3TR4 Lab 1 Report

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Contents

Design and Simulation

Design

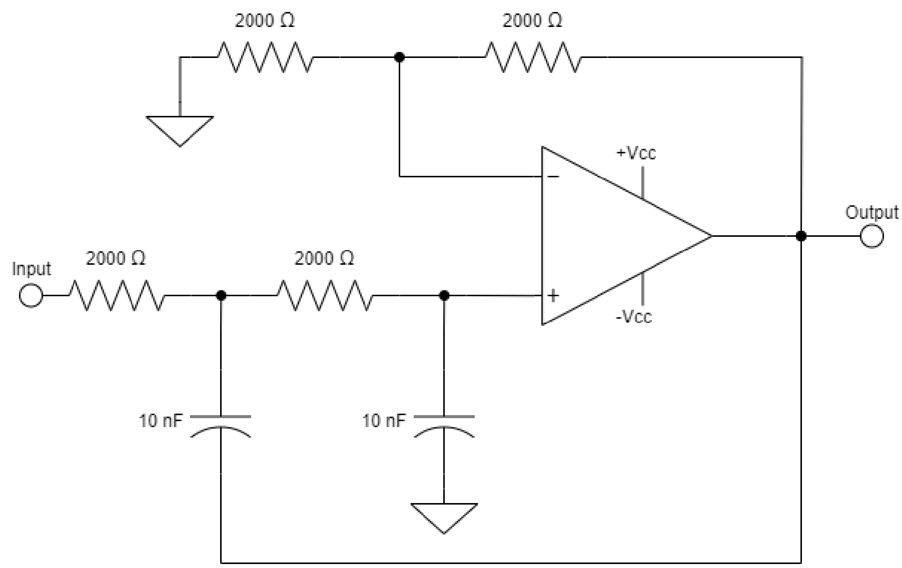


Figure 1. 2nd Order Active Low Pass Filter

A Butterworth filter design is presented here. It is a type of active low pass filter that provides a maximally flat frequency response in the passband. In practical designs, the cutoff frequency is defined by the -3dB point, which is where the magnitude of the filter response drops by 3dB (approximately 0.707 of the maximum response in the passband).

Cut-off Frequency

$$f_c = \frac{1}{RC \times 2\pi} = \frac{1}{2000 \times 10 \times 10^{-9} \times 2\pi} \approx 7957.74\ Hz$$

