INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR

Analog Circuits (EE 321)

Project Report 1

Group No. – 1

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Introduction:

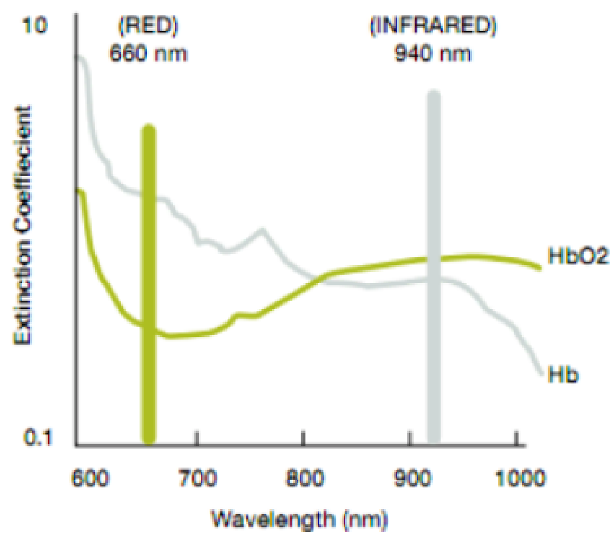
Keeping track of our health is more vital than ever in the current society. Our invention, "PulsePAL," will measure your heart rate and pulse via your finger and display it on the screen. What is the significance of this? Monitoring your heart rate and pulse allows you to gain a better understanding of your overall health. This project report looks into the development of the PulsePAL, including the technology and science that went into its development. This project also includes a preliminary sketch and components of our circuit.

Motivation:

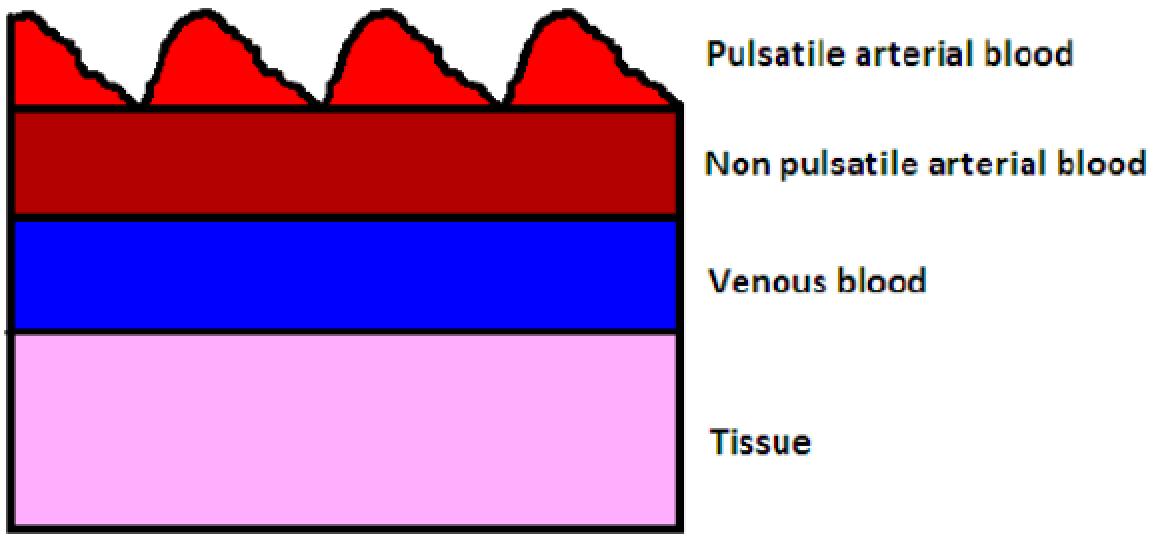
Our motivation for undertaking this project stemmed from a blend of curiosity and a deep-seated desire to know about human pulse behavior in different situations. Firstly, our fascination with understanding the working process of the Pulse Oximeter, mainly how it measures oxygen saturation levels in the blood, ignited our interest. Second, our motivation was boosted by the appeal of applying Operational Amplifiers (Op Amps) in real-world scenarios. We want to know the real-life significance of Op Amps and Explore the potential applications of Op Amps, especially in the context of health monitoring. We are also driven by the curiosity of tracking and comprehending the variations in pulse rates across various contexts.

