NATIONAL INSTITUTE OF TECHNOLOGY TIRUCHIRAPPALLI –15

ECLR12: ELECTRONIC CIRCUITS LABORATORY

Project Report

CONTACTLESS ELECTRONIC THERMOMETER

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ABSTRACT

The year 2020 saw one of the worst nightmares of humanity come true, a global widespread pandemic killing millions of people. With no proper treatment yet to be discovered for COVID it has become a social responsibility to stop further spread of corona virus.

Lockdown and social distancing are the best precautions against COVID-19, but the adverse economic impact of lockdown cannot be neglected.

Indian government is slowly lifting the restrictions imposed on its citizen, it has become important for organisations to separate potential COVID patients from the bulk. Elevated body temperature is one of the early signs of corona and isolation of people with elevated body temperature can help in breaking the transmission chain of Corona. Current thermal screening measures require an operator, and this puts the operator in greater risk of getting infected.

For the project we are planning to build an Automatic COVID Thermal Screener. The screener can be deployed at entry points of public places and it will detect a person's temperature automatically as he/she approach it. If the person's body temperature is more than the recommended body temperature by WHO the officials will be alerted and the entry will be denied. Unlike the existing screening methodologies this technology doesn't require an operator which further reduces the likeliness of disease transmission. With this project we intend to help our frontline workers who put their lives at risk to keep us protected and safe.