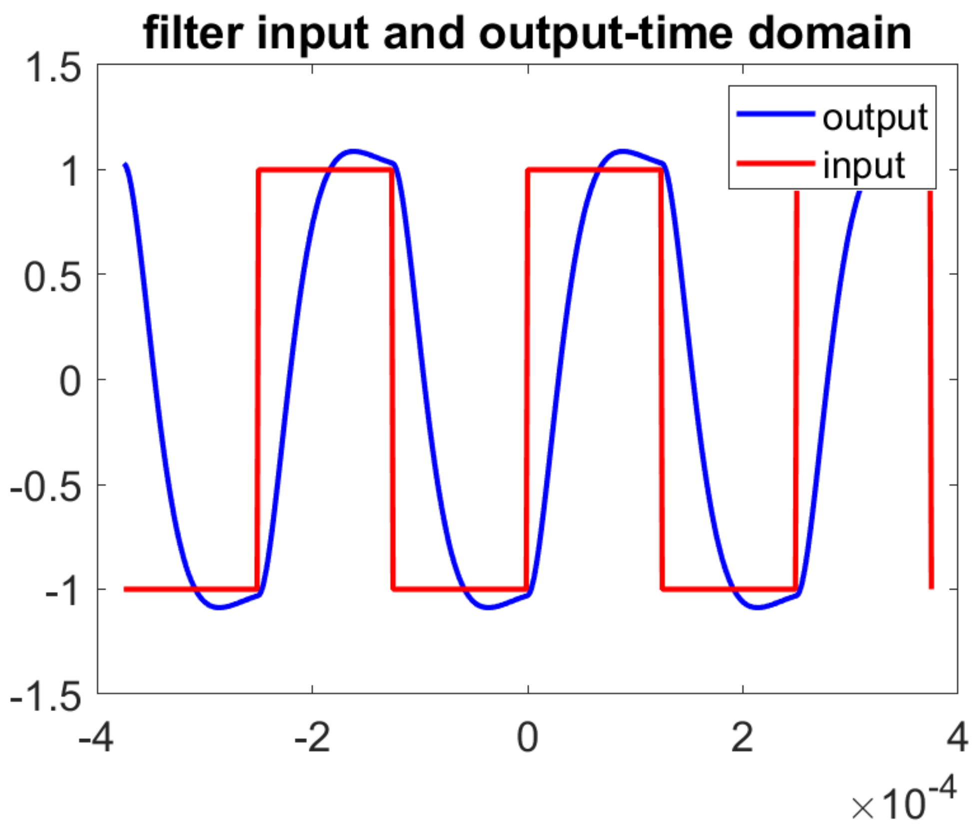
Gain

$$A = \frac{R_1 + R_1'}{R_1} = \frac{2000 + 2000}{2000} = 2$$

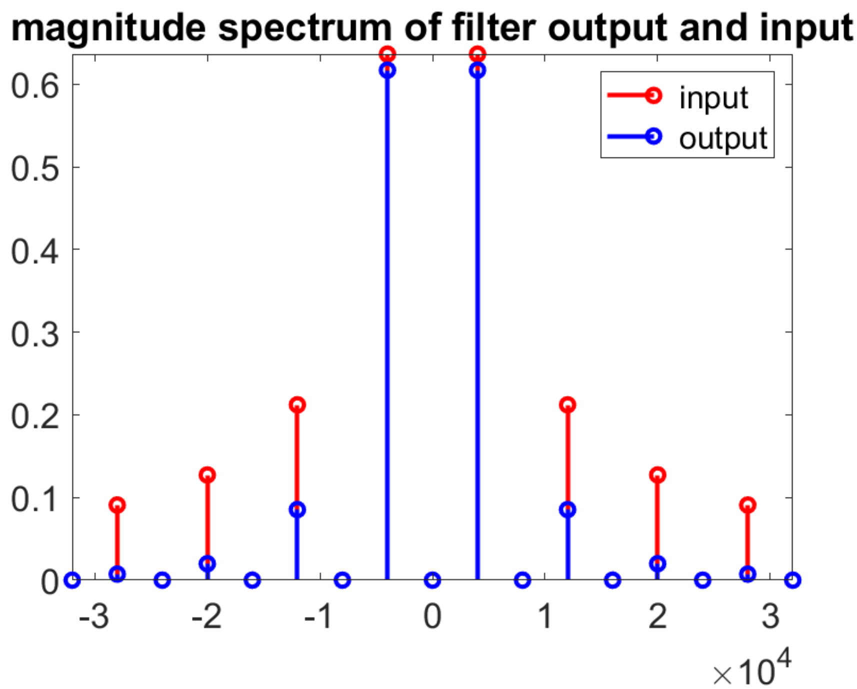
Simulation

3 frequencies are selected to test the active low pass filter. They are half of the cut off frequency, the cut off frequency itself, and twice the cut off frequency. Since the value of the cut off frequency in the current filter circuit is 8000 Hz, frequencies of 4000 Hz, 8000 Hz and 16000 Hz will be applied.

