EEE208 Project

Photoplethysmography (PPG) Sensor System

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Q1. Explain the working principle of TCRT5000 Reflective Optical Sensor, and how it is used to acquire PPG signal from the body.

An infrared (IR) sensor that is frequently used for proximity sensing and object detection is the TCRT5000 Reflective Optical Sensor. The TCRT5000 emits infrared light from the LED and records any reflected light on its phototransistor. This modifies the current flow between its emitter and collector depending on the amount of light it receives. It may be modified for this purpose even though it is not intended to be used for collecting photoplethysmography (PPG) signals specifically.

The TCRT5000 sensor's operation is based on the detection and reflection of infrared light. An infrared emitter and a phototransistor make up the sensor. When the emitter comes into contact with a surface or an object, the infrared light it generates is reflected back to the sensor. There are other features on this board where you can frequently find it that make it easier to utilize. It also has a potentiometer to allow for sensitivity adjustment and a voltage comparator chip in the form of the LM393. We are given four pins by it. GND, VCC, D0, and A

Through the VCC and Ground pins, we provide a working voltage that ranges from 3.3 to 5 volts. Through one of the two remaining pins, we get sensor data.

A constant readout in the form of fluctuating voltage is provided by the analogue pin A0; the greater the voltage, the more infrared light is being picked up.

The transmissive mode of the TCRT5000 sensor may be utilized to obtain a PPG signal from the body. In this mode, a light source, usually an LED, is mounted on the side opposite from the body part's sensor (such as the finger or earlobe). The phototransistor in the TCRT5000 sensor detects the LED light after it has passed through the body portion.

Blood flow through the body's arteries creates differences in the volume of blood present in the vessels, which affects how well the tissue reflects and absorbs light. These alterations, which are connected to the cardiac cycle, can be found as PPG signals. The pulsatile variations in blood volume are represented by the PPG signal.

The infrared light generated by the LED in the TCRT5000 sensor travels through the affected body part and is partially absorbed by the blood in the arteries. The blood volume and its changes determine how much light reaches the phototransistor in the sensor. In order to extract the PPG waveform, an electrical signal must first be created by the phototransistor from the incoming light.

It's crucial to remember that while the TCRT5000 sensor may record PPG signals, its findings might not be as precise or dependable as those from PPG sensors created especially for this use. The fact that this sensor is easily influenced by external factors is a significant disadvantage. The sensor may be tampered with by any additional infrared light source, including home lights and sunlight.

Q2. Derive the transfer function of the second order bandpass filter when the output is taken from the ANALOG_OUT pin shown in Figure 7. (Assume that the operational amplifiers are ideal and the reference level construction with the two diodes is omitted). Plot the frequency response of this filter in MATLAB.

The transfer function of the filter permits signals with frequencies lower than the higher cutoff frequencies and attenuates signals with frequencies greater than when the output is an active bandpass filter of the second order sort. The frequency range within which a bandpass filter allows a signal to pass is referred to as the band with.

