GHENT
UNIVERSITY

FACULTY OF ENGINEERING
AND ARCHITECTURE

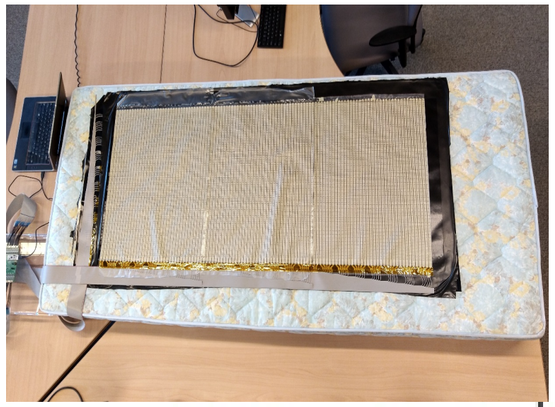
HOP06
SENSOR MATRIX

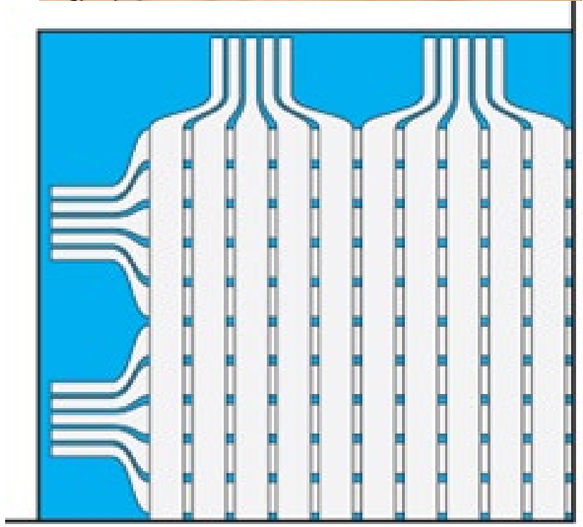
Instructors: Pieter Bauwens, Herbert De Pauw

Group member: Xiaoke Wang, Haowei Bi

GHENT
UNIVERSITY

PROJECT BACKGROUND





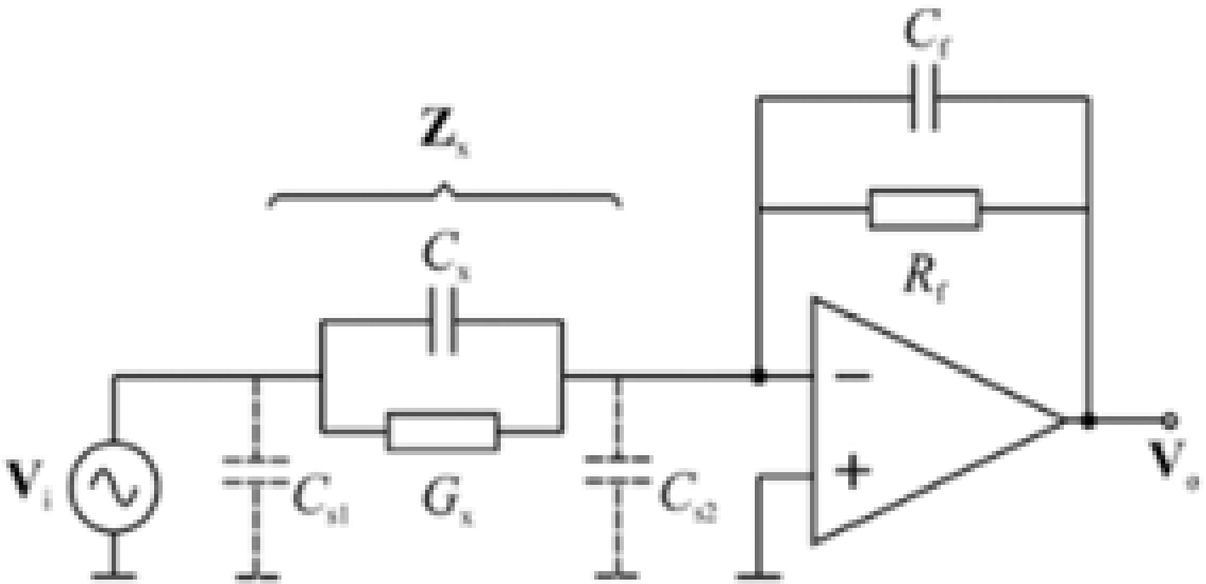
PROBLEMS:

- Reading speed: slow
- Parasitic capacitance

GHENT UNIVERSITY

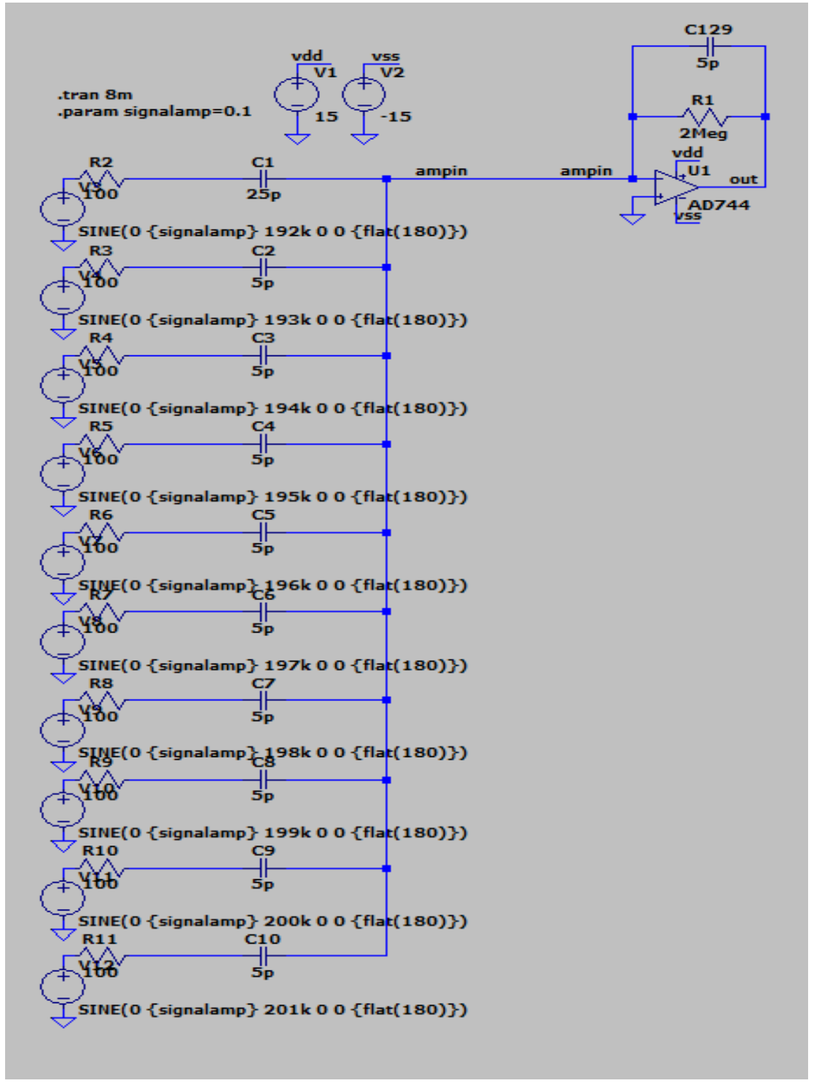
PROJECT GOAL

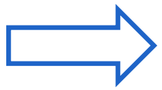
Fast Fourier Transform(FFT) → faster

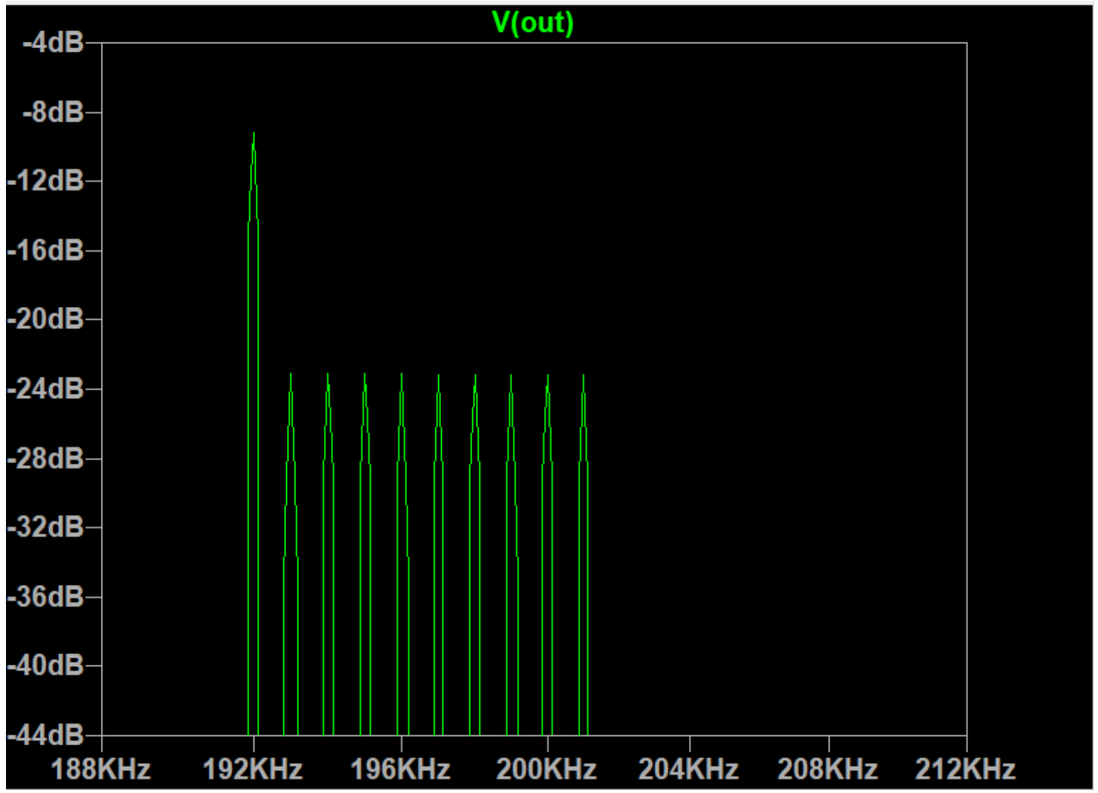


→ more accurate

PROJECT IDEA







GHENT UNIVERSITY

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)

GHENT UNIVERSITY

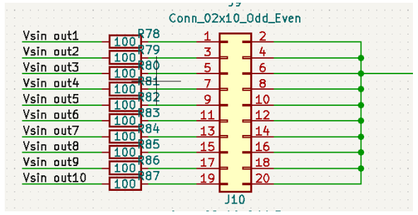
SCHEMATIC AT INTERIM PRESENTATION

– The Sine wave generators

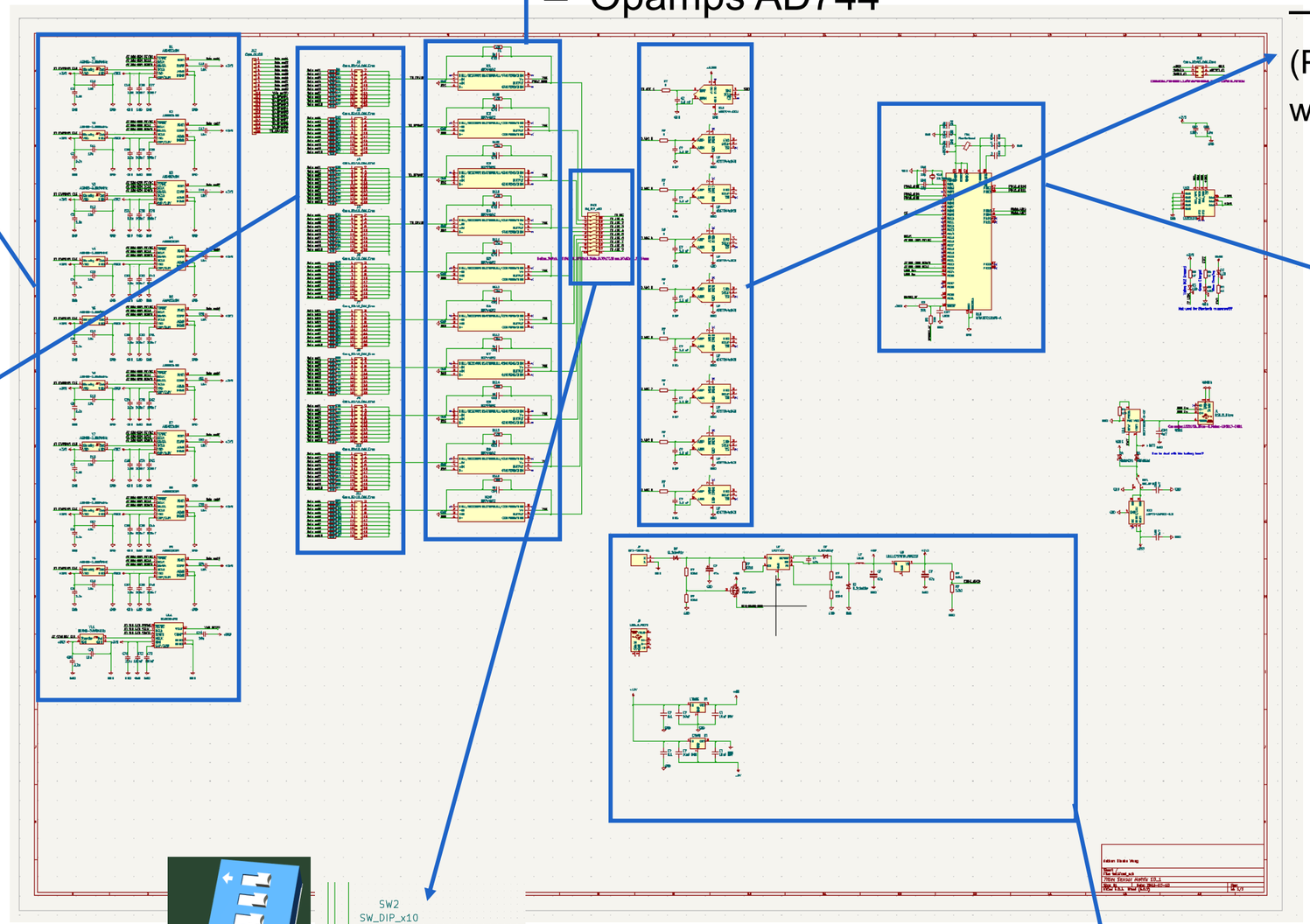
– Opamps AD744

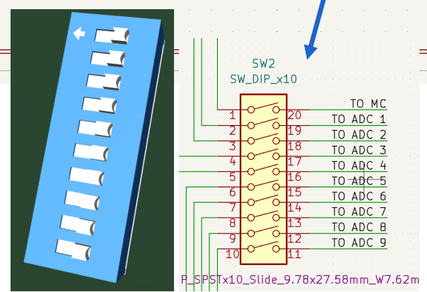
– Differential ADC
(Pseudodifferential Input Operation with Single-Ended Configuration)

– Micro Controller:
ATSAMD21G18A-A



– Resistors and connectors for capacitors





– DIP Connectors

– Power component

– USB micro and Jack DC socket

GHENT UNIVERSITY

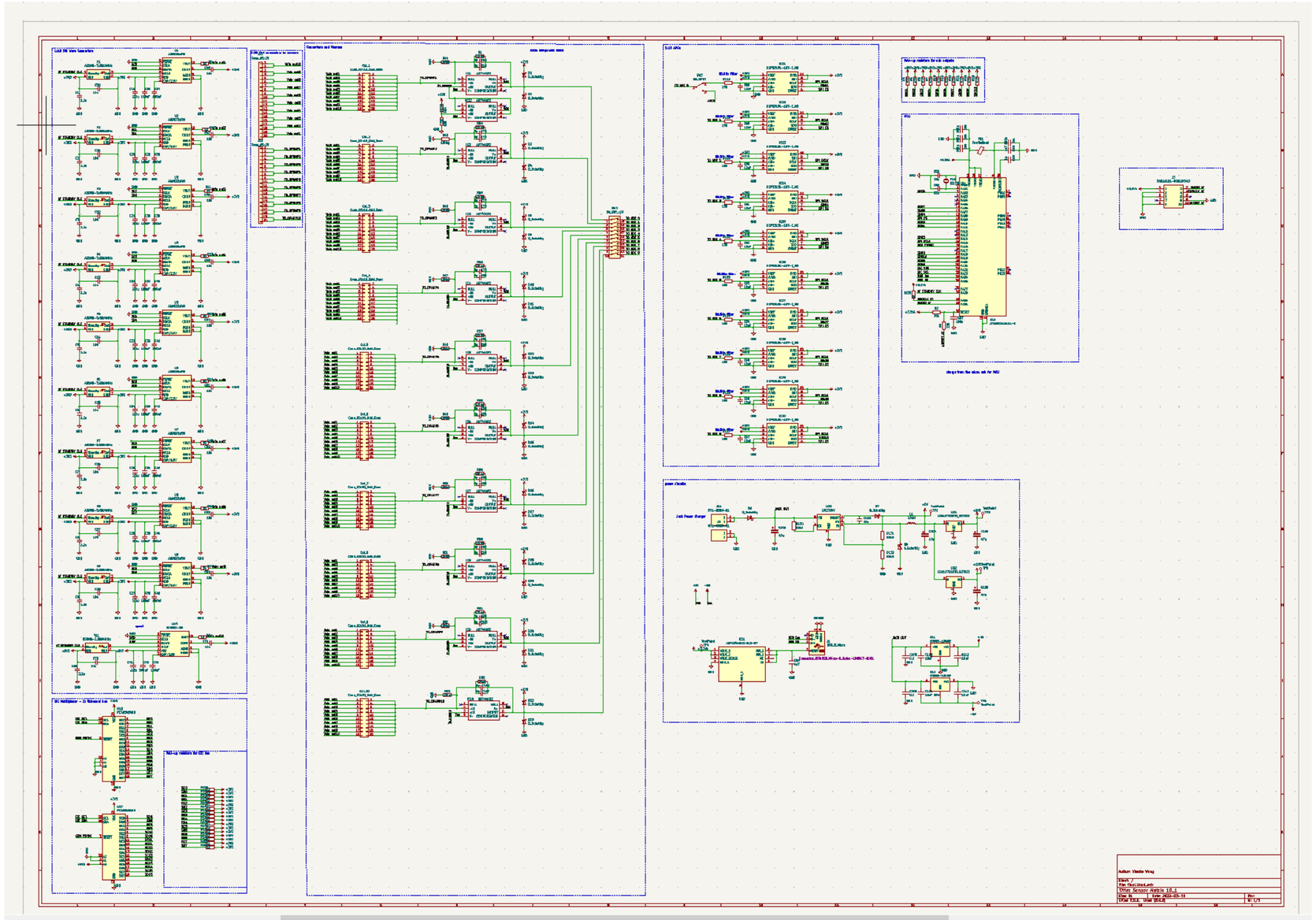
SECOND HALF PERIOD

Progress:

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

GHENT UNIVERSITY

FINAL SCHEMATIC

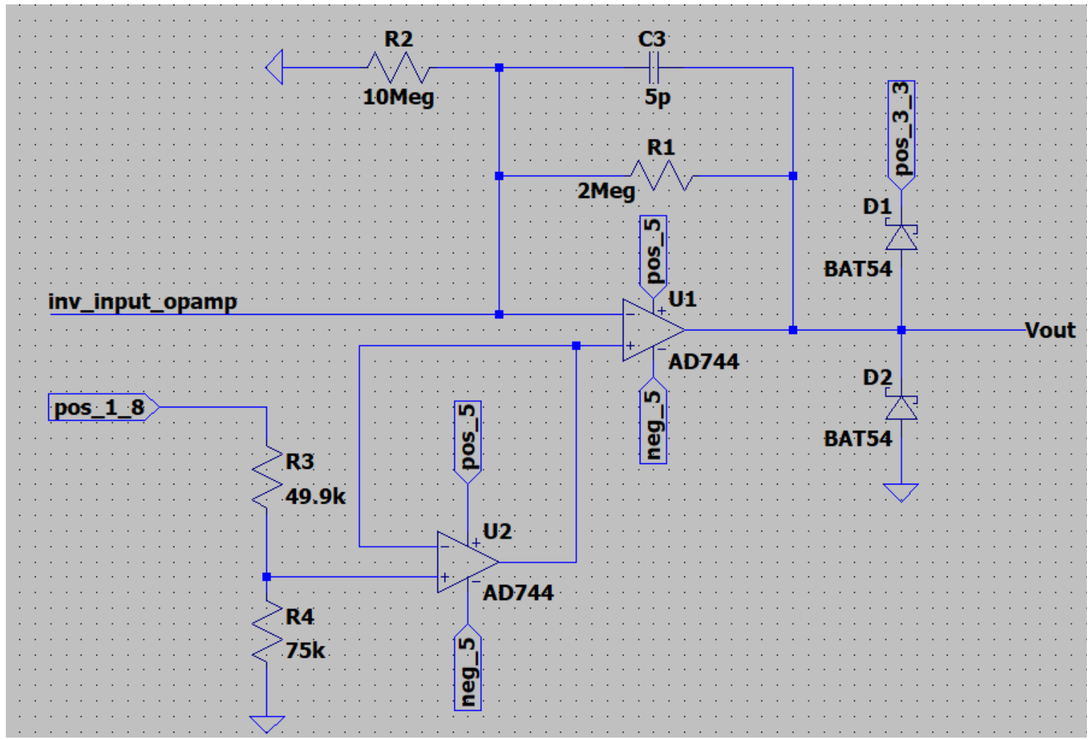


GHENT UNIVERSITY

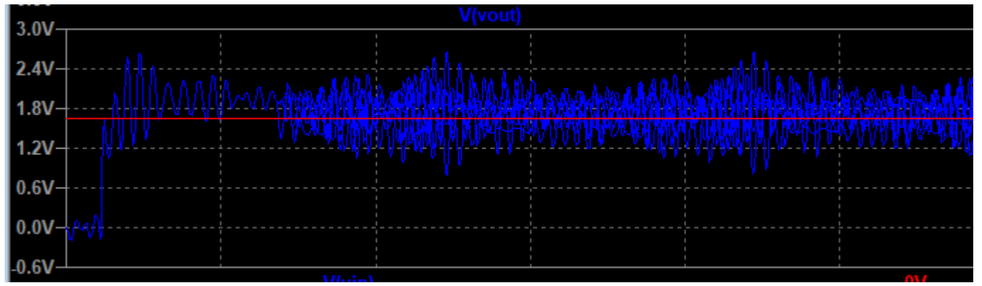
EXTRA CIRCUIT FOR OPAMP

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

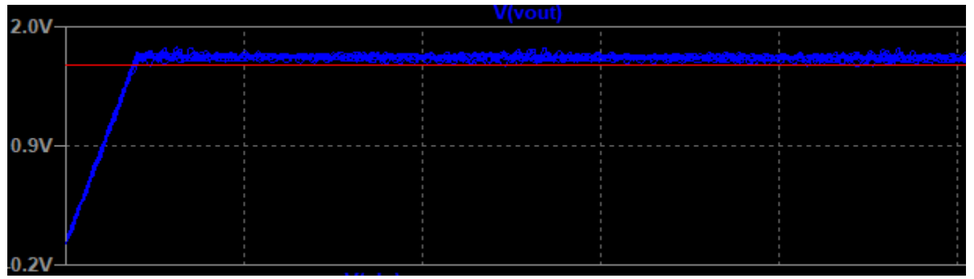
Solution: add 3.3/2 V DC voltage



Extra circuit for adjusting the voltage



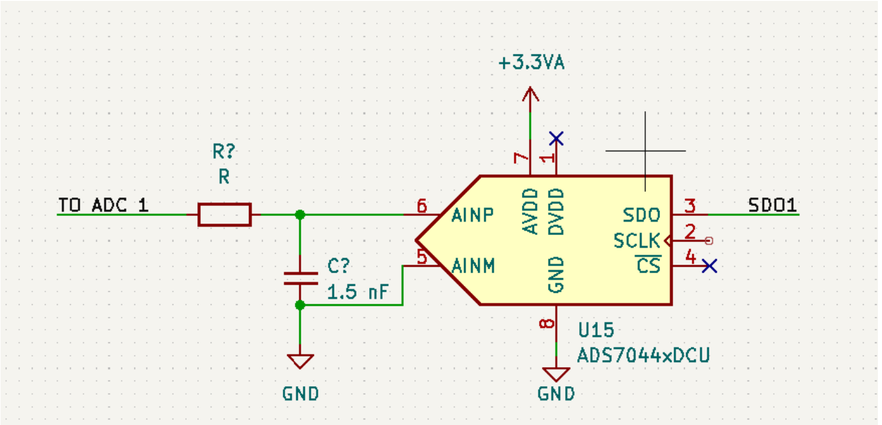
Output voltage of the opamp

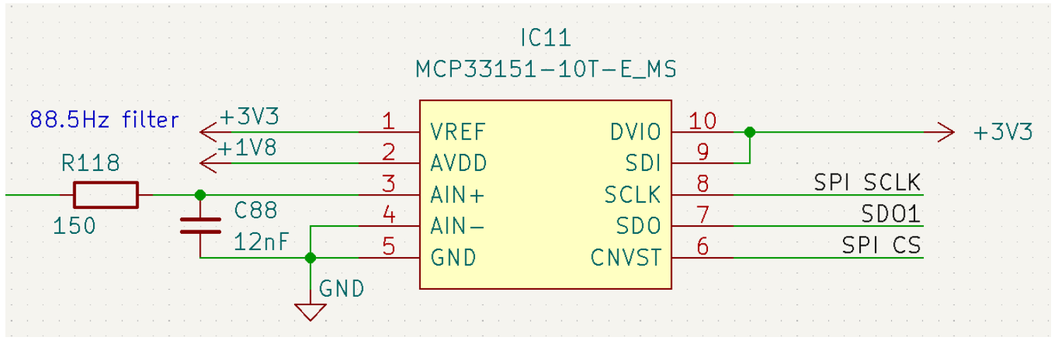


an issue: input voltage lower than 3.3V

GHENT UNIVERSITY

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

GHENT UNIVERSITY

PCB LAYOUT DESIGN

Microcontroller and bootloader

Power circuits:
3.3V ±5V and 1.8V

two **I2C** multiplexers

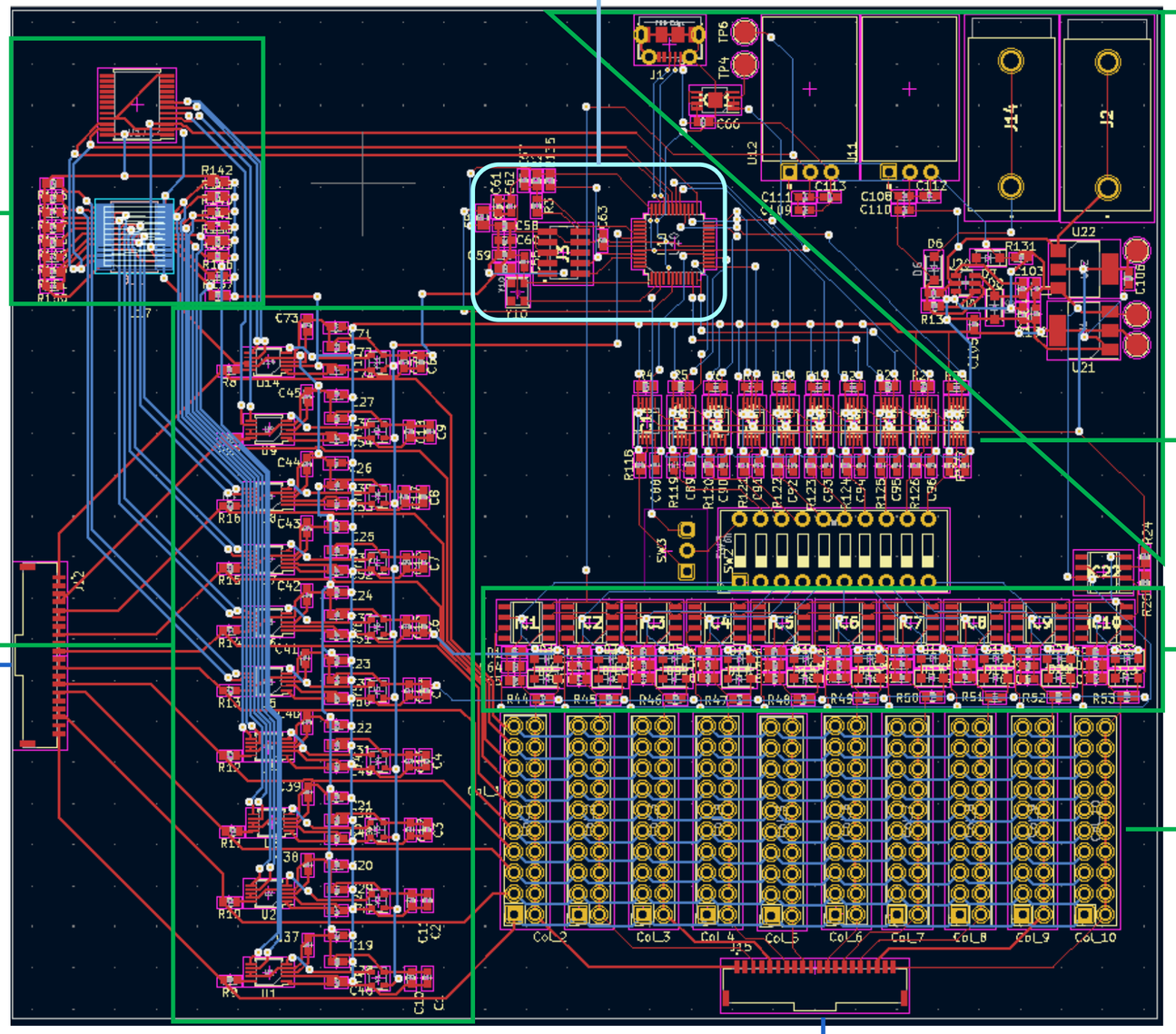
10 **external ADCs**
(14 bits and 1Msps)

