ELEC2104 Project: Pulse Blood Oximeter

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1. Introduction

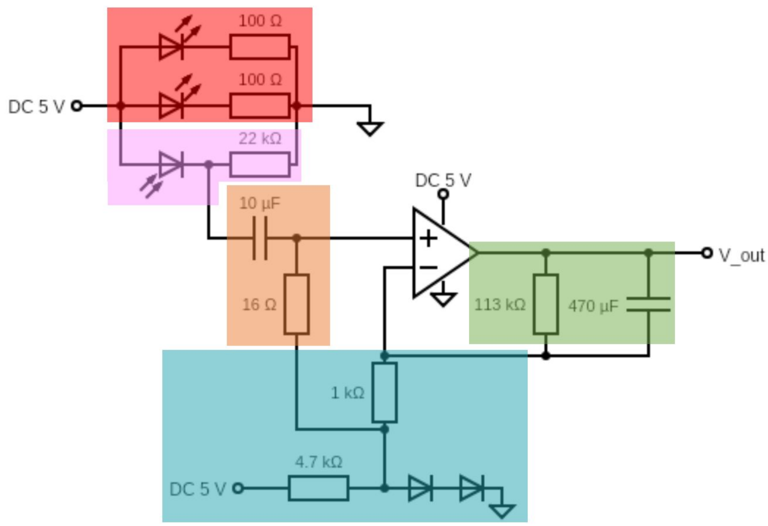
Blood oxygen level is a vital factor when monitoring the physical condition of a person. We need to breathe to replenish our oxygen from the air. The amount of oxygen required varies over a small range. If kept within that proper saturation range, it means one's body and tissues are receiving enough oxygen to maintain homeostasis. A microelectronic device can be designed to measure the concentration of oxygen in the blood.

In this lab project, we were required to build a circuit to monitor the blood oxygen level, termed a "pulse oximeter". The degree of red light absorption by the blood is proportional to the oxygen concentration. Thus, by taking advantage of this property, the basic principle behind our pulse oximeter is to process the transmitted light signal.

For the oximeter, we tested two light sources: a red LED and an IR LED. As the light passes through the finger, the intensity of the signal received varies. To receive this signal, a photo-transistor outputs a current proportional to the received light. In order to compare the ratio of two kinds of light with different wavelengths, a filter, amplifier and biasing process are used to generate the outputs. Results are then simulated on MatLab for analysis, which reveals the oxygen saturation of the individual.

2 Circuit Design and Testing

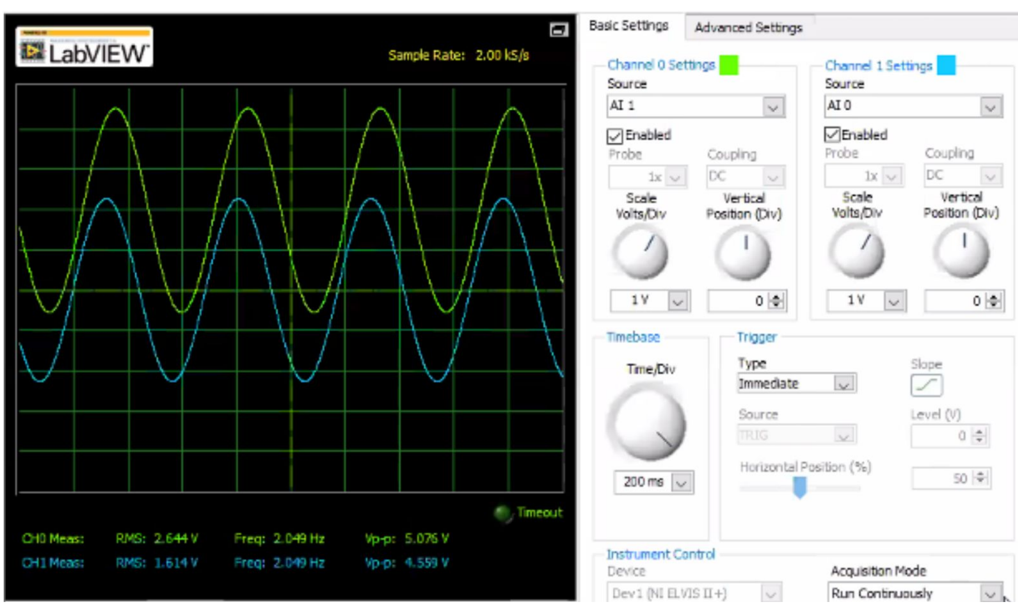
Red: Signal input and transmission
Pink: Signal Receiver (photo-transistor)
Orange: High Pass Filter
Green: Low Pass Filter
Blue: Voltage and current regulation