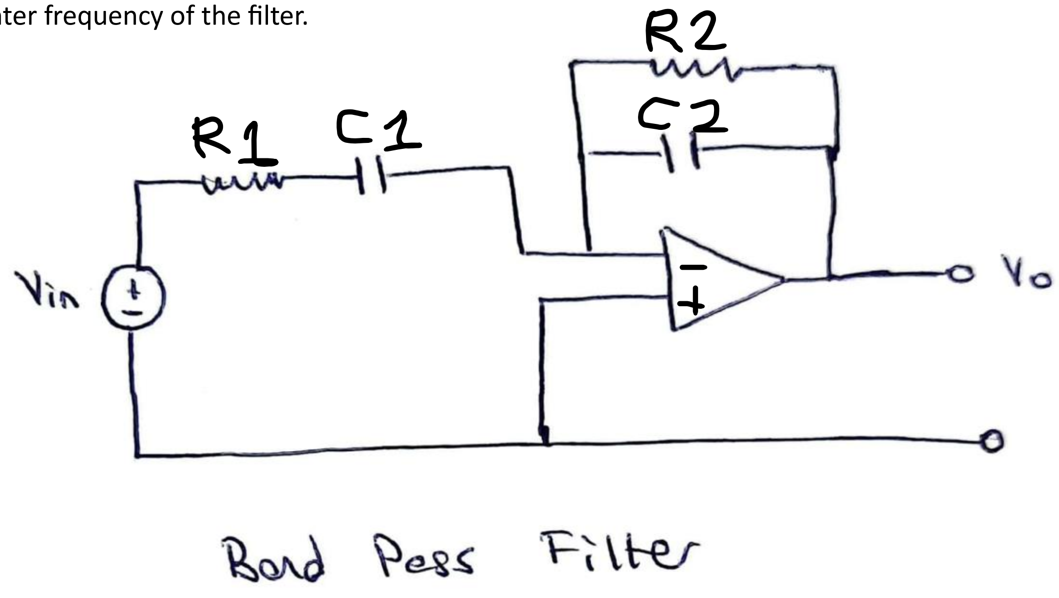
$$H(jw) = \frac{Z_2}{Z} = -\frac{R_2}{\left(R_2 + \frac{1}{jwC_2}\right)\left(R_1 + \frac{1}{jwC_1}\right)}$$

$$= \frac{\frac{R_2}{jwC_2}}{\left(\frac{R_2 jw C_2 + 1}{jwC_2}\right)\left(\frac{R_1 jwC_1 + 1}{jwC_1}\right)}$$

$$= \frac{R_2 jw C_1}{j(1 + jwC_2 \cdot R_2)(1 + jwC_1 R_1)}$$

$$= -\frac{jw C_2}{(1 + jwC_2)(1 + jwC_1)}$$

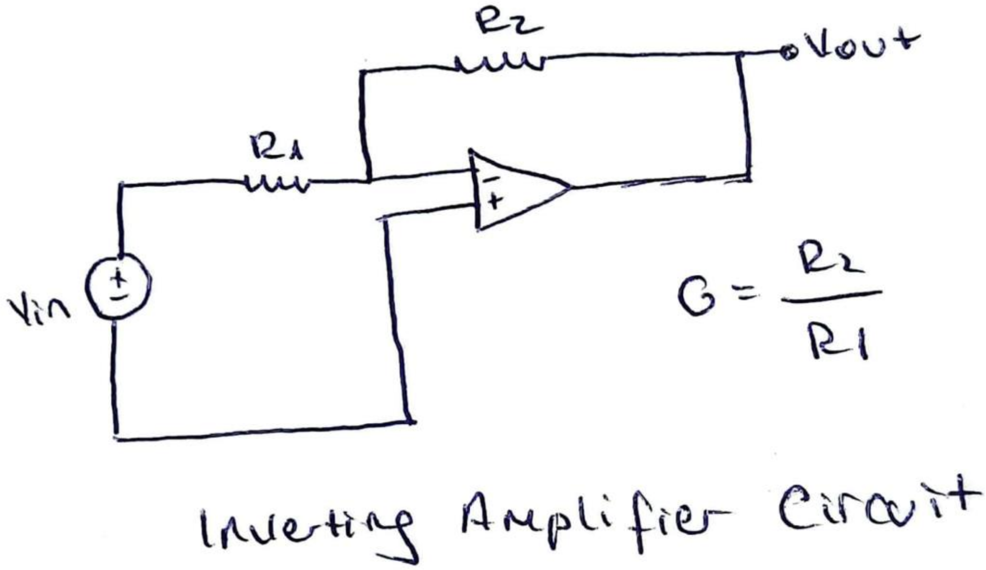
Two reactive components are incorporated into the circuit of an active band pass filter, a 2nd order type filter. These two reactive components will result in a peak value or resonance frequency at the center frequency of the filter.



