International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013 1809
ISSN 2229-5518

Wireless Telemetry Based Temperature Detection System

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Abstract— The main objective of this project is to build a wireless telemetry system that has the capability to sense the ambient temperature of the source location through a temperature sensor, the corresponding signal from the sensor is then transduced to a suitable form of energy, which is then relayed to the transmitter section. The transmitter at the application zone is set to a certain set point (threshold temperature) which when exceeded sends a signal to the receiver location as a notification of the rising temperature of the source location.

Index Terms— Antenna, Modulation, Temperature Sensor, Transducer, Wireles Telemetry

1 Introduction

In recent times industrialization has expanded and so has there been an improvement in the equipments and machinery used. In aspect of these complex processes which involve manufacturing, processing, transporting of goods and raw materials new concepts of engineering are being implemented not only to improve the quality of the product but also ensuring and safeguarding the workers or manpower involved in this process. As is cited in the case of an iron and steel plant it is not possible for a human being to physically measure the temperature inside a furnace to provide a safeguarding limit for temperature without causing injury to himself. Thus we require such a system which not only provides the value of a parameter to be measured in a hazardous environment but also eliminates human intervention.

We thus apply the system of telemetry to measure such parameters in a hazardous environment. Telemetry is the science of measuring a parameter in a hazardous environment and transmitting an equivalent signal to a place where this information can be recorded, displayed or manipulated for application. Thus the project here is moreover a simple application of the telemetry principle on a small scale to detect and indicate by some alarm that the threshold temperature has been exceeded and an action needs to be taken to control the temperature.

2 Methodology

The methodology used in this project is the principle of telemetry. A heater is used whose temperature is to be measured by a temperature sensor. Now all signals are not suitable enough to be transmitted using basic transmitter and modulation techniques available. So this signal received from the sensor needs to be converted to a more amiable or likeable form which can be easily transmitted with cost –effective transmission and modulation equipments and also involving less external disturbances and noise. The most readily available equipments in the markets today deal with analogue signals in the form of voltage or current. Therefore we have used a transducer to convert this temperature signal received from the sensor to a equivalent voltage signal. In order to notify that the temperature indicated has crossed the threshold value, an op-amp has been used which drives the transistors to saturation which is further conveyed in series with a relay. Now the signal from the relay is transmitted using a suitable transmitter circuit with a proper modulation method. This signal is received at the receiver end through proper synchronization and is utilized to raise an alarm signal indicating that the temperature has crossed the danger level. In order to combat the effects of noise and external disturbances we have used capacitors to counter the ripple effect and transistors of suitable gain to amplify the signal along with inductors for coupling. The different steps involved in carrying out the work are illustrated as follows:

2.1 Problem Definition

The main objective being acheived here is to indicate or raise an alarm signal at the receiving end when the temperature of the heater has crossed the danger threshold (that is 200 degrees centigrade) in this case.

2.2 Planning and Approach

The principle of telemetry was employed with the purpose of attaining the above mentioned objective. Now telemetry is concerned with the transmission of a signal from a hazardous area to a safer area. In order to implement the principle of telemetry we therefore require a transmitting and receiving part. But before designing the transmitting and receiving part, the signal needs to be converted to a more likeable form to enable easier and cost-effective transmission. Therefore, by designing a proper transducer circuit, as will be shown in the design aspects, the incoming signal was converted into an equivalent

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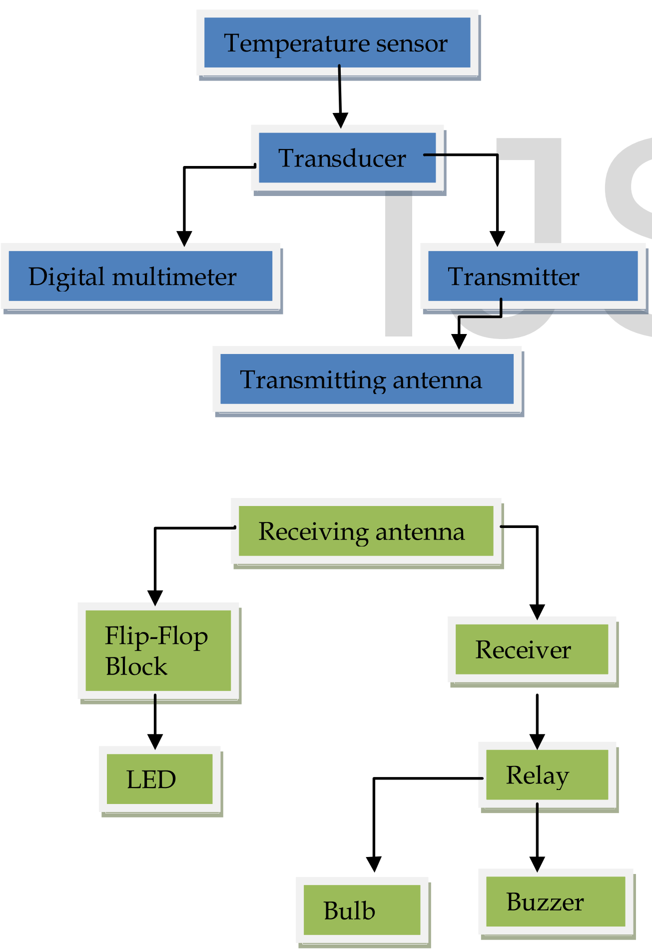
ISSN 2229-5518

