PSU AND A&D REPORT

Josiah Brough
Student ID: 22160417

Introduction

This report includes two different projects; a power-supply unit (PSU) and an electronic Piano. The PSU is a half wave bridge dual rail power supply which gave me the required voltage outputs of ± 12 volts. This supplied a regulator which gave an additional 5-volt output which served the purpose of driving the load of the piano. The purpose of the piano was to have two different ways of making musical notes. One from a 555-timer circuit which is analogue, and another from a microcontroller circuit which is digital. The schematic design for each of the projects was provided by the lecturer Jian Huang. I copied over these schematic diagrams on Altium and designed the printed circuit board (PCB) layout. Jian then ordered my specific PCB design and the components required so that I was able to assemble and test them within the lab.

Theoretical Session

Half Wave Bridge Dual Rail Power Supply Project

The PSU circuit had several protective devices each will be explained in detail below. The components referred can be found in the attached schematics.

Fuse – F1

The fuse MC36207 is used to limit the current to in fault conditions to 0.4A and will open the circuit to ensure the faulty device is not able to cause harm to the operator.

Schottky Diodes – D4, D5

Schottky diodes are used because of their high reverse voltage of 40-volts and their low forward voltage at one amp of 600 mV. This ensure that the user of the PSU is not able to accidently plug in a device into the PSU with reverse polarity. The high reverse voltage ensures that current is not going to be drawn in the wrong direction, and the low forward voltage ensures that the power losses due to this safety feature will be small.

Resistors – R4, R5

The 0.5-watt resistors allow for extra overcurrent protection.

Using the formula: $P = I^2R$, and rearranging to get: $I = \sqrt{P/R}$

We can see that our resistors can operate with a maximum of $\sqrt{0.5} = 707.1\ mA$

The reason for the choice of resistors instead of fuses is that the resistors allow for current spikes whereas a fuse would open the circuit. Therefore, the resistor is used to clear sustained high current faults.

Analogue and Digital Piano Project

Analogue Piano

The analogue piano circuit uses a button in series with a particular value of resistor to change the time taken for the capacitor to charge and discharge. Each time the capacitor becomes full charged the 555-timer resets, and when completely discharged it becomes set. Values for the desired frequency were calculated using the formula:

$$f = (1.44 / (Rn+2(R9))\ C3)$$

where Rn is Resistor 1 to 8 depending on the button pushed.
The advantage of this circuit is that the 555-timer is cheaper than a microcontroller, the calculations are simple and easy to implement. The disadvantage is that the design requires a good understanding of analogue electronics and the 555-timer.

Digital Piano

The digital piano uses a single button with connected to a microcontroller (MC) which has an internal pull-up resistor (setting PORTA1 = 1). This makes the button active low and stops a floating voltage at the pin which in turn reduces noise. The MC checks when the input pin PA1 goes low due to a button press. When this goes low, it outputs to the base of a BJT on port PB4 which controls the current to the speaker. By using timer1 for fast PWM which has a 50% duty cycle on the MC, a range of piano notes were able to be set. This is done by using ICR1 as the top value and having a 1us cycle for each tick. By finding the half of the reciprocal of the frequency I was able to find the half period of the required waveform in microseconds, which I then set the top value to. All this functionality is implemented through code, and with each consecutive button press the program cycles through each note, looping back to the start after the last note is played. A button debounce was also implemented using code, which checks for a button press. It has a delay to wait for the initial noise to settle and become stable before running the desired code within a while button-pressed loop.

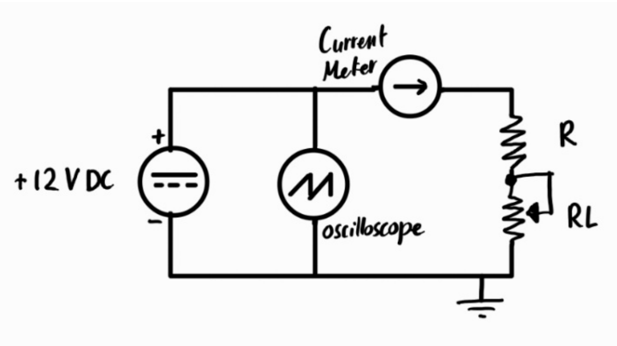
The advantage of this circuit is that there are few components, and it is easy to replicate once the code has been written. The disadvantage is that it requires a lot of upfront work, code to be written and a deep understand of microcontrollers and their datasheets.

