# Blood Pressure

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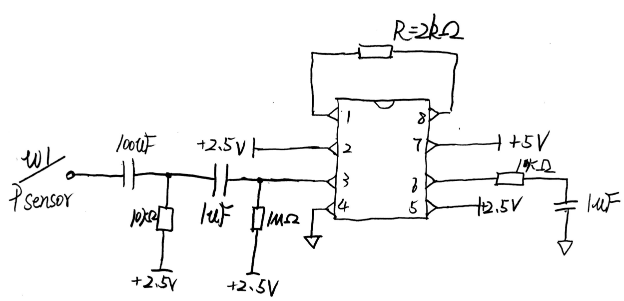
**Abstract**

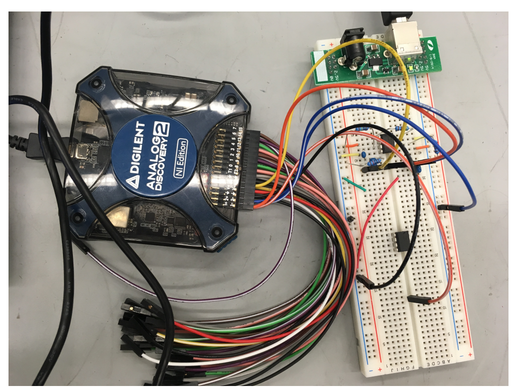
The purpose of this lab is to use appropriate high-pass and low-pass filters to process the voltage outputs measured from the arterial pressure. The author was expected to select the right resistors and capacitors to accomplish this task.

## 1 Description

In this lab, I built a circuit that could filter out the frequency of the heartbeat reflected through the voltage output of a pressure sensor. The circuit in general consists of two high pass filters that precede the amplifier AD623 and one low pass filter in the end. The combined effect should filter out the heartbeat frequency. However, the resistor and capacitor values were not given in this lab, and it is the author’s task to figure out the appropriate configurations for each filter. The schematics in the Figure 1(a) shows the resistor and capacitance values I picked for the circuit, and the actual circuit layout on the breadboard is shown in Figure 1(b). The replay of the recorded pressure sensor reading was output through Analog Discovery W1. The same connection applied to both W1 and the pressure gauge. A bode plot of the final circuit would also need to be collect by hand.




(a) Schematics. Values for capacitors and resistors later chosen are also shown.

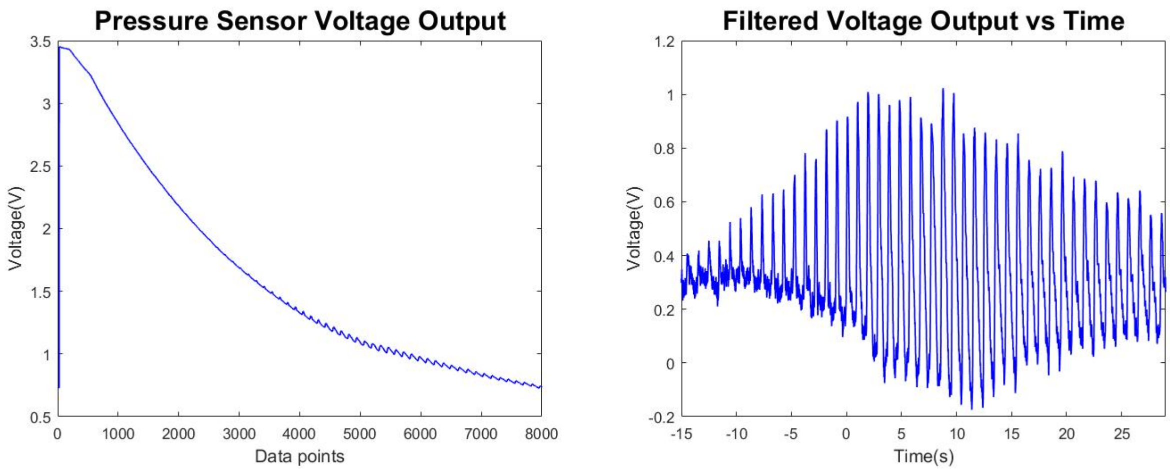



(b) The blood pressure measuring circuit layout on breadboard.

Figure 1: The blood pressure lab.

## 2 Evidence

The raw data from the pressure sensor and the filtered signal are both plotted in Figure 2. Although the raw data doesn’t have any time component to it, by making the whole data replay at around 16.6 mHz, it is possible to make the data to span across a one-minute period. That is the reason why the time scale in Figure 2(b) covers a $\pm$ 30 seconds.




(a) Raw data

(b) Filtered Output

Figure 2: Blood Pressure Readings

To study the behaviors of the circuit, a Bode plot data was recorded at different frequencies manually and shown below. Channel $\pm 1$ is the amplitude measured at the input, and Channel $\pm 2$ is the amplitude

Table 1: Channel 1 and 2 Output versus Frequency

| **Frequency(Hz)** | 0.1 | 0.2 | 0.5 | 1 | 2 | 5 | 10 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| **Channel$\pm$1(mV)** | 98.6 | 98.6 | 98.6 | 98.6 | 98.6 | 98.6 | 98.6 | 93.3 | 93.3 |
| **Channel$\pm$2(mV)** | 429.7 | 1093 | 2048.1 | 2304.3 | 2362.7 | 2304.3 | 2041.8 | 729.2 | 379.2 |