The mentioned transfer function is of the second order, and as a result, the system is known as a second order system. Whenever a second order system's impulse response has two fictitious roots;

There are two different types of op-amps. There are two different kinds of power supplies for op-amps with a single supply: single and dual. Vcc is positive when applied to dual supply op-amps in terms of GND.

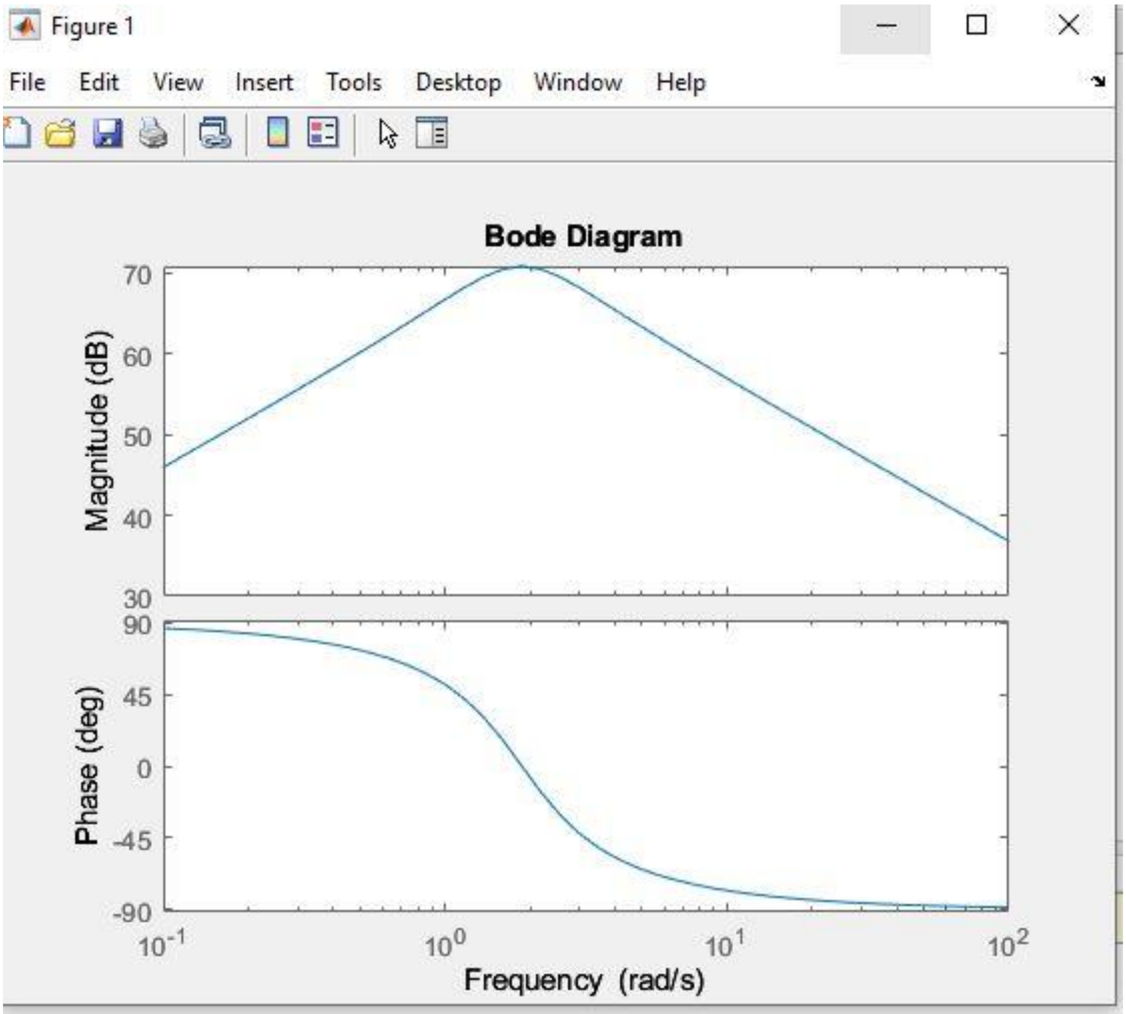
GND is opposed by Positive and Vee. Weak electric impulses are capable of being amplified by an integrated circuit known as an operational amplifier. An operational amplifier consists of one output pin and two input pins. Its major function is to output the voltage difference between the two input pins after being amplified.