Practical and Simulation Session

Half Wave Bridge Dual Rail Power Supply Project

Practical session

Tests were carried out with the use of; a multifunction tester for measuring current; an oscilloscope for precise measurements of the waveform; and a variable resistive load to test the circuit under load and compare it with no-load conditions. The test circuit is shown below:

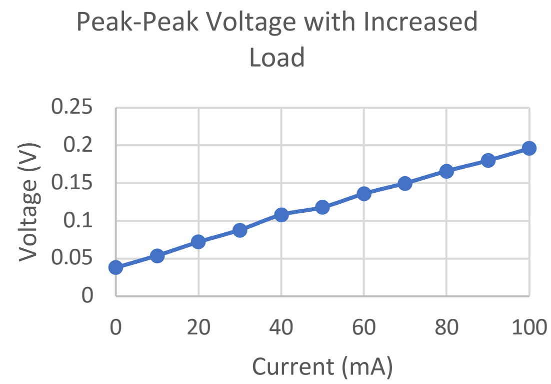


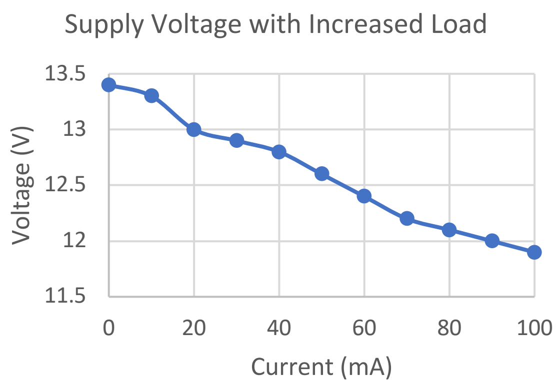
With the oscilloscope, use of the DC and AC coupling function was used to take measurements. Which when DC coupling is switched on shows the DC offset, which was useful to measure the magnitude of the DC power supply's voltage and how it changes under load. When it is turned to AC coupling it shows the waveform without the DC offset by use of measuring the voltage through a capacitor to block the DC. This was useful to measure the amount of DC ripple present in the circuit and how it changes under load.

Oscilloscope Measurements

+12v measurements

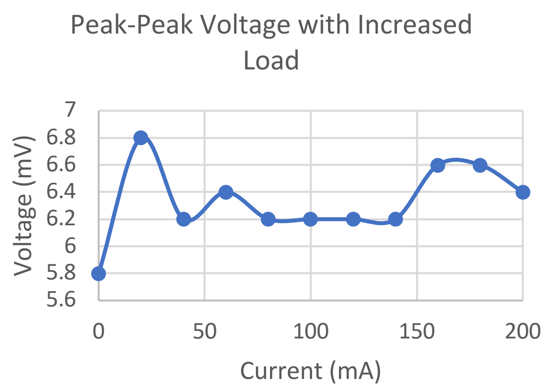
Current	V_{rms} (V)	V_{pp} (V)
0	13.4	0.038
10	13.3	0.054
20	13	0.072
30	12.9	0.088
40	12.8	0.108
50	12.6	0.118
60	12.4	0.136
70	12.2	0.15
80	12.1	0.166
90	12	0.18
100	11.9	0.196

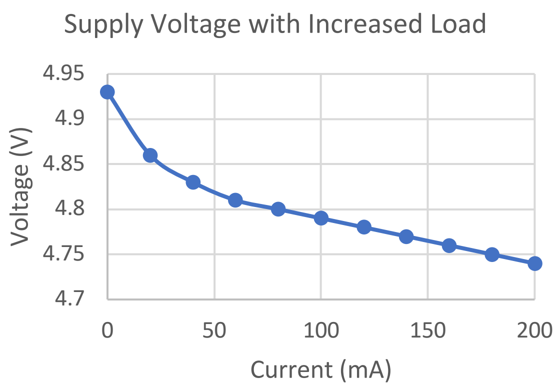




+5V Measurements

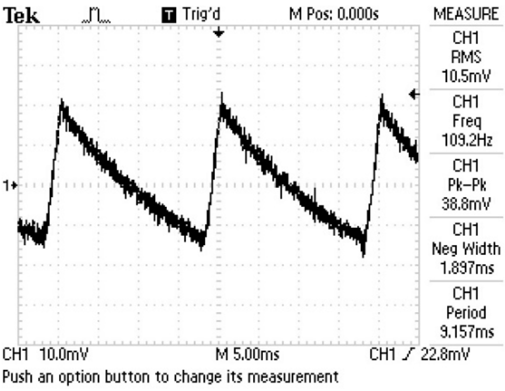
5v Supply		
Current	V_{rms} (V)	V_{pp} (mV)
0	4.93	5.8
20	4.86	6.8
40	4.83	6.2
60	4.81	6.4
80	4.8	6.2
100	4.79	6.2
120	4.78	6.2
140	4.77	6.2
160	4.76	6.6
180	4.75	6.6
200	4.74	6.4

