Indian Institute of Science

Bio amplifier

Project work at CPDM IISc

BioSystems Science and Engineering

Indian Institute of Science
Centre for Product Design and Manufacturing

Guidance

Dr Manish Arora, Assistant Professor, CPDM, IISc Bangalore

Laboratory:
Universal Technology Solutions for Accessible & Affordable Healthcare (UTSAAH) Laboratory

Collaborations:
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Objective

To test and use Bio amplifier published in:
Journal of Undergrad Neurosci Educ. 2012 Spring; 10(2): A118–A124.

Bio-amplifier with Driven Shield Inputs to Reduce Electrical Noise and its Application to Laboratory Teaching of Electrophysiology

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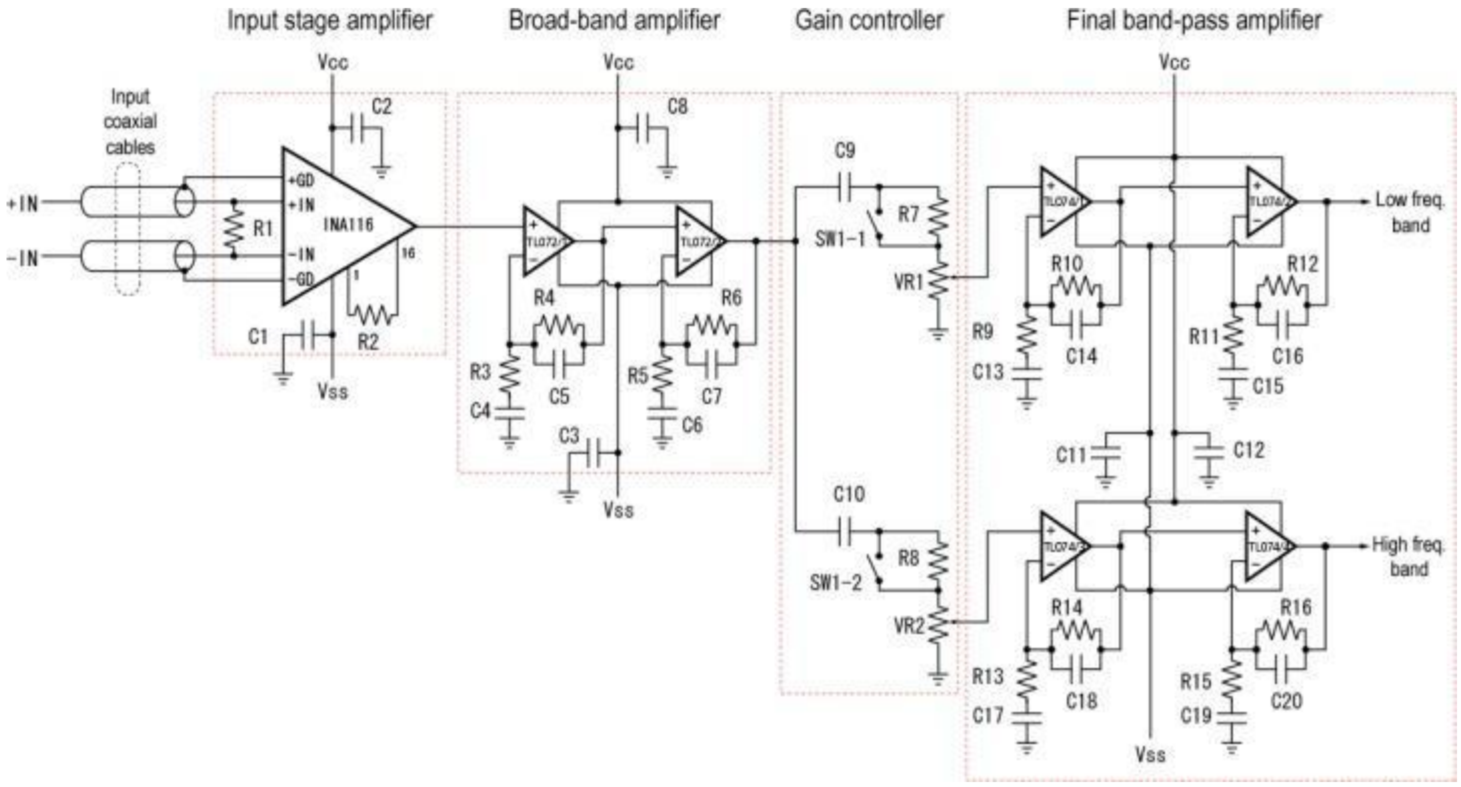
Motivation

- My interest in Biomedical Instrumentation
- Bio signals, specially EEG
- Low cost medical devices, which is the objective of UTSAAH Lab

Matsuzaka Bio amplifier



Stages

- *1st stage*: Instrumentation amplifier, normal differential amplifier, removing common mode noise,”driven” shield inputs,high input impedance. Gain=19.5

- *2nd stage*: Broad band amplifier:1Hz-3.7kHz,covering most of the physiological signals of interest , low cost,easy availability,good frequency response.Gain=93.4

- *3rd stage*: Gain controller

- *4th stage*: Consists of band pass filters with gain,two sets of them. Gain = 58.8.The passband of these filters to 1–340Hz (for surface EMG, EEG and local field potential) and 320Hz-3.4kHz (for neuronal action potentials).

Problem

- PCBs fabricated from the Gerber files mentioned in the paper had problems.
- In the third stage there were offset voltages on the output pins. i.e.,pins 8 and 14 of TL074
- Offset voltages were in the order of Volts which are not acceptable.~-6V, as they already saturate the output

