Electronics and Electrical Measurement
Project Report

AMBIENT TEMPERATURE MONITOR

SUMIT KUMAR PRADHAN

SOUMYA RANJAN PADHY

ANSUMAN SWAIN

AKASH KUMAR NAHAK

SANTOSH KUMAR PANDA

AMLAN

Table of Contents

INTRODUCTION

Temperature is an environmental factor which greatly influence every electronic component at an intrinsic level. Consequently, the idea about instantaneous temperature at which they are working becomes essential, particularly for precision devices. Even the general idea about the ambient temperature may prevent serious errors in devices.

In this project, implementing the behaviour of negative temperature coefficient thermistor in accordance with an astable 555 timer IC, a broad range of temperature is displayed on ten levels through ten LEDs.

Components

Name of Component	Specification	Quantity
555 Timer IC	NE555L	1
Dot/Bar Display driver	LM3914N1	1
Linear Voltage Regulator IC	KA7805	1
Thermistor	NTCLE100E3104GB0	1
LED		10
Capacitor	0.1uF (Ceramic)	1
Capacitor	100uF (Electrolytic)	1
Resistor	1K, 82K,1.2K,3.3K	1 each

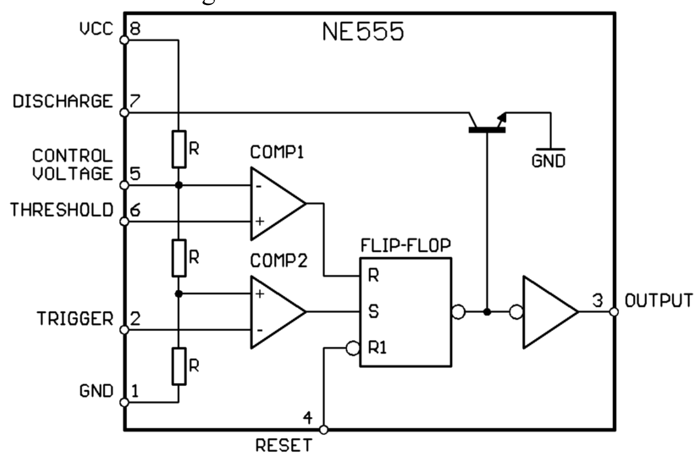
Theory

1.1 555 Timer

The most essential component in this project is the 555 timer IC. The 555 timer IC is an integrated circuit (chip) used in a variety of timer, delay, pulse generation, and oscillator applications.

The 555 IC has the following operating modes:

Astable (free-running) mode – The 555 can operate as an electronic oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse-position modulation, and so on. The 555 can be used as a simple ADC, converting an analog value to a pulse length (In this project by using a thermistor as timing resistor allows the use of the 555 in a temperature sensor with the period of the output pulse determined by the temperature). The use of a microprocessor-based circuit can then convert the pulse period to temperature, linearize it, and even provide calibration means.



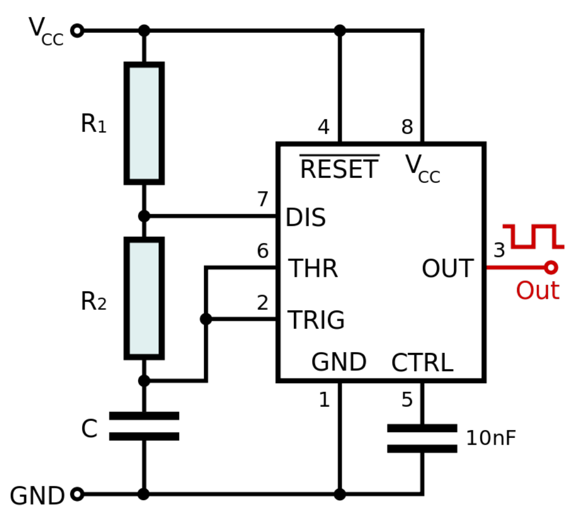
Monostable (one-shot) mode – In this mode, the 555 functions as a "one-shot" pulse generator. Applications include timers, missing pulse detection, bounce-free switches, touch switches, frequency dividers, capacitance measurement, pulse-width modulation (PWM), and so on.

Bistable (flip-flop) mode – The 555 operates as an SR flip-flop. Uses include bounce-free latched switches.

