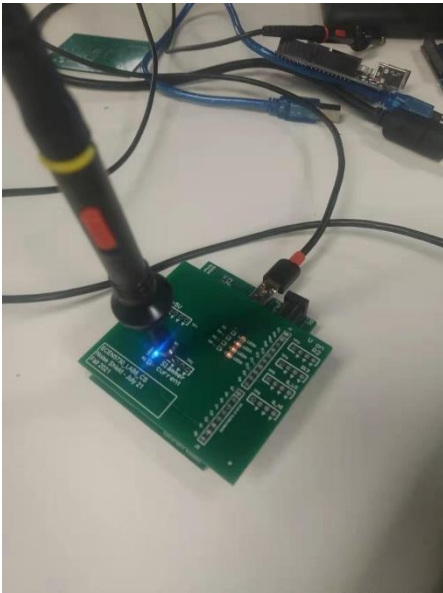
The orange trace is the noise on board, its pk to pk is about 200mV.

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

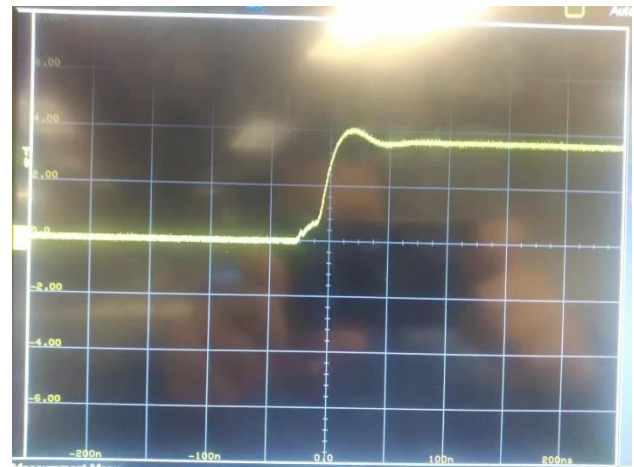
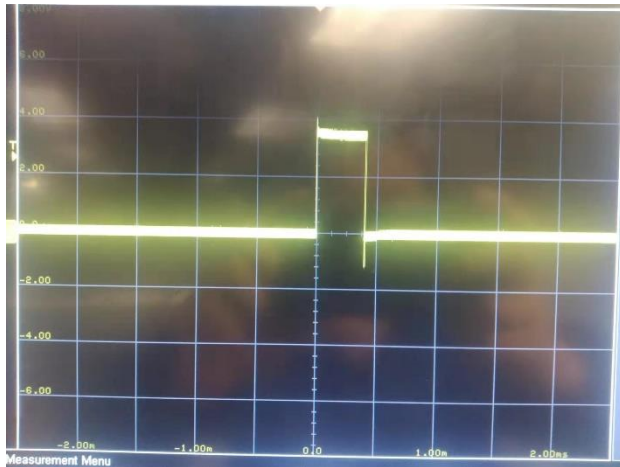
Conclusions: the noise on the board is significantly lower than the noise on the die when the IO pins are switching.

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.

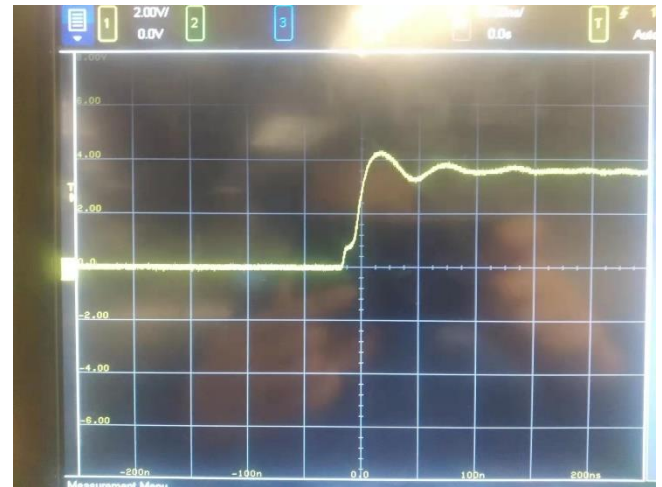
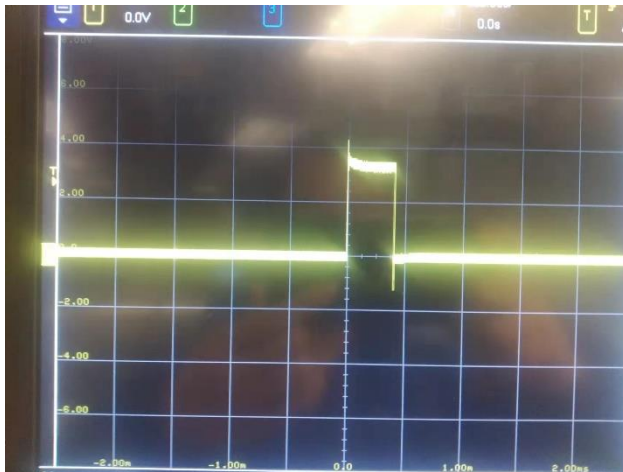


