Board 3 Report

Golden Arduino Board

ECEN5730 Fall 2025

Hyounjun Chang

Project Overview

Plan of Record (POR)

- Test various components for Golden Arduino Board (XTAL, TVS)
- Create Schematic for Booting Golden Arduino Board off USB **(Completed Week 7)**
- Test Solderless Breadboard version of Golden Arduino **(Completed Week 7)**
- Test oscillator and TVS for Golden Arduino **(Completed Week 8)**
- Do CDR of PCB Design **(Completed Week 10 with TA)**
- Bring-up PCB Board 3 post-assembly, and record notable differences between commercial Arduino **(Completed Week 12)**

Project Goals (Working Board)

- Selectable power through 5V Power Jack or USB
- 3.3V LDO output and 5V Analog VCC with Ferrite Inductor for more stable power
- Place enough test points and indicator lights to debug potential issues with the board
- Assemble the board without burning through entire supply of boards/parts (only 5 PCB boards)
- No issues with board assembly (no shorts)
- Compatible header pins with existing Arduino Board
- Reduce power-rail and switching noise compared to commercial board
- Reduce crosstalk compared to commercial board
- Reset button for Arduino Reset Pin
- Recognizable COM port device
- Be able to burn Arduino Bootloader to the device
- Be able to program custom program via Micro-USB port
- Be on Schedule

Sketch of the Schematic

Power Tree

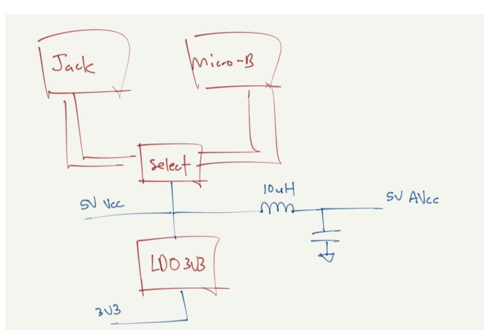


Figure 1: Power Tree for 5V, 3V3, and 5V AVcc

A switch is used to select 5V power between 5V Power Jack and Micro USB. The output from the selected 5V source is used to create 3.3V output (from LDO) and AVcc (with Ferrite Inductor).

Reset Circuit

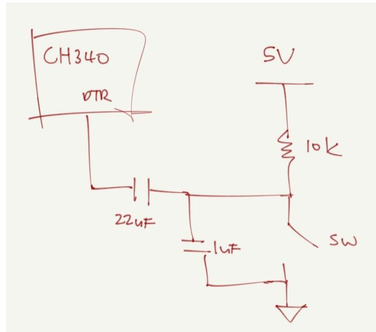


Figure 2: Reset Circuit for Arduino

DTR pin from CH340 (used by RS-232) and a switch is used to pull the reset pin low. A 1uF capacitor is used for debouncing, and the series capacitors are used as high-pass filters for negative edge triggers.

