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Design and Simulation of a Weather Activated Window System

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Abstract

This paper presents the design and implementation of a Weather Activated Window System. A weather activated window system is a weather (temperature, humidity and wind) operated system that open or closes a window depending on the status of the atmospheric weather. This system compares a weather condition with a predefined weather condition. However, in this work, our results are based on temperature using temperature sensor to sense the atmospheric temperature and compares it with the predefined temperature. The system closes the window at a temperature less than 19 degree Celsius and open the window for any temperature greater than 19 degree Celsius. The reference temperature was set using a variable resistor via a comparator. The variable resistor is used to set one's preference temperature. A 5V DC power supply was designed in order to provide a biasing voltage to most of the active devices used in the system design circuit. The DC power supply was designed and simulated using Multisim software. The testing and simulation of the circuit design was done in Proteus environment. The system was simulated and working according to the design specifications.

Keywords: Design; Room temperature; Control system; Proteus; Simulation; Window; Temperature Sensor; Humidity.

INTRODUCTION

With the advancement of technology, automation has become part of our lives. The Home is usually the most occupied place in any culture. Any opening in a wall or roof that allows a passage of light through is categorized as a window [1]. Initially windows were basically just unglazed passages cut on part of a roof to for light admittance. Later on, pieces of animal hide, cloth, or wood were used to cover the openings. Soon after that shutters that could open and close manually were implemented. Eventually windows were constructed such that they protect the inhabitants from the weather elements as well as transmitting light [2]. The Roman Empire was the first to use glass in windows. Modern windows are on an ordinary situation covered in transparent or translucent material. Windows are held in place by frames. Many windows have the ability to be opened, which is to provide for air ventilation, or can be closed, to protect from the external conditions. They regularly are equipped with a latch to shut the window [3-11].

Weather is forever varying and changes on short intervals, and as a result, the external conditions always have an influence changes on the indoor conditions. The temperature control systems that are currently in use have limitations. One of these limitations is that the user has to adjust the system every time the external conditions change. This is very tiring and proves out not to be an effective way of controlling temperature of a room [12-15]. Also, disabled people get to face a lot challenges when they want to operate temperature control system in their houses because this systems require them to use physical contact or some hand remote devices to operate them. To reduce the need to do this, a system that works automatically needs to be put in place.

However, in a forever changing world people have different abilities, some are disabled and unable to do Simple things for themselves like reach the windows. Sometimes its children who can't reach for the nearest window to open it for themselves, sometimes its high windows that are not easily accessible. Despite all this, ventilation is very important and opening windows is even encouraged in the medical field.

This work propose a window that can open and close itself solely based on the current weather and environmental conditions. This development would benefit the disabled, the children who can't reach the windows and it would also hugely benefit hard to reach windows, people with a lot of windows in their houses and basically people who don't have much time to spare.

The Weather Activated Window System (WAWS) will be an effective way of helping those with disabilities and generally can't reach the window ledges, or have too much work on their plate. The work tends to design and implement a system that will open and close windows automatically based on the weather conditions at the said time. The system is be able to do all this without any user interference or input.

MATERIALS AND METHODS

The Weather Activated Window System comprises of four (4) main subsystem: Power supply unit, the sensor unit, amplifier/comparator unit and the control/ Switching unit as shown in the system block diagram in Figure 1.

POWER SUPPLY

The power supply system supply a 5V DC power supply to the other units, which is stepped down with a transformer (240V to 12V). This power supply include a full wave rectifier (4 of 1N4001) which converts AC power to DC power and a filter (Capacitor) to smoothen the output from the rectifier. Voltage regulator were also included in the power supply in order supply regulated DC voltage to the other main units (LM7805 (5V).

SENSING UNIT

This section of the system include a temperature sensor (LM35). A temperature sensor is a device that is temperature sensitive, and it responds to changes in temperature. The LM35 is used as the temperature sensor that sensed environmental temperature and converts it to electrical signal. The LM35 is equipped with a large range that should be enough. In the circuit, at 19 degrees and below, the circuit should close the window, and at 20 degrees and above it should open the window. The choice of these range of temperature is because it is influenced by most other weather elements like wind, rain and humidity

AMPLIFIER/ COMPARATOR UNIT

The Amplifier/ Comparator unit houses the operational amplifier (LM741), a comparator (LM393) and timer circuit (NE555). The LM741 as an Op-Amp is used to properly manipulate the voltage, so that we can get a range of temperatures that we desire from the LM35. The LM35 works in such a way that as the input temperature goes higher it outputs voltage increases as well. The amplifier has a feedback loop comprising of a 4k ohm resistor and also a 1k Ohm resistor at its inverting input side with an adjusted 1volt in to it to ensure that the output is a steady 5volts.

The LM393 is a low offset voltage dual comparator. The comparators function is to monitor the voltage at the particular time and indicate an output after comparing the input voltage by the predefined (reference) voltage. The output of the comparator is either of High or Low. The comparator is of input terminals of positive (V+) and negative (V-). The LM555 is in charge of timing. The 555 timer operates in a monostable mode.

SWITCHING/ DRIVER UNIT

The Switching/ Driver unit houses the bipolar transistors, relays, motor driver and the motor itself. The system uses 2N3904 bipolar transistor, for which purpose in the circuit is to amplify the voltage needed for relay switching and activation. The 5Vdc Relay open (isolate) or close (link) the second circuit based on the parameters that will be fed to it. When one side of the circuit is open, the other closes, thus turning the Dc motor in the desired direction. When one side has a higher voltage than the other the relay will activate. L293D is the motor driver and its purpose is to interface between the DC motor and the rest of the circuit. The L293D is capable of running a motor in both directions and can control 2 motors simultaneously. The L293D can also drive a regular Dc motor as well as a Servo motor. So, in this design, the L293D help with direction of the DC motor. The servo motor serves as a rotary actuator that allows for precise control of linear actuation. With a servo motor, one can control the velocity as well as the acceleration. This gives us the perfect speed to open the window, so that it is not too slow but also not too fast as that could damage the window. The L293D motor driver is in charge of controlling the servo motor.

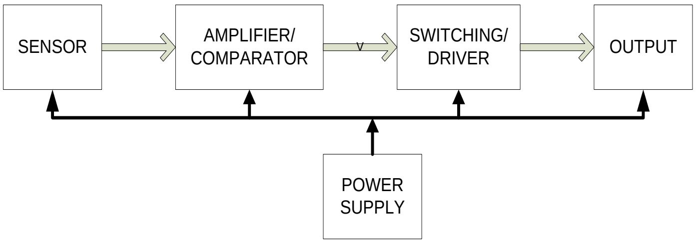

Figure 1: Block diagram showing the major parts of the system

Power supply: The power supply was designed considering the available resources while meeting the design specifications. All the components operates on 5V DC, hence the need to step down the normal power supply voltage from mains (Approx. 240V AC), to a reasonably voltage that will have to be rectified (convert to DC) and further filter to remove unwanted pulsation. The 240V AC power was stepped down to 12V AC (12V RMS value wherein the peak value is around 17V) as can be seen from the calculation that follows, and the 17V was further regulated using a voltage regulator (LM7805) to 5V. A transformer of turn ratio of 20:1 was used for the purpose of stepping down the voltage and rectifier diodes (IN4001) were also used for rectification.

Using the turn ratio:

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}, i.e\ \frac{20}{1} = \frac{240}{V_S}$$

$$V_{RMS} = V_S = \frac{240\ V}{20} = 12V \quad (1)$$

$$V_P = 12 \times \sqrt{2} = 16.9705 \approx 17V \quad (2)$$

Assuming a ripple voltage of 20%

$$dv = \frac{20}{100} \times 17 = 3.4V \quad (3)$$

$$df = \frac{1}{2f} = \frac{1}{100} = 0.01$$

$$C_1 = \frac{1 \times 0.01}{3.4} = 2.94 \times 10^{-3}F \quad (4)$$

A preferred value of 3300μF was however employed for the filtering of the assumed ripples as the value is higher than the calculated value, hence will filter much more than expected. Figure 2 shows the designed power supply circuit.

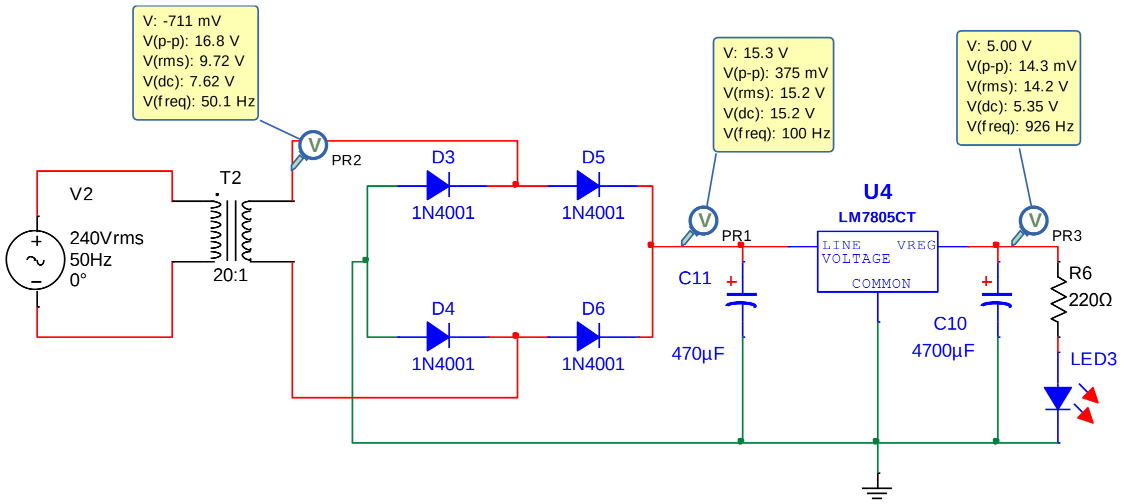

Figure 2: Power supply circuit

Sensor and amplifier: For the calibration of the temperature sensor, we use the linear modeling approach. We take the maximum temperature to be 100 degree Celsius and maximum voltage to be +5V as the supply voltage is +5V. But we equate the 100 degree Celsius to 1V as we amplify the voltage 5 times the input voltage to the op-amp using the gain factor of the non-inverting amplifier. Hence,

Temperature range: 0 ^{O}C – 100 ^{O}C

100 ^{O}C = 1V

This implies that 10 ^{O}C = 0.1V or 1 ^{O}C = 0.01V

For the output voltage of the operational amplifier (output at pin 6),

$$V_{out} = \left(1 + \left(\frac{R_f}{R_{in}}\right)\right) V_{in} \tag{5}$$

Where V_{out} represents output voltage, V_{in} as input voltage, R_{in} the input resistance and R_f the feedback resistance.

The maximum voltage corresponding to the maximum temperature (100 ^{O}C) can be gotten from equation (5) as:

$$V_{100\,^oC} = \left(1 + \left(\frac{4\ k\Omega}{1\ k\Omega}\right)\right) 1V$$

$$V_{100\,^oC} = (1+4)1V = 5V \tag{6}$$

By ratios, 5V is dissipated at 100 ^{O}C and therefore, 0.5V is the output at 10 ^{O}C.

To get the voltage at 20 ^{O}C, we can use the relationship as:

100 ^{O}C = 5V, and 20 ^{O}C = X (V)

Therefore, $X(V) \times 100 = 20 \times 5$

This implies that,

$$X(V) = \frac{20 \times 5}{100}$$

$$X(V) = 1 \tag{7}$$

And therefore, the voltage at 20 ^{O}C = 1V

From the same relationship, when temperature is at 19 ^{O}C, the output of the sensor will be 0.95V.

Timing circuit: For the timing circuit, the time interval for the 2 monostable circuit is calculate using equation (8) as:

$$T = 1.1 \times RC \tag{8}$$

Where R is the resistance of the timing resistor and C the capacitance of the timing capacitor.

Therefore,

To get a time of about 52µs, we have:

$$52\mu = 1.1 \times 10nF \times R$$

Where

$$R \approx 4.7k\Omega \tag{9}$$

Hence, the circuit is expected to stay ON for 52µs after it is triggered before going off to wait for the next trigger signal.

Switching Circuit: Also, considering the switching circuit and to get a proper base biasing voltage of approximately 0.7V since silicon based semiconductor, noting that the current from the output of the timing circuit is also approximately 160µA, we can get the value of current limiting resistor at the base of the transistor that will guarantee a base voltage of 0.7V as:

$$V_b = I_b \times R_b \tag{10}$$

This implies that,

$$R_b = \frac{V_b}{I_b} = \frac{0.7}{162\times10^{-6}} = 4.32\ k\Omega \tag{11}$$

From which we choose an appropriate value of 4.7 kΩ

The complete circuit diagram showing all the design work is shown in Figure 3.

RESULTS AND DISCUSSION

Figure 4 shows part of the circuit comprising of the temperature sensor, op-amp and the comparators. From the Figure 4 the voltage is less than 1V so it is fed into the negative terminal of component U2: A and fed into the positive component of U2:B.This means that these two are sort of a mirror of one another, the reverse in polarity ensures that when one is active, the other is not active and vice versa. Since the input at the U2: A negative terminal is 0.95, and less than the desired threshold, the output at the end of the LM393 returns back to 5Volts.

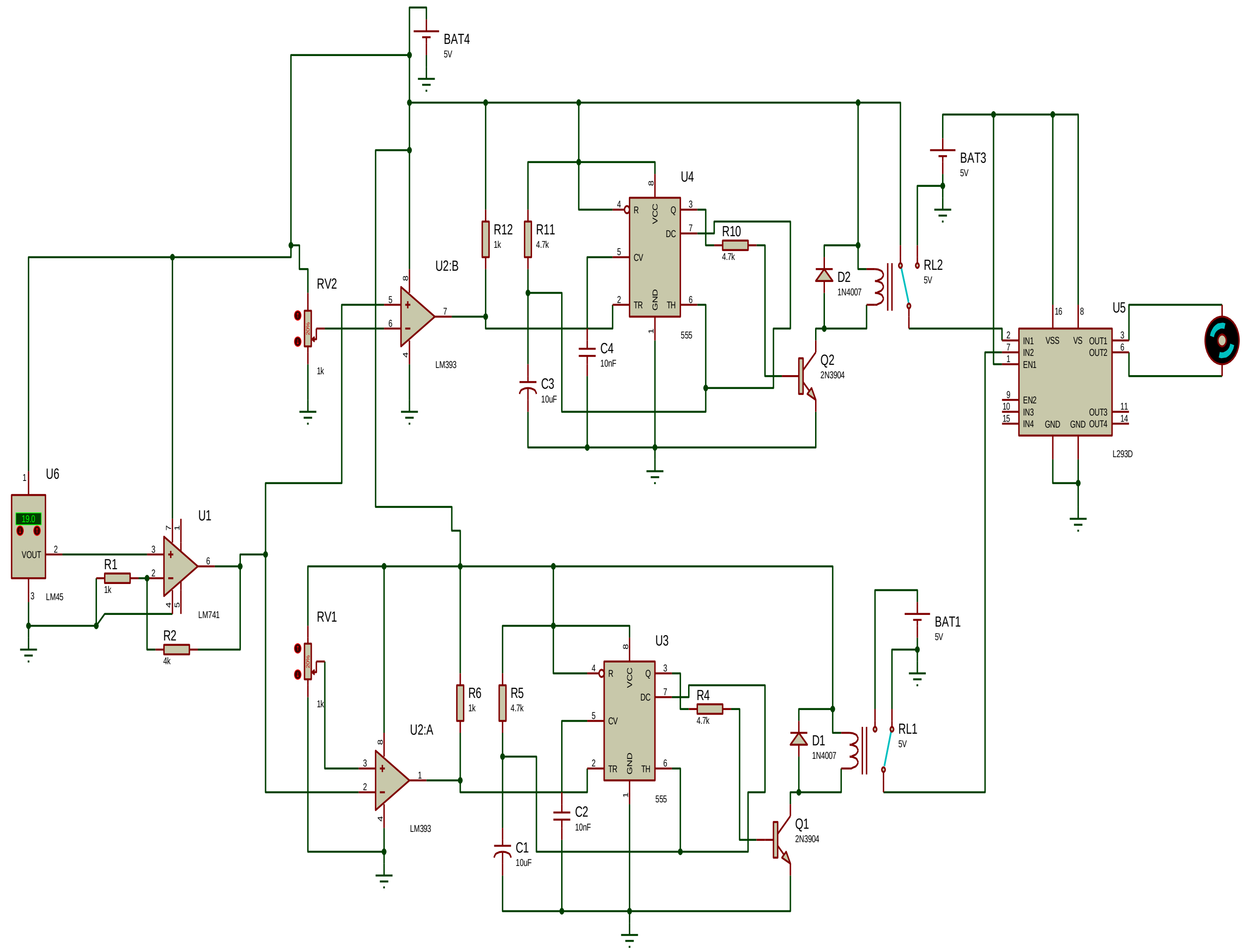

Figure 3: Complete circuit diagram of a Weather Activated Window System

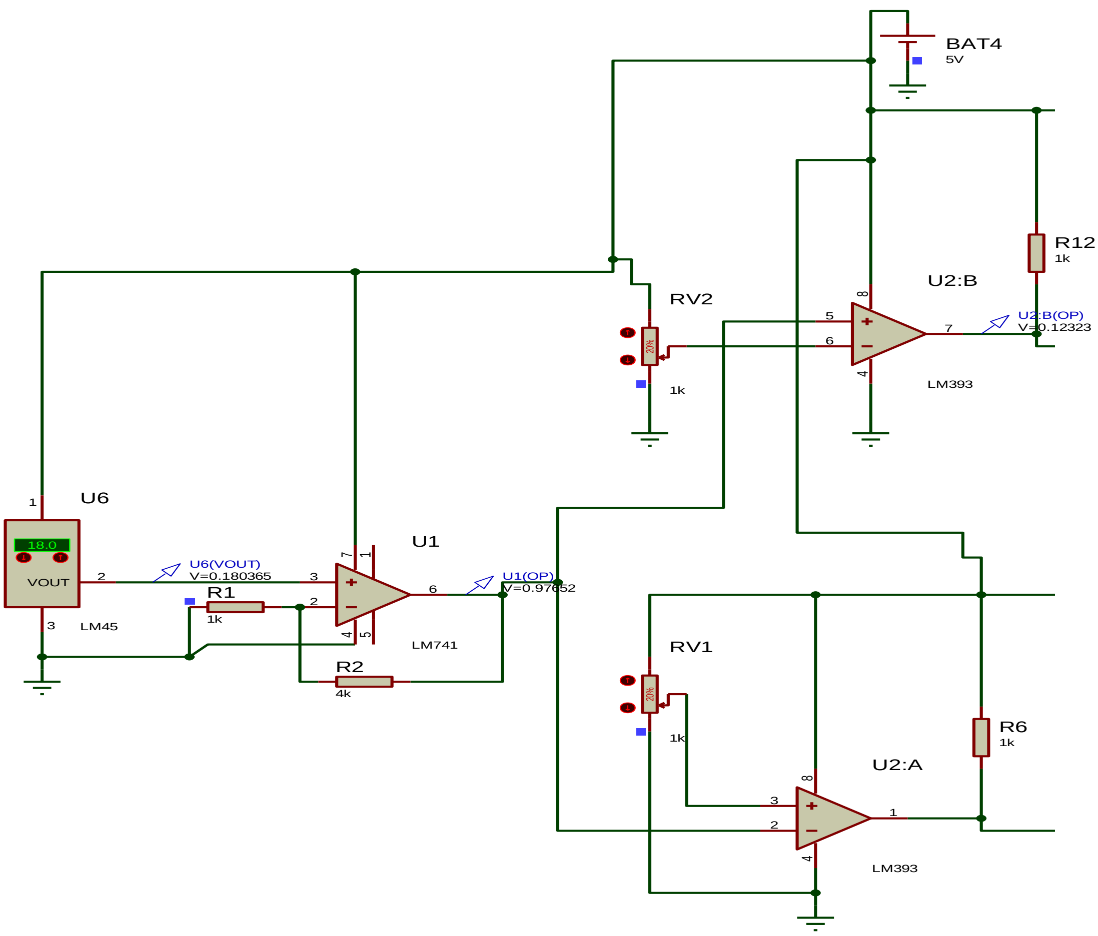

Figure 4: Circuit showing the Sensor, Op-Amp and the Comparators

The diagram in Figure 5 shows the 555 timers and their outputs in the circuit. They are U3 and U4 respectively, and the output at DC and Q is high. Pin 7 Goes HIGH and stays HIGH when pin 2 detects 1/3 rail voltage and pin 6 is LOW.

Also, it can be seen that relay 2 (RLY2) is activated via 2N3904 transistor. Going to do the math based on the hypothetical temperature of 20 ^{0}C, now from pin 3 of the 555 timer (U4), the output voltage will be about 5V, before part of it is dropped across element R4 which is a resistor rated 4.7kΩ. The output current from pin 3 is 162µA. With the high voltage seen at the output of the timer circuit, it helps in proper base bias of the transistor, which in effect activate the relay via proper magnetising of the relay coil and this activate the relay and switching property is experienced.

The 1N4007 diode across the relay coil receives only a fraction of the voltage that is dropped across the transistor, and it is called the fly back diode and its function is to provide a path for current when the coil is switched off. This is essential because without it the 2N3904 transistor would basically get destroyed by excessive current.

The signal at the output of the Relay goes to the motor driver (L293D), which will either drive the motor in a clockwise or anticlockwise direction depending on which comparator output is high.

Two situations are shown:

Situation 1 is depicted by Figure 56, at 17 ^{0}C the relay component RL2 is the one that gets activated and required voltage is dropped across the motor driver input 1 pin. This means that that voltage will be delivered to the output pin 1, and since the current flows as a result of voltage drop, the voltage seen at the output pin 1 to the output pin 2 is then enough to drive the motor, and the motor driver will drive in a clockwise manner thus closing the window.

Situation 2 is depicted by Figure 7, at 24 ^{0}C the relay component RL1 is the one that gets activated and required voltage is dropped across the motor driver input 2. This means that the voltage will drive from the output pin 2 to output pin 1 of the motor driver, thus the motor will turn anti-clockwise and the window will open.

In both instances the circuit functions as it was intended at first by closing the window at any temperature less than 19 ^{0}C and opening up the window at any temperature that is more than 19^{0}C.

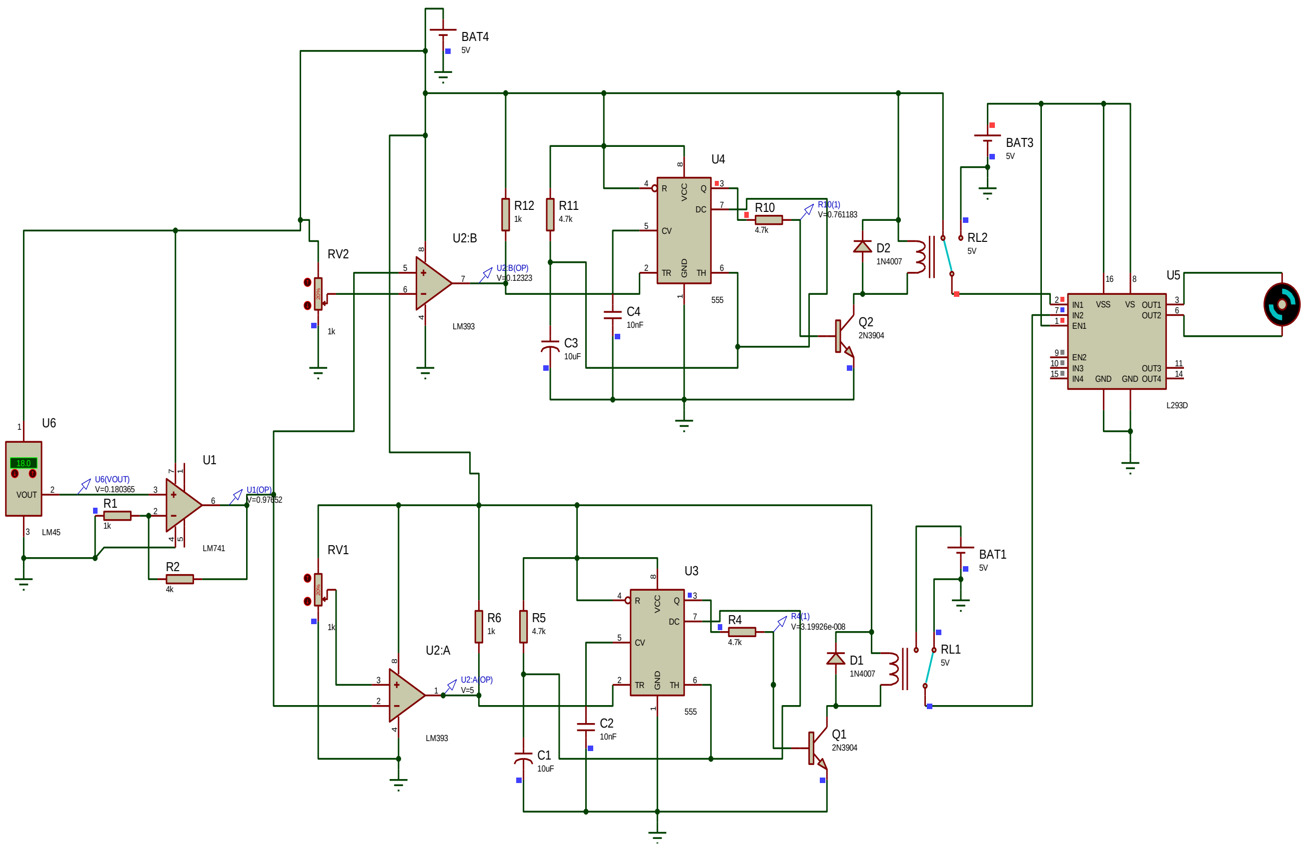

Figure 5: Circuit showing the output of timer U4 when temperature is less than 19 ^{O}C (18 ^{O}C)

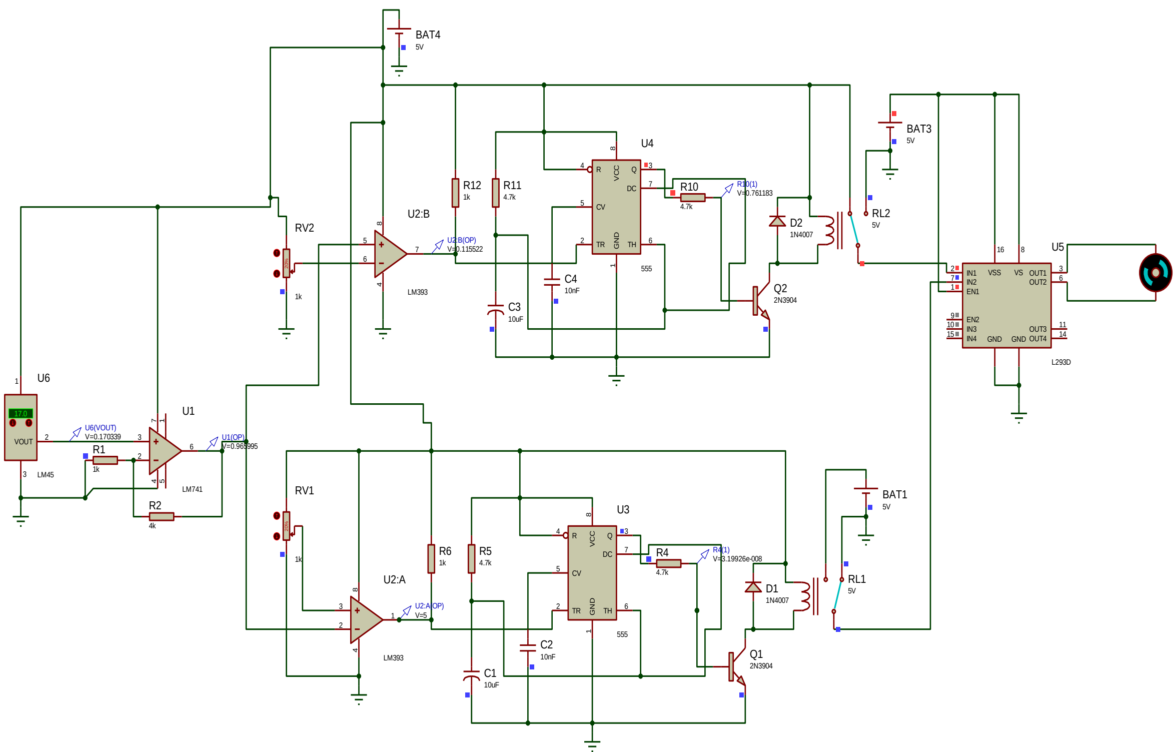

Figure 6: Situation 1 of temperature less than 19 ^{O}C (17 ^{O}C)

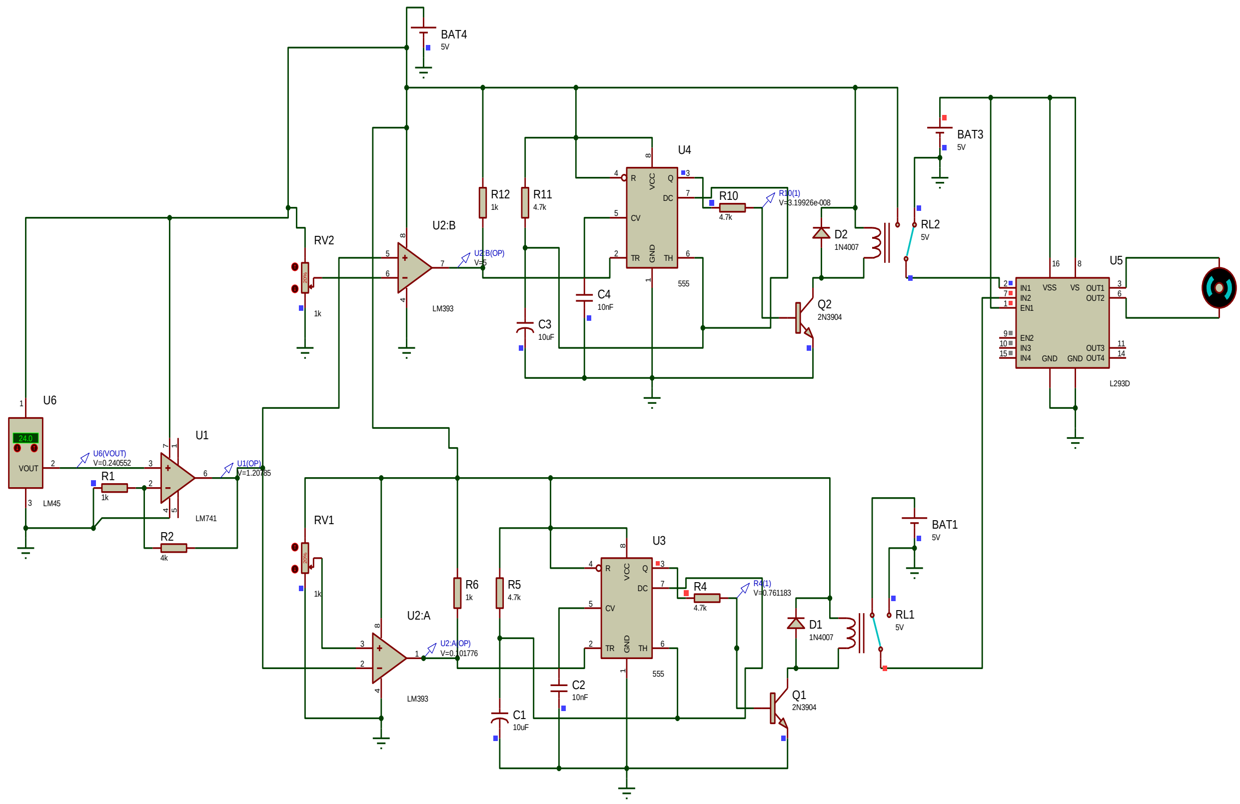

Figure 7: Situation 2 of temperature greater than 19 ^{O}C (24 ^{O}C)

CONCLUSIONS

In this paper, we present the design, simulation and analysis of a Weather Activated Window System. The system uses comparators and timers for the control unit and LM35 as the temperature sensor. The output was varied by setting the temperature at various levels and it was discovered that the motor was able to drive in both directions (clockwise and anticlockwise). The system is exceptionally helpful for people who are disabled. This system can be utilized as a part of Industry and in addition in Home. The system was designed using Proteus and Multisim Software. The system was simulated and working according to the design specifications

Declarations

Availability of data and material

Note Applicable

Competing interests

The authors declares that we have no competing interests

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Authors' contributions

All Authors participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

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REFERENCES

[1] Harris, Cyril M. American architecture: an illustrated encyclopedia. New York: W.W. Norton, 1998. Print

[2] J.E. Johnson, P.F. Maccarini, D. Neuman, P.R. Stauffer, “Automatic Temperature Controller for Multi element Array Hyperthermia Systems,” IEEE Transactions on Biomedical Engineering, 53 (6), pp. 1006-1015, 2006.

[3] A. Cuthill and J. Mcbroom, "Hydraulic control for windows and the like", US 2607195 A, 1952.

[4] A. ABLOY, "Lockwood Elevation Electric Window Actuator - Lockwood Australia", Lockweb.com.au, 2017. [Online]. Available: http://www.lockweb.com.au/en/site/lockweb/lockwood-

products/electromechanical-solutions/electric-window-control-system/elevation-electric-window-actuator/. [Accessed: 13- Mar- 2017].

[5] Pawlak, Sensors and actuators in mechatronics. Boca Raton, FL: CRC/Taylor & Francis, 2007.

[6] I. Boldea and S. Nasar, Linear Electric Actuators and Generators. Cambridge, GBR: Cambridge University Press, 2009.

[7] T. Bailly, "Linear Actuator Range| Kuroda Jena Tec Inc", Kurodajenatec.com, 2017. [Online]. Available: http://www.kurodajenatec.com/linear-actuators.php. [Accessed: 20- Mar- 2017].

[8] M. Laughton and D. Warne, Electrical engineer's reference book. Oxford [England]: Newnes, 2003.

[9] A.M. Zungeru, K.D. Maidawa, J.G. Ambafi, J.T. Omokhafe "Design and Implementation of a Low Cost Digital Bus Passenger Counter", Innovative Systems Design and Engineering, Vol. 3, No. 4, pp. 29–41, 2012.

[10] "Types of Actuators", Forbesmarshall.com, 2017. [Online]. Available: https://www.forbesmarshall.com /fm_micro/news_room.aspx?Id=seg&nid=146. [Accessed: 04- Mar- 2017].

[11] Sclater, N., Mechanisms and Mechanical Devices Sourcebook, 4th Edition (2007), 25, McGraw-Hill

[12] G.J. Fiedler, J. Landy, "Multi-loop Automatic Temperature Control System Design for Fluid Dynamics Facility Having Several Long Transport Delays," IEEE IRE Transactions on Automatic Control, 4 (3), pp. 81-96, 1959.

[13] R.E. Hedges, "Automatic Temperature Control for Transport Airplanes," IEEE Transactions of the American Institute of Electrical Engineers, 66 (1), pp. 1197-1202, 1947

[14] L. Chengxiang, Y. Zhenhua, W. Xu, L. Feng, "Design of Automatic Temperature Control System on Laser Diode of Erbium-Doped Fiber Source," In Proceedings of the IEEE International Conference on Intelligent Computation Technology and Automation, pp. 404407, 2011.

[15] T, Fu, X. Wang, G. Yang, "Design of Automatic Temperature-Control Circuit Module in Tunnel Microwave Heating System," In Proceedings of the IEEE International Conference on Computational and Information Sciences, pp. 1216-1219, 2010.