Science related to pulse oximetry:

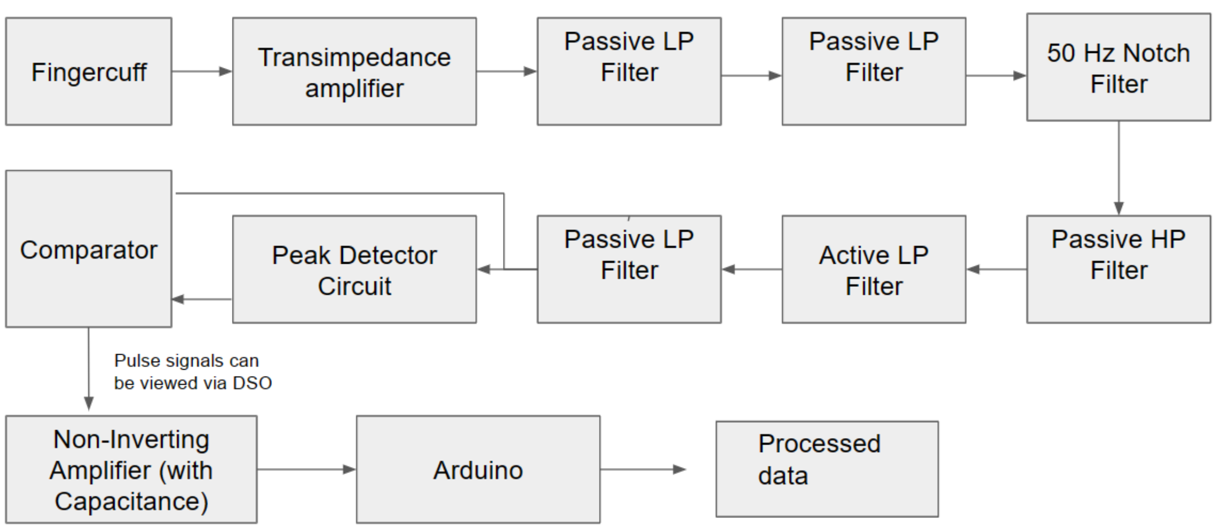
Pulse oximetry is a non-invasive method of measuring the oxygen saturation (SpO2) in blood. It is based on the detection of Hemoglobin and Deoxyhemoglobin. Two different light wavelengths, 660 nm (red light spectra) and 940 nm (infrared light spectra), are used to measure the actual difference in the absorption spectra of HbO2 and Hb. The bloodstream is affected by the concentration of HbO2 and Hb, and their absorption coefficients are measured using these two wavelengths. Deoxygenated hemoglobin (Hb) has a higher absorption at 660 nm, while oxygenated hemoglobin (HbO2) has a higher absorption at 940 nm.



