Design and Construction of a Tri-Sensor Temperature Control System

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Abstract

Temperature is often the most measured environmental quantity which corresponds to primary sensations. It is the degree of hotness or coldness ofbody. A sensor is a device that measures a physical quantity and converts it into an electrical signal. Some sensors measure physical properties directly, while other sensors use conversions or calculations to determine the value. Sensors are usually categorized by the type of property that they measure. The surface temperature of an object can be acquired directly using a thermistor, thermocouple, etc. The purpose of the research was to monitor the temperature of indoor equipment, especially a power substation, a communication data center, with embedded danger, and to aid us in recognizing the phenomenon of temperature rise-rate or the critical temperature point. However, in the case of too much exposure of some electronic components to high extreme temperature, there will be an adverse effect on them which could lead to the damage of the components. Though, some of the components could be affected and damaged by low temperature values. Most temperature monitoring devices are designed to respond to a particular (critical) temperature level. They are usually incorporated with different kinds of alarms and lights indicator units, which are triggered ON at an unacceptable temperature level. These temperature monitoring devices work with temperature sensors normally transducers which generate accurate voltage output that vary linearly with temperature. They are mainly used for monitoring industrial machines, electric boilers, ovens and other heat energy related activities. The temperature monitoring was done by ensuring that the temperature sensor and its leads are at the same temperature as the object to be measured. Several temperature sensing techniques are in widespread usage. The most common of these are: Thermocouples, Thermistors, Sensor IC's and Resistive Temperature detectors (RTDs). Temperature measurement and detection devices play an important roles in the field of mechanical, electrical and telecommunication systems that could be used to speed up work. The test result recorded at its output terminal shows that an increase in temperature increases the voltage at its output and vice–versa. The temperature sensor (LM 35) was used to monitor variations in temperature level of the two devices to which it was connected. This research describes the concept of IC voltage regulators, Amplifiers, comparators and there applications. The tri- sensor temperature system is an important device used in providing audible means of alertness to humans in case of outbreak.Thermal phenomenon cannot be described by the three fundamental quantities i.e. length, mass, and time. A fourth fundamental quantity is used to explain thermal phenomenon and the quantity is referred to as temperature.

Keywords: *Tri-sensor, temperature control, system*

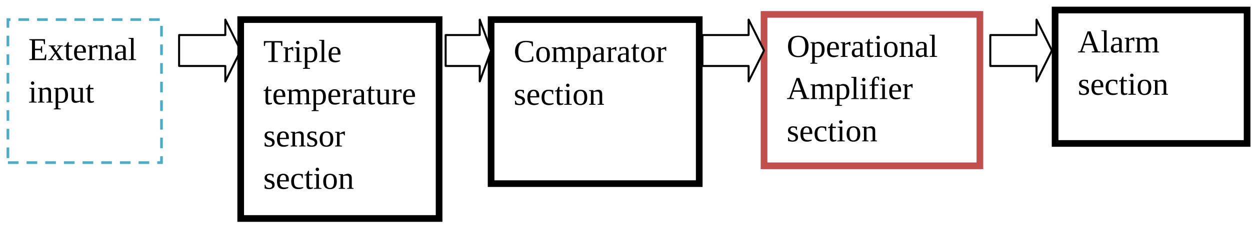
I. INTRODUCTION

Temperature instruments and temperature indicators was designed for temperature measurements monitoring and analysis. These instruments were equipped with integral temperature sensors, or require temperature sensor inputs. Temperature is analogous to electrical potential in electricity, and heat is analogous to quantity of electricity. The temperature monitoring system is so relevant in our modern equipment to detect the rise and fall of temperature with a control system. The ability to sense temperature changes by a sensor is to protect the user system from damages, ensure that the effectiveness is intact and that there is no compromise of reliability standard of the user system. It is portable and cheap, measures rapidly changing temperature due to its small thermal capacity, extremely accurate, cover wide range of temperature beyond 1000 Kelvin. IkehE.E. (2006).Temperature sensors provide inputs to control systems like an electric boiler, industrial machine and other heat energy related systems. Adamu Murtala Zungeru1et al (2012).

