Remote Temperature Sensor Implementation Using Amplitude Shift Keying

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Abstract
The project "Remote Temperature Sensor" implemented using the Amplitude Shift Keying (ASK) was designed and constructed to ensure that the temperature of an environment or object (where the Sensor/Transmitter unit is located), can be monitored from a completely different remote location (where the Receiver/Display unit is located)

In the sensor/transmitter unit, an IC temperature sensor (LM 335) senses the temperature of the environment or object to be measured, from which pulses are generated. The pulse switches "ON" and OFF a Colpitt oscillator and the period in which the oscillator is switched "OFF" is proportional to the temperature being sensed.

The receiver unit which comprises mainly the TDA 7000 single IC and a "slack handful" of capacitors picks up the Radio Frequency (RF) signal generated by the Colpitt oscillator. This processes the signal to give seven-segment display read-out values, which corresponds to the temperature being sensed by the Sensor/Transmitter unit.

The system is able to monitor the temperature of a remote location up two meters away. About 100% accuracy was achieved for temperature ranging from 30 to 59^{0}C and an average of about +2.5^{0}C accuracy was achieved for temperatures above 59^{0}C.

Introduction

Eventually all electrical and electronics components used today, are largely affected by the temperature of their immediate surroundings (Rayner, 1971). Over the years, analyses have shown that high temperature is one key environmental factor that affects electronic manufacturing companies such as computer, telecommunication industries (Akpaida, 2004). The effect of high temperature has led to increased rate of depreciation in value of various electrical and electronics systems while moderate temperature have led to appreciation in value of such systems. It is for this very important reason that the need for sensing and monitoring of temperature at any point of time in a technologically advanced society in of utmost important

The Fahrenheit and the Celsius scale used in thermometers, which was invented, by the Dazing born scientist Gabriel Fahrenheit (1686-1736) and the Uppsala born Anders Celsius (1701-1744) respectively have so far been used traditionally for temperature measurement. These scales employ some physical property of thermometric substance like Mercury, which changes in proportion relative to temperature changes (Rayner, 1971). Though these scales are widely used in thermometers and to a large extent reliable, they have their peculiar limitations and restrictions. For example, the Mercury-in-glass thermometer scale is not suitable for accurate measurement of temperature variation because the glass expands with respect to temperature change in an irregular manner and as such, precision is not always achieved. Mercury thermometer scales also have a relatively small range of temperature determination. Most importantly, monitoring and reading of these temperature scales cannot be assessed outside their locations.

For these reasons, this project seeks to design and construct "REMOTE TEMPERATURE SENSOR", using the Amplitude Shift Keying (ASK) for the purpose of sensing and transmitting the temperature variations of an environment at any point in time (where the Transmitting Unit is located) and hence can be monitored from a complete different remote location (where Receiver Unit is located) in digital read-out display form.

The remote temperature monitoring system consists basically of two units. These are;

i. The Sensor/Transmitter Unit and
ii. The Receiver/Display Unit

This unit is responsible for sensing the temperature, converting it to pulse, and then the transmission of the modulated signals.

Here, the temperature of an object or environment which is to be measured is first sensed by a THERMISTOR. This is a temperature transducer which converts a change in temperature (a physical quantity) to change in resistance (an electrical quantity). This is very important because without first converting temperature to a corresponding electrical quantity, no electrical processing can be performed.

With the aid of an Integrated Circuit (IC) temperature sensor-LM 335, the change in resistance in converted to a change in voltage (also an electrical quantity), which can easily be manipulated by the appropriate circuit. This IC in connection with a 555 timer amplifies this very small voltage, minimizing loading effects, ensuring an easily adjustable gain as well as ensuring an almost linear response. All this is done without introducing additional error.

The signal at this point which is continuous (Analogue) is converted into discrete pulse (Digital) signals, whose pulse duration is proportional to the temperature being measured. These pulses are then fed into a Monostable Multivibrator, which modifies the waveform such that the pulse duration is constant while the duration when there is no pulse switches "ON" the Colpitt Oscillator during the period of pulse. A high frequency carrier is transmitted during this period. During the time of no pulse the transmitter is switched OFF i.e the carrier is suppressed.