2.1 Sensor Readings (Red and Pink)

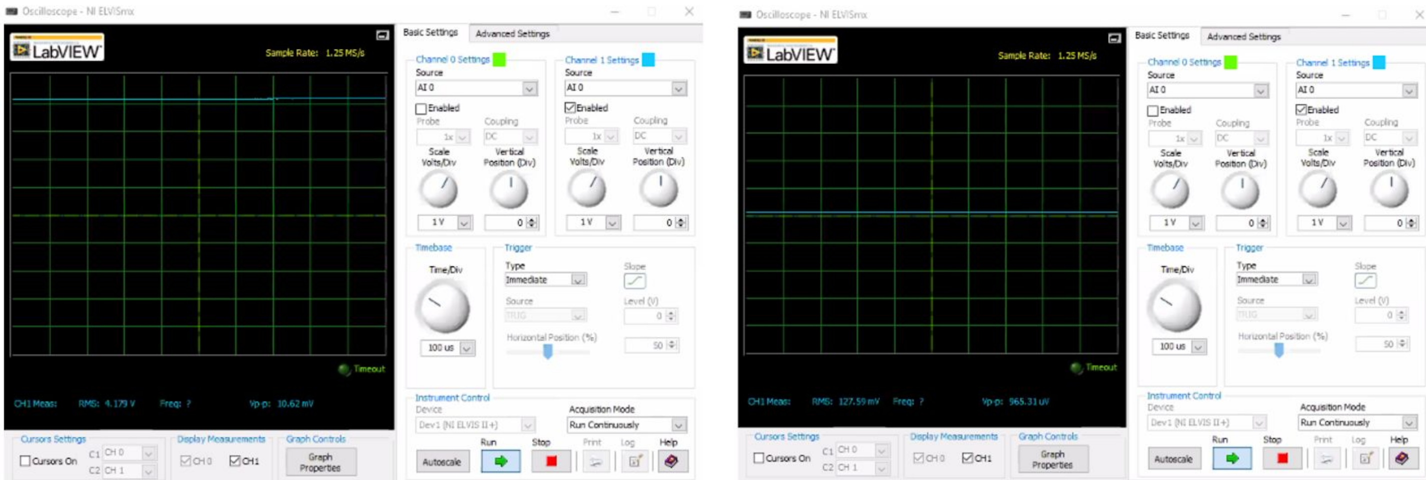
2.1.1 LED

Used a square wave input to see if light blinked. Generated using the LabView Function Generator using a 1 Hz wave so the blinking was visible to the human eye. Then tested the sensor by displaying a square wave output on the LabView oscilloscope, and observed that the frequency was the same. This is shown in the below figure:



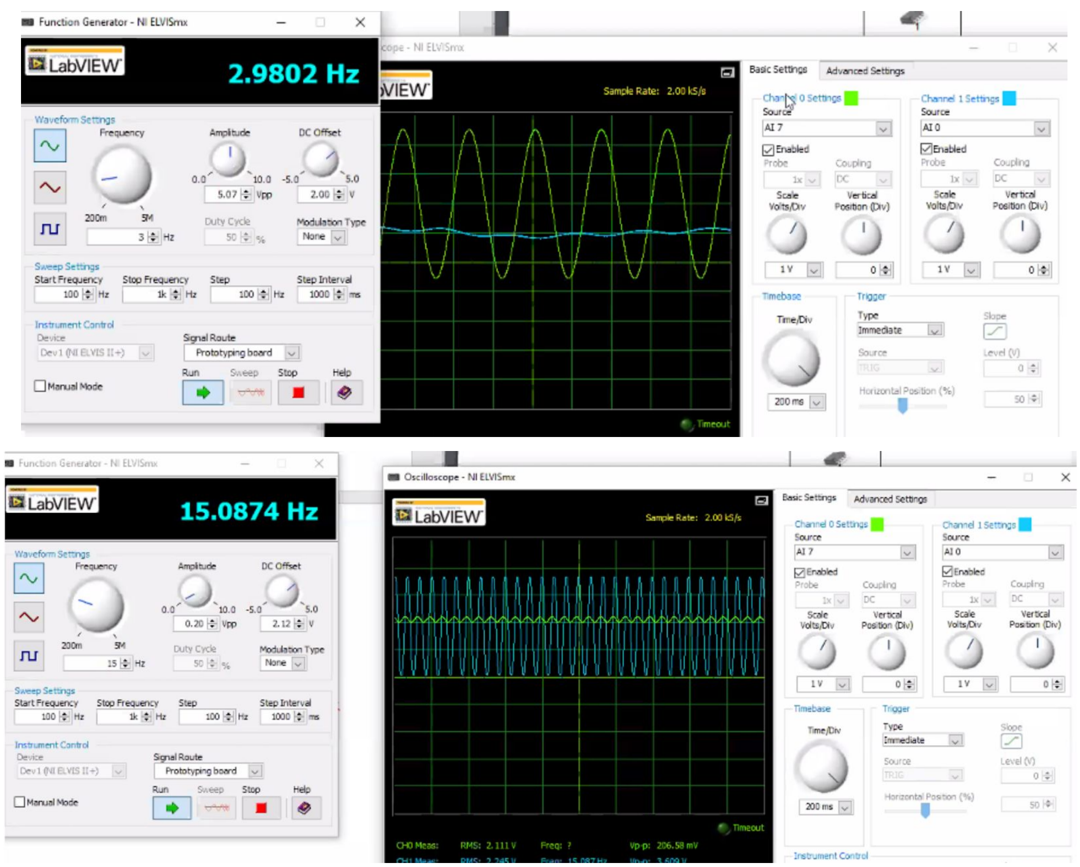
2.1.1 IR sensor

Applied square wave to the transistor and observed the square wave through IR sensor output to verify the circuit worked. This shows the difference in voltage output when the transmitter is on (left) and off (right).



2.3 High pass and low pass filter (Orange and Green)

Tested with a sine wave input to approximate the pulse needed to measure. Observed a significant drop off in voltage at high frequencies as seen from the RIGOL oscilloscope. Blue represents the input function whereas green is the output in the figures below. It is evident that the signal is amplified at frequencies close to 1-2 Hz while the out of range frequency (15.09Hz) signal is significantly attenuated as its amplitude is reduced.



3. Troubleshooting procedure

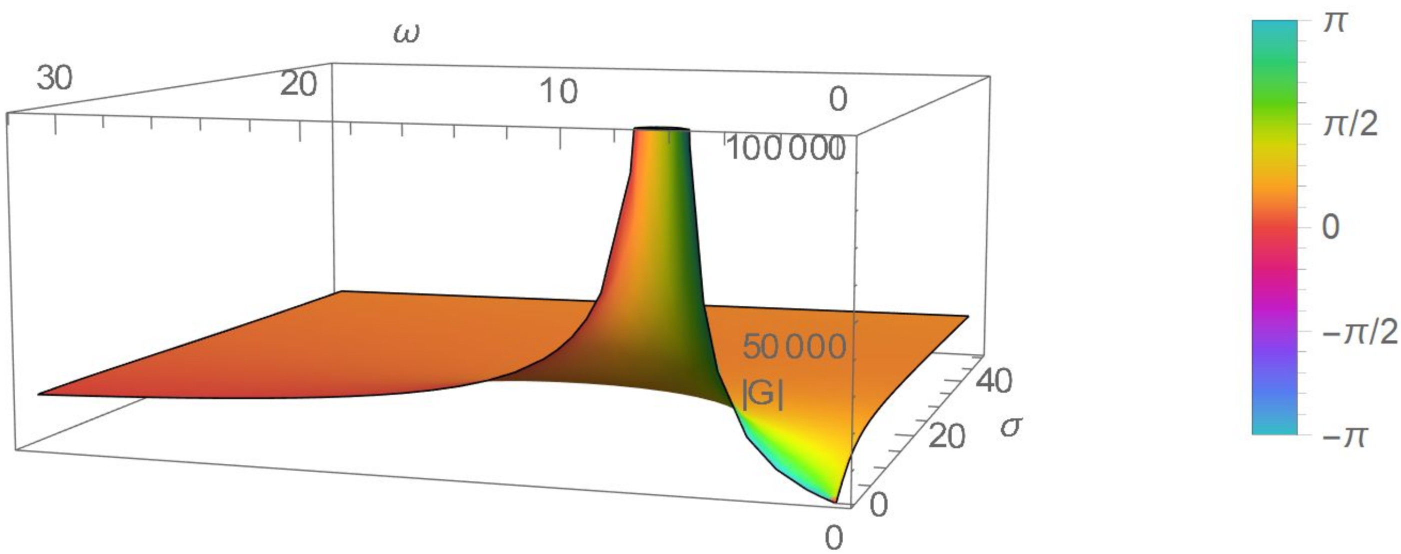
1. Use a multimeter to check for shorts
2. Double-check resistance values
3. Check connections, loose wires, faulty connections on the breadboard.
4. Check sensor orientation and whether the signal is accurate (sine wave in FGEN) and check the output before frequency filtering.
5. Check frequency filtering circuit by inputting out of range sine wave frequencies using the FGEN, check output is significantly attenuated.
6. Attempt again using a different person’s pulse.

4. Analysis

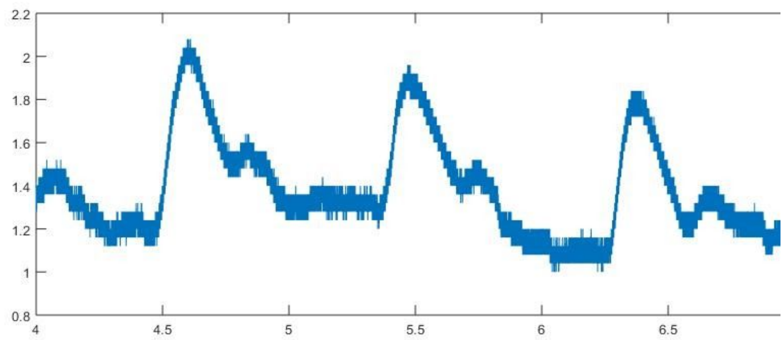
After solving the circuit algebraically, we produced the transfer (gain) function of the band-pass active amplifier (G(s)).

$$G(s) = \frac{j\,s\left(2.12746 \times 10^{6} - s\right)}{\left(s + j\,133.689\right)\left(s - j\,6.28338\right)}$$

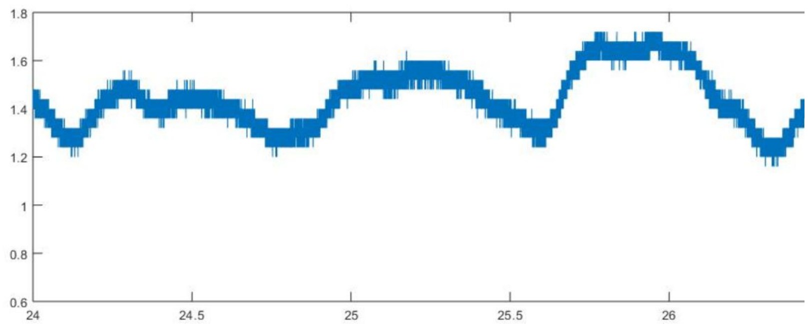
A complex phase-coloured 3D plot was produced using Mathematica for a real domain of σ ∈ [0, 50], where G(s’ = 0 + jω) represents the Fourier Transform (non-logarithmic Bode Plot). As can be seen, the filter passes and amplifies frequencies in the domain of ω ∈ [6.3, 12.6] ([1, 2] Hertz).



Results from LED signal:
Frequency is in the expected range, amplitude and shape are as expected from a human pulse.



Results from IR signal:
Frequency matches the LED signal, however, the larger peak is not clear. This could be the result of positioning the sensor poorly and also from interference such as the temperature of the sensor and the hand, or the ambient temperature of the room.



5. Final Results

The following results were obtained from the amplified signals.

Measurement Category	**Voltage [V]**
iRedAC	0.85
iRedDC	1.4
iIRAC	0.71
iIRDC	1.4

Using the formula below, the normalised absorbance (R) was calculated to be 1.19718.

$$R = \frac{\left(\frac{\mathtt{iRedAC}}{\mathtt{iRedDC}}\right)}{\left(\frac{\mathtt{iIRAC}}{\mathtt{iIRDC}}\right)}$$

The normalised absorbance was then used to calculate the saturation of oxygen in the blood, using the formula below.

$$S_p O_2 = \frac{100\ (0.81 - 0.18\,R)}{0.63 + 0.11\,R}$$

Our measurements gave a saturation level of 78.051%.

6. Conclusions

Amplification and attenuation of the signal by the filter circuit were effective and matched the theoretical results that were simulated by the transfer function.

The results are significantly below the expected values of (90%-100%). The LED results were clear and had a reasonable amplitude, so the error was likely caused by introduced noise from the IR values since there was significant noise from the light in the room which would have affected the signal from the IR transmitter.