II. MATERIAL AND METHODS

A. The Circuit Design Analysis

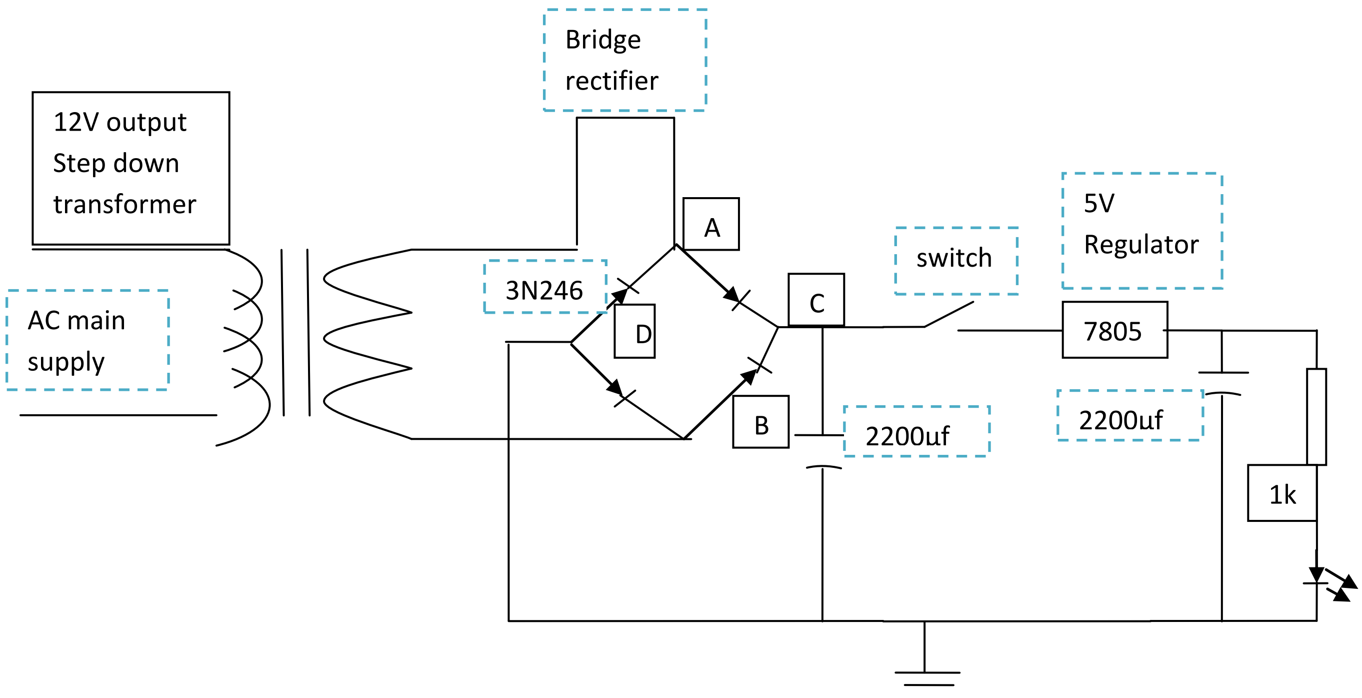
The circuit was designed based on the mode of operation and functions of each componentprovided by the data sheets. The whole component manufacturers' specifications were carefullytaken into consideration. The circuit was aimed at minimum and limited number of components forsimplicity. The modular design of the system is shown in the block diagram below.



The external input segment is one that includes that contains the power supply which could either be a DC or an AC.

LM35 is the temperature sensor which was carefully chosen due to its reliability, efficiency and linearity (Rev D 2013). The operational amplifier is the most useful and single device in analog electronic circuitry. The comparator unit compares two signals or voltage levels with no need for external components (B.L. Therajaetl2005). The alarm section is the part that triggers and sends warning signal to users that the sensors had sensed danger

Power Supply Unit



The difference in voltage between two points in space is defined as

$$\Delta V = \frac{\Delta PE_{elect}}{q} \qquad 1$$

Where ΔPE_{elect} is the change in the potential energy of a particle with charge q as it moves from the initial point to the final point. The amount of power dissipated (i.e. rate at which energy is transformed by the flow of electricity) is then given by the equation. Benjamin Crowell (2002

$$P = I\,\Delta V \qquad 2$$

Where I is the current and ΔV is the change in the potential difference.The voltage from an A.C was stepped down to 12V using a step down transformer and converted to D.C

But $Ripple\ factor\ r = \frac{1}{4\sqrt{3R_L F C_1}}$ 3

Where F = frequency

R_L = load resistance

C = capacitance of the filter capacitor.