The block diagram of the Sensor/Transmitter unit is shown in Fig.1.

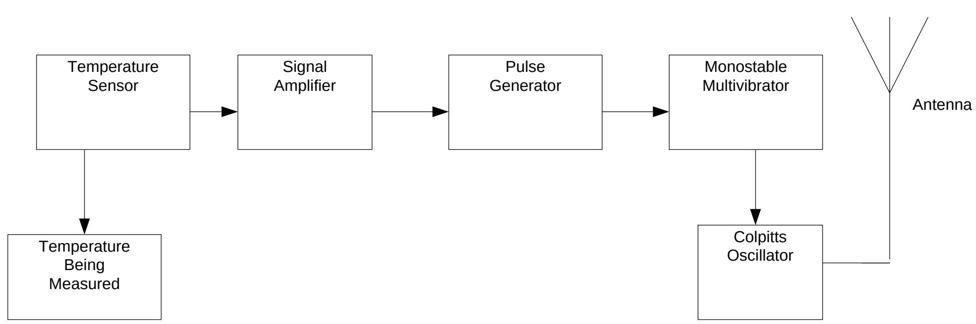

Fig.1. Block diagram for the Sensor/Transmitter Unit

The Need for Modulation

In this designed and constructed of a remote temperature monitoring system, the temperature is measured in one location and then converted to digital form (pulses). These signals are then carried via modulation to a receiver, where they are finally displayed. An alternative method would have been to transmit the digital pulses to the receiver without modulation. This method is known as baseband digital transmission. In many cases, however, the characteristics of the communication channel for example bandwidth restrictions, makes it difficult or impossible to transmit data at baseband. The most publicly quoted example is that of a Public Switched Telephone channel, which is severely band limited between 300Hz and 3.3KHz, restricting transmission of baseband signals. Other example are Optical Fiber channels, which can only pass frequencies in few hundreds of GHz range or radio and microware channels, which could not be very accurate for digital transmission.

In all these cases, the information of the digital signals has to be carried by an analogue waveform, which is suitable for transmission over a particular channel. In order to carry the information, some properties of the analogue waveform have to be modified in accordance with the original signal. Some properties of waveform which can be modified at the transmitter and recognized at the receiver are the Frequency, the Amplitude and the Phase angle of the carrier wave.

Changing the carrier wave in accordance with the original (intelligence) signal is called MODULATION. However, it is common to refer to the various schemes for transmitting digital data by the terms; Amplitude Shift Keying (ASK) also known as ON-OFF Keying (OOK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK) because these changes are introduced by the various processes of discrete format rather than a continuous variable. However, for the purpose of this project the Amplitude Shift Keying (ASK) in employed.

Amplitude Shift Keying (ASK)

This is the type of digital modulation that was employed in the project. This modulation method usually involves using one amplitude at a frequency to convey a logic HIGH and a zero logic (absence of signal) to convey a logic LOW (Theraja, 2002).

Meanwhile amplitude other than zero can be used to convey a logic zero. When zero is used to convey logic it is termed ON-OFF Shift Keying.

An analogue waveform, say X (t), can be described by the equation.

$$X_{(t)} = Ai\ Sin[w_{(t)} + \emptyset] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.1)$$

Where, A is the Amplitude function with “i” taking and integer value (usually confined to 0 or 1)

w is carrier frequency and

$\emptyset$ is an arbitrary phase angle.

Although the performance of ASK band width in the presence of noise is not as perfect as that of the FSK and PSK yet in this project we used ASK because it is much easier and cheaper to manipulate and detect using appropriate circuit.

The Receiver/Display Unit

This unit is responsible for the reception of the transmitted signal from the transmitter unit, demodulating and displaying the signals in digital form.

