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Ecen 3730  
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Brd3 report

Contents

[Introduction: 1](#_Toc182390259)

[POR: 1](#_Toc182390260)

[Risk reduction: 2](#_Toc182390261)

[Circuit sketch: 3](#_Toc182390262)

[Circuit Schematic: 4](#_Toc182390263)

[Altium layout: 6](#_Toc182390264)

[Assembled board: 7](#_Toc182390265)

[Noise shield: 8](#_Toc182390266)

[Analysis: 15](#_Toc182390462)

[What worked well? 16](#_Toc182390463)

[What went wrong/future improvements: 17](#_Toc182390464)

[Conclusion: 17](#_Toc182390465)

### Introduction:

* In this lab the design of an Arduino uno was modified to create a minimal atmega32 development board.
* This design was then later tested with a simple led blink program.
* Board plugged into a noise shield test board which allowed readings of the onboard switching noise.
* This procedure was repeated with a commercial Arduino uno board, in order to compare the switching noise of both boards.
* Qhigh, Qlow, Sense resistor V, Near field emissions, 5v line switching noise info collected.

### POR:

Below are the requirements that the board must fulfill to be considered successful. The overall goal  
of this board is to design something that features less signal noise than a commercial board.

**Power block**

* 3v being produced by LDO
* 5v being produced by barrel jack?
* does sw2 switch between usb and barrel jack power?

**Microcontroller block**

* is crystal oscillator outputting 16Mhz signal?
* Can Microcontroller be bootloaded?
* Can microcontroller be programmed?
* does reset button work?
* Is reset voltage within readable range?
* Xtal 16 frequency acceptable?
* Is exp2 rising edge quiet low noise on brd3 less than commercial board?
* Is exp2 falling edge quiet low noise on brd3 less than commercial board?
* Is exp2 rising edge quiet high noise on brd3 less than commercial board?
* Is exp2 falling edge quiet high noise on brd3 less than commercial board?
* Is exp3 5v voltage noise on brd3 lower than noise on commercial board?
* Is exp3 quiet high noise on brd3 lower than on commercial board?
* Is exp4 rise time of slammer circuit higher on brd3 than on commercial brd?
* Is exp4 quiet high noise on brd3 (rising high) less than on cb?
* is exp4 5v noise on brd3 less than (rising high) on cb?
* is exp4 quiet high noise on brd3 (rising high) less than on cb?
* is exp4 5v noise on brd3 less than (rising high) on cb?
* Is exp4 near field emissons on brd3 lower than NFE on commercial board?

**USB block**

* Are rx and tx signals being produced by the ch340?
* Is the crystal oscillator outputting 12MHZ?
* Can Usb be used to communicate with the board? Is it detected in the Arduino IDE?

### Risk reduction:

There are many potential risk sites for this board, for one is the close proximity of the switches and headers to other components in the board. In the case that there are any mistakes that require resoldering of components, I would need to desolder these to access whatever needs soldering. This time during the assembly process I plan on using a high powered microscope to solder components to the board, which should cut down on assembly error.

 Another risk site is accidentally using the wrong capacitors when soldering the board together. To avoid this issue, I will have my laptop open with reference documents while I solder, to ensure everything will be soldered with the proper components.

In addition, another thing that could go wrong is that I could accidentally burn out my eyes with splashes of stray solder when soldering. One way to avoid this is to wear safety goggles while soldering.   
  
Another thing that could go wrong is that I solder the IC's upside down. I will also have reference documents pulled up while I solder to combat this, and make sure the chip orientation matches that found online.

Another issue is that I might accidentally lose some of the components. The TVS chip is incredibly small, and if I am not careful, it might just get lost. The way I plan on handling this potential issue, is to only pull out components one at a time, when I am ready to solder them. I also plan on doing my soldering in an isolated room, preventing the components being lost by various table movements caused by other people.

### Circuit sketch:

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Figure , simple circuit diagram

* A simple sketch of brd3 with its major components. This is fleshed out in more detail in the circuit schematic.

### Circuit Schematic:

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Figure , overall schematic design

* Here is the overall design of the circuit, design decisions are discussed in further detail in each block breakdown.

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Figure , circuitry controlling USB to UART communication

* In order to communicate with the microprocessor, a CH340 USB to UART communication chip was added to the USB block.
* This chip reads in the D+ and D- data lines of the USB port, and converts that data into RX and TX signals.
* Moreover, a TVS chip was added to the D+ and D- data lines in order to prevent ESD voltage spikes, protecting the CH340 chip.