The ripple voltage was calculated as;

Peak Voltage, $V_{pk} = V_s \times \sqrt{2}$ (V_s = secondary voltage) 4

$V_{pk} = 1 \times 1.414 - 16.97\ V_{pk}$

$= 0.11879\ V_{ripple}$

And the value of the capacitor, $C = \frac{I_{load}}{2F V_{ripple}}$ 5

Where the load current was measured (I_{load}) as 0.2A and frequency from PHCN supply
f = 50Hz.
C= 168.4μF
The value of the series resistor is given below;

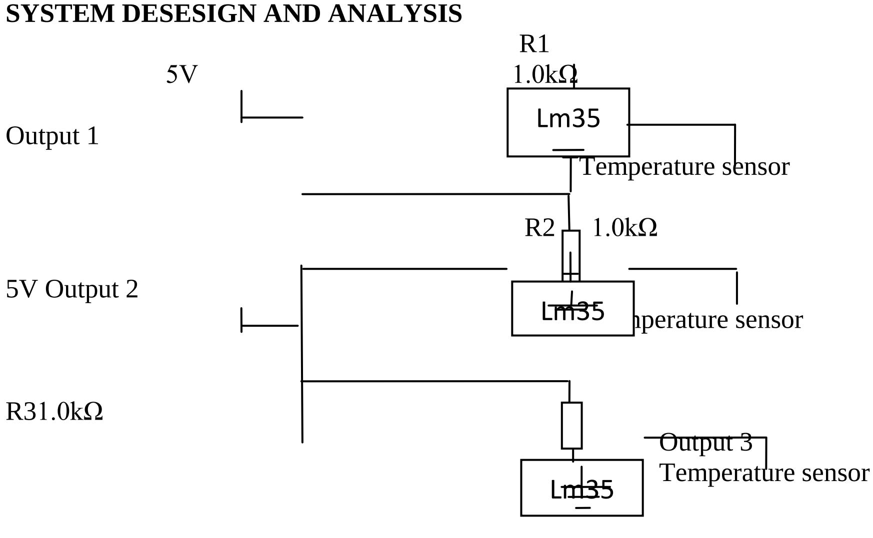
$$R = \frac{voltage\ \ across\ \ the\ resistor}{currnt\ \ flowing\ \ through\ the\ resistor} \quad 6$$

R = 701.22Ω
The 12V and 5V power supplies through the power unit are for the purpose of the integrated circuits and alarm output respectively.