The TDA 7000 IC Frequency Modulated receiver (FM) receives the wave transmitted from the transmitter. This wave is then amplified and then passed through an envelope detector, which attempts to convert the output from the amplifier to pulses (the shapes of these pulses are very far from the shape of a perfect pulse). This imperfect pulse is perfected with the aid of a comparator, which also takes care of the noise. The comparator inverts the pulse so that it's pulse duration is once again proportional to the temperature being measured. Final perfection of the pulse is attained with the aid of a Schmitt Trigger.

This pulse is then fed into an AND gate along with the output of a Voltage Controlled Oscillator (VCO). The VCO is adjusted so that the number of pulses counted during the duration of a pulse is the same as the corresponding temperature. Therefore, the pulses are then counted and displayed with the aid of a BCD counter, a decoder and a seven segment displayed. The block diagram of this unit is shown in Fig. 2.

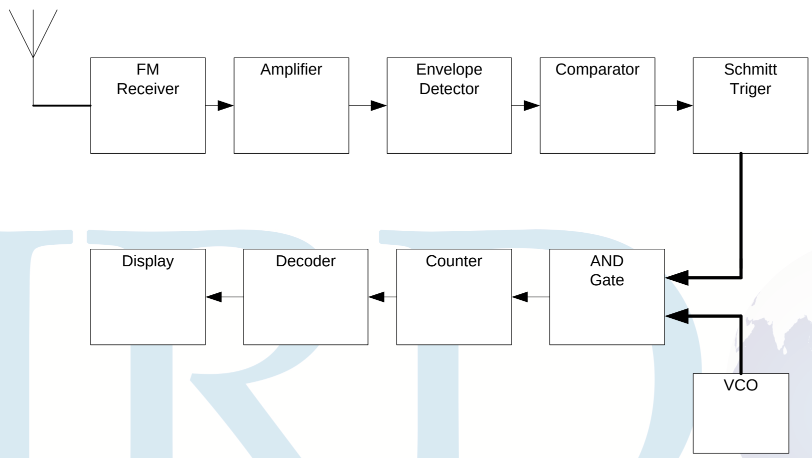

Fig.2. Block Diagram of the Receiver/Display Unit

Materials, Methods, Design Analysis and Calculations

The design analysis started with the temperature sensor/transmitter unit. In this design, an I.C temperature sensor (LM 335) that would give an output voltage corresponding to the temperature change in employed. The output voltage from the IC temperature sensor is fed to a ramp generator that generates a time variable pulse. The duration of this pulse depends on the magnitude of the input voltage. The output of the ramp generator feeds its output to the FM transmitter stage hence, it switches the transmitter in its "ON" and "OFF" states.

The intelligence that is being transmitted is embedded in the voltage dependent time variables pulse generated by the ramp generator.

At the receiving end (receiver/ display unit), the circuit starts with an FM receiver that demodulates the FM signal. The receiver retrieves the time variables pulse back after due shaping. Thereafter, it uses this time variable property to gate-clock pulse to a counter circuit which in turn displays the result in digital read-out form through a seven segment display.

Power Supply Design

The power supply stage comprises of a step-down transformer, rectifier circuit, filter circuit and a voltage regulator. In this design, an IC (LM 7805) was employed. It was used because of its high performance level i.e most stable output voltage, best load regulation and the best ripple rejection ratio. The schematic diagram is shown in figure 3.