MATLAB Code:

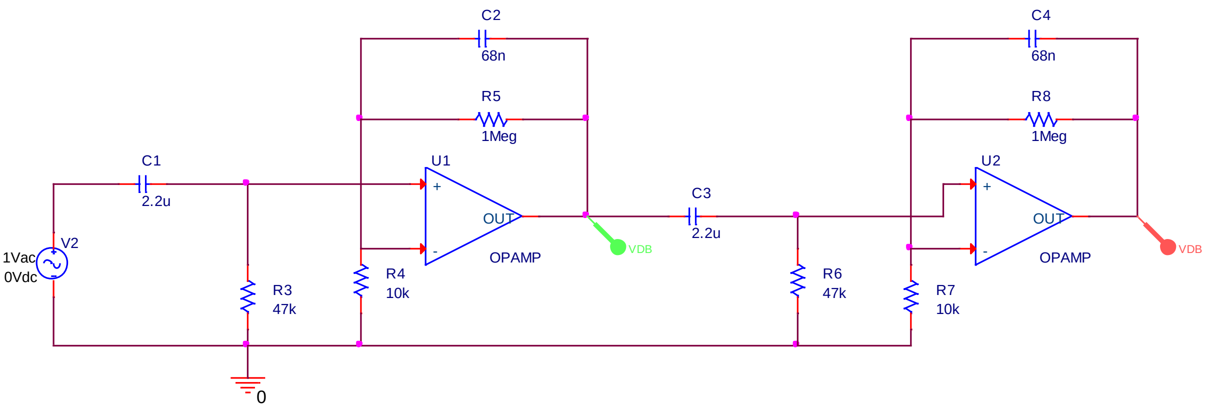
```
R1 = 10e3;
R2 = 47e3;
R3 = 100e3;
C1 = 2.2e-6;
C2 = 68e-9;

num = [3700 / 1.8708, 0];
den = [1 / (1.8708 * 1.8708), 1 / (0.9354 * 1.8708), 1];

sys = tf(num, den);
bode(sys)
```

MATLAB Graph:

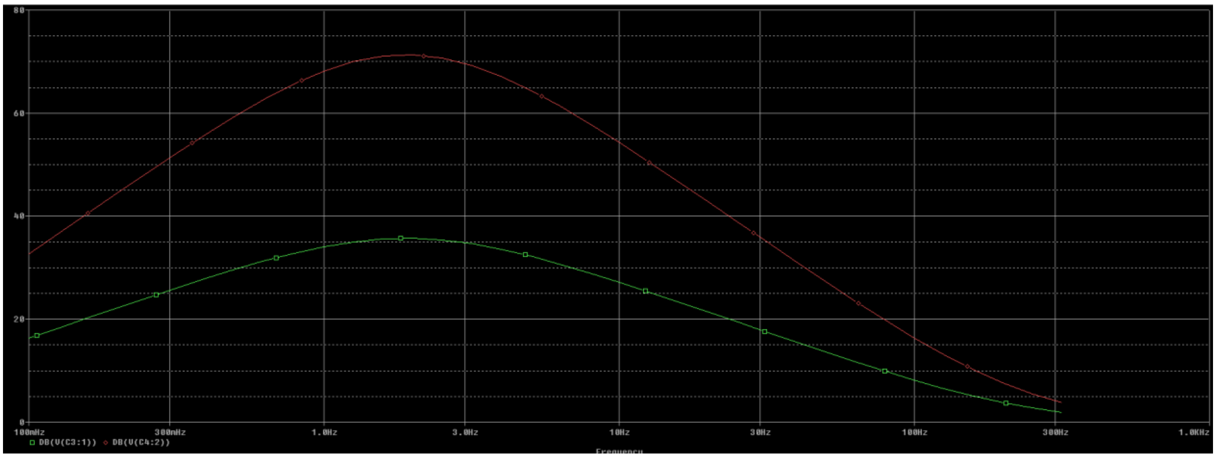


Q3. Plot the frequency response of this bandpass filter by performing AC Sweep Analysis in OrCAD/PSpice.

