



**GHENT
UNIVERSITY**

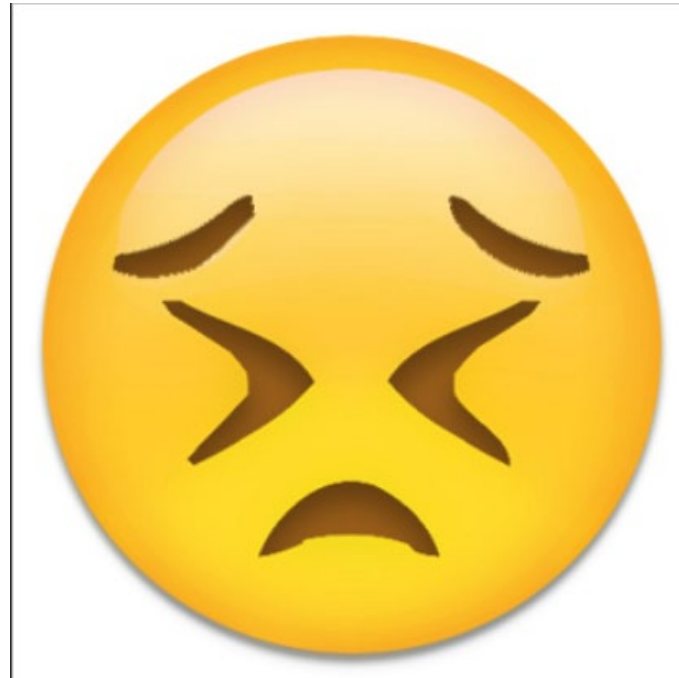
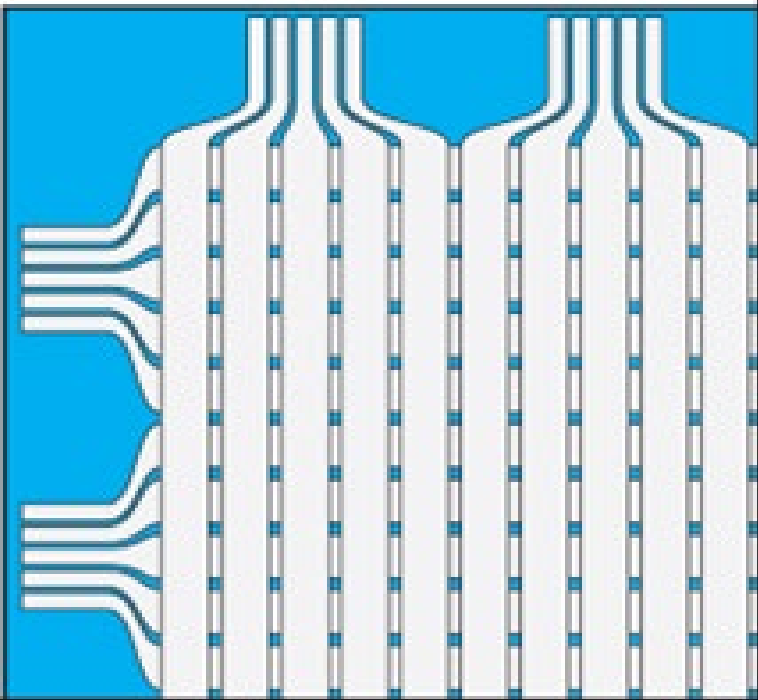
HOP06

SENSOR MATRIX

Instructors: Pieter Bauwens, Herbert De Pauw

Group member: Xiaoke Wang, Haowei Bi

PROJECT BACKGROUND

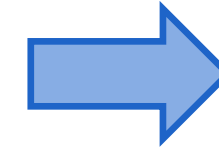


PROBLEMS:

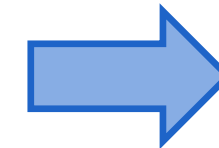
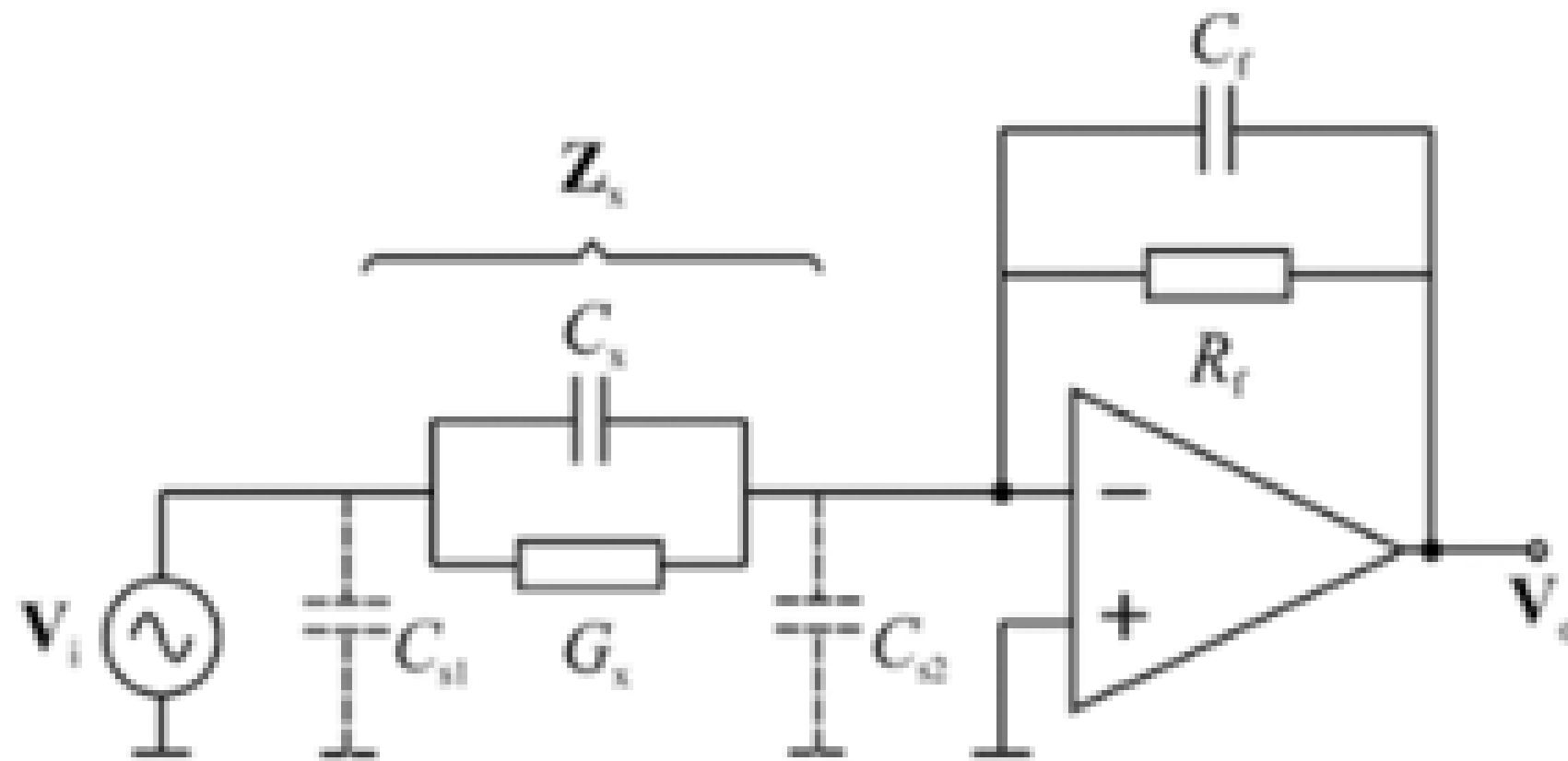
- Reading speed: slow
- Parasitic capacitance

PROJECT GOAL

Fast Fourier Transform(FFT)

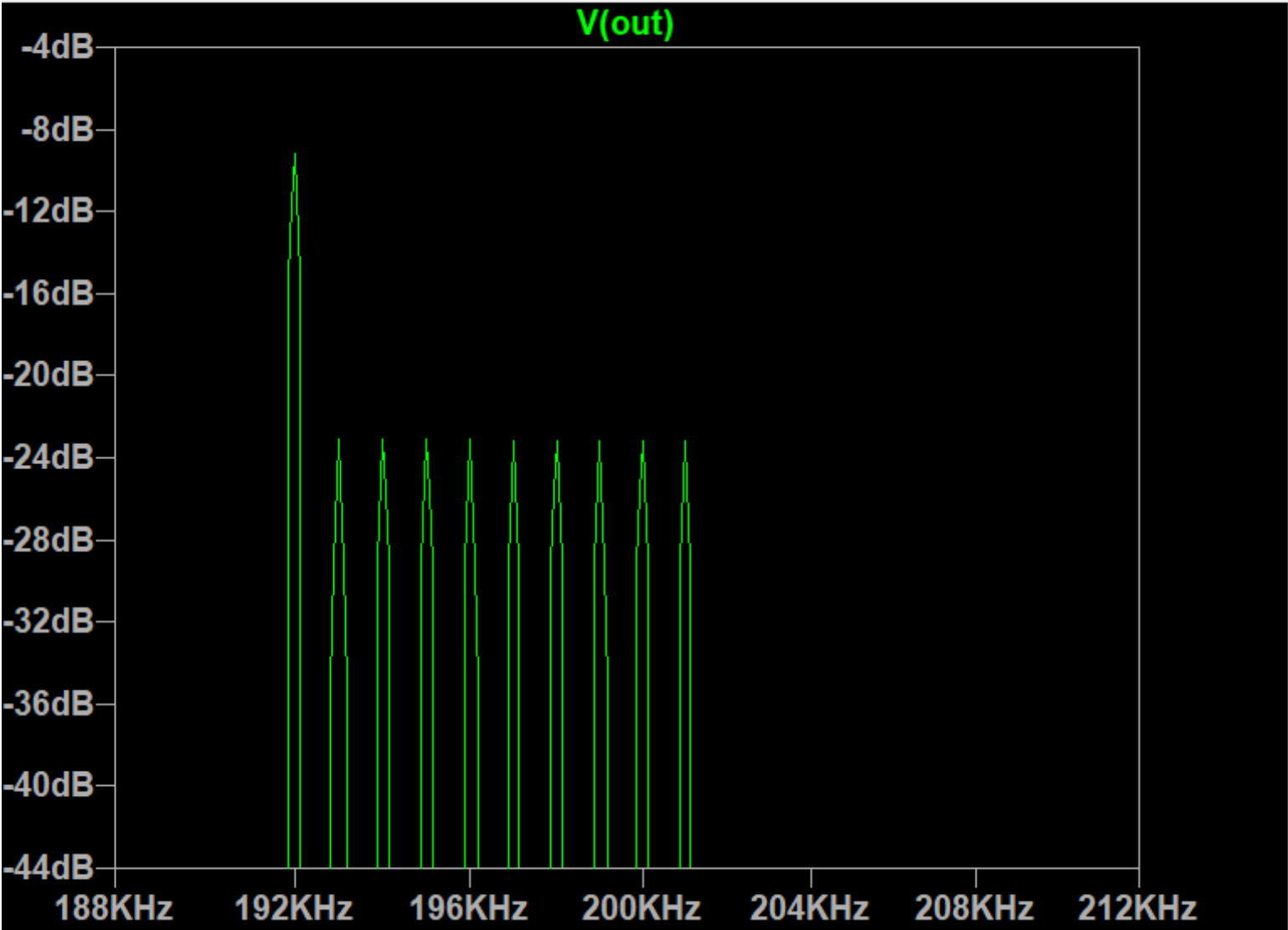
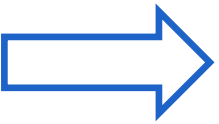
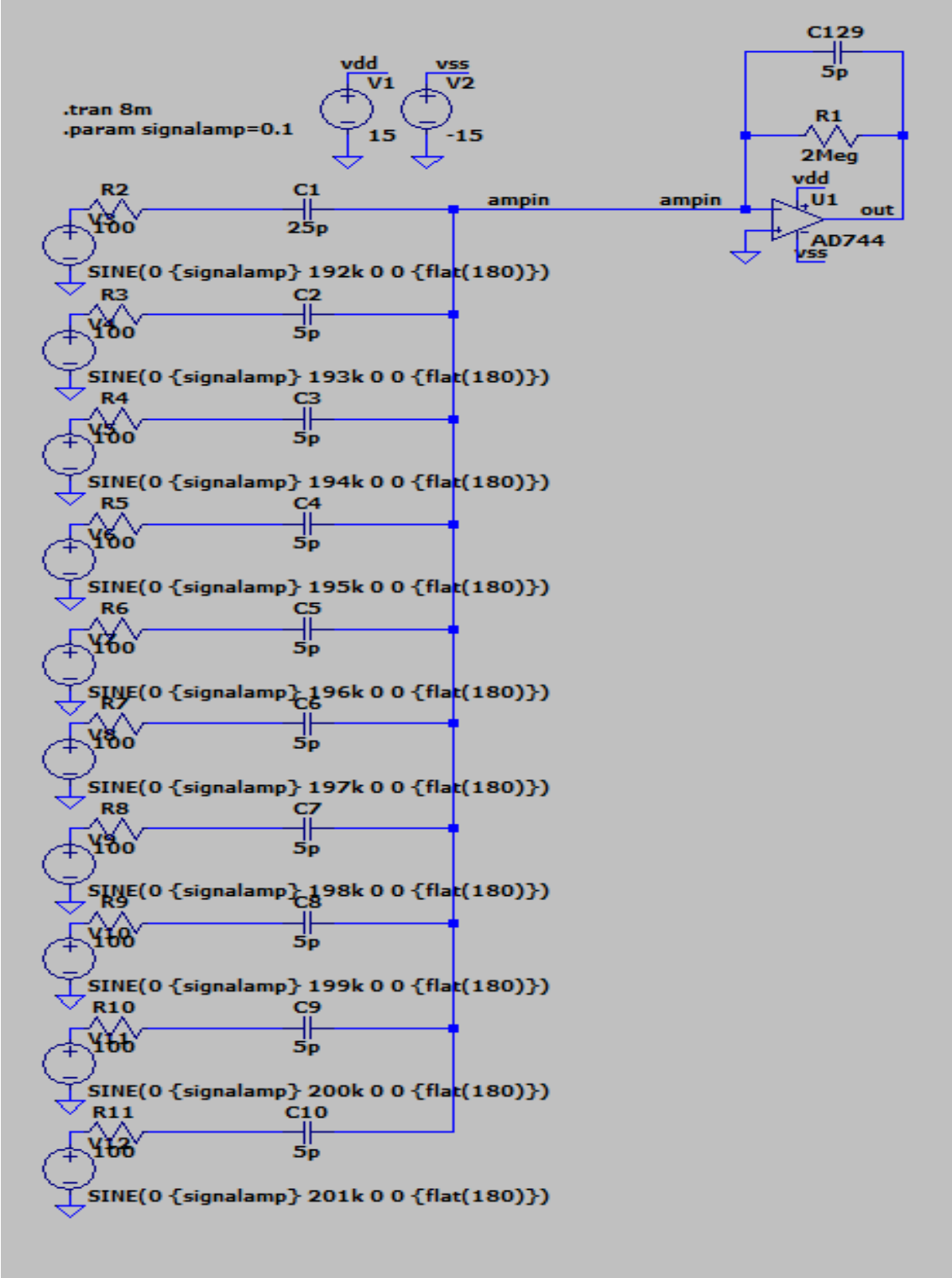


faster



more accurate

PROJECT IDEA



GENERAL PROGRESS

Hardware design

- Simulation of an optimized solution (finished before interim presentation)
- PCB schematic design (main structure before interim, finished after)
- PCB layout (finished after interim presentation)

Software design

- Generator control, FFT(finished after interim presentation)

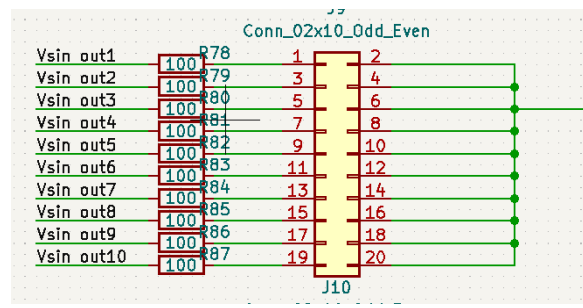
SCHEMATIC AT INTERIM PRESENTATION

– The Sine wave generators

– Opamps AD744

– Differential ADC
(Pseudodifferential Input Operation with Single-Ended Configuration)

– Micro Controller:
ATSAMD21G18A-A



– Resistors and connectors for capacitors

– DIP Connectors

– Power component
– USB micro and Jack DC socket

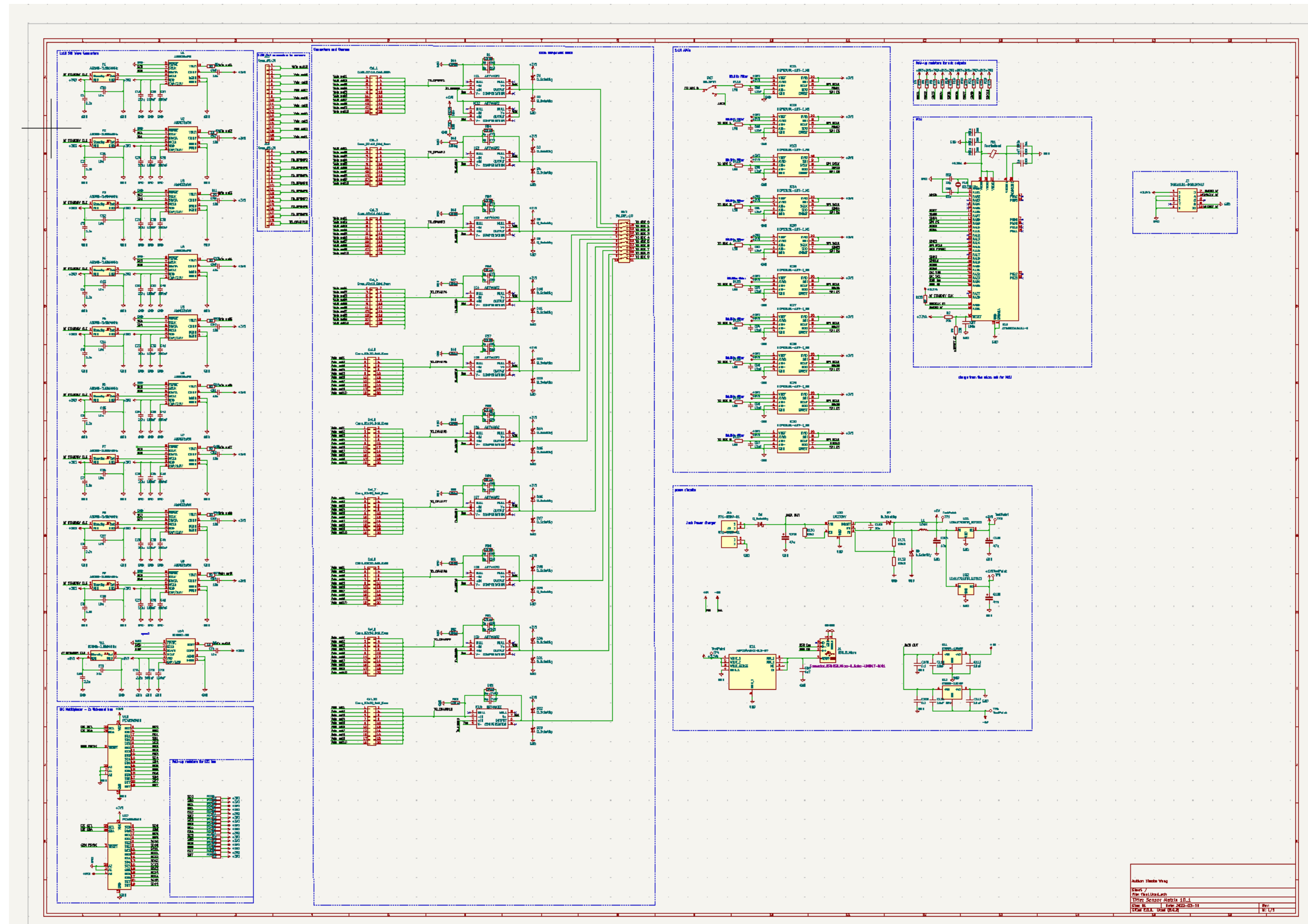


SECOND HALF PERIOD

Progress:

- Finished the schematic design
- Finished the PCB layout design
- Started testing and programming software uC

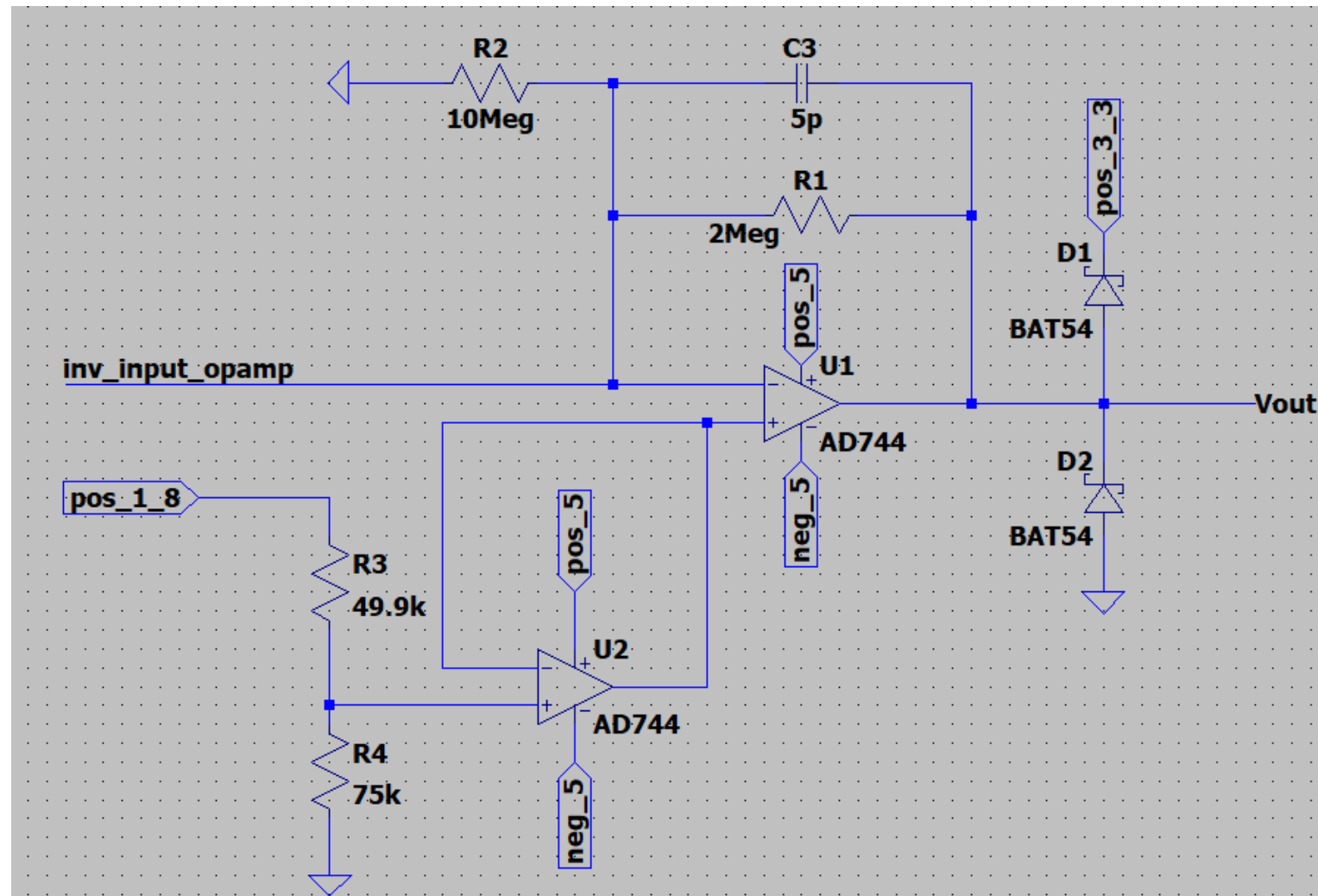
FINAL SCHEMATIC



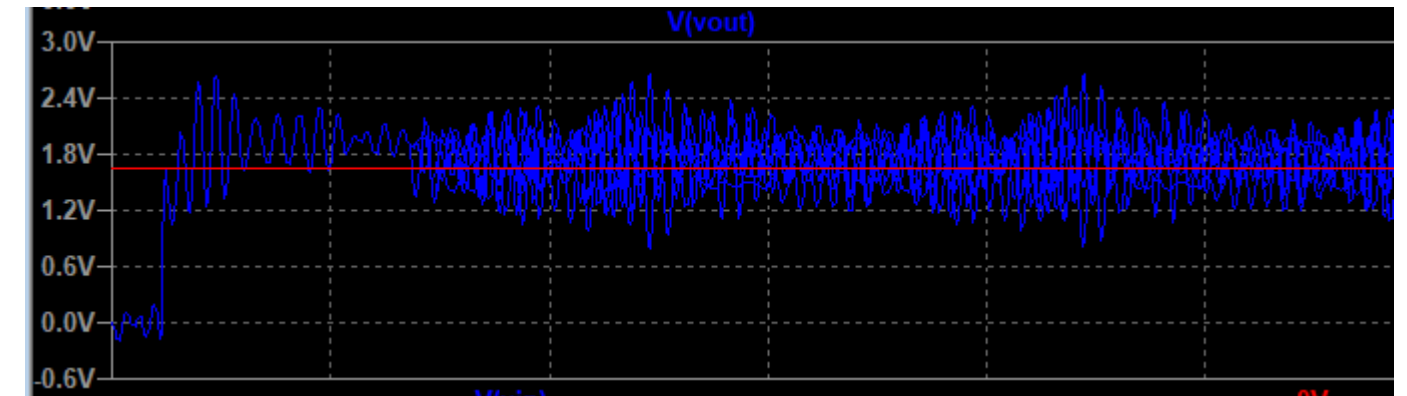
EXTRA CIRCUIT FOR OPAMP

Reason: the input signal of ADCs and output of opamps do not match

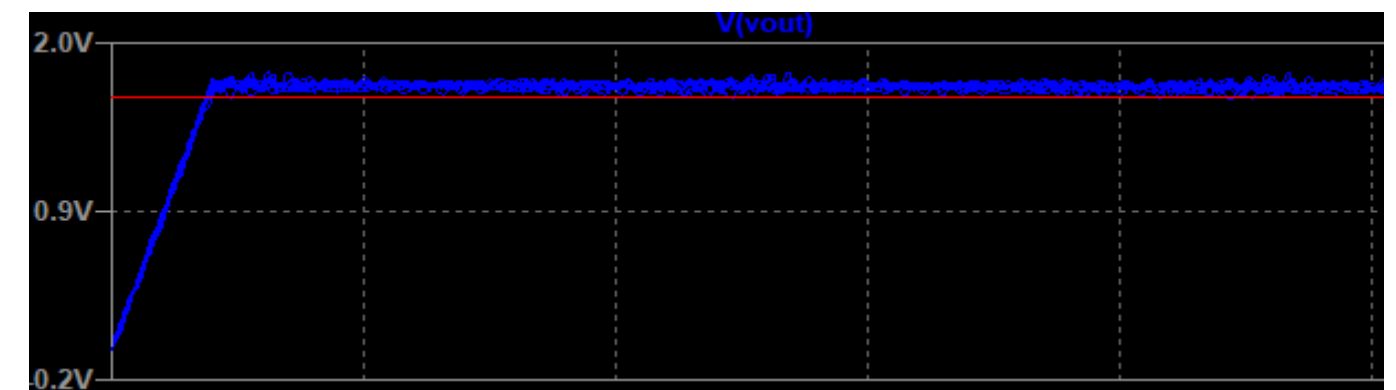
Solution: add 3.3/2 V DC voltage



Extra circuit for adjusting the voltage

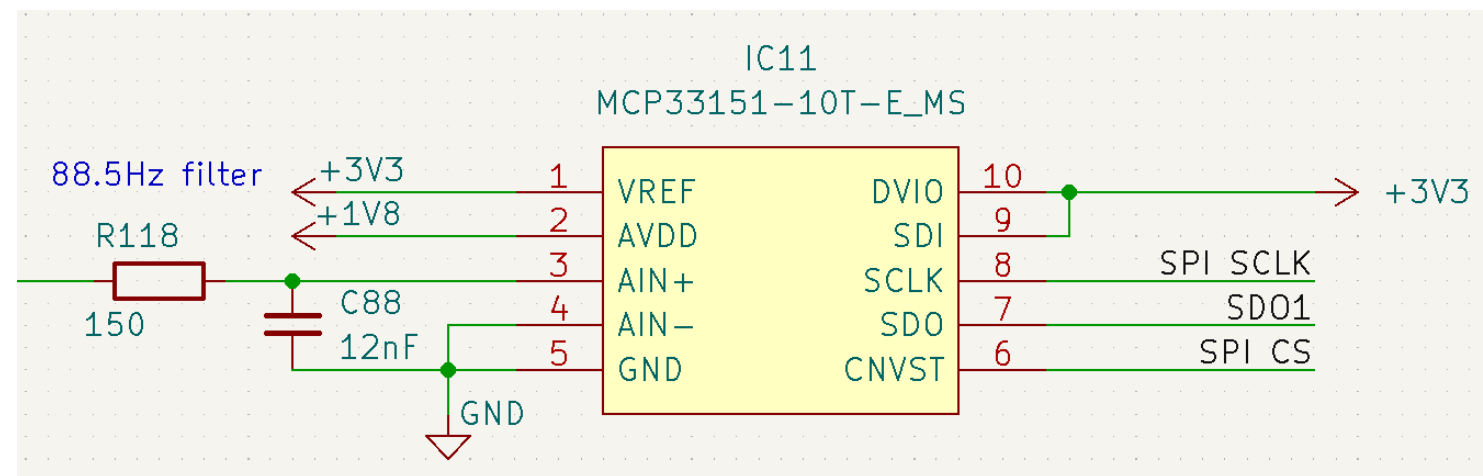
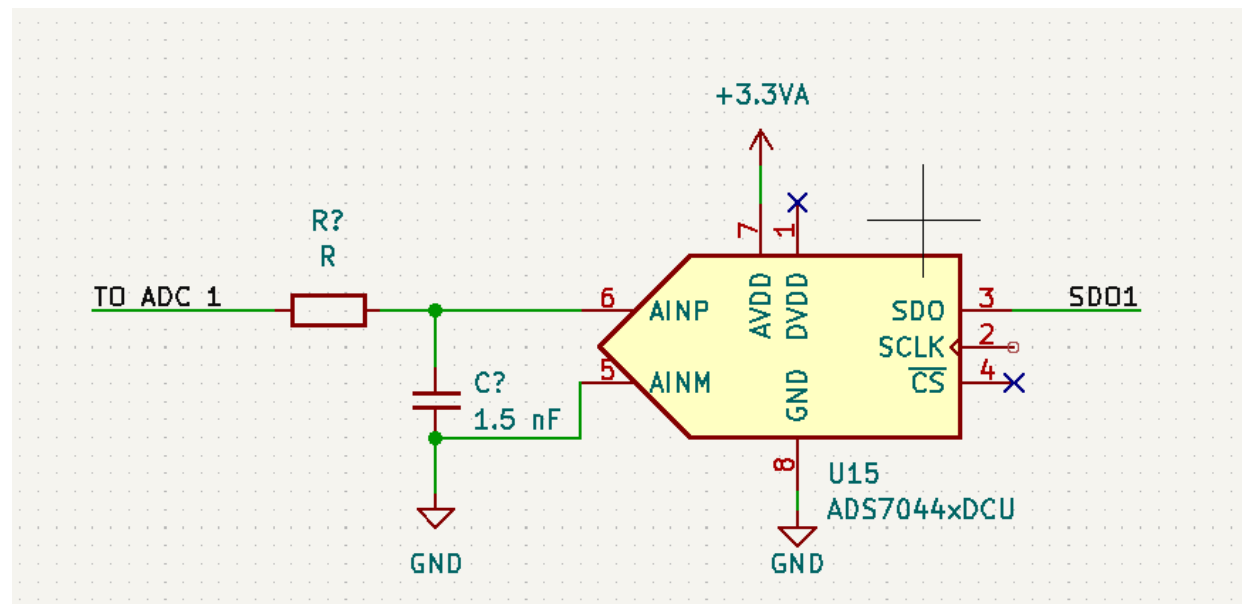


Output voltage of the opamp



an issue: input voltage lower than 3.3V

UPDATE ON COMMUNICATION BUS



SPI compatible interface:

- The output pins should connect with the digitalRead() available pin in Microcontroller separately
- \overline{SS} signal: same as daisy-chained SPI bus

PCB LAYOUT DESIGN

Microcontroller and bootloader

Power circuits:
3.3V \pm 5V and 1.8V

two **I2C** multiplexers

10 external ADCs
(14 bits and 1Msps)

10 Generators

10 Opamps

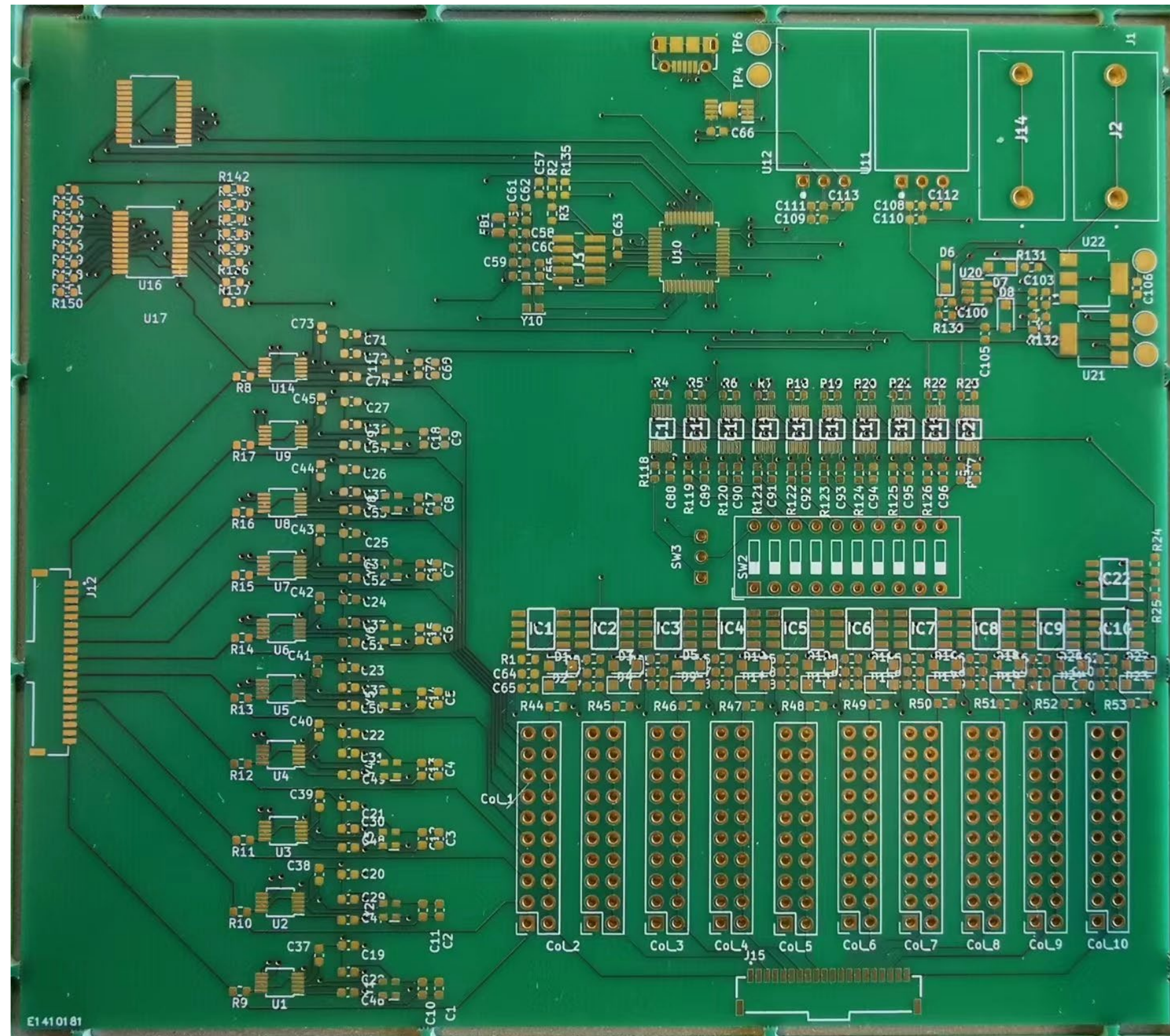
External connectors

20 pin connector
Same standard with
sensor matrix we have

10 2x10 pin sockets
Ceramic pin capacitors
as sensor matrix

Footprint of the PCB design (12.2x13.9cm)

PCB LAYOUT DESIGN



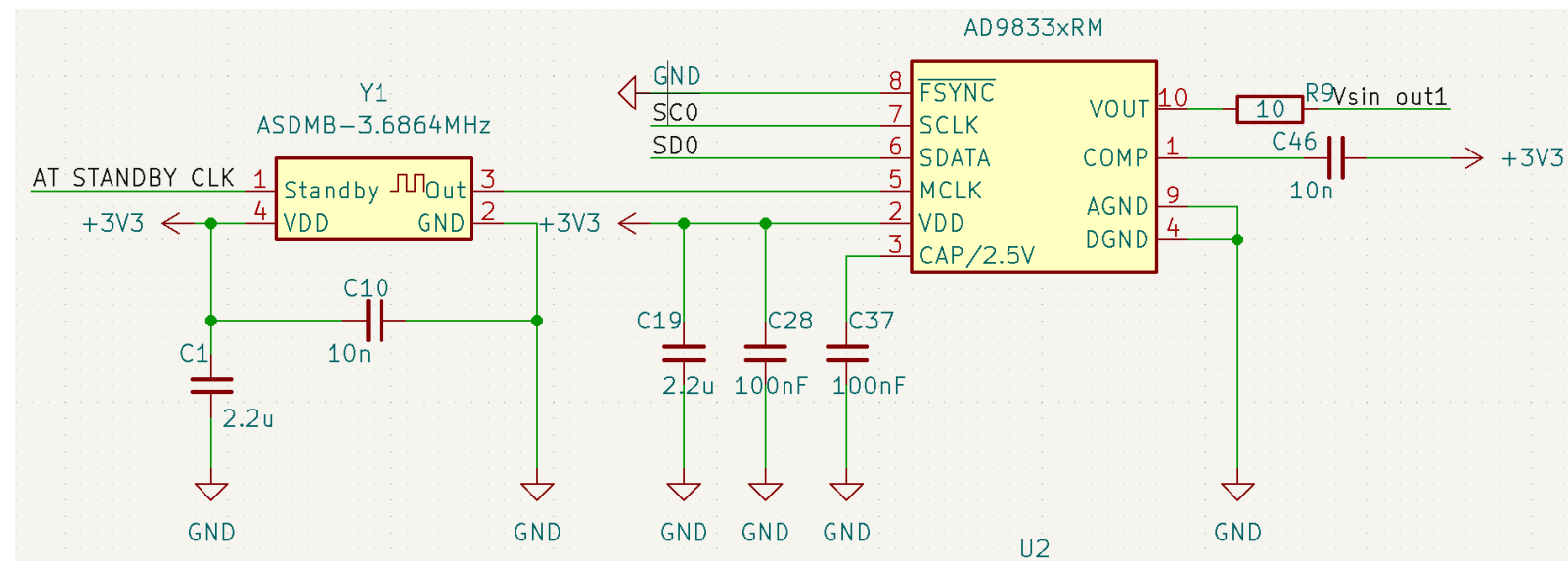
Final PCB board (12.2x13.9cm)

MICROCONTROLLER PROGRAMMING

- Generator programming <AD9833.h>
- FFT programming <ArduinoFFT.h>
- ADCs controlling
- Assemble

GENERATOR PROGRAMMING

Program the generator circuit on a test board



Generator circuit

Some Issues Here:

- Frequency accuracy
- High-frequency harmonics → extra LPF
- Low amplitude: 276 mV < 3.3V

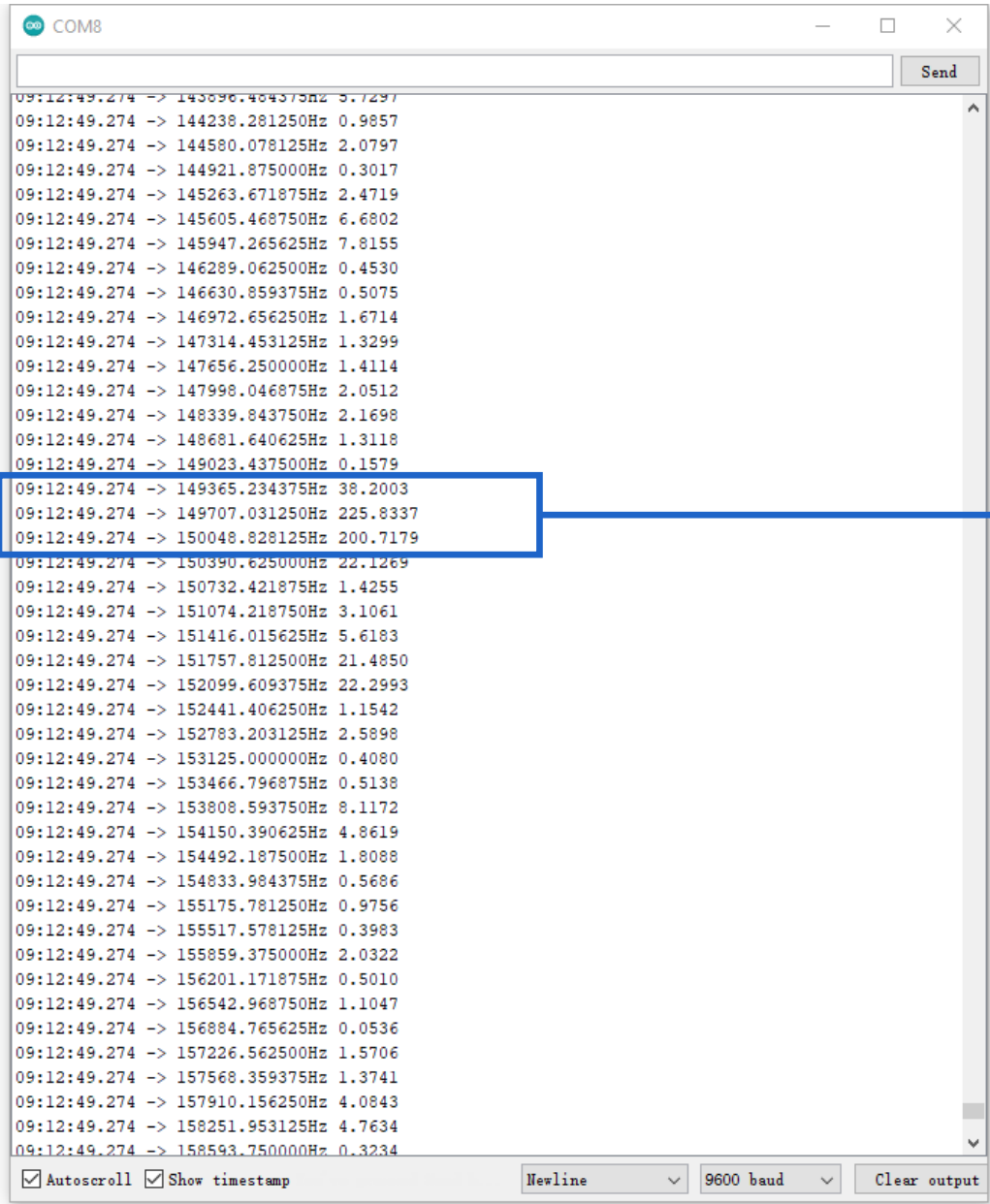


The wave output with the setting at 150kHz

FAST-FOURIER TRANSFORM (FFT)

Samples for FFT(power of 2):

N = 1024



Settings: $F_s = 350\text{kHz}$, $F = 15\text{kHz}$, $N_s = 1024$

- Frequency peak we get
- The resolution $\delta f = 341.79\text{ Hz}$

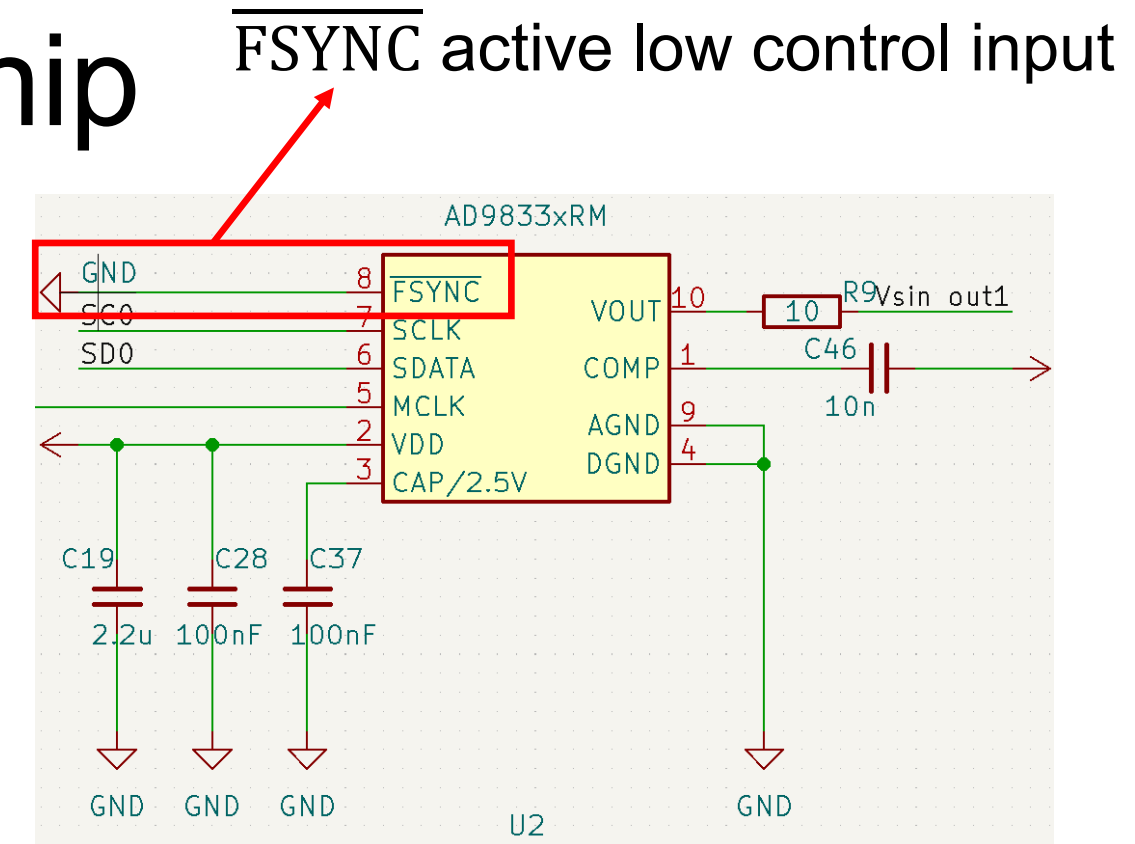
N = 2048

Memory stack overflowed: (SRAM size of ATSAMD21: 32KB – 4Kbytes)

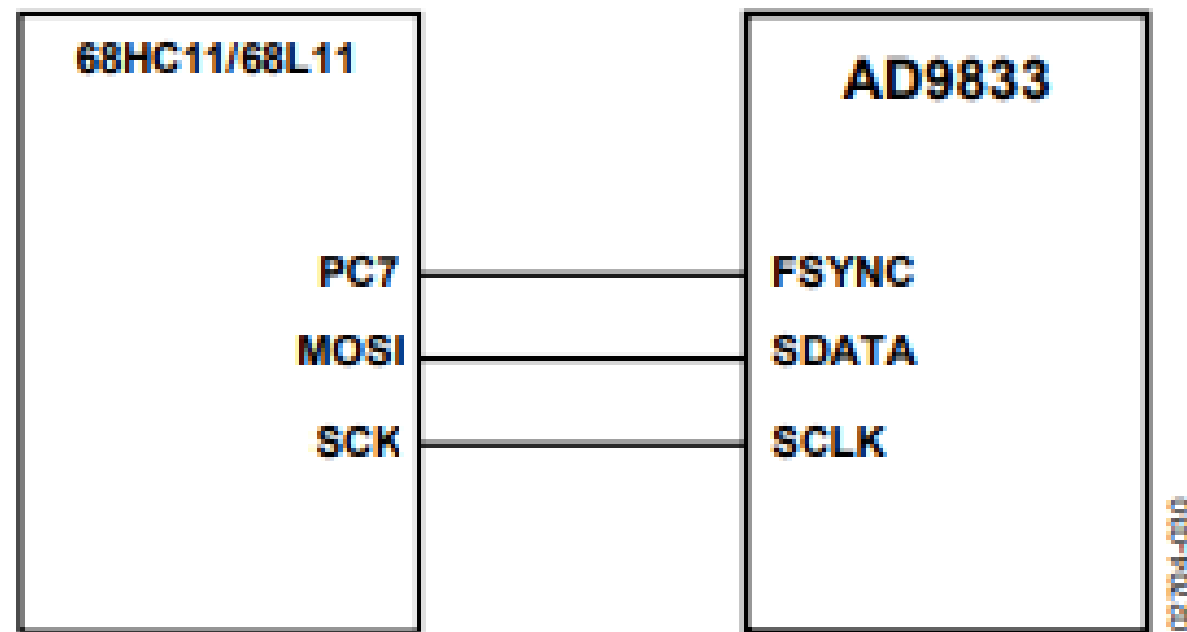
```
../arm-none-eabi/bin/ld.exe: region RAM overflowed with stack
../arm-none-eabi/bin/ld.exe: region `RAM' overflowed by 2452 bytes
```


SOME ISSUES

- Enable signal connection of AD9833 chip
- Extra low frequency pass filter
- Signal amplification
 - low SNR and low accuracy
- FFT computation memory usage



I2C AND SPI INTERFACE



SPI compatible interface

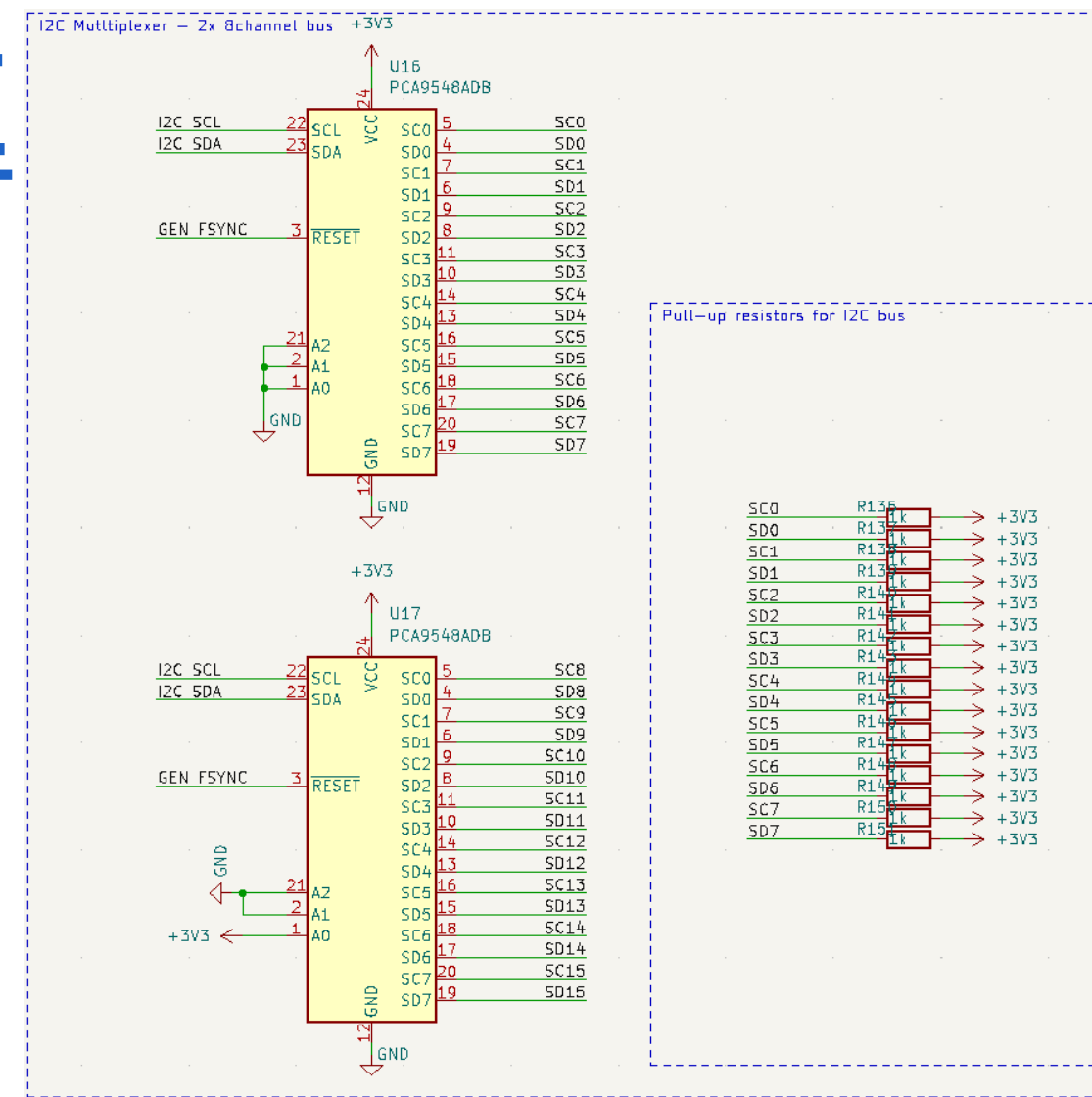
Pros

- Ready-to-use code <AD9833.h>

Cons

- Not enough pins on microcontroller for the control signal

Solution: try to change the AD9833.cpp code to achieve single FSYNC pin control 10 chips



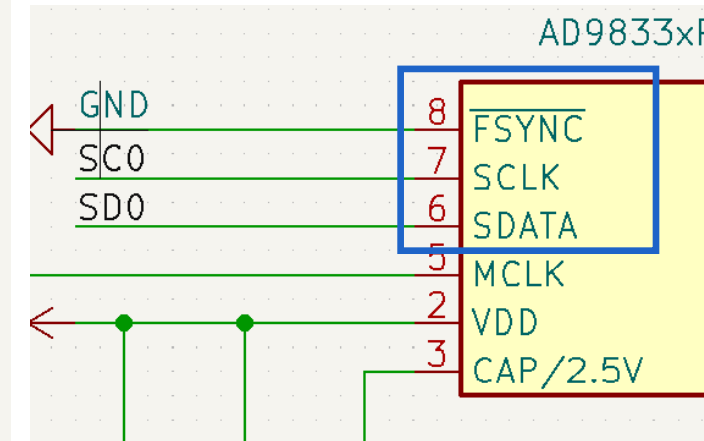
I2C compatible interface

Pros

- Save connection port on uC

Cons

- More codes in controlling the I2C bus with two multiplexer



ANALYSIS FOR FFT

- Spectrum resolution:

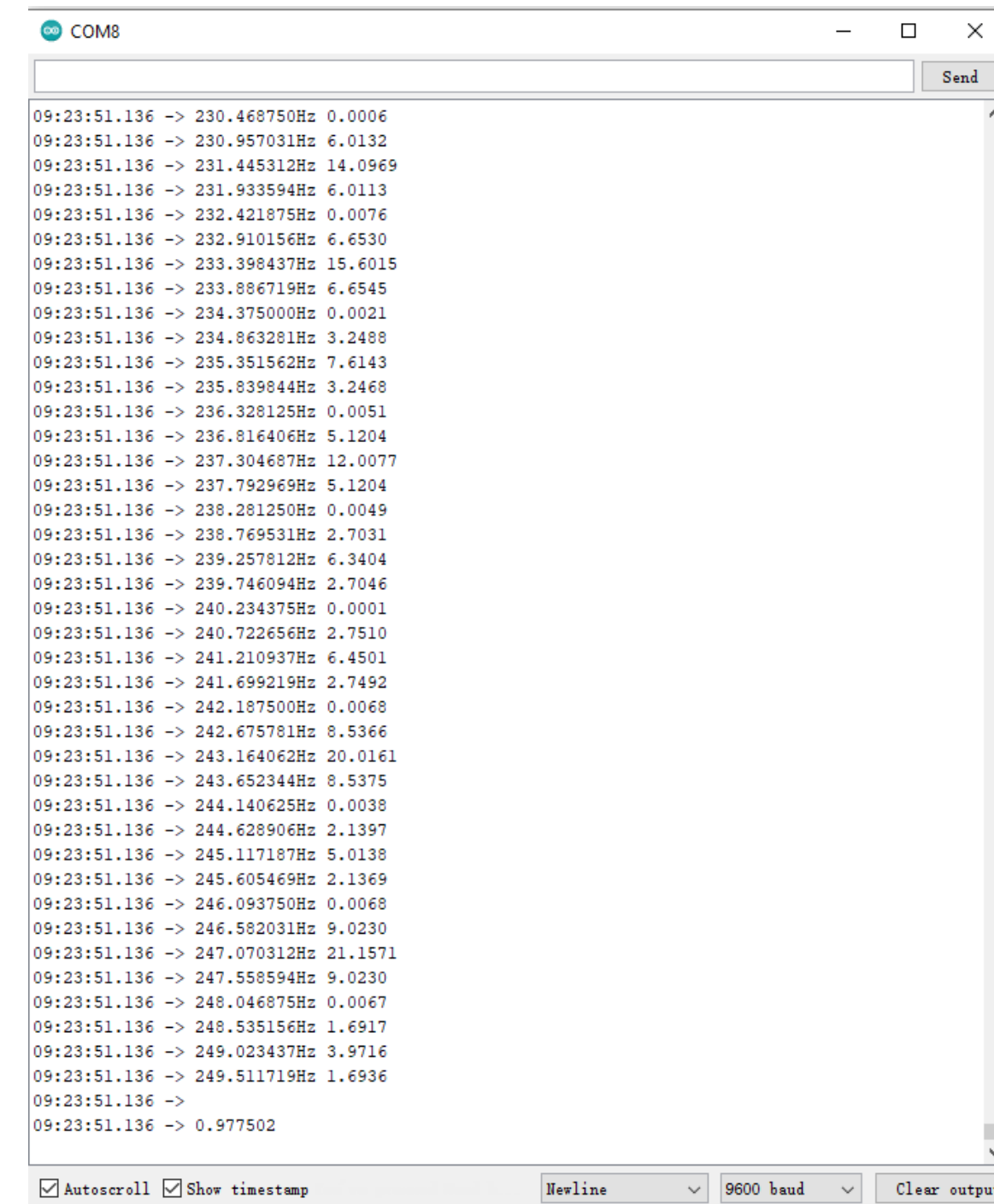
$$\delta f = \frac{F_s}{N_s} = \frac{1}{T_{capture}} \leq 1KHz$$

$$N_s \leq 1024$$

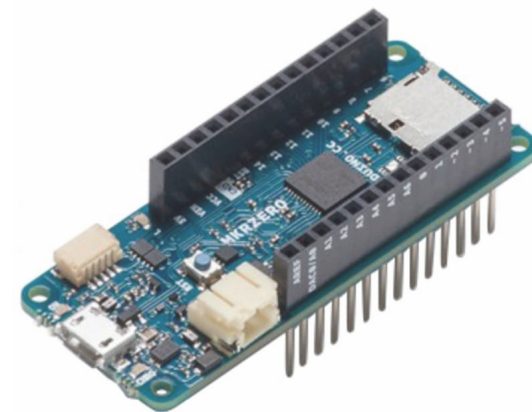
Solution:

- use uC/FPGA with large RAM size
e.g. R5F5651EDDBP CPU Micocontroller, 2MB mem

- Settings: $F_s = 1000\text{Hz}$, $F = 500\text{Hz}$, $N_s = 1024$



```
COM8
Send
09:23:51.136 -> 230.468750Hz 0.0006
09:23:51.136 -> 230.957031Hz 6.0132
09:23:51.136 -> 231.445312Hz 14.0969
09:23:51.136 -> 231.933594Hz 6.0113
09:23:51.136 -> 232.421875Hz 0.0076
09:23:51.136 -> 232.910156Hz 6.6530
09:23:51.136 -> 233.398437Hz 15.6015
09:23:51.136 -> 233.886719Hz 6.6545
09:23:51.136 -> 234.375000Hz 0.0021
09:23:51.136 -> 234.863281Hz 3.2488
09:23:51.136 -> 235.351562Hz 7.6143
09:23:51.136 -> 235.839844Hz 3.2468
09:23:51.136 -> 236.328125Hz 0.0051
09:23:51.136 -> 236.816406Hz 5.1204
09:23:51.136 -> 237.304687Hz 12.0077
09:23:51.136 -> 237.792969Hz 5.1204
09:23:51.136 -> 238.281250Hz 0.0049
09:23:51.136 -> 238.769531Hz 2.7031
09:23:51.136 -> 239.257812Hz 6.3404
09:23:51.136 -> 239.746094Hz 2.7046
09:23:51.136 -> 240.234375Hz 0.0001
09:23:51.136 -> 240.722656Hz 2.7510
09:23:51.136 -> 241.210937Hz 6.4501
09:23:51.136 -> 241.699219Hz 2.7492
09:23:51.136 -> 242.187500Hz 0.0068
09:23:51.136 -> 242.675781Hz 8.5366
09:23:51.136 -> 243.164062Hz 20.0161
09:23:51.136 -> 243.652344Hz 8.5375
09:23:51.136 -> 244.140625Hz 0.0038
09:23:51.136 -> 244.628906Hz 2.1397
09:23:51.136 -> 245.117187Hz 5.0138
09:23:51.136 -> 245.605469Hz 2.1369
09:23:51.136 -> 246.093750Hz 0.0068
09:23:51.136 -> 246.582031Hz 9.0230
09:23:51.136 -> 247.070312Hz 21.1571
09:23:51.136 -> 247.558594Hz 9.0230
09:23:51.136 -> 248.046875Hz 0.0067
09:23:51.136 -> 248.535156Hz 1.6917
09:23:51.136 -> 249.023437Hz 3.9716
09:23:51.136 -> 249.511719Hz 1.6936
09:23:51.136 ->
09:23:51.136 -> 0.977502
Autoscroll Show timestamp Newline 9600 baud Clear output
```



The frequency spans limited up to 250 Hz.

CONCLUSIONS

- FFT idea for matrix read out
 - Some issues challenged the feasibility
- What we learned?
 - How to solve practical problems.
 - Skills for a whole hardware design flow

DISTRIBUTION OF TASKS

Xiaoke Wang: Simulation, PCB Design(schematic and layout),
Microcontroller programming

Haowei Bi : Simulation, PCB Design(layout)



– MKR ZERO Arduino Board

Xiaoke Wang, Haowei Bi

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