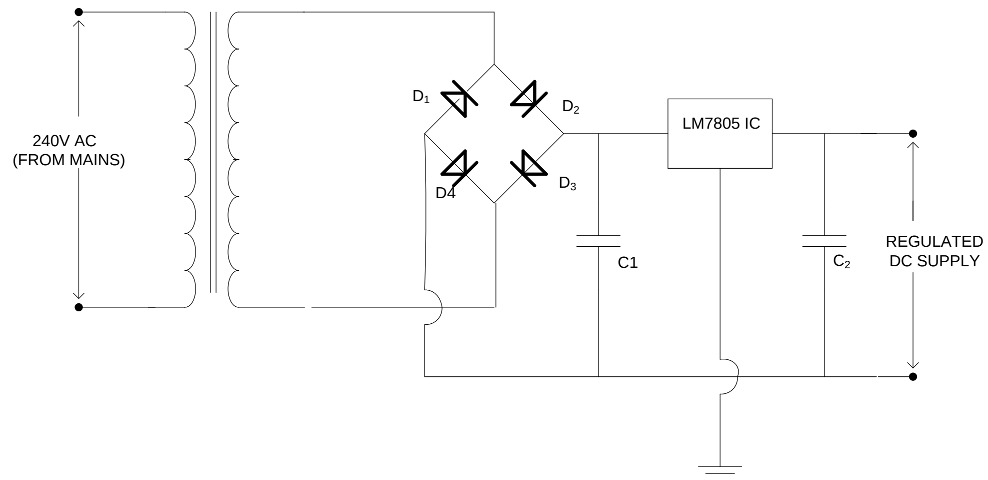

Fig3. Power Supply Unit (P.S.U)

With a load resistance, R_L of 100Ω i.e R_L = 100Ω
Since the output of an LM 7805 regulator gives an output voltage of 5v, the load current is give by

$I_L = \frac{v_{cc}}{R_L} = \frac{5}{100} = 0.05A$

The maximum ripple input voltage of 0.25v is required at the input of the LM 7805IC. Therefore, a capacitor whose value is determined by:

$C_1 = \frac{I_L}{2FV_r}$ --- (3.1)

Where F, Supply Frequency = 50Hz
Vr ripple voltage required = 0.25v
I_L Load Current = 0.05A

Hence, $C_1 = \frac{0.05}{2x50x0.25} = 200\mu F$

In this design, a capacitor value of 200µF was used. We also used a capacitor C_2 with a value of 0.1µF as recommended by the data book in order to improve the transient response of the regulated output voltage.

Temperature Sensor (Lm 335) Stage

The temperature sensor used in this design is the LM 335 IC. It is basically a two terminal temperature sensor that behaves like a Zener diode with a voltage of +10Mv/^{0}K. One of the advantages of the IC sensor is that it gives room for external trimming up to 0.1 accuracy.

According to the manufacturer's specifications, when biased with a current of 1mA and for the values shown in Fig 4., it will give a value of 2.98V at 25^{0}C, which corresponds to 298^{0}K.

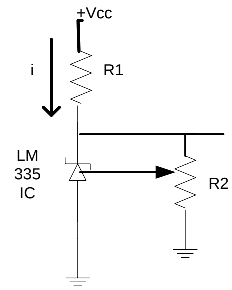

Fig. 4. LM335 Temperature Sensor Circuit

For a supply voltage of 5v and a current of 1mA, the output voltage that is expected is 2.98V. Thus, R_1 will be

$R_1 = \frac{v_s - v_0}{I} = \frac{5-2.98}{1x\,10^{-3}} = 2020\Omega = 2.02K\Omega$ …………………(3.2)

Hence, a resistance of 2KΏ having 1KΩ in series with a filter capacitor of 10µF was used. R2 as stipulated by the specification is 10KΏ.

Design Of The Ramp Generation

The ramp generator is made up of three main parts, these are;

(i). the constant Current Source

(ii). the comparator with a delay stage (pulse stretcher) and

(iii.). the switch stage. The constant current source schematic diagram is shown in figure 5.

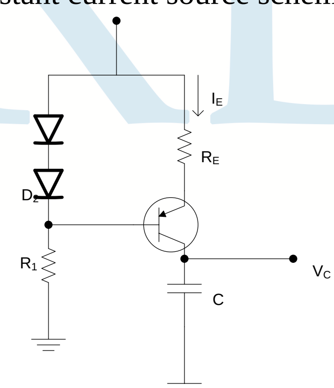

Fig.5. Constant Current Source Circuit

From the diagram this voltage across the resistors, R_E can be calculated from the expression:

$V_E = 2V_d - V_{be}$ -- (3.3) Assume that $V_d = V_{be} = 0.62$V

Hence, $V_E = 2(0.6) - 0.6 = 0.6V$

Current, $I_E \cong \frac{V_E}{R_E} = \frac{0.6}{R_E}$ --- (3.4)

Since 0.6 is diode voltage drop, V_d the voltage across the emitter resistor will be equal to one diode voltage drop. For a constant supply of 100µA, capacitor of 22µF, R_1 is 8.2kΩ. This was so chosen as it is not critical.

