Conception of 2nd-Order MAX274 Filter

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I- Description

The MAX274 and MAX275 are continuous-time active filters consisting of independent cascadable 2nd-order sections. Each section can implement any all-pole bandpass or lowpass filter response, such as Butterworth, Bessel, Chebyshev, and is programmed by four external resistors. The MAX274/MAX275 provide lower noise that switched-capacitor filters, as well as superior dynamic performance—both due to the continuous-time design. Since continuous-time filters do not require a clock, aliased and clock noise are eliminated with the MAX274/MAX275.

The MAX274 comprises of four 2nd-order sections, permitting 8th-order filters to be realized. Center frequencies range up to 150kHZ, and are accurate to within ±1% over the full operating temperature range. Total harmonic distortion (THD) is typically better than -86dB.

The filter operates from a single +5V supply or from dual ±5V supplies.

II- Key Features

- Continuous-TIme Filter - No Clock, No Clock Noise
- Implement Butterworth, Chebyshev, Bessel and Other Filter Responses
- Lowpass, Bandpass Outputs
- Operate from a Single +5V Supply or Dual ±5V Supplies
- Design Software Available
- MAX274 Evaluation Kit Available
- 8th-Order-Four 2nd-Order Sections (MAX274)
- 4th-Order-Two 2nd-Order Sections (MAX275)
- Center-Frequency Range :

1. *150kHz for MAX274*
2. *300kHz for MAX275*

- Low Noise :

1. *-86dB THD Typical for MAX274*
2. *-89dB THD Typical for MAX275*

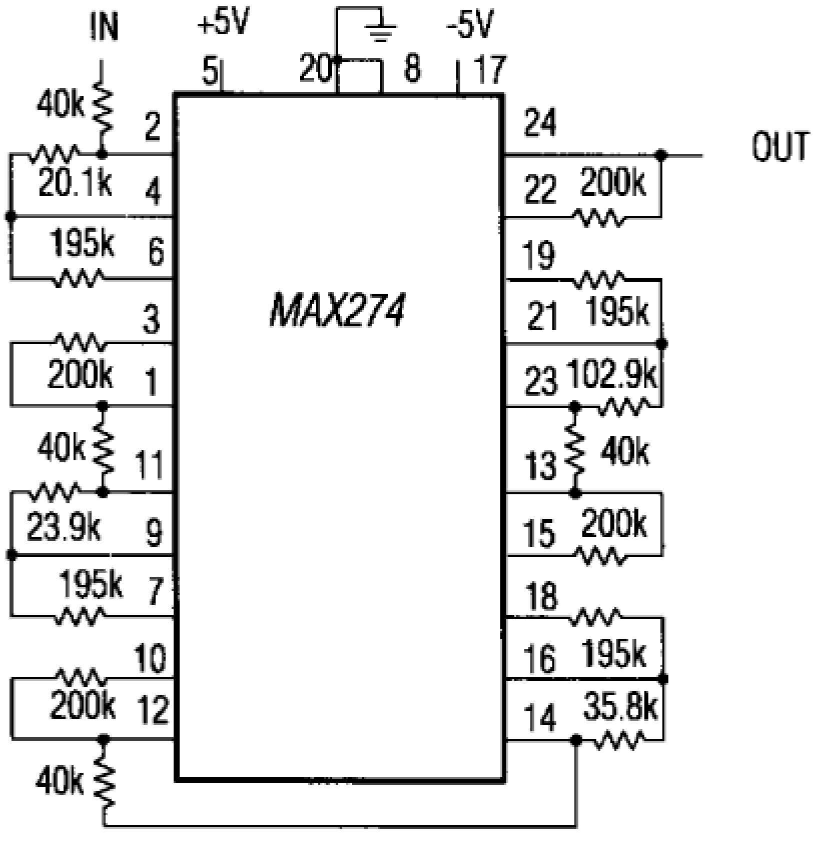
- Center-Frequency Accurate Over Temp :

1. *within ±1% for MAX274*

2. *within ±0.9% for MAX275*

III- Applications/Uses

- Audio/Sonar/Avionics Frequency Filtering
- DAC Output-Smoothing Filters
- Low-Distortion Anti-Aliasing Filters
- Modems
- Vibration Analysis

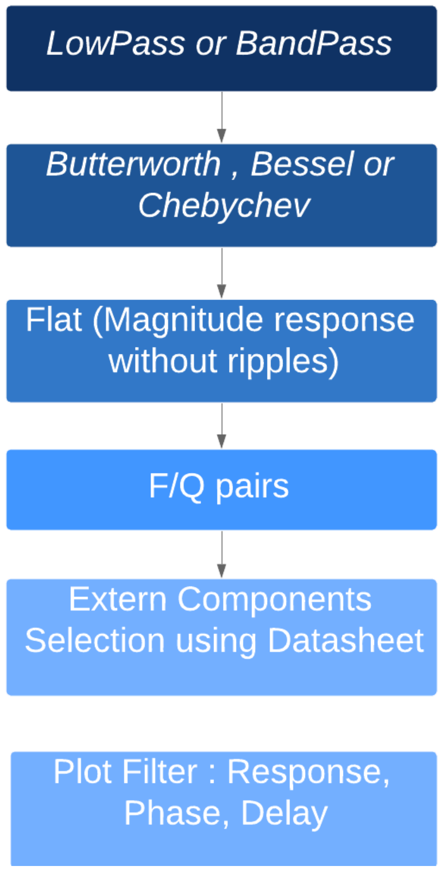


10kHz 8TH-ORDER BUTTERWORTH LOWPASS FILTER

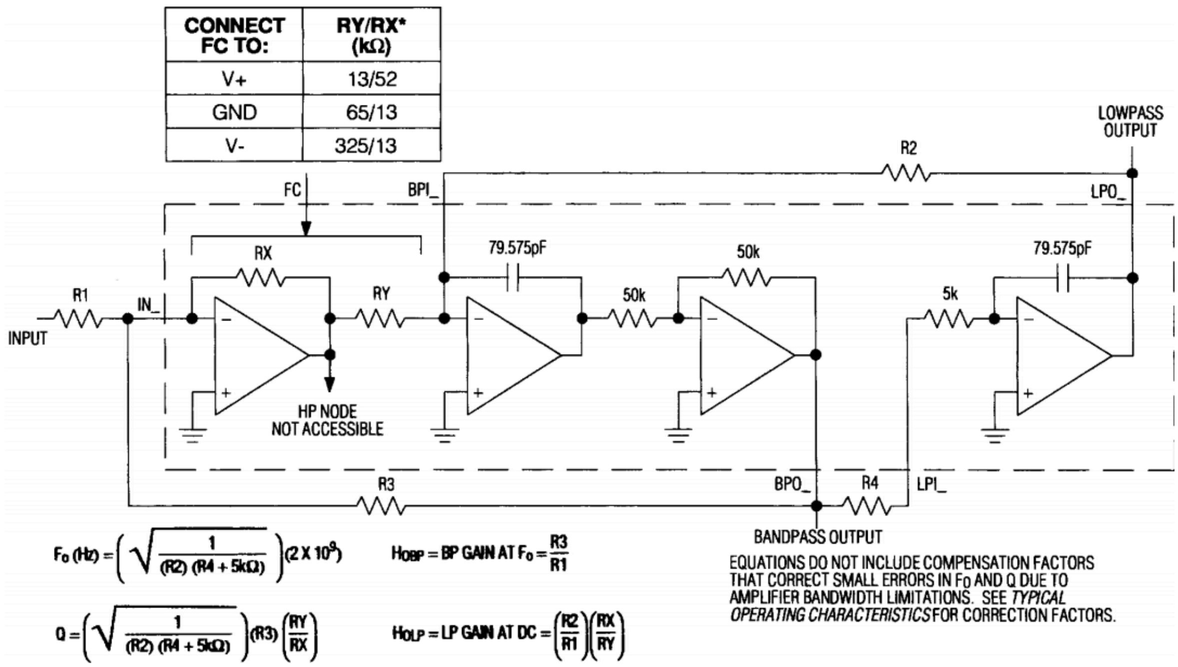
PIN NUMBERS ARE FOR DIP.