voltage signal. Now, as per the project objective the system was required to generate a signal only if the measured temperature exceeds the threshold value. For this purpose, an op-amp which is set to a particular preset voltage was used. The preset voltage is the threshold voltage when the temperature recorded is the threshold temperature. Once the particular temperature exceeded, the op-amp drives the transistors in series to saturation. After the required signal was generated, it was modulated and transmitted, through a transmitter. The transmitted signal was synchronized and demodulated at the receiver end which was used to trigger the alarm signal. Here we implemented the method of wireless telemetry by using antennas to transmit and receive.

2.2.1 System Design

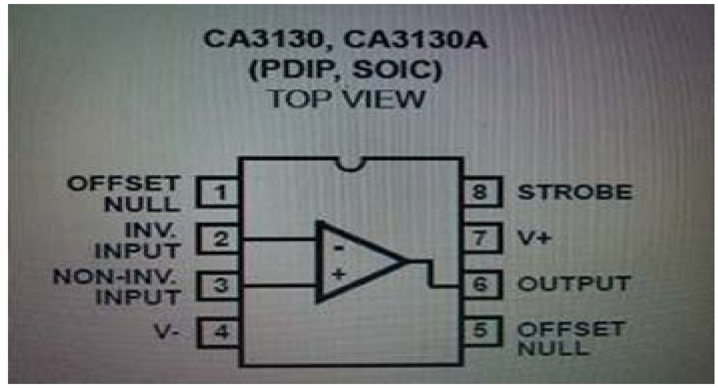
Overall Block Diagram



2.2.1.1 Details of the Used Components:

OP-AMP CA3130: 15MHz, BiMOS Operational amplifier with MOSFET Input/CMOS Output

Fig.1 Internal circuit of CA3130



CA3130A and CA3130 are op amps that combine the advantage of both CMOS and bipolar transistors. Gate-protected P-Channel MOSFET (PMOS) transistors are used in the input circuit to provide very-high-input impedance, very-low-input current and exceptional speed performance.

The use of PMOS transistors in the input stage results in common-mode input-voltage capability down to 0.5V below the negative-supply terminal, an important attribute in single-supply applications. A CMOS transistor-pair, capable of swinging the output voltage to within 10mV of either supply-voltage terminal (at very high values of load impedance), is employed as the output circuit. The CA3130 Series circuits operate at supply voltages ranging from 5V to 16V, (±2.5V to ±8V). They can be phase compensated with a single external capacitor, and have terminals for adjustment of offset voltage for applications requiring offset-null capability. Terminal provisions are also made to permit strobing of the output stage. The CA3130A offers superior input characteristics over those of the CA3130.

RELAY (JQC-3FC/T73): A relay is an electromagnetic switch. It switches a circuit on/off.

Features

- Superminiature, High power.
- Low coil power consumption.
- PC board mounting.
- Suitable for household applications, automation system, electronic equipment, instrument and meter, communication facilities and remote control facilities.