4000 Hz

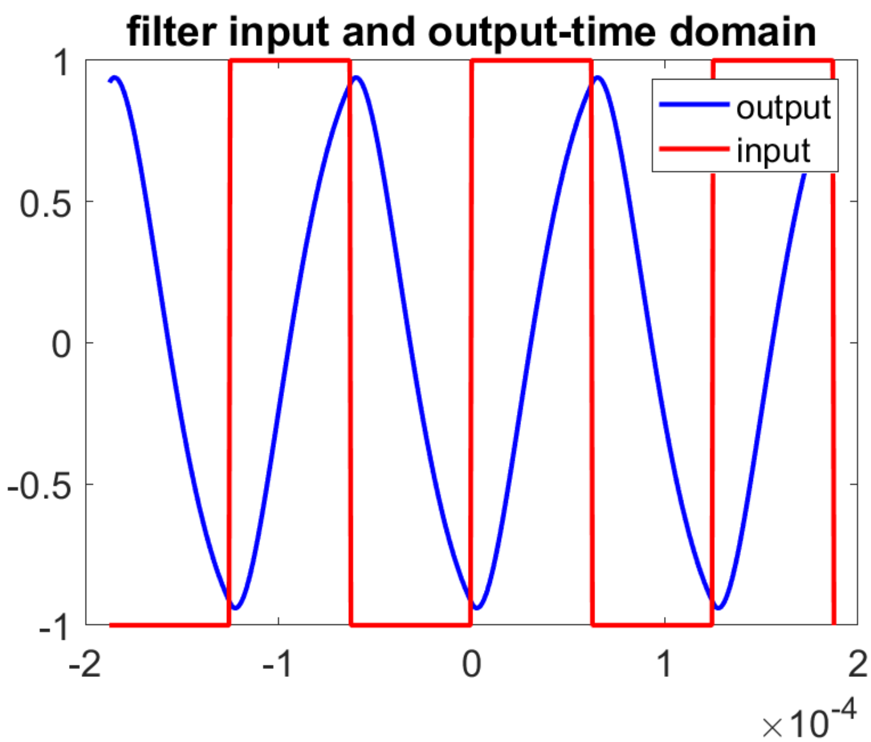


Waveform 1. Input and Output When f_{in} = 4000 Hz

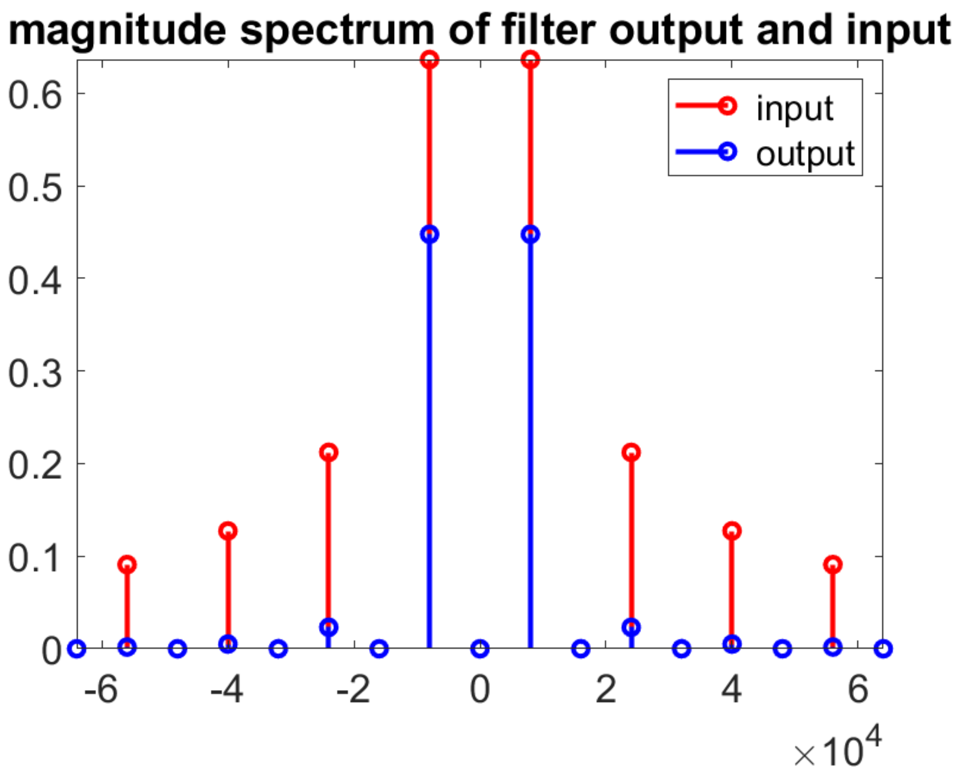


Waveform 2. FFT of Output with f_{in} = 4000 Hz

8000 Hz