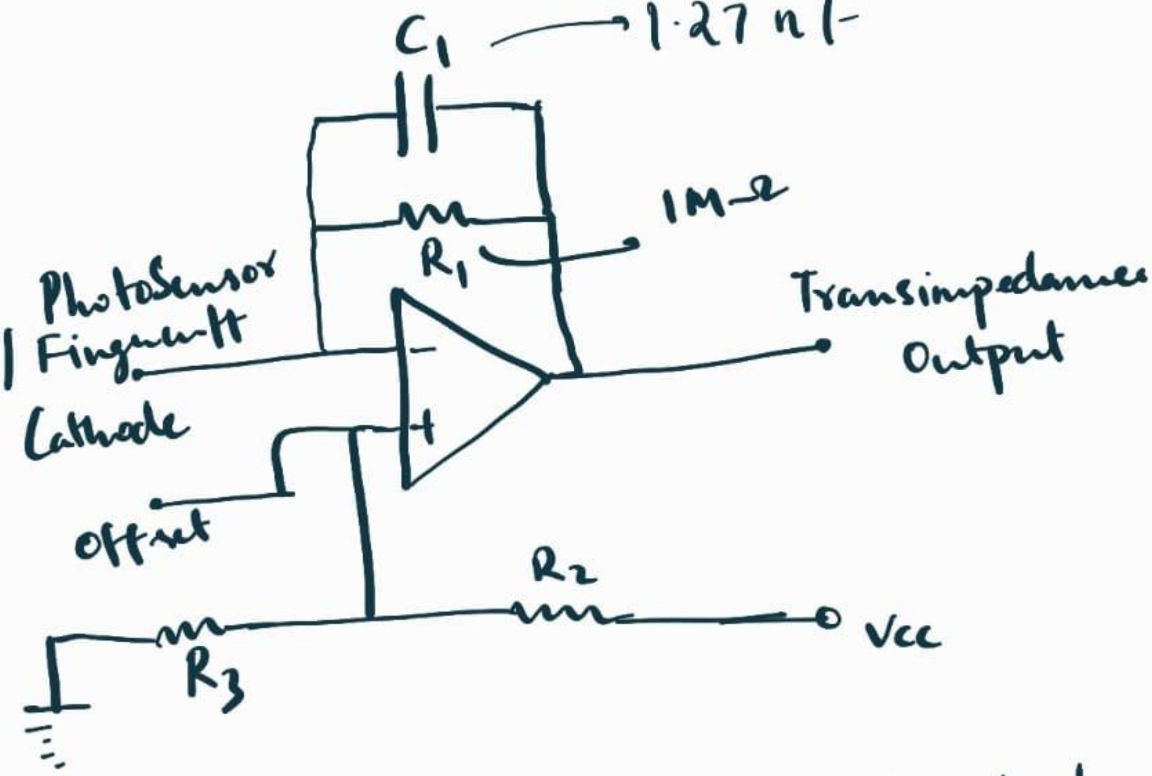
Therefore, to get the pulse, there is a photodetector or a finger cuff that perceives the non-absorbed light from the LEDs. This signal is inverted using an inverting operational amplifier (OpAmp), and the result contains a DC component, which represents the tissue, venous blood, and non-pulsatile arterial blood, and an AC component, which represents the pulsatile arterial blood.



Block Diagrams and circuits:



Transimpedance Amplifier



Since the current produced by a photodiode can be pretty small, we use a very high resistor of 1MΩ as gain setting resistor.

$$\Rightarrow f_c = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi(1.27\times10^{-9})(1\times10^{6})}$$

$$\Rightarrow \boxed{f_c \approx 125 \text{ Hz}}$$

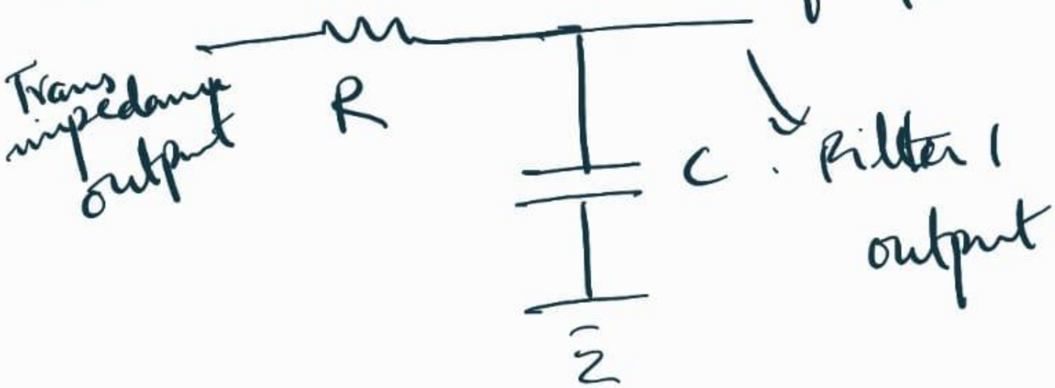
Therefore, this circuit also works as a low pass filter of cutoff 125 Hz to improve signal treatment

Filters and Amplification

↳ 4 passive
↳ 1 active

Both $\boxed{660nm}$ and $\boxed{940nm}$ signals are processed using these filters for noise elimination and amplification

