Understanding Data Conversion by implementing Sigma Delta and Flash Analog to Digital Convertors

Team 7

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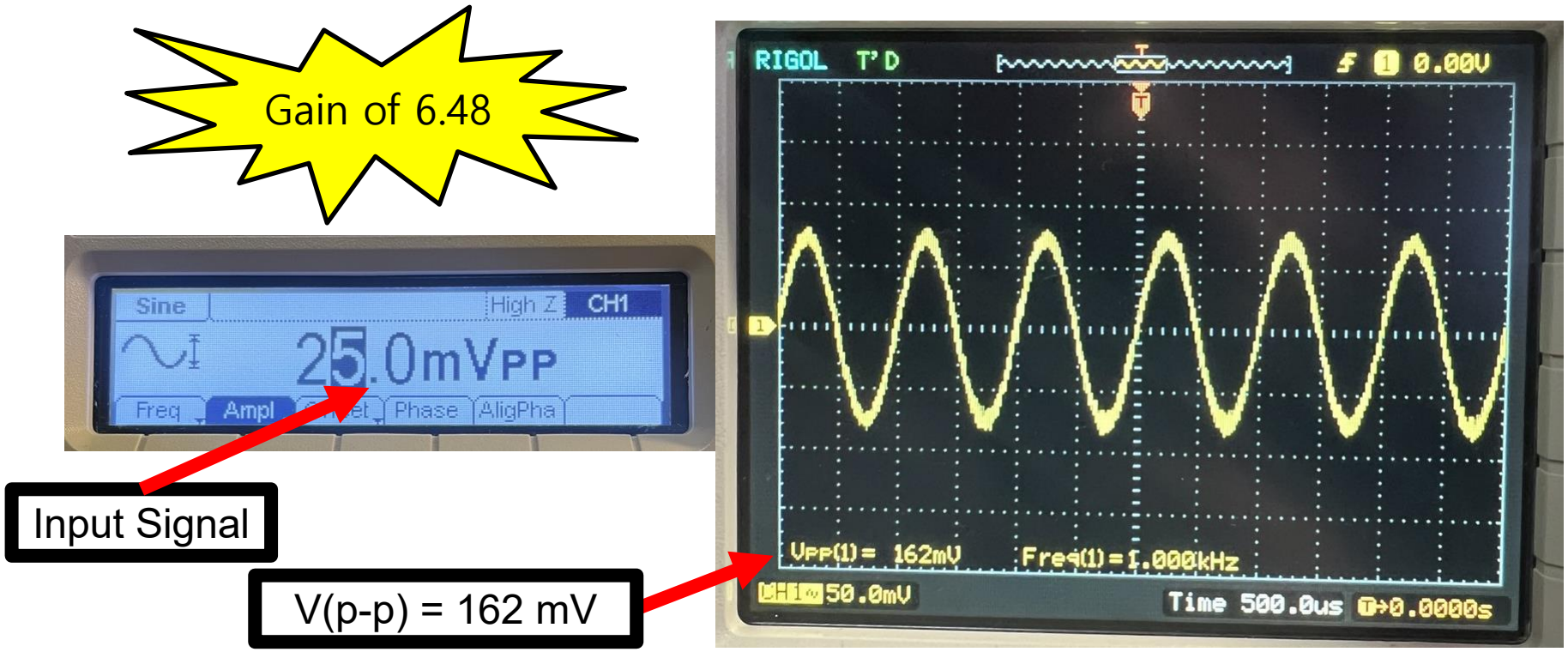
Contents

Chapter 1 : Operational Amplifier

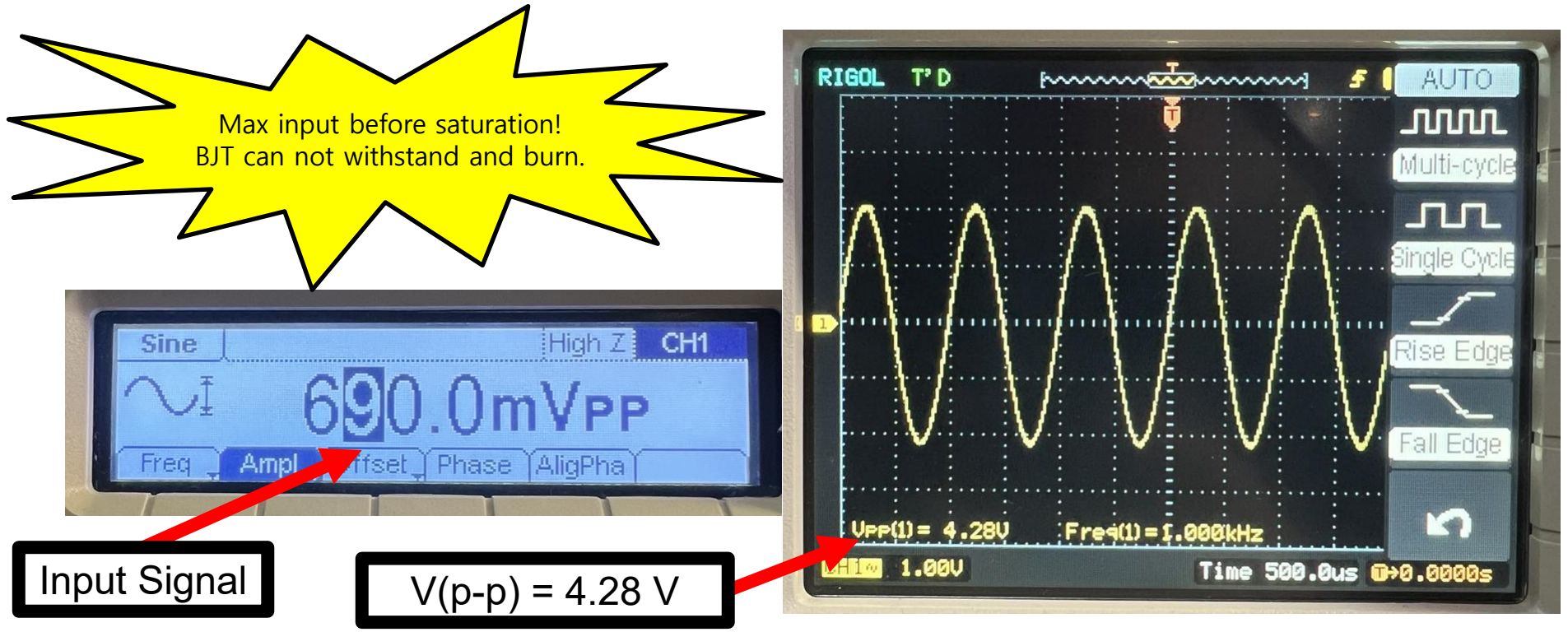
- Output of Operational Amplifier (+Vin = 25mV @ 1kHz, VCC = 12V, VEE = -12V)



- Figure 1. Output of Operational Amplifier

Operational Amplifier (Cont.)

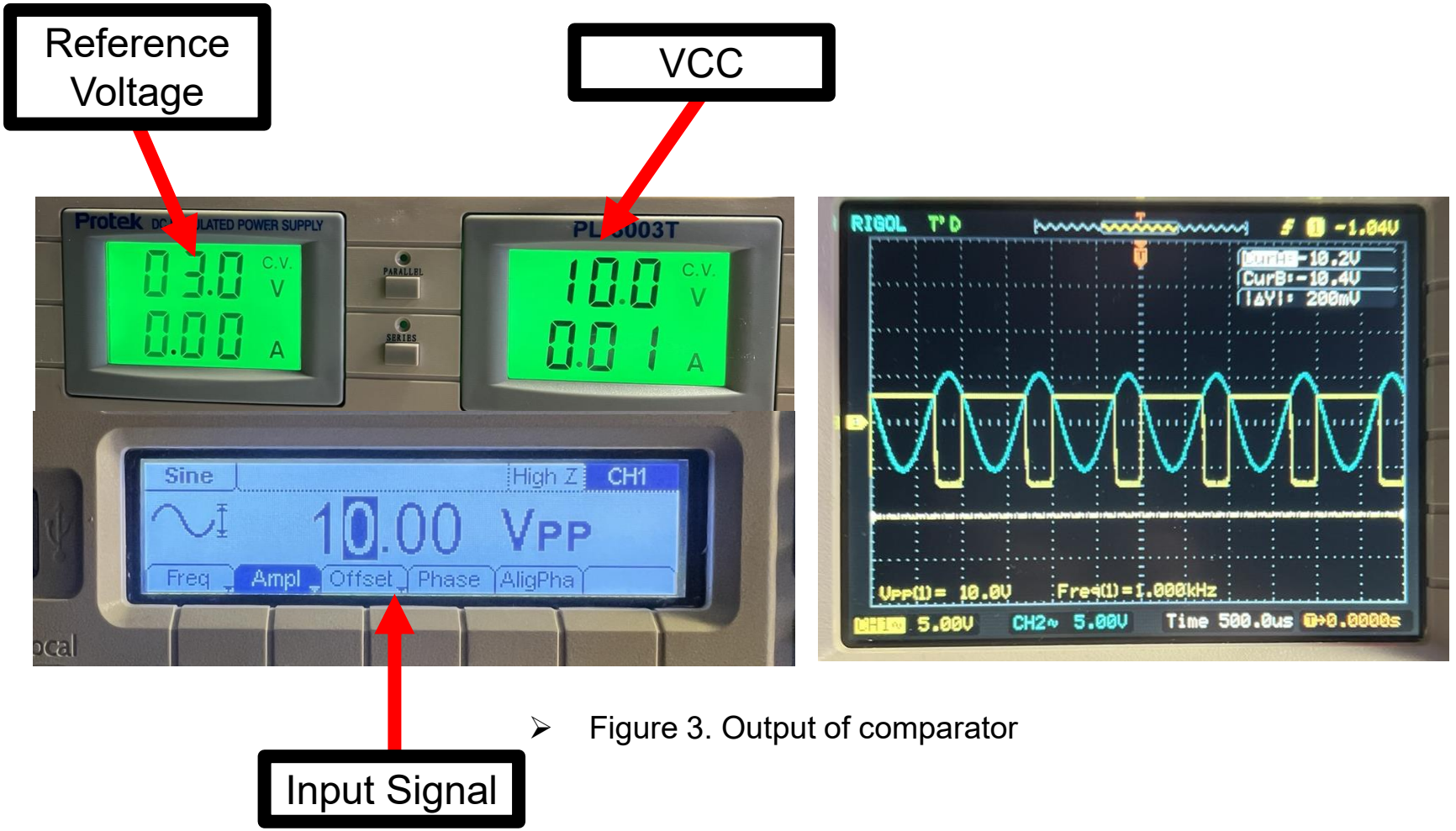
- Output of Operational Amplifier (+Vin = 25mV @ 1kHz, VCC = 12V, VEE = -12V)