**A diagram of a circuit board

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Figure , the microcontroller block

* Both the CH340 and the atmega32 feature crystal oscillators, with both featuring filter circuitry to smooth out its output waveforms.
* The CH340 oscillator has a frequency of 12MHZ whereas the atmega32 oscillator has a frequency of 16MHZ. The header pin layout complies with the standard spacing and pin layout as a commercial Arduino UNO, with the exception of not featuring an extra copy of ICSP header pins.
* On the reset pin of the atmega32, there is a pullup resistor which keeps the value of the reset pin high until pulled down by an activation of the reset button. To prevent ground bounce on the reset button, a 47nf capacitor allows for a gradual decline in the reset pin voltage levels, as opposed to multiple triggers of the reset pin.

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Figure , the power block

* In the power block, 3v signal and 5v signal is produced via a barrel jack.
* The same design for the power block is reused from my brd2 [design](https://github.com/O11WL1D/ECEN3730_PCBS/tree/master/BRD2).
* Power to the board can be either switched to the USB 5v line, or the barrel jack 5v line.

### Altium layout:

**A blue circuit board with red and green lines

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Figure , component placement and board routing

* One might notice that the USB port is hanging off of the board slightly. This is an intentional design since having the port recessed into the board creates access issues for USB cables.
* Issues and countermeasures concerning this design are discussed in further detail in the what went wrong section of this report.

### Assembled board:

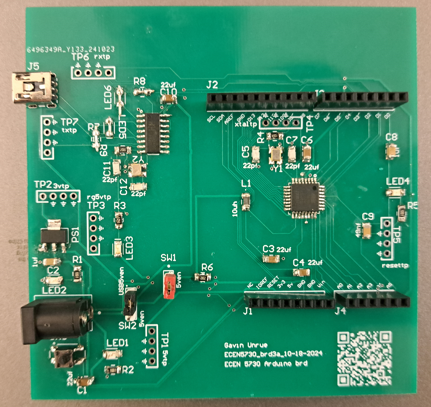
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Figure , the assembled version of brd3

* The soldering process was much more time efficient with this board due to utilizing a high powered microscope during the assembly process.
* This photo was taken prior to some corrections to the board, namely the value of r6, c8, and replacing the jumper wires on rx and tx with 0Ω jumper SMD resistors.

### Noise shield:

**A green circuit board with white text

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Figure , the noise shield used to gather noise measurements on brd3 and the commercial board

* To measure and compare the switching noise on both brd3 and a commercial Arduino board, this board was used with both tested boards running a simple Arduino digital pin blink program.
* The slammer circuit features a mosfet, which when d7 activates allows current into r1.
* Pins d13-d10, along with d7 switch on and off after a 10 ms delay.
* The 5v rail, along with q low and q high are measured for switching noise.

### Code used:

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Figure , Arduino blink code used in noise measurements

* As you can see above, pins d13-d10, along with d7 switch on and off after a 10 MS delay.

### Scope captures:

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Figure , brd3 (0.512v drop, 0.0081A draw, 24.2ns rise time, 2.8us pw ) vs CB (0.503v drop, 0.0079A draw, 25ns rise time, 2.8us pw)

* The figure above show the current draw and voltage drop of the two boards, both have nominal values. It seems that the commercial board has somewhat less voltage, this might be due to inefficient high inductance routing which dissipated higher amounts of voltage up until the sense resistor.
* When summed, this results in a total current of 0.0325a current for brd3, and 0.031a for the CB

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Figure , qlow on falling edge, brd3 (627.14 mv), vs CB (1410 mv), Blue is pin d13, yellow is measured signal.

* As one can see, brd3 has 782mv less noise than the CB. This indicates better design practices or other external differentiating factors.

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Figure , Qlow on rising edge, brd3 (88.95mv ) vs CB ( 360 mv), Blue is pin d13, yellow is measured signal.

* Brd3 is has 271mv lower noise than the CB. This indicates better design practices or other external differentiating factors.

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Figure , 5v line, d13 and qhigh signals, brd3 (blue is 5v line, yellow qhigh) vs CB (blue is qhigh, yellow is 5v).

* In the figure the noise on the 5v line of brd3 is 90mv, as opposed to the cb’s 720mv. This is a difference of -630mv. Moreover, there is 0.402v of noise on brd3 on qhigh, and 0.8v of noise on the cb. This is a difference of 0.398v. This indicates better design practices or other external differentiating factors.

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Figure , brd3 vs cb, qhigh (140mv vs 510mv) is yellow, 5v (10mv vs 133mv) is purple, blue is slammer circuit output(TP2).

* Brd3 features 123mv less noise on the 5v line, and 370mv less noise on the qhigh line, on the rising high signal of d13. This indicates better design practices or other external differentiating factors.
* The slammer circuit would get up to 430mv on brd3, and 425mv on the CB.
* The slammer circuit featured a 346.9us rise time on brd3 and a 50ns rise time on the CB.
* With 10Ω sense resistor and 63Ω led indicator, 0.04866a total drawn by slammer circuit on brd3, and 0.04924a total drawn by CB.
* There is a 0.01v difference between the voltage read on the noise shield and the 5v line on the board. Totaling the slammer and io current draw to be 0.0811A, using ohms law this gives us a  
  Thevenin resistance of 0.125Ω

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Figure , brd3 vs cb, qhigh (402mv vs 520mv) is yellow, 5v (50mv vs 160mv) is purple

* Brd3 features 110mv less noise on the 5v line, and 118mv less noise on the qhigh line, on the rising high signal of d13. This indicates better design practices or other external differentiating factors.