Testing of 3rd stage

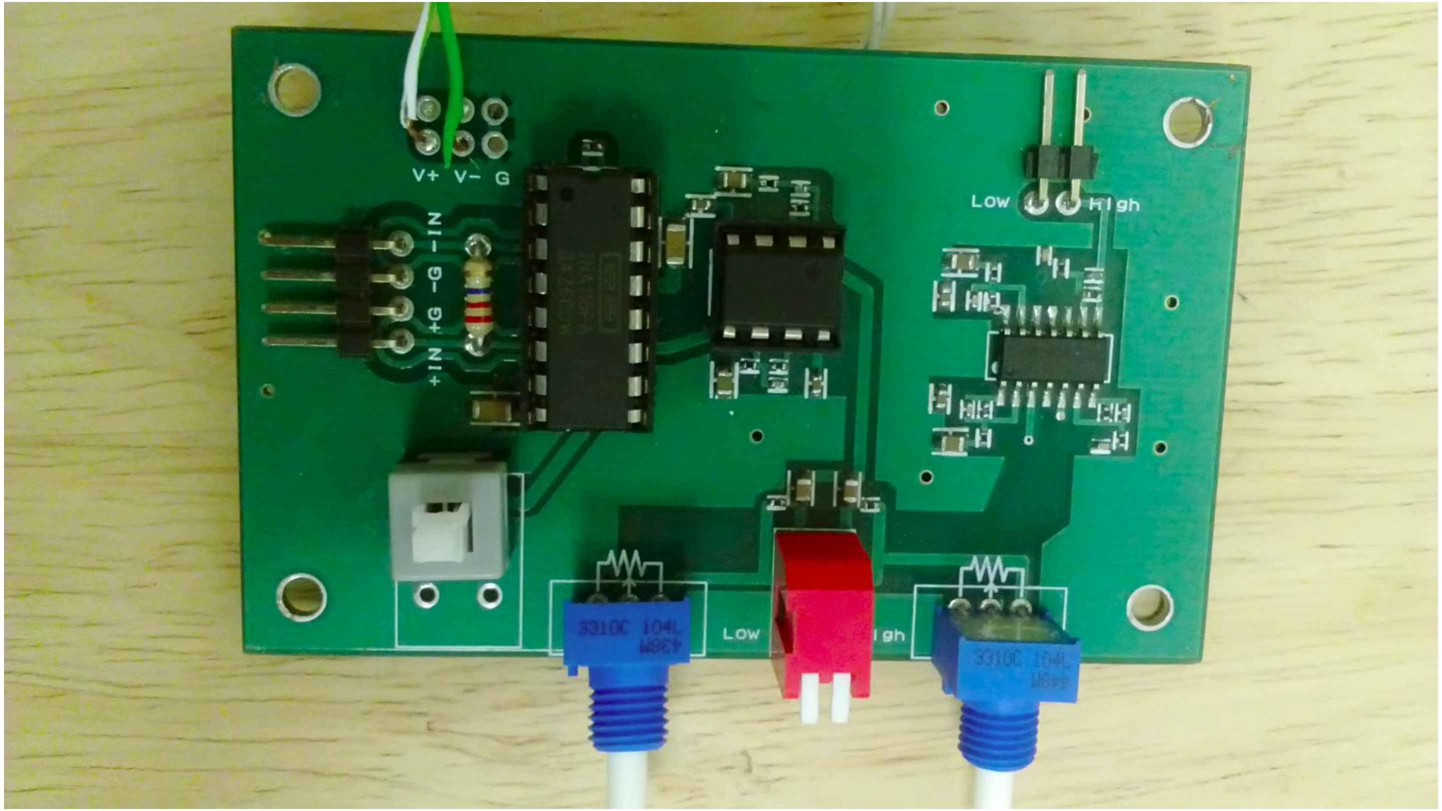
HARDWARE:

- Tektronix MDO 3014 Oscilloscope
- Wave Station 2052 Teledyne LeCroy Waveform generator
- Power Supply

SOFTWARE:

- MATLAB
- Python(PyVISA)

PCB



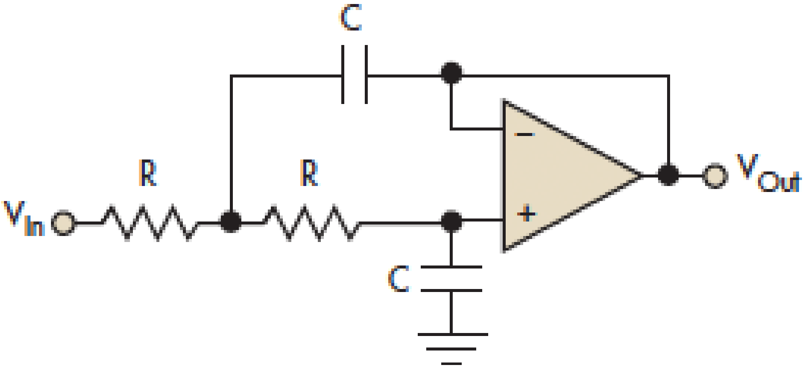

Tektronix

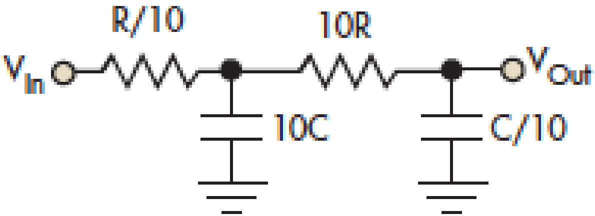

LeCroy
waveStation 2052
50MHz Waveform Generator
Sine CH1
Sine CH2
Frequency
10.000Vpp
0.000Vdc
CH2 Waveform
Load: Hi-Z
Phase
Offset
Freq
Period
Ampl
HLevel
LLevel
EqPhase
CH1/2
Square
Ramp
Pulse
Noise
Arb
Mod
Sweep
Burst
Store/Recall
Utility
Help
Output
CH1
CH2
CH1 50Ω-3V Pk/HIZ-6V Pk
CH2 50Ω-10V Pk/HIZ-20V Pk

Procedure for testing

- Making the circuit on breadboard
- Powering it up and measuring the offset voltages by grounding the input pins of this IC
- Sending in sinusoidal signals of different frequencies using Waveform generator and noting the output readings from oscilloscope
- Plotting frequency versus gain curve
- Evaluating the transfer function for the schematic and plotting its Bode in MATLAB
- Comparing experimental plots with theoretical plots
- Manually done.Frequency range used:30-50k Hz(at 55 points)