- Figure 2. Output of Operational Amplifier

Comparator

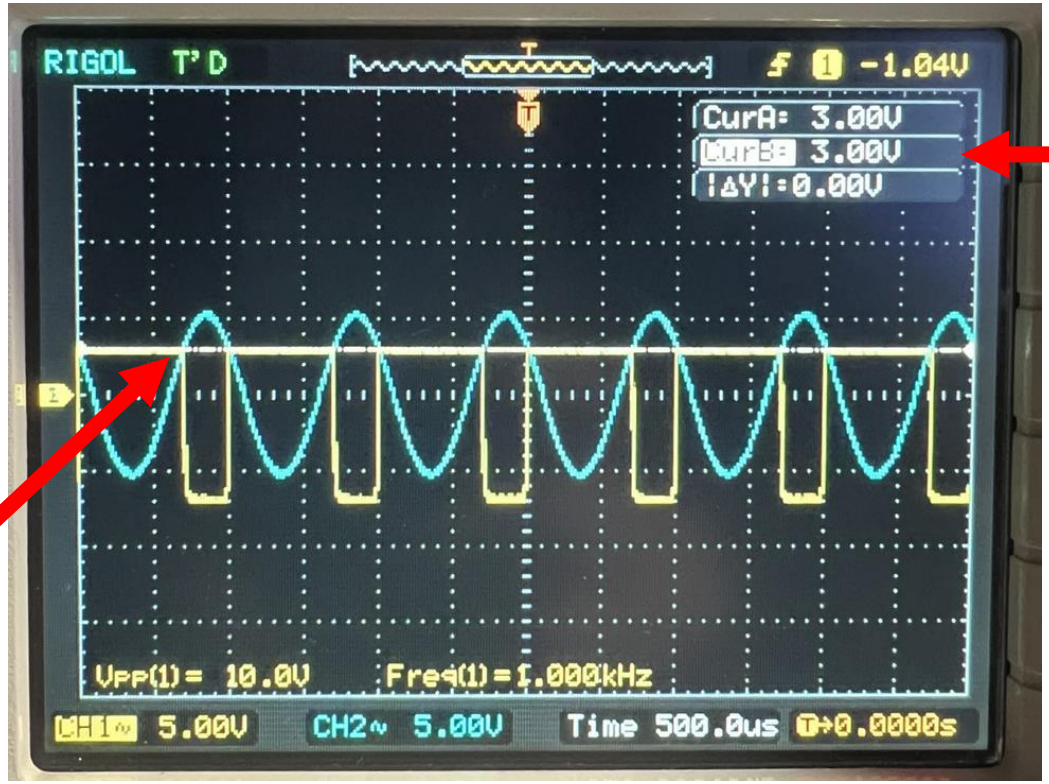
- Output of comparator (+Vin = 10V(p-p) @ 1kHz, -Vin = 3V, VCC = 10V, VEE = 0V)



- Figure 3. Output of comparator

Comparator (Cont.)

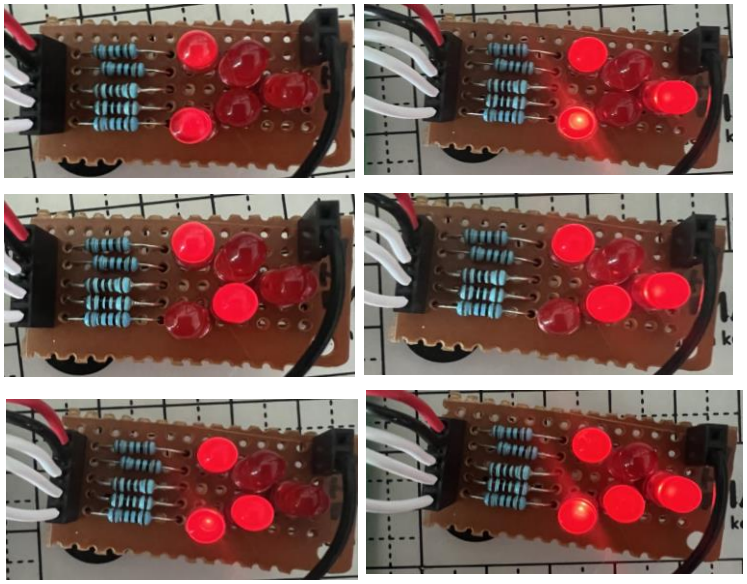
- Output of comparator (+Vin = 10V(p-p) @ 1kHz, -Vin = 3V, VCC = 10V, VEE = 0V)

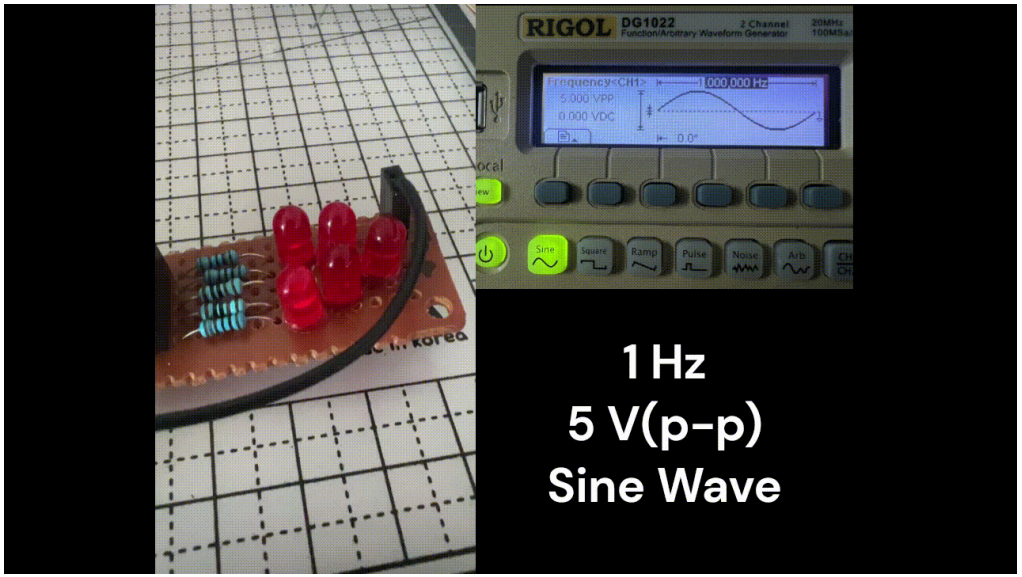


- Figure 4. Output of comparator

Chapter 2 : FLASH ADC

- Output of DAC





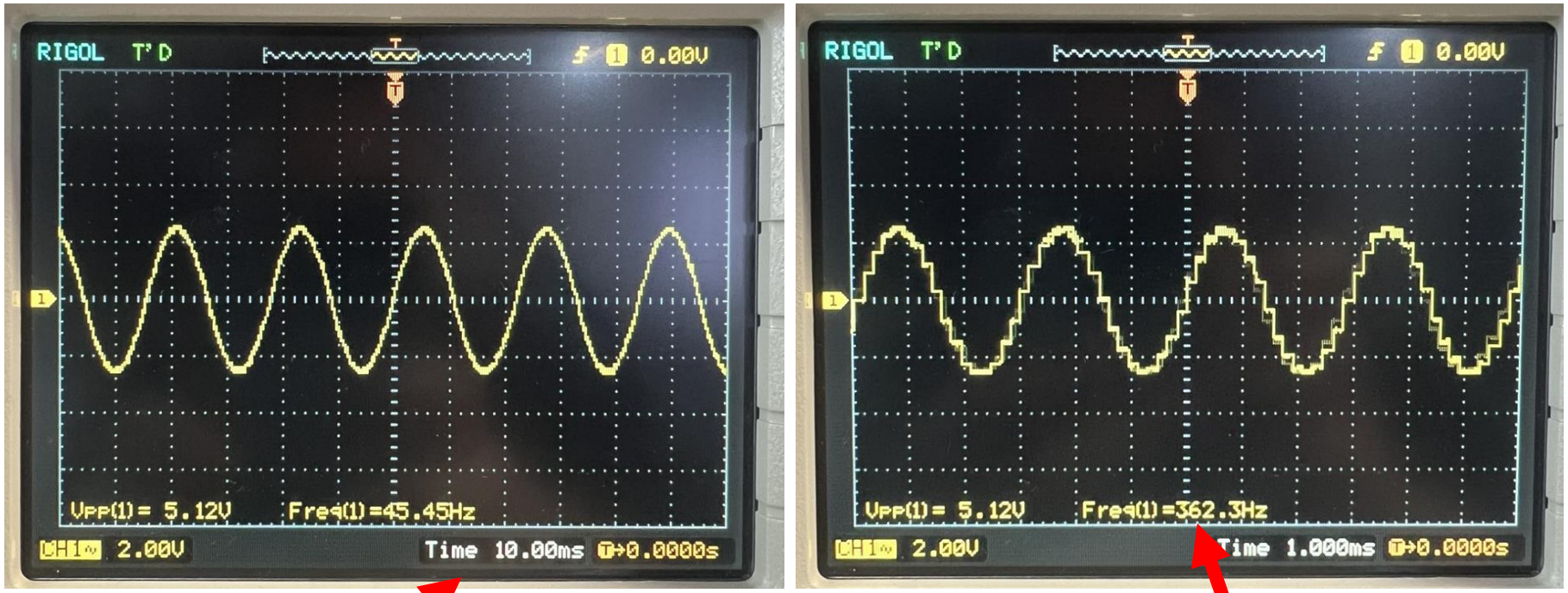
Outputs				
A_2	A_1	A_0	GS	EO
H	H	H	H	H
H	H	H	H	L
L	L	L	L	H
L	L	H	L	H
L	H	L	L	H
L	H	H	L	H
H	L	L	L	H
H	L	H	L	H
H	H	L	L	H
H	H	H	L	H

- Figure 5. Flash ADC Output

R-2R DAC

- Output of DAC

Importance of a good DAC!



- Figure 6. Flash DAC Output

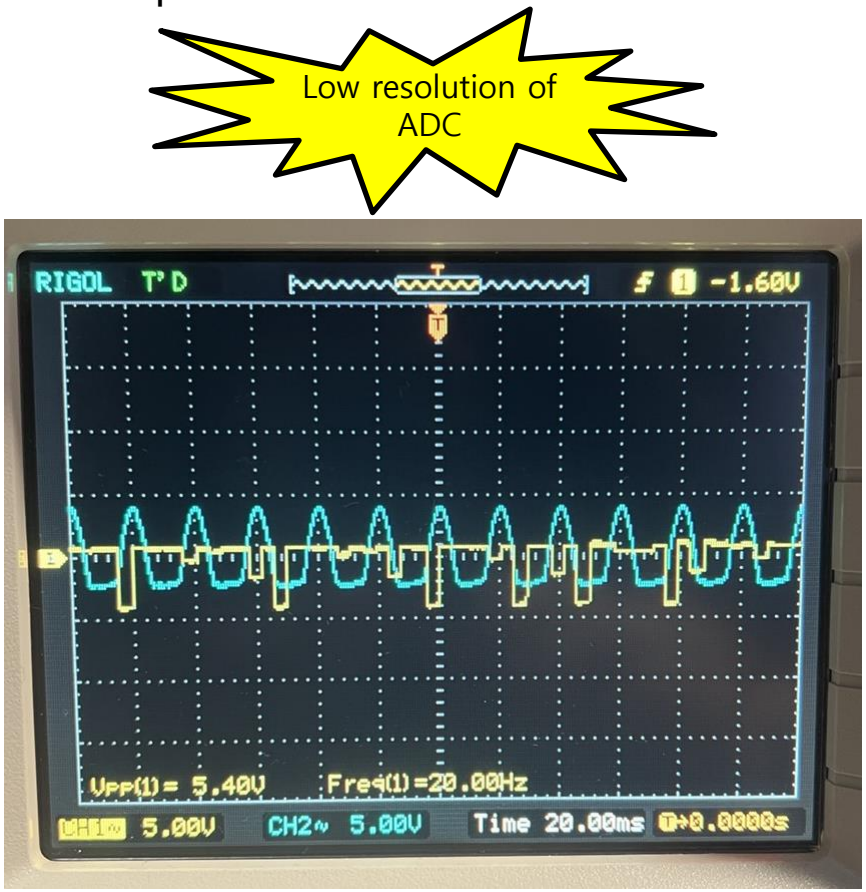
45.45 Hz

362.3 Hz

We can see the steps.