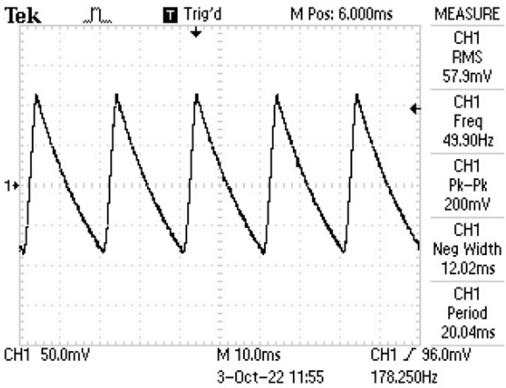


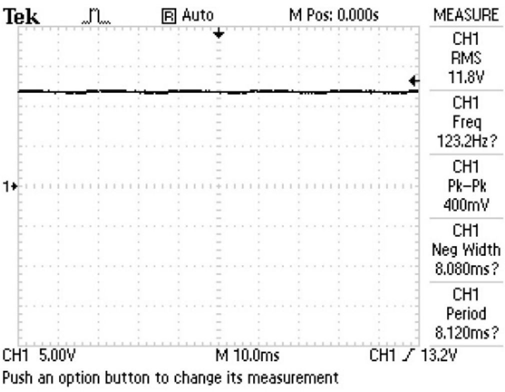


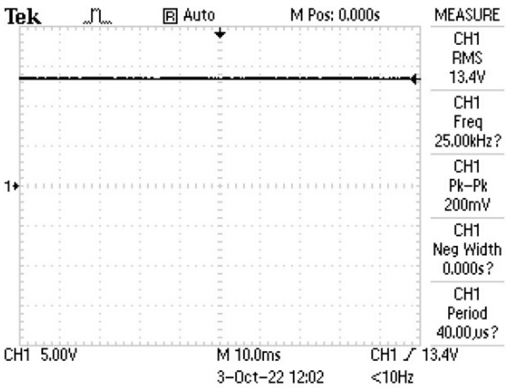
Figures

+12v No load vs Full load (100mA)

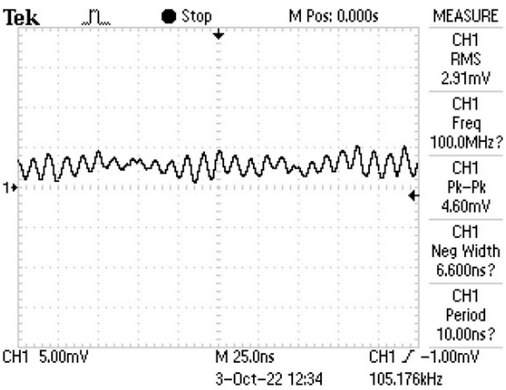


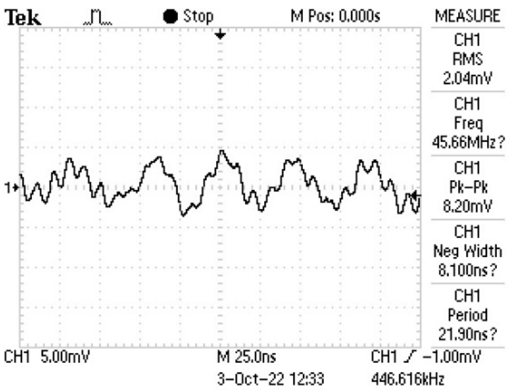


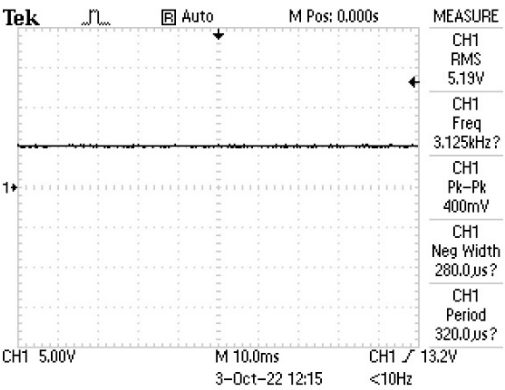


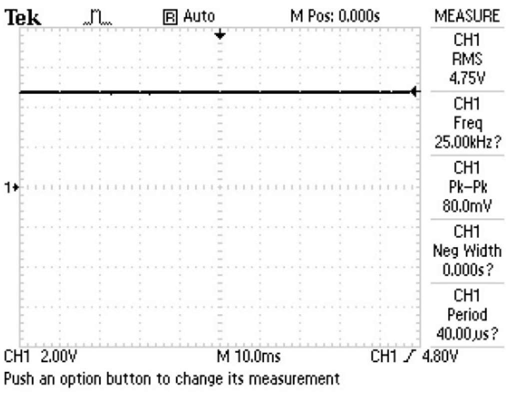


+5v No load vs Full load (200mA)









Comments on Measurements

The 12-volt supply's DC ripple increased with an increase in load current, whereas the 5-volt supply stayed steady throughout due to the additional filtering from the regulator.

Noise as DC ripple can cause components to heat up and operate improperly. This can be avoided by reducing the load on the circuit, increasing the amount or size of the filtering capacitors ($V_{rpp} = \frac{I}{fC}$) and or adding regulators.

Simulation

	100mA, 470uF	100mA, 2200uF	300mA, 2200uF
V_PP	3.0743	0.8152	2.1451
V_RMS	7.6505	8.7943	8.1038

Comments on simulation measurements

It was observed that when the filter capacitance is increased, then the DC ripple decreases which satisfies the formula $V_{rpp} = \frac{I}{fC}$. There is a downside to this, because when a bigger capacitor is used there is a larger inrush current required to charge the capacitors when initially switched on.

When the load was increased to 300mA from 100mA the ripple increased because there was more load draining the capacitors before the next half cycle charges them up.