COMPONENTS

I. Operational Amplifiers (OP2177, AD8698, OP1177) /INA333 -

II. Resistors R1 15OKΩ
R2, R3, R4, R5 50kΩ
R6 0.5kΩ
R8, RG/2 10kΩ

III. CAPACITOR C1-C2 0.1μF
C3-C4

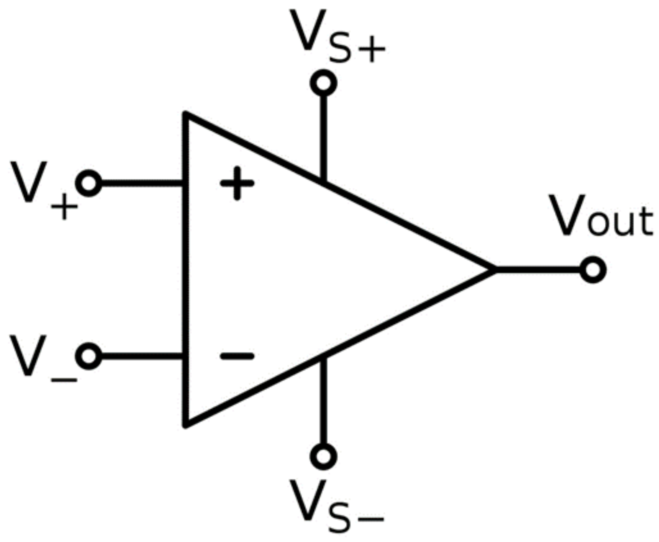
IV. VU METER - -

V. THERMOPHILE SENSOR MLX90247

VI. THERMISTOR - -

VII. Battery - 9V

OPERATIONAL AMPLIFIERS

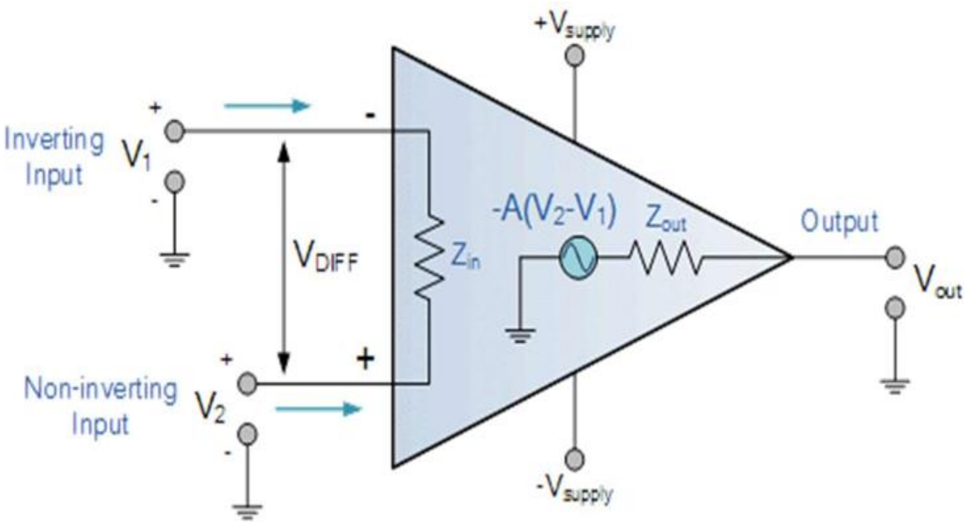


An operational amplifier is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op amp produces an output potential (relative to circuit ground) that is typically 100,000 times larger than the potential difference between its input terminals. Operational amplifiers had their origins in analog computers, where they were used to perform mathematical operations in linear, non-linear, and frequency-dependent circuits. The popularity of the op amp as a building block in analog circuits is due to its versatility. By using negative feedback, the characteristics of an op amp circuit, its gain, input and output impedance, bandwidth etc. are determined by external components and have little dependence on temperature coefficients or engineering tolerance in the op amp itself. Op amps are used widely in electronic devices today, including a vast array of consumer, industrial, and scientific devices. Many standard IC op amps cost only a few cents; however, some integrated or hybrid operational amplifiers with special performance specifications may cost over US$100 in small quantities. Op amps may be packaged as components or used as elements of more complex integrated circuits.

The op amp is one type of differential amplifier. Other types of differential amplifier include the fully differential amplifier (similar to the op amp, but with two outputs), the instrumentation amplifier (usually built from three op amps), the isolation amplifier (similar to the instrumentation amplifier, but with tolerance to common-mode voltages that would destroy an ordinary op amp), and negative-feedback amplifier (usually built from one or more op amps and a resistive feedback network). Slew rate is defined as the maximum rate of change of an op amp's output voltage and is given units of volts per microsecond.

The operational amplifier is arguably the most useful single device in analog electronic circuitry. With only a handful of external components, it can be made to perform a wide variety of analog signal processing tasks. It is also quite affordable, most general-purpose amplifiers selling for under a dollar apiece. Modern designs have been engineered with durability in mind as well: several "op-amps" are manufactured that can sustain direct short-circuits on their outputs without damage.

One key to the usefulness of these little circuits is in the engineering principle of feedback, particularly negative feedback, which constitutes the foundation of almost all automatic control processes. The principles presented in this section, extend well beyond the immediate scope of electronics. It is well worth the electronics student's time to learn these principles and learn them well.



EQUIVALENT CIRCUIT OF THE OPERATIONAL AMPLIFIERS

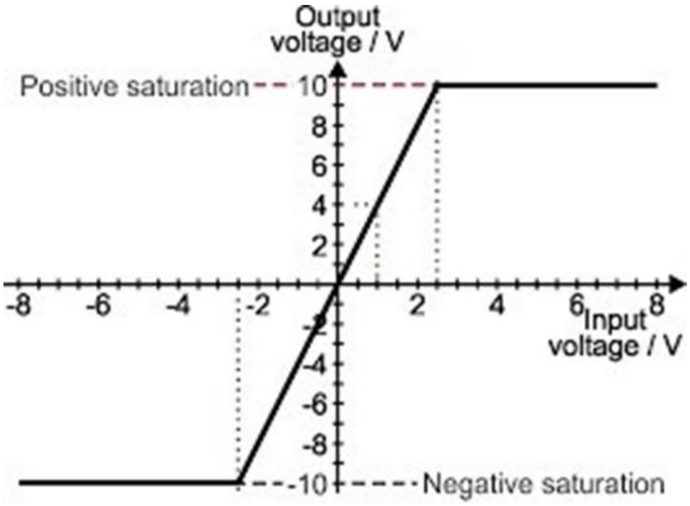
Input Impedance of the ideal OpAmp is = ∞

Output Impedance of the ideal OpAmp is = 0

Gain of ideal OpAmp is =∞

Slew rate of ideal OpAmp=∞

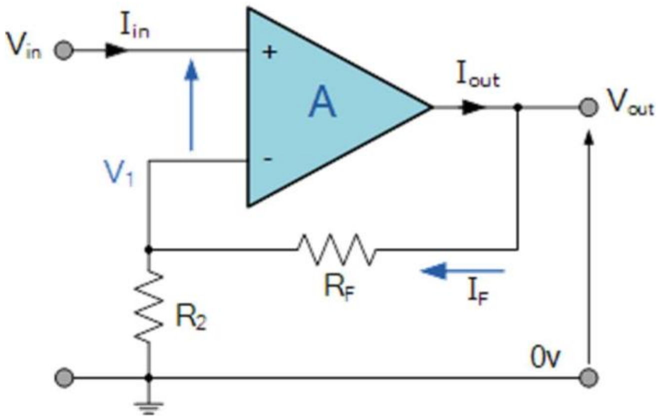
REAL OPERATIONAL AMPLIFIERS



Gain of ideal OpAmp is =10 to 10

However, this very high gain is of no real use to us as it makes the amplifier both unstable and hard to control as the smallest of input signals, just a few micro-volts, (μV) would be enough to cause the output voltage to saturate and swing towards one or the other of the voltage supply rails losing complete control of the output.

Non-inverting Operational Amplifier Configuration



"No current flows into the input terminal" of the amplifier and that "V1 always equals V2". This was because the junction of the input and feedback signal (V1) are at the same potential.

$$V_1 = \frac{R_2}{R_2 + R_F} \times V_{OUT}$$

Ideal Summing Point: $V_1 = V_{IN}$

Voltage Gain, $A_{(V)}$ is equal to: $\frac{V_{OUT}}{V_{IN}}$

Then, $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = \frac{R_2 + R_F}{R_2}$

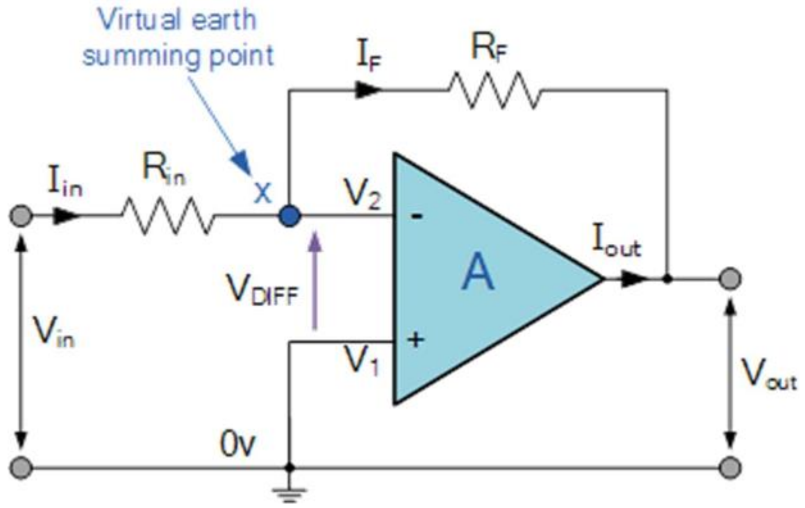
Transpose to give: $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_2}$

$$A_{(v)} = 1 + \frac{R_F}{R_2}$$

So, by giving the negative feedback to the OpAmp we can control the gain of the OpAmp by varying the applied resistors externally, and the output and the input signals are in the same phase.

The input Impedance of the Non-inverting Operational Amplifier Configuration is very high (infinity in ideal case) but if we used the Inverting Operational Amplifier Configuration then the input impedance is dependent upon the applied resistors which is not ideal.

