EE 204 - Analog Circuits
Lecture 18

Harsh S Roniyar

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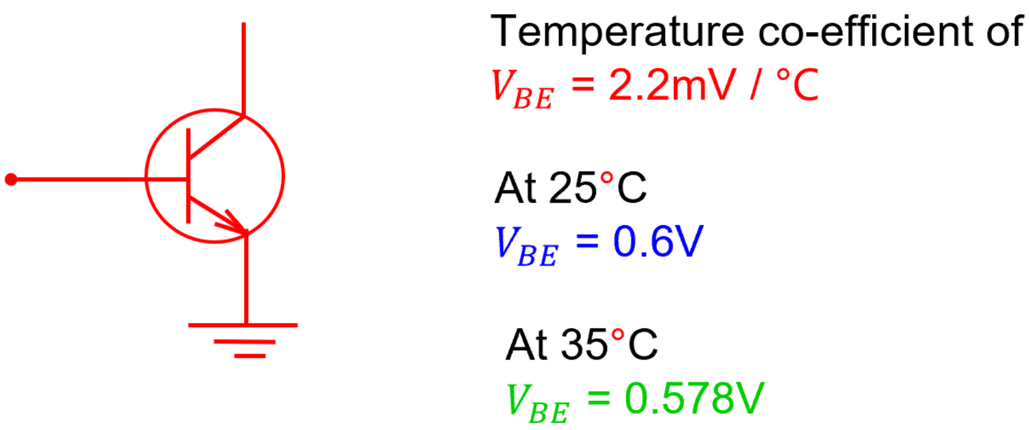
Contents

1 Temperature Sensor

A temperature sensor is a device used to measure temperature. In this lecture, we studied about how can we make a temperature indicator and the possible circuits that can be used for the same.

1.1 BJT as a Temperature Sensor

One of the most basic devices which can be used for temperature indication is the BJT. The BJT has some fixed parameters which can help us determine temperatures based on V_{BE} and the change in its value with temperature.



This, in principle is a very rudimentary idea and can't be thus used for a lot of applications; hence not put in common use.

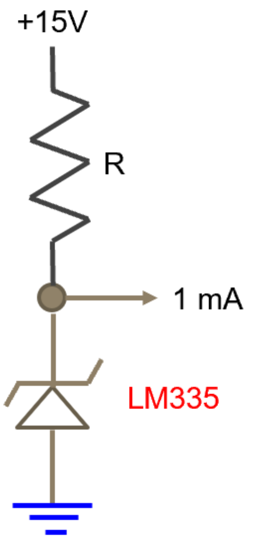
A much more accurate device in the form of LM-335 can be used as a temperature sensor.

1.2 IC Sensor: LM-335

The sensor LM-335 needs a minimum of 1mA current to operate, and thus has particular current requirements. The sensor can tolerate a maximum of 10mA current through it. Its sensitivity is higher as compared to our previous indicator, the BJT; by virtue of it having a higher temperature coefficient.

In general, the operation temperature is from $0°C$ to $100°C$.

The image below shows the parameters for the LM-335 sensor which can be suitably compared with the parameters for BJT as shown in the previous section.



- Min. current should be 1 mA. However you can send upto 10mA
- What is value of R?

Lets assume operation temp is from **0C to 100C**

The operation temperature = 10mV / °K

At 0°C voltage across the sensor would be = 2.73 V

(0°C corresponds to 273K)

At 100°C voltage across the sensor would be =(273+T°C)x10mV
= 3.73 V

At 25°C voltage across the sensor would be =(273+25)x10mV
= 2.98 V

(Complex number)

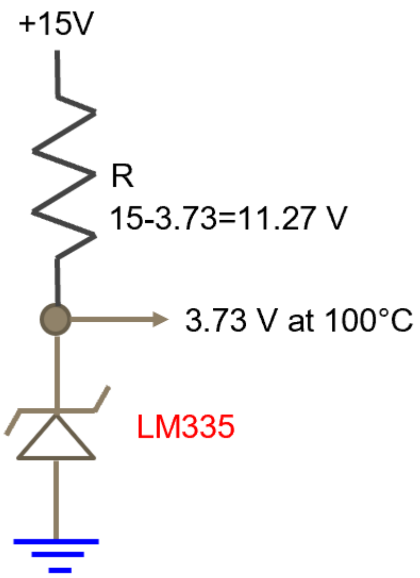
2 Temperature Indicator Circuit

To use this sensor as part of our circuit, we need to connect it to various other components, which would naturally include the OpAmp.