Josiah Brough (22160417)

Fig.1 - 470uF Capacitors with 100mA Load

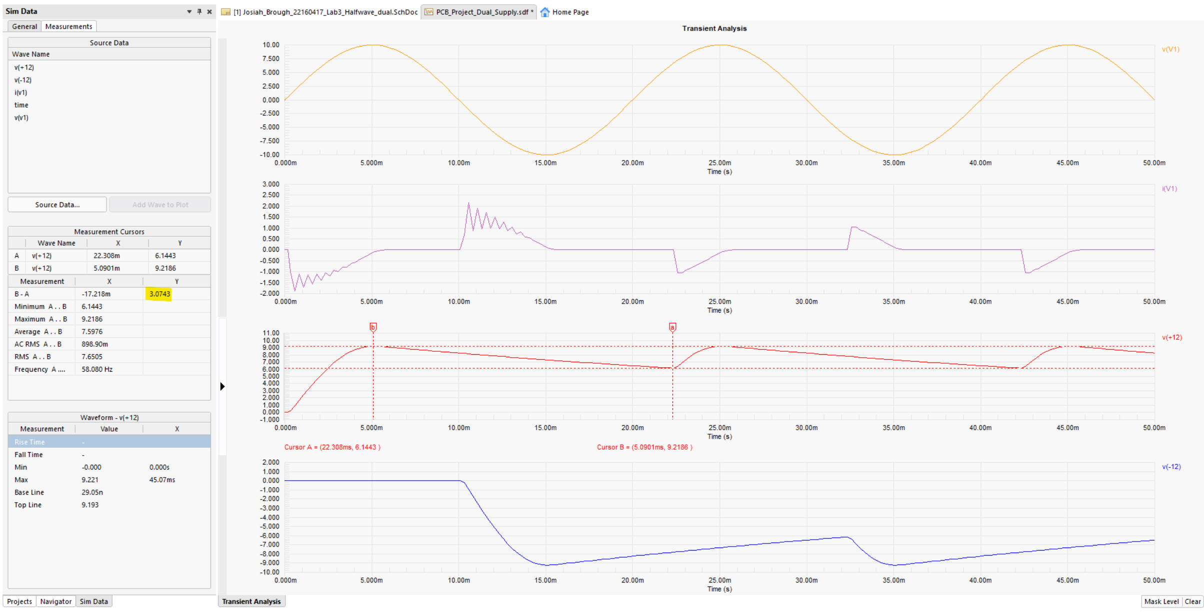


Fig.2 - 2200uF Filter Capacitors with 100mA Load

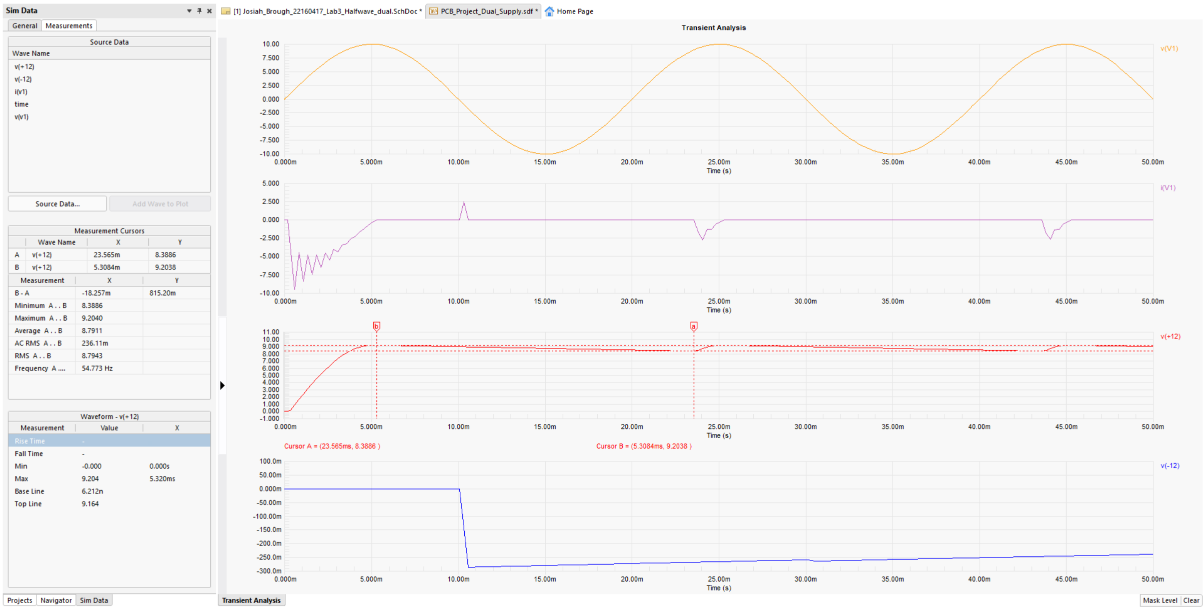
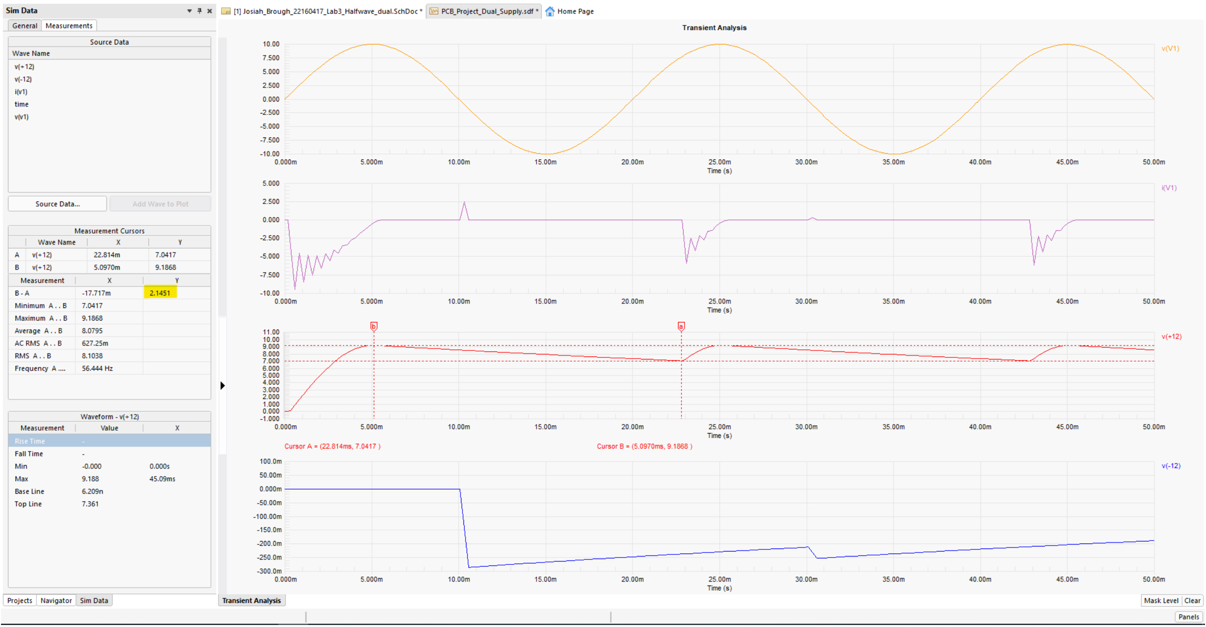