IV- 6 steps to build a best 8th order filter

6 Steps for building a fit 8th Order Filter



IV- 1- 2nd-Order Filter Schematic



The figure above shows a 2nd-Order Filter with one input and *(LowPass , BandPass)* outputs.

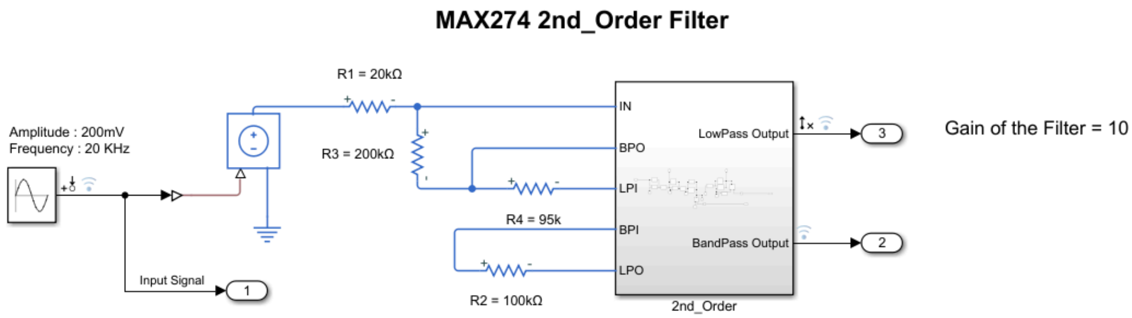
The R1, R2, R3, R4 and Fc variables are responsible of how the filter's outputs look like.

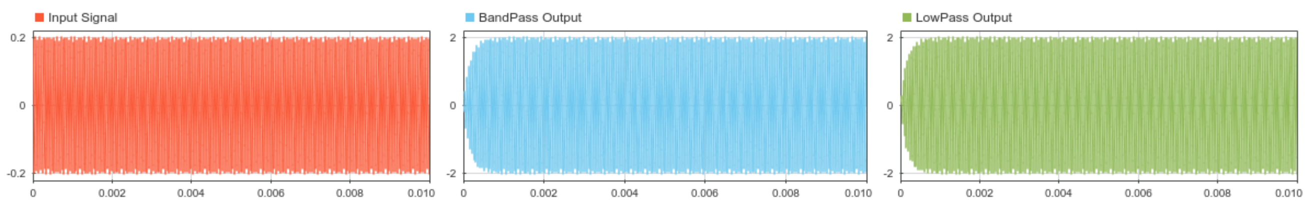
Objective :

Our objective is to build either Lowpass or Bandpass filter with $F_0 = 20Khz$ as *Center Frequency* with a maximum Energy in this desire $Passband = [18 \text{ Khz}, 22\text{Khz}]$.

So, to achieve this goal we should choose the best fit values of the parameters, and if we want to build a high order filter based on 2nd-Order filter we just need to cascade.

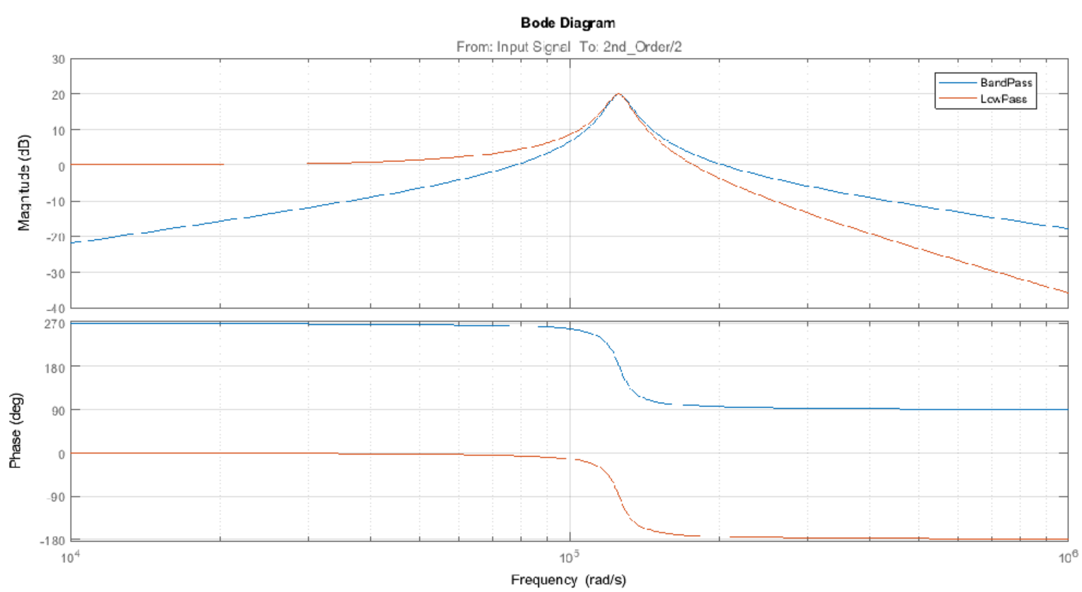
V- MAX274 2nd-Order Simulink Model



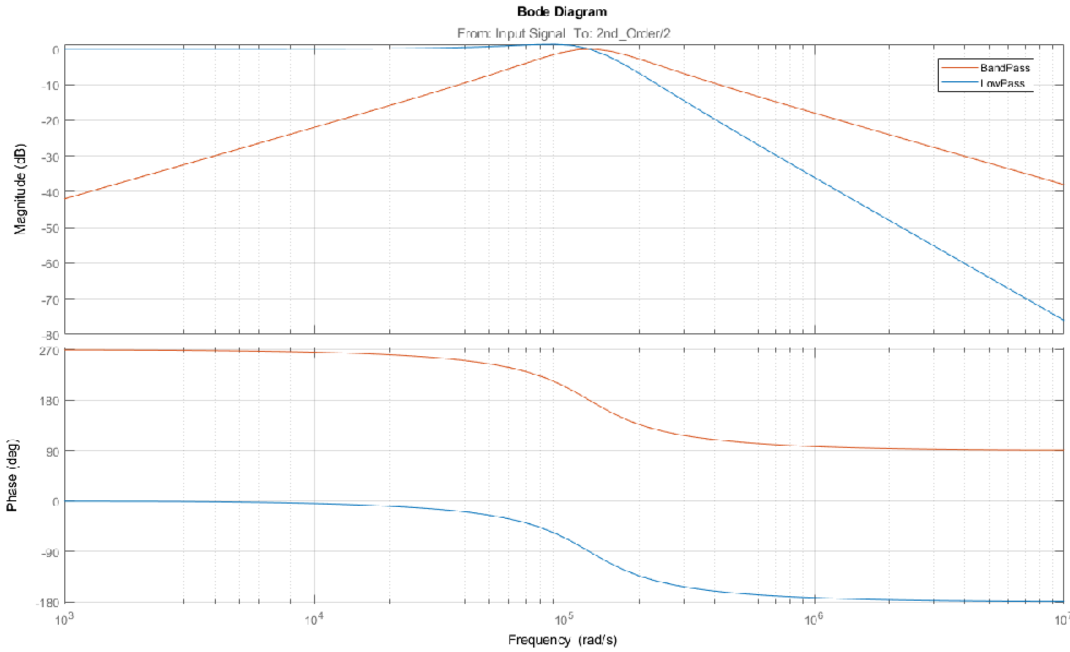


VI- Bode Diagrams

Bode Diagram with a $Gain = 10$, $Gain_{db} = 20\,dB$



Bode Diagram with a $Gain = 1$, $Gain_{db} = 0\,dB$



VII- Gain vs input voltage vs output voltage

First of all our filter's output is 5V thus we can not exceed this value or we shall have saturation at the amplitude of the signal. We established a relation between the three parameters above :