CH340 and Atmega328

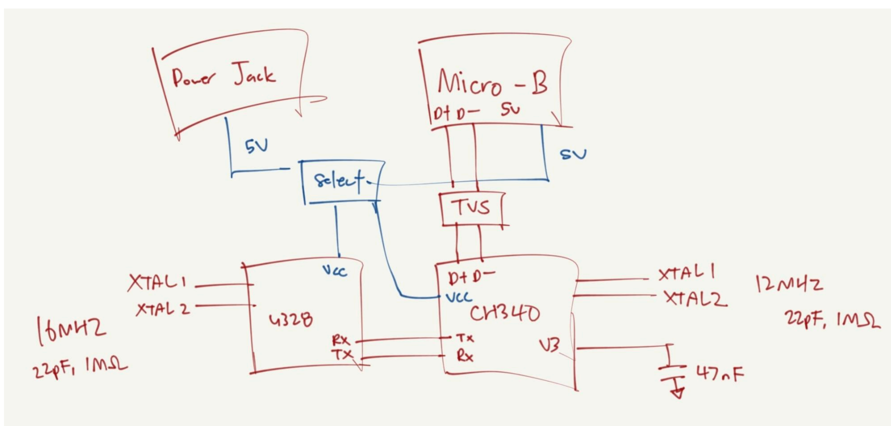
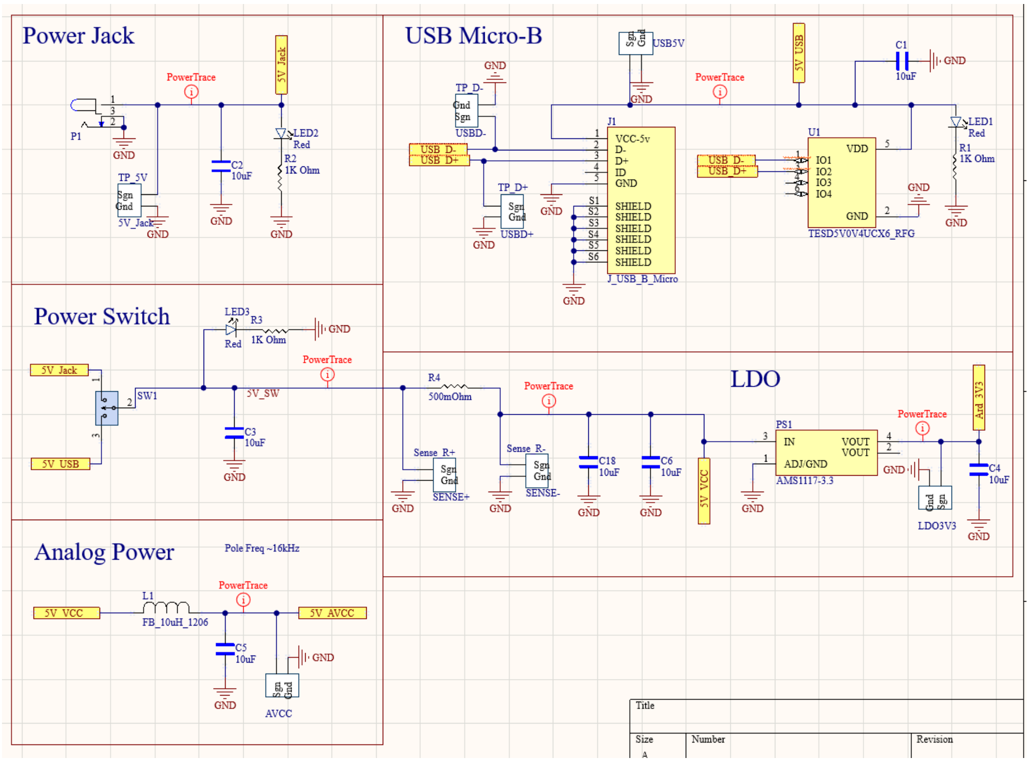
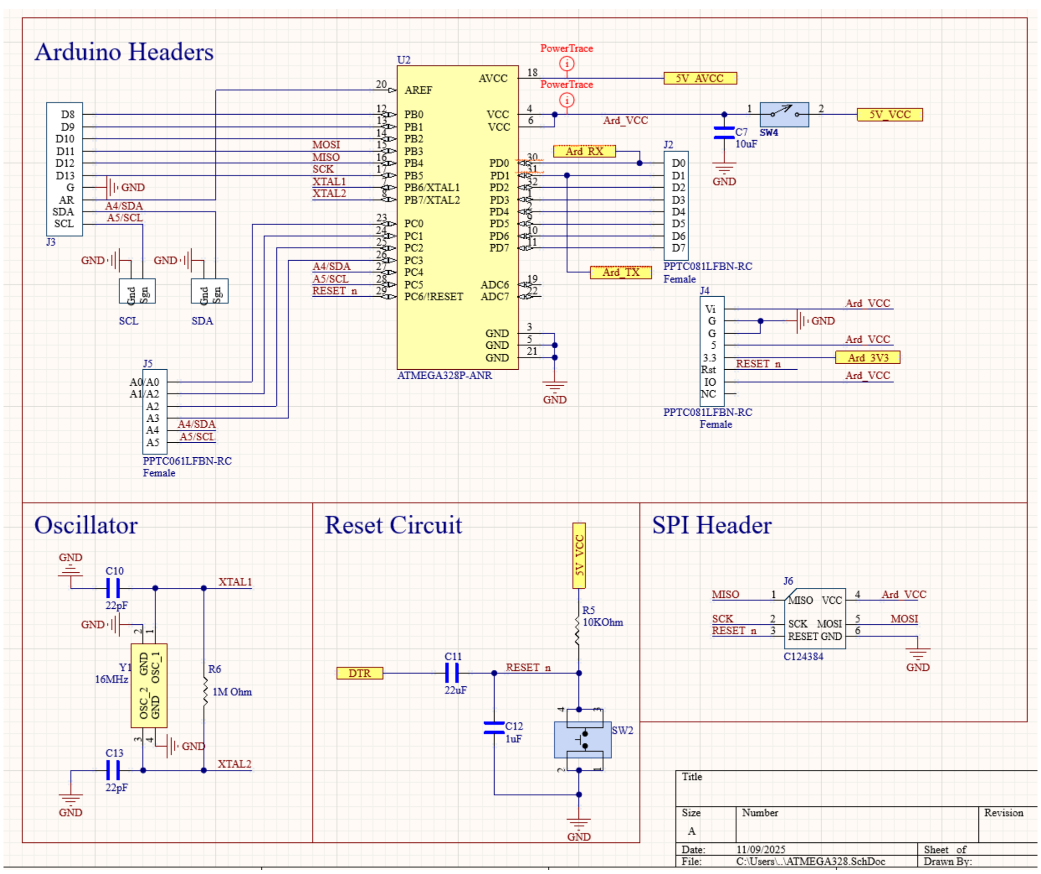


