Lab 14 (Final Project) – Notes

Spring 2024

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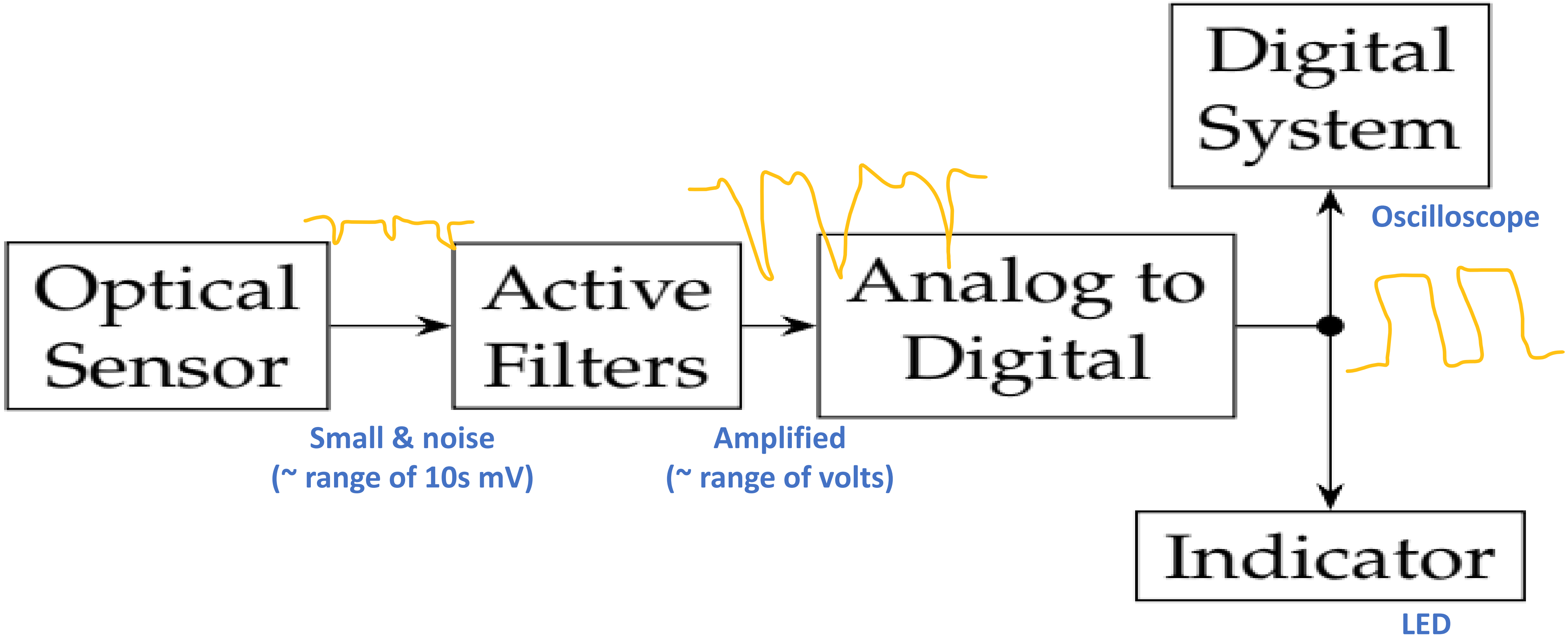
General Notes

- The report for the project is a formal report, please make sure to check the "Project and Formal Report Rubric" in lab 14 on Brightspace, as well as "Lab Report Hot-To-Guide" in lab 1.
- If you are planning on doing the extra credit, then you need to show it during the demo.