Obtaining theoretical curves:Transfer functions

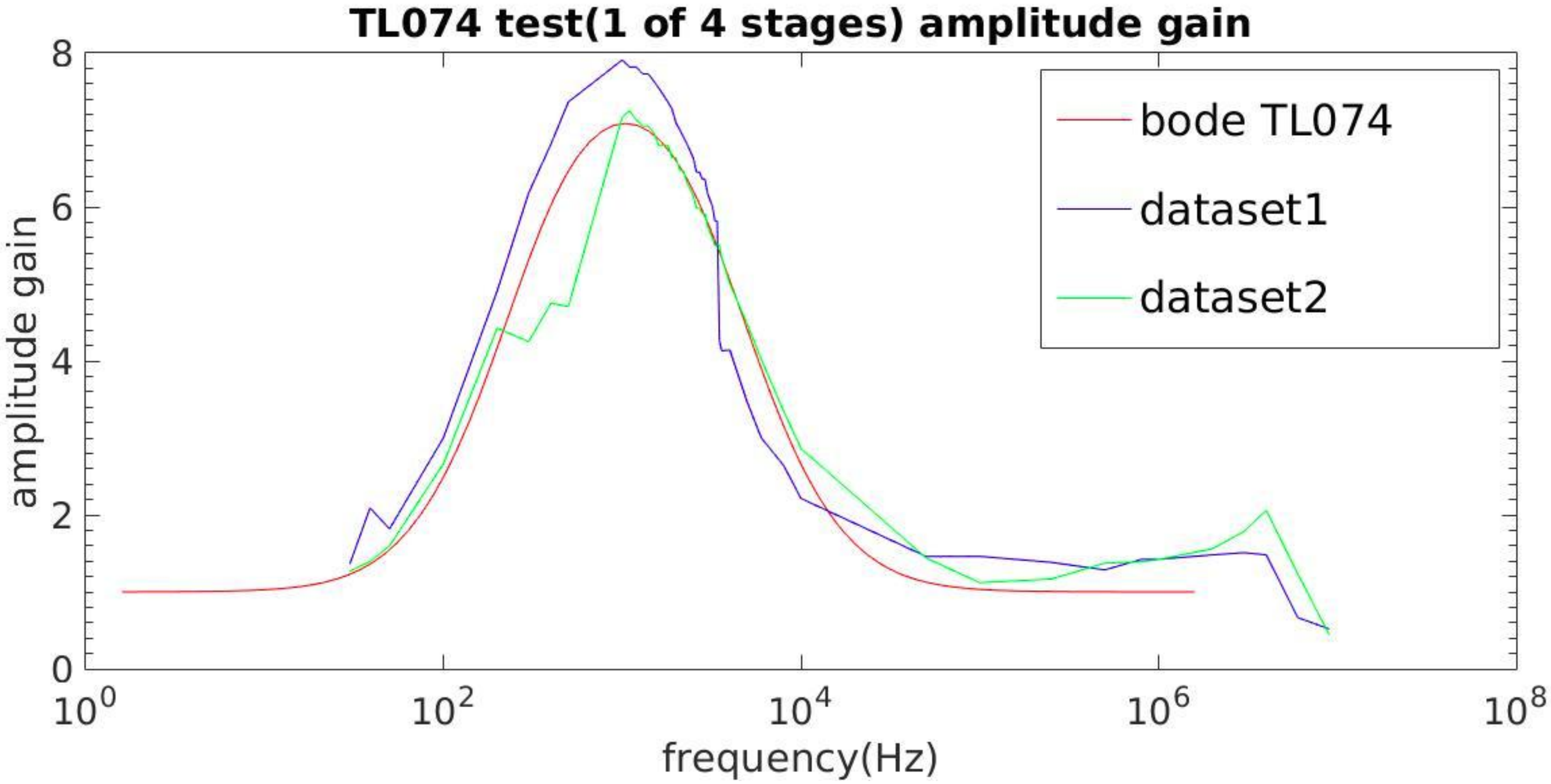




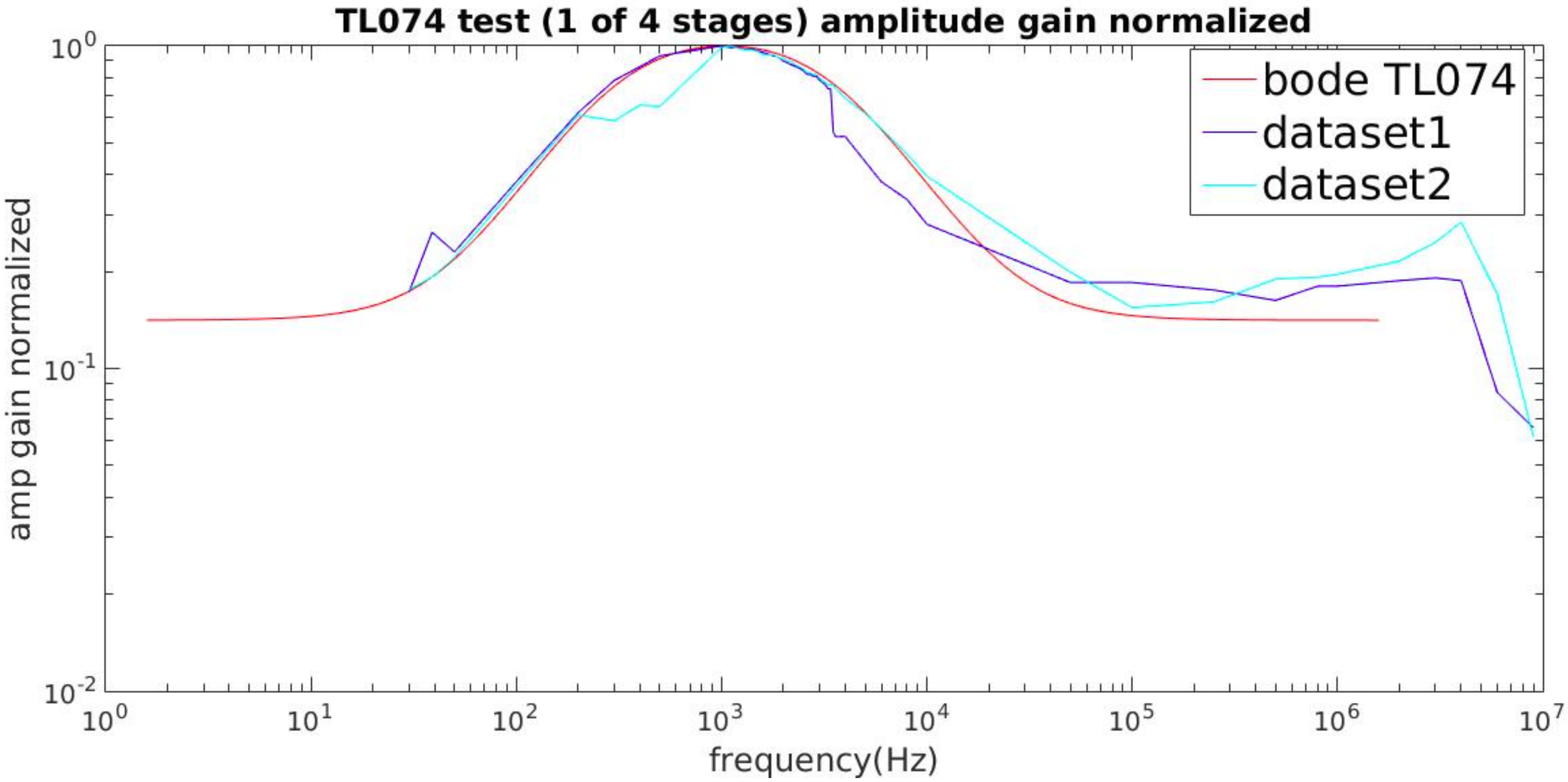
$$H(s) = \frac{1}{(sRC)^2 + 2(sRC) + 1}$$