Schmitt trigger (inverter) mode – the 555 operates as a Schmitt trigger inverter gate which converts a noisy input into a clean digital output.

The project incorporates the astable mode of 555 timer to produce an analog voltage which is a function of resistance of thermistor. The connection for astable mode is given below. Here the resistance R2 is replaced with a thermistor. And the duty cycle of the output PWM signal is given by the equation:

$$D\,(\%) = \frac{t_{\text{high}}}{t_{\text{high}} + t_{\text{low}}} \cdot 100$$



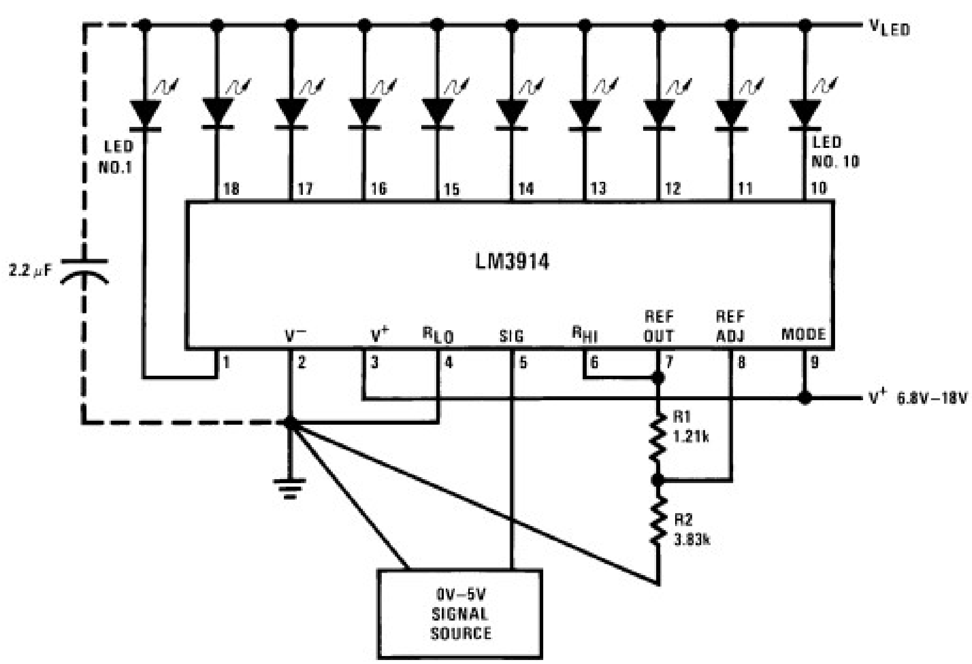
$$= \frac{R_1 + R_2}{R_1 + 2R_2} \cdot 100$$

1.2 Dot/Bar Display Driver (LM3914)

The LM3914 is an integrated circuit (IC), designed by National Semiconductor in the late 1970s, used to operate displays that visually show the magnitude of an analog signal. It can drive up to 10 LEDs, LCDs, or vacuum fluorescent displays on its outputs. The linear scaling of the output thresholds makes the device usable, for example, as a voltmeter. In the basic configuration it provides a ten step scale which is expandable to over 100 segments with other LM3914 ICs in series.

In this project the LM3914 takes the analog voltage level output by the 555 timer and drives the led corresponding to the voltage level. As the rage of analog output of 555 timer is 5V each LED indicates 0.5V of change in analog voltage.

The LM3914 is used in a basic configuration as shown below:



1.3 Linear Voltage Regulator IC (7805)

Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 Voltage Regulator, a member of the 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC).

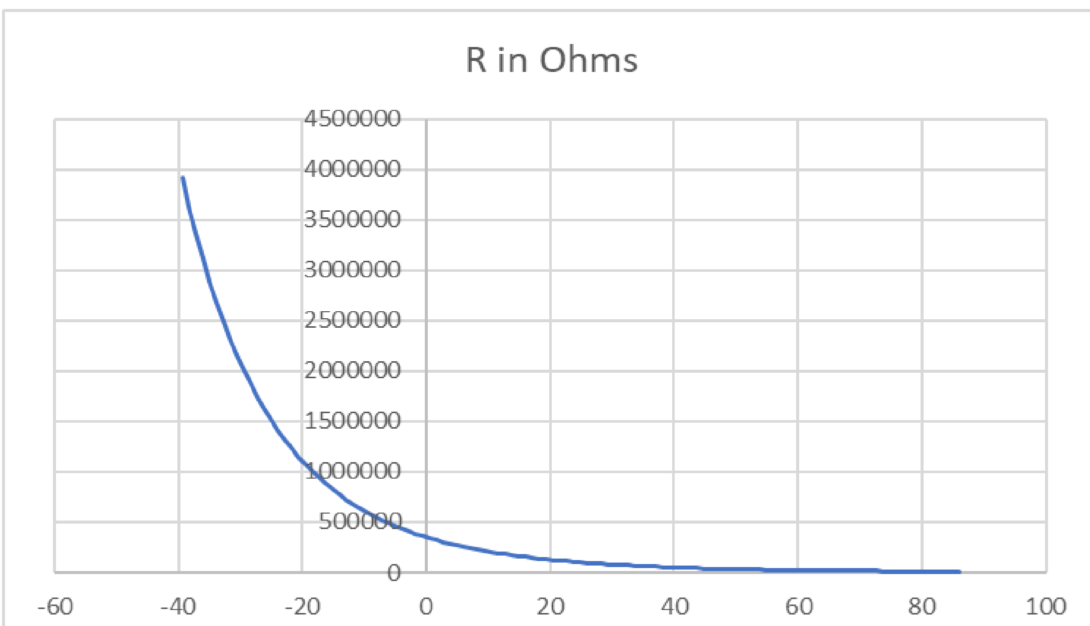
The xx in 78xx indicates the output voltage it provides. 7805 IC provides +5 volts regulated power supply with provisions to add a heat sink.

1.4 Thermistor (NTCLE100E3104GB0)

A thermistor is a type of resistor whose resistance is strongly dependent on temperature, more so than in standard resistors. The word thermistor is a portmanteau of thermal and resistor.

Thermistors are divided based on their conduction model. Negative Temperature Coefficient (NTC) thermistors have less resistance at higher temperatures, while Positive Temperature Coefficient (PTC) thermistors have more resistance at higher temperatures.

The 100K NTC thermistor used in this project has the resistance verses temperature characteristics as shown below:



Working Principle

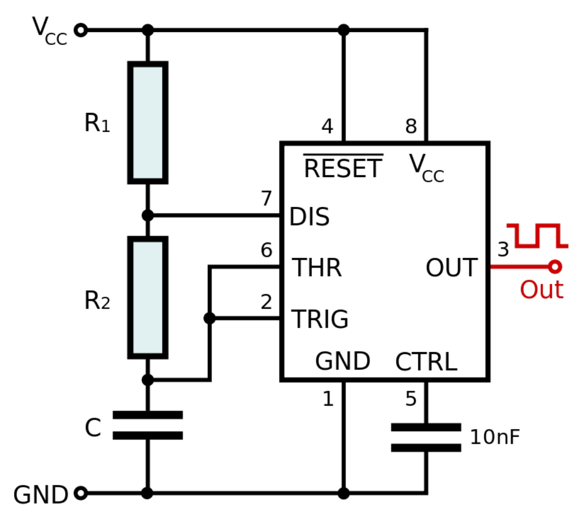
The complete working of this project can be divided into three stages.

2.1 Stage I: Generation of PWM wave whose Duty cycle depends on Temperature.

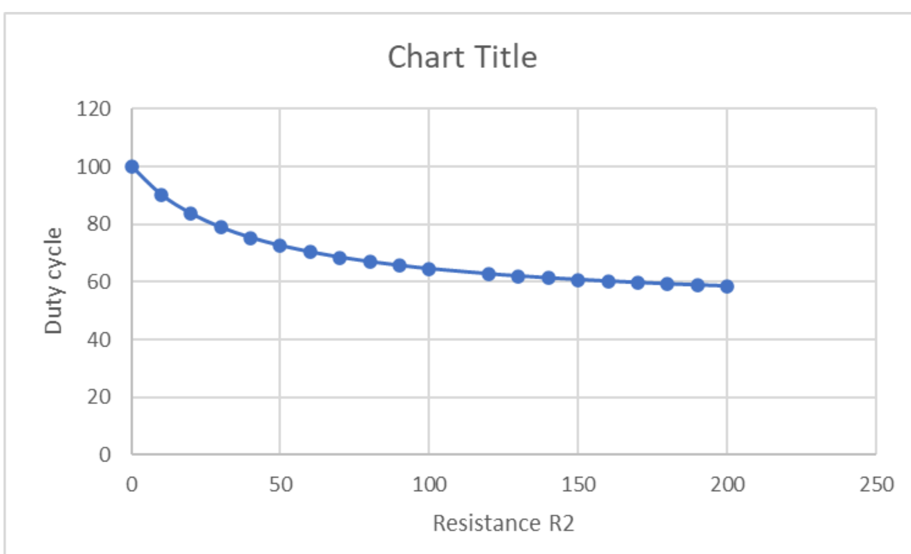
In the astable mode the 555 timer produces a PWM signal whose duty cycle depends on the combination of resistance used.