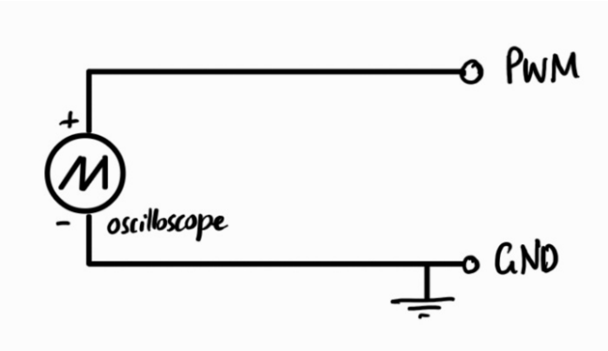
Fig.2 - 2200uF Filter Capacitors with 100mA Load



Analogue and Digital Piano Project

Practical Session

Tests were carried out with the use of an oscilloscope for measuring the frequency of the waveform using the test circuit below.



Oscilloscope Measurements

Musical Note	C5	D5	E5	F5	G5	A5	B5	C6
Frequency Required	523	587	659	698	784	880	988	1047
Recorded Analogue Values	529	595	669	707	796	888	992	978
Recorded Digital Values	1049	1178	1321	1401	1569	1764	1981	2092

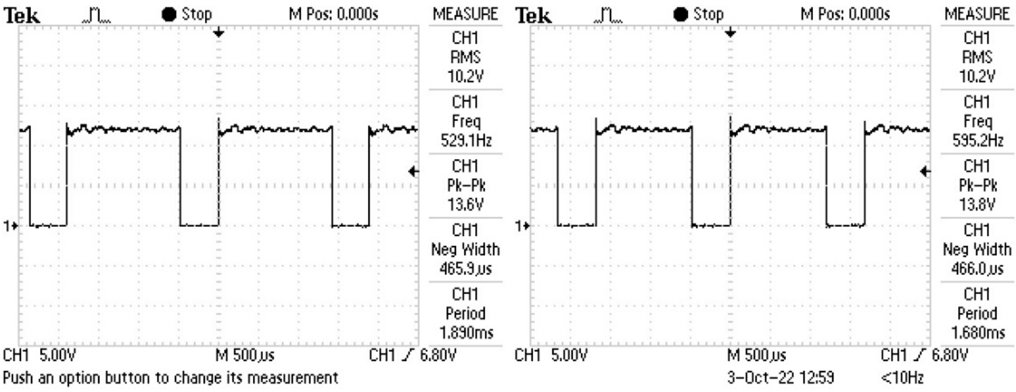
Comments on Measurements

The output of the analogue circuit C6 was measured to be 68.8Hz below the frequency required for the musical note C6. The resistor calculation was double checked and found to be correct, so a review of the 555-timer data sheet maximum ratings is required before further progress, to rectify this problem.