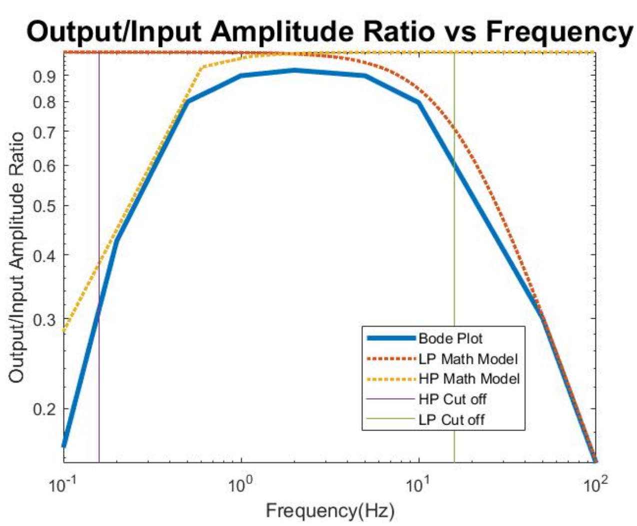



Figure 3: Bode Plot of the circuit with a gain of 26.

To generate a Bode plot, the following equation is used for the values, which are the ratios between output and input amplitudes on the y axis.

$$A = \frac{Channel2}{26 \times Channel1}, \tag{1}$$

where 26 is the programmed gain of the amplifier. The resulting ratios are plotted against their corresponding frequencies in a logarithmic scale.

A Bode plot based on a gain of 51 is also given out below.

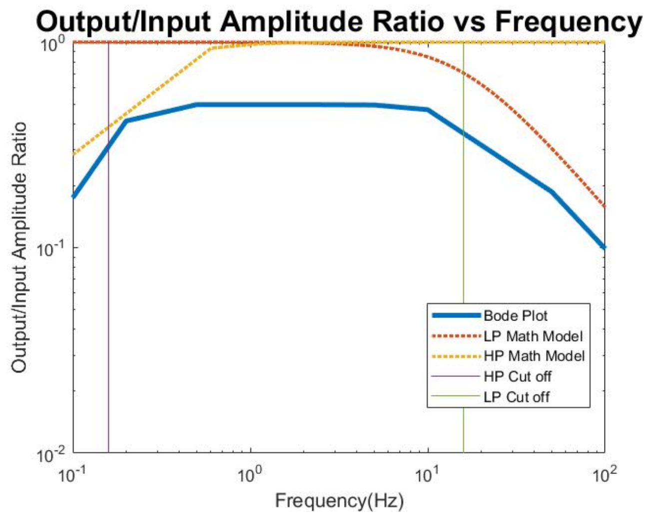



Figure 4: Bode Plot of the circuit with a gain of 51.

## 3 Interpretation

To select for the appropriate filters to filter out the frequency of the heartbeat, it is necessary to first narrow down the range of frequency we want and don't want. The pulse has a frequency of around 1 Hz, so that is about the frequency that should be allowed to pass through. One of the major noises is again the 60Hz AC power in the wall; thus, a low pass filter that has a cut-off frequency way below 60Hz. In addition, a long decay is present in a raw data. It is around 0.0166Hz since that was the frequency at which the data was replayed. A high pass filter with a cut-off frequency higher than 0.0166Hz would be necessary in the circuit.

The resistor and capacitor chosen for the low pass filter in the end were 10 $k\Omega$ and 1 $\mu F$, which gives a cut-off frequency of:

$$Frequency = \frac{1}{2\pi RC\omega} = \frac{1}{2\pi \times 10k\Omega \times 1\mu F} = 15.9Hz \tag{2}$$

The ones chosen for the high pass filters were $10k\Omega$ and $100\mu F$ and $1M\Omega$ and $1\mu F$, both of which have a cur-off frequency of:

$$Frequency = \frac{1}{2\pi RC\omega} = \frac{1}{2\pi \times 10k\Omega \times 100\mu F} = 0.159Hz \tag{3}$$

The second high pass filter in the series was chosen to have the same cut-off frequency as the first one but had a much higher resistor value so that it would draw significantly less current and allow the system to mimic the behavior of an ideal second order high pass filter.

As it can be seen in the schematics, both of the high pass filters are connected to the positive 2.5V. The reason for that is that the voltage supplied to AD623 was 5V, and referencing the circuit at +2.5V would allow the amplifier to go up and down up to 2.5V given that the power supply is 5V and the ground is 0V. In order for the input voltage from the pressure sensor to start at +2.5V in the first place, it is important to pull those high pass filters to +2.5V.

The gain of the amplifier was programmed to be 26 with a $4k\Omega$ resistor. The equation to calculate the gain is as follows:

$$Gain = \frac{100k\Omega}{4k\Omega} + 1 = 26 \tag{4}$$

The signal passing through the amplifier would be 26 times larger. Such a resistor value is an appropriate choice since a gain that is too large might make the amplitude peak out at 2.5V while the actual amplification, given the proper supply supply, goes much higher than 2.5V. This happen to having a $2k\Omega$ resistor which would generate a gain of 51. As shown in Figure 4, there is a huge vertical gap between the mathematical model and the data taken exactly because the measurement peaked out at 2.5V. The Bode plot based on the 26-times gain corresponds to the mathematical model a lot better. However, the general trend doesn't fit as well as the Bode plots in the past. Such a minor deviation is due to the low number - nine - of data points used in the measurement, so there are sharp corners on the line and slight difference from the mathematical models. Overall, the circuit behaves in the expected way in the Bode plot.