Figure 3: Block Diagram for CH340g and Atmega328 Microcontroller

There are separate oscillators for Atmega328 (16Mhz) and CH340g (12Mhz). CH340g receives data from USB pins, and communicates with Atmega328 through TX/RX pins. 1 Megaohm resistors are placed between 2 XTAL pins to get the oscillators to correct resonant frequency. The TVS chip is inserted after the USB port to protect against voltage spikes.

Altium Designer Schematic





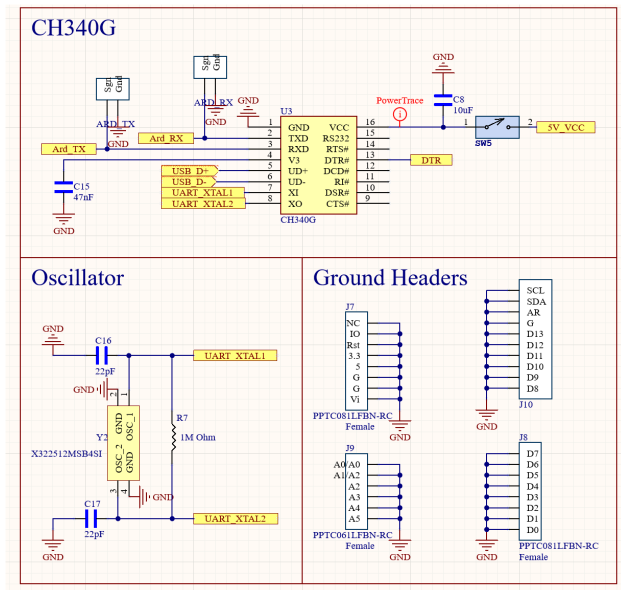


Figure 4: Altium Schematic for Board 3 (Top: Power Circuit, Middle: Atmega328 Circuit Bottom: CH340g and Arduino Header pins)

Indicator lights and test points were added for debugging. Jumpers were added to isolate circuits during the Bring-up phase. Test points include: Power, Current Sense Resistor, USB D+/D-, TX/RX between CH340g and Atmega328, and SDA/SCL pins. Matching headers were added to match that of a commercial Arduino board, with additional GND headers.

PCB Board Layout

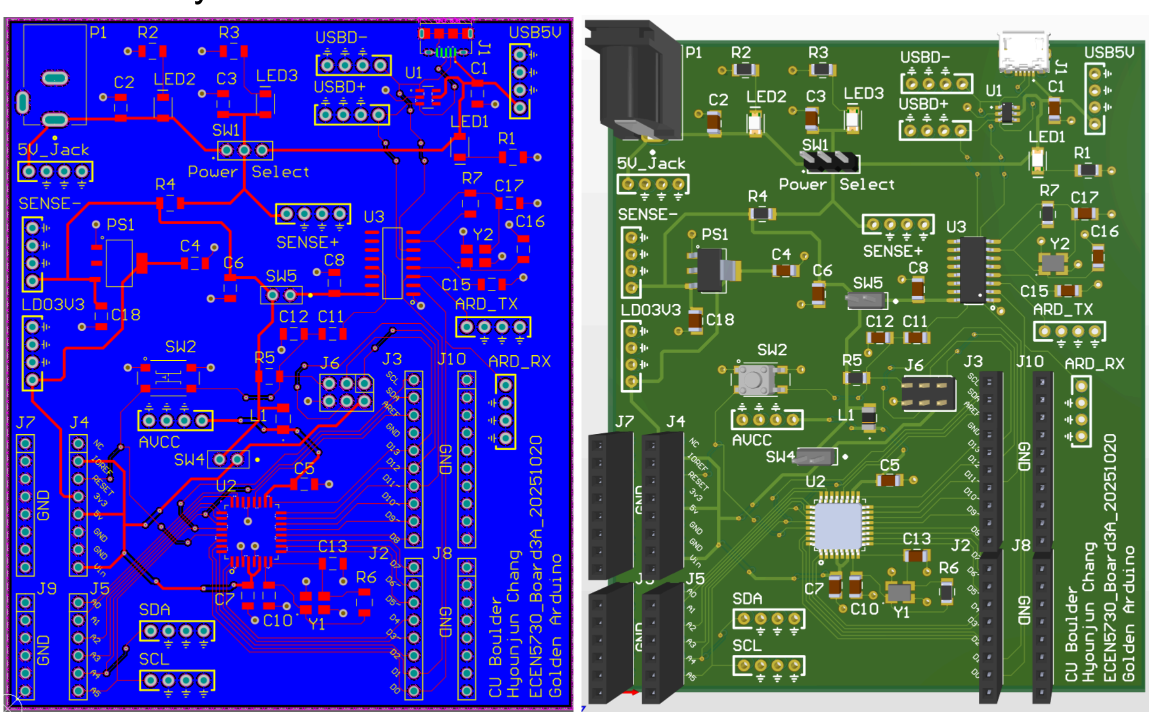


Figure 5: PCB Design on Altium Designer 2D view (Left), 3D view (right)

Dimension of the PCB board is 3200mil by 3900mil, which is bigger than commercial Arduino boards. The header pin placements are the same as commercial ones. There are additional ground pin headers. Micro-USB port is placed on top-right, and 5V Power Jack is placed on top-left.

Picture of Physical Board

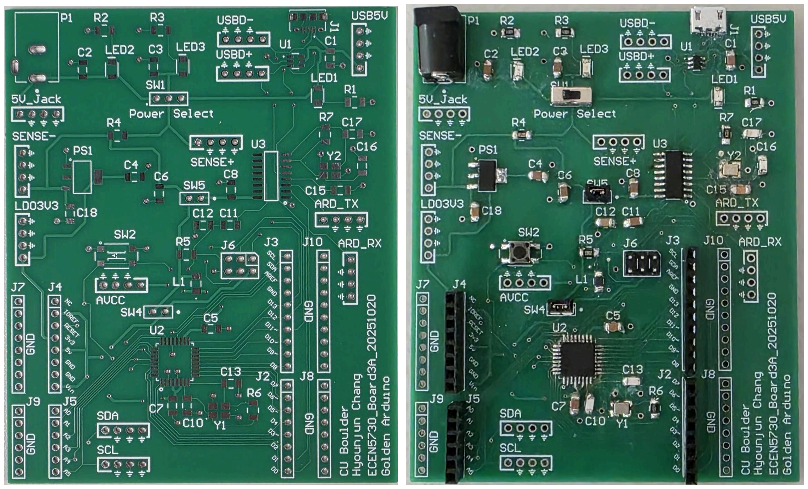


Figure 6: Physical PCB for Board 3 (Left: Unassembled, Right: Assembled)

Board Functionality:

Test Points:
5V_Jack: 5V Power Jack Test Point
USB5V: USB Power Test Point
LDO3V3: 3.3V LDO Test Point
AVCC: 5V Analog Power Test Point
Sense+/Sense-: Sense Resistor Test Point
USBD+/USBD-: USB Data Test Point
ARD_TX/ARD_RX: CH340g/Atmega328 Test Point
SDA/SCL: I2C Test Point

Expected Working Board:

- Stable 5V power-rail output from power jack or USB, with respective LEDs turning on
- Selective 5V power from power jack and USB, with only one power source selected
- 3.3V output from LDO, and 5V output for Analog VCC
- Header Pins matching Commercial Arduino board, with shield board fitting the headers
- Isolation switches to isolate CH340g and ATmega328 microcontroller
- COM port recognized when USB plugged into the board and laptop
- Relatively low power-rail noise, switching noise, EMI/crosstalk noise compared to commercial board

- Lower power rail collapse (<500mV) from GPIO switching
- Able to Bootload through existing ArduinoISP
- Debuggable test points for I2C, USB, CH340g

Actual Assembled Board:

Selective Power

Three Indicator LEDs were placed at the top for power (Left: Power Jack, Middle: Vcc for CH340g and ATmega328, Right: USB power). The middle indicator light only lights up when the correct power is selected from the switch. ATmega328 can be powered through selected power source.