FLASH ADC and DAC

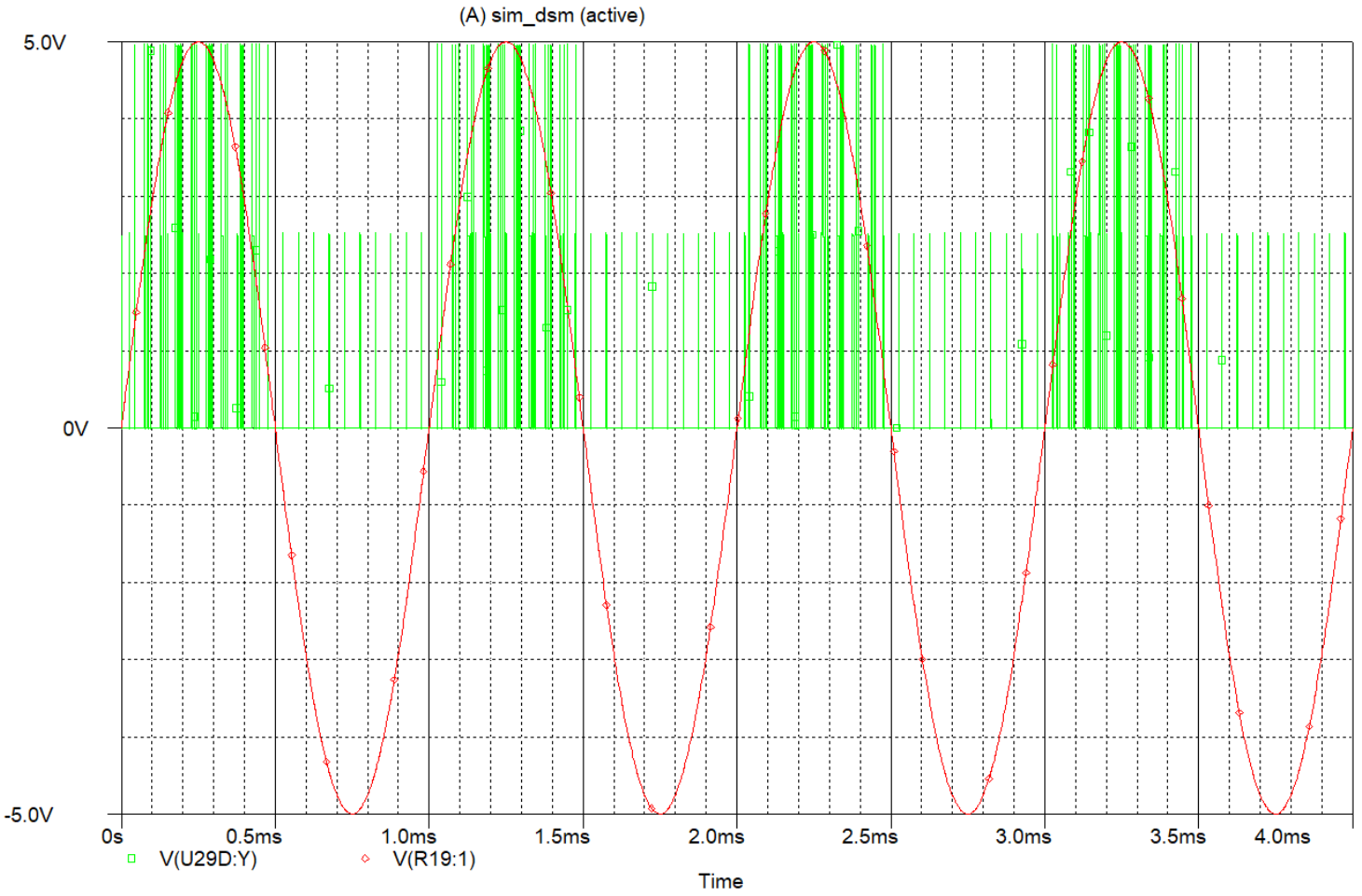
- Output of DAC from the input of the DIY FLASH ADC.



- Figure 7. Flash ADC Output from flash ADC

Chapter 4 : Simulation of Sigma Delta

- Output of ADC (Signal = 5V @ 1kHz Sine Wave, Sampling Rate = 20kHz)



- Figure 8. Sigma Delta ADC Output

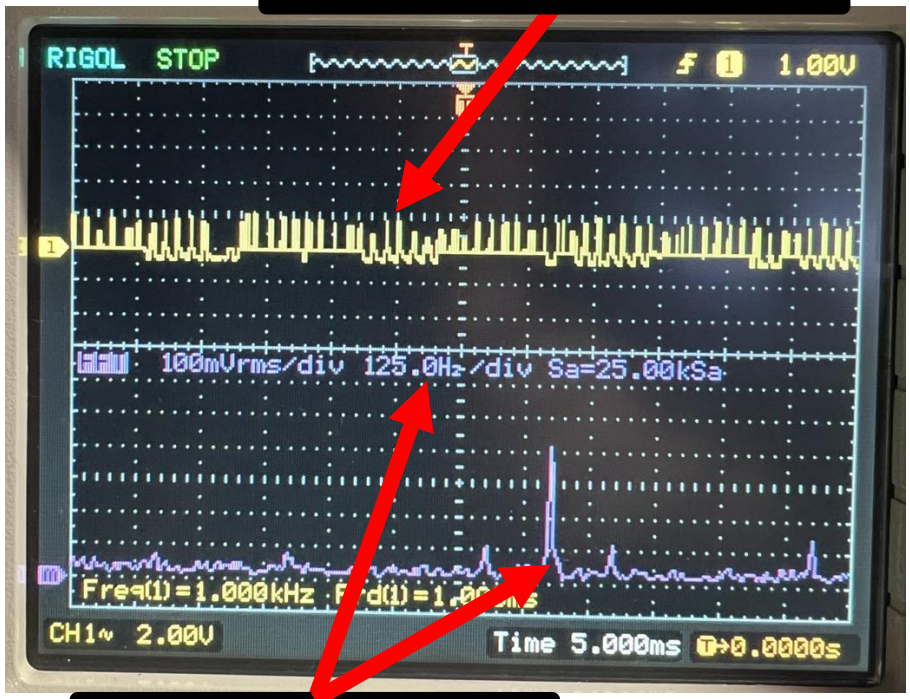
Result

- Output of ADC (Signal = 5V @ 1kHz Sine Wave, Sampling Rate = 2kHz)

1 kHz Signal

2 kHz Sampling

Time domain Sigma Delta ADC

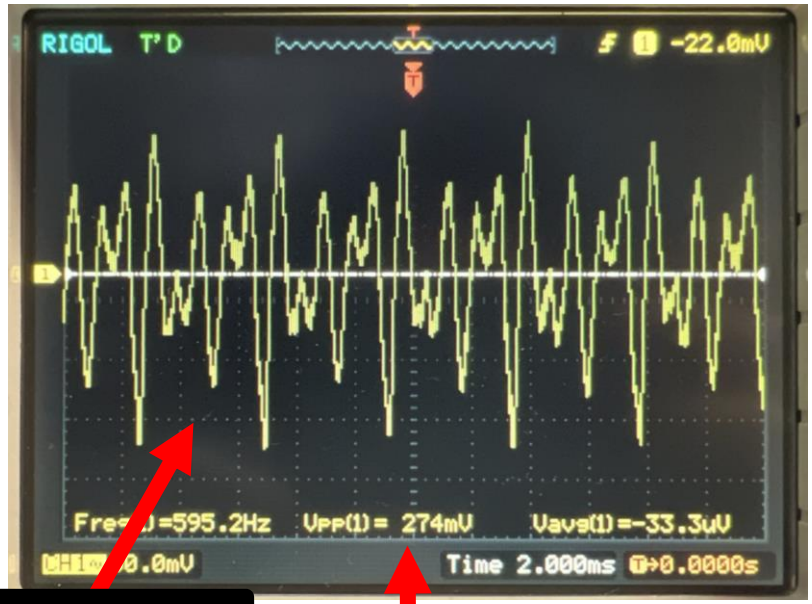


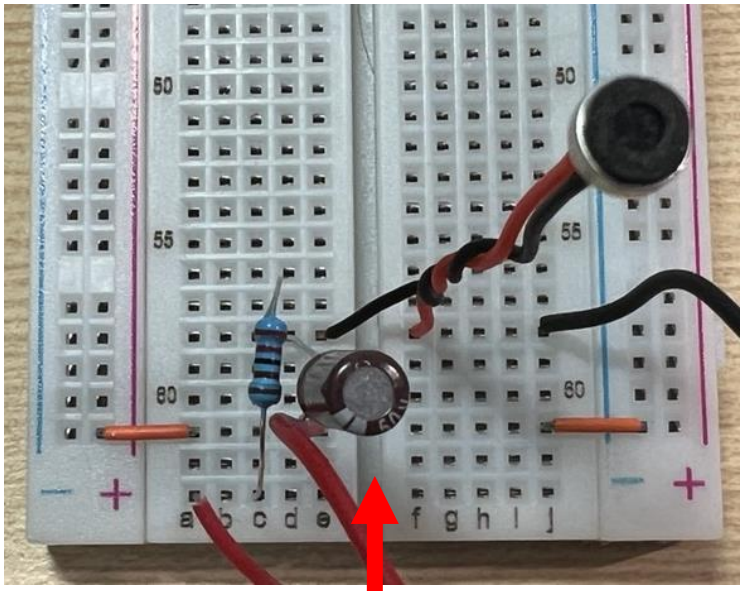
Frequency Domain 1 kHz Signal!