Inverting Operational Amplifier Configuration



Negative Feedback is the process of “feeding back” a fraction of the output signal back to the input, but to make the feedback negative, we must feed it back to the negative or “inverting input” terminal of the opamp using an external Feedback Resistor called Rf. This feedback connection between the output and the inverting input terminal forces the differential input voltage towards zero.

In this Inverting Amplifier circuit, the operational amplifier is connected with feedback to produce a closed loop operation. When dealing with operational amplifiers there are two very important rules to remember about inverting amplifiers, these are: “No current flows into the input terminal” and that “V1 always equals V2”. However, in real world op-amp circuits both of these rules are slightly broken.

This is because the junction of the input and feedback signal (X) is at the same potential as the positive (+) input, which is at zero volts or ground then, the junction is a “Virtual Earth”. Because of this virtual earth node, the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors.

$$i = \frac{Vin - Vout}{Rin + Rf}$$

$$\text{therefore, } i = \frac{Vin - V2}{Rin} = \frac{V2 - Vout}{Rf}$$

$$i = \frac{Vin}{Rin} - \frac{V2}{Rin} = \frac{V2}{Rf} - \frac{Vout}{Rf}$$

$$\text{so, } \frac{Vin}{Rin} = V2\left[\frac{1}{Rin} + \frac{1}{Rf}\right] - \frac{Vout}{Rf}$$

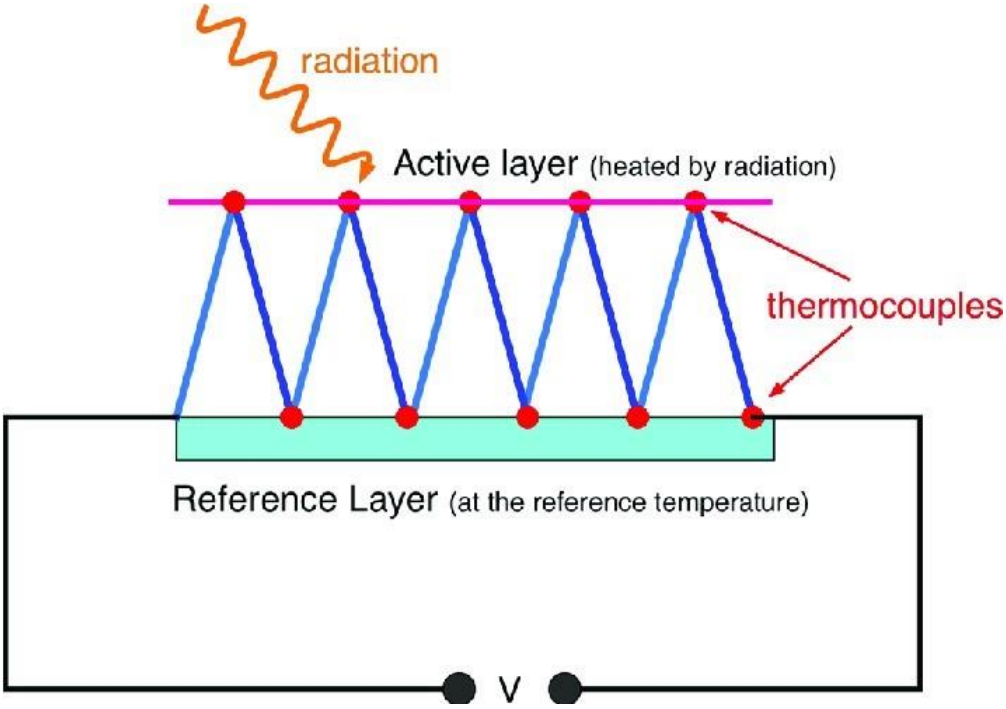
$$\text{and as, } i = \frac{Vin - 0}{Rin} = \frac{0 - Vout}{Rf} \qquad \frac{Rf}{Rin} = \frac{0 - Vout}{Vin - 0}$$

$$\text{the Closed Loop Gain (Av) is given as, } \frac{Vout}{Vin} = -\frac{Rf}{Rin}$$

The Closed-Loop Voltage Gain of an Inverting Amplifier is given as:

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

Thermopile Sensor



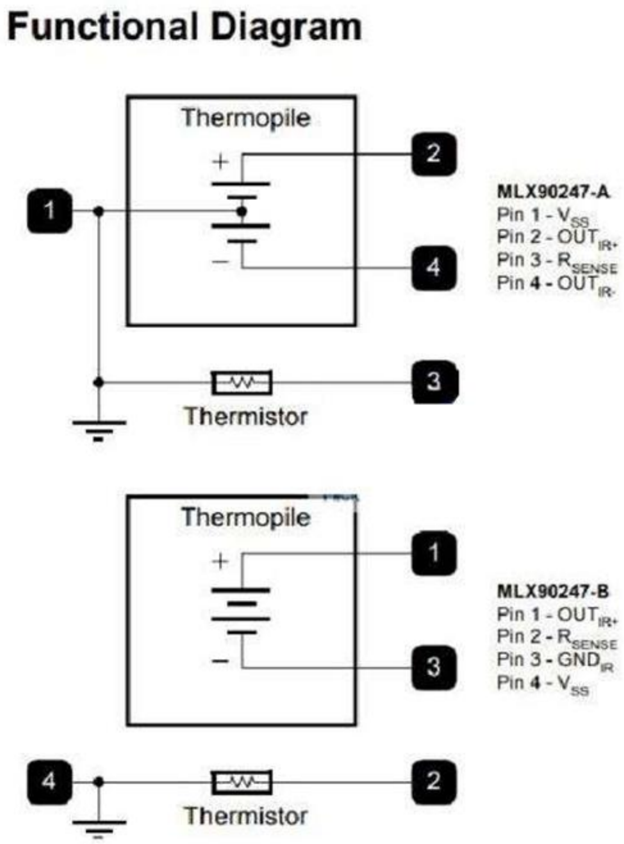
The IC MLX90247 is an excellent example of a versatile thermopile sensor device which can be ideally used for making a thermal scanner device or a contactless thermometer device.

The heat receptive junctions of the thermocouple are strategically positioned near the centre of the base membrane, while the differential cold junctions are placed at edge of the device which form the silicon bulk area of the unit.

Since the membrane is designed to be a bad conductor of heat, the detected heat from the source can rise quickly near the membrane centre than the bulk edge of the device.

Due to this a quick difference of heat is able to develop across the thermopile junction ends causing an effective electrical potential to develop across these terminals through thermo-electric principle.

The best part of the thermopile sensor is that, unlike standard ICs it does not require an external electrical supply to work, rather it generates its own electrical potential for enabling the required measurement.



In the above IC MLX90247, we can see a thermistor being included in the device package. The thermistor plays an important role in creating a reference level output for the external measuring unit stage.

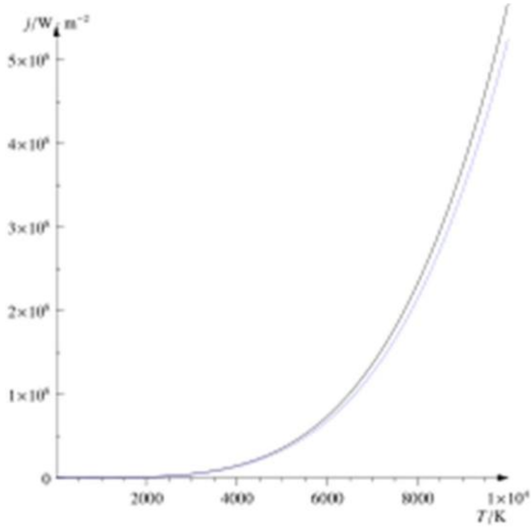
The thermistor is incorporated to detect the ambient temperature or the body temperature of the device. This ambient temperature level becomes the reference level for the output op amp stage.

long as the IR temperature from the target is below or equal to this reference level, the external op amp amplifier stage does not respond, and its output remains 0 V.

