EE 204 - Analog Circuits
Lecture 20

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Contents

1 Overview

In the previous lecture, we discussed the Temperature Controller using a Darlington Pair, also known as the ON/OFF controller.

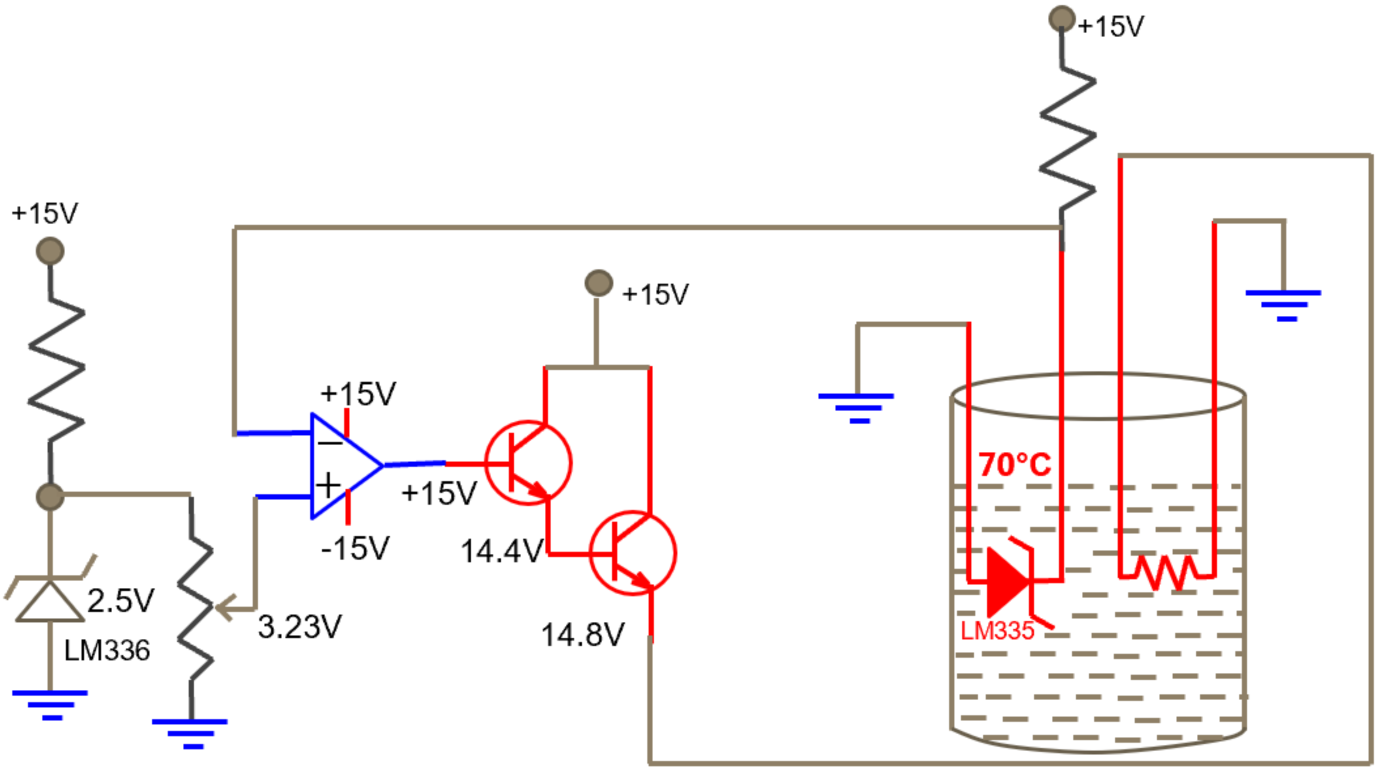
In this lecture, we discussed the Proportional Temperature Controller. A proportional temperature controller, which, as against the normal temperature controller, caused proportional changes in the supply voltages to the temperature regulators.

We first go over the ON/OFF controller and then proceed to analyse the Proportional Controller.

2 Temperature Controller using Darlington Pair

The ON/OFF controller works on the following principle that when the temperature is low the heater is switched **ON** and when the temperature is high the heater is switched **OFF**

The controller looks like the following -



This controller is also called as an **ON/OFF controller**.