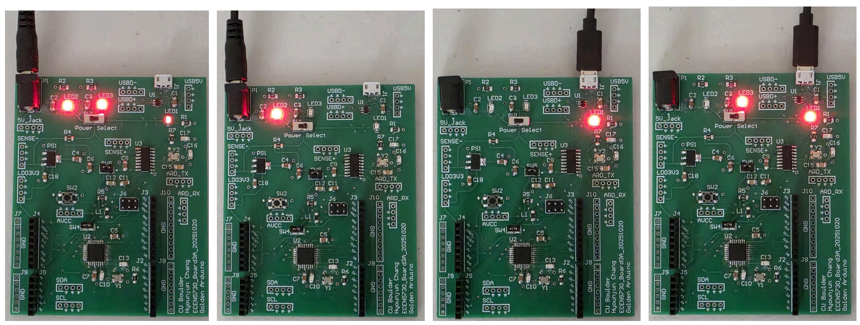


Figure 7: Selective Power Indicator LEDs. From Left to Right: Jack/Jack selected, Jack/USB selected, USB/Jack selected, USB/USB selected

There is leakage current through CH340g to the USB if a jumper connects 5V Power Jack supply to CH340g chip. This is a design error, as CH340g is only used through USB, and was not caught during a CDR. Power Jack and USB should not be plugged-in at the same time with the current design.

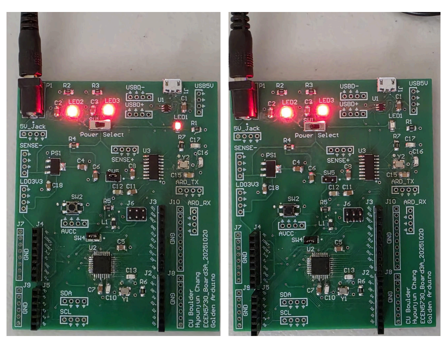


Figure 8: Power Jack power with SW5 (CH340g) Isolation Jumper (Left: On, Right: Off)

3V3 LDO, 5V AVCC with Ferrite Inductor

The 5V power jack input is noisy, with 74mV peak-to-peak. High frequency noise is filtered out on the AVcc pin by the ferrite inductor, reducing the power rail peak-to-peak noticeably to 45mV. However, it is not able to reduce the low frequency power rail noise at approximately 1Hz. LDO outputs stable 3.3V, with <4mV peak-to-peak.

Figure 9: 5V Power Jack Input (Left), 5V AVCC (Middle), 3V3 LDO (Right)

Burning Bootloader and Programming the Device

No issues were encountered during bootloading and programming of the device. The device manager detects the COM port, and using another Arduino to burn the bootloader allows the Golden Arduino to be programmed by a PC in ArduinoIDE. Example blink program toggles D13 pin.

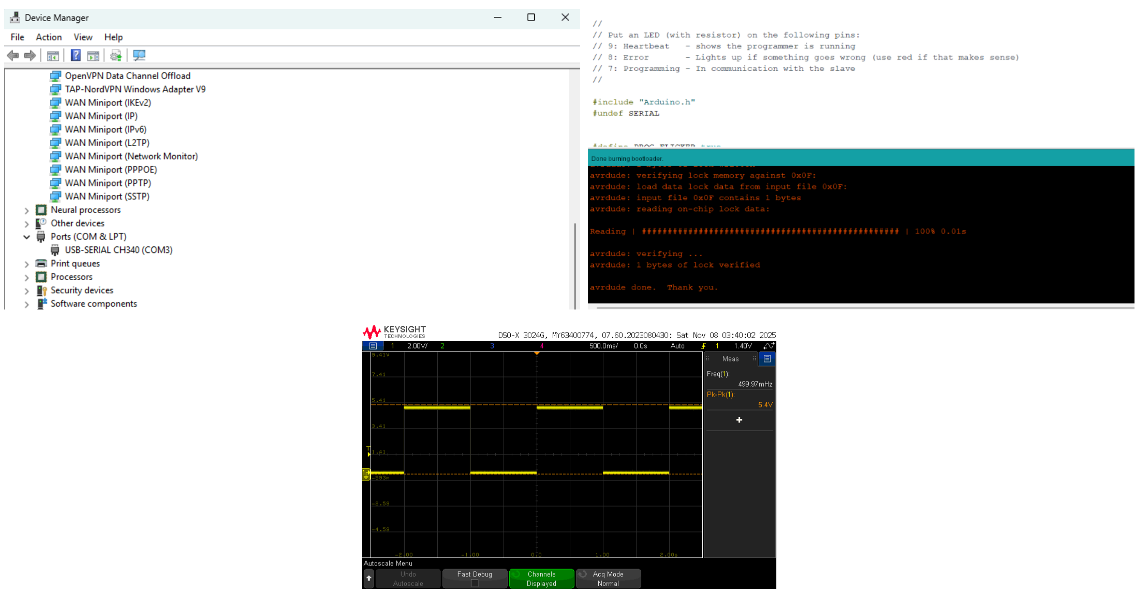


Figure 10: CH340g COM port (Top-Left), Bootloader Burn (Top-Right), Blink Program Output(Bottom)