Schematic:

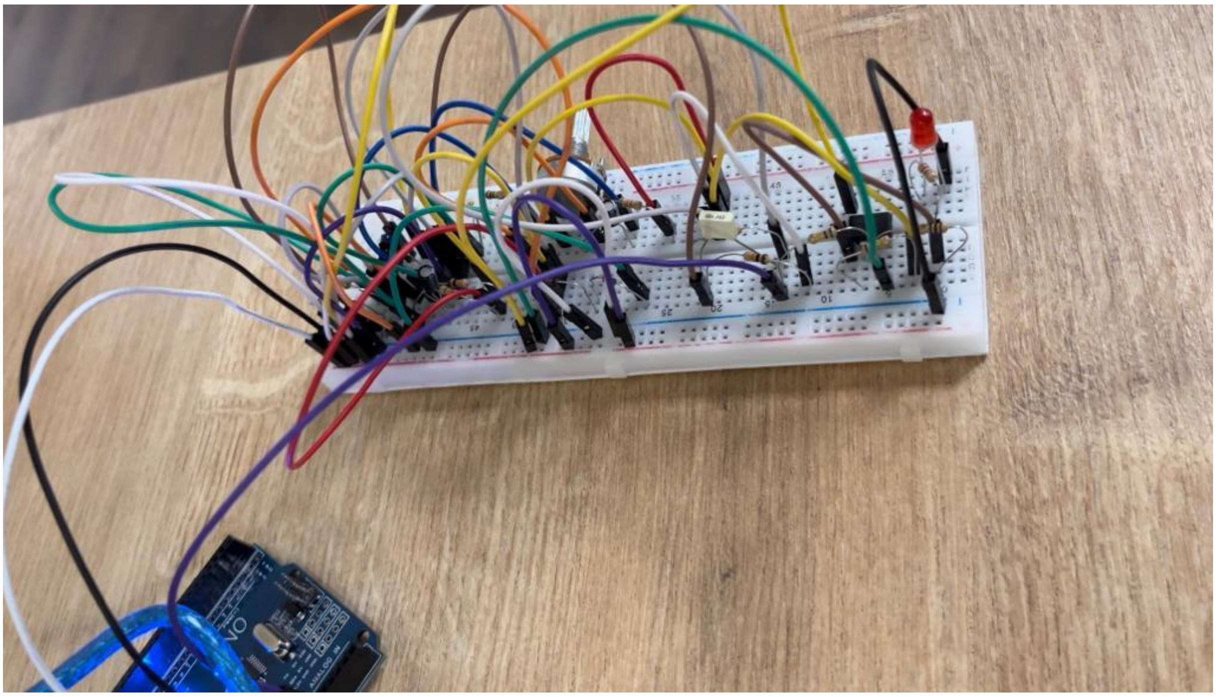


Simulation:

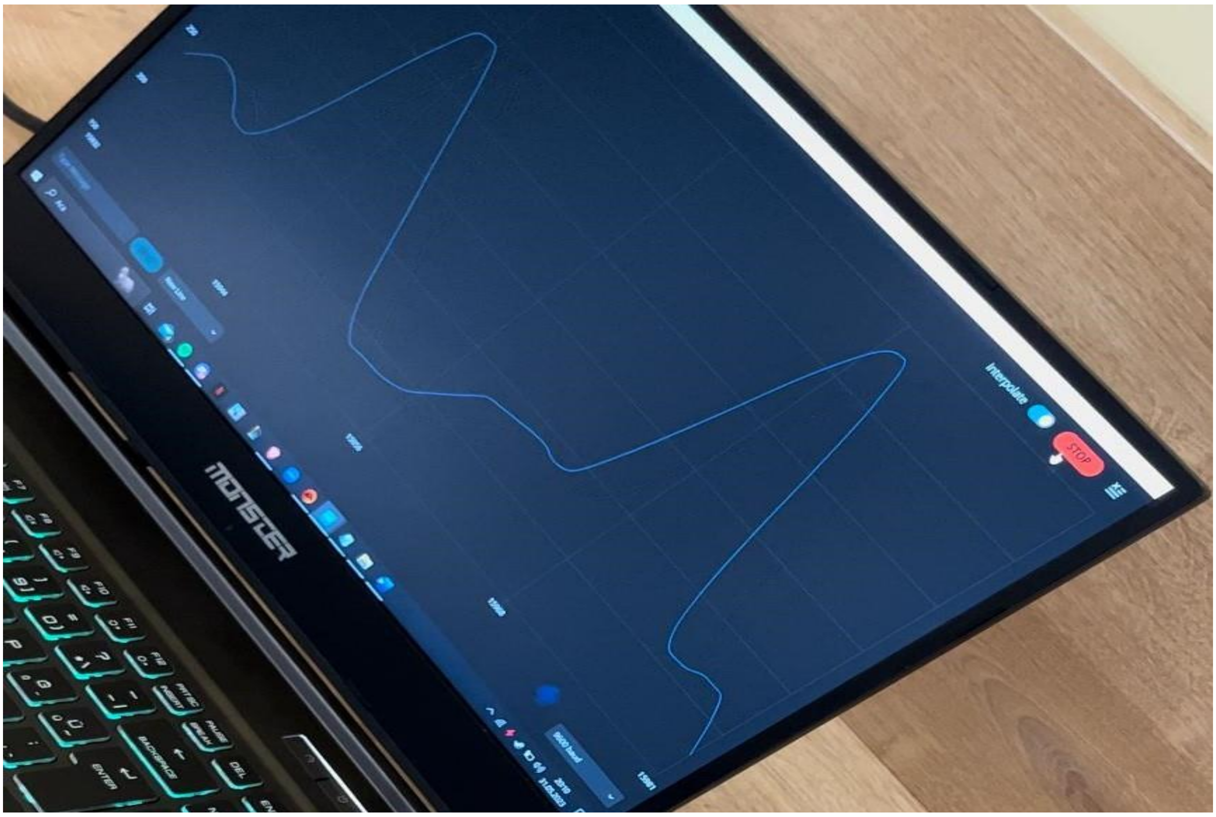


Q4. Build the complete PPG circuit (Fig. 7) on breadboard and read the PPG signal of a subject using an Arduino Uno. Please include the waveform in your project report. (Hint: You may use the code given in Figure 10).

Breadboard:



Output:

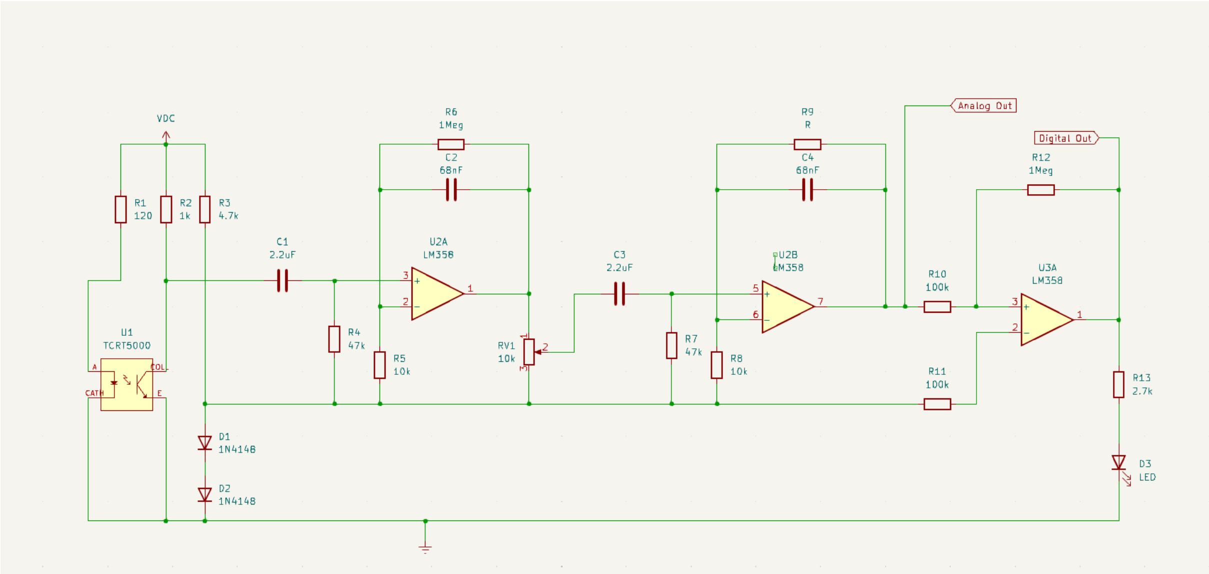


Breadboard and Output Video:

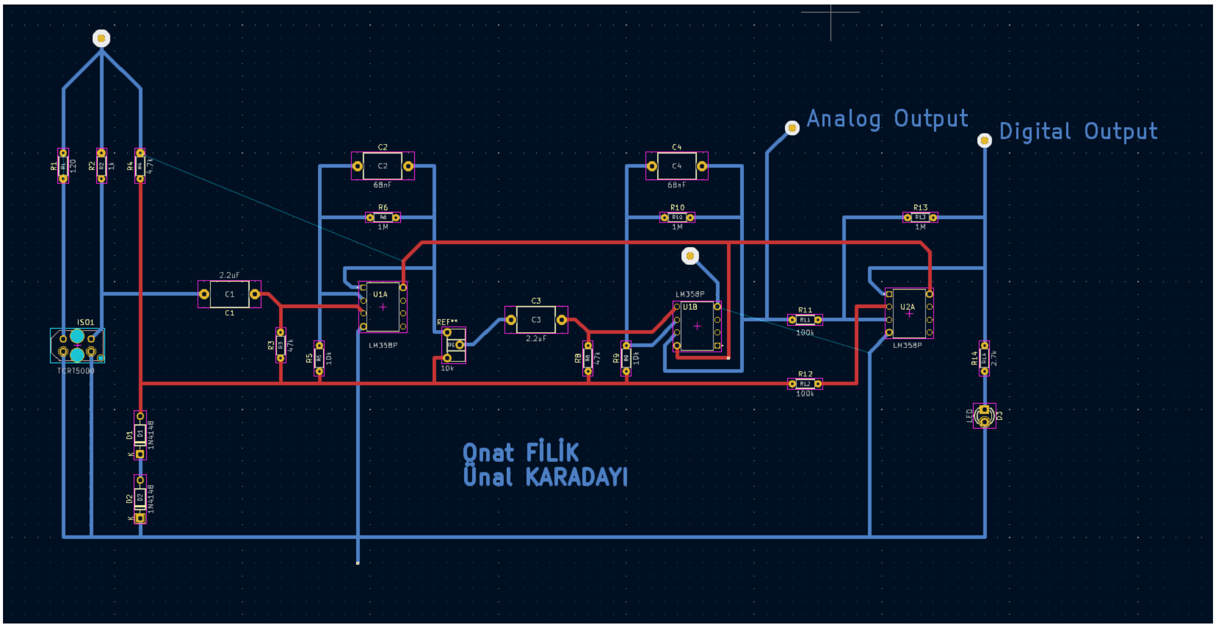
EEE208ONATUNAL.mp4

Q5. Discuss the steps of PCB (Printed Circuit Board) design and manufacturing process, and provide your KiCad schematic diagram and PCB layout for the whole PPG circuit.

Schematic:



PCB View:



PCB 3D View: