ISim Lab 7: Blood Pressure

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1 Introduction

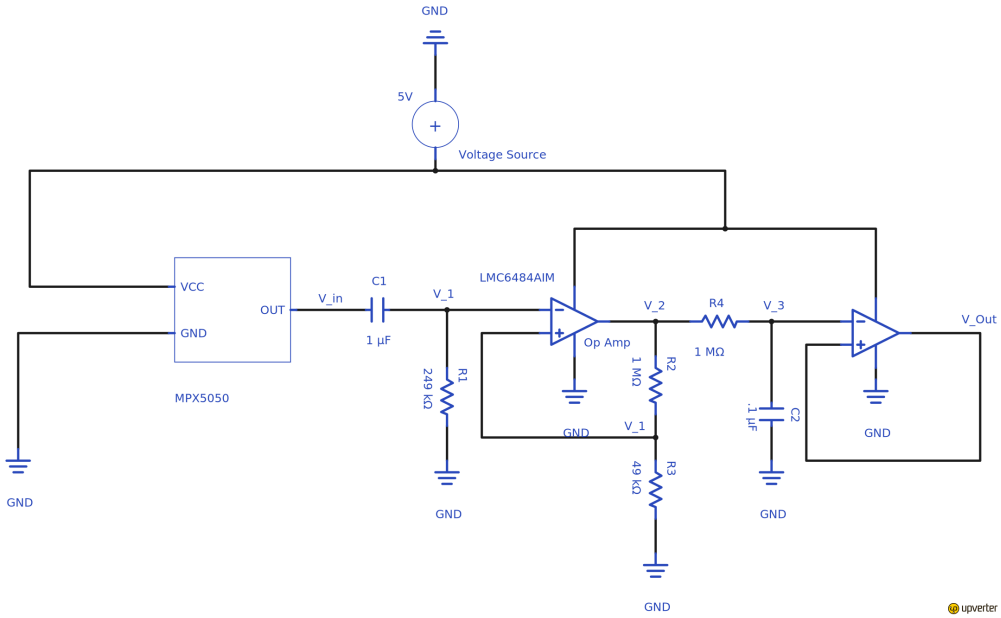

Figure 1: Diagram of the whole circuit, drawn with Upverter.

Since operational Amplifiers draw no current, each subcomponent may be treated as a separate system; naturally, in the following sections, I will process the voltage in each phase separately, rather than combining them into a singular expression that relates V_{out} directly to V_{in}. In this scenario, the circuit is composed of four phases: high-pass filter, amplifier, low-pass filter, and unity-gain follower.[1]

[1] the low-pass filter only depends on the voltage after the amplification, and is more or less a separate system.

2 Circuit Analysis

2.1 High-pass Filter

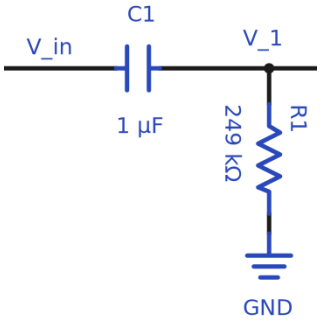

Figure 2: First Phase : High-pass Filter from V_{in} to V_1

$$\begin{aligned} \frac{V_1 - V_{in}}{1/j\omega C_1} &= \frac{0 - V_1}{R_1} \\ V_1(j\omega C_1 + 1/R_1) &= V_{in} * j\omega C_1 \\ V_1 &= \frac{V_{in} * j\omega C_1}{j\omega C_1 + 1/R_1} \end{aligned}$$

2.2 Amplifier

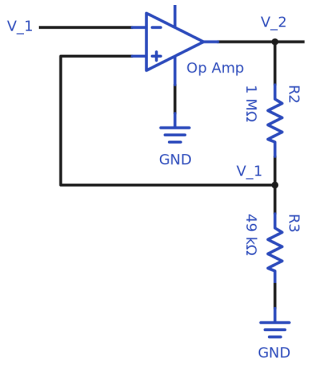

Figure 3: Second Phase : Amplifier from V_1 to V_2

$$\begin{aligned} \frac{V_1 - 0}{R_3} &= \frac{V_2 - V_1}{R_2} \\ V_1(1/R_3 + 1/R_2) &= \frac{V_2}{R_2} \\ V_2 &= R_2 V_1 \frac{R_2 + R_3}{R_2 R_3} \\ V_2 &= V_1 \frac{R_2 + R_3}{R_3} \end{aligned}$$

2.3 Low-pass Filter

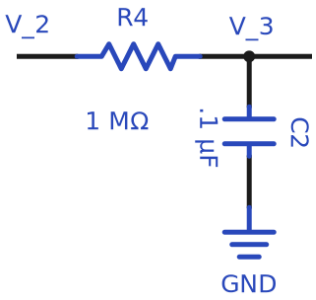

Figure 4: Third Phase : Low-pass Filter from V_2 to V_3

$$\frac{V_3 - V_2}{R_4} = \frac{0 - V_3}{1/j\omega C_2}$$
$$V_3(1/R_4 + j\omega C_2) = \frac{V_2}{R_4}$$
$$V_3 = \frac{V_2}{1 + R_4 j\omega C_2}$$

2.4 Unity-Gain Follower

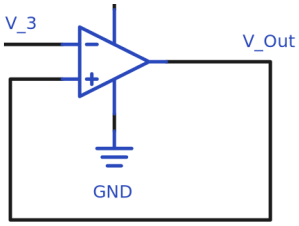

Figure 5: Fourth Phase : Unity-Gain Follower from V_3 to V_{out}

Given that the voltage is not stuck at the extreme values(rails), it is the property of the Op-Amp that $V_{out} == V_3$. This Unity-Gain Follower was implemented in order to facilitate the measurement of voltage, by the Analog Discovery.

3 Results

3.1 Verification

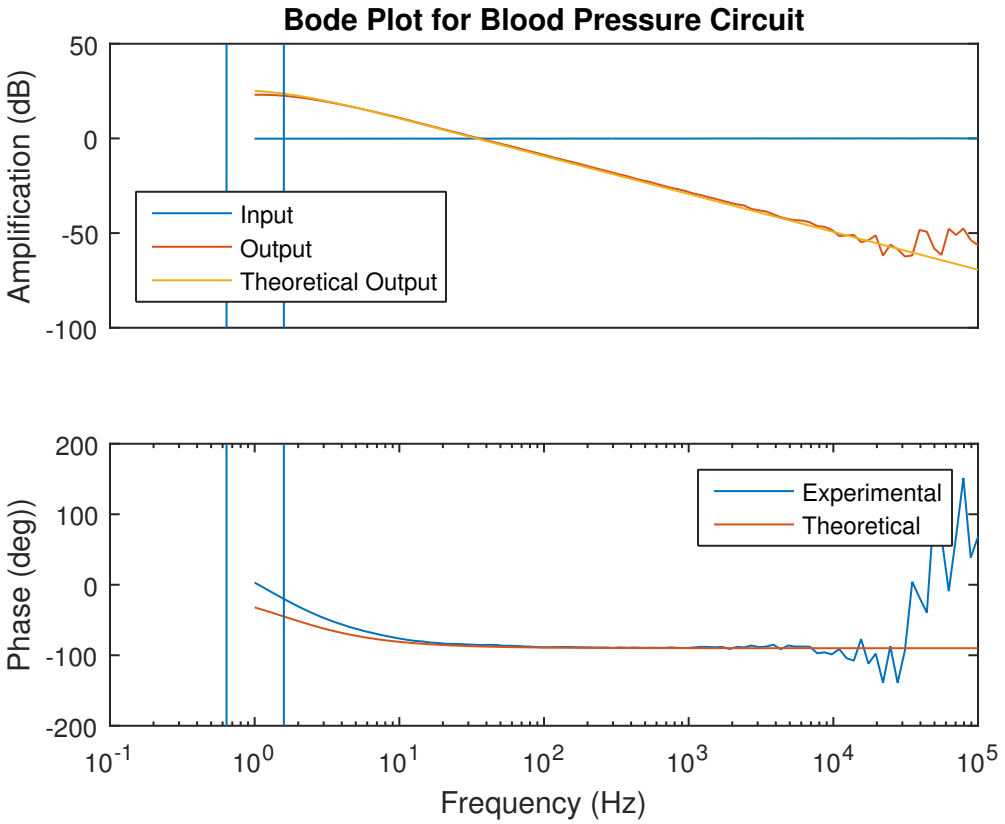

Figure 6: Bode plot of the circuit. The Analog Discovery was unable to create the bode plot below 1 Hz – hence the cutoff in the left part of the plot. Cutoff Frequency for the High-pass filter was .693 Hz, and the cutoff frequency for the Low-pass filter was 1.59 Hz.

Experimental data and Theoretical data showed a clear coherence except at higher frequencies, where the measurement is known to be unstable.

3.2 Application

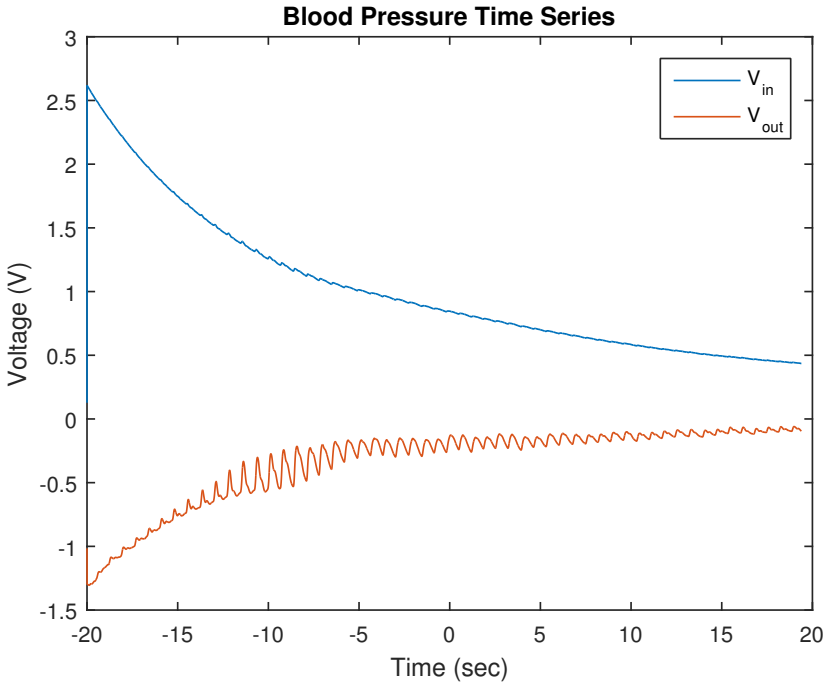

Figure 7: The time series of the Blood Pressure. As shown, the processed signal shows a greater indication of recurring blood pressure than the raw signal.

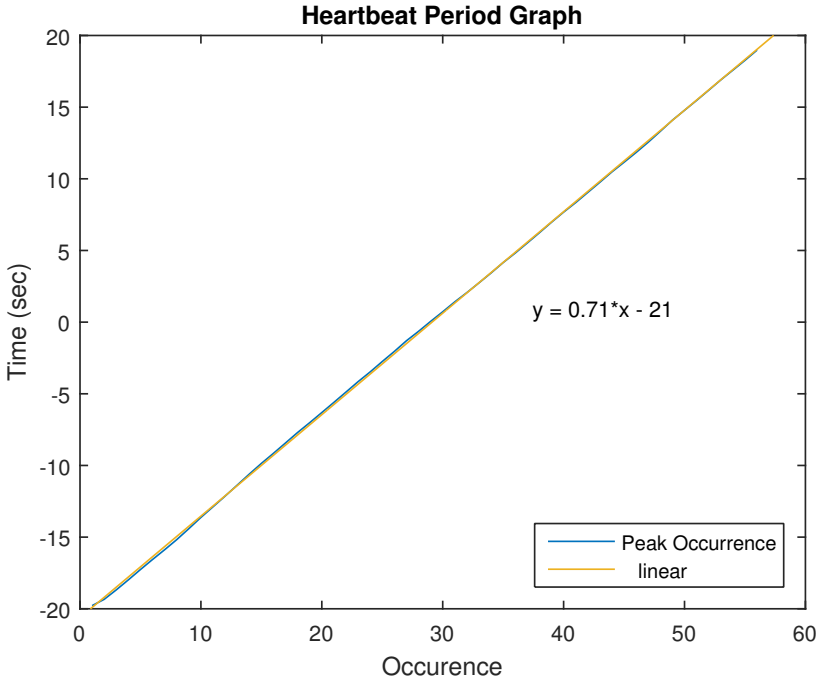

Figure 8: The time series was analyzed to find the period of the blood pressure: as shown in the fit line, each peak occurred every 0.71 seconds.