We need to create a circuit which indicates the temperature using voltage measurements. That is, the device should measure 0 when the voltage across it is 0V and should display 100 when the voltage across it is 1V.

We limit the current flowing through the sensor to 2mA, by applying an external resistor.

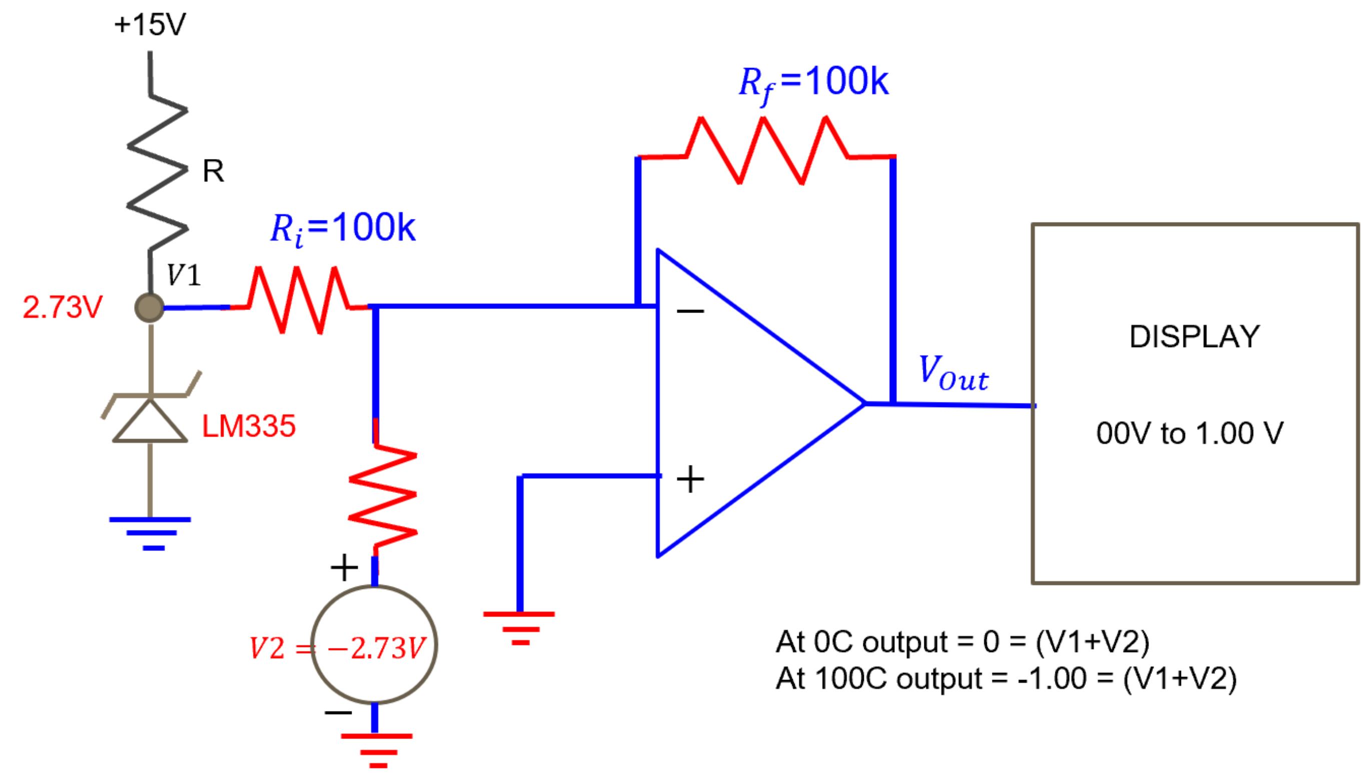
The circuit below represents the calculation of the value of the external resistance for limiting the current.