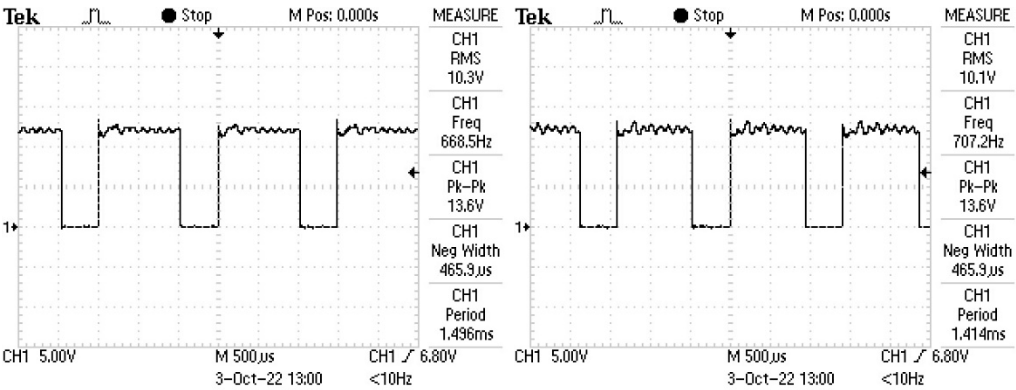
Although the digital keyboard sounded okay, the frequency was incorrect and was exactly double the required value. It was also noted that the duty cycle of the waveform was also not the desired 50%.