In-Rush Current

In-rush current was measured through a 500 milliohm resistor placed right after the Power-Select switch. Peak voltage difference between the two was 1.74V, which equates to **3.48A of in-rush current**. It remains **over 1A for 100us**, which is way too high. This is due to 2 parallel 22uF decoupling capacitors placed in the power-rail. The schematic was created with 2 10uF decoupling capacitors in mind, but during assembly 22uF capacitors were placed, leading to much larger in-rush current. One of the capacitors should have been labeled DNP with a 22uF capacitor.

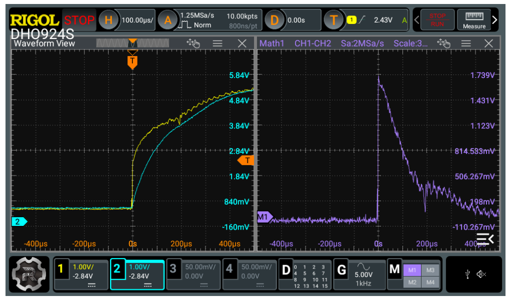


Figure 11: 500miliOhm Sense Resistor during Power-up

Switching Noise

A simple micro-code controlling GPIO pins D8 to D13 was used to test switching-noise on GPIO pins of both Golden Arduino and Commercial Arduino. Switching noise Shield Board provided by ECEN5730 TAs was used to measure switching noise and power-rail noise.

```
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);
}
```

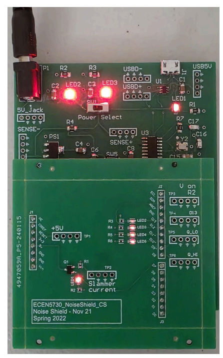


Figure 12: Microcode used for Noise Testing (Left), Golden Arduino with Shield Board (Right)

Rise time and fall time of GPIO pins on the commercial board and Golden Arduino board are similar, so noise measurements do not need to be adjusted. Switching noise was measured on a 47 ohm resistor next to LED and Quiet High/Low. Pin D13 was used as a trigger for all signals.

	Golden Arduino	Commercial Arduino
Rise Time	3.7ns	4.1ns
Fall Time	4.7ns	4.4ns

Figure 13: Rise/Fall Time for D13 pin for Commercial/Golden Arduino

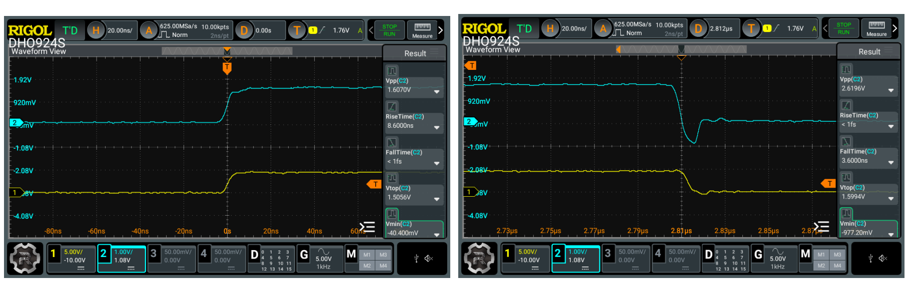


Figure 14: Switching Noise on 47 Ohm Resistor next to LED for Golden Arduino (Blue)

There are spikes during switches in both Quiet High and Quiet Low. Peak-to-peak voltage is higher for Quiet low. Overall, switching noise of the Golden Arduino board is better than that of the commercial Arduino board.

