Due to the COVID-19 outbreak we will NOT actually build the heart rate monitor. We will only simulate it.

Each student in the class must design a circuit that will allow them to observe their heart beating using an oscilloscope. The heart rate sensor will be provided and the principles of sensor operation will be discussed in class. The output of the sensor is a current and must be converted to a voltage. Since the resulting voltage is quite small, significant amplification will be required. An additional feedback loop will be required to establish an appropriate DC level on the output.

Your output signal should resemble the waveform shown below. The DC level is not important (somewhere between 2 VDC and 3 VDC is certainly acceptable). The idea is that the output waveform be roughly centered between the supply rails. The peak-to-peak amplitude should be between about 1 Volt, but the exact value is not important. All that is really important is that the waveform be easily observable on an oscilloscope and that the peaks are not clipped! If you wish, you can make a LED blink in synchrony with your heart beating.
Learning Objectives:

- Students will learn how to use a reflective optical sensor (TCRT1000 / TCT1010).
- Students will learn how to use a diode-connected transistor to implement automatic gain control (AGC) to deal with the wide variety of user skin types.
- Students will learn how to use op amps and negative feedback to perform voltage amplification.
- Students will learn how to bandlimit signals.
- Students will learn how to implement a negative feedback loop for the purposes of establishing a DC baseline. Students will learn the importance of non-linear signal processing in quickly establishing the output DC baseline.
- Students will learn how to design a modern (low-power, single supply voltage) electronic system operated from a battery. This will entail using both a voltage regulator and a circuit to generate an analog signal ground.

Design Specifications:

- **Your circuit must operate from a single 9 Volt battery.** You must use the LM2931 voltage regulator to produce a 5 Volt supply for the op amps. You will also need to use a TLE2425 bandgap voltage reference which will serve as the analog signal ground (AGND).
- The output waveform should possess a peak-to-peak amplitude of approximately 1 Volt riding on a DC pedestal of approximately 2.5 Volts (+/- 0.5 Volt). Approximately 65 - 70 dB of voltage gain will be needed to achieve this desired output signal level. Your circuit must implement some sort of automatic gain control (AGC) to accommodate a wide variety of skin types.
- The bandwidth of the circuit should be approximately 0.2 Hz to 30 Hz (suggested) but not critical. The important thing is that you have sufficient bandwidth so as not to significantly alter the shape of the heart rate waveform.
- Since the required gain is very high, you will need to cascade two gain stages. The two stages will be implemented using the TLC2274 op amp (included in your parts kit).
- A slow DC offset canceling feedback loop should be added so as to center the waveform about roughly half the supply voltage. The feedback loop should establish the DC baseline on the output quickly (i.e. in less than 3 or 4 seconds) after the user places his finger on the sensor. This can be accomplished through the use of non-linear signal processing.
You must do the following:

a) Design the requested circuit (select appropriate resistor and capacitor values).

b) Simulate your design using SPICE. A MATLAB generated heart beat signal (heart_beat.txt) will be provided to you (via my webpage) for testing your design. You should perform both transient and ac analyses. You should annotate your simulations to demonstrate that all specifications have been met.

Evaluation:

Design report: 100 points

The design report should convince the instructor that you understand the operation of the circuit. You should present simulations that prove that the circuit would work well if it were actually built.

Two online lectures will be devoted to the design of the heart rate monitor (R April 9 and T April 14). You will then have to end of the semester to run the necessary simulations and submit a 3-5 page report due on the last day of the semester (Thursday April 30, 2020).