$$\text{Gain} = \frac{\text{Output Voltage}}{\text{Input Voltage}}$$

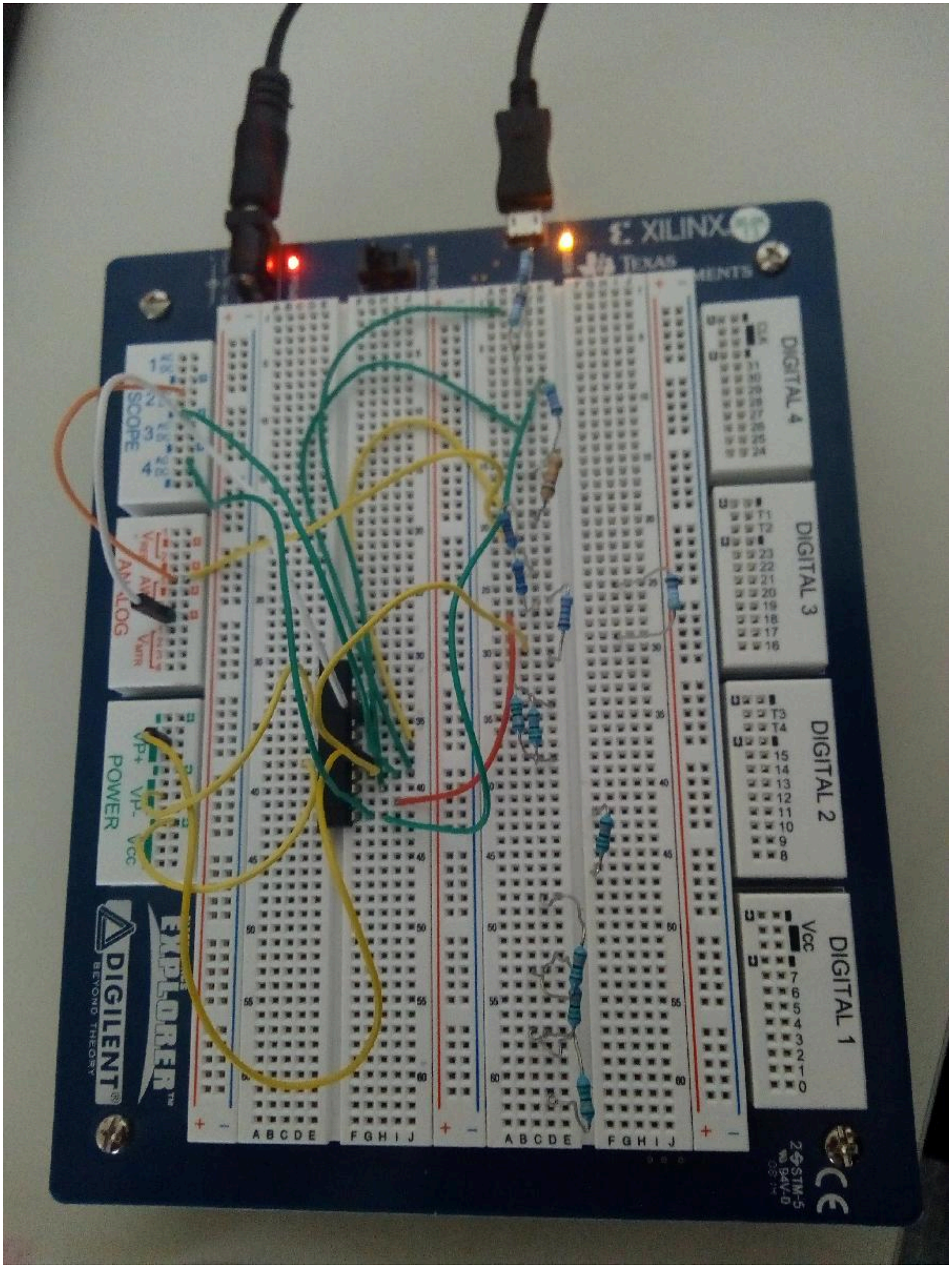
Example :

$inputSignal = 0.2\sin(2.\pi.20.10^3.t)$ so to calculate the maimum Gain we apply the previous equation :

$$Gain = \frac{5}{0.2} = 25$$

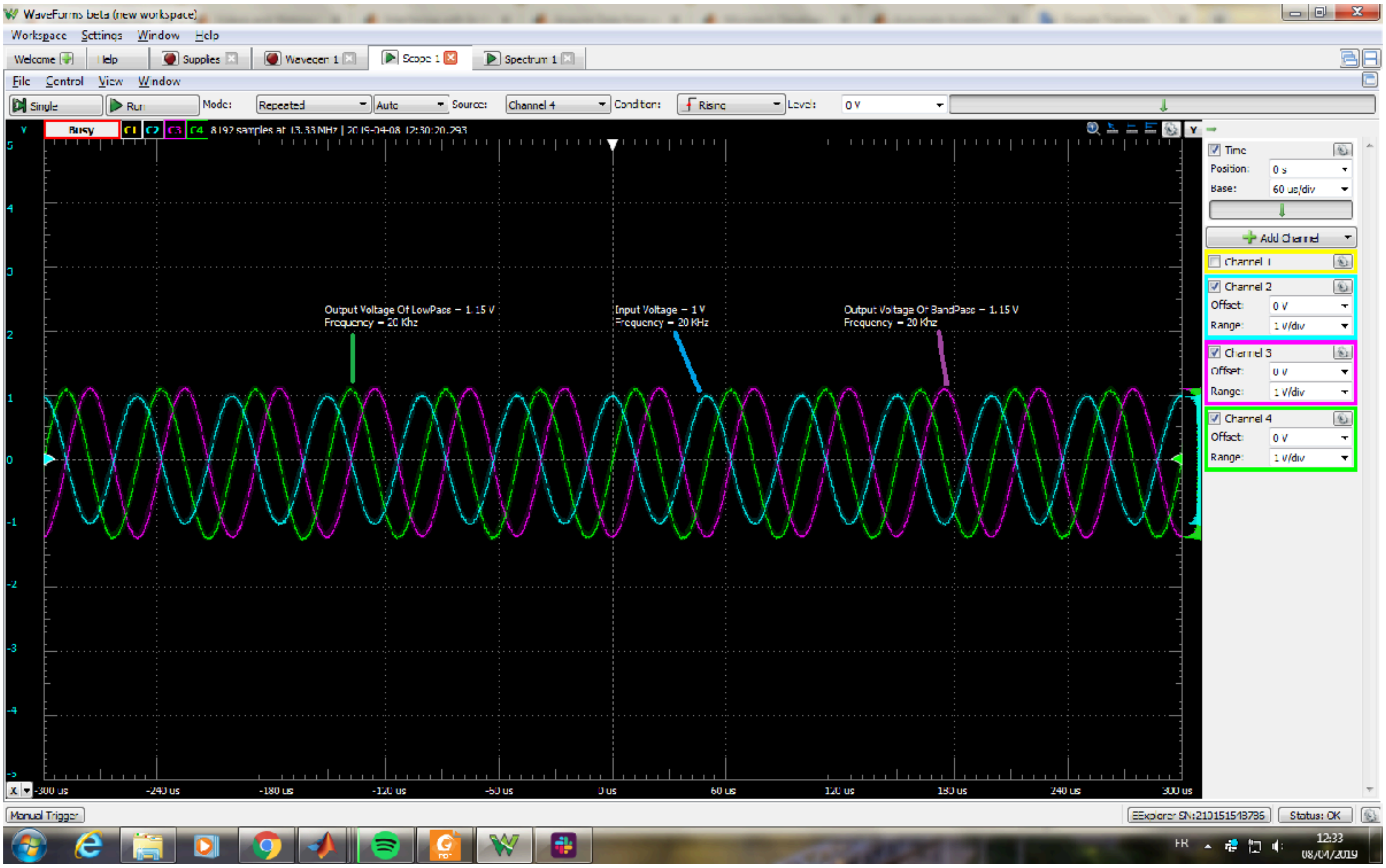
So, at $20.10^3\,Hz$ we obtain a maximum $\text{Gain}_{\text{db}} = 20.\ log_{10}(25)\ \text{dB}$.