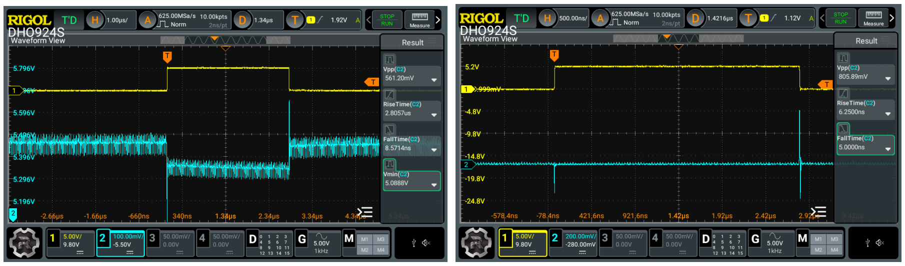


Figure 15: Switching Noise for Quiet High (Left), Quiet Low (Right), zoomed out

	Golden Arduino	Commercial Arduino
47Ohm Posedge	8.6ns(rise), 1.99Vpp, 1.9V(Vtop)	8.6ns(rise), 1.6Vpp, 1.5V(Vtop)
47Ohm Negedge	3.2ns(fall), 2.90Vpp, -1.0V(Vmin)	3.6ns(fall), 2.61Vpp, -0.98V(Vmin)
Quiet High Posedge	423mVpp	610mV
Quiet High Negedge	358mVpp	519mV
Quiet Low Posedge	280mVpp, -258mV(Vmin)	442mVpp, -400mV(Vmin)
Quiet Low Negedge	905mVpp, -371mV(Vmin)	1.57Vpp, -755mV(Vmin)

Figure 16: Switching Noise table for Golden Arduino and Commercial Arduino

Power Rail Noise

Power rail noise was measured with a change in GPIO pin (D13) and a slammer circuit on the shield board. Power rail noise was significantly worse on the Golden Arduino board. There is a voltage drop throughout slammer circuit duration on the Golden Arduino, while it is less present in the commercial board. There is also noise during posedge and negedge.

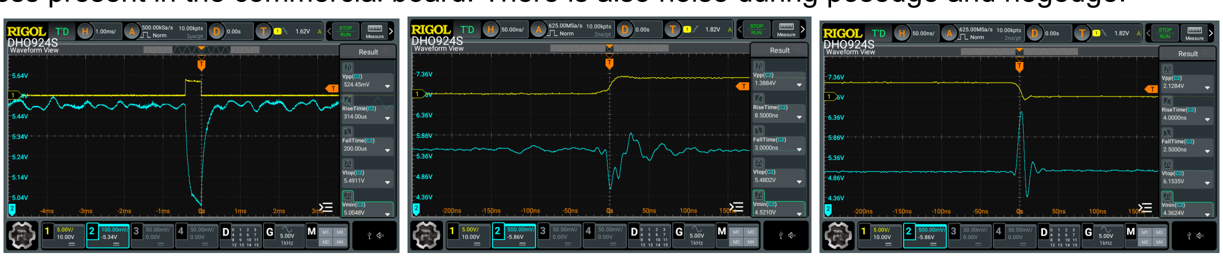


Figure 17: Power Rail Noise from Slammer Circuit (Left: Whole Duration, Middle: Posedge, Right: Negedge)

Figure 18: Power Rail Noise from GPIO pin

	Golden Arduino	Commercial Arduino
Pin D13 Power Noise	135mVpp	108mVpp
Slammer Posedge	1.38Vpp, ~1V drop	581mVpp, 440mV drop
Slammer Negedge	2.13Vpp, 1.5V jump	962mVpp, 800mV jump

Figure 19: Power Rail Noise table for Golden Arduino and Commercial Arduino

Near-Field Emissions/EMI

Near-Field emissions were measured by creating a loop with an oscilloscope probe and placing the probe under the Arduino board. Near-field emissions were the highest under the Arduino board. Trigger was set at posedge change of D13 pin. Noise is highest during posedge. Emissions were noticeably lower on the Arduino Board.

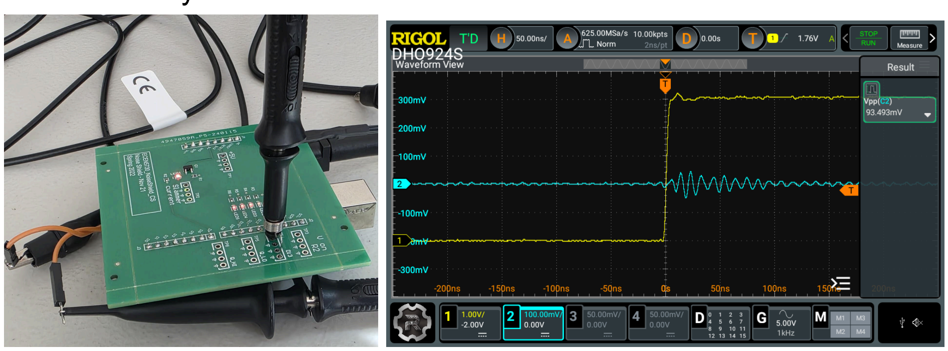


Figure 20: Measurement set up for Near-Field Emissions (Left), Oscilloscope Measurement (Right)

	Golden Arduino	Commercial Arduino
Near-Field Emissions	93mVpp	143mVpp

Figure 21: Measured Near-Field Emission from both Boards

Conclusion:

PCB design choices affect noise and signal integrity. Wrong capacitor size selection can significantly increase in-rush current, and cause power-rail problems.