10 Generators

10 **Opamps**

External connectors
20 pin connector
Same standard with
sensor matrix we have

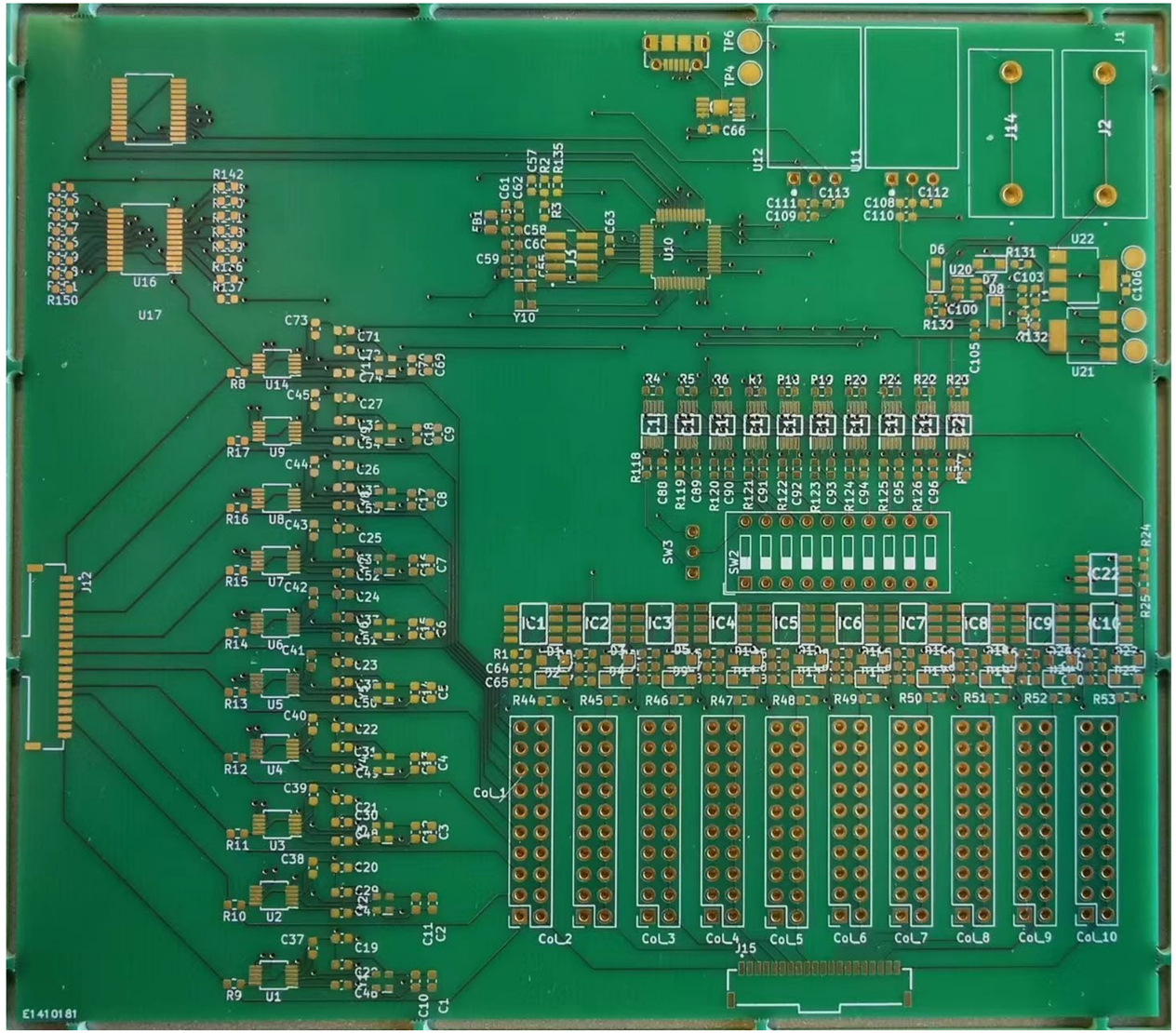
10 2x10 pin **sockets**
Ceramic pin capacitors
as sensor matrix



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

GHENT UNIVERSITY

PCB LAYOUT DESIGN



Final PCB board (12.2x13.9cm)