Therefore, $R_E = \frac{0.6}{100x10^{-6}} = 6K\Omega$ (from $V = IR_E$)

Mathematically, the capacitor voltage, V_C gives as;

$V_C = \frac{1}{C}\int idt$ -- (3.5)

This gives the value of the capacitor voltage for time, t. the time it takes the ramp (capacitor) voltage; V_C to build up to the input voltage, Vin can be deduced from the equation

$t = \frac{CVc}{I}$ -- (3.6)

For a given V_{in} value $V_c = V_{in}$ substituting this into eq. (3.6), we have

$t = \frac{CVin}{I}$ --- (3.7)

For a constant current supply I, it is obvious that the time of charging capacitor, C is directly proportional to V_{in} so that as V_{in} increases, t increase also.

A comparator IC_I that compares the capacitor voltage Vc, to the input voltage, V_{in} was employed in this design. The output of the comparator is high until the Vc charges to a value of which the comparator switches to low state. This turn triggers the delay stage made up of 555 timers (IC_2) configured as a monostable multivibrator.

This introduces some time delay to allow the MOSFET switched "OFF" so as to completely discharge the capacitor before the next cycle. For a time, T of 0.5 seconds and a capacitance of 4.7µF, T=1.1RC ---------- (3.8)

$$t = \frac{T}{1.1C} = \frac{0.5}{1.1x4.7x10^{-6}} = 96.7K\Omega$$

The value of 100KΩ resistor was used as the nearest standard value. The gate resistance, Rg was chosen to be 4.7kΩ. However, any value of resistance below 10kΩ could be used for this purpose, as it is not too critical.

For this design, we choose a frequency of 100MHZ in such a way that it falls within the FM radio broadcast range and away from any of the local stations because of interference. To a good approximation, assuming that the junctions' capacitance is very small, the frequency of oscillations of a Colpitts oscillator circuit is given as;

$F = \frac{1}{2\Pi\sqrt{LC}}$ --- (3.9)

It is obvious that capacitors are much available than inductors, therefore for a given inductance the corresponding capacitance can be determined. In this design, the inductor is necessary and the expression below can be employed.

$L = \frac{\mu_o \mu_r A N^2}{l}$-- (3.10)

Where μ_o = Permeability of free space
μ_r = Relative permeability of dielectric material
A = Cross-sectional area of dielectric material
N = Number of turns
L = Length of the inductor coil

The inductor employed has a coil wire diameter of 0.2cm and the core diameter is 1.0cm consisting of 7 turns, then

Cross-sectional Area, $A = \frac{\Pi D^2}{4}$ -- (3.11)

$$= \frac{Л(1.0x10^{-2})^2}{4} = 7.855x10^{-2}m^2$$

Length of inductor coil, L = N x d ------------------------ (3.12)

Where N = Number of turns

D = Diameter of wire used

Therefore, L = 7 x 0.2 x 10^{-2} = 0.014m

μ_o = 4Л x 10^{-7}mH for free space.

The inductance of the coil, L is given by;

$$L = \frac{4Лx10^{-7}x7.855x10^{-5}x7^2}{0.017} = 3.455x10^{-1}\mu H$$

$$c = \frac{1}{(2Лf)^2L}$$

$$= \frac{1}{[2Л(100x10^6)]^2x3.45x10^{-7}}$$

$$= [1.364x10^{-12}]^{-1} = 7.32x10^{-12}F = 7.32pF$$

A variable capacitance of 10pf was used and adjusted to 7pF.