Comparing results of a PCB design to an existing design helps us assess performance of the design. Golden Arduino performed better than the commercial board in switching noise. There is an issue with power rail in the design, as evidenced by power rail noise, and switching noise from the slammer circuit, which uses high amounts of current.

As designs get more complex, there are many issues that may arise, from circuit design to assembly to signal integrity. Finding ways to minimize risks in each step will lead to better results. We can learn from mistakes made during the PCB design to improve future designs. Adding sense resistors and test points for precise circuit measurement helps at debugging the board and measuring signal integrity.

Project Analysis

There were many errors in the board in the circuit design, PCB layout, and assembly.

Hard Errors:

- 3 PCB boards were lost during assembly due to misuse of heat gun, leading to burnt boards, falling PCB trace and solder mask layer.
- Misassembly of the Reset Circuit led to a short in the CH340g, damaging the device.
- CH340g is powered through 5V Power Jack, which leaks current to the USB port, which can cause damage if both Power Jack and USB are plugged in at the same time. Circuit design revision is required

Soft Errors:

- Much more parts were used during assembly of the board due to poor soldering skills: extra oscillators, ATmega328, and CH340g parts were used, increasing the cost
- Larger capacitor sizes were placed then intended: design initially was intended for two 10uF decoupling capacitors in parallel for power, but two 22uF decoupling capacitors were soldered during assembly instead.
- High in-rush current due to large decoupling coupling capacitors, leading to over 3A during its peak.
- Messy board due to mishandling of parts during assembly
- Significant power rail noise when using large amounts of current from the power rail

What went well:

- Switching noise with GPIO pins and Near-Field Emissions: board performs better than commercial board with little current consumption
- Device functionality after full assembly: bootloading the Golden Arduino and reprogramming through ArduinoIDE went without issues.
- Proper placement of Arduino headers and USB ports: no modifications were necessary to fit micro-USB cable and shield boards
- Persistence to go through 3 boards to improve assembly skills on the 4th board
- Good placement of indicator lights, switches, and test points for debugging

- Good measurement techniques to evaluate board performance compared to the competitor

What didn't go well:

- Lack of soldering skills for small parts (Atmega328, TVS, CH340g) led to long assembly time (3 days), with many failures in between
- Large decoupling capacitors led to bad in-rush current and performance in power-rails when Arduino is consuming high current
- Circuit design and CDR: error in CH340g power supply was left out during review. Both 5V power jack and USB can power the device, which will cause problems if both are powered
- Making sure right size capacitors are placed, and double-checking before placing capacitors, especially when there are many different sizes in the design
- Not being too careful with the assembly parts led to extra parts being used, which increased the cost of assembly

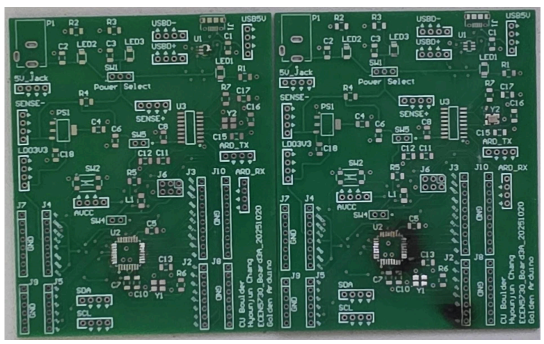


Figure 22: Damaged boards during assembly (Left: Falling out Solder Mask, Right: Burnt Board)

Future Improvements:

- Placement of PCB traces can be done more tightly: current board is larger than the commercial board, but size can be reduced with better design
- Experimentation with different parts: exploring USB-C can be done in the future. Known parts were used for this project for consistency, but for future revisions, new parts can be considered
- Soldering techniques for small parts, such as with micro-controllers. Minimizing number of de-soldering significantly reduces risks during assembly
- Better heat-gun techniques during de-soldering. Less boards can be lost during assembly with proper techniques