3 Proportional Temperature Controller

The Proportional controller works on a logic very different from the ON/OFF controller.

For a proportional temperature controller, Heater voltage is proportional to the error, where the error is defined as the set temperature minus the actual temperature.

This leads to more efficient performance and lesser power consumption.

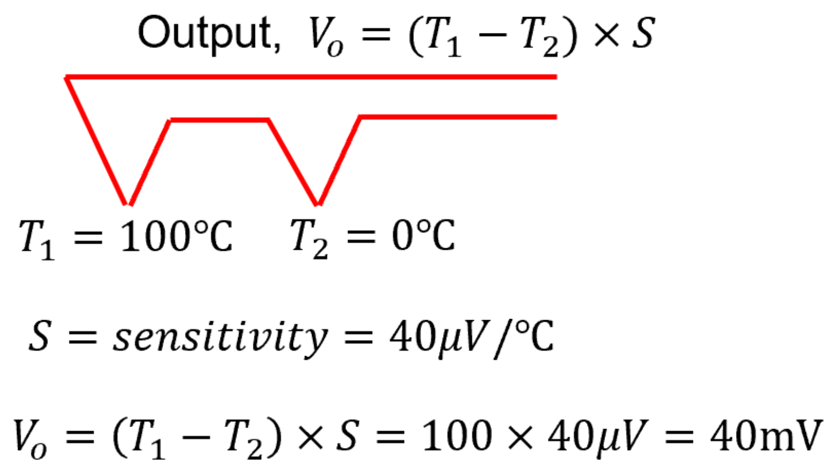
For the proportional temperature controller, we use a thermocouple. Hence, understanding the device properties of Thermocouple is important.

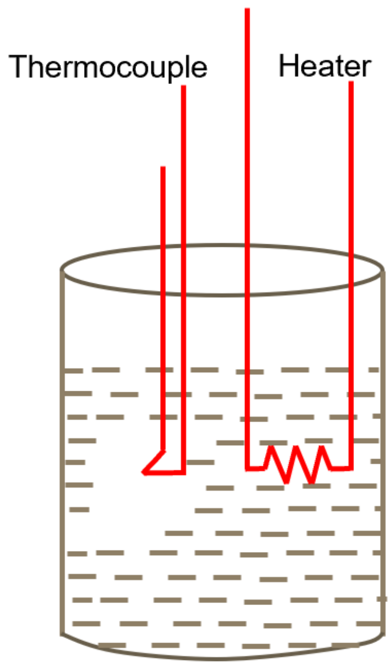
4 Thermocouple

The thermocouple is a simple device having one or two junctions made up of different metals, which when submerged or are brought in contact with bodies at different temperatures, measures the temperature difference between them.

This device is used in this controller, as here, we are concerned with the difference in temperature of our body with the parameter we have set, and not very concerned with the absolute value of the temperature.

We only care about the deviation of the body temperature from the desired temperature, and hence this sensor is preferred over the LM-335 sensor.



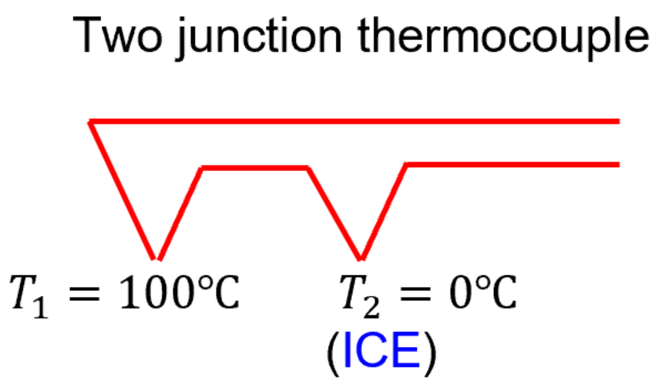


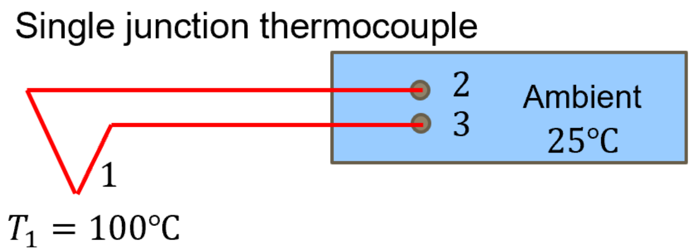
The thermocouple has a parameter known as the sensitivity, which is ideally $40\mu V/°C$. This parameter is in essence similar to the temperature coefficient of the LM-335 sensor, which had a temperature coefficient of $10mV/K$

4.1 Single Junction Thermocouple

There is also a single junction thermocouple which has only one junction.

The function of the other junction is done by the room temperature.



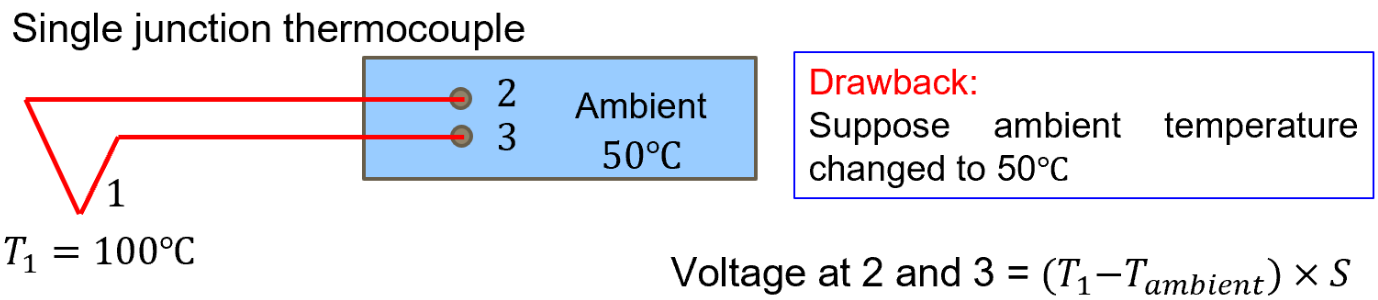


Voltage at 2 and 3 = $(T_1 - T_{ambient}) \times S$
= (100-25)×40μV
= 3 mV

The basic difference between the two junction and the single junction thermocouple is that in the two junction thermocouple, the reference temperature is set as per desired, whereas in a single junction thermocouple, the reference temperature is fixed to be the room temperature.

4.2 Drawback of Single Junction Thermocouple

The single junction thermocouple has an obvious drawback, that the reference temperature has to be the room temperature, and if it changes, then the potential difference across the two terminals exiting from it, also changes.

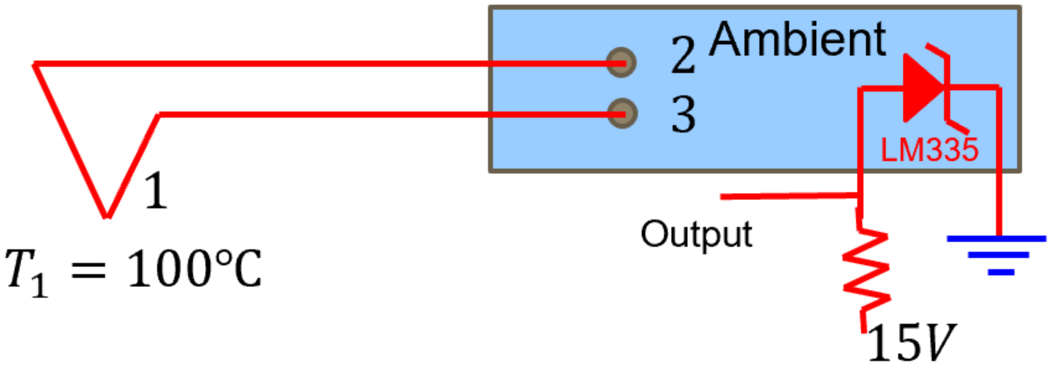


Voltage at 2 and 3 = $(T_1 - T_{ambient}) \times S$
= (100-50)×40μV
= 2 mV

As in the figure above, the voltage between the terminals 2 and 3 reduce to $2mV$, as the reference or the ambient temperature increases from $25°C$ to $50°C$.

4.3 Calibration for the Ambient Temperature

The measurement of the ambient temperature is the base of the working of the controller, and hence the ambient temperature needs to be measured by an LM-335 sensor, for accurate measurements.



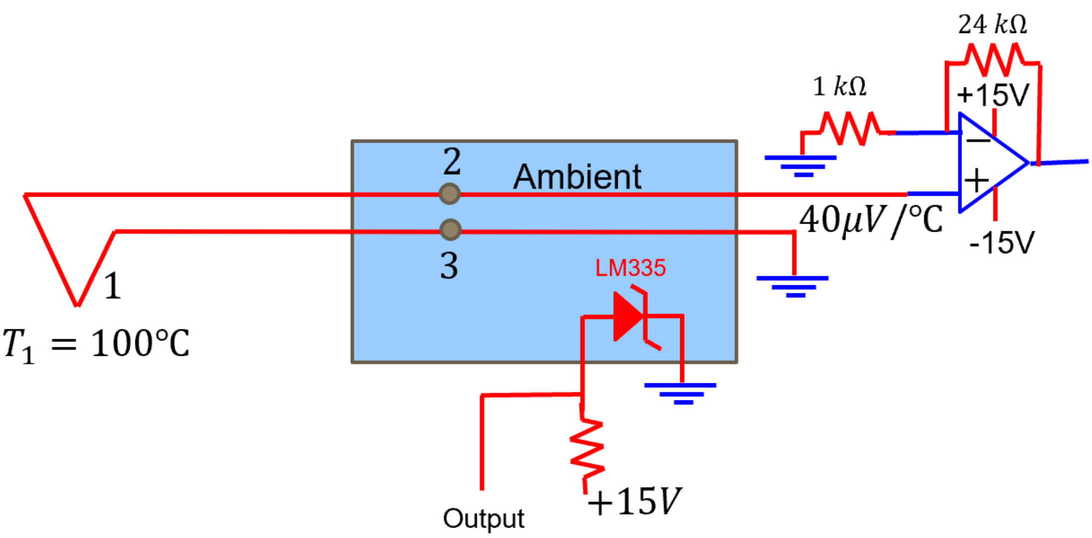
We then use this system to measure the actual temperature of the body and regulate it. We accomplish this using the following equations -

Thermocouple voltage = $V_o = (T - T_{ambient})S$

$$\frac{V_o}{S} = T - T_{ambient}$$

$$\frac{V_o}{S} + T_{ambient} = \mathrm{T}$$

Now, our next goal is to measure the output voltage and amplify it successively in stages such that we are able to correspond the right temperature values with the right voltage differences. This aspect of the circuit is accomplished in the next section.



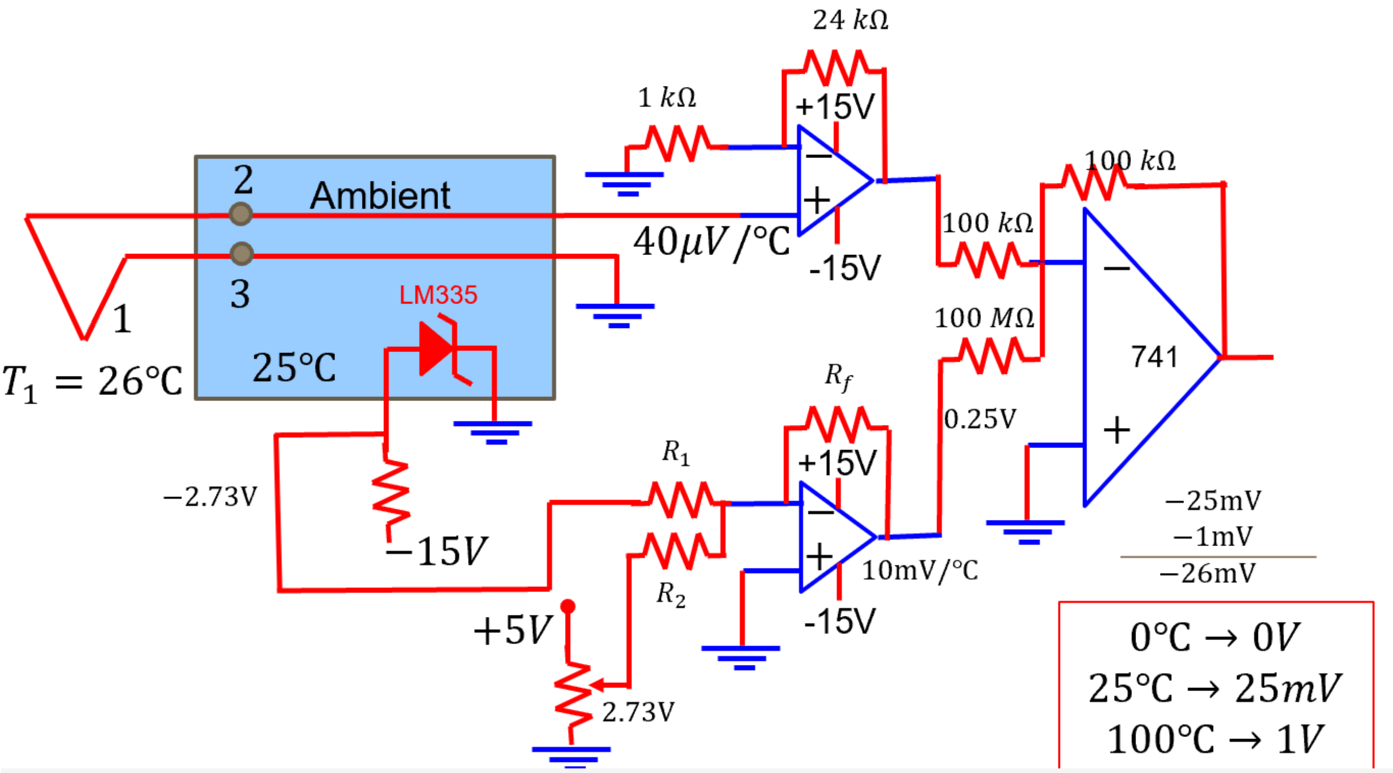
5 Voltage and Temperature correspondence

As discussed at the end of the previous section, our goal is to measure the output voltage and amplify it successively in stages such that we are able to correspond the right temperature values with the right voltage outputs.

A set of OpAmps is used to measure the output voltage and amplify it. The thermocouple only provides voltage proportional to the difference between the ambient and the junction temperature.

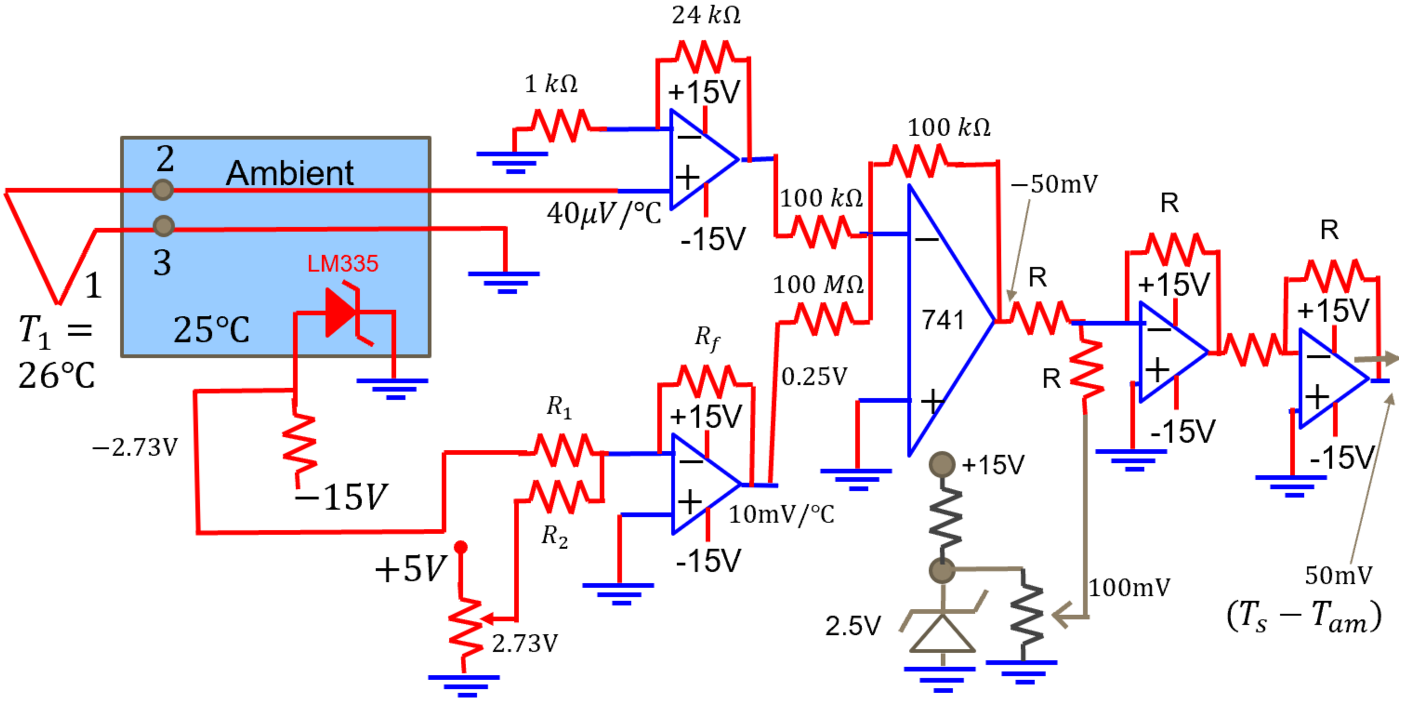
So, to calculate the actual temperature of the body, we need to know the ambient temperature, then find out the voltage corresponding to that temperature and add it to the voltage output of the thermocouple to get a voltage proportional to the absolute temperature of the body.

The absolute temperature of the body is required to check whether the body is cooler, warmer or just at the desired temperature.



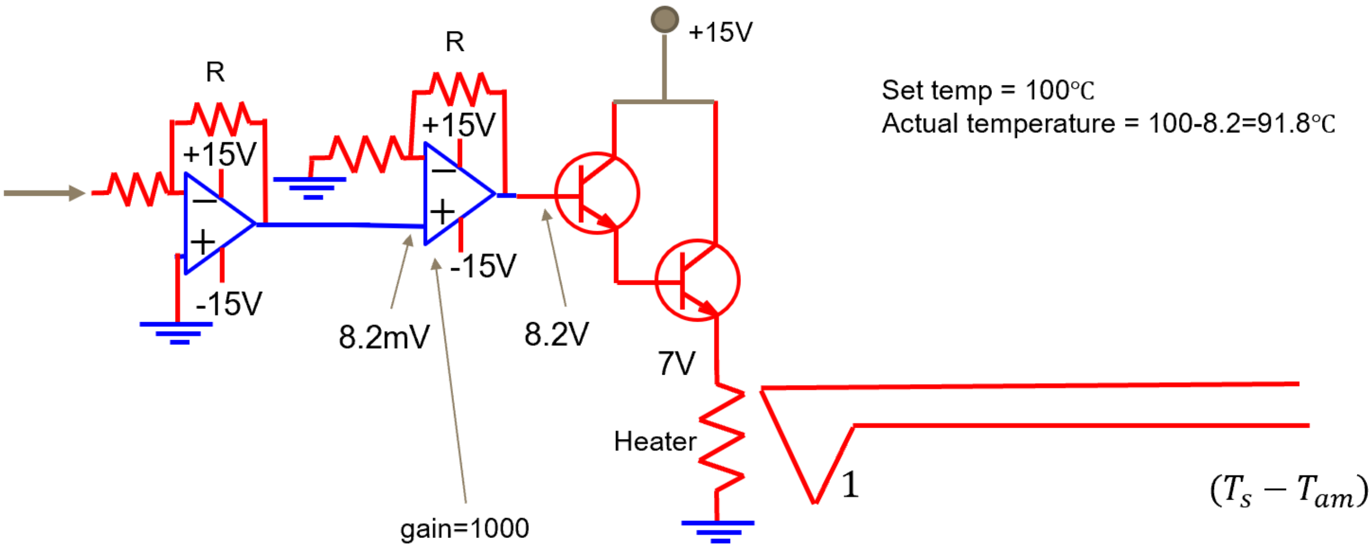
But there is a problem if we leave the circuit as it is, upon adding the two voltages, we get a negative voltage value, which needs to be inverted to its positive analogue because this voltage is going to drive the heater and thus control the temperature.