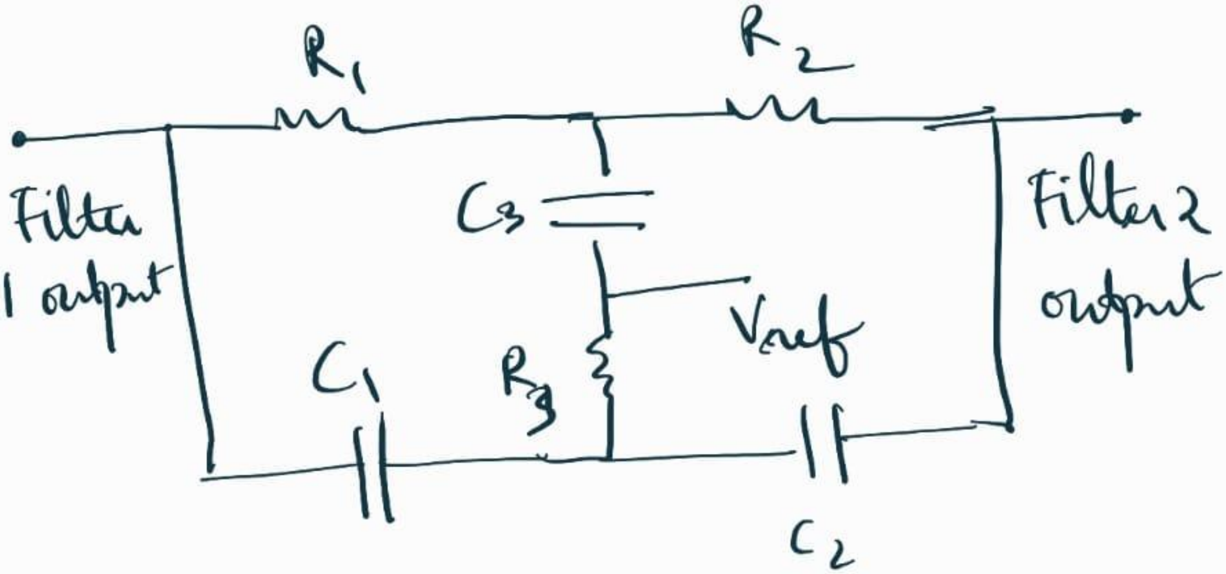
1st Filter → Passive Low Pass Filter of $f_c = 6\,Hz$



considering $C = 100\,\mu F$,

$$\Rightarrow R = \frac{1}{2\pi f_c C} \approx 265\,\Omega$$

2nd Filter → 50Hz Notch Filter



Referenced to $V_{CC}/2$ to add an offset voltage.

Considering $C_1 = C_2$ and $R_1 = R_2$.

and $\boxed{C_1 = 10\mu F}$.

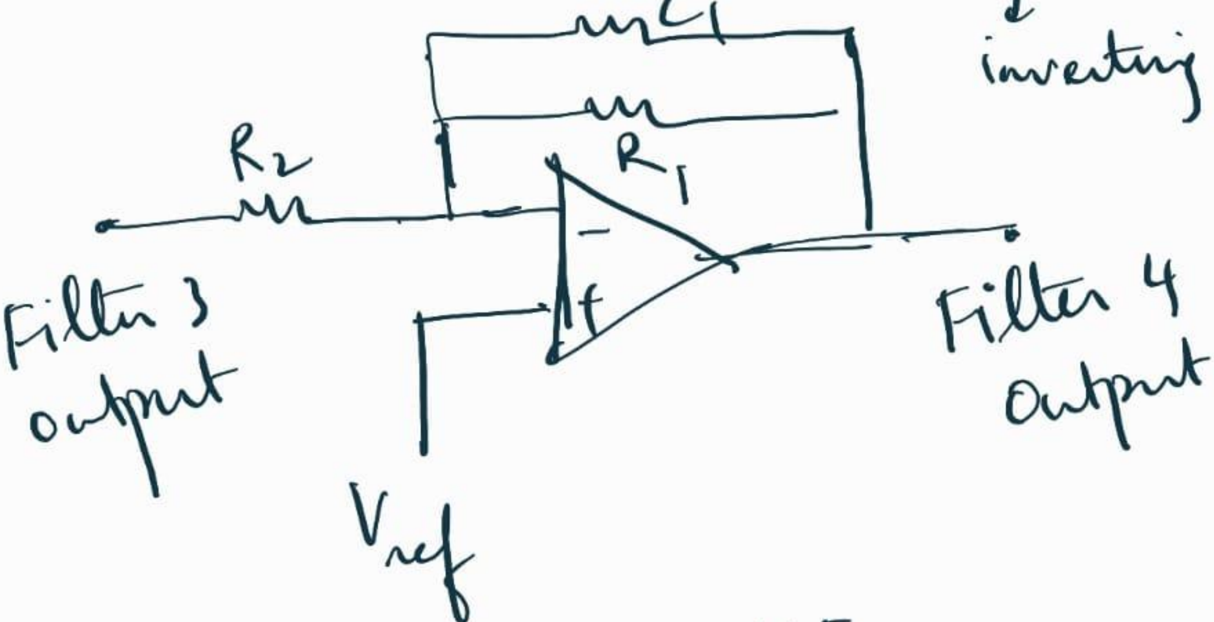
$$R_1 = \frac{1}{2\pi(50)(10\times10^{-6})} \Rightarrow 159\,k\Omega$$