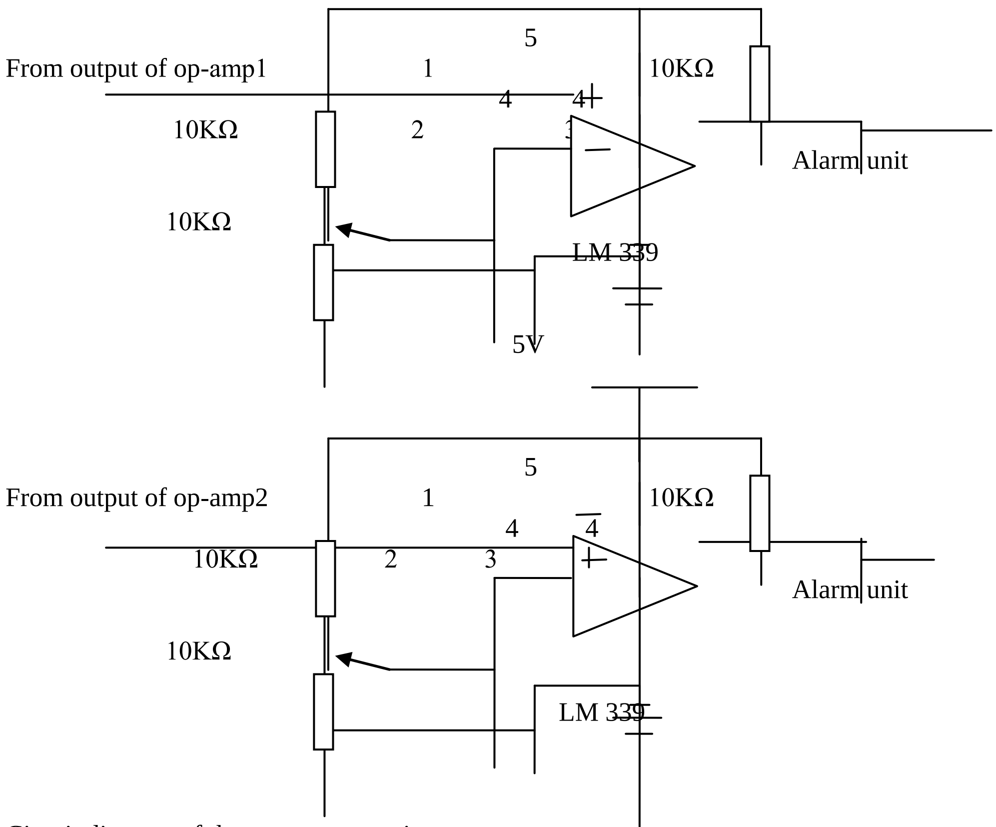
The Temperature sensing

The three temperature sensors used for this design was LM35, the LM35 series are precision integrated-circuit temperaturesensors, whose output voltage is linearly proportional to theCelsius (Centigrade) temperature. The LM35 has anadvantage over linear temperature sensors calibrated in Kelvin than to obtain convenient Celsius scale.The LM35 does not require any externalcalibration or trimming to provide typical accuracies at room temperature and over a full temperature range. Low cost is assured by trimming andcalibration at the wafer level (Rev D 2013). LM35-temperature sensor mounted on the bread board was used for monitoring room temperature. The advantage of this sensor has more memory, processing and communication capabilities than other sensor nodes. The LM35 series are precision integrated – circuit temperature sensors, whose output voltage was linearly proportional to the Celsius scale. The LM35 thus has an advantage over linear temperature sensors calibrated in 0^0K, as the user is not required to subtract a large constant voltage from its output to obtain convenient Celsius scale. The LM35 does not require any external calibration or trimming to provide typical accuracies of ± -1/40C at room temperature and +- 8/40C over a full -55 to +1500C temperature range. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60μA from its supply, it has very low self-heating, less than 0.10 in still air. The LM35 is rated to operate over a -550 to +1500 temperature range (Poonam et al. 2013).