The value of the feedback capacitor C_1 is chosen such that the gain is less than Kc and the gain (voltage). A_V>/C/C_1 ---------------------------------- (3.14)

Where Av is the voltage gain

K is the ratio of the capacitance

Assuming a gain slightly greater than 1 say 1.5, the value of C_1 can be determined thus,

$$c_1 = \frac{L}{A_V} = \frac{7.32x10^{-12}}{1.5} = 4.88pF$$

5pF capacitor, C_1 was used as the nearest value since the transistor employed for the transmitter is a low power type, a collector current, I_C was set for an emitter voltage of 0.47V.

$I_E = V_E/R_E$ --- (3.15)

$$R_E = \frac{0.47}{10x10^{-3}} = 47\Omega$$

Base voltage, $V_B = V_{BE} + V_E$ -- (3.16)

= 0.6 + 0.47

= 1.07V

The transistor, C945 used has a gain of 100

Since $I_E \cong I_C$

$I_C = \beta I_B$ -- (3.17)

$I_B = I_C/\beta$ = 10x10^{-3} /100 = 100µA

$R_B = V_{CC} - V_B/I_B$

$$R_B = \frac{5 - 1.07}{100x10^{-6}} \approx 39K\Omega$$

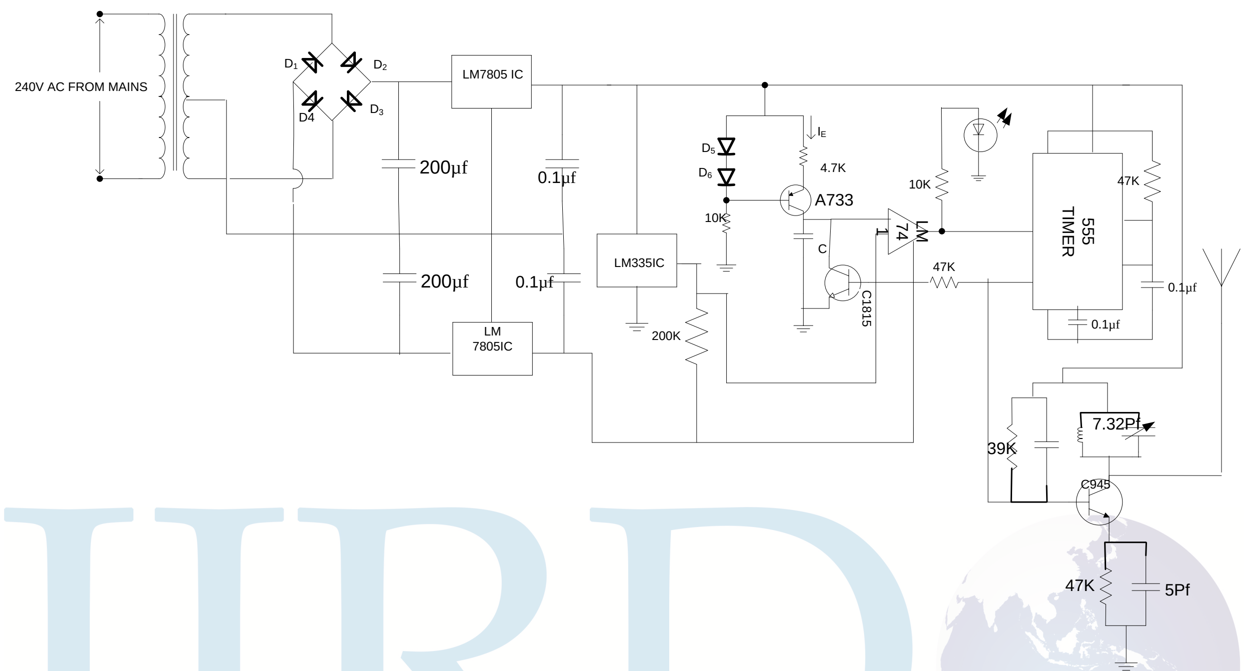

Fig. 6. Schematic of the simple FM transmitter

The Antenna

The antenna used in this design is a simple vertical telescope antenna rod. The necessary length for this operation would be adjusted to 1/8 of its wavelength. Thus

$$Л = \frac{C}{F} \quad \text{-- (3.19)}$$

Where C = Speed of wave in space

F = Frequency of Oscillation (chosen to be 100MHz)