Filter 4 → Active low-pass filter

$(f_c = 6Hz,\ gain = -30)$.

↓

inverting



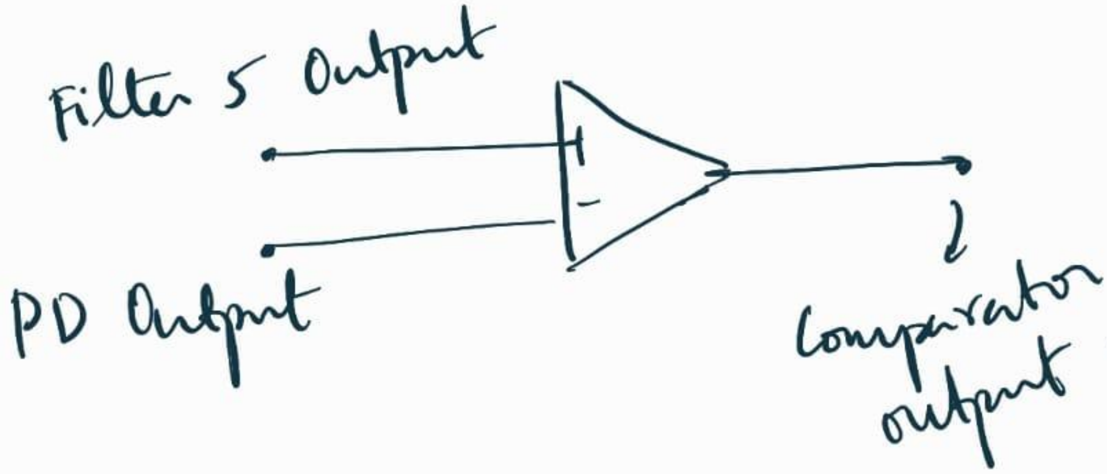
Considering $C_1 = 10\mu F$

$$\Rightarrow R_1 = \frac{1}{2\pi(6)(10\times10^{-6})}.$$

$$\boxed{R_1 = 2.7k\Omega}$$

$\Rightarrow$ Gain $\Rightarrow -R_1/R_2 = -30 \Rightarrow \boxed{R_2 = 90\Omega}$