$$H(s) = \frac{1}{(sRC)^2 + 2.01(sRC) + 1}$$

TL074 testing :Results



TL074 testing :Results



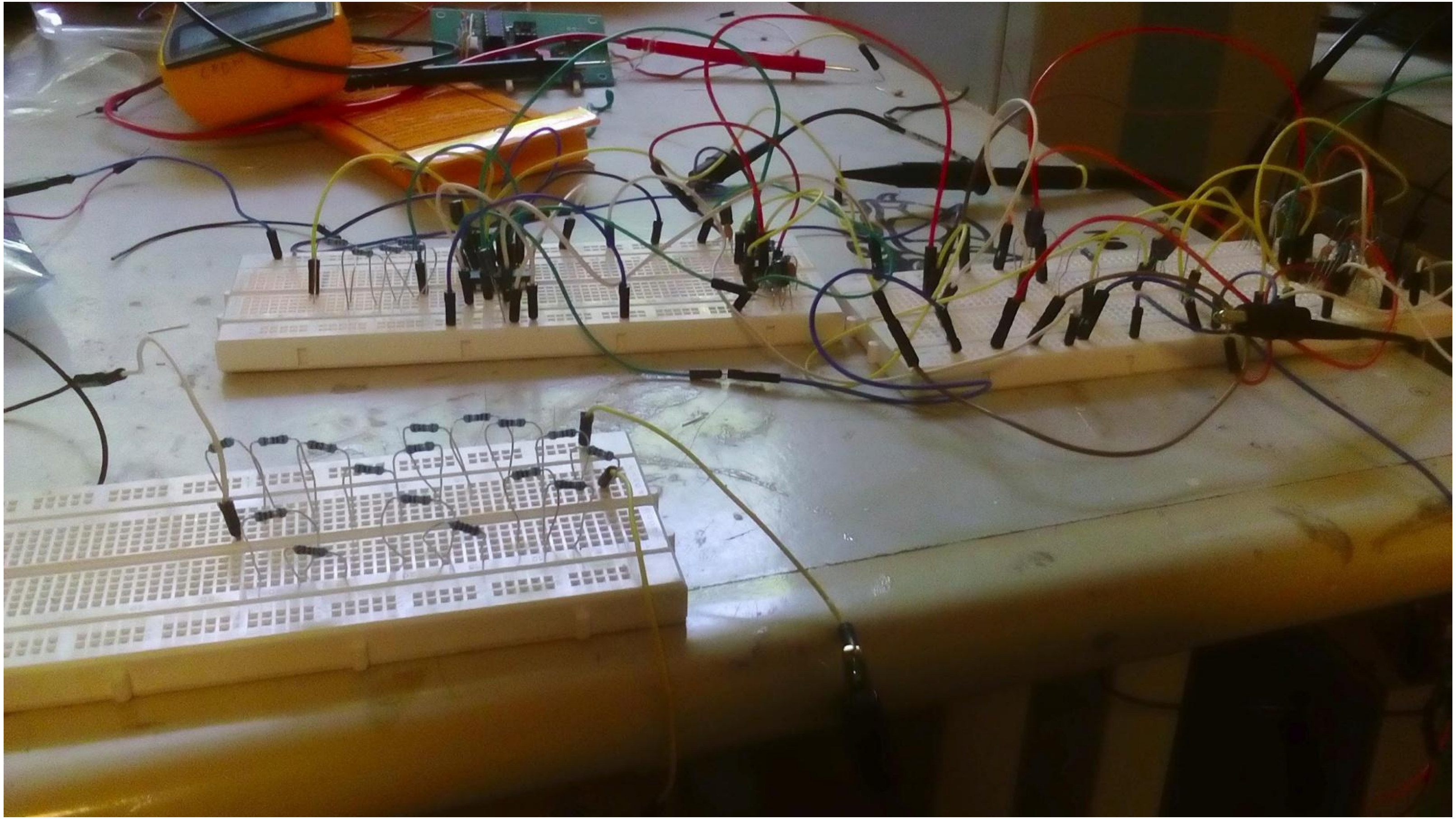
TL074 testing :Results

- No offset voltages , i.e., zero output corresponding to zero input.
- Theoretical and Experimental plots were similar.
- The last stage is working properly, something else might have gone wrong.
- Next step was to test the whole amplifier schematic.

Next step: Testing the whole amplifier together

- Same steps as used for TL074 &
- Checking step wise gains

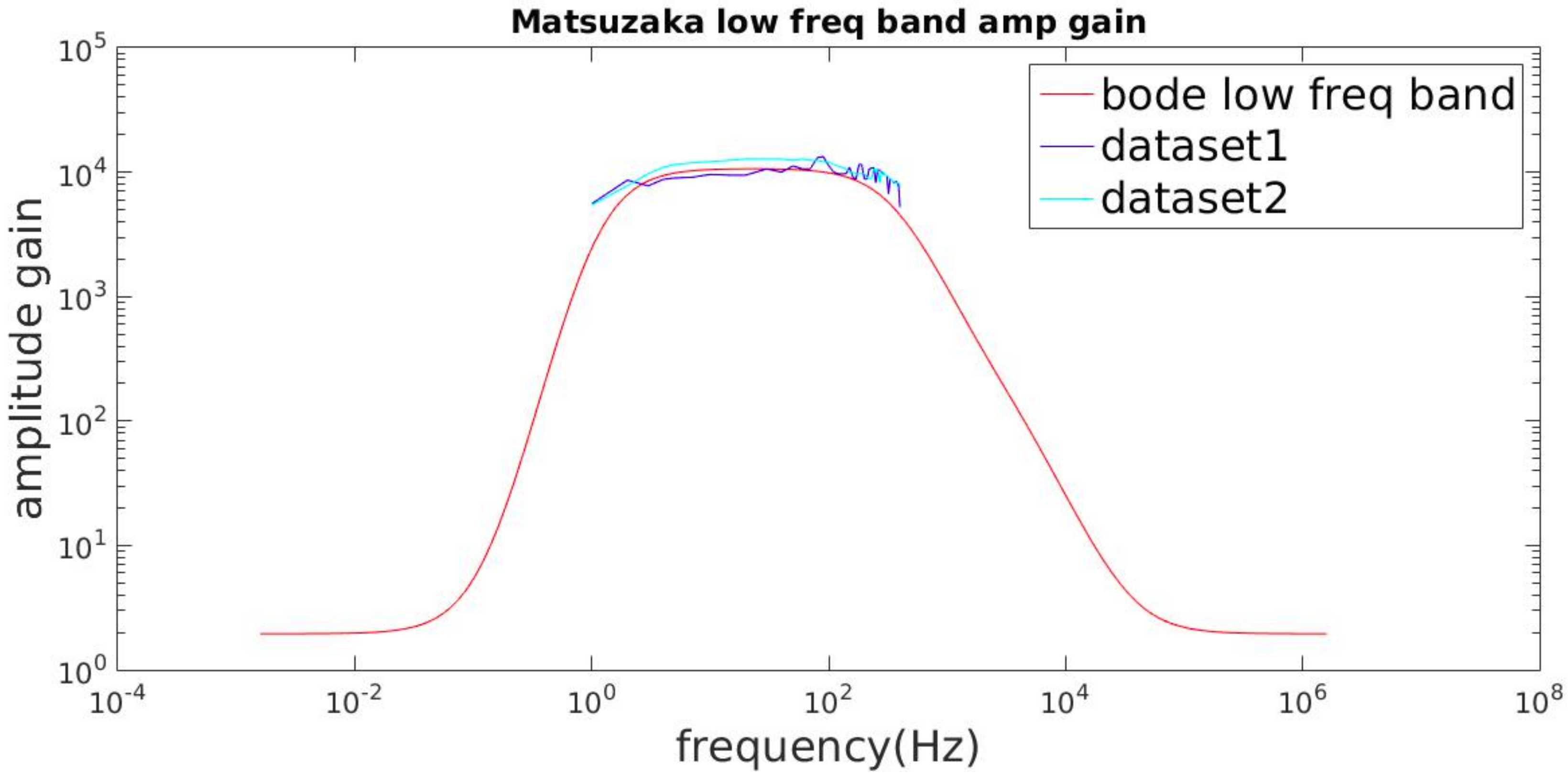
- Frequency range used:1-400 Hz for low pass side(47 points)
- 320-5k Hz for High pass side(55 points)