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Figure , Near field emissions of brd3 (602mv vpp) vs CB (802mv vpp)

* In the figure there is a -200mv vpp difference between the near field emissions of brd3 and the CB. This is detected by shorting a probe’s signal and ground lines and placing the shorted probe near the board. This detects the mutual inductance coming from the board, or EM interference.

### Data:

Table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Requirement** | **Requirement fulfilled?** | **Measurement** | **unit** | **Min value** | **Max value** |
| 3v being produced by LDO | TRUE | 3.31 | v | 3 | 3.5 |
| 5v being produced by barrel jack? | TRUE | 5.23 | v | 5 | 5.5 |
| does sw2 switch between usb and barrel jack power? | TRUE |  |  |  |  |

Table , General measurements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **GENERAL** | **Measurement** | **unit** | **CB measurement** | **unit** |
| Is reset voltage within readable range? | 3.51 | v | 5.23 | v |
| Xtal 16 frequency acceptable? | 15.97 | MHZ | 16.5 | MHZ |

Table , experiment 2 POR vs measurements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EXP 2** | **Measurement** | **unit** | **CB measurement** | **unit** | **Difference** | **unit** |
| Is rising edge quiet low noise on brd3 less than commercial board? | 88.95 | mv | 360 | mv | -271.05 | mv |
| Is falling edge quiet low noise on brd3 less than commercial board? | 627.14 | mv | 1410 | mv | -782.86 | mv |
| Is rising edge quiet high noise on brd3 less than commercial board? | 140 | mv | 560 | mv | -420 | mv |
| Is falling edge quiet high noise on brd3 less than commercial board? | 440 | mv | 520 | mv | -80 | mv |

Table , experiment 3 POR vs measurements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EXP3** | **Measurement** | **unit** | **CB measurement** | **unit** | **Difference** | **unit** |
| Is 5v voltage noise on brd3 lower than noise on commercial board? | 90 | mv | 720 | mv | -630 | mv |
| Is quiet high noise on brd3 lower than on commercial board? | 0.402 | v | 0.8 | v | -0.398 | v |

Table , experiment 4 POR vs measurements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EXP4** | **Measurement** | **unit** | **CB measurement** | **unit** | **Difference** | **unit** |
| Is rise time of slammer circuit higher on brd3 than on commercial brd? | 25 | ns | 24.2 | ns | -0.8 | ns |
| is quiet high noise on brd3 (rising high) less than on cb? | 140 | mv | 510 | mv | -370 | mv |
| is 5v noise on brd3 less than (rising high) on cb? | 10 | mv | 133 | mv | -123 | mv |
| is quiet high noise on brd3 (falling edge) less than on cb? | 402 | mv | 520 | mv | -118 | mv |
| is 5v noise on brd3 less than (falling edge) on cb? | 50 | mv | 160 | mv | -110 | mv |

* The only item which fell short of the POR’s expectations is the rise time, as seen on row 1 of this table. This is discussed later in this report.

Table , experiment 5 POR vs measurements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EXP5** | **Measurement** | **unit** | **CB measurement** | **unit** | **Difference** | **unit** |
| Is near field emissons on brd3 lower than NFE on commercial board? | 602 | mv vpp | 802 | mv vpp | -200 | mv |

Table , Power budget and rise times.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **BRD3 Value** | **Unit** | **CB Value** | **Unit** |
| tot i/o current | 0.032508 | a | 0.031937 | a |
| sense resistor current | 0.008127 | a | 0.007984 | a |
| sense resistor resistance | 63 | Ω | 63 | Ω |
| slammer circuit voltage | 0.42 | v | 0.425 | v |
| slammer circuit rise time | 346.9 | us | 50 | ns |
| indictor current | 0.006667 | a | 0.006746 | a |
| sr current | 0.042 | a | 0.0425 | a |
| total | **0.048667** | a | **0.049246** | a |

### Analysis:

On the rising edge of brd3, the quiet low signal has 51mv more signal noise than the quiet high signal. On the falling edge of brd3, the quiet low signal has 187.14mv less signal noise than the quiet high signal.

On the rising edge of the CB, the quiet low signal has 200mv more signal noise than the quiet high signal. On the falling edge of the CB, the quiet low signal has 890mv less signal noise than the quiet high signal.