Hence we use a double inverter using two OpAmps to invert our output. The output of this system is the voltage corresponding to the temperature difference of the body and the ambient temperature. In this entire system, we have used a simple mapping, where 1°C corresponds to 1mV.



5.1 Difference between set and actual temperature

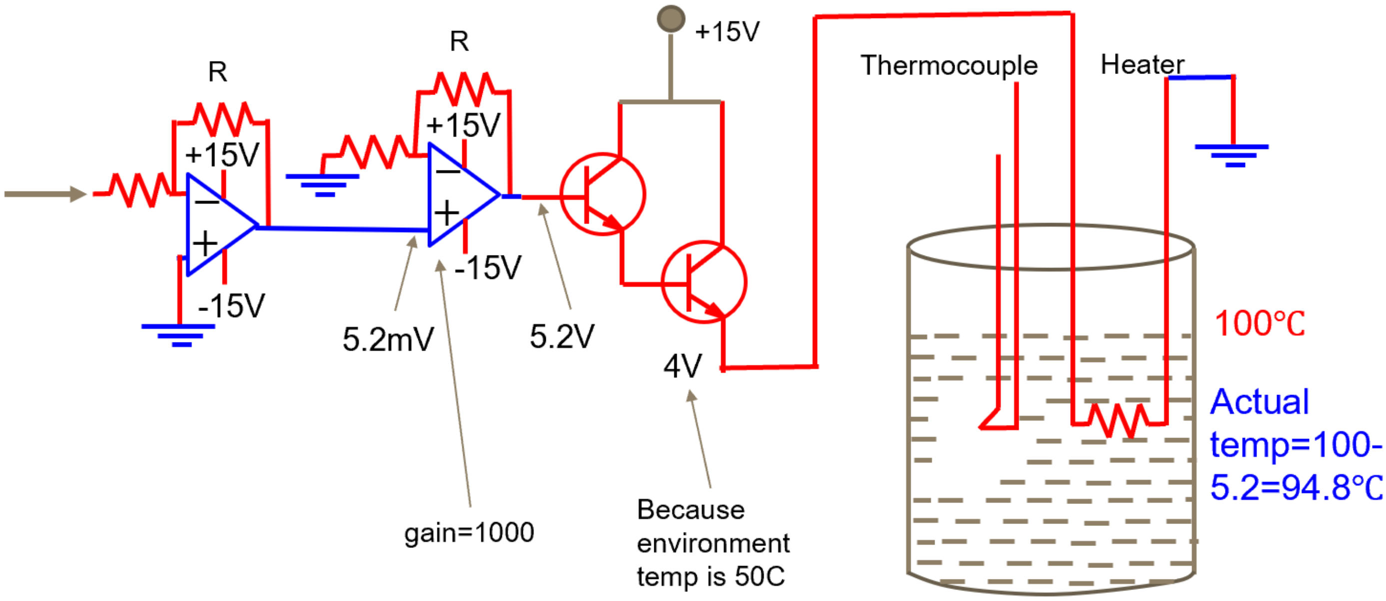
the output of the previous system is again passed through 2 OpAmps which magnify its magnitude to the orders of volts from milivolts. Then, a Darlington pair of transistors is used, which due to the base-emitter voltage of the two transistors causes a decrease in the voltage reached to our final heater.



Due to this voltage loss, the actual temperature is actually measured to be less than the set temperature.

6 Drawback of Proportional Temp. Controller

The proportional temperature controller has the same drawback that is present in the single junction thermocouple that is any change in the ambient temperature, also causes changes in the voltages at almost all the points in the circuit, thereby causing voltage drops, and leading to lesser voltages coming up to the heater, which further leads to wrong measurements of temperatures of the body.



Since the environment temperature changes, error is induced in the thermocouple since the ambient temperature was the environment temperature. This error thus propagates through the entire controller circuit leading to an error in the output voltage, and due to the mapping between output voltage and the temperature, the temperature that is actually measured also deviates by a considerable margin in comparison to the set temperature.