Lets consider 2mA current flowing through the circuit.
Then the resistance R = $\frac{11.27V}{2mA} = 5.57\ k\Omega$

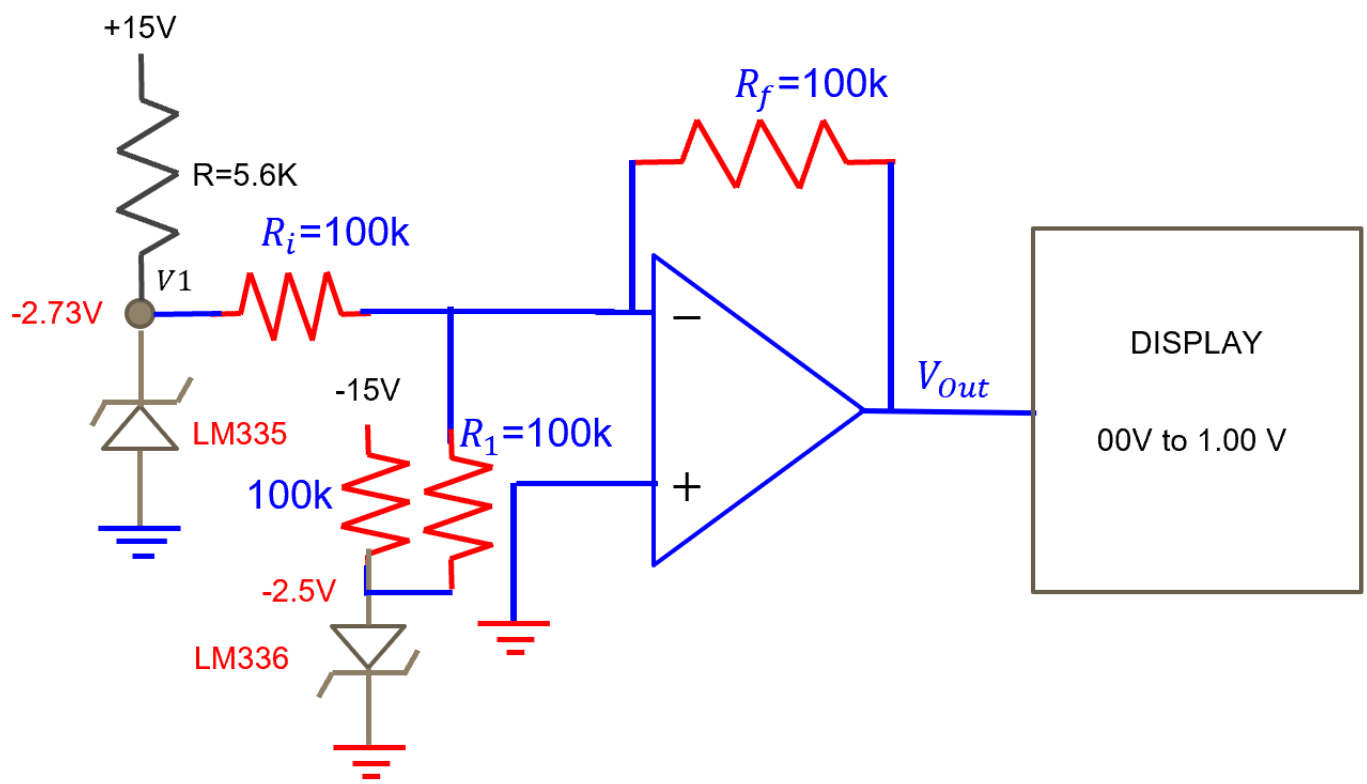
The voltage at the terminal is then passed on to the OpAmp after adding a power/voltage source in the circuit. The output of the OpAmp is then fed to the display which produces the required result.