However, as soon as the IR radiance from the body goes past the ambient temperature, the op amp begins responding to produce a valid measurable output which linearly corresponds with the rising thermal output of the body.

PRINCIPLE

Stefan–Boltzmann Law



The Stefan–Boltzmann law describes the power radiated from a black body in terms of its temperature. Specifically, the Stefan–Boltzmann law states that the total energy radiated per unit surface area of a black body across all wavelengths per unit (also known as the black-body radiant emittance) is directly proportional to the fourth power of the black body's thermodynamic temperature T:

$$E(T) = \varepsilon\, \sigma \boldsymbol{T^4}$$

ε signifies the emissivity.

σ denotes the Stefan–Boltzmann constant which is equivalent to the quantity:

$$\sigma = \frac{2\pi^5 k^4}{15c^2 h^3} = 5.670373 \times 10^{-8}\ \mathrm{W\,m^{-2}K^{-4}},$$

The above equation suggests that when the temperature of a body rises, its infrared radiance also increases proportionately. This IR radiance could be measured from a distance without the need of any physical contact. The reading can provide us with the instantaneous temperature level of the body.

WORKING

The basic principle of the project is to detect the Energy Radiated by the body (given by Stefan–Boltzmann Law) using a Thermopile Sensor and amplify the output analog signal using a OpAmp to the desired output analog signal and then using a millivolt VU meter or a digital mV meter for getting an instant interpretation of the temperature level of the body.

The potential generated by the Thermopile Sensor is very small but OpAmp having very high gain can amplify the signal to the desired output which the VU meter can detect.

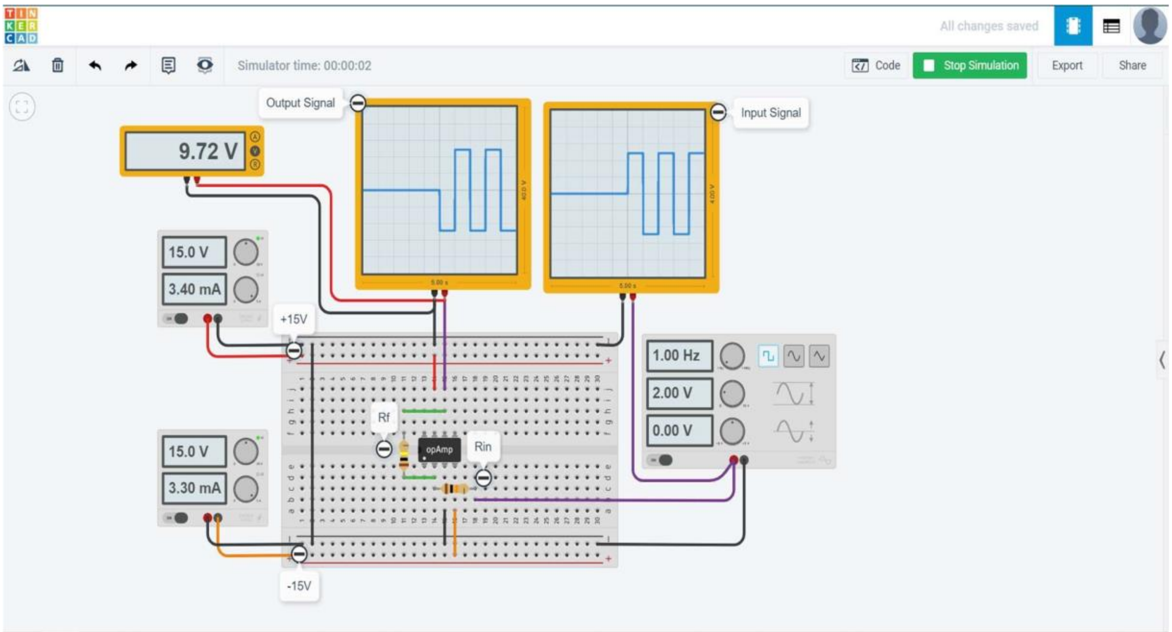
The OpAmp has very high gain but the output signal very quickly saturates to the applied voltage and hence the linear variation of the input and output signal is lost. Hence, we use the OpAmp in the Noninverting Operational Amplifier Configuration to ensure the linear variation of the input and output signal, in which the gain of the OpAmp is controlled by the resistance of the Resistor applied.