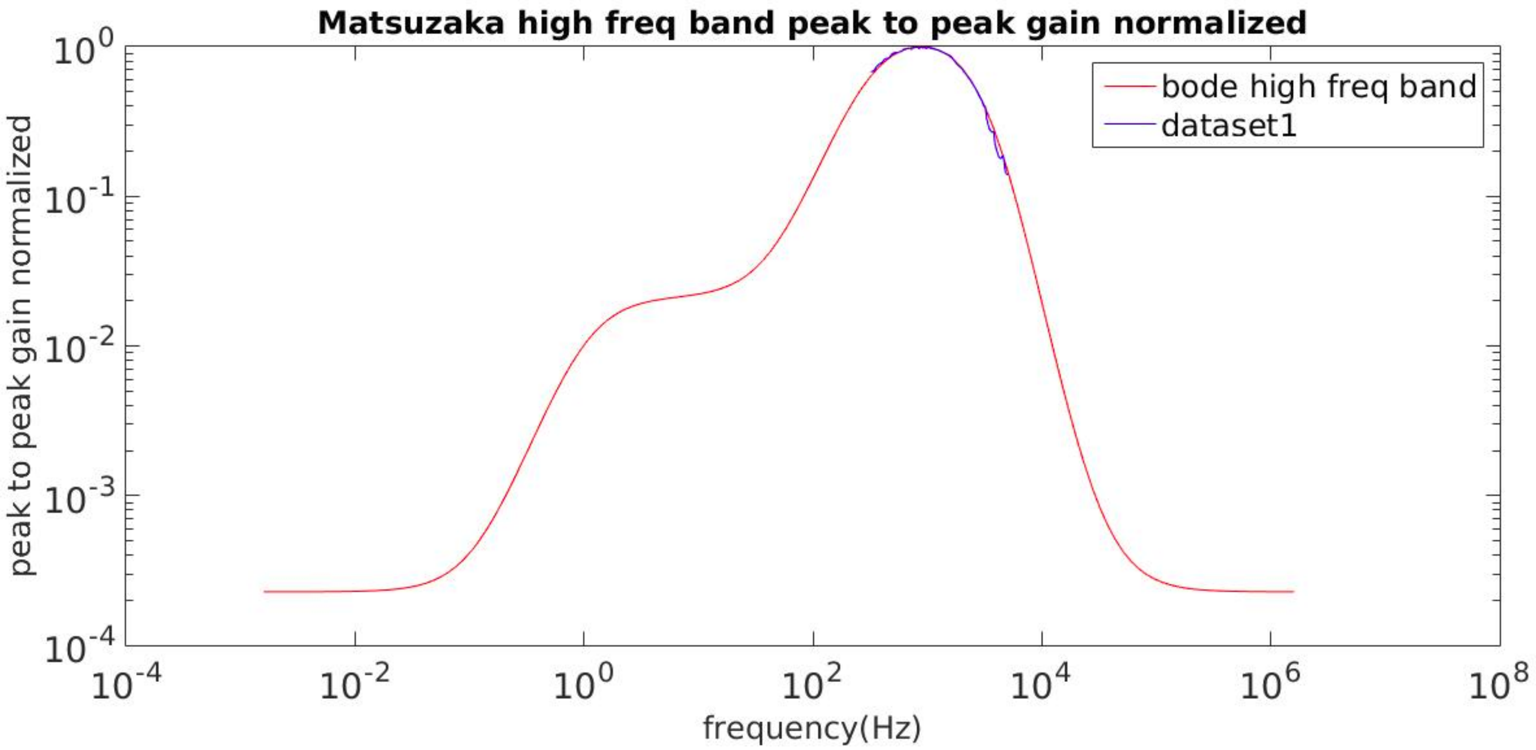
Results

- Offset voltages : acceptable , of the order of ~0.1 mV (low pass) and ~2mV (high pass).
- DC volatges of low magnitude don’t affect the output.

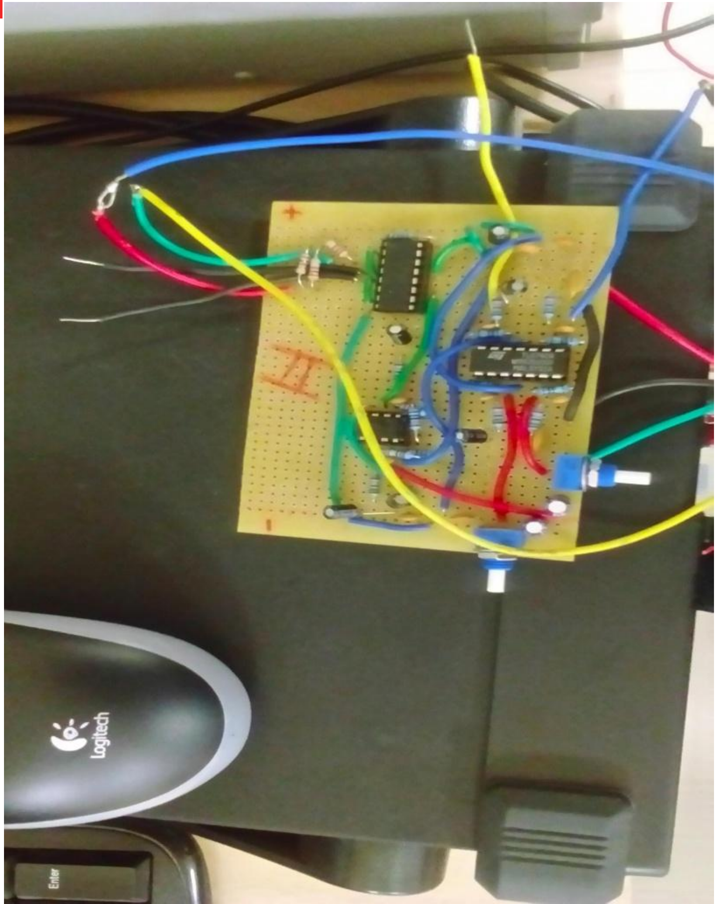
Low frequency side response

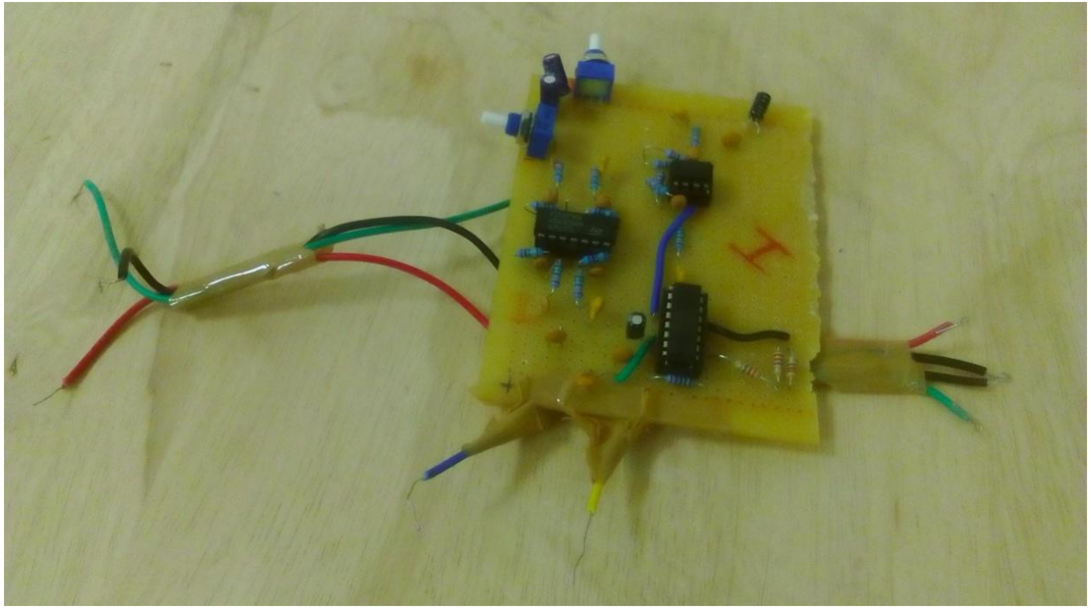


High frequency peak to peak response



Compacted versions of board to be used further





Automating the testing procedure

Hardware:
Matsuzaka Amplifier, Oscilloscope(Tektronix MDO 3014),Waveform Generator(Wavestation 2052),USB cables as USB interfacing is used.Other modes of interfacing:Ethernet, GPIB