The complete circuit after construction looks like the following -



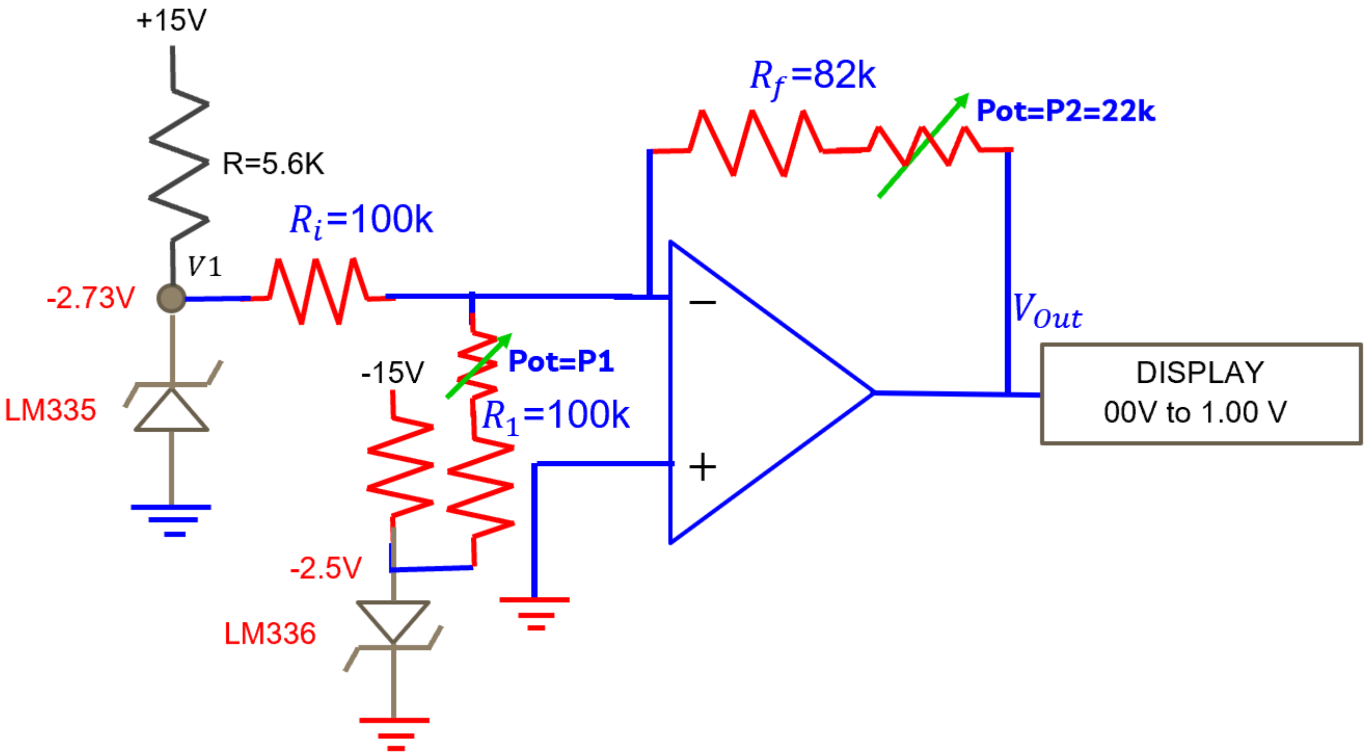
Now, instead of using the power source which could be unstable, we use another IC sensor to maintain the required particular voltage which is not being met in the current circuit.

The circuit is modified after including the IC sensor LM336 in the circuit instead of the voltage source. The circuit looks as following -



Now, in order to be better able to control the output of the circuit, it is obvious that we add variable resistors with R_1 and R_2. This process is called as **calibration**.

The following image shows the construction of one such circuit.



2.1 Calibration

For calibration, we map the extreme conditions i.e. $0°C$ and $100°C$ to the required voltages, $0V$ and $1V$ respectively.

Steps for calibration are -

- Put LM335 in ice and adjust P_1 and adjust output to $0V$
- Put LM335 at $100°C$ and adjust P_2 and output to $1V$
- Repeat the above two steps multiple times

3 Errors in measurement of LM335

The errors in the measurement of LM335 are as follows -

- **What is the temperature range ?**
  -20°C to 80°C = 100C

- Ambient temperature change = 100C (Industrial grade equipment)

- Temperature drift = 30x100 PPM = $\frac{30\times100}{10^6}$

- The original voltage = 2.5V

- The change for 2.5V for ΔT = 100C = $\frac{2.5\times30\times100}{10^6} = 7.5\ mV$

- The Zener will $= \pm\ 0.75C$ drift