$$D\,(\%) = \frac{t_{\text{high}}}{t_{\text{high}} + t_{\text{low}}} \cdot 100$$

$$= \frac{R_1 + R_2}{R_1 + 2R_2} \cdot 100$$



Here, R2 is the thermistor which varies its resistance as a function of temperature as a result the duty cycle of the output PWM signal. The Duty cycle at different values of resistance of R2 is given below (R1 is 82K Ohms):



The frequency of the PWM signal generated at room temperature (R2=100K) is given by:

$$f = \frac{1}{t_{\text{high}} + t_{\text{low}}} = \frac{1}{\ln(2) \cdot (R_1 + 2R_2) \cdot C}$$

Substituting, C=0.1uF, R1=82K ohms and R2=100K Ohms we get the frequency to be equivalently to 52Hz.

2.2 Stage II: Converting the PWM signal to analog signal.

The output produced by the 555 timer is a PWM signal which needs to be converted to a corresponding analog value before providing it to the bar display driver. There are many ICs which can achieve this easily and with precision but here we are using a simple Low pass R-C filter.

The nominal DAC voltage observed at the output of the low-pass filter is determined by just two parameters, namely, the duty cycle and the PWM signal's logic-high voltage. The relationship between duty cycle, amplitude, and nominal DAC voltage is fairly intuitive: In the frequency domain, a low-pass filter suppresses higher-frequency components of an input signal. The time-domain equivalent of this effect is smoothing, or averaging—thus, by low-pass filtering a PWM signal we are extracting its average value.

The R-C filter attenuates the high frequency components of the PWM signal and only the average (DC) value remains behind. The cut-off frequency of a low pass filter is given by:

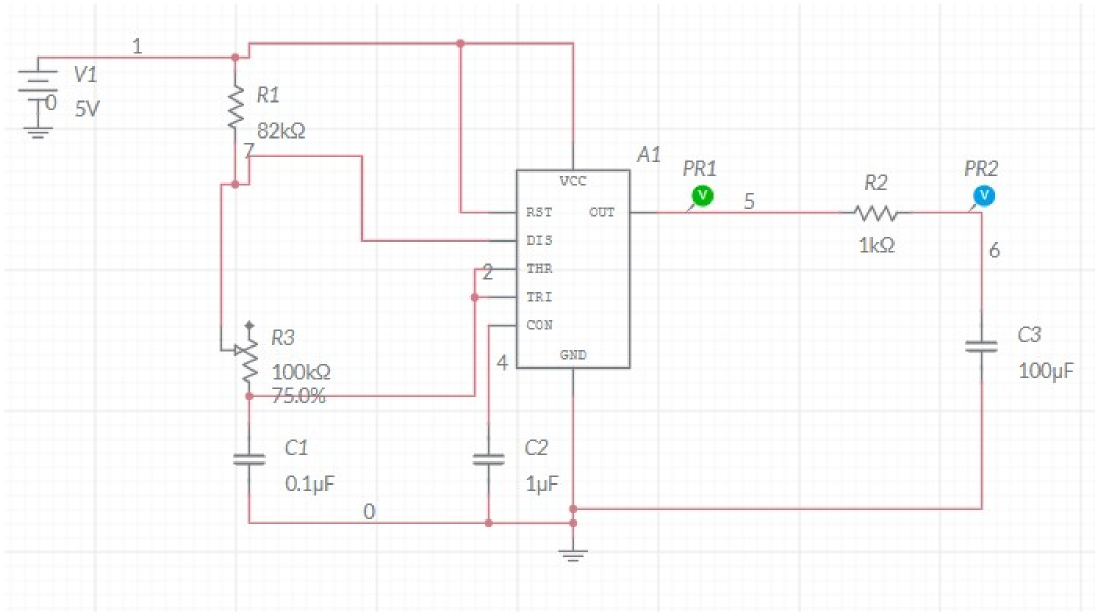
$$f_c = \frac{1}{2\pi RC}$$

In the circuit we have designed the frequency of PWM signal generated is equivalent to 52 Hz.

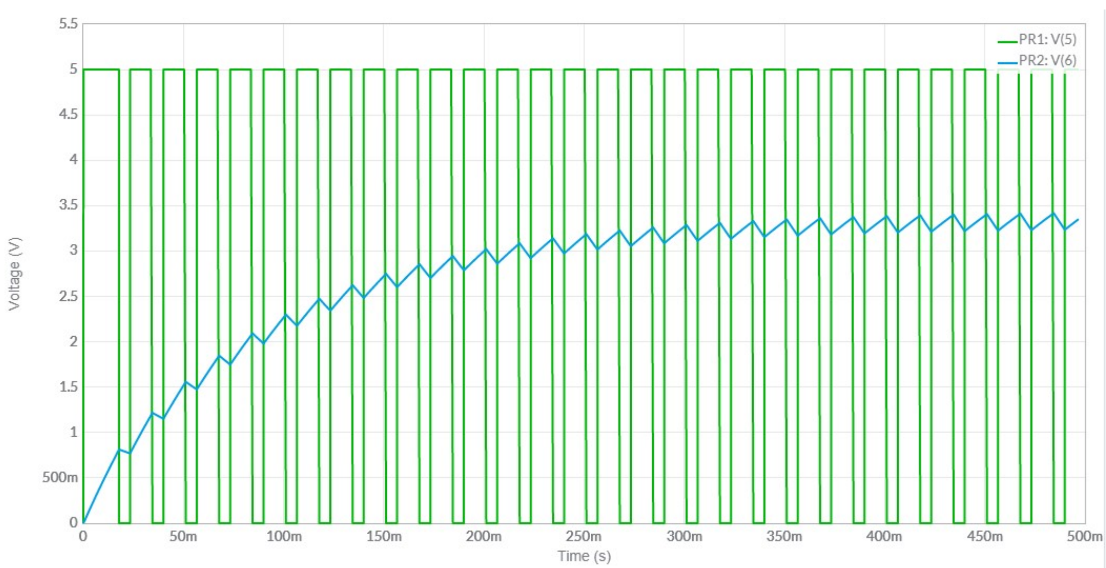
Now, for the filter circuit we have take the values of R and C as 1K ohms and 100uF. That gives a cut-off frequency of 1.6Hz. Which suitably converts the PWM signal to analog level without too much delay (200ms).

The circuit diagram for the discussed two stages is given below:

Here R3 acts as the thermistor.



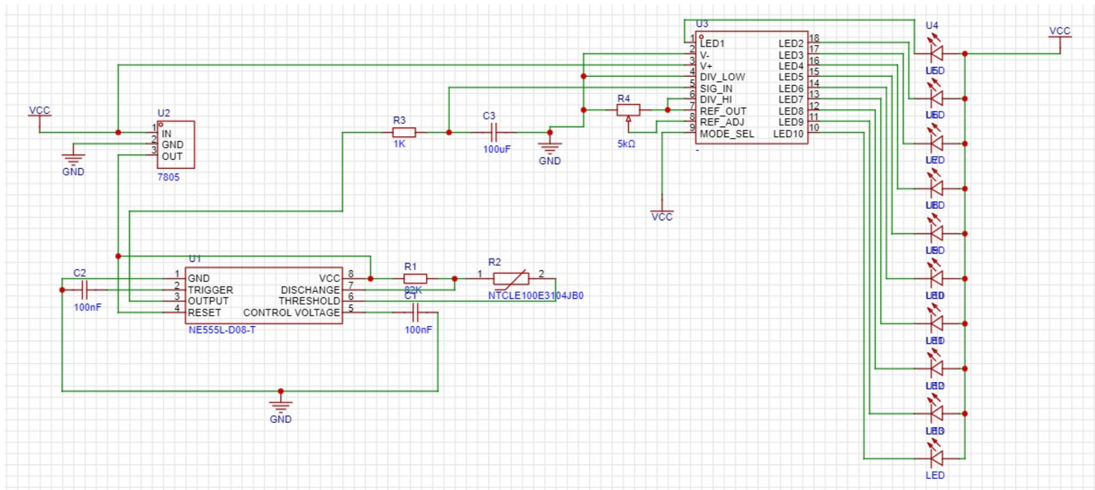
Now, the response when the thermistor is at 75K ohms.:



2.3 Stage III: Analog signal to Bar Graph.

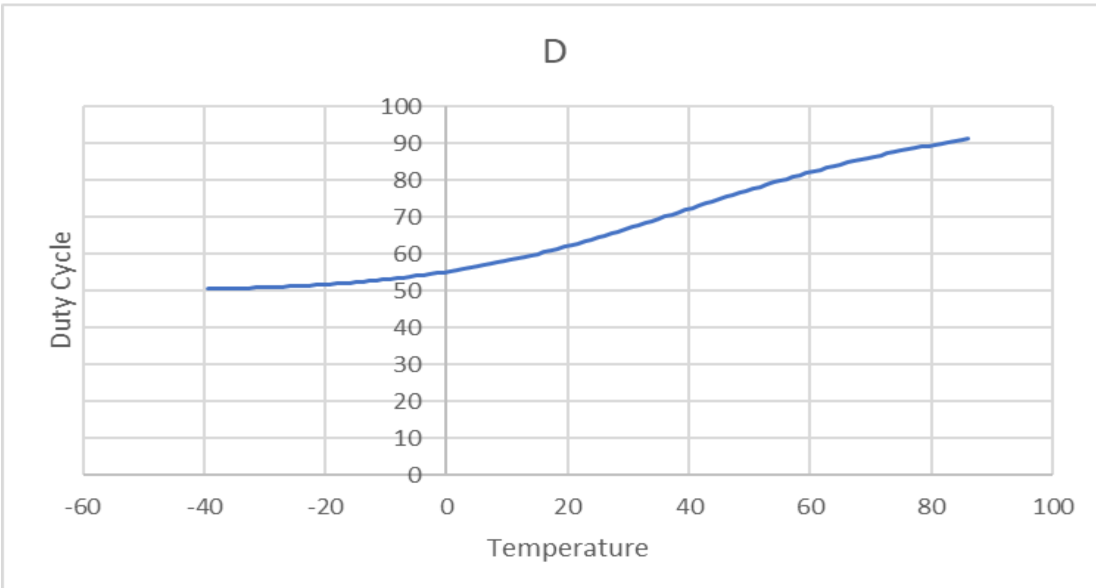
For this an IC (LM3914) is used. In essence, the IC has an array of 10 comparators and resistors connected to the internal 1.25V reference voltage. In this case, for each 125mV that the input signal increases, a comparator will switch on another indicating LED.

The complete circuit diagram is given below.



Analysis

Armed with the knowledge of how the circuit works and characteristics of various components we can now derive a relation between every level of the bar and temperature. We know the relation between Resistance and Duty cycle; and Temperature and Resistance. From which the relation between Temperature and duty cycle can be achieved. The temperature v/s duty cycle is as shown below:



The graph is neither linear nor does the duty cycle reaches below 50% duty cycle. However for the range (0-80 C) it is fairly linear.

Hence the temperature range the circuit can indicate are:

Temperature (°C)	No. of LEDs turned on.
<15	5
15 to 35	6
35 to 55	7
55 to 82	9
>82	9

Conclusion

In the final analysis we found that the circuit can indicate temperature beyond 15 degree Celsius in a fairly linear scale with the obvious shortcoming of limited duty cycle which is locked at 50%. To eliminated this limit we can simply add a fast diode parallel to the Thermistor with the cathode on the capacitor side. This bypasses R2 during high part of the cycle, so high cycle depends on R1 and C (capacitor) only.

Nonetheless, the circuit works, with practical errors surprisingly low, as intended.

Bibliography

[1] Dave Cohen and Carlos Matos. *Third Year Projects – Rules and Guidelines*. Royal Holloway, University of London, 2013.