VIII- Preparing the prototype into Electronic Explorer board

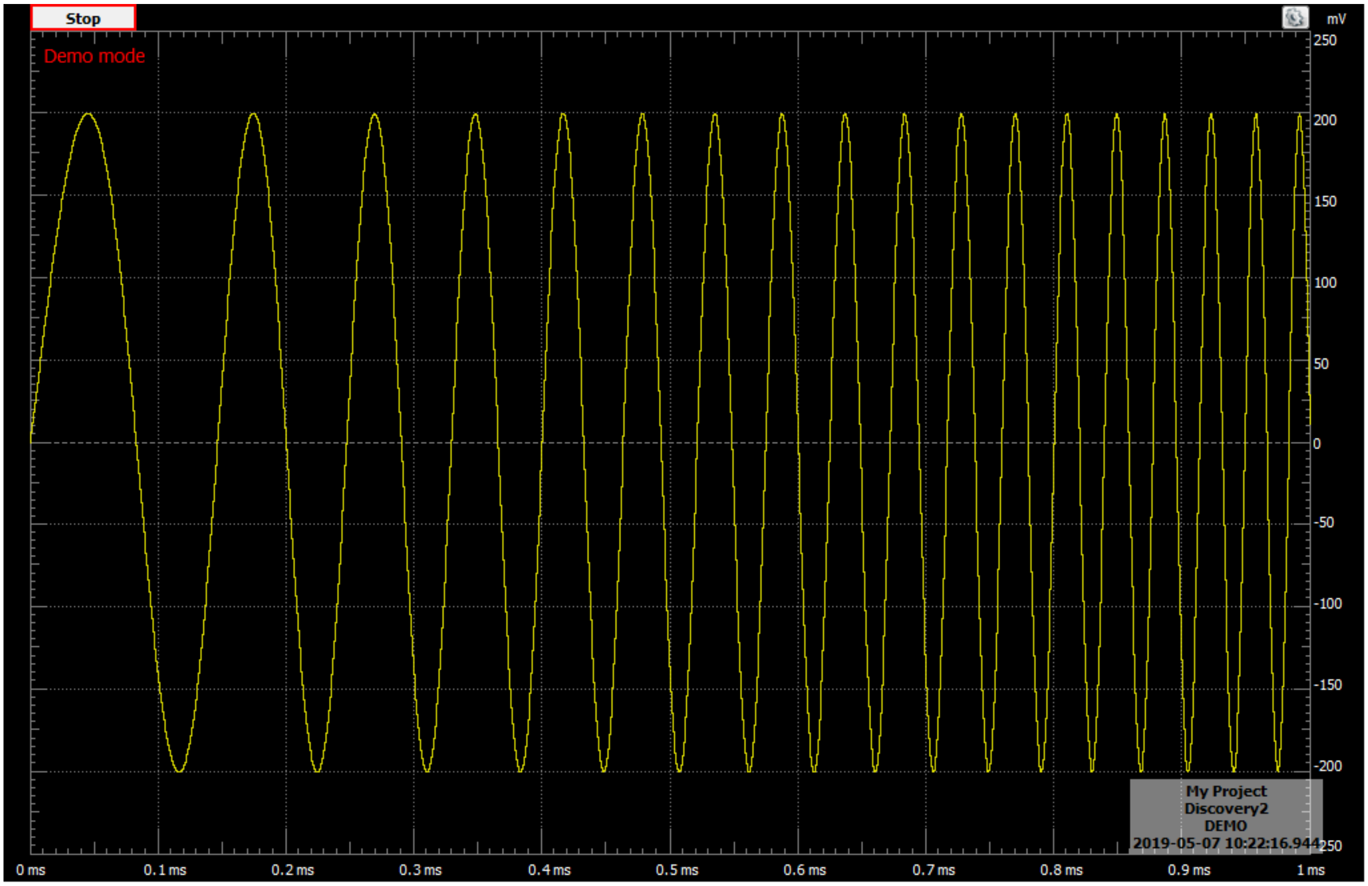


IX- Test into waveforms

1. $Input\ Voltage = 1V$ and $Gain = 1$:

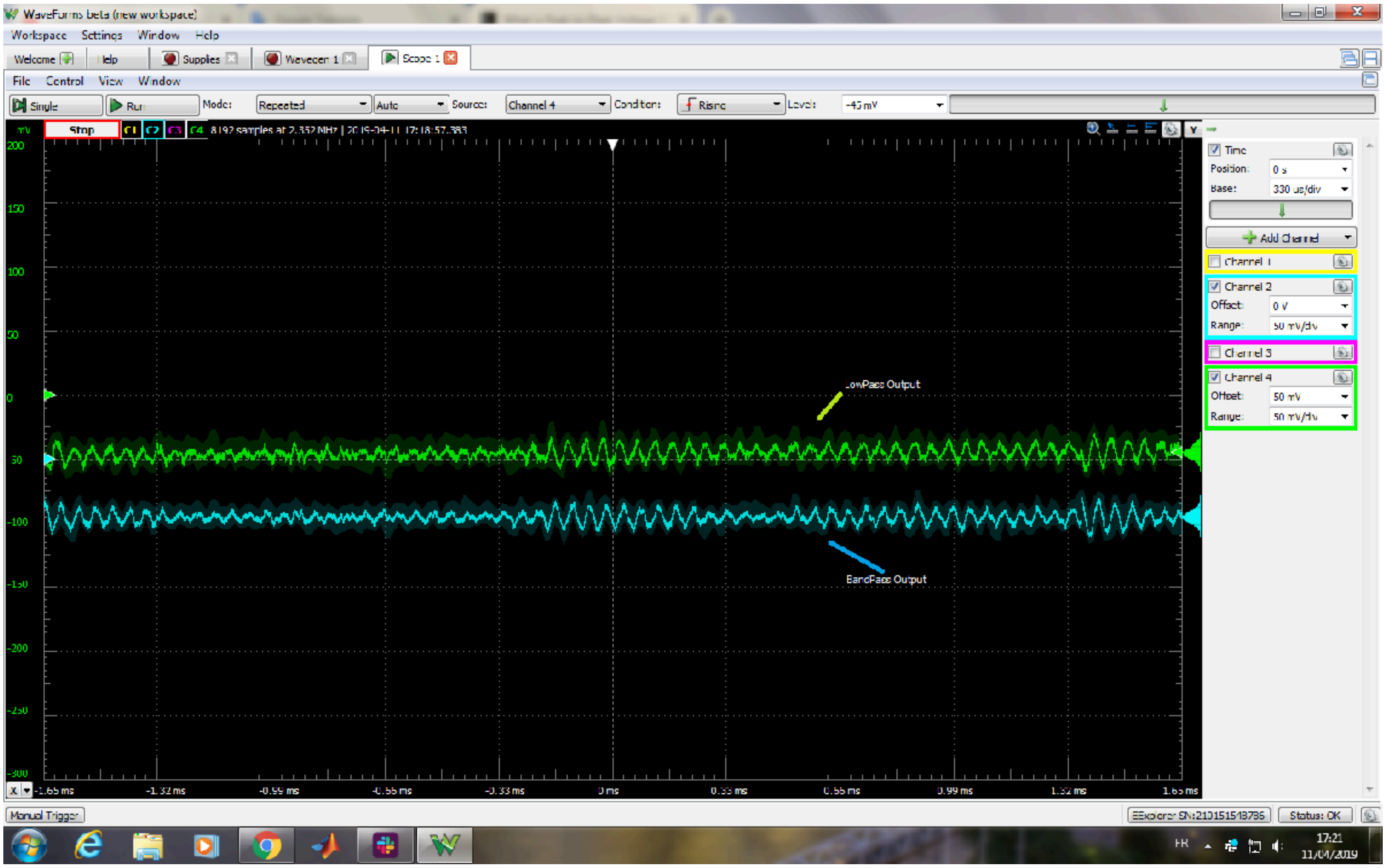


2. We attacked our filter with a $sweep\ wave$ with $FrequencyRange = [5Khz, 30Khz]$ with an amplitude of $1mV$ and $Gain = 10$:

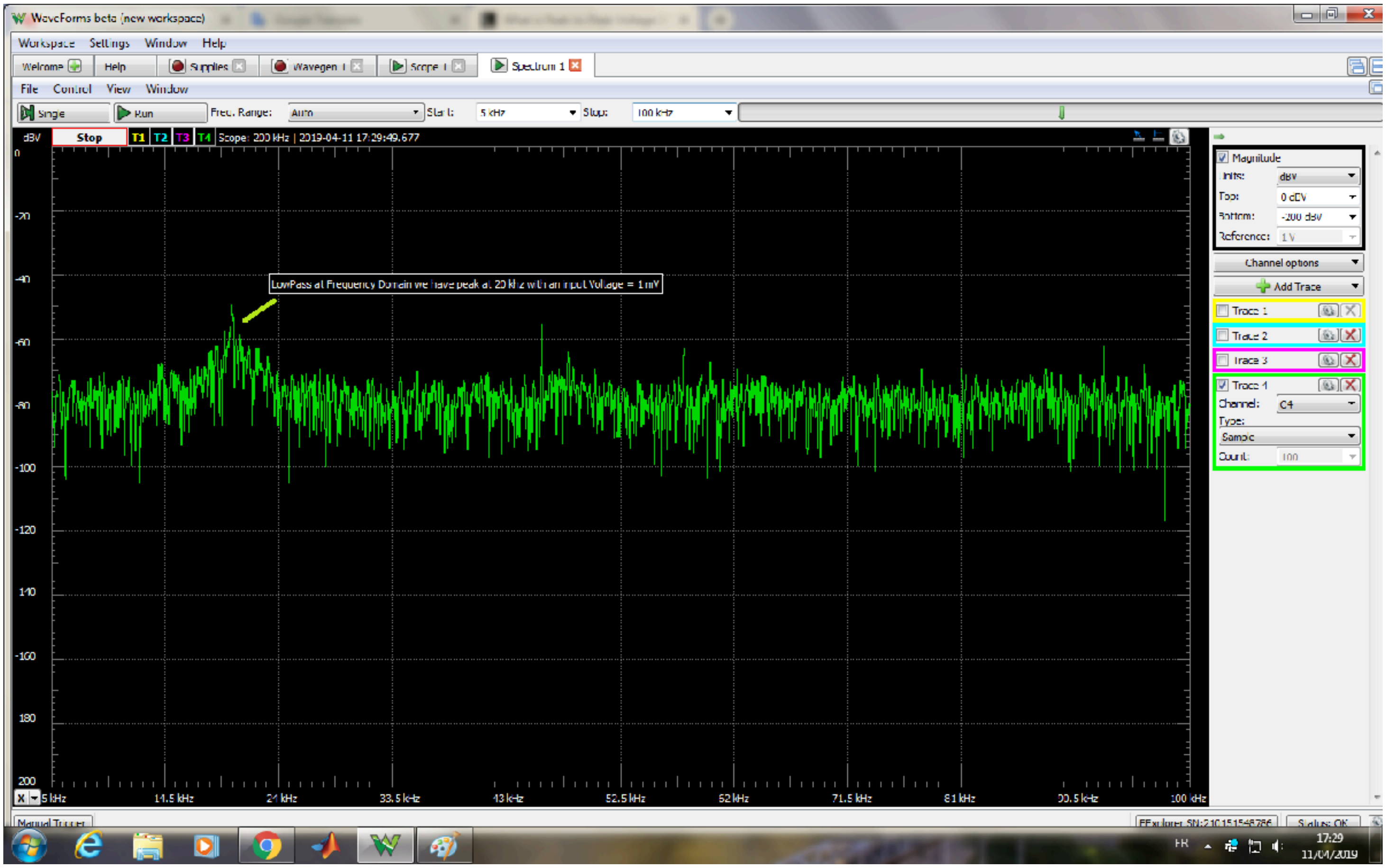


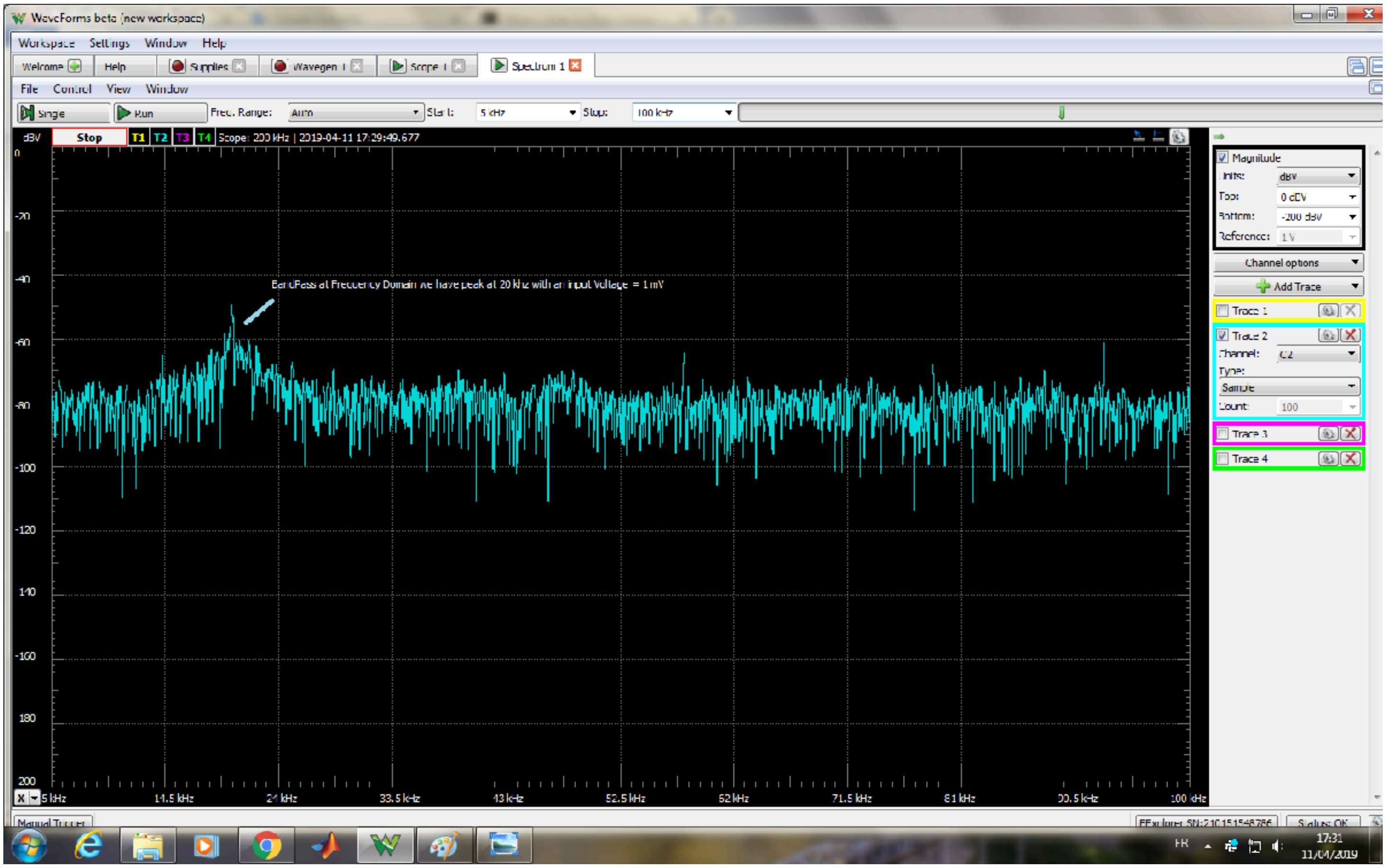
$GreenColor : LowPassResponse.$

$BlueColor : BandPassResponse.$



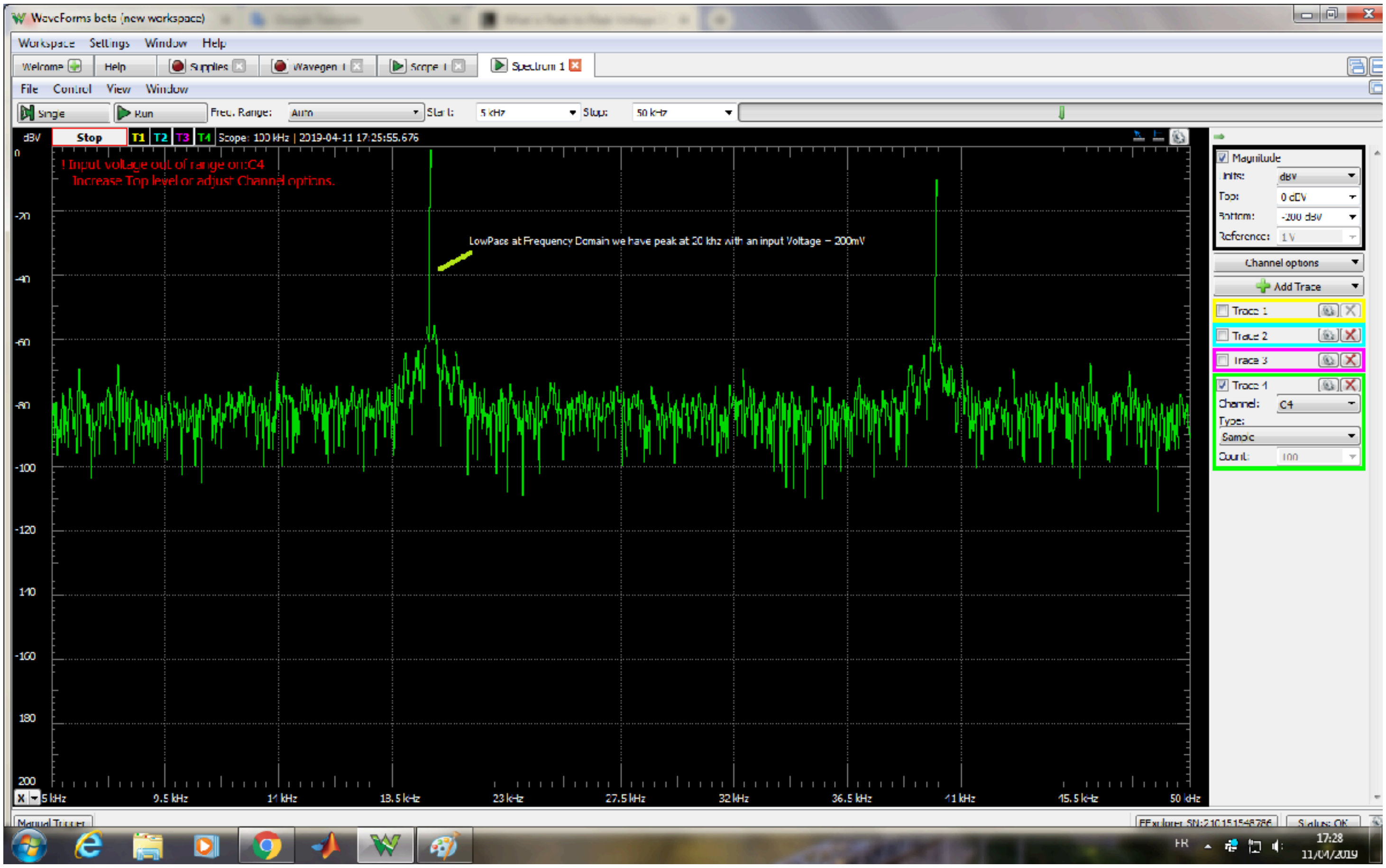
3. Fourier Transform of LowPass and BandPass outputs with $inputVoltage = 1mV$ and $Gain = 10$:

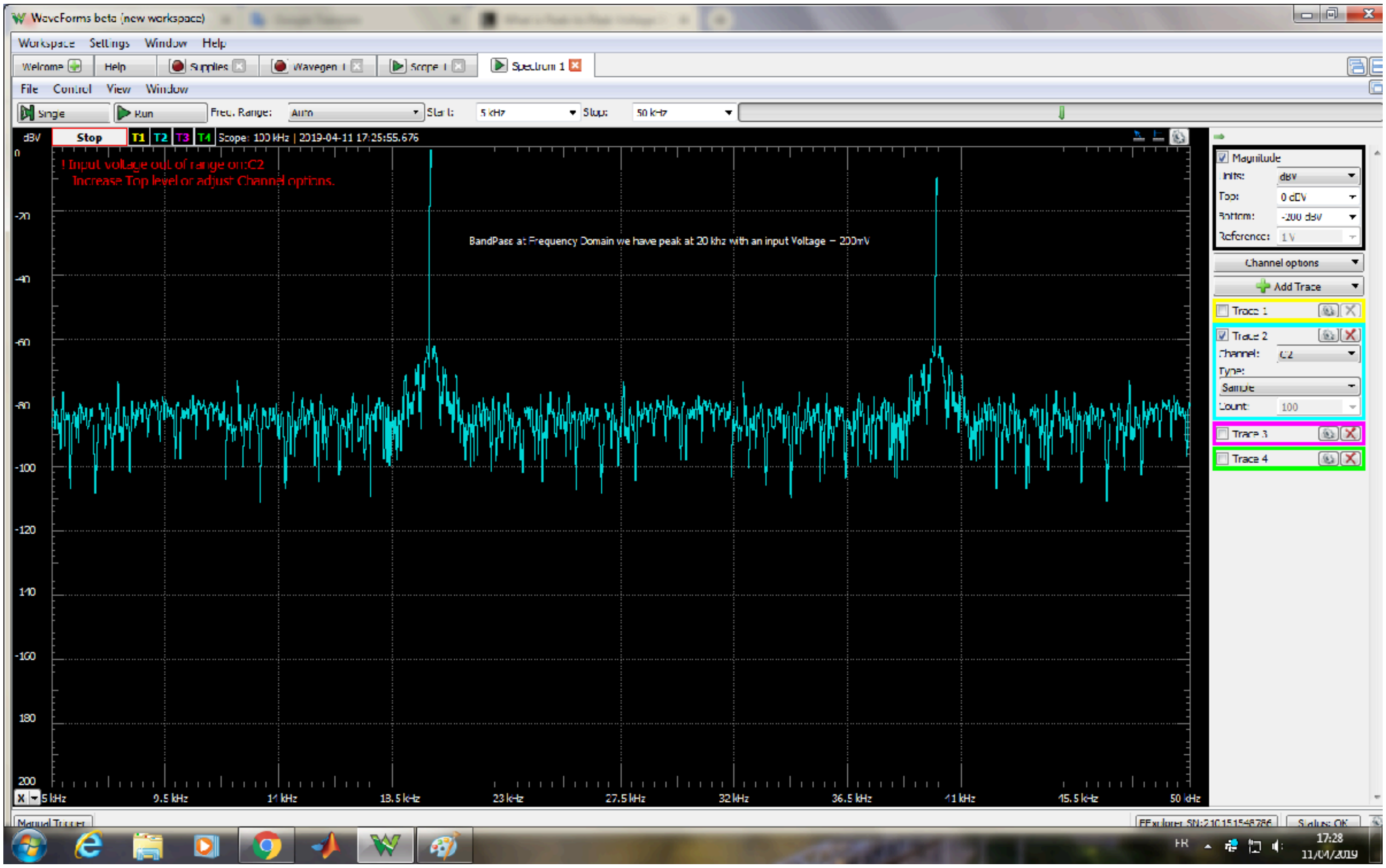

LowPass at Frequency Domain we have peak at 20 kHz with an input Voltage = 1 mV



4. Fourier Transform of an $inputVoltage = 200mV$ and $Gain = 1$.

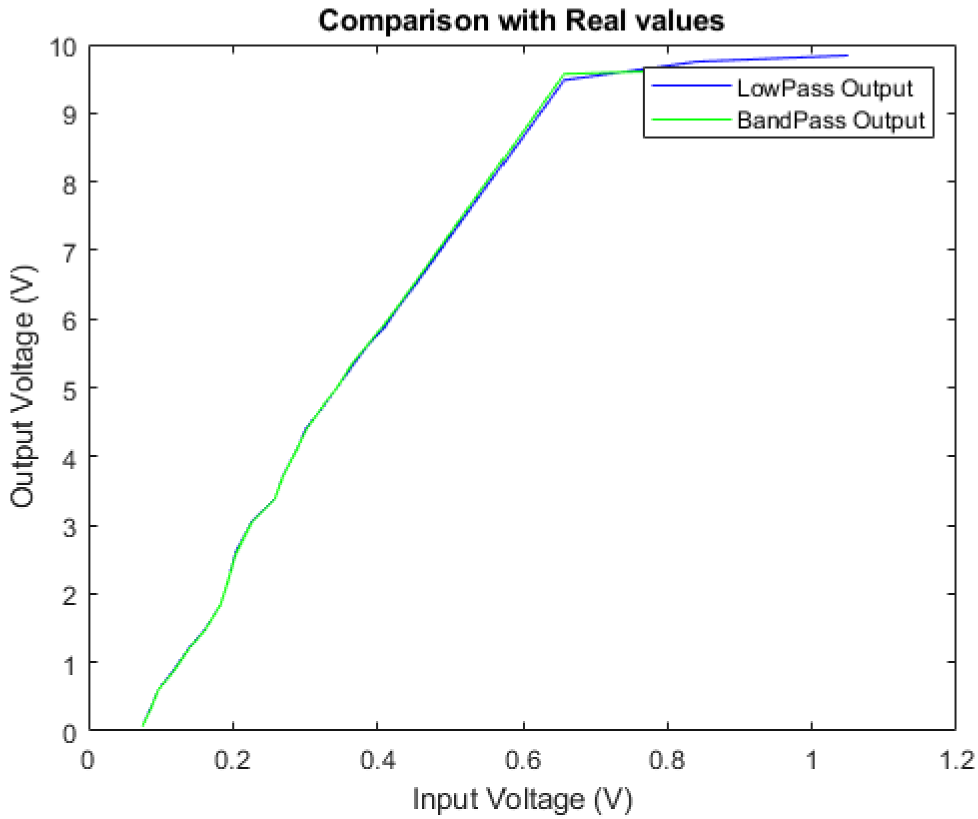
We obtain the same result as Bode diagram in Simulink, at $20Khz$ we have the $\mathrm{Gain}_{\mathrm{db}} = 0$:

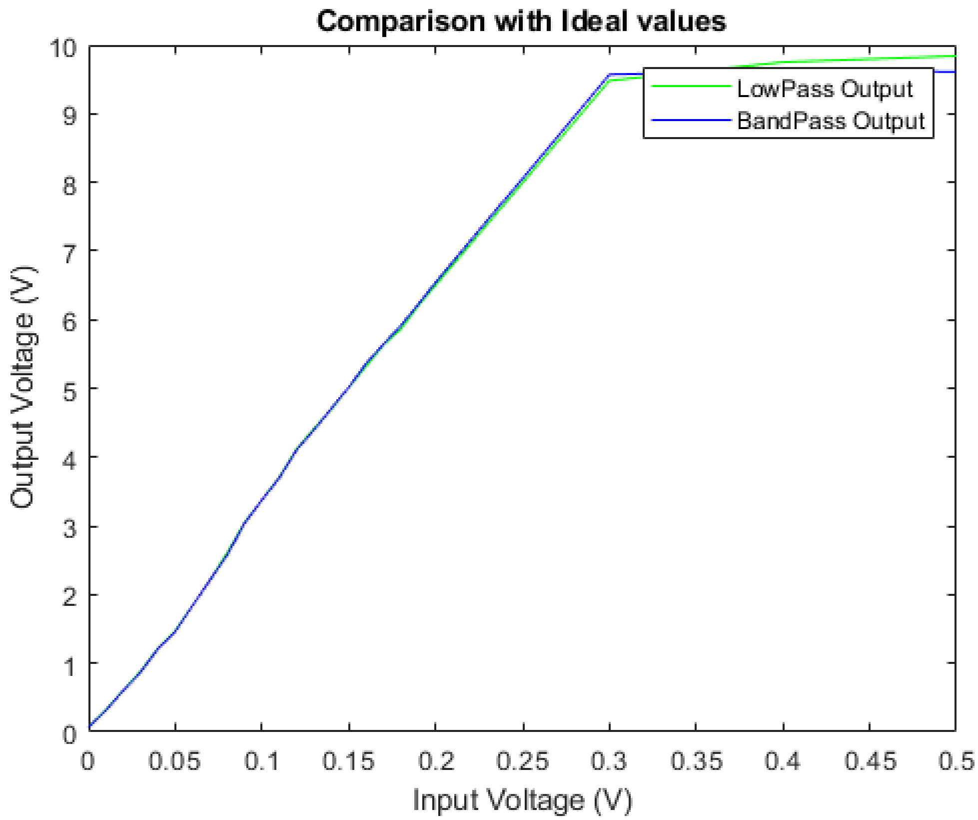

WaveForms beta (new workspace)
Input voltage out of range on:C4
Increase Top level or adjust Channel options.
LowPass at Frequency Domain we have peak at 20 khz with an input Voltage = 200mV
Scope: 100 kHz | 2019-04-11 17:25:55.676
Magnitude
Channel options
Add Trace
Trace 1
Trace 2
Trace 3
Trace 4



X- Dynamic and static outputs

1. Studying static output :

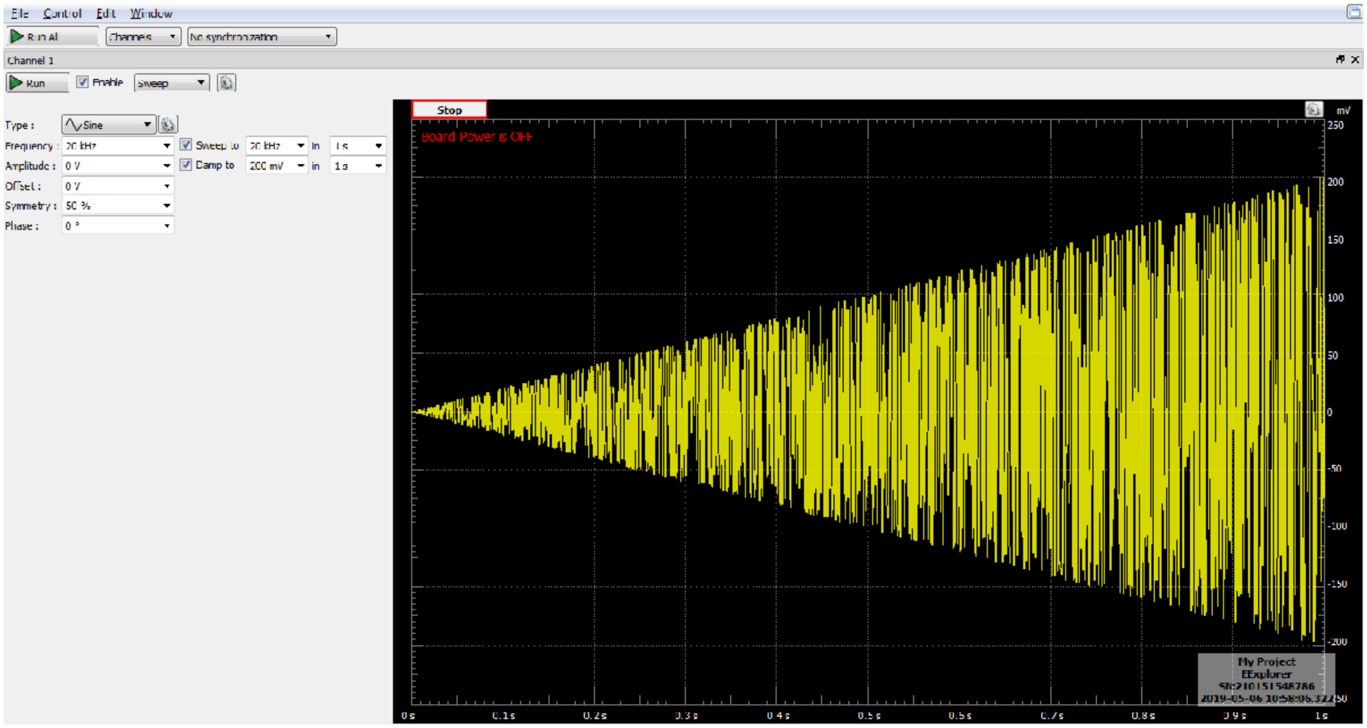




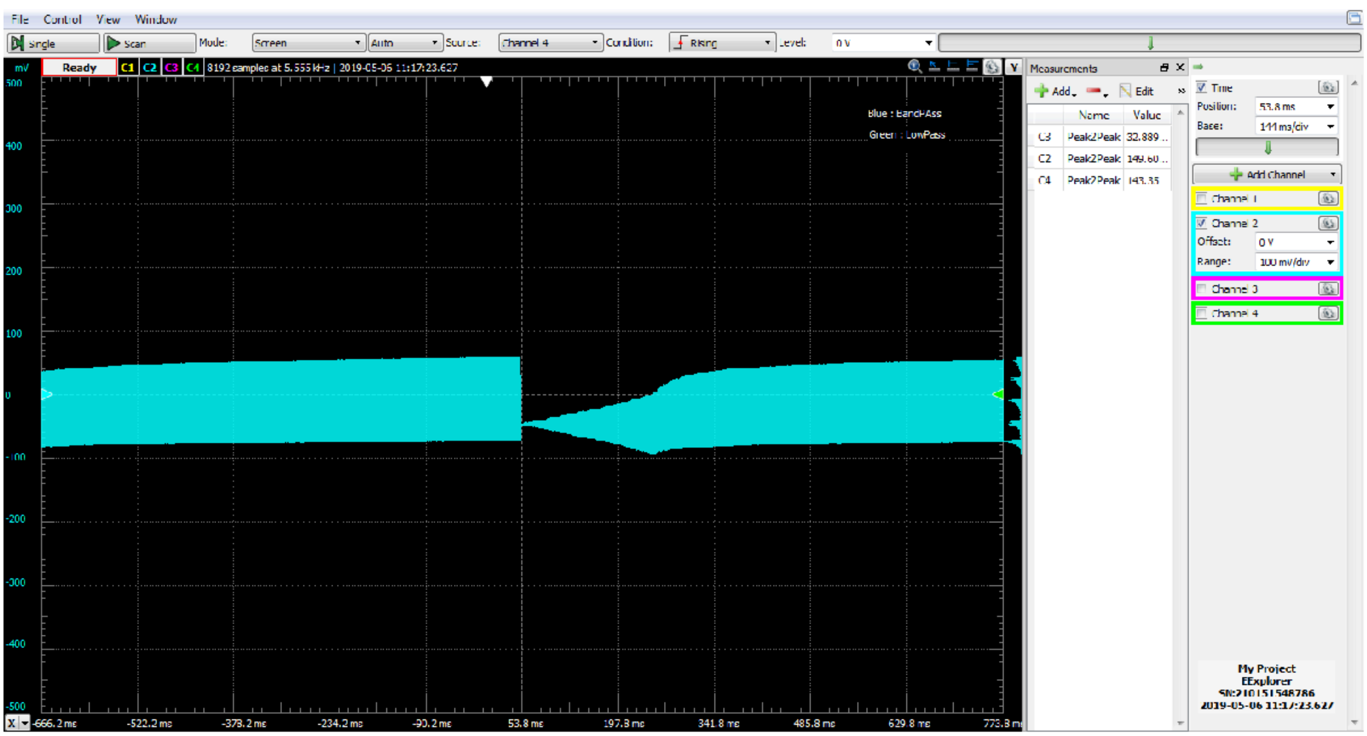
Although we have chosen the $Gain = 10$ we see that the signal doesn't amplified by 10, thus it relies on input voltage. So, after a certain value of input voltage the instability of the Gain faded away.

2. Studying dynamic output :

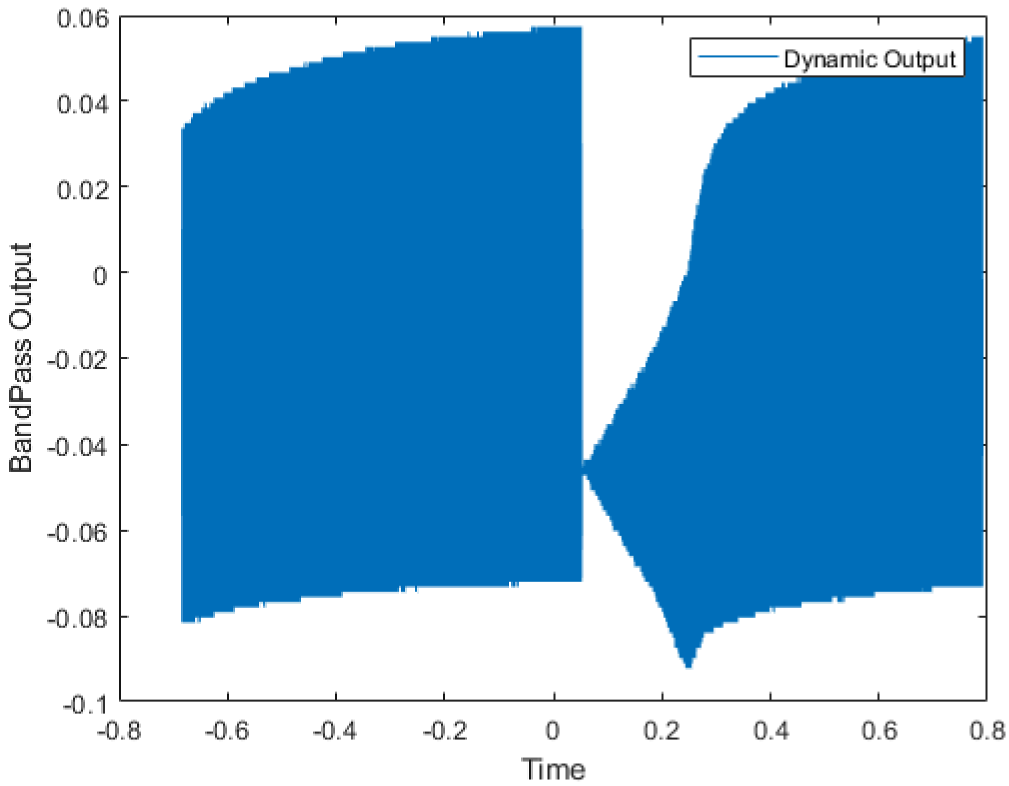
We attacked our filter by a sweep of amplitude $[0\ ,\ 200\text{mV}]$ and we fixed the frequency at $20KHz$ for $1s$.



BandPass Output over waveforms :



BandPass Output over MATLAB :



XI- Pros and Cons

1. Pros :

- Gain can vary from 1 to 200 in 2nd-Order filter.
- The gain shall multiply by 4 if we want to implement the 8th-order filter.
- If we implement the 8th-order filter its Passband shall be flexible.
- If we implement the 8th order filter, the magnitude shall be dropped(declined) by 80 dB / decade.

2. Cons :

- Response time of the output increases by increasing the Gain.

XI- References

- MAX274 Datasheet
- https://www.maximintegrated.com/en/datasheet/index.mvp/id/1452
- Butterworth Filter over MATLAB
- Electronic Explorer Board

- EEBoard Getting Started
- WaveForms Analog Discovery