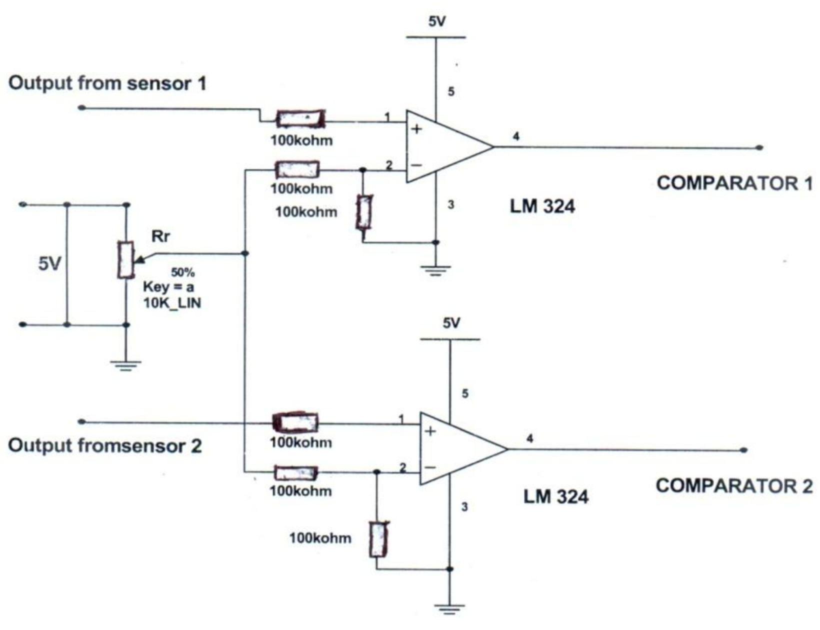
SYSTEM DESESIGN AND ANALYSIS



Circuit diagram of the temperature sensor unit



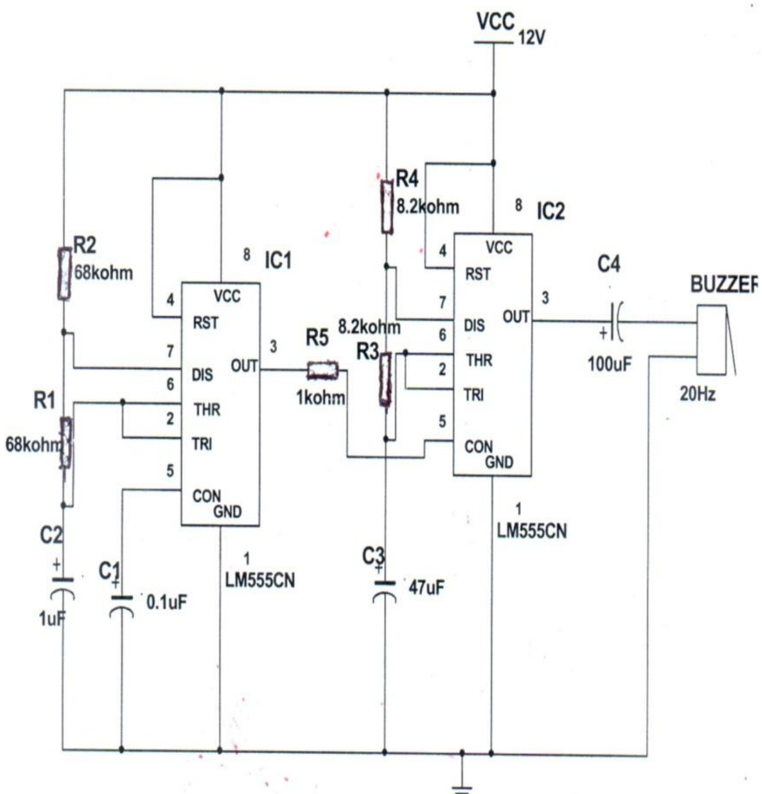
Circuit diagram of the comparator unit.



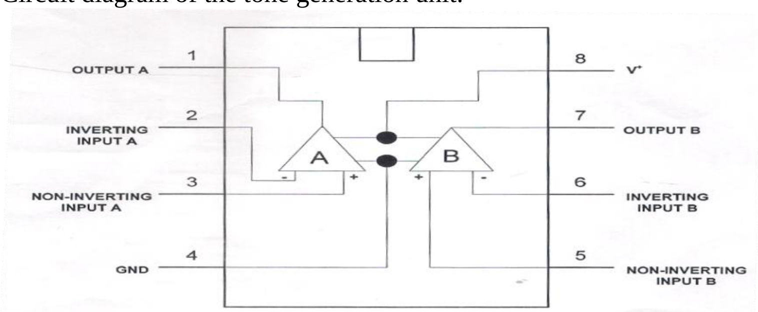
Circuit diagram of operational amplifier unit

The Alarm Unit

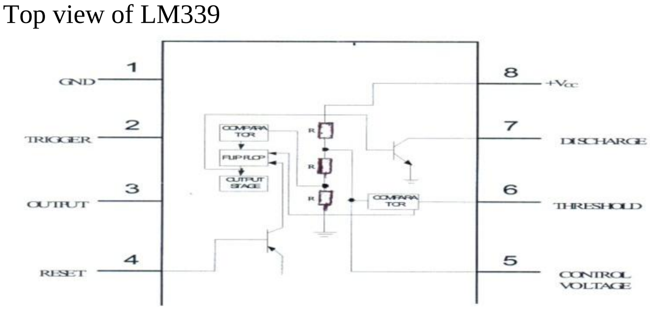
The Tone Generator Unit was built on the 555 Timer IC, but in the Astable mode. Unlike in the Monostable state, the Astable mode has no stable state; the output was continually changing between 'low' and 'high'.



Circuit diagram of the tone generation unit.