- Figure 9. Sigma Delta ADC Output

Chapter 5 : Commercial ADC and DAC

- Mic output





Vocal Signal

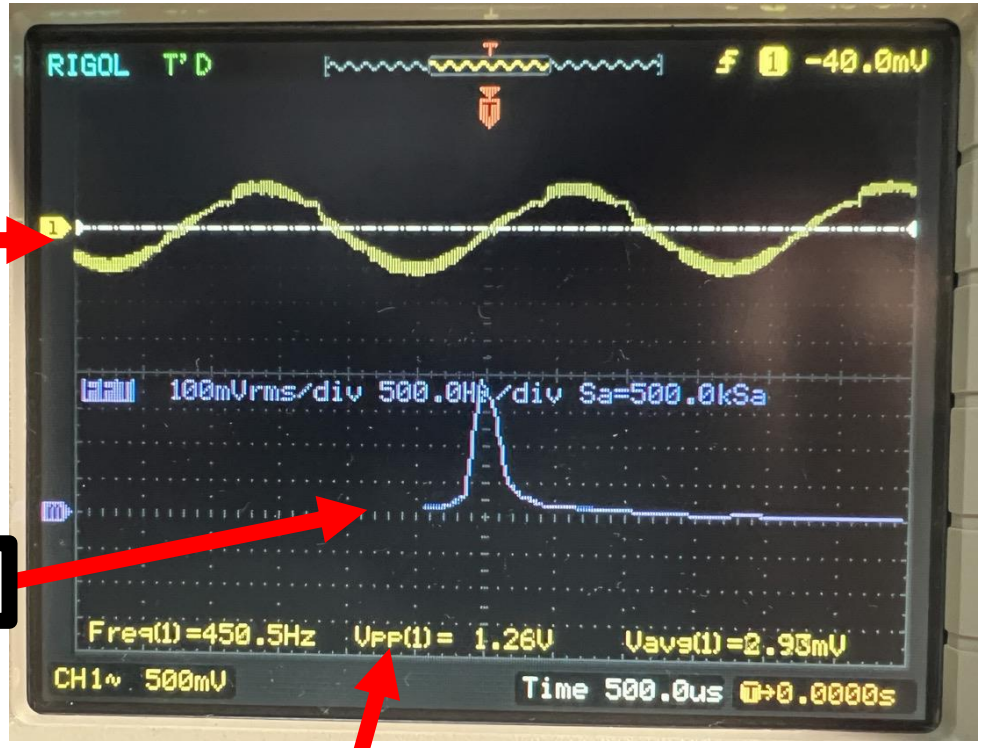
Mic Circuit Pull - Up

- Figure 10. Microphone output

Signal is still small
Vp-p = 274mV (When Screaming)

Commercial ADC and DAC (Cont.)

- Tone Generator Output



Tone Generated Signal 450Hz

Frequency Domain

Signal Boosted to Vp-p = 1.26 V

- Figure 11. Microphone output

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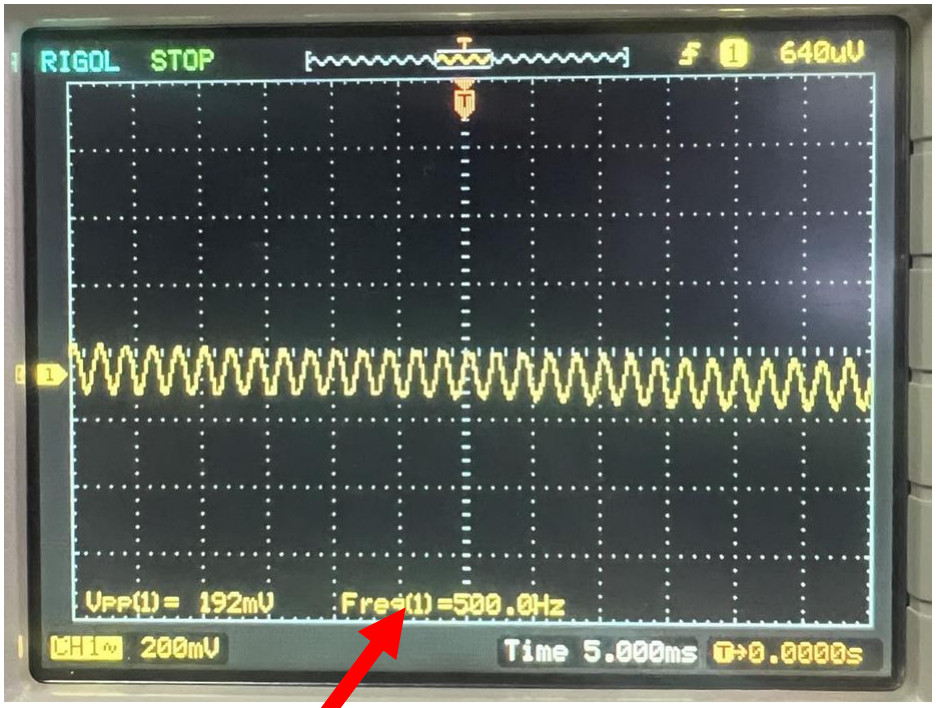
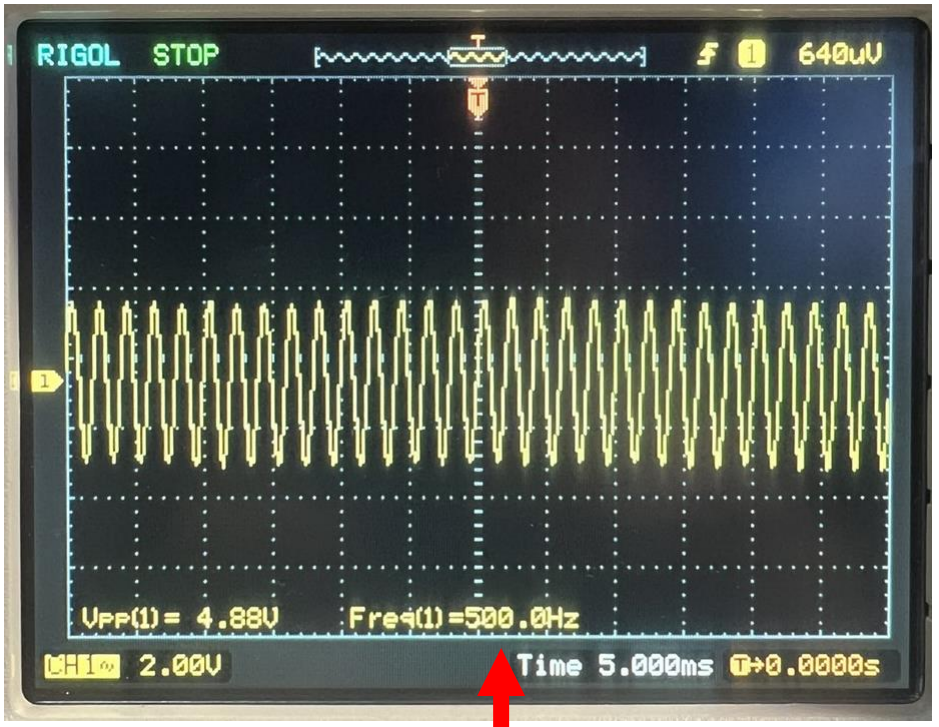
Commercial ADC and DAC (Cont.)

- Pre - Amplifier





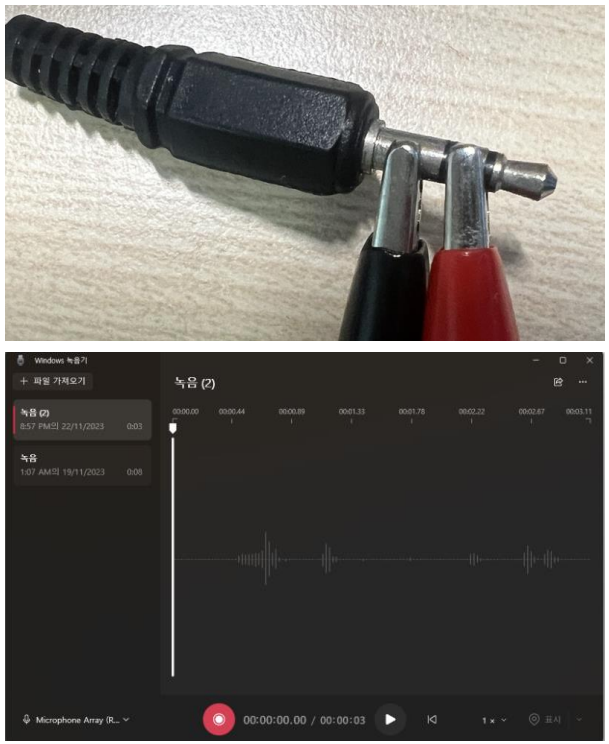
- Figure 12. Microphone output after passing pre-amplifier

Tone Generated Signal 500Hz

Output of pre-amplifier

Commercial ADC and DAC (Cont.)

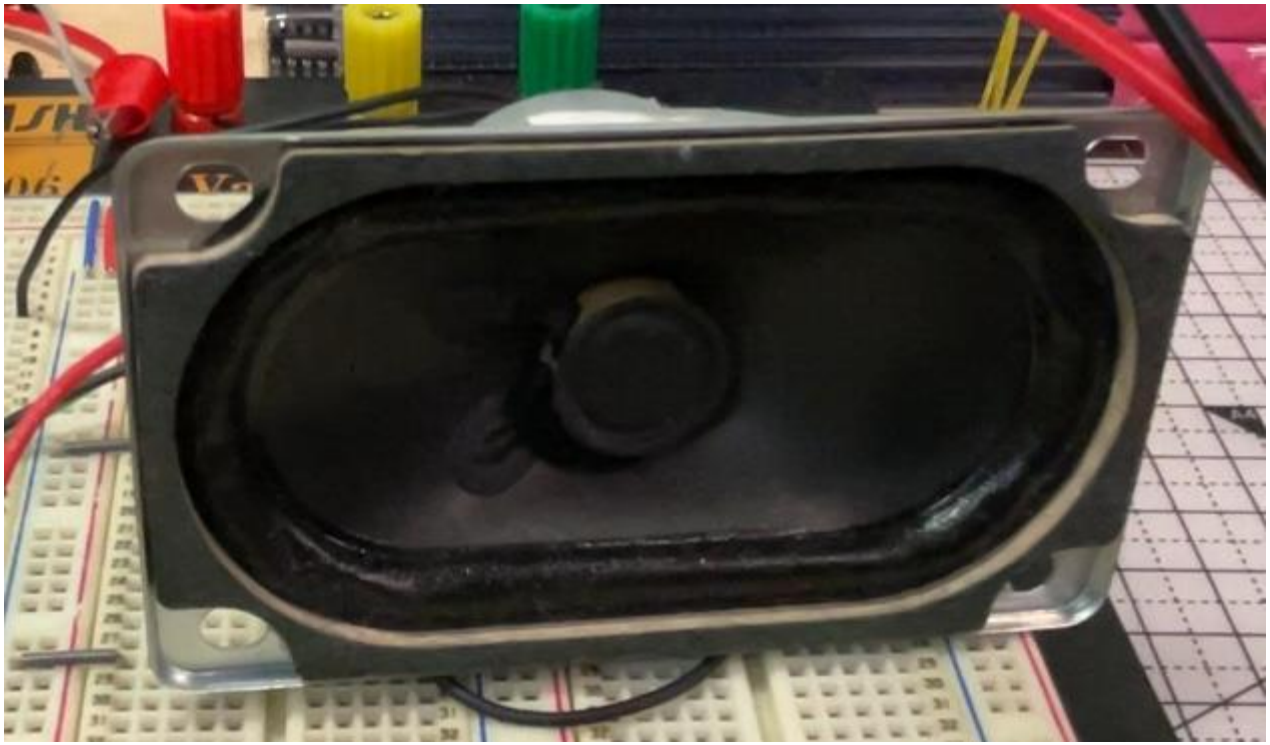
- Using the computers sound card interface ADC.



- Figure 13. Microphone connection and recording sound using a 3.5 microphone jack

Commercial ADC and DAC (Cont.)

- Full Demo.



- Figure 14. Full Demo of sound recording and playing

Chapter 6 : Project Overview Role Division

Name	Role
고종완	1. Sigma Delta ADC Circuit Design 2. Sigma Delta ADC Circuit Simulation 3. Comparator Circuit Design 4. Comparator Circuit Simulation 5. Audio Amplifier Design 6. PCB Design 7. Project Assembly
신동호	1. Flash ADC Circuit Design 2. Flash ADC Circuit Simulation 3. Operational Amplifier Circuit Design 4. Operational Amplifier Simulation 5. PCB Schematic Design 6. DAC Design & Arduino Coding
안동린	1. Flash ADC Circuit Design 2. Flash ADC Circuit Simulation 3. Operational Amplifier Circuit Design 4. Operational Amplifier Simulation 5. Project Assembly

Project Timeline

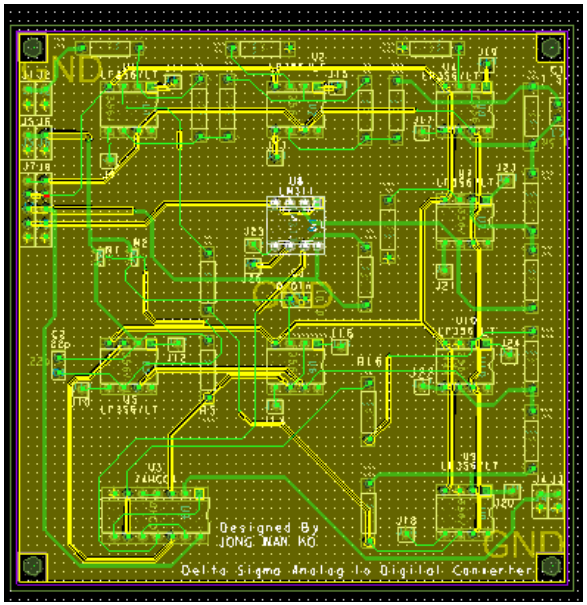
TIMELINE		Fall Semester								
Detail	Name	2023-09-05	2023-09-12	2023-09-19	2023-09-26	2023-10-03	2023-10-10	2023-10-17	2023-10-24	2023-10-31
<Phase1> Preliminary Research	고종완		Preliminary Research					Mid - Term		
	신동호		Preliminary Research							
	안동린		Preliminary Research							
	etc.									
<Phase2> Circuit Desgin	고종완				Audio Amplifier Design		SD ADC			
	신동호				DAC Design and Coding		Flash ADC			
	안동린						Flash ADC			
	etc.									
<Phase3> Assembly & Verification	고종완									
	신동호									
	안동린									
	etc.									

Project Timeline (Cont.)

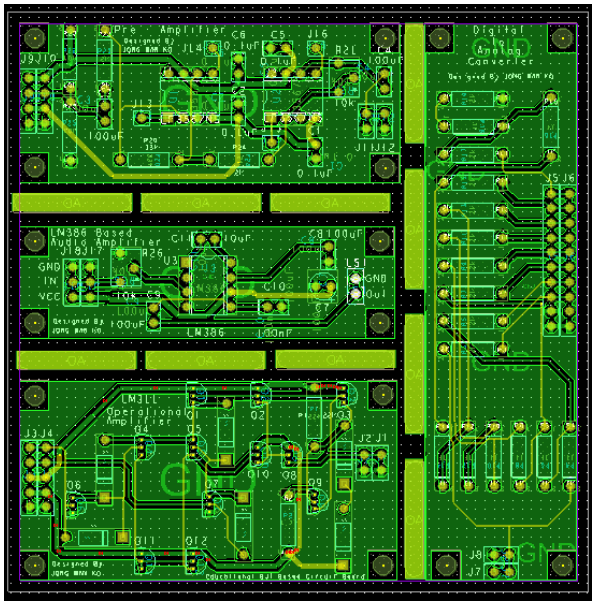
Fall Semester									
2023-10-17	2023-10-24	2023-10-31	2023-11-07	2023-11-14	2023-11-21	2023-11-28	2023-12-05	2023-12-12	2023-12-12
Mid - Term							Finals		
			Sigma Delta ADC						
			Flash ADC						
			Flash ADC						
			Verification / Assembly						Final Presentation
			Verification / Assembly						
			Verification / Assembly						

PCB Design (Version 1)

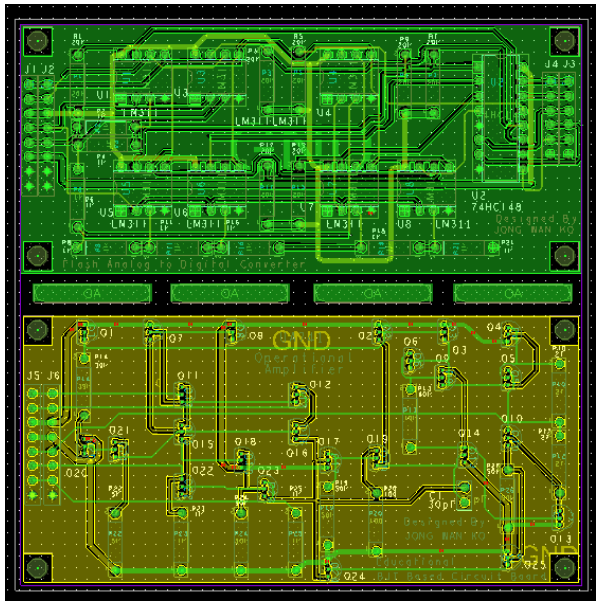
- PCB Schematics



- Figure 15. Sigma Delta ADC Board



- Figure 16. First Version Module 1
  - Includes(Pre-amplifier, Audio Amplifier, Comparator and Flash DAC)

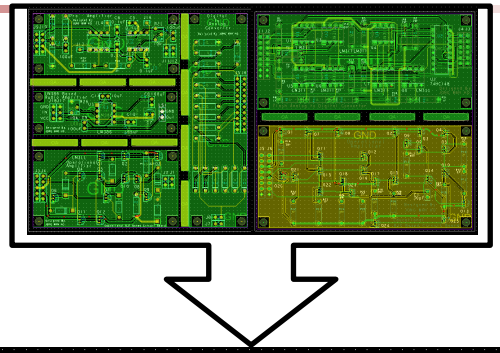


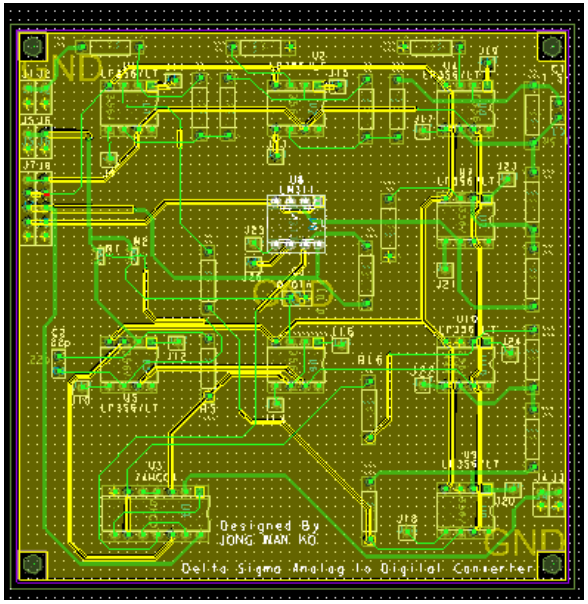
- Figure 17. First Version Module 2
  - Includes(Flash ADC and Operational Amplifier)

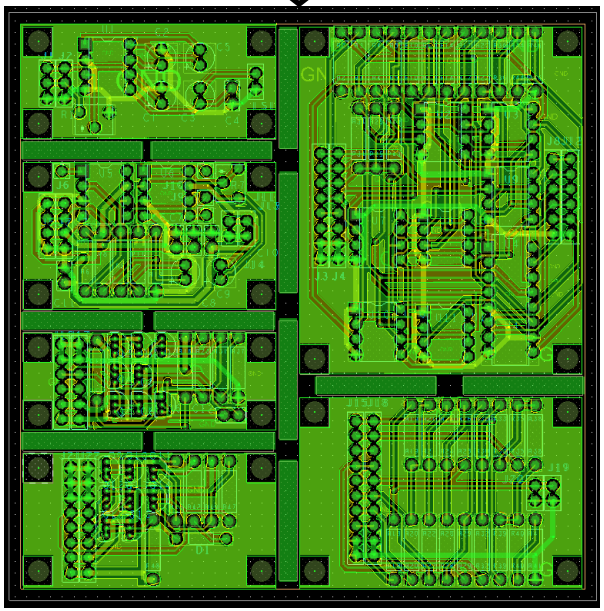
PCB Design (Version 2, Final Version)

- PCB Schematics

Module 1 and Module 2
have been merged.



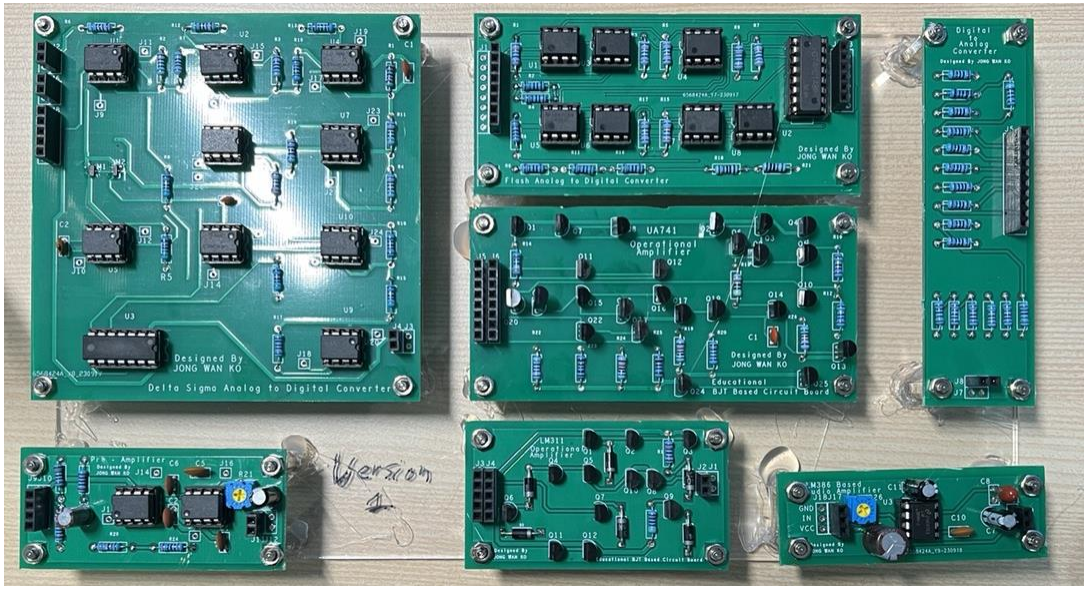




- Figure 18. Sigma Delta ADC Board
- Figure 19. Second Version (New Version)
  - Includes(Pre-amplifier, Audio Amplifier, Comparator and Flash DAC, Flash ADC and Operational Amplifier)

PCB Design Result (Version 1)

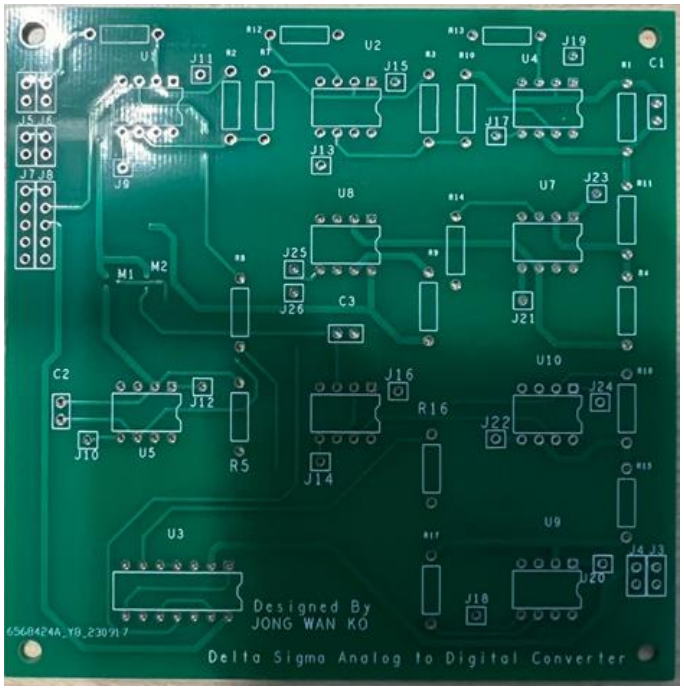
- PCB



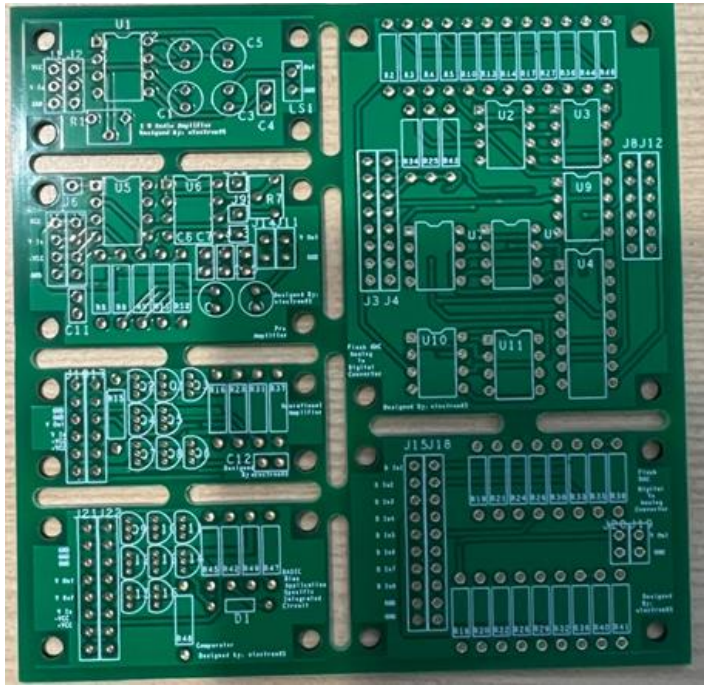
- Figure 20. First Version (Delta Sigma ADC, Module 1 and 2)
  - Includes(Sigma Delta ADC Board, Pre-amplifier, Audio Amplifier, Comparator and Flash DAC, Flash ADC and Operational Amplifier)

PCB Design Result (Version 2, Final Version)

- PCB



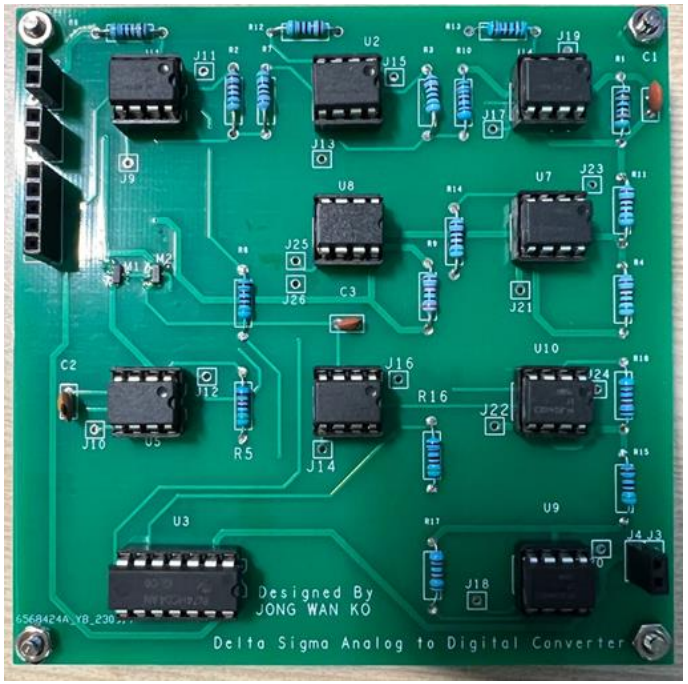
- Figure 21. Sigma Delta ADC Board



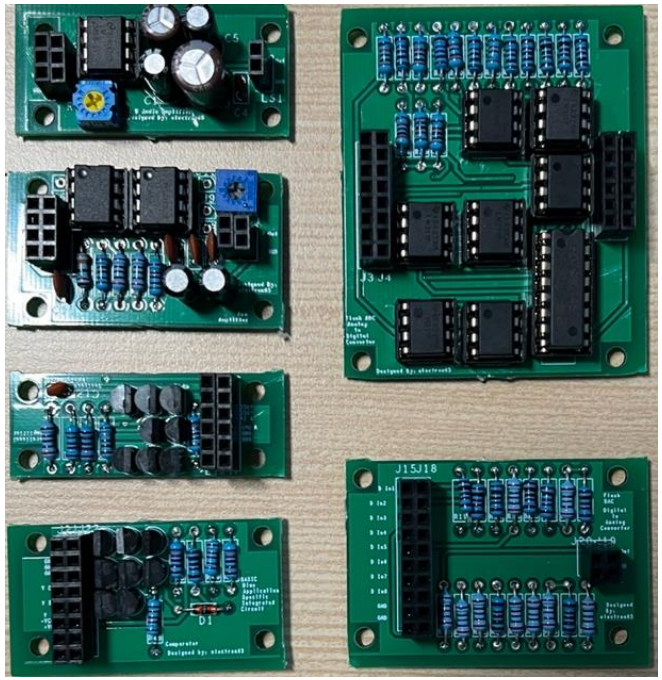
- Figure 22. Second Version (New Version)
  - Includes(Pre-amplifier, Audio Amplifier, Comparator and Flash DAC, Flash ADC and Operational Amplifier)

Final Product

- PCB



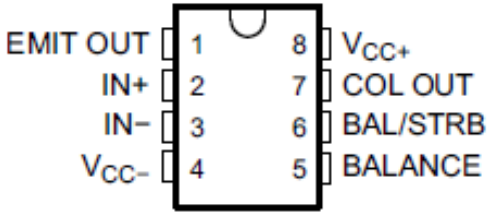
- Figure 23. Sigma Delta ADC Board



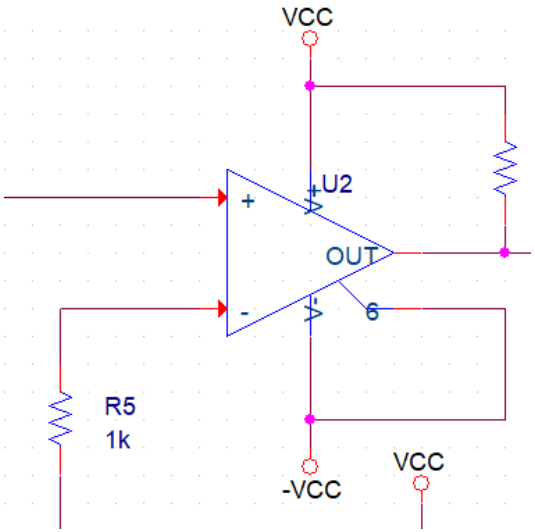
- Figure 24. Second Version (New Version)
  - Includes(Pre-amplifier, Audio Amplifier, Comparator and Flash DAC, Flash ADC and Operational Amplifier)

Problems Encountered & Solutions

- Comparator does not match with datasheet and Pspice model.
  - Pspice models sometimes are not perfect due to human errors.



- Figure 25. Pin numbers on the datasheet



- Figure 26. Pspice Pin reference and Circuit

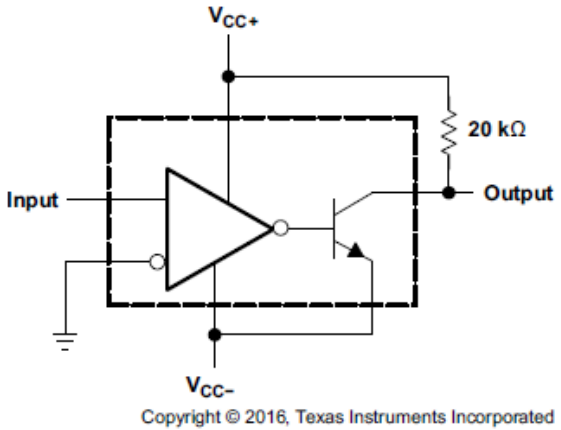
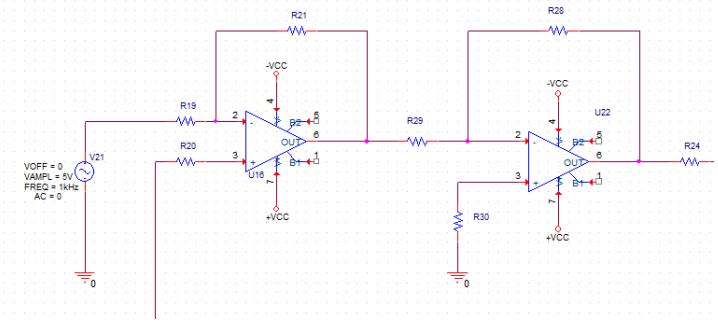


Figure 13. Zero-Crossing Detector

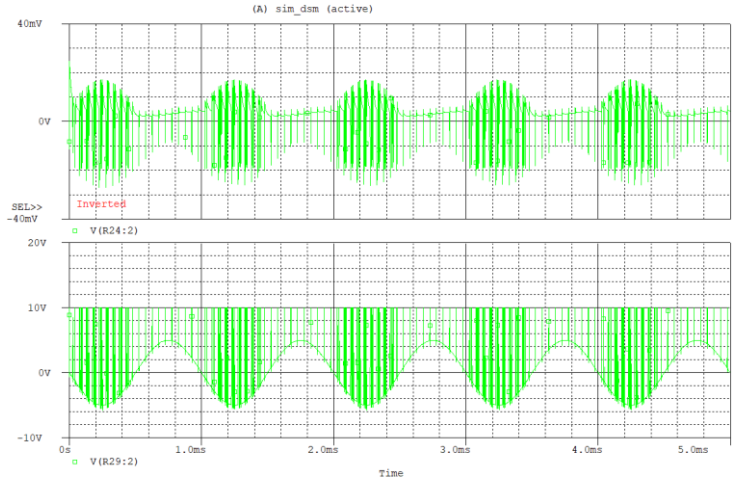
- Figure 27. Datasheet given circuit

Problems Encountered & Solutions (Cont.)

- Sigma Delta ADC not working based on theory.
  - Debug Circuits piece by piece module by module.



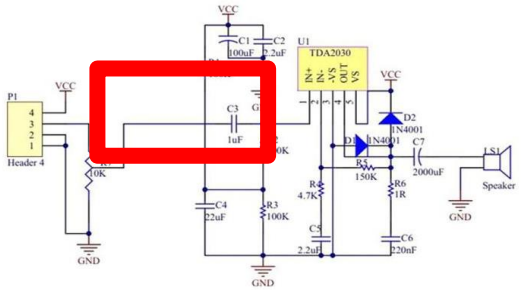
- Figure 28. Sigma Delta Difference Circuit

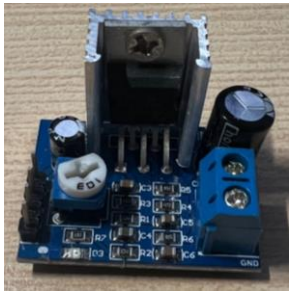


- Figure 29. Non- Inverted Signal (Unwanted), Inverted Signal (Wanted)

Problems Encountered & Solutions (Cont.)

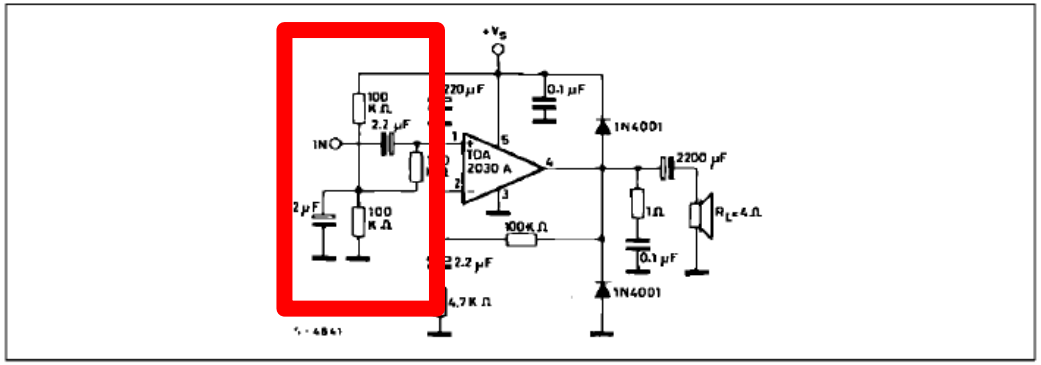
- Mic does not amplify using a audio amplifier
  - Needs to pre-amplify before amplifying into a audio amplifier.
  - Double check circuits made from manufacturers. They may have defected circuits.
  - Made our own LM386 based audio amplifier.





- Figure 30. Arduino Amp Module
- Figure 31. OPAMP Based Audio Amp

Figure 1 : Single Supply Amplifier



- Figure 32. TDA2030A Datasheet

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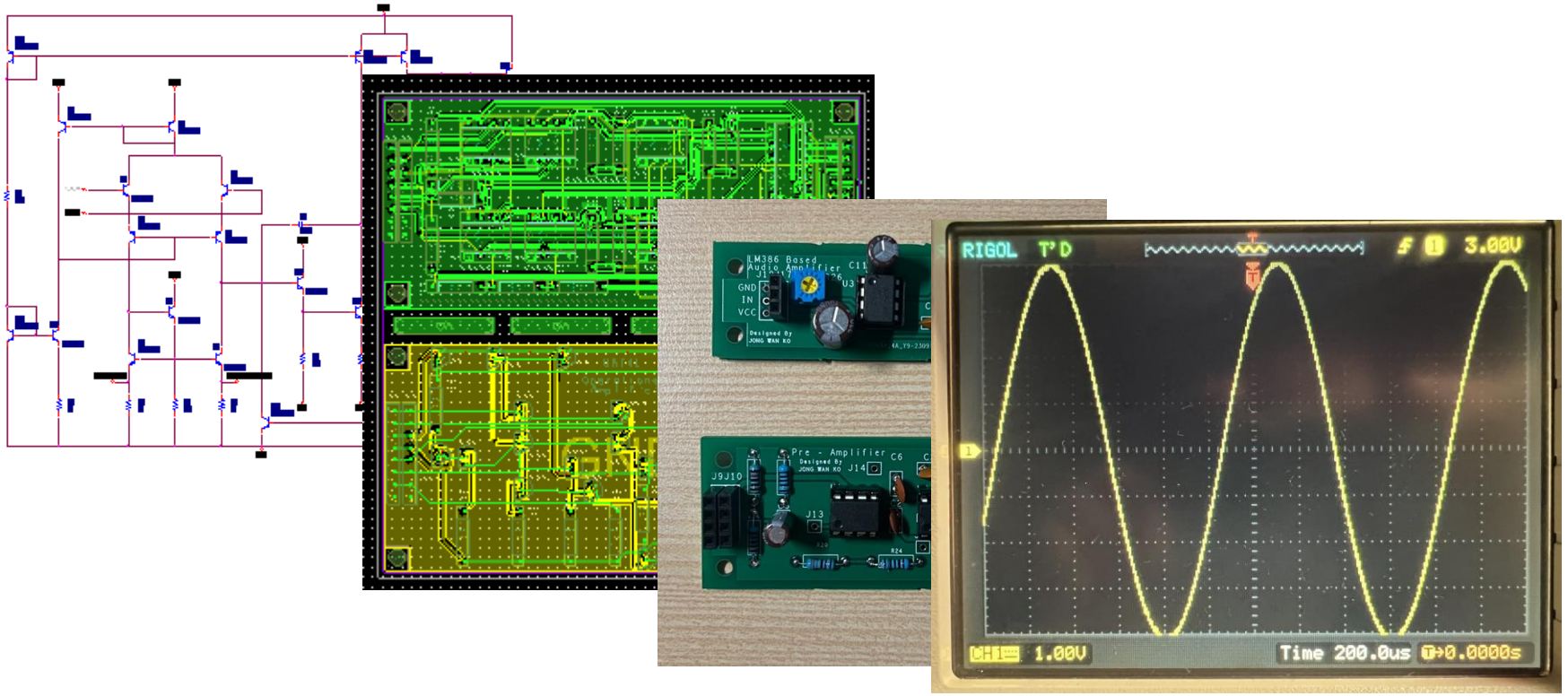
Problems Encountered & Solutions (Cont.)

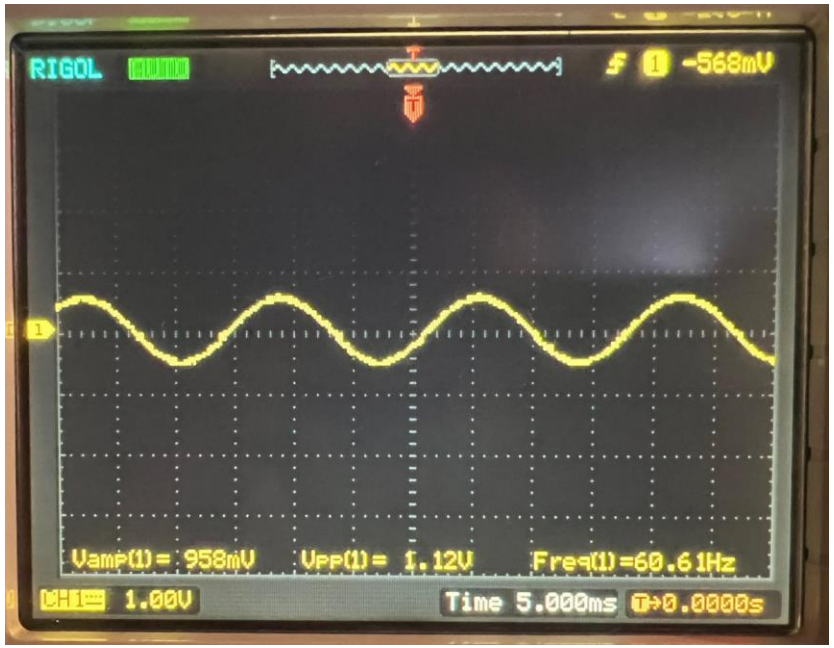
- Too much circuitry for soldering and testing afterwards
  - PCB reduced time for soldering and testing circuits.



Schematic → PCB Design → Solder → Verification

Problems Encountered & Solutions (Cont.)

- PCB has some minor grounding issues where ground was not connected properly.
  - How did we know? => *60Hz Oscillation without any input.*

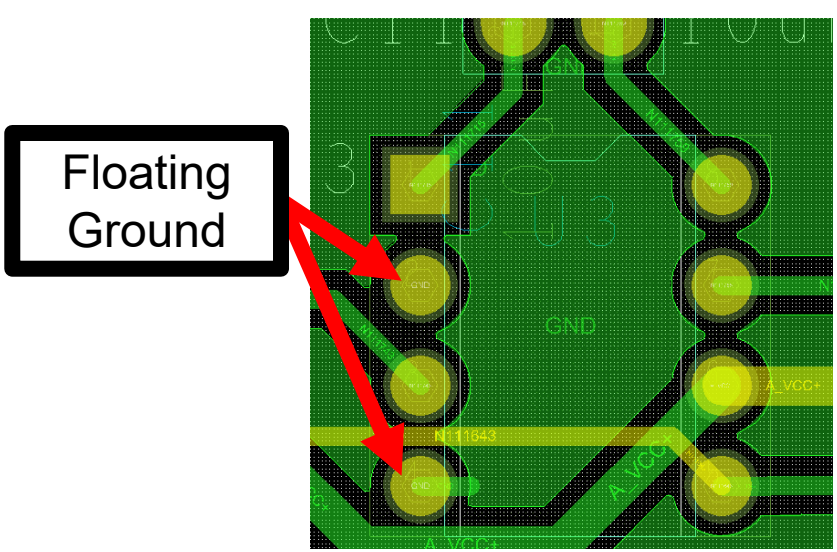


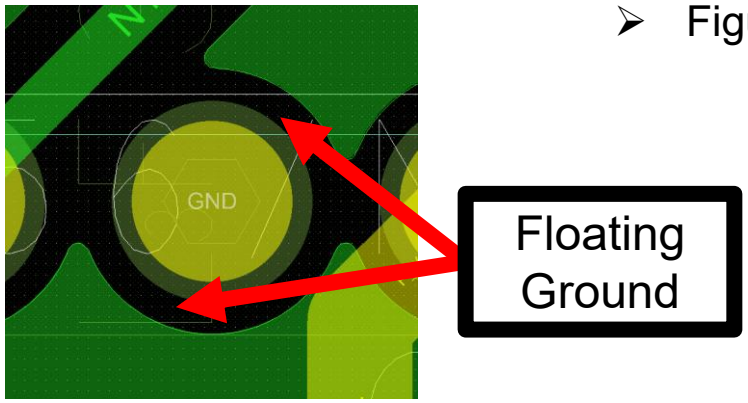
- Figure 33. 60Hz Wave without any inputs.

- Both pre-amplifier and Audio amplifier had the same problem.
- Simulation worked fine. => Other problem? => Power supply problem? => … Something else.

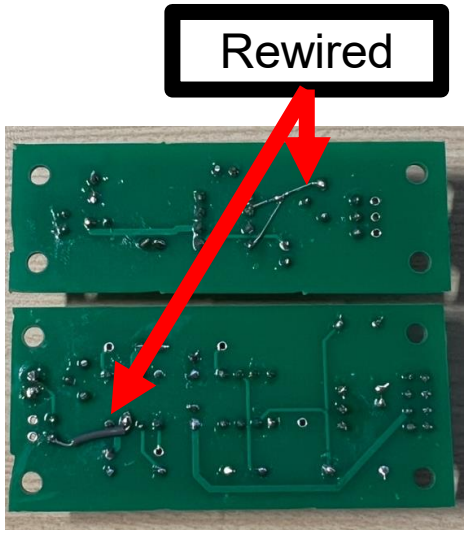
Problems Encountered & Solutions (Cont.)

- PCB has some minor grounding issues where ground was not connected properly.
  - Rewire ground using wires. => Later version upgraded Circuit





- Figure 34.Floating grounds

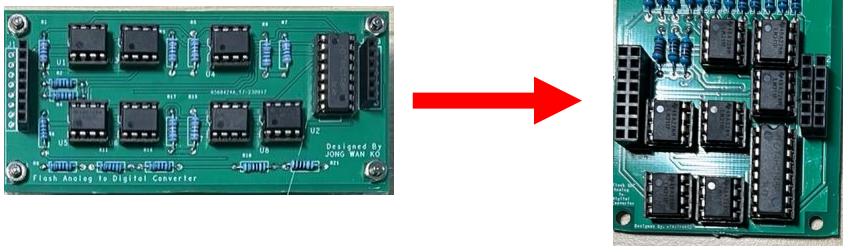


- Figure 35.Rewired Grounds.

- Figure 36.Upgraded Version.

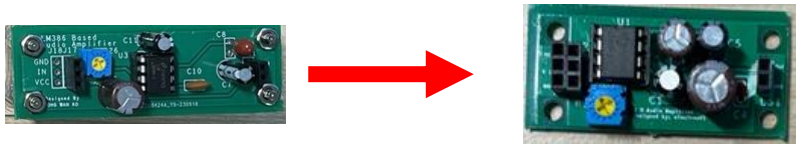
Problems Encountered & Solutions (Cont.)

- Modules where upgraded.

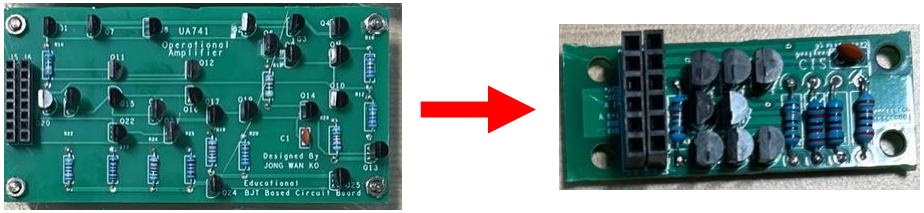


- Figure 37. Flash ADC Upgraded (Compact Size)

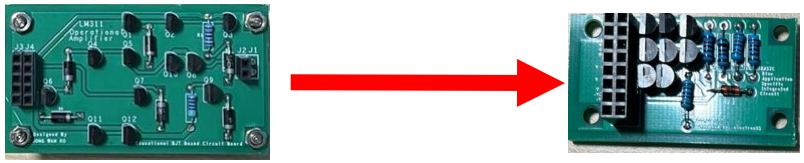
- Figure 40. Pre-Amplifier Upgraded (Grounding Issue, Compact Size)



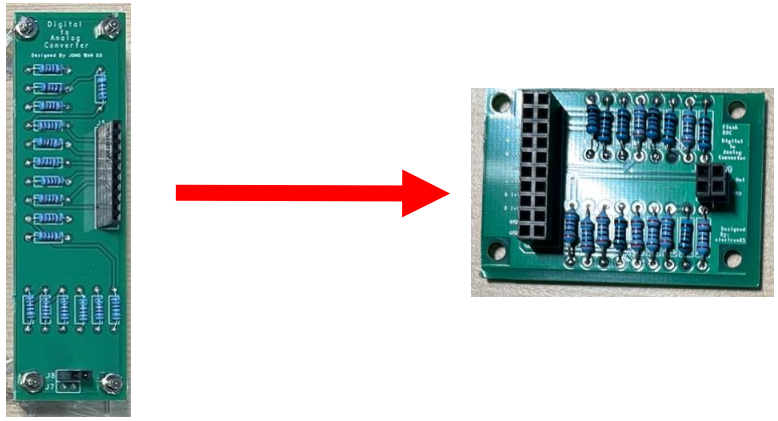
- Figure 41. Audio Amplifier Upgraded (Grounding Issue, Compact Size)



- Figure 38. Operational Amplifier Upgraded (Not working, Compact Size)



- Figure 39. Comparator Upgraded (Not working, Compact Size)



- Figure 42.R-2R DAC Upgraded (Compact Size)

Components and Budget

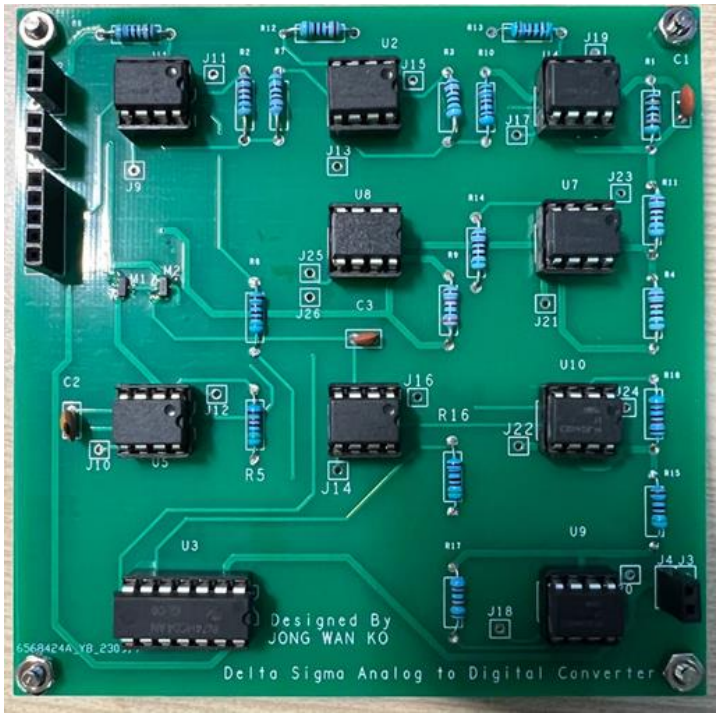
Name	pcs.
Resistors	65
Capacitors	15
BJT/FET	39
74Series	2
Operational Amplifiers	19
Connectors	50
Diodes	6
Total Price	₩ 89,123

Reference

- ADC spec, https://microchipdeveloper.com/adc:adc-offset-error
- Block diagram https://www.ti.com/lit/an/slyt423a/slyt423a.pdf?ts=1688603768637&ref_url=https%253A%252F%252Fwww.google.com%252F
- 1-bit adc, https://www.analog.com/media/en/training-seminars/design-handbooks/Basic-Linear-Design/Chapter6.pdf
- SIGMA-DELTA CONVERTERS Practical Design Guide, JOSÉ M. DE LA ROSA, 2nd Ed
- Delta sigma chip ic, https://www.mdpi.com/2079-9292/9/3/498
- Understanding Delta-Sigma Data Converters, Richard Schreier Gabor C. Temes, Transform function

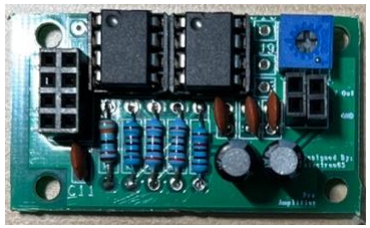
Demo (Entire product List)

- PCB

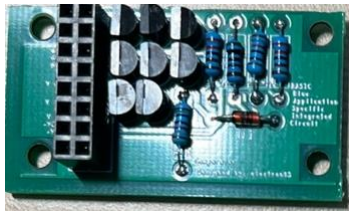


- Figure 43. Delta Sigma ADC

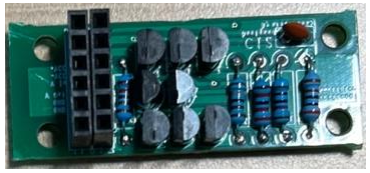
- Figure 44. Audio Amplifier



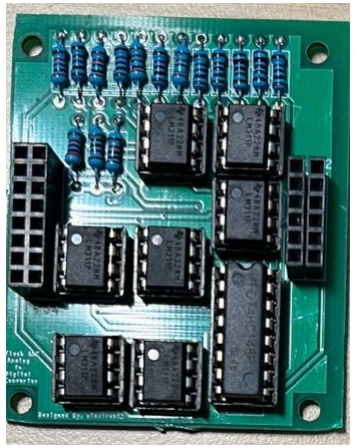
- Figure 45. Pre - Amplifier



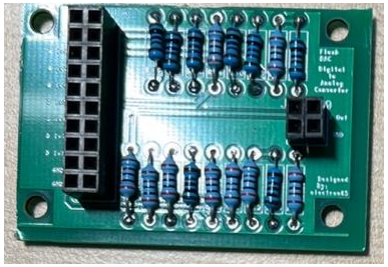
- Figure 46. Comparator



- Figure 47. Operational Amplifier



- Figure 48. 3 bit Flash ADC



- Figure 49. R-2R DAC

Q & A