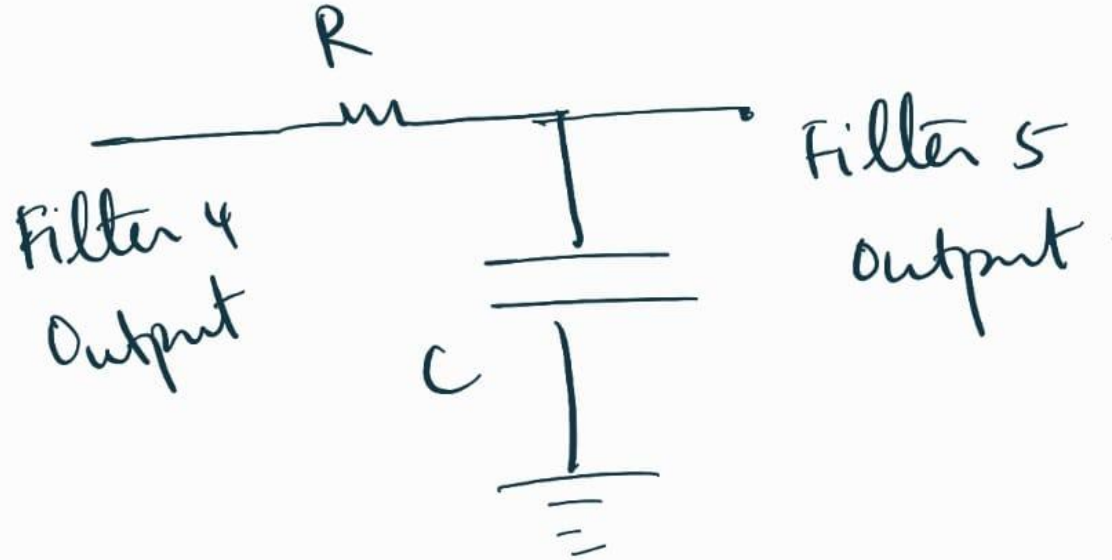
Comparator:



→ Used to allow detection of weak pulses caused by sudden changes in position of photodetector on the body.

Filter 5 $\rightarrow$ Passive low pass filter

($f_c = 4.8\,Hz$).

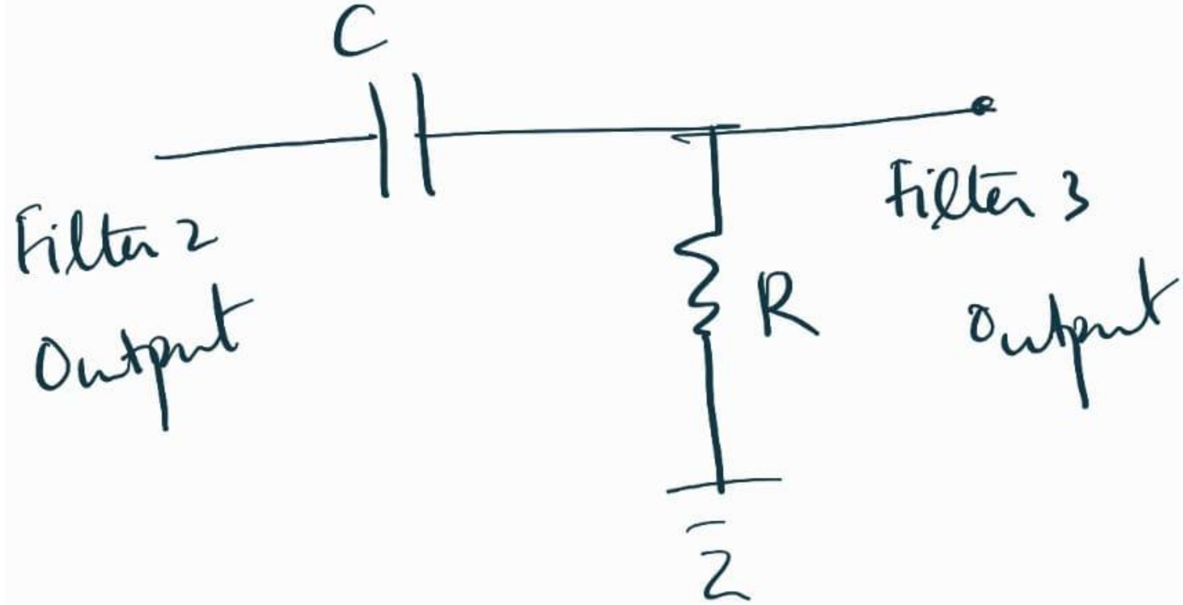


Considering $C = 10\mu F$,

$$\Rightarrow R = \frac{1}{2\pi(4.8)(10\times10^{-6})}.$$

$$\Rightarrow \boxed{R = 3.3k\Omega}$$

3rd Filter → Passive High Pass Filter ($f_c = 0.8 \, Hz$)