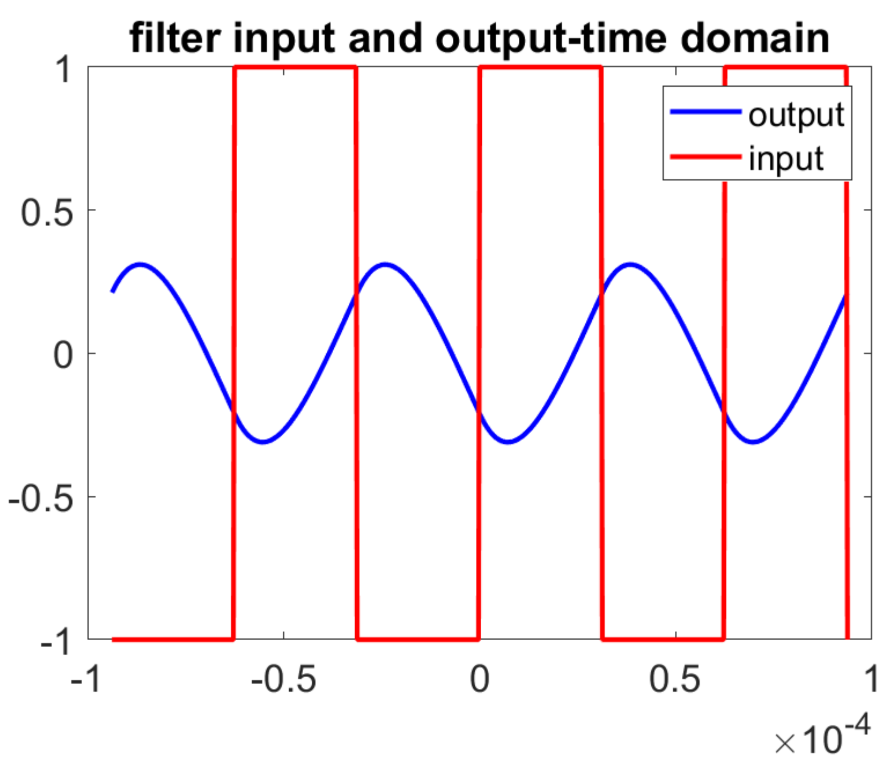


Waveform 3. Input and Output When f_{in} = 8000 Hz

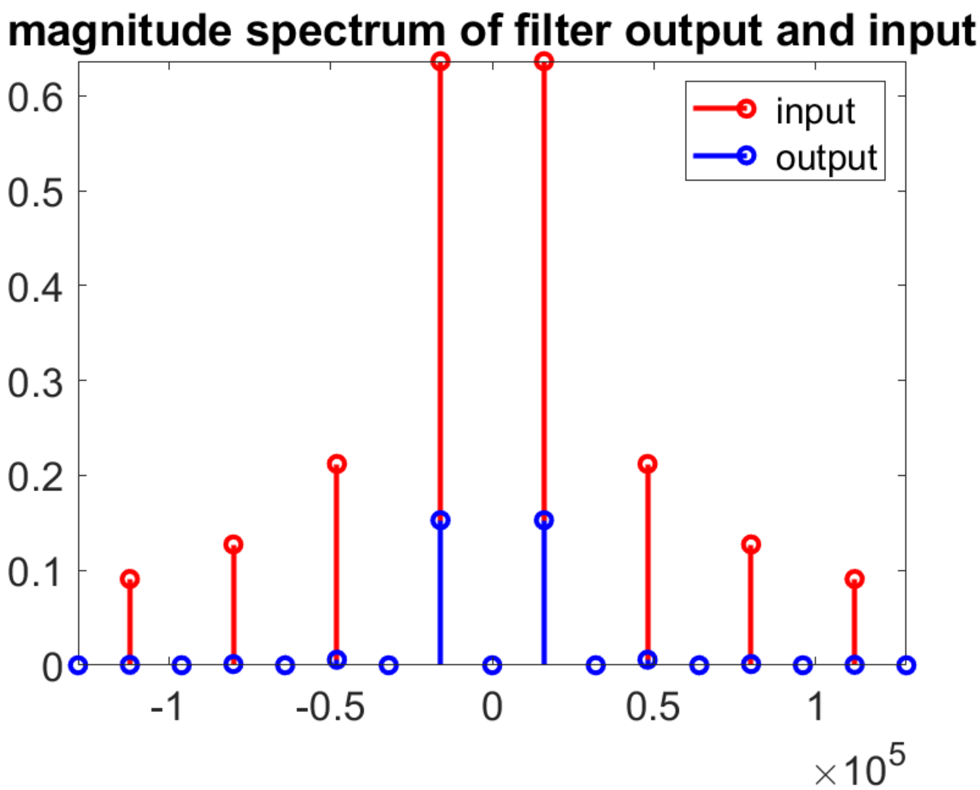


Waveform 4. FFT of Output with f_{in} = 8000 Hz

16000 Hz



Waveform 5. Input and Output When f_{in} = 16000 Hz



Waveform 6. FFT of Output with f_{in} = 16000 Hz

Butterworth Filter Experiments

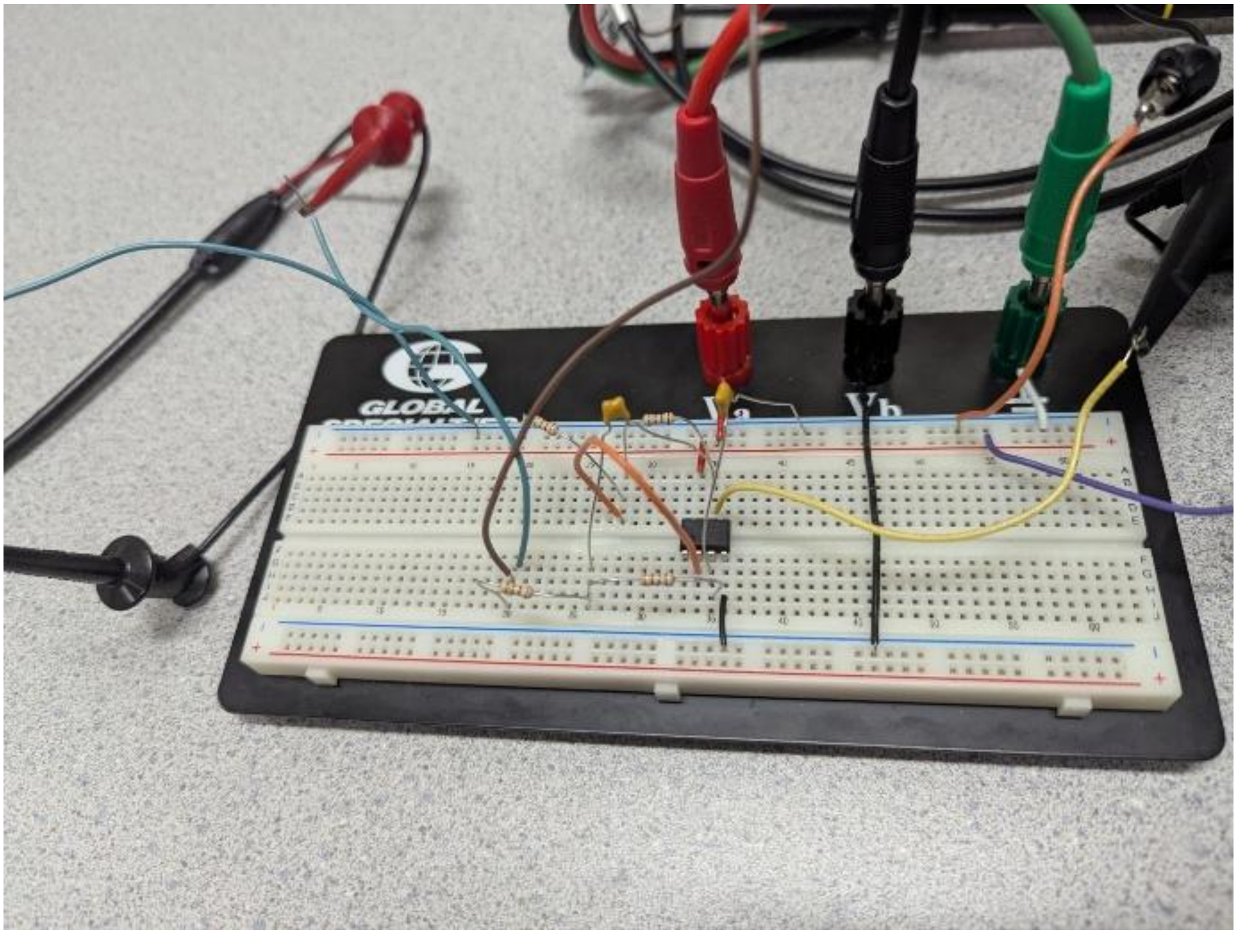


Figure 2. Assembled Circuit

Note: The Op Amp UA741CP is used in this circuit.