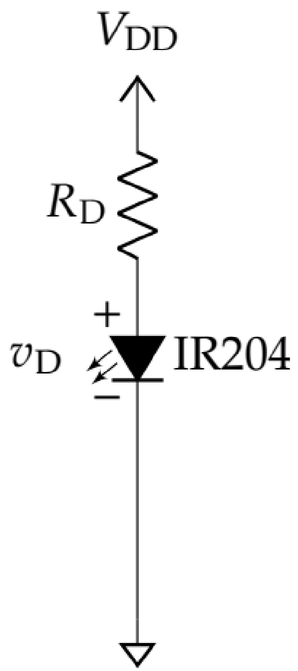


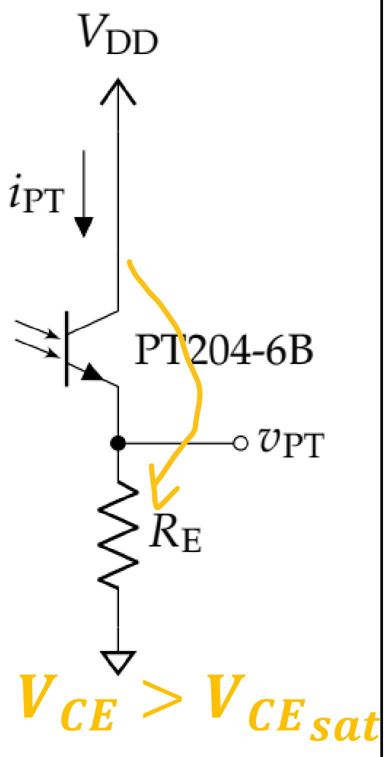
Stage 1: Optical sensor: You need to design RD and RE

LED

- Try to maximize the current flowing through IR204 (check the max current in the datasheet and make sure to be less than that).
- Max power rating of the resistors in your kit is 0.25 W, if the power in RD is higher then you can do one of the following:
  1. Decrease the current (by increasing RD).
  2. Put 2 resistors in parallel or in series to get the required equivalent RD.

$$I_D = \frac{V_{CC} - V_D}{R_D}$$





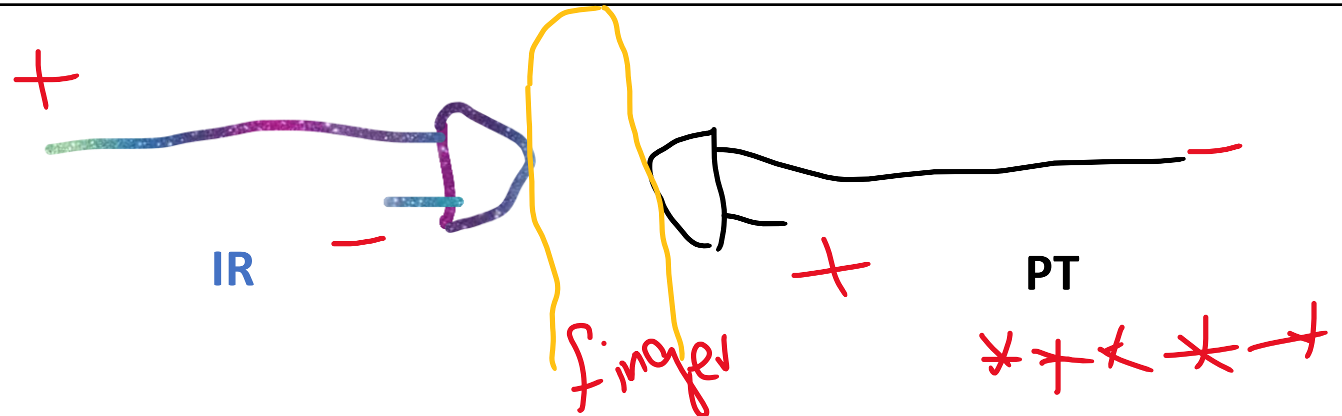
PT

- RE needs to be designed experimentally while your finger is placed.
- The output at v_{PT} is a very small signal AC signal (heartbeat signal) sitting on a large DC offset.
- The goal is to maximize the DC offset which in turn increases the hear beat signal.
- Make sure that the DC voltage < 5- $v_{CE\,sat}$. Check the datasheet for the value of $v_{CE\,sat}$, practically, try to design it to be in the range of 2-4 V. You can do that by changing RE
- The value of RE in lab 13 is a good start.