Scope of current through 5v on the die, duration and rise time on my board.



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

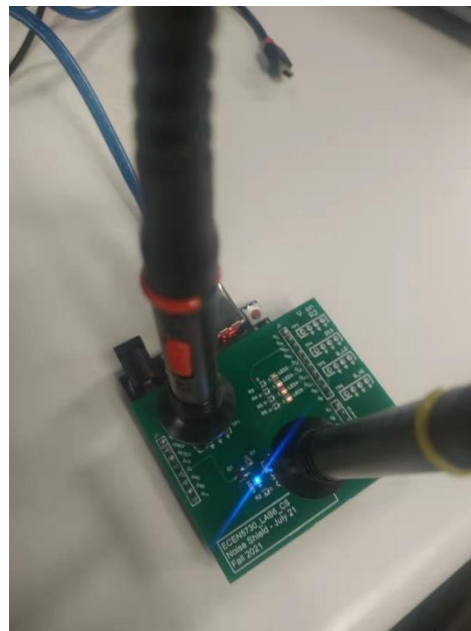
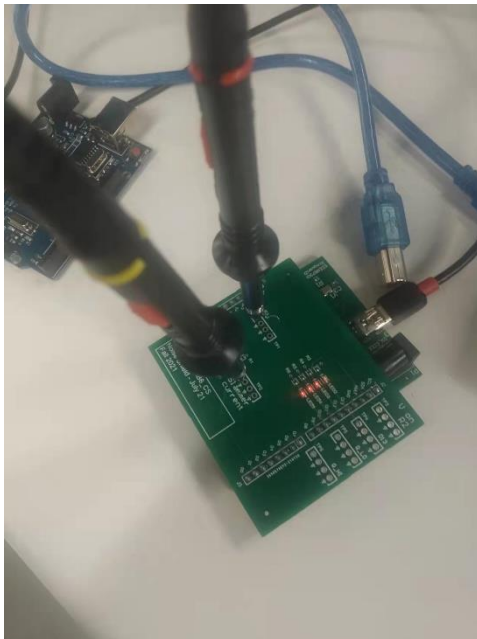
Scope of current through 5v on the die, duration and rise time on commercial arduino.



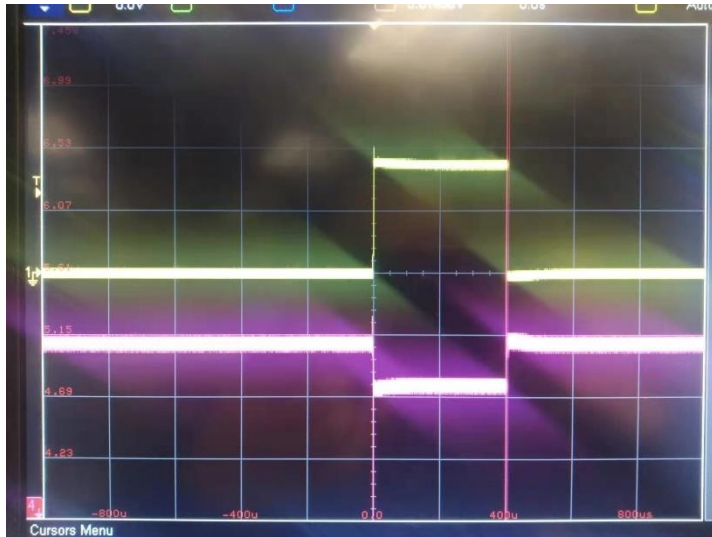
The voltage is about 3.6v, The current $I = 3.6\text{v}/10\text{ohm} = 360\text{mA}$. The duration is 400milsec. The rise time is about 17ns

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 $360\text{mV}/360\text{mA} = 1\text{ohm}$

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 $280\text{mV}/360\text{mA} = 0.78\text{ohm}$

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.