Frequency Sweep

4000 Hz

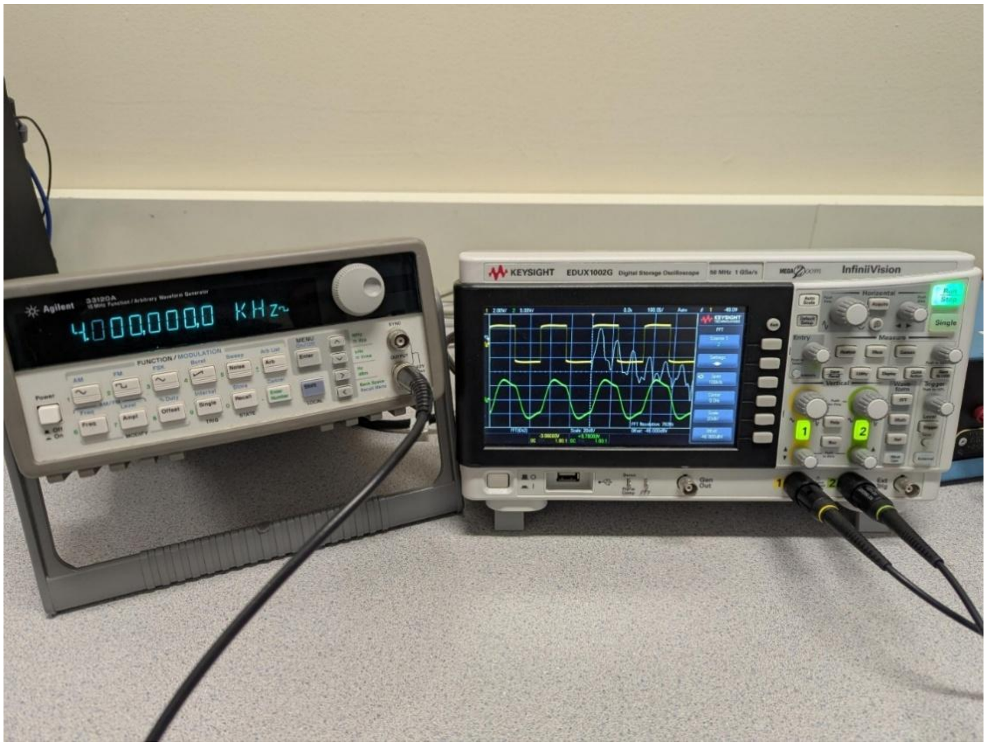


Figure 3. Waveform at half of f_c

At 4000 Hz, not all frequencies are filtered by the filter. On the FFT waveform (white line) set with a scale of 100 MHz, the distances between peaks are very close, and the voltage waveform in time domain at the output still tends to look like a periodic square wave. This indicates that not much signal has been filtered in this part.

Compared with simulation at 4 kHz, the result is almost identical in terms of wave form and gain. The only difference is the input square wave is not perfect due to the non-ideal physical op-amp being used in this lab.