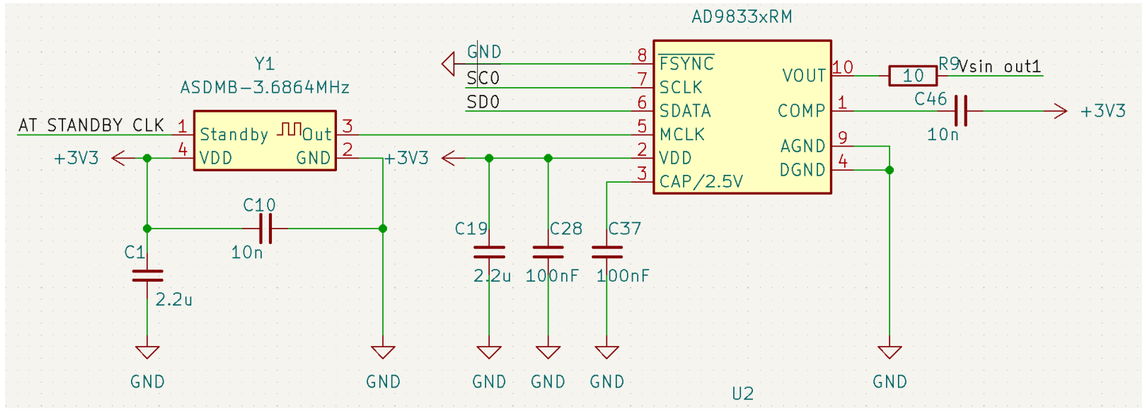
MICROCONTROLLER PROGRAMMING

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

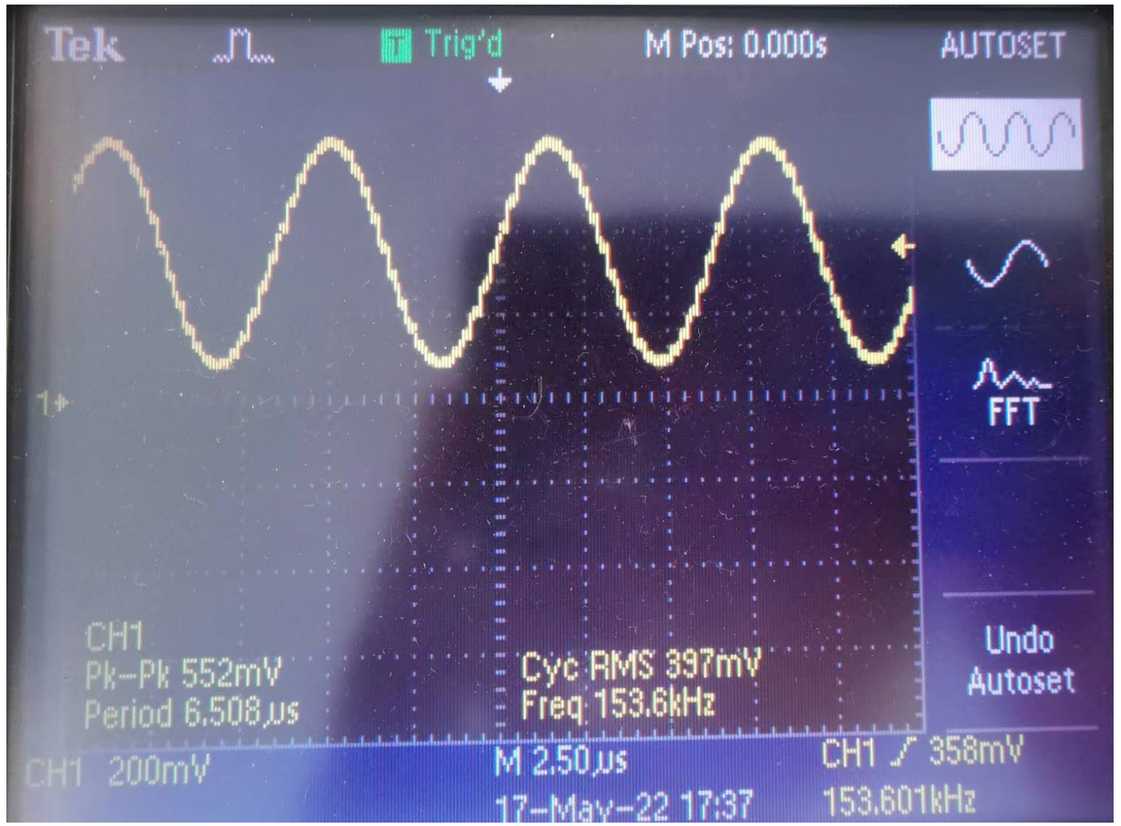
GHENT UNIVERSITY

GENERATOR PROGRAMMING

Program the generator circuit on a test board



Generator circuit



The wave output with the setting at 150kHz

Some Issues Here:

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

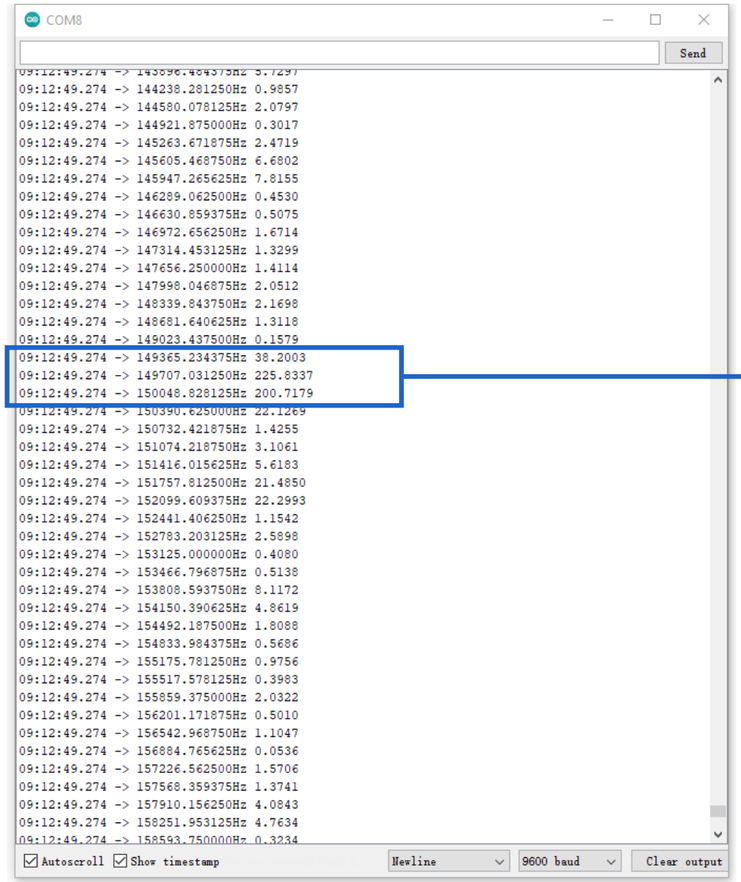
GHENT UNIVERSITY

FAST-FOURIER TRANSFORM (FFT)

Samples for FFT(power of 2):

N = 1024

N = 2048



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

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

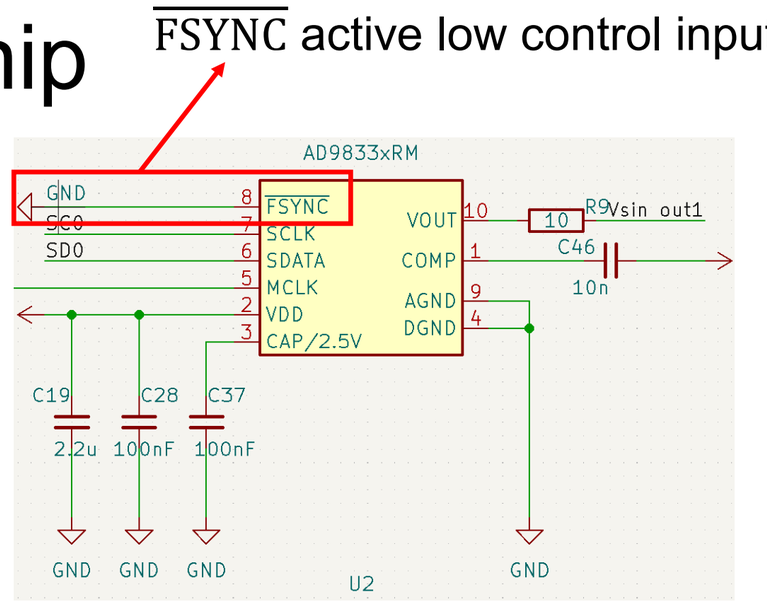
Memory stack overflowed: (SRAM size of ATSAMD21: 32KB – 4Kbytes)

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

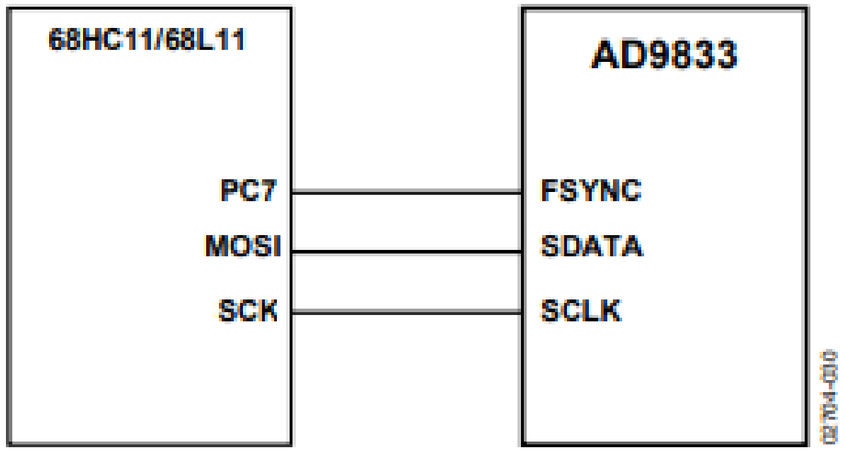
GHENT UNIVERSITY

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

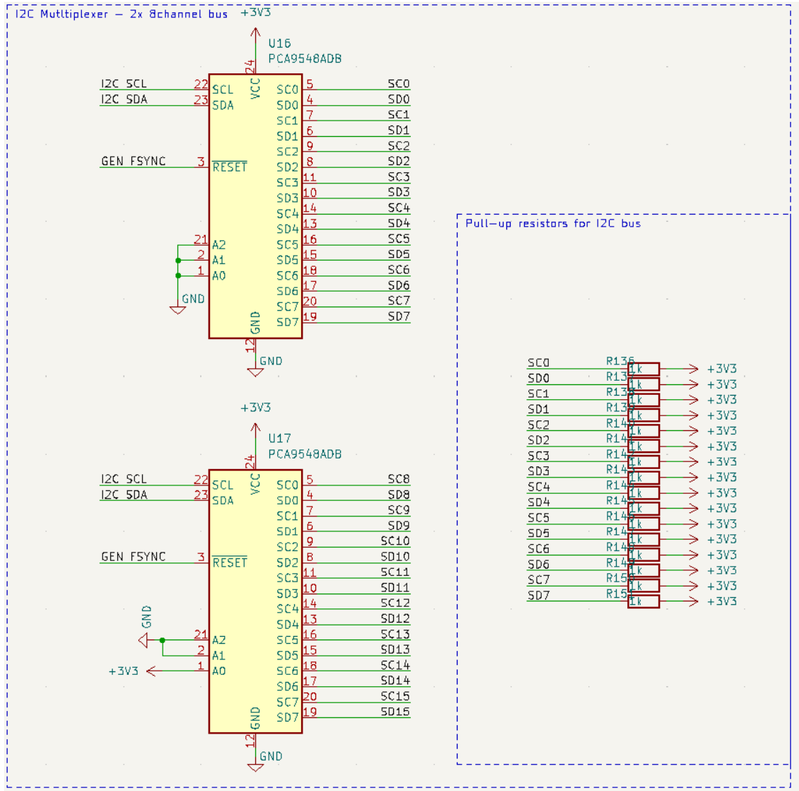
Pros

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

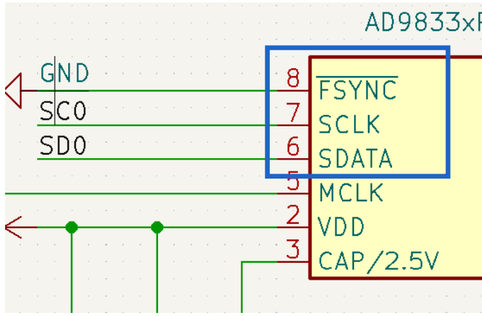
Cons

- 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

GHENT UNIVERSITY

ANALYSIS FOR FFT

– Spectrum resolution:

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

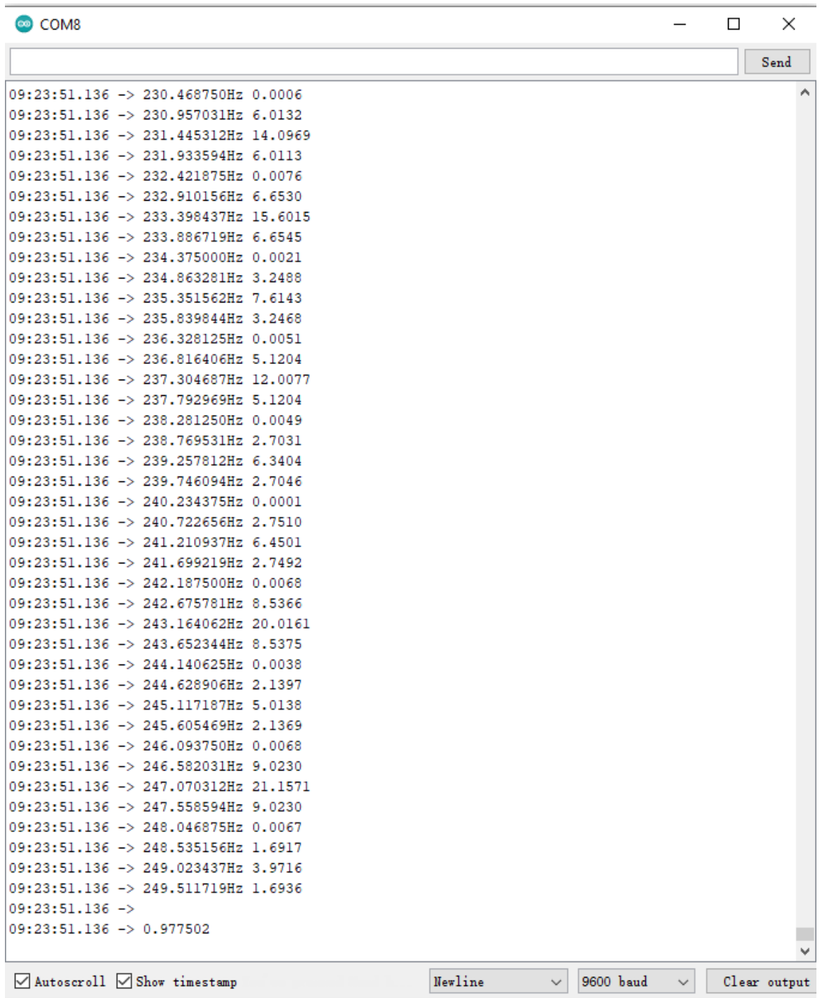
$$N_s \leq 1024$$

Solution:

- use uC/FPGA with large RAM size

  e.g. R5F5651EDDBP CPU Micocontroller, 2MB mem

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



The frequency spans limited up to 250 Hz.

GHENT UNIVERSITY

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

GHENT UNIVERSITY

FACULTY OF ENGINEERING
AND ARCHITECTURE

Xiaoke Wang, Haowei Bi

Email: <first name>.<surname>@ugent.be

www.ugent.be

Universiteit Gent
@ugent
@ugent
Ghent University

GHENT
UNIVERSITY