Figures for Analogue outputs

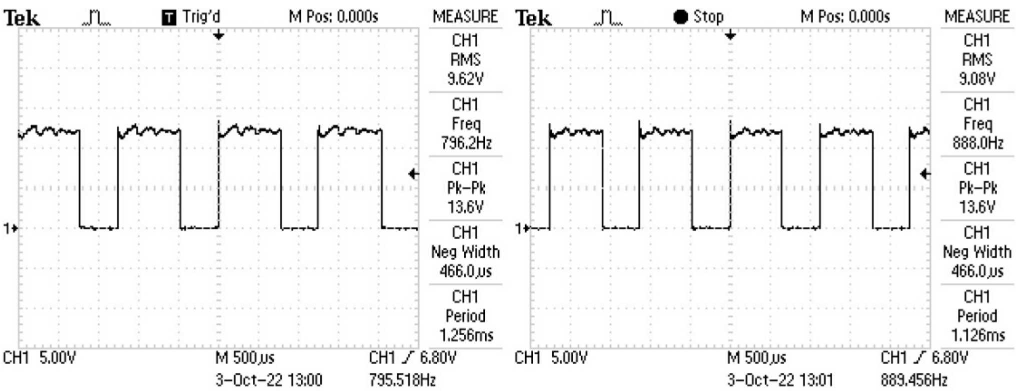
C5 and D5



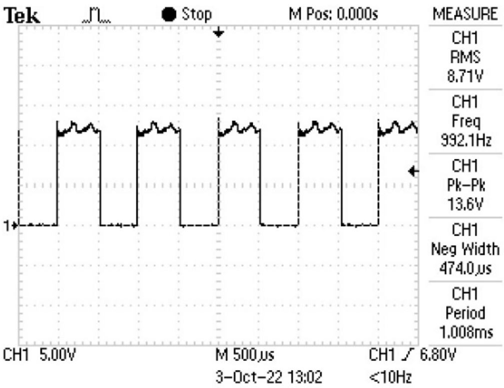
E5 and F5

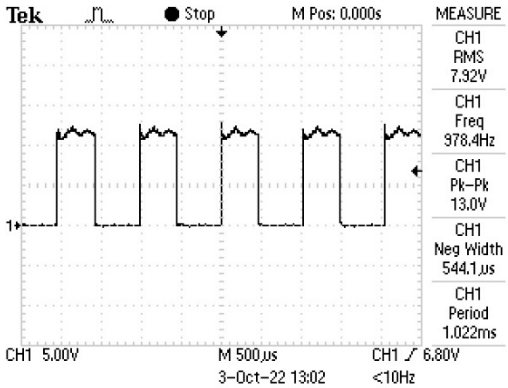


G5 and A5



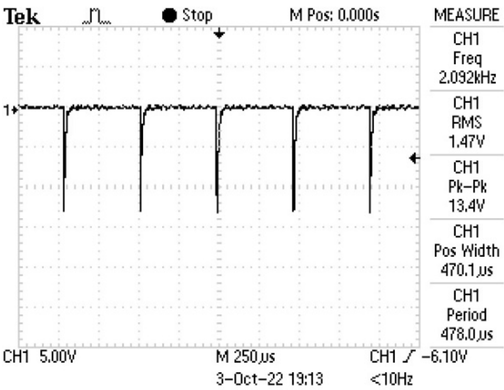
B5 and A6

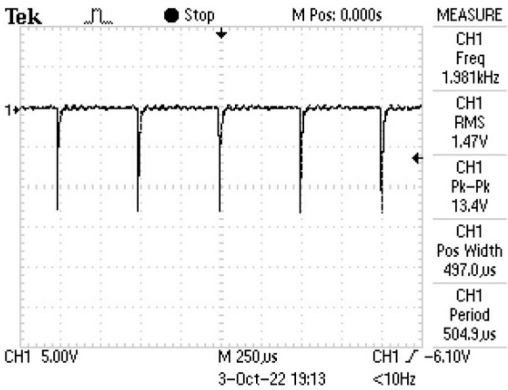




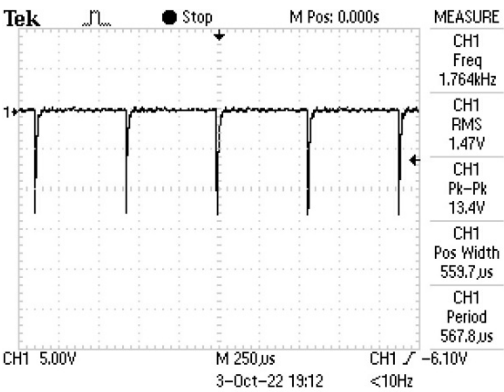
Figures for Digital Outputs

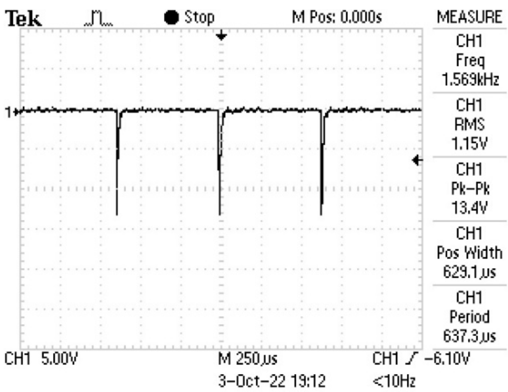
C5 and D5



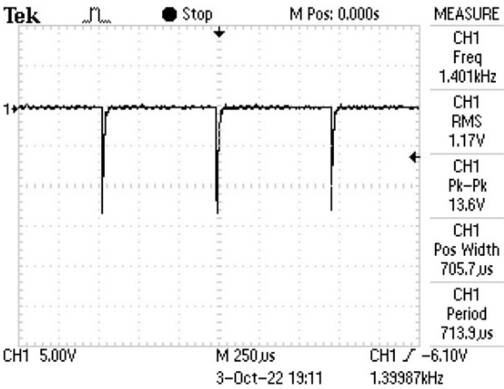


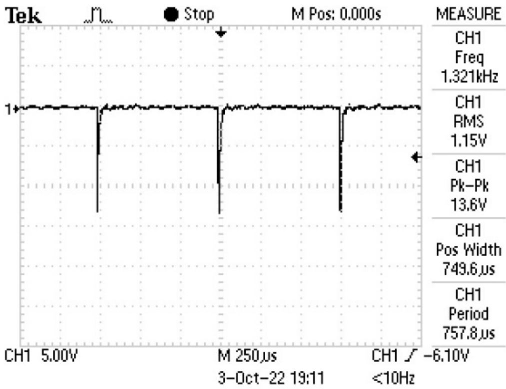
E5 and F5



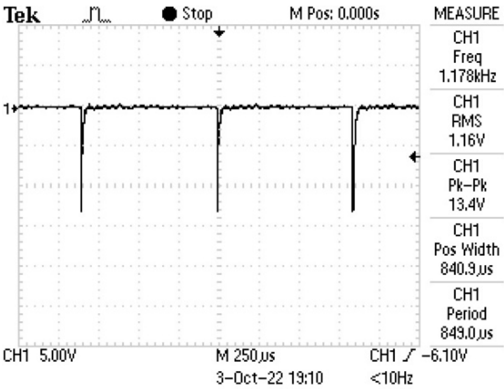


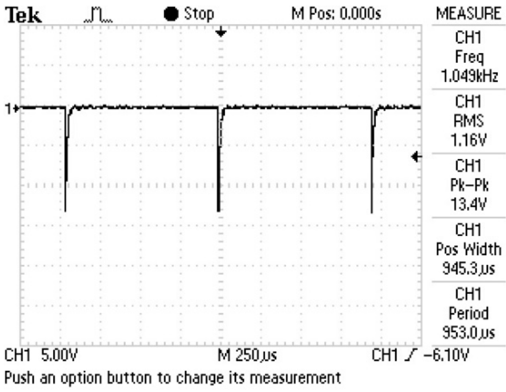
G5 and A5





B5 and A6



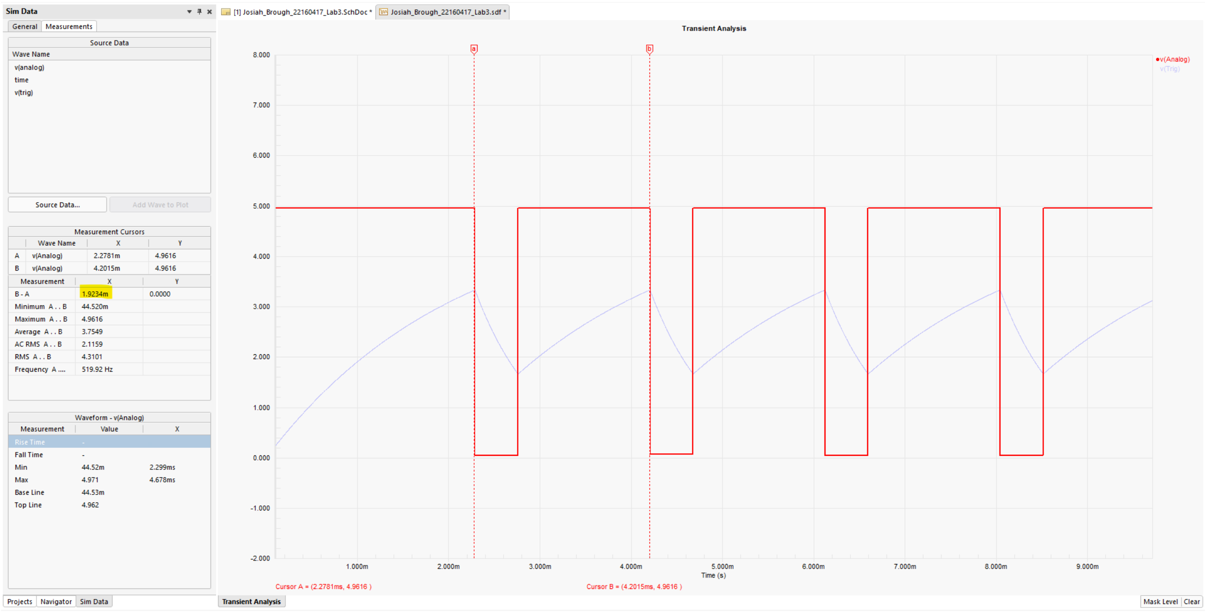


Simulation

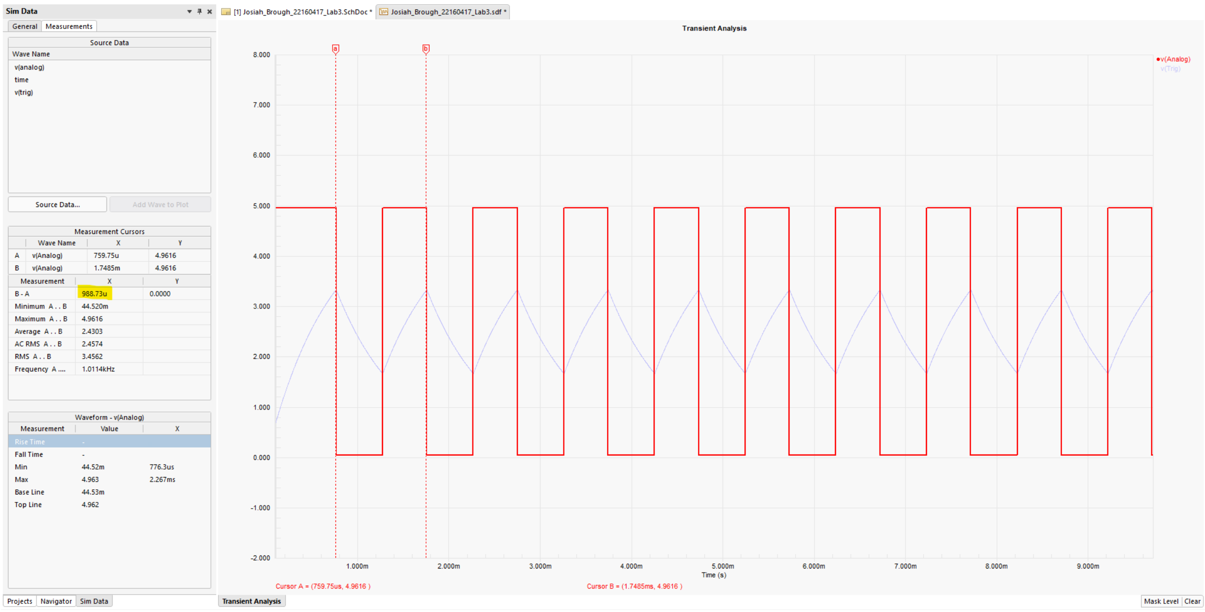
Measurements

	Period	Mark	Duty Cycle
14kΩ	1.9234	1.4491	75%
150kΩ	0.98873	0.48085	49%

14kΩ Resistor



150Ω Resistor



Conclusion

For the +12v power supply it was found that an increase in load increased the DC ripple, decreased the DC output voltage. An increase in filter capacitance was found to increase the filtering from the AC ripple but also increased the inrush current.

The +5v power supply was found to have little to no change in DC ripple had a decrease in DC output voltage when increasing the load current.

For the piano project on the analogue side, it was found from testing with an oscilloscope that the last note was incorrect and had a frequency less than the desired amount. This would need to be rectified for the finished product.

It was also found that the Digital side of the piano had exactly double the required frequency of what was needed to play the musical notes and did not have the required 50% duty cycle. This can be easily rectified through programming the microcontroller correctly.

References

Specifications - Farnell. (2022, 09 25). Retrieved from https://www.farnell.com/datasheets/1678471.pdf?src-supplier=Element14

Specifications - Farnell. (2022, 09 25). Retrieved from https://www.farnell.com/datasheets/2303873.pdf?src-supplier=Element14