8000 Hz

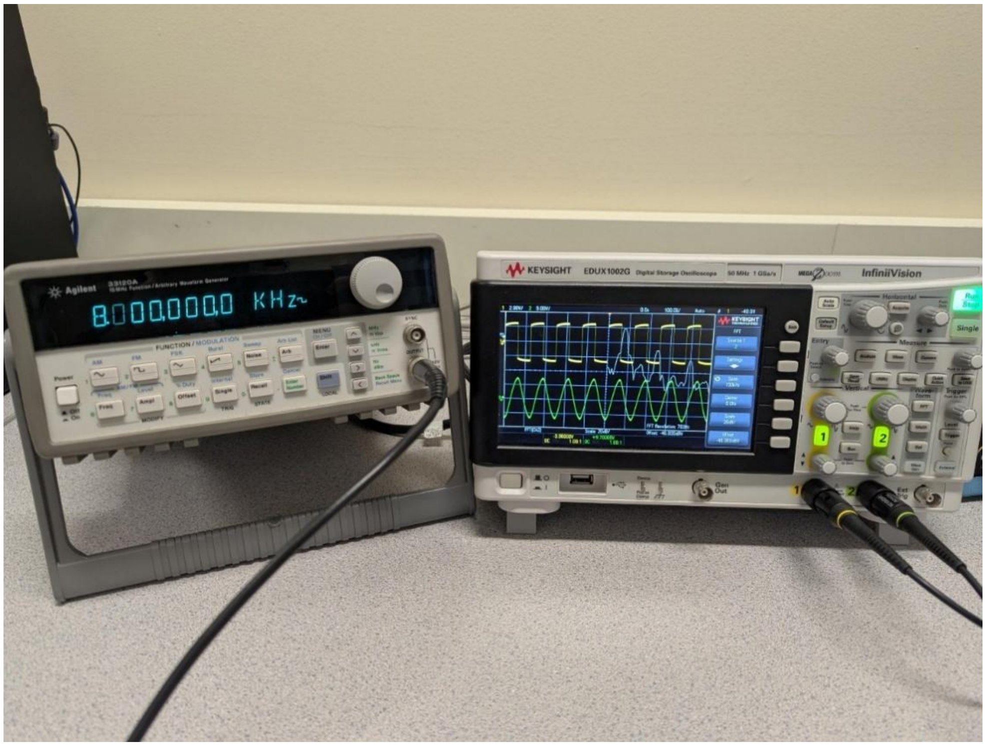


Figure 4. Waveform at f_c

At cutoff frequency, the signal in the time domain looks like a sine wave. In the frequency domain, the signal starts to drop at high frequencies, while some of them still pass through, shown as the peaks in the FFT channel. It is obvious to see the amplitude of the signal at high frequencies drops drastically.

At cutoff frequency, the physical circuit gain starts to differ from the simulation gain. Instead of an ideal gain of 2, the physical circuit exibits a gain slightly lower than 2, indicating that a small amount of power is lost in the process.

16000 Hz

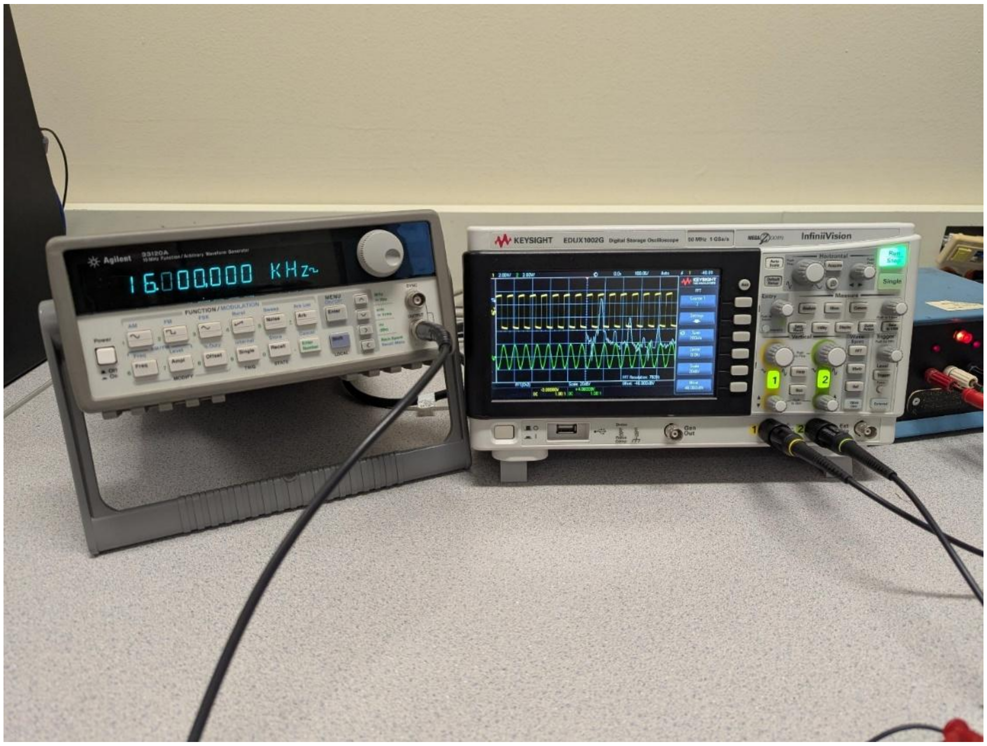


Figure 5. Waveform at Twice of f_c

Note that the scale of the FFT waveform has been turned to 200 MHz here. For the 16000 Hz spectrum, only a few peaks can be seen after the initial peak. That means most of the HF signals are filtered out, while some signals still pass through due to the gain created by the op amp. Compared with previous results on the same scale, the number of signals being filtered out at this frequency is substantial.

Similar to the last case, the gain is not strictly 2 and the detected square wave at input is not perfect.

Audio Signal Filtering

After going through the low pass filter, the audio sounds muffled, where all HF information is lost.

The band pass filter cuts off parts of the LF and HF in the original audio, making it sound strange. The speech is the most audible among the 3 filter results.

The high pass filter cuts off most of the low frequency information in the audio, making the speech almost inaudible.