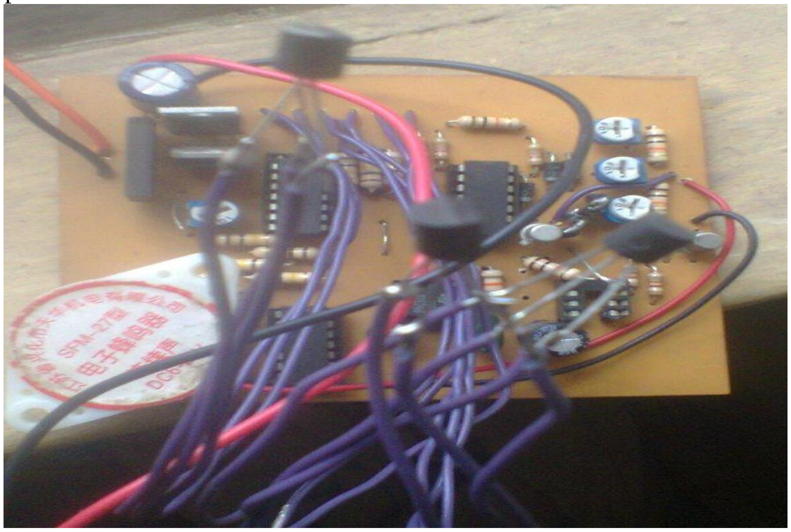
Top view of LM339



Functional diagram of 555 Timer

The above circuit consists of two comparators, a flip-flop, two control transistors and a high current output stage. The two comparators compare input voltage to an internal reference voltage which are generated by an internal voltage divider of three 5K resistors. The reference voltages provided are one third and two third of V_{CC}. When the input voltage to either of the comparators is higher than the reference voltage for the comparator, the amplifier goes to saturation and produces an output signal to trigger the flip-flop. The output of the flip-flop controls the output stage of the timer. The 555 timer chip works within the range of 3-15VDC.

Pin 1: This is ground pin and should be connected to the negative side of the power supply voltage.
Pin 2: This is the trigger input. A negative voltage pulse cannot be applied to this pin when falling below 1/3 $V_{CC,}$ it causes the comparator output to change state. The output level then switches from LOW to HIGH. The trigger pulse must be of shorter duration than the time interval set by the external CR network otherwise the output remains high until trigger input is driven high again.
Pin 3: This is the output pin and is capable of sinking or sourcing a load requiring up to 200mV and can drive TTL circuits. The output voltage available is approximately -1.7V
Pin 4: This is the rest pin and was used to reset the flip-flop that controls the state of output pin3. A reset was activated with a voltage level of between 0V and 0.4V and forces the output to go low regardless of the state of the other flip-flop inputs. If reset is not required, then pin 4 should be connected to the same point as pin 8 to prevent constant reset.
Pin 5: This is the control voltage input. A voltage applied to this point to this pin allows the timing variations independently of the external timing network. Control voltage was varied from between 45 to 90 of the V_{CC} value in Monostable mode. In Astable mode the variation is from 1.7 to the full value of supply voltage. This pin was connected to the internal voltage divider so that the voltage measurement to ground should read 2/3 of the voltage applied to pin 8. If this pin was not used it should be bypassed to ground, typically 10nF capacitor. This helps to maintain immunity from noise.
Pin 6: This is the threshold input. It resets the flip-flop and hence drives the output low if the applied voltage rises above two-third of the voltage applied to pin 8. Additionally a current of minimum value 0.1 A must be supplied to this pin since this determines the maximum value of resistance that can be connected between the positive side of the supply and this pin. For a 15V supply the maximum value of resistance is 20M.
Pin 7: This is the discharge pin. It is connected to the collector of an NPN transistor while the emitter is grounded. Thus the transistor is turned on and pin 7 is effectively grounded. Usually the external timing capacitor is connected between pin 7 and ground and is thus discharged when the transistor goes on.
Pin 8: This is the power supply pin and is connected to the positive end of the supply voltage. The voltage applied was varied from 4.5V to 16V. The reset input (555 pin 4) overrides all other inputs and the timing may be cancelled at any time by connecting reset to 0V, this instantly makes the output low and discharges the capacitor. If the reset function is not required the reset pin should be connected to +Vs.



PCB circuit of tri-sensor temperature system

TESTING AND RESULT

Measurement of temperature is critical in modern electronic devices, especially expensive laptop computers and other portable devices with densely packed circuits which dissipate considerable power in the form of heat. Knowledge of system temperature can also be used to control battery charging as well as prevent damage to expensive microprocessors. Compact high power portable equipment often has fan cooling to maintain junction temperatures at proper levels. In order to conserve battery life, the fan should only operate when necessary. Accurate control of the fan requires knowledge of critical temperatures from the appropriate temperature sensor (Walt Kester et. al.

1999). IC sensors with its high linearity are apt to providing reliable temperature sensing. All electronic systems, from portable consumer products to precision industrial devices, are affected by extremes of heat and cold. If not protected, the components in these systems can be damaged by temperatures that fall outside the components' operating ranges.