Software:

Ubuntu 16.04 LTS
Python 2.7.11+
PyVISA 1.8
py(python backend for VISA) 0.3.dev0
PyUSB 1.0.0
Spyder(Python2.7)

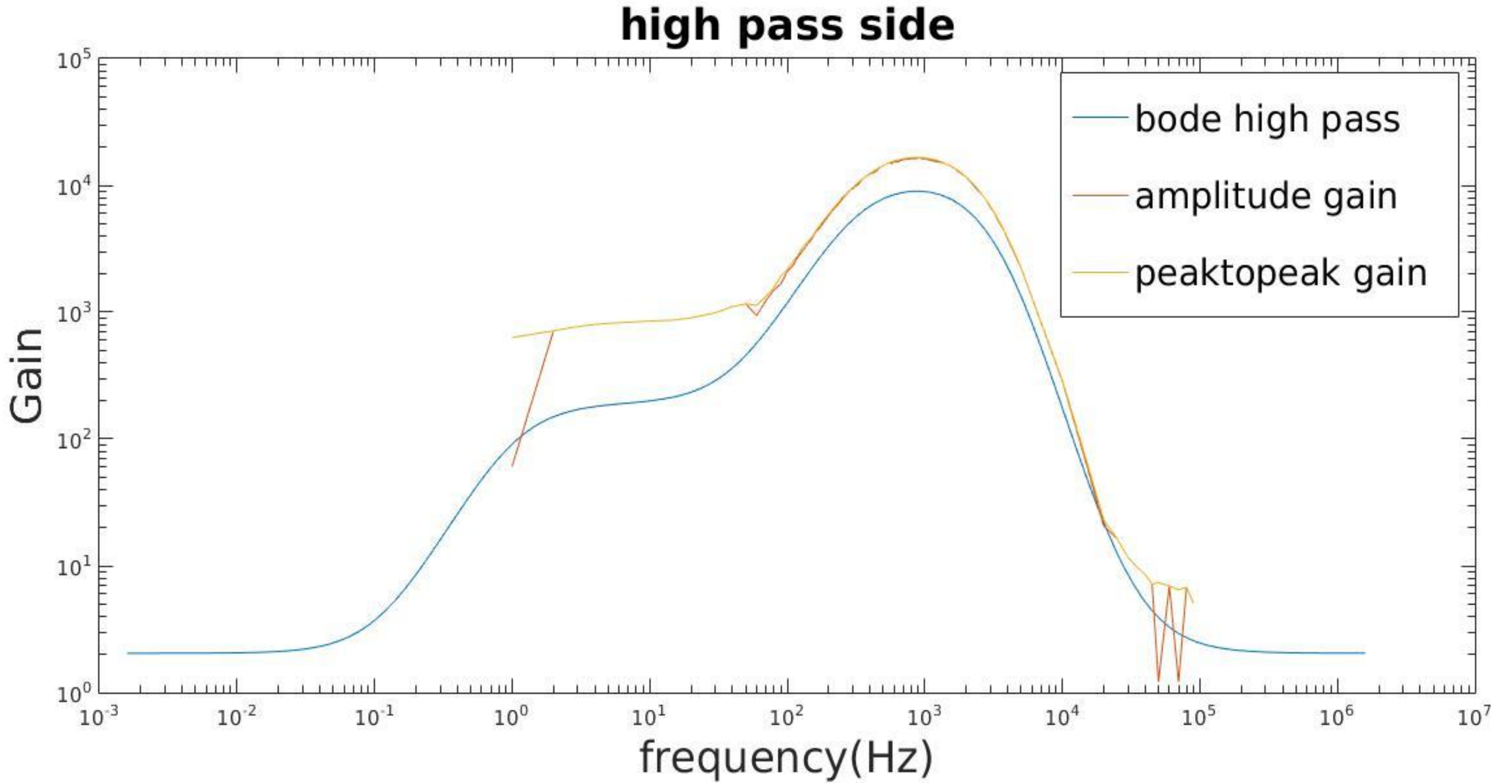
Learning SCPI

- Standard Commands for Programmable Instruments (SCPI; often pronounced "skippy") defines a standard for syntax and commands to use in controlling programmable test and measurement devices.
- set operation (e.g. switching a power supply on) or a query operation (e.g. reading a voltage).
- Some commands for both setting and querying an instrument..
- Concatenating commands
- Each instrument has its own set of identifiable commands for performing various functions on them, the standard syntax being the same.
- e.g.,tek.query(“*IDN?”) ,tek.write(‘ACQ:MOD:AVE’) etc