SIMULATIONS

Inverting Operational Amplifier Configuration

(TinkerCad)

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$



Input Signal Amplitude (Vin)=1V

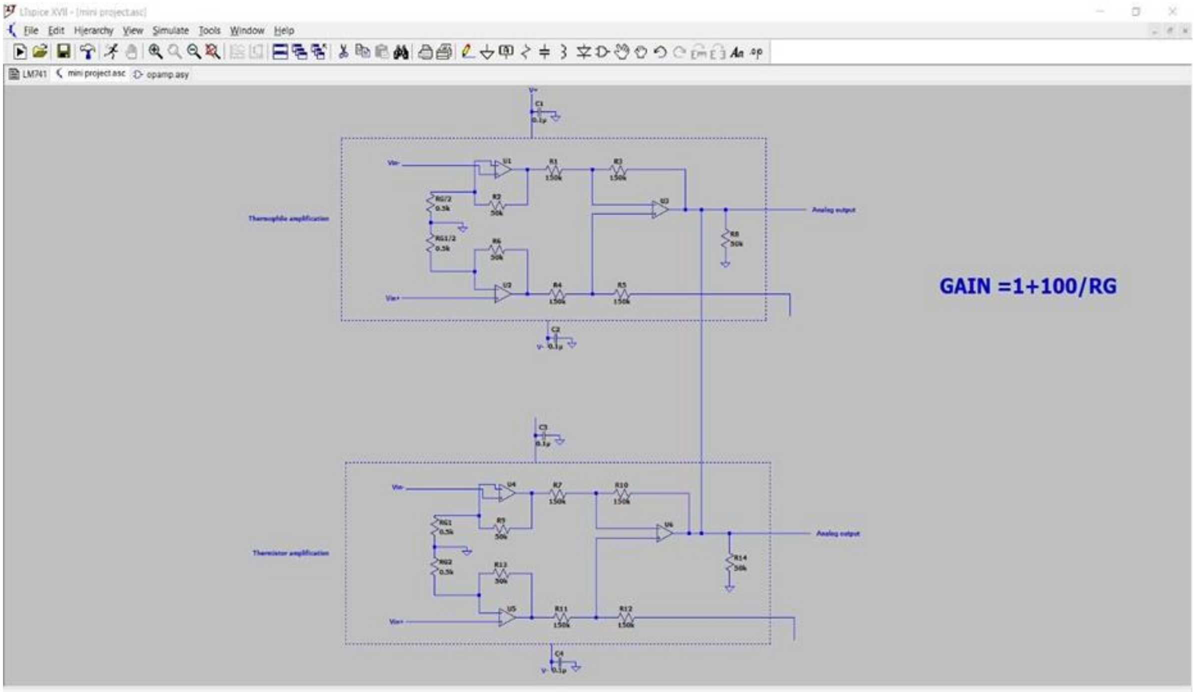
Rf=100KΩ Rin=10KΩ

Gain=1+(100/10) =11

Output Signal Amplitude=11V

(input and output signals are in phase)

CIRCUIT DIAGRAM FOR THE PROJECT



RESULT

Our project tends to help our COVID warriors in these unprecedented times and our primary goal was to bring down the cost of the existing thermal screener. Other methods of making a thermal screen requires an Arduino setup which reduces the complexity of the project but also increases its cost. With this project we intend to help the people who are putting the lives at threat to help the community overcome from this global pandemic. This solution requires calibration but once calibrated it can be used foolproofly. Our Project is easy to use and does not require any training and the complexity of the device is hidden from the user which improves the user experience. The Thermopile Sensor gives pretty good accuracy and can detect change in thermal temperature accurately.

We highly intend to encourage people to wear mask and maintain social distancing and get themselves tested if the symptoms of COVID arises