TESTING THE TEMPERATURE SENSORS

Testing these sensors was quite easy but one needs a power supply. A regulated 5Volts DC power supply was connected so that ground is connected to pin 3 (right pin), and power is connected to pin 1 (left pin). Then a multimeter in DC voltage mode was connected to the ground and the remaining pin 2 (middle). At room temperature (about 27°C), the voltage should be about 0.60V. Note that if one is using a LM35, the voltage will be 0.27V.

One can change the voltage range by pressing the plastic case of the sensor with your fingers; you will see the temperature/voltage rise. Or you can touch the sensor with an ice cube, preferably in a plastic bag so it doesn't get water on your circuit, and see the temperature/voltage drop.

The three LM35 used in the design and construction are integrated circuits that combines both active and passive components together on a tiny sheet of silicon. (B.L. Theraja et. al 2005), reacts adequately fast and respond actively to rise in temperature within an electronics system.

Table 1: Temperature Sensor Characteristics

	NTC Thermistor	Platinum RTD	Thermocouple	Semiconductor
Sensor	Ceramic (metal oxide spinel)	Platinum wire wound or metal Film	Thermoelectric	Semiconductor Junction
Temperature Range (typical)	-100 to +325˚C	-200 to +650˚C	-200 to +1750˚C	-70 to 150˚C
Accuracy (typical)	0.05 to 1.5 ˚C	0.1 to 1.0˚C	0.5 to 5.0˚C	0.5 to 5.0˚C
Long-term Stability @	100˚C 0.2˚C/year (epoxy) 0.02˚C/year (glass)	0.05˚C/year (film)	0.002˚C/year (wire) Variable, some types very prone to aging	>1˚C/year
Output	NTC Resistance -4.4%/˚C typical	PTC resistance 0.00385Ω/Ω/°C	Thermovoltage 10μV to 40μV/°C	Digital, various Outputs
Linearity	Exponential	Fairly linear	Most types nonlinear	Linear
Power Required	Constant voltage or current	Constant voltage or current	Self-powered	4 to 30 VDC
Response Time	Fast 0.12 to 10 seconds	Generally slow 1 to 50 seconds	Fast 0.10 to 10 seconds	Slow 5 to 50 seconds
Susceptibility to Electrical Noise	Rarely susceptible High resistance only	Rarely susceptible	Susceptible/Cold junction compensation	Board layout Dependent
Lead Resistance Effects	Low resistance parts only	Very susceptible. 3 or 4-wire configurations required	None over short runs. TC extension cables required.	N/A
Cost	Low to moderate	Wire-wound – High Film – Low	Low	Moderate

Table 2.1: Sensor Characteristics
TEST RESULTS

Working voltage…………..12 DC

Output power handling……100watts

Max current consumption....2500 mA

Max load current………….200mA

Max load voltage………… 240VAC.

Max Temp detection range – 40^{o}c – 150^{o}c

Weight 600g

APPLICATION OF THE DEVICE

The constructed device can be used in the following areas; computing, cellular /PCs, power supply embedded systems and telecommunication

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SIGNIFICANCE OF THE RESEARCH.

Thermal phenomenon cannot be described by the three fundamental quantities i.e. length, mass, and time. A fourth fundamental quantity is used to explain thermal phenomenon. This quantity is referred to as temperature. The physical properties of a material change with application of heat. These properties are known as thermometric properties. The science and technology dealing with the measurement of temperature below 500^{o}C is referred to as thermometry, while on the other hand pyrometry deals with temperature above500^{o}C. Since the sense of touch cannot ascertain the degree at which a system has increased or decreased in temperature, an objective, numerical measure of temperature, a detector that could give a reliable and accurate reading to the change in temperature in a system is employed.

DISCUSSION

The results from this research could not have been accomplished without the DC power supply. It forms the main building block on which all other section of the project relies on. The design of the power supply was possible because, the necessary components needed for its design were all met.

Linear IC voltage regulator plays an important role in providing a constant DC output irrespective of the fluctuations present at the input line. LM35 linear temperature sensor was used in other to actualize the desired aim. The test result recorded at its output terminal shows that an increase in temperature increases the voltage at its output and vice–versa.

In electronics, a comparator is a device that compares two voltages or currents and switches its output to indicate which one was larger. They are commonly used in devices such as analog-to-digital converter

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