ECEN 5730 Board 3 Golden Arduino Report

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Purpose: The purpose of this board is to understand the design flow, test and evaluate different features on the golden Arduino board.

POR:

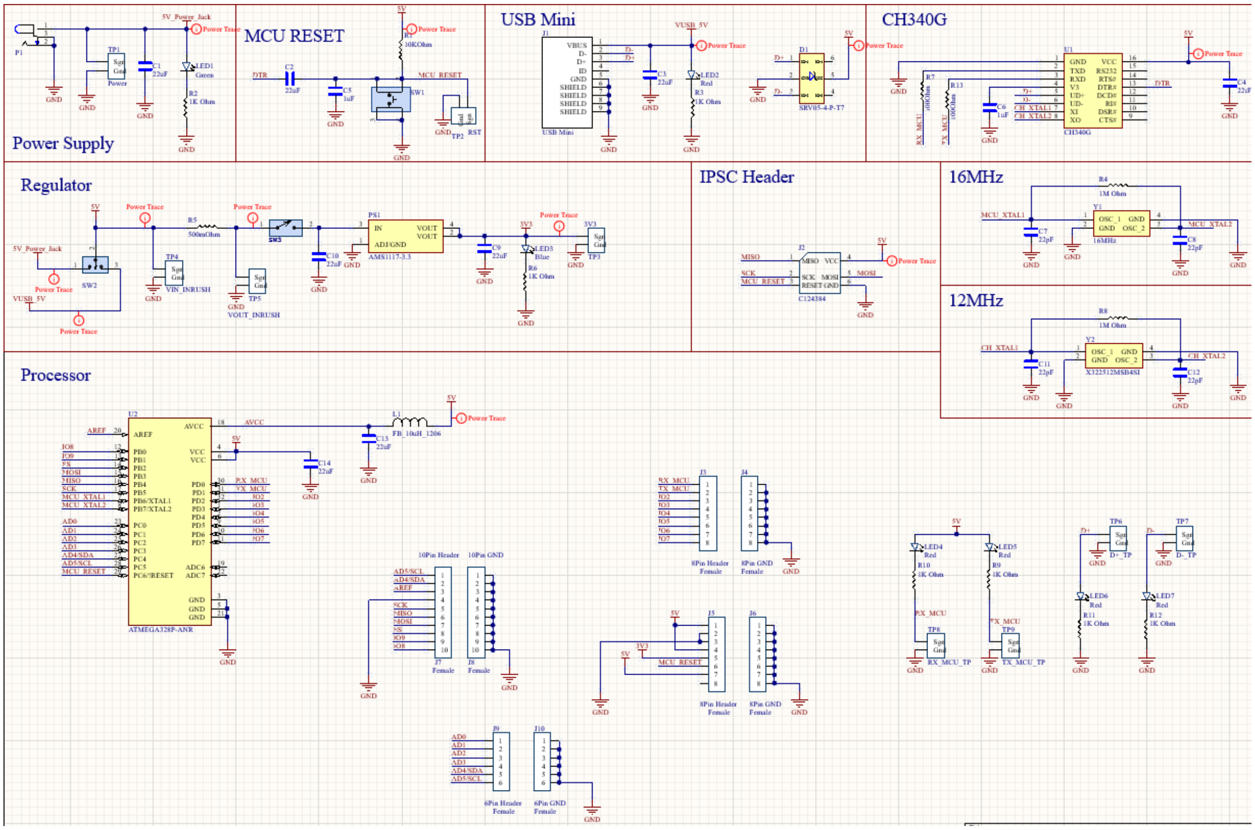
There are certain steps to be followed for developing as per the requirements. (Plan of Record)

1. The ATmega 328 is boot loaded and turned into an Arduino.
2. The Arduino IDE is run on the board with the blinking program.
3. The footprint of the headers is the same as the regular Arduino, so that the shield fits.
4. The noise on the board should be around 20-50% of the commercial board.
5. The near field emissions should be much less than 10% of the commercial board.

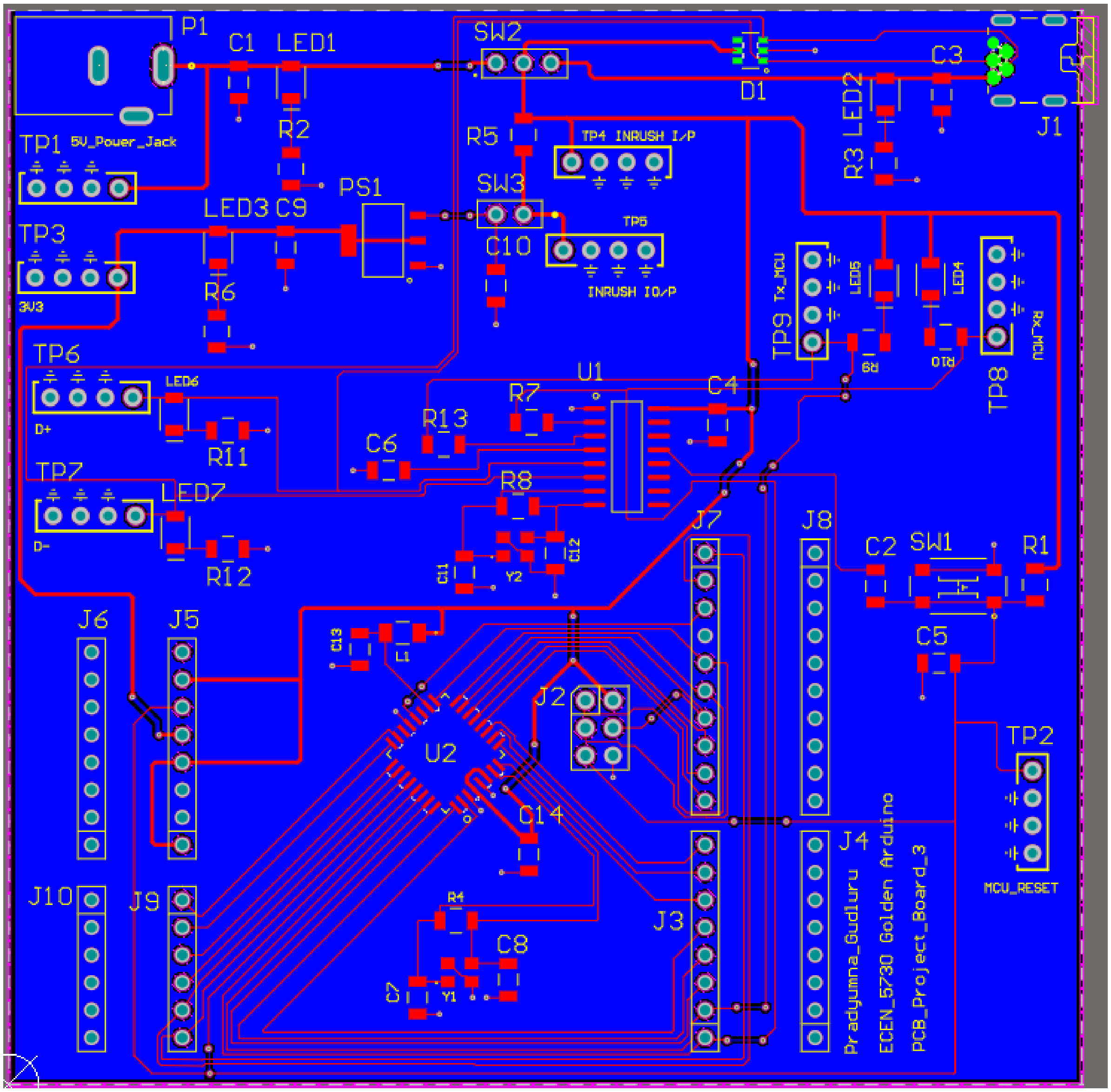
Some of the special features added are,

1. A TVS chip to protect the data pins from ESD.
2. Power from power plug or USB with a SW to select.
3. A reset switch with a debounce capacitor.
4. For lower switching noise, header pins 300 mils center to center placed outside digital I/O pins.
5. Test points to sniff USB, UART, I2C and monitor in-rush current.
6. A ferrite filter on the AVCC pin to the ADC circuit.

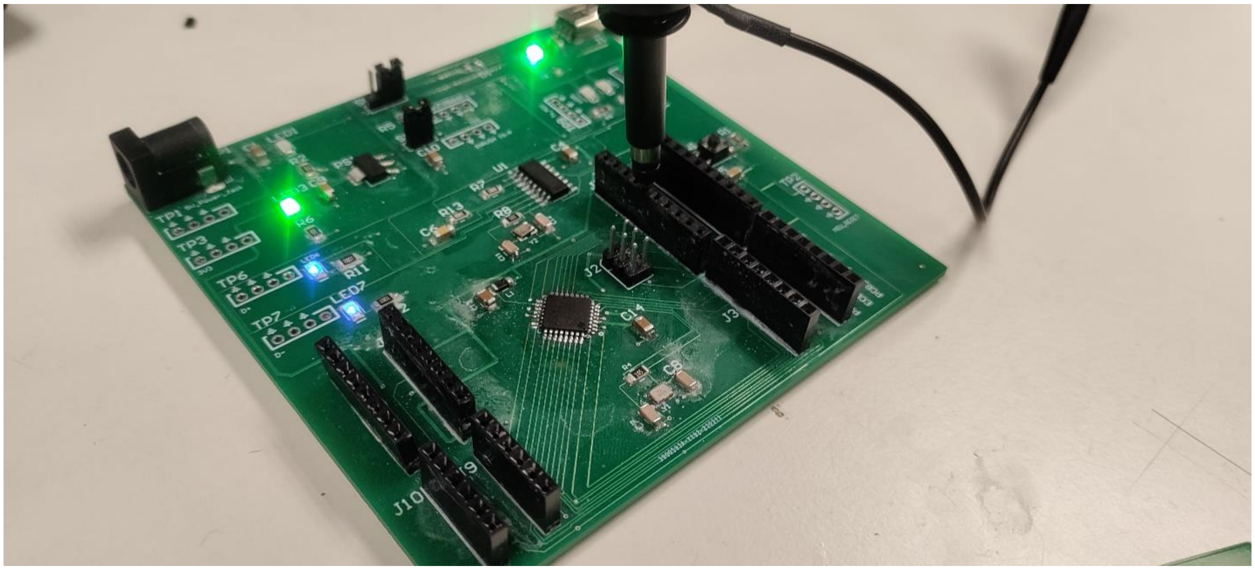
Based on the above requirements, the schematic design for my golden Arduino board is as follows,



The layout for the above schematic is as follows,



After getting the general PCB from JLCPCB the board after soldering all the components looks like the following:



Working:

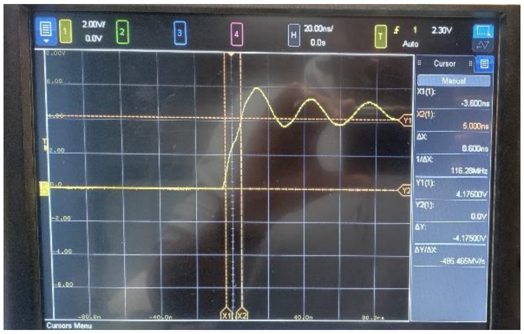
The board is in working state. The input power lines through USB or power jack can be selected. In the above picture, I've selected a USB power source. The shield is attached to the Arduino board and the working of Arduino with blinking program and switching signal noise is analysed using the shield.

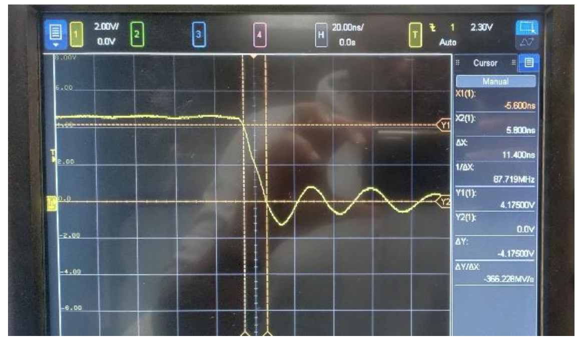
The yellow curve is the switching signal on Digital input/ Output pin 13. The green curve is 3.3V output of LDO (Test point on brd).

The following are checked using a shield on an Arduino board.

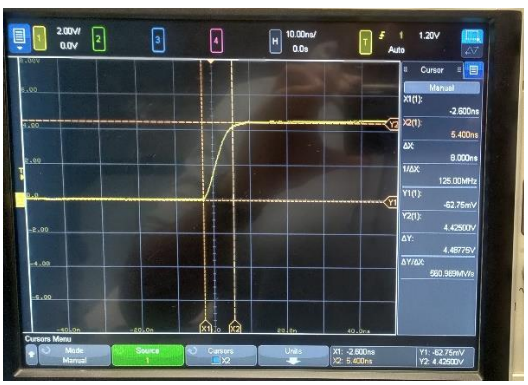
1. **Switching of pin 13**

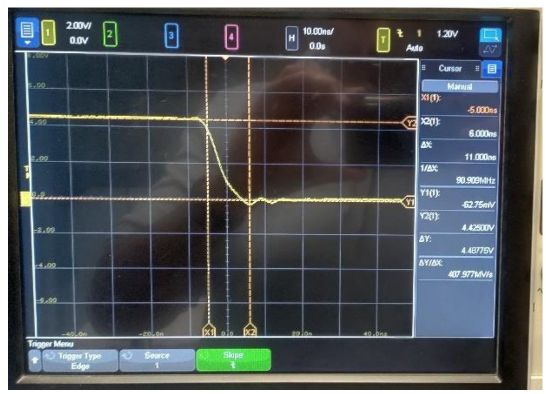
The rise time calibrated for digital signal is 8.6ns and the fall time for the digital signal is 11.4ns on the switching signal of the digital input output pin on the golden Arduino custom made board.





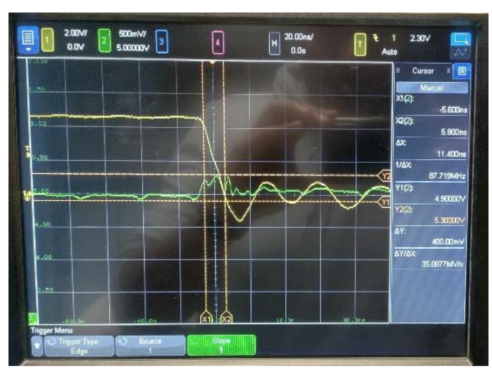
Whereas on a commercial Arduino board, the same experiment gives the rise time of 8nsec and fall time of 11nsec. The following are the screenshots.





2. **Switching noise on QHIGH signal**

The noise is calculated on QHIGH signal for the golden Arduino board. The noise at rise time is around 406.25mV and noise at fall time is around 400mV. The screenshots as below.

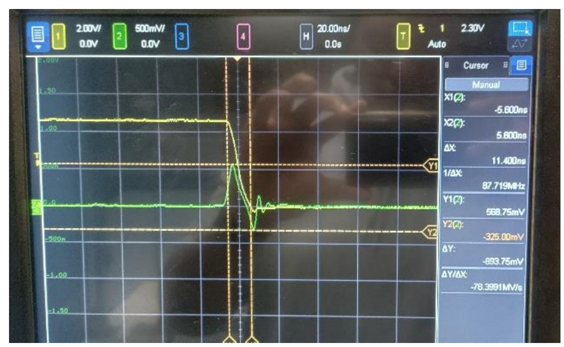


Whereas on a commercial board, the noise at risetime is around 665mV and noise at fall time is around 680mV.

By this we can conclude that at Qhigh signal, the noise on the commercial board is higher than custom made board, but it is expected much lesser noise.

3. Switching noise QLOW signal

The noise is calculated on QLOW signal for the golden Arduino board. The noise at rise time is around 256.25mV and noise at fall time is around 893.75mV. The screenshots as below.

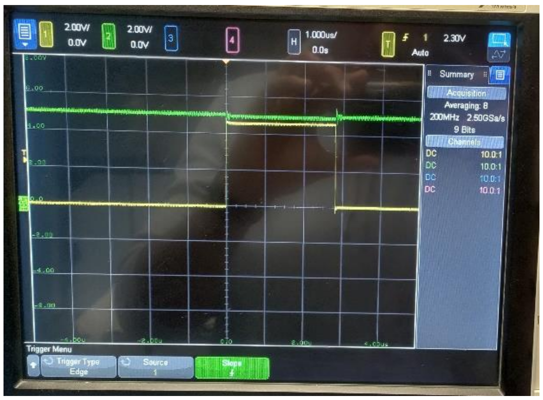


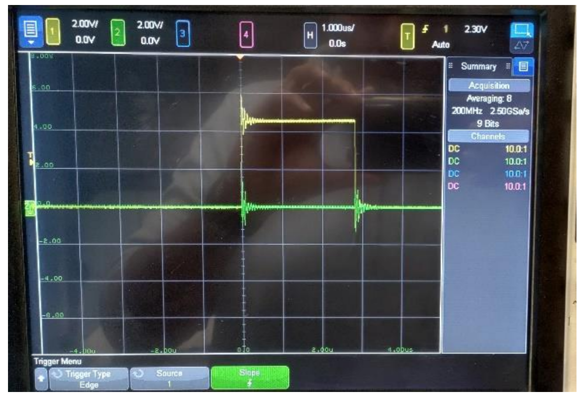
Whereas on a commercial board, the noise at risetime is around 322mV and noise at fall time is around 1.02V.

By this we can conclude that at QLOW signal, the noise on the commercial board is higher than custom made board, but it is expected much lesser noise.

4. Generic Noise switching

The overall signal for Qhigh and Qlow at switching looks like the following on the custom made Arduino board.



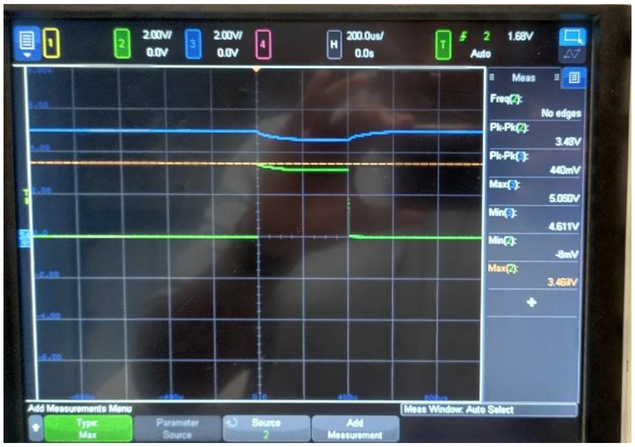


Whereas the noise at Qhigh and Qlow at switching looks like the following on the commercial Arduino board.

5. Slammer Circuit

Using a slammer circuit as per available on the shield, the voltage dip on the 5V power line is calibrated and observed while the slammer circuit switches. This is done using the trigger on slammer circuit output and the 5V line is checked for output with respect to QHIGH signal also.

The voltage dip is around 440mV and noise on Qhigh at rising edge is 610mV on the custom made Arduino board.



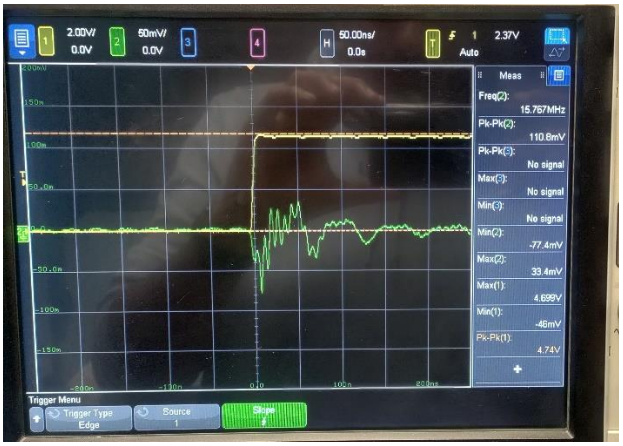
Whereas the voltage dip is around 600mV and the noise on the rising edge is 606mV on the commercial Arduino board.

In the above screenshots, the blue curve is the test point at 5V power line, the green curve is the slammer circuit test point and the yellow curve is QHIGH point on the shield provided.

There is no visible change in the noise at QHIGH for custom board and commercial board, but considerable noise difference of 160mV on 5V power line voltage dip.

6. Near field emissions

After connecting the 10x probe as a pickup loop under the board while the scope triggered to digital input output pin 13, the noise on the custom board is rising edge at 110mV and falling edge is 122mV.



Whereas for the commercial board the noise calculated is around 120mV for rising edge and 224mV for falling edge.

In the above screenshots, the yellow curve is the digital signal, the green curve is the noise of the probe atatched to the ground plane.

There is no great change in the noise estimated. It is expected that the noise on the custom board is almost 10% of the commercial board, but it is way higher than expected.

7. Inrush Current

For measuring the inrush current, the trigger on the scope is set to the rising voltage of the resistor and the displayed voltage difference on the scope is the inrush current itself. This can be achieved using the normal mode of trigger operation since in auto mode, the scope triggers only on trigger event unless nothing comes in the first 50msec.

The circuit is connected and to measure the inrush current, the power is switched OFF and when it is switched on the on normal mode, the first trigger is displayed with the voltage difference which shows the in-rush current as follows:

The sense resistance is around 0.5Ohms and the maximum voltage reached is 0.812V. So the inrush current is I = V/R = (0.812V)/(0.5) = 1.624A. The board does not use a large current and using a power line of 20mils.

Conclusion:

The following is the tabular column of the observations made in signal and noise.

Parameter	Custom Golden Arduino	Commercial Board
Rise time - Signal	8.6 nsec	8 nsec
Fall time - Signal	11.4 nsec	11 nsec
Noise - Rise Time - Q_HIGH	406.25mV	665mV
Noise - Fall Time - Q_HIGH	400mV	680mV
Noise - Rise Time - Q_LOW	256.25mV	322mV
Noise - Fall Time - Q_LOW	893.75mV	1.04V
Voltage Dip - Power Line	440mV	600mV
Voltage noise Q_HIGH	610mV	606mV
Ground Noise Rise Time	110mV	120mV
Ground Noise Fall Time	122mV	224mV

From the above observations, there is a visible change that custom board is comparatively better than the commercial board, but there is a lot of chance for improvement. According to my understanding, there are a tens of cross under in the layout which is creating a lot of noise.

A better design can be made with good noise immunity with the reduced number of cross under in the layouts.

The Arduino component placement went well with the board design and would like to repeat that with respect to future boards. The labelling of every component made it easy while placing the components. The switch that differentiated the power side and the signal side helped to debug the issue easily.

While assembling the components, there was a short in the pins of the IC, which made the whole Arduino get shorted at initialization with power switch. So, in future, care shall be taken to solder IC's and shorts are checked once the IC is soldered before soldering all other components. The oscillator component is checked and placed with polarities while soldering in the future.

There were no hard errors noticed in the golden Arduino board.

Adding additional LED's for digital input output pins would help in easily analysing working code. Working on routing for a bit longer time would have reduced the cross under making the golden Arduino less noisy.

Some of the best design practices like isolating switches, connecting the ground plane on the layout, identifying the blocks of orientation on schematic helped is understanding and profiling signals on the PCB. Labelling every component and the test points made soldering and probing easier. The signals are probed using the spring tip edges which reduce the noise while signal transmission of profiling.

References:

1. Lab manual provided by Prof. Eric Bogatin
2. https://sites.google.com/colorado.edu/practicalpcbdesignmanufacture/erics-altium-workshop