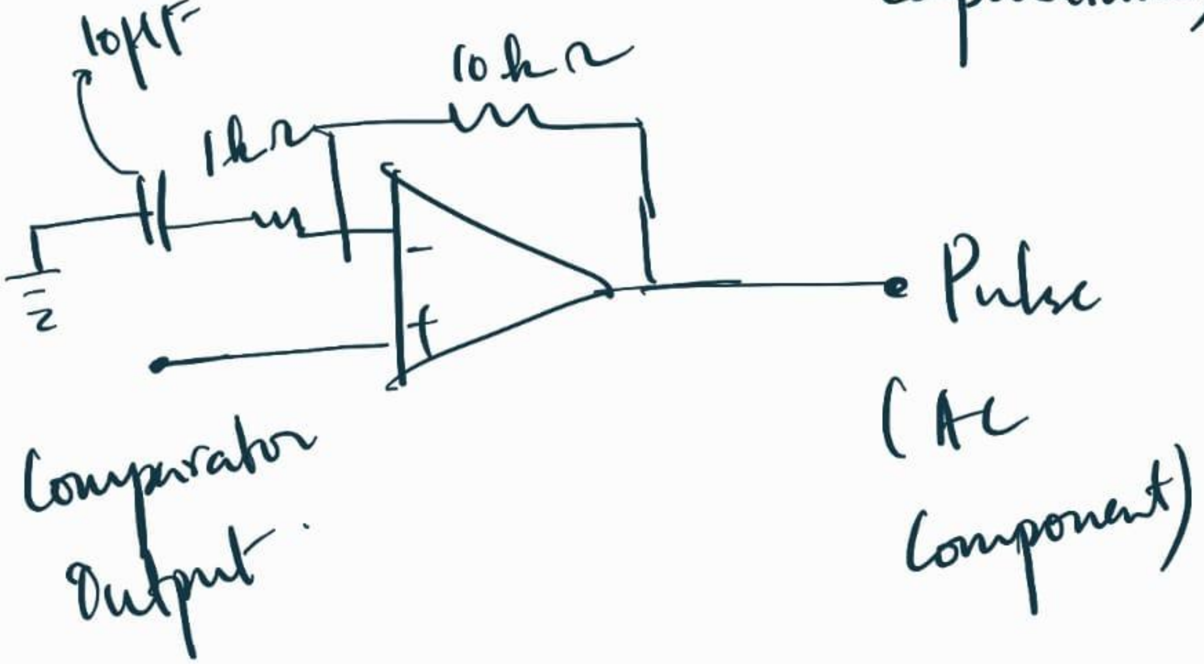


Considering $C = 10 \mu F$,

$$\Rightarrow R = \frac{1}{2\pi (10 \times 10^{-6})(0.8)}$$

$$\Rightarrow \boxed{R \simeq 20k\,\Omega}$$

Non-Inverting Amplifier (with Capacitance)



Progress:

After completing our presentation, we diligently collaborated to finalize the project's block diagram. With careful consideration and detailed discussions, we outlined the essential components and connections that will form the backbone of our project. We dedicated substantial time to sketching the circuit layout, ensuring its functionality aligns seamlessly with our project objectives.

Furthermore, our team has meticulously calculated and determined the approximate values of the various components integral to our circuit design. This meticulous approach not only enhances the efficiency of our project but also lays a strong foundation for successful implementation. We emphasized precision and reliability in selecting these values, aiming to optimize performance and minimize potential errors.

The comprehensive planning stage sets the stage for the subsequent phases of our project, providing a clear roadmap for the development and testing processes. Our meticulous attention to detail and collaborative spirit during this phase demonstrates our team's commitment to delivering a high-quality, well-structured project that aligns perfectly with our goals and expectations.

References

[1] *Edn.com*.Available:https://www.edn.com/simple-pulse-oximetry-for-wearable-monitor/.

[2] M. A. O., "DIY Arduino Pulse Sensor," *Instructables*, 11-Nov-2014. [Online]. Available: https://www.instructables.com/Simple-DIY-Pulse-Sensor/.