Overall it seems brd3 experiences more signal noise on the quiet high signal during the rising edge,   
and more signal noise on the quiet low signal during the falling edge. The exact opposite is true for the commercial board for both the rising and falling edges.

This sort of information might be useful if there is flexibility in chip selection. If its possible to find chips which are active high, they might be better used on a board which experiences less signal noise on the rising edge. This could result in less error during clock cycles of a circuit, if operating based off of a central clock.

When I/O were switching on brd3, the quiet high signal experienced -312mv more signal noise than on the 5v line.

On the commercial board, the two amounts of noise were relatively similar, with the quiet high signal only experiencing 80mv more signal noise than on the 5v line.

Regardless of this difference, in terms of overall signal noise brd3 still outperforms the CB.

It would seem that more noise makes its way onto the die of the atmega32 rather than the 5v line of brd3. This might be due to the close proximity of switching I/O inside of the atmega32 to the internal 5v line.

It would seem that all switching noise on brd3 is greatly lower than that of a commercial board. While its tempting to say that most of this can be attributed to best design practices, there is a 0.8 ns difference in switching noise between the two boards. Since the commercial board is faster, this is guaranteed to result in an increase in signal noise on the commercial board. To truly compare the two boards, one approach might be to divide up the amount of noise by the rise time of the board. This would create a noise per rise time per noise ratio, and by comparing this value for each measured datapoint on the two boards, one might get a better idea of the relative performance of both boards.

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Figure , Commercial Arduino design, atmega16 is seen to the left.

Another reason why there might be less signal noise on my board as opposed to a commercial Arduino is the secondary atmega processor on commercial Arduinos. The commercial Arduino uno design utilizes an atmega16 microprocessor in order to convert incoming USB data signals into RX and TX signals. This likely is the culprit of the large jump in noise levels when comparing brd3 to a commercial board.

### What worked well?

In my design I copied and pasted some sections of hardware used in previous boards. Since  
the sections worked well in the previous board, i.e. the power block, the nominal operation of said blocks carried onto my design for brd3. The technique of re-using old designs worked well in this instance, so I plan on carrying on this design practice into future designs.

Everything in the POR was fulfilled, so following best design practices also seems to work out pretty well. Three days before the scheduled assembly date for these boards I had an opportunity to assemble my board early. Knowing the next few weeks would be very busy, I assembled my board early. This put me in a position to get my board troubleshot in time to write this report and work on the design files for the next board. This is also a practice that has served me well, and would do me well to repeat in the future.

### What went wrong/future improvements:

During the assembly process, both crystal oscillators to the ch340 and to the atmega328p had accidentally been shorted to ground since the solder bridged between the outer case of the crystal and their respective oscillation pins. This was remedied by applying a heat gun to the crystals and moving them around a little, which re-distributed the solder on crystals.

another issue with my board design was that the led indicators for the rx and tx had accidentally been put in serial with the signals rather than in parallel, rendering UART communication impossible. This was fixed by adding in jumper wires in-between the component pads, shorting the components and removing them from my design.

Another issue that had occurred was that the voltage on the reset pin of my board was far too low for the board, and as a result the board would always be in a reset state. This was fixed by changing the 10k pullup resistor to be a 1k resistor. This fix allowed the pullup resistor to reduce its voltage drop and as a result keep the reset pin at a 3.5v high level voltage until grounded by the reset button.

 Moreover, the dtr pin on my board had a capacitance that was too low to enable UART communication on my board, so I swapped it out for a 22uf capacitor, but during the process of removing the 1uf capacitor I accidentally pulled out the trace connecting to the ch340g chip. This required a jumper wire to be soldered to the DTR pin of the ch340, and connected to a trace conducting the reset pin of the atmega32.

Also, when I first began the design process, wanting a sleek and miniaturized design, I had made the board dimensions business card sized, knowing that for brd2 I was able to implement such a compact form. This ultimately resulted in a cramped less efficient design that needed to be redesigned.

Ultimately I learned that many mistakes during the assembly process may be prevented with spending more time during the design process. By implementing measures such as spice circuit simulations and more intensive reviews of the board file.

 Another lesson I learned during the assembly process was to slow down while putting the board together. Unfortunately I've gotten into the habit of drinking several cups of coffee during the day, which ultimately resulted in some mistakes caused by general impatience, such as the trace on the dtr pin being separated from the board.

 In addition, I learned that sometimes you need to start with a larger board, then simplify down. The final design of my board included at least 3/4ths of an inch of extra space. In my next design, I can start with a large pcb, then afterwards shrink the board down to wrap around the components.

### Conclusion:

The design and assembly of brd3 can be considered a success since all vital requirements in the POR were fulfilled.

This board was both highly challenging and rewarding to design and assemble. This entire lab  
has taught me plenty about the design process of PCBS, and PCB production best practices. Surely the skills I’ve learned in this lab will enrich my life for years to come.