Specifications

HK RELAY

- OUTLINE DIMENSIONS:15.4*19.5*15.0MM
- MAX. SWITCHING CURRENT:7A, 10A
- MAX. SWITCHING VOLTAGE:28V DC/ 250V AC
- DIELECTRIC STRENGTH VR.M.S: BETWEEN OPEN CON TACTS ≥750VAC;
  BETWEEN COIL AND CONTACTS ≥1000VAC;
  BETWEEN CONTACTS FORM ≥1000VAC;
- AMBIENT TEMPERATURE: -40-+85oC;
- OPERATION/RELEASE TIME:≤10/8MS
- CONTACT CAPACITY: 10A 240VAC, 6.3A 28VDC

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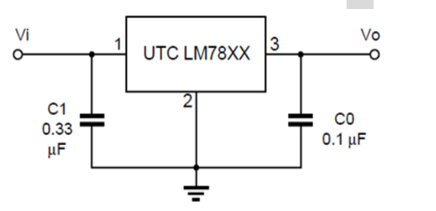
•The relay is in normally open condition (N/O). When the transistors in series acting as a switch are driven to saturation by the output of the op-amp (when temperature exceeds threshold 200 degrees centigrade) the relay condition is changed to normally closed condition (N/C) thus feeding the signal to the transmitter.
We have not used a diode across the relay since we are using a 9V battery instead of an ac supply.

FIXED REGULATORS (LM78XX): "Fixed" three-terminals linear regulators are commonly available to generate fixed voltages of plus 3V, and plus or minus 5V, 6V, 9V, 12V or 15V when the load is less than 1.5 amperes.

Often the last two digits of the device number are output voltages.The regulating device is made to act like a variable resistor continuously adjusting a voltage divider network to maintain a constant output voltage.

Fig.2 UTC LM 78XX



Transmitter IC (TX-2B):

After the signal has been relayed to the transmitter section we must now modulate it and prepare the signal for transmission. For our project we have used the amplitude modulation method using transmitter TX-2B chip.

Fig.3 Pin Configuration of TX-2B

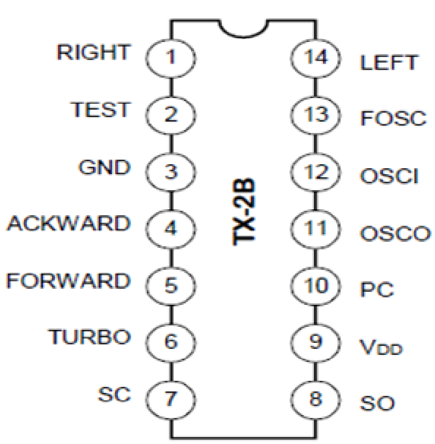


Fig.4 Pin Description

1. TX-2B

Pin No.	Symbol	Description
1	RIGHT	The rightward function will be selected, if this pin is connected to GND
2	TEST	This pin is used for testing mode
3	GND	Negative power supply
4	BACKWARD	The backward function will be selected, if this pin is connected to GND
5	FORWARD	The forward function will be selected, if this pin is connected to GND
6	TURBO	The turbo function will be selected if this pin is connected to GND
7	SC	Output pin of the encoding signal with carrier frequency
8	SO	Output pin of the encoding signal without carrier frequency
9	VDD	Positive power supply
10	PC	Power control output pin
11	OSCO	Oscillator output pin
12	OSCI	Oscillator input pin
13	FOSC	This pin is used for testing mode
14	LEFT	The leftward function will be selected, if this pin is connected to GND

Receiver IC (RX-2B):

After the signal has been modulated and transmitted by the antenna at the transmitting block, it has to be received and demodulated at the receiving end for providing the alert against the excessive change in temeperature at the site where it is being monitored. This demodulation is done by the receiver counterpart of the transmitter chip-RX-2B. It is a 16 pin IC.

Fig.5 Pin Configuration of RX-2B

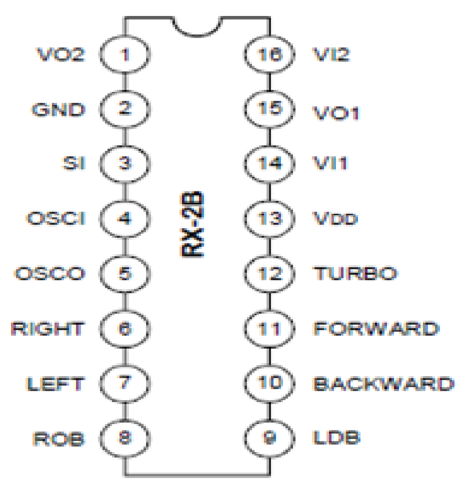


Fig.6 Pin Description

2. RX-2B

Pin No.	Symbol	Description
1	VO2	Inverter 2 output pin for power amplify
2	GND	Negative power supply
3	SI	Input pin of the encoding signal
4	OSCI	Oscillator input pin
5	OSCO	Oscillator output pin
6	RIGHT	Rightward output pin
7	LEFT	Leftward output pin
8	ROB	Rightward function disable, if this pin is connected to GND
9	LDB	Leftward function disable, if this pin is connected to GND
10	BACKWARD	Backward output pin
11	FORWARD	Forward output pin
12	TURBO	TURBO output pin
13	VDD	Positive power supply
14	VI1	Inverter 1 input pin for power amplify
15	VO1	Inverter 1 output pin for power amplify
16	VI2	Inverter 2 input pin for power amplify

2.2.1.2 System Blocks:

The project design basically consists of five sections-

1. Temperature Sensor Block

There were two temperature sensors used in the project. They were LM35 and NTC. The sensors are protected from damage by using sparkles which were glued to aluminium foil. The sensors recorded the temperature of the heater. The reason behind using two sensors is that LM35 which is a surface mount device is not compatible with the multimeter that we have used to give us a temperature reading of the heater. Thus NTC is connected with the multimeter to give us a temperature reading while LM35 couples the signal to the transducer. There are two wires coming from the sensing circuit. The black wire is connected to LM35 and the red wire is connected to the NTC.

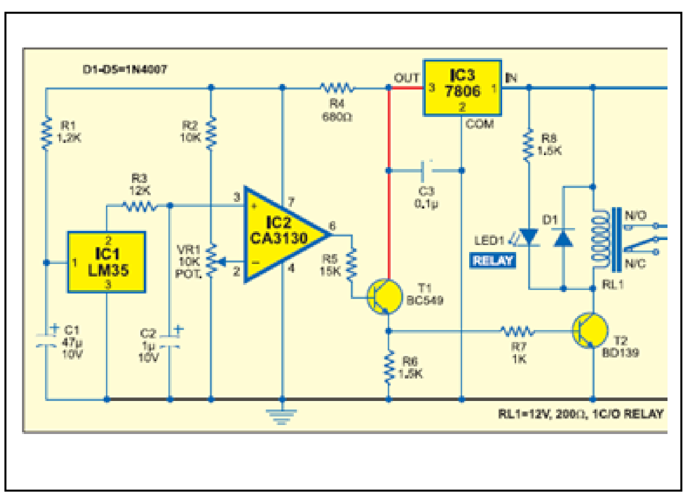
2. Transducer Block

At the heart of this heat-sensitive switch is IC LM35 (IC1), which is a linear temperature sensor and linear temperature-to-voltage converter circuit. The converter provides accurately linear and directly proportional output signal in millivolts over the temperature range of 0°C to 155°C. It develops an output voltage of 10 mV per degree centigrade change in the ambient temperature. Therefore the output voltage varies from 0mV at 0°C to 1V at 100°C and any voltage measurement circuit connected across the output pins can read the temperature directly. The input and ground pins of this heat-to-voltage converter IC are connected across the regulated power supply rails and decoupled by R1 and C1. Its temperature-tracking output is applied to the non-inverting input (pin 3) of the comparator built around IC2. The inverting input (pin 2) of IC2 is connected across the positive supply rails via a voltage divider network formed by potentiometer VR1.

Since the wiper of potentiometer VR1 is connected to the inverting input of IC2, the voltage presented to this pin is linearly variable. This voltage is used as the reference level for the comparator against the output supplied by IC1. So if the non-inverting input of IC2 receives a voltage lower than the set level, its output goes low (approximately 650 mV). This low level is applied to the input of the load-relay driver comprising npn transistors T1 and T2. The low level presented at the base of transistor T1 keeps it nonconductive. Since T2 receives the forward bias voltage via the emitter of T1, it is also kept non-conductive. Hence, relay RL1 is in de-energised state, keeping mains supply to the load 'off' as long as the temperature at the sensor is low. Conversely, if the non-inverting input receives a voltage higher than the set level, its output goes high (approximately 2200mV) and the load is turned 'on.' This happens when IC1 is at a higher temperature and its output voltage is also higher than the set level at the inverting input of IC2. So the load is turned on as soon as the ambient temperature rises above the set level. Capacitor C3 at this pin helps iron out any ripple that passes through the positive supply rail to avoid errors in the circuit operation. By adjusting potentiometer VR1 and thereby varying the reference voltage level at the inverting input pin of IC1, the temperature threshold at which energisation of the relay is required can be set. As this setting is linear, the knob of potentiometer VR1 can be provided with a linear dial calibrated in degrees centigrade. Therefore any temperature level can be selected and constantly monitored for external actions like turning on a room heater in winter or a room cooler in summer. The circuit can also be used to activate emergency fire extinguishers, if positioned at the probable fire accident site. The circuit can be modified to operate any electrical appliance. In that case, relay RL1 must be a heavy-duty type with appropriately rated contacts to match the power demands of the load to be operated.

The a.c. power supply in the circuit diagram in the right side block has not been used in our design. Instead we have used a dc power supply through a 9Vbattery where the power to the entire transducer and transmitter block has been regulated to 6V by using a voltage regulator IC LM7806 for making it compatible with LM35 whose range is 2.7-7.5V.

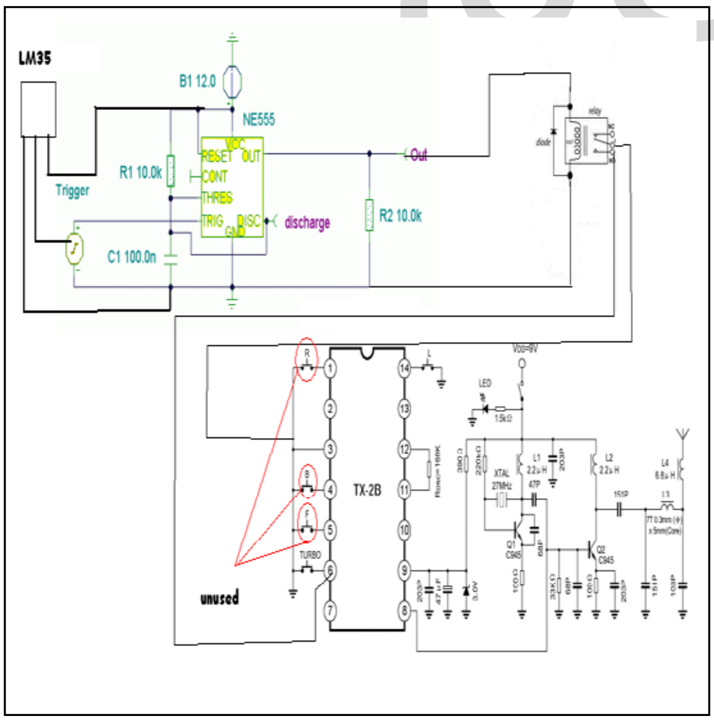
Fig.7 Transducer Block-General Circuit Diagram



3. Transmitter Block

The signal from the relay comes to the transmitter block via the red wire. The transmitter block is centered around the IC TX-2B which is a 14 pin chip. It modulates the signal and transmits the same to the receiver counterpart via an antenna. Before that a gang capacitor has been used to fix the signal transmission at 27MHz. Transistors have been used in Darlington configuration to increase the gain of the signal to be transmitted. We have used an open wire as a unidirectional antenna. The type of modulation used is amplitude modulation (A.M.).
We have used a gang capacitor which is tuned to 27MHZ to modulate the input signal. The modulated signal is then transmitted through the transmitter TX-2B chip.

Fig.8 Transmitter Block-Application Circuit Dagram



Here, in the above figure, we see pins 3 and6 are the i/p of the chip and we get our o/p from pins 8 and 9 of the same chip accordingly, the crystal in the circuit referred to as the XTAL provides the necessary operating frequency of 27MHz, the combination of two transistors is basically used to provide a significant gain to the otherwise weak o/p signal received from the chip, which is then subsequently transmitted using the antenna as shown in the figure above, the LED used above is used to indicate the time of operation of the above circuit. Here the resistors are used as the current limiters, capacitors to counter ripple effect and inductors for input coupling.

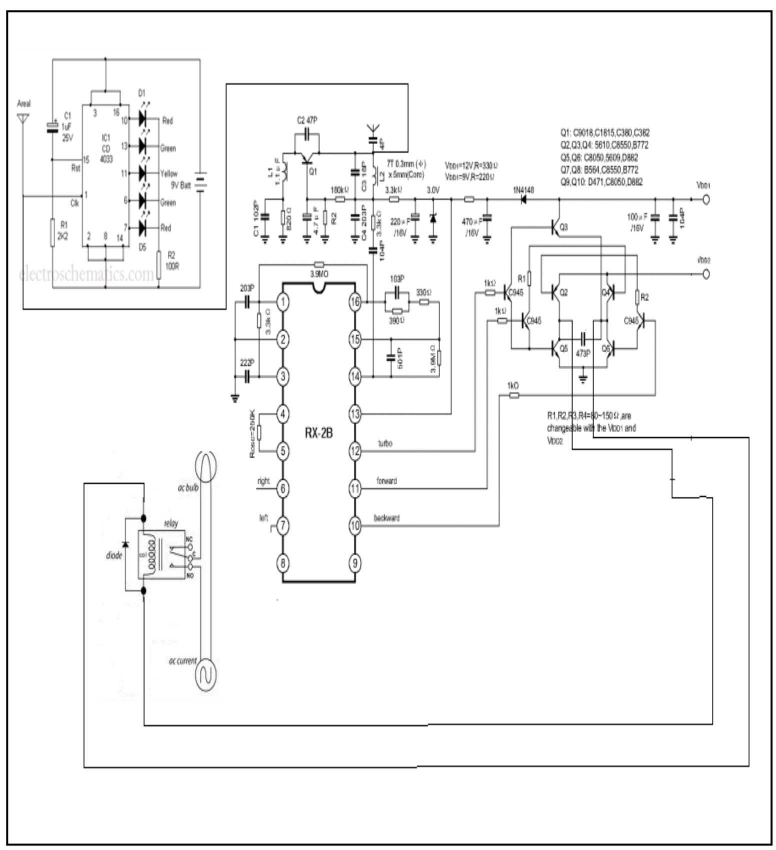
4. Receiver Block

The receiver circuit is centred on the 16 pin IC RX-2B. Just like the transmitter circuit, the receiver block also consists of an antenna in the form of an open wire which receives the signal at 27 MHz again and sends it to the tank circuit(R-C circuit). From the tank circuit it goes to the flip flop circuit (which is discussed in details later on) to activate the LED-s and also to the receiver chip. The receiver block is connected to 230 V A.C. and has a step down transformer which brings it down to 12 V, which in return drives the flip flop circuit and the receiver circuit. When the receiving antenna receives a signal it triggers the tank circuit and in return the RX-2B demodulates the signal and activates the relay. The relay switches from Normally close(N/C) to Normally open(N/O) on receiving a signal at the output of RX-2B and activates the bulb and buzzer.

The RX-2B is basically used as a counterpart of the transmitter chip TX-2B that had been used in the transmitter section, both the chips are equivalent to one another except for the function of each chip, where one is used only for modulation, the other or the chip RX-2B is used for demodulation of the received signal that had previously been modulated and transmitted by it's counterpart and duly received at the receiver section with the suitable antenna.

Thus, the combination of these transmitter and receiver chip i.e TX-2B and RX-2B are used in close range signal transmission such as in car remote sensing .These chips are basically used for amplitude modulation as specified by the manufacturer. The only difference between the two chips are the two extra pins on the RX-2B chip in the form of inverter 2 i/p and o/p pins respectively.

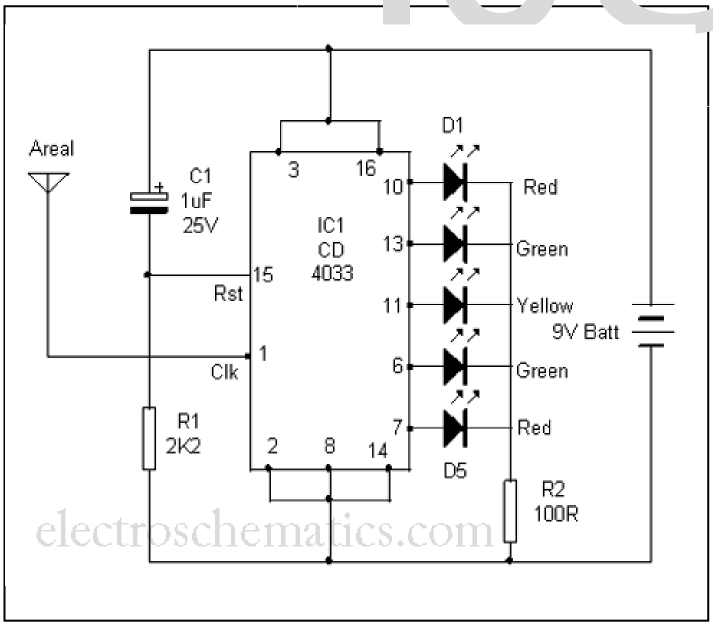
Fig.9 Receiver Block- Circuit Diagram



5. The Flip –Flop Block

As discussed before, the signal received from the tank circuit is fed to a Flip/Flop block to activate the LEDs, which in turn will give a running light pattern at the moment the circuit senses the electromagnetic radiation from the device.The IC CD 4033 is a decade counter cum 7 segment display deiver. It has seven inputs to drive LEDs or seven segment display.The clock input pin (pin1) of IC is very sensitive and readily accepts energy. The reset pin 15 of IC is connected to C1 and R1 to reset the IC after completing a cycle, so that the functioning of IC continues till the input pulse ceases.Thus this chip is used as radiation signaling sensor, the transmitted signal is feedbacked to an emitting device which in turn glows the LEDs.

Fig.10 Radiation sensor circuit diagram



3 Testing

For the testing of the project an external power source is applied to both the transmitter section and the receiver section. In the transmitter the power source is a 9V battery which drives the circuit.

The power source in the receiver circuit is the A.C. supply of 230 volts. A step down AC/DC transformer is used to convert the 230V A.C. to a 12V D.C. supply for the receiver chip and the flip flop circuit. This voltage drives the L.E.Ds via the flip-flop circuit. The bulb and buzzer are connected to the 230 V mains A.C. supply and activated the relay.

A multimeter with temperature measurement facility is connected to the output of the NTC sensor so as to know the temperature at the test-site.

4 Results and Discussions

The sensor is fitted inside the system whose temperature is to be monitored. We have taken a candle and brought the sensor in contact with it. As temperature of the system increases and crosses the preset value of 200 degree celcius, the op-amp output triggers the relay and it in turn activates the transmitter circuit. The same signal is modulated and transmitted at 27MHz and received at the receiver end at the same frequency. The receiver circuit activates the LED-s and demodulates the signal to activate the bulb and buzzer.

The Transmitter circuit is triggered at around 210 degree celcius and the receiver circuit received the signal at 220 degree celcius. After receiving the warning once the power supply to the test site is switched off, the receiver stopped the warning and got disconnected as the temperature at the test site reduced to 110 degree celcius.

Here, we see that the use of appropriate antenna greatly influences the range of the signal transmission, further if we could tune the oscillator a higher frequency and correspondingly change the transistors compatible with the relevant frequency, the range of transmission can be greatly increased. Also signal strength or noise immunity can be greatly improved by changing the kind of modulation that is more immune to noise thus making the project more effective as a wireless temperature detection system.

5 Conclusion

This project was a small application of a wireless telemetry system with huge prospects of development. This system has an important application in the form of an Emergency temperature detection system, wherein it could be used to alert a control room in case of an excessive rise in temperature at a work station.

We could further tap in, on the potential benefits of this system with extensions in the form of increase in the range of transmission or employing multi-channel multiplexing in order to realize a Wireless Sensor Network (WSN) which consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location.

6 System Snapshots

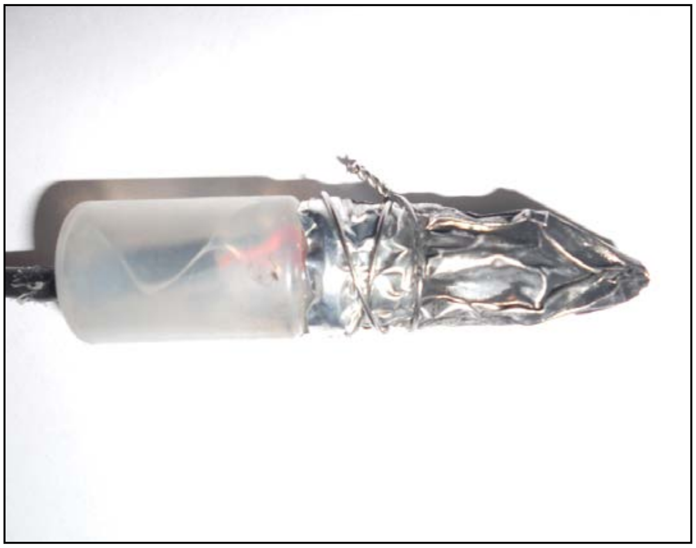


Fig.11 Temperature Sensors: LM35 and NTC. The sensors are protected from damage by using sparkles which were glued to aluminium foil.

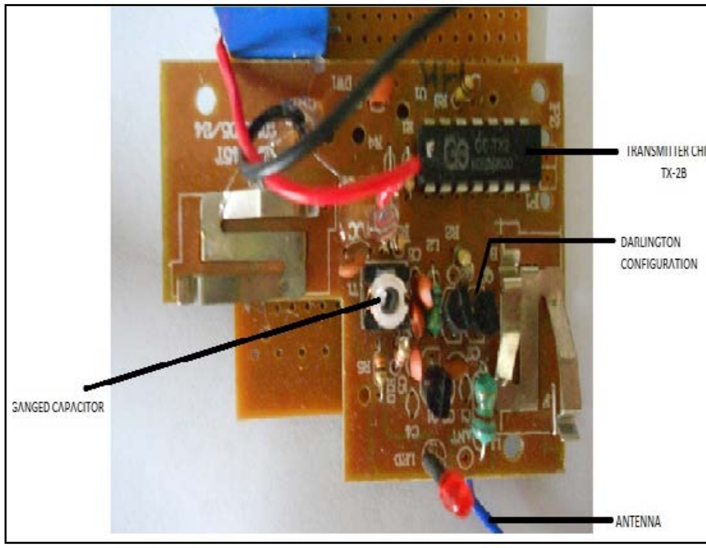


Fig.13 Transmitter Section: TX-2B signal modulation (Voltage-Frequency) chip with Darlington configuration of transistors for signal gain and gang capacitor for tuning the signal transmission to 27 MHz.

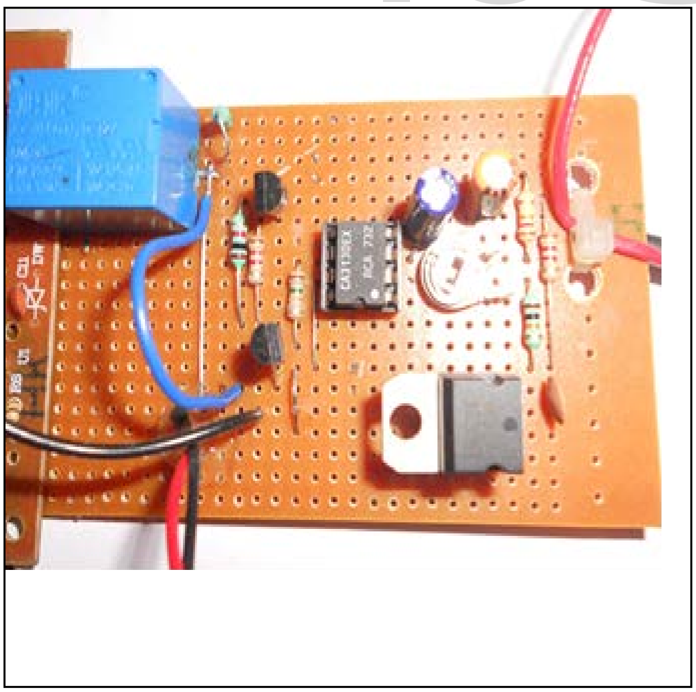


Fig.12 Transducer Block: LM35 which is a a linear temperature sensor and linear temperature-to-voltage converter circuit with Fixed regulator UTC LM 7806, OP-AMP CA3130 and Relay.

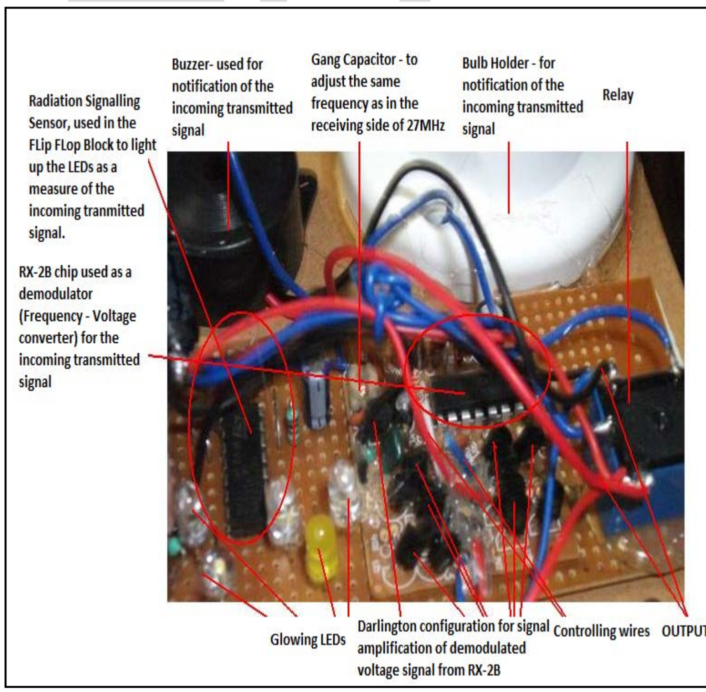


Fig.14 Receiver Section: RX-2B chip used for demodulating (Frequency-Voltage) which is then amplified and fed to a tank circuit and used for Buzzer and Bulb activation through relay and Flip Flop block for LED lighting.

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