Stage 1: Optical sensor (Cont'd): You need to design RD and RE

Some useful notes:

- The IR and the PT should be pointing towards each other and your finger should be placed in between.
- Make sure that IR and PT are very close to each other, such that when you place your finger it touches both.
- Try to make the IR and PT to be very close to the bread board, so that when you place your finger in between it rests on the board. This will help to reduce your finger shaking during the measurement.
- It might be helpful to add a scotch tape on the IR and PT to fix them.
- Try different fingers and different orientations.
- It might be helpful to use the shift mode in the oscilloscope.
- Set the time scale to be in the seconds range (the range of the heart beat signal).
- It's very challenging to measure to the heartbeat signal (~10s mV) because it sits on a large DC voltage (~ volts). Try to check first with a large voltage scale (volts/div) to locate the signal, then decrease the scale (and change the offset) till you zoom in and see the heartbeat signal. If you are using the benchtop oscilloscope, it would be helpful to use the AC mode to block the DC offset.
- Try to get an output with an AC signal (heartbeat signal) in the range of 10-100 mV peak to peak.



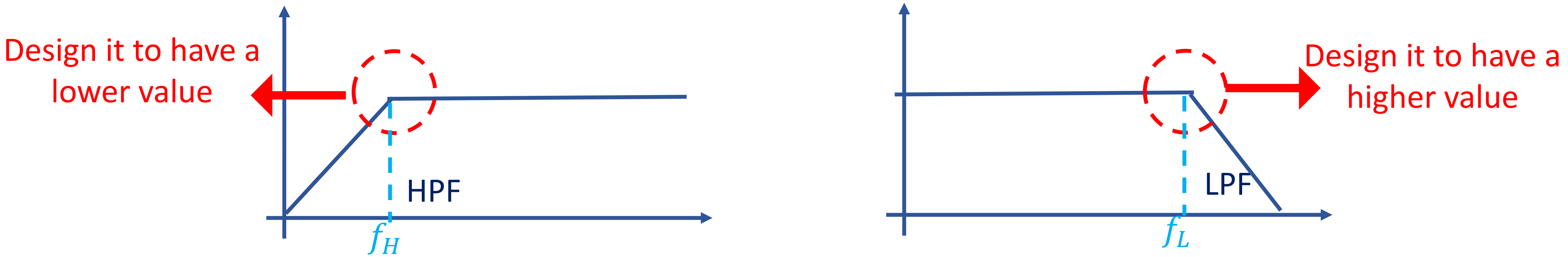
NOTE: That polarity of the PT is reversed

Stage 2: Active Filters: Design HPF + LPF (40-200 BPM)

- Convert the Beats Per Minute (BPM) to frequency (Beats per second) first to be able to design the filters.
- $\boldsymbol{\omega_o = 2\pi f_o}$

Some useful notes:

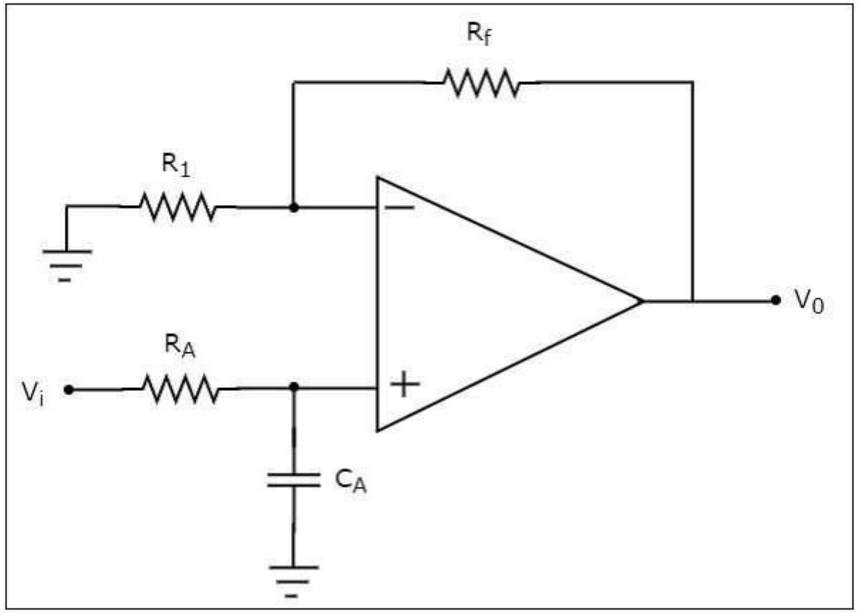
- 1st order filters are sufficient for the project, but you can use 2nd order filters (+ amplifier stage) if you want.
- The non-inverting amplifier configurations might be easier to design because they offer more degrees of freedom.
- Calculate first the total required gain by the filters so that to get an output p-p voltage in the range of voltages after the filters. For example, if you get after the first stage a hearbeat signal with p-p of 50mV and you want the output after the filter to be 5V, then you need a total gain of 5/0.05 = 100.
- $Total\ Gain\ = Gain_{HPF} * Gain_{LPF}.$
- Try to keep the gain in the 2 stages to be balanced.



Stage 2: Active Filters (cont'd): Design HPF + LPF (40-200 BPM)

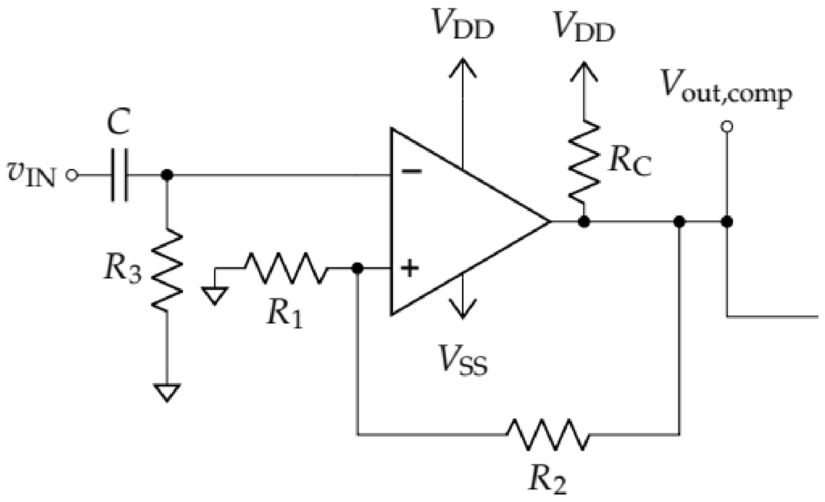
The offset issue:

- Try to keep R1 and RA as close to each other as possible, at least within the same order of magnitude.
- If there is a high mismatch between them, you might find that the output is stuck at +5 or -5 volts due to the high offset.

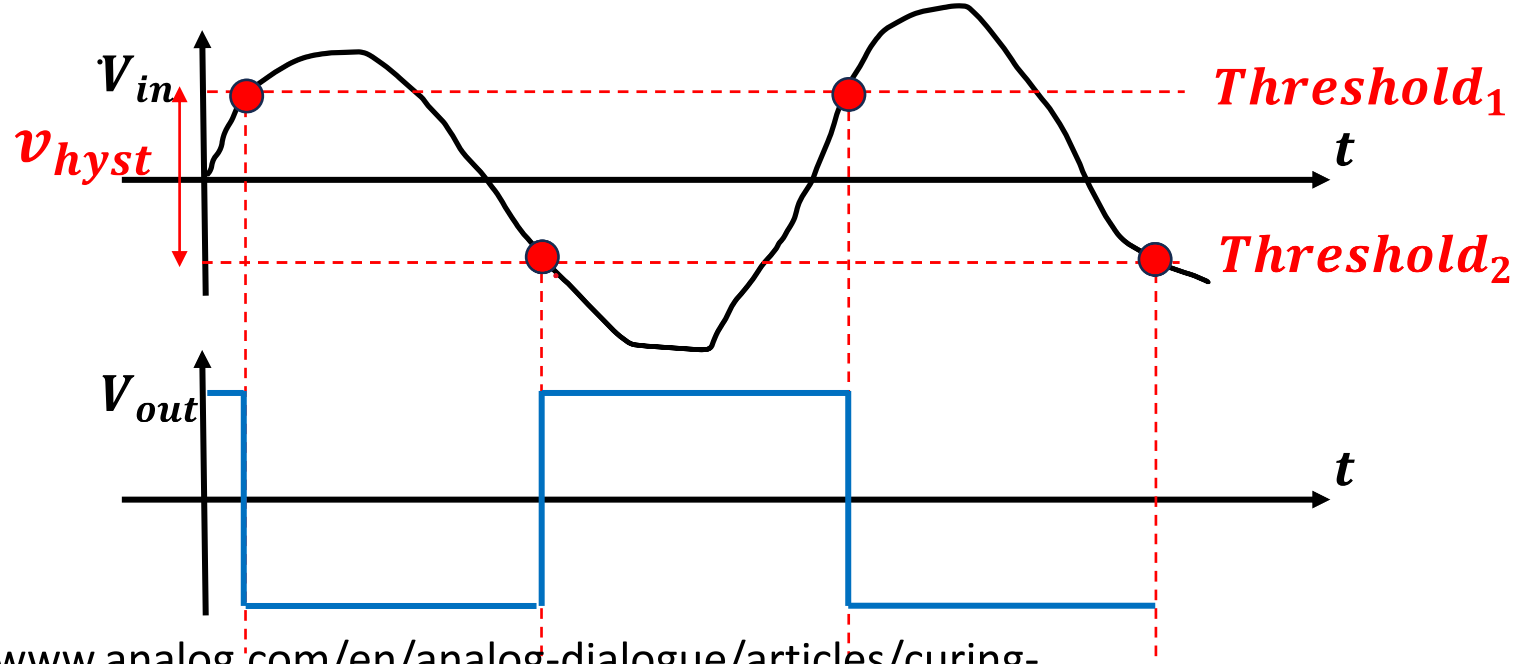


Stage 3: ADC: Design HPF (2-Hz cut off freq.) + v_{hyst}

- v_{hyst} needs to be designed experimentally.
- You need to design v_{hyst} : $Noise\ in\ your\ Heartbeat\ singal < v_{hyst} < Heartbeat\ signal_{PP}$.
- You need to use a comparator (393 or 339).
- $R_C = 1k\Omega$.
- It might be helpful to use either R_1 or R_2 as a potentiometer to tune it till you get a consistent toggling in the output with your heart beat.



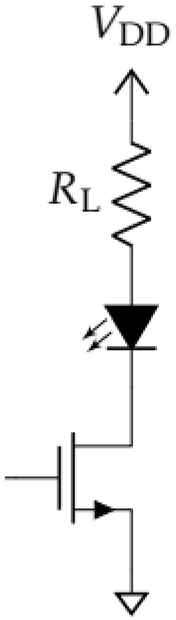
$$v_{hyst} = (V_{DD} - V_{SS})\frac{R_1}{R_1 + R_2}$$



https://www.analog.com/en/analog-dialogue/articles/curing-comparator-instability-with-hysteresis.html

Stage 4: Indicator: Design RL

- Pick an LED with any color that you like.
- Design RL to maximize the current flowing in the LED to appear bright.
- Check the current rating in the “ECE parts kit List” on Brighspace.



Extra credit: Single 5v supply: 20% bump on your grade

- You need to use just one supply +5 from the AD2 to power the whole circuit.
- There are 2 approaches:
  - **A.** **Approach (A) from lab 10:** Design an inverted boost converter to generate the -5v out of the +5v. In this approach you cannot use the function generator to feed the switches, instead, you need to build a 555-timer circuit to generate the square wave, like the one in lab 11, task 1.
  - **B.** **Approach (B) from lab 13:** Add an offset to your signal (to the gnd terminals). This the same as the extra credit part in lab 13, task 2.