Л = Wavelength

Therefore, $Л = \frac{3x10^8}{100x10^6} x \frac{1}{8} = 0.375m$

Design of the FM Receiver

The Philips TDA 7000 fully integrated FM-radio receiver Ic was used in the design of the FM receiver. The IC is an 18 pin dual-in-line (D.I.L) IC and has a Frequency Lock Loop (FLL) structure internally, just like Phase Lock Loop (PLL) structure and works on the same principle. The IC cores a manufactures data of the necessary components needed to get the IC working as a full FM-radio receiver. It has a tunable local oscillator, which was incorporated by the manufacturer for the designer. The filtered output of the FM discriminator frequency modulates the local oscillator to provide negative feedback modulation. This negative feedback modulation result in compression of the signal of the output of the mixer. This the intermediate frequency, IF band pass filter and the FM discriminator deal with narrow band FM signals for compression factors of K = 3, the FM bandwidth, which is 180kHz, reduce to

180/3=60kHz.

The values given by the manufacturer (i.e. the capacitor values) sets the intermediate frequency, IF at 70kHz and a bandwidth of 180kHz. The IC also incorporates a correlation muting system that responses arising from detuning. The schematic of the FM receiver using TDA 7000 is shown in Fig. 6.

Design of the Variable Controlled Oscillator (VCO)

To design the local oscillator tank circuit, we could use the values for the transmitter to design this tank circuit. But this time, it is desirable for the capacitor to be a variable type so that it can be tuned within the FM range in case of adjustment or drift of the transmitter.

Hence, the capacitance of the capacitor can be determined as follows;

For a frequency range of 88MHz to 108MHz and L = 3.455 x 10^{-1}μH

From $c = \frac{1}{(2Лf)^2 L}$ -- (3.20)

For f = 88MHz, $c = \frac{1}{(2Лx88x10^6)^2 x3.455x10^{-7}} = 9.46pF$

For f = 108MHz, $c = \frac{1}{(2Лx108x10^6)^2 x3.455x10^{-7}} = 6.28pF$

A variable capacitor was used so that the capacitance could be varied from (88-108) MH_Z range.

Design of the Signal Amplifier

This is the design stage of the amplifier output of the FM-radio receiver. It is made up of the inverting amplifier. The output of the amplifier is fed to a voltage comparator for threshold shaping. The output in connected to CMOS 4093 Schmitt NAND gate to help further shape the pulse for processing (at least 35mV) from the output of the FM receiver, the bias resistors can be determined as follows;

$$A_v = \frac{R_f}{R_1}$$

$$R_f = A_v R_1 = 100x1000 = 100k$$

Clock Generation

The clock pulses are generated by the 555 timers. A frequency of 10Hz was chosen for the expression;

$$F = \frac{1.44}{(R_1 + 2R_2)C_1}$$

$$R_2 = [\frac{1.44}{FC_1} - R_1]/2$$

Where F = 10Hz

C_1 = 1μF

R_1 = 100kΩ

$$R_2 = [\frac{1.44}{10x1x10^{-6}} - 100{,}000]/2$$

$$R_2 = 22k\Omega$$

Envelope Detector Design

In demodulating the signal at the receiver unit, it is a duty to retrieve the original waveform from the output of the pulse generator which is made up of pure pulse. Hence, we need to remove the oscillating part of the waveform. The envelope detector circuit is used for this purpose.

The time constant, T for an RC network is given by T = RC…………(3.25)

For this design, it is obvious that T must be greater than the period, T of the incoming signal i.e T = 1/F

Where Frequency, F = 70kHz (chosen)

T = 1/70 x 10^3 = 14.29µsec.

Also, T must be much greater than the period for which the transmitter is switched "ON" (i.e. 1second). Therefore, 14.29µsec$< \tau < 1sec.$

Hence, a compromise value of $\tau = 1msec.$ Setting the capacitance, C to 