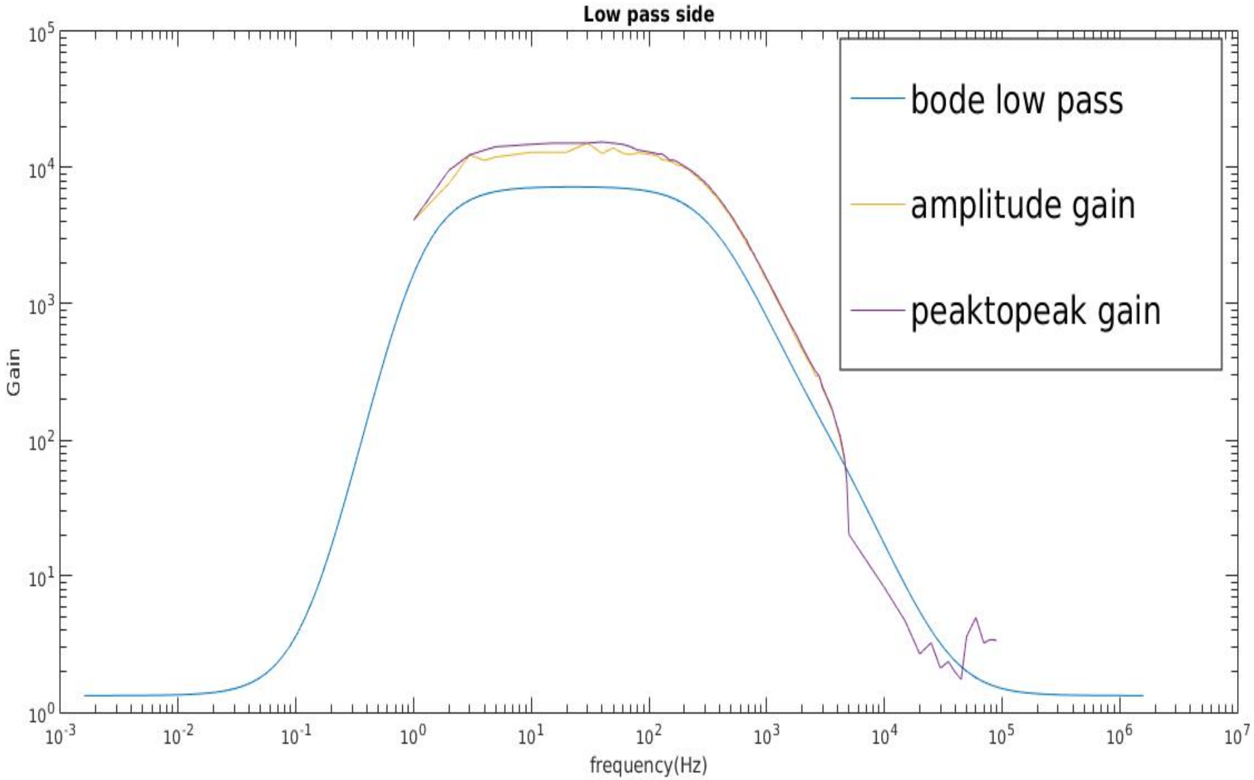
Coding in Python IDE

- Opening the USB resources and initializing them , doing all the settings required using SCPI commands
- Changing frequencies in waveform generator and simultaneously changing x and y scales for proper display
- Changing settings of oscilloscope(acquisition mode,no. of averages,and other settings for proper readings)
- Saving .isf files as well as amplitude, frequency and peak to peak values obtained in an excel file, for each test frequency.
- Optimizing time settings and other parameters at each test frequency for accurate measurements.
- All of the above done automatically by code reducing the testing time from manual **2 hours** to automated **15 minutes**

Automated testing high pass side :Results



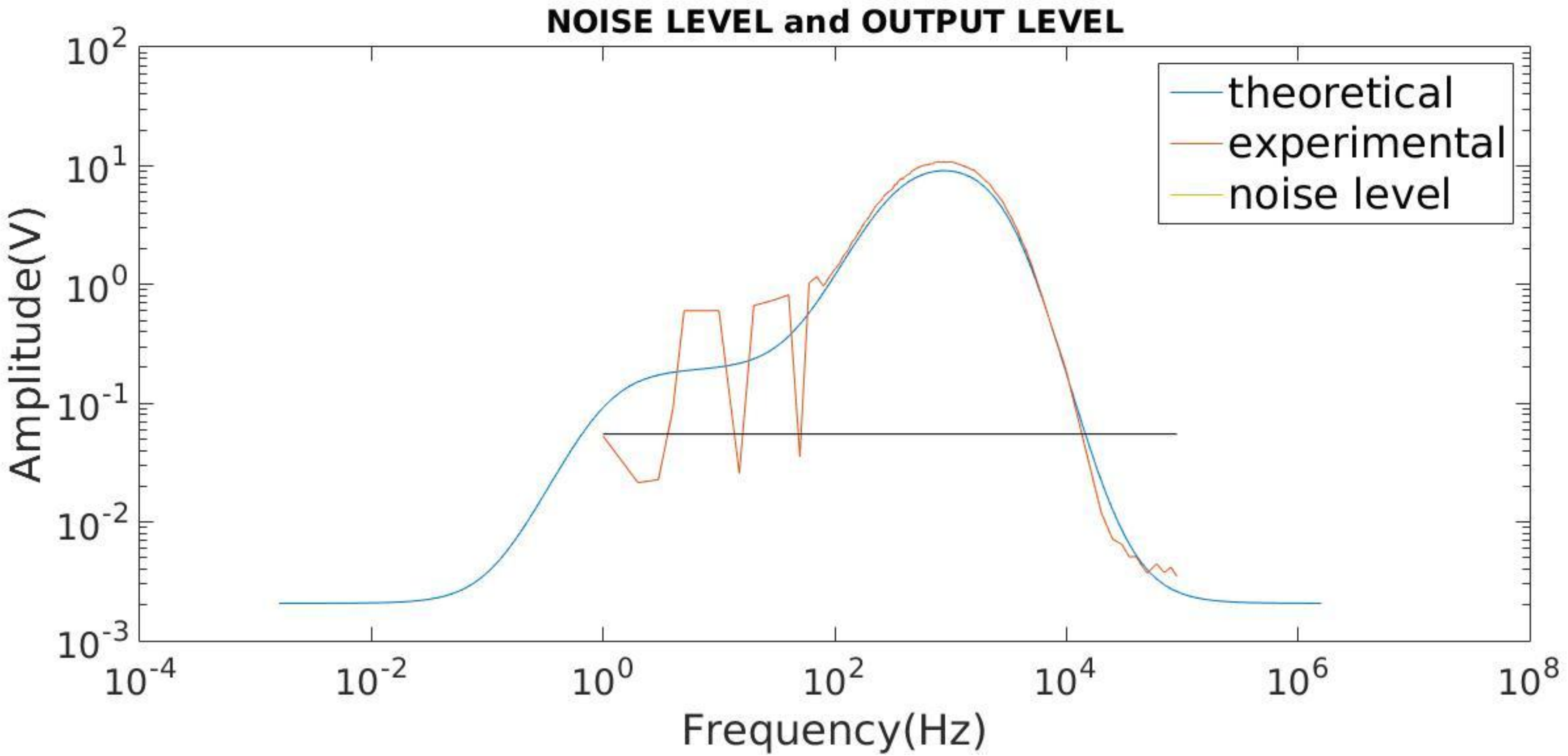
Automated testing low pass side :Results

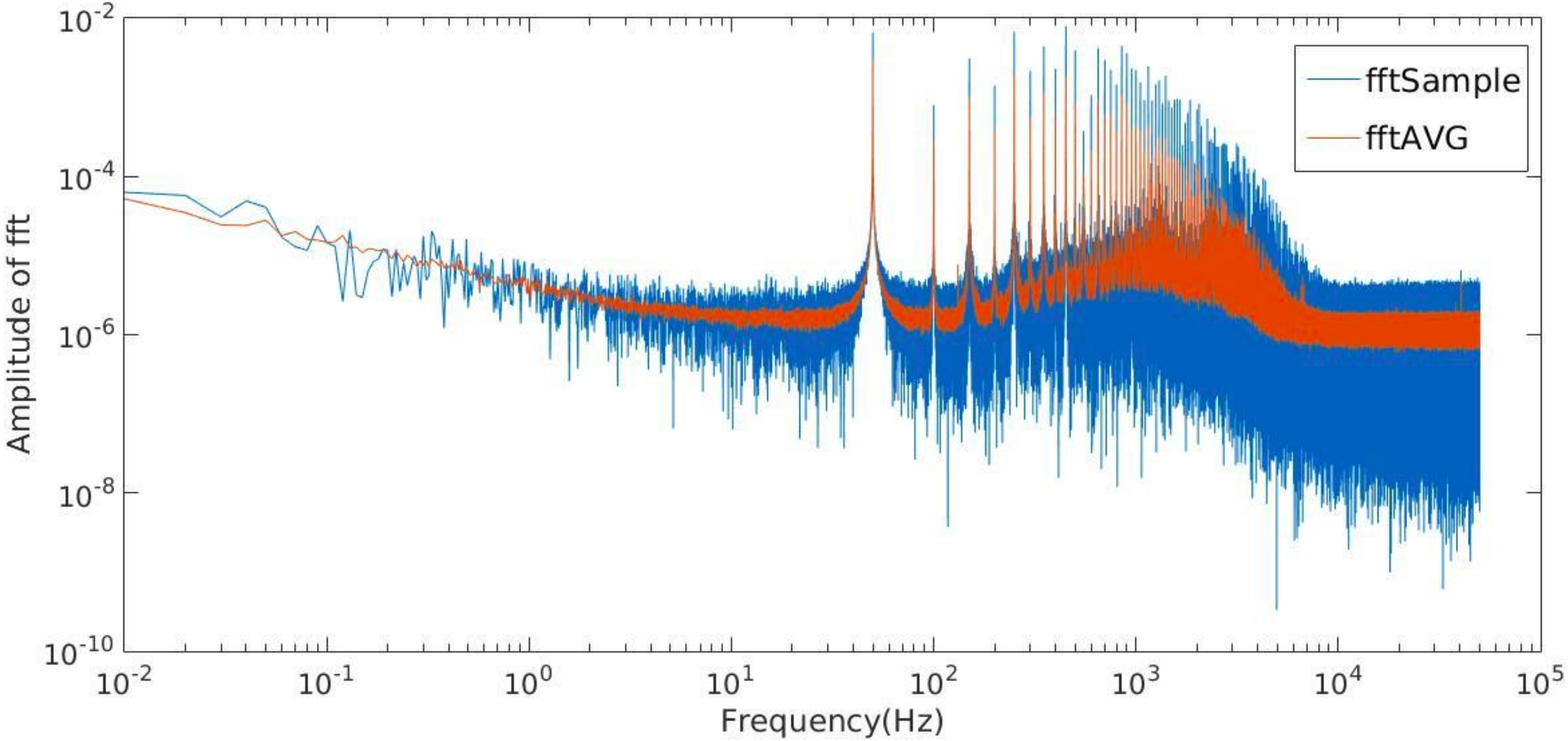


Next steps:

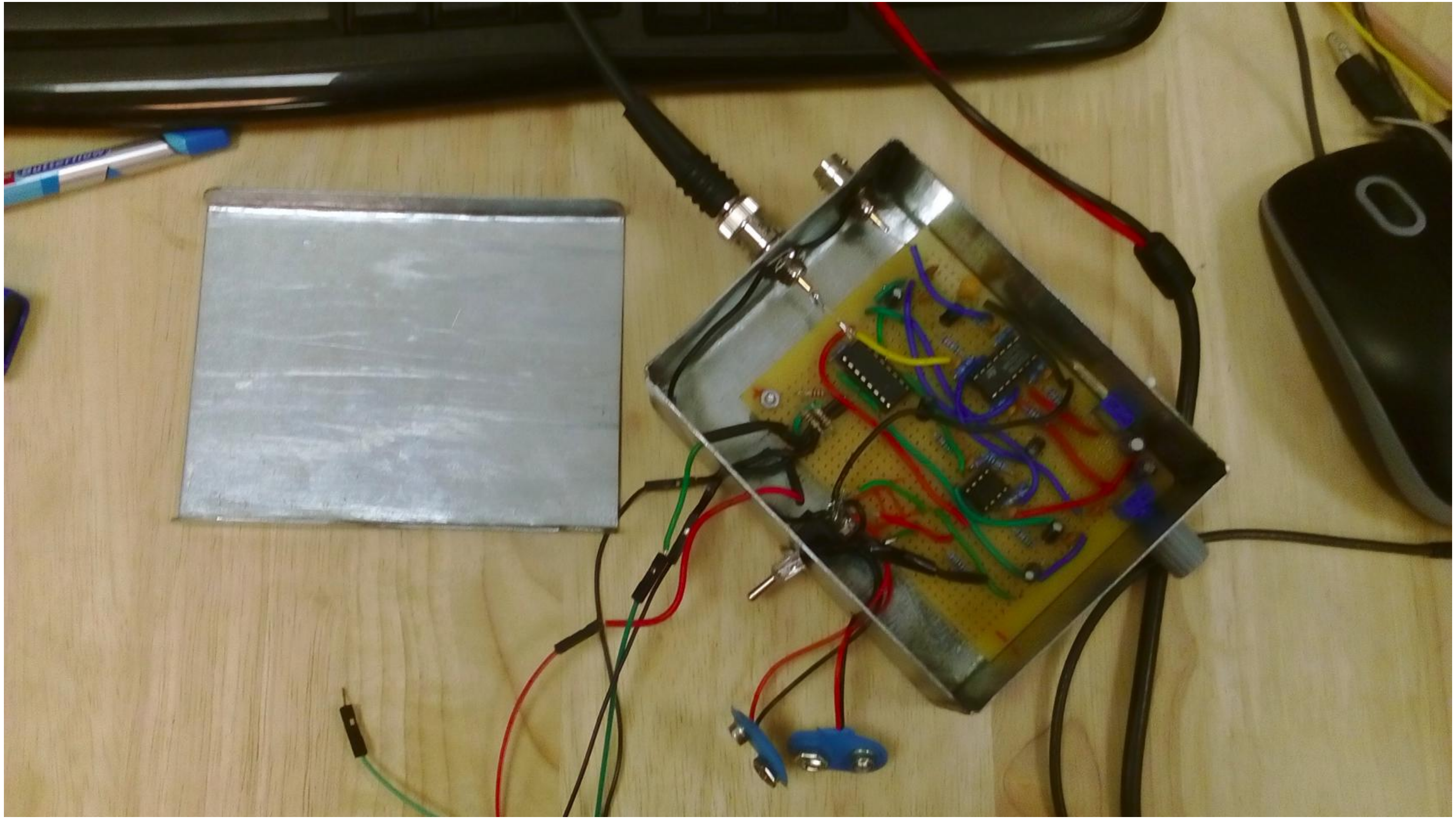
- Code optimization, to reduce time and increase accuracy.
- Noise characteristics of the system:Using signal processing techniques like FFT(Fast fourier transform)

Noise level and output signals




fftSample
fftAVG
Amplitude of fft
Frequency(Hz)
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}

Casing with all the connections for electrode inputs and output pins,switches



Using it to measure EMG

Summary

- The amplifier was tested successfully ,assuring that the schematic can be taken further.
- The testing procedure was automated, reducing the efforts and time taken, and can be used for testing any amplifier with slight modifications in code.
- Noise analysis of the amplifier and acquisition system was done.
- The final prototype to be used was developed and tested successfully on human subject.

Future work

- Final prototype as a model to design new PCBs

- Teaching Neurophysiology to Undergraduate students and experiments in lab.

- Making the whole acquisition, digitization and display system, to be used for Clinical applications: Measuring EEG, EMG for measuring brain and muscle function respectively, lowering the cost to 1/10th(20-30k) of currently available systems(2-5 lakhs).

Acknowledgements

My sincere thanks to my mentor Dr.Manish Arora, for the consistent guidance, support, patience and providing lot of technical knowledge throughout the project.

I'd like to thank Dr. Mahesh Jayachandra for indirectly guiding me on the application aspects of the bio amplifier and sharing his work experiences in neurophysiology.

Also, thanks to Nitin, Research Assistant , under Dr.Mahesh.

I'd also like to thank Hemang from CPDM lab for helping out when needed.

Finally I'd like to thank the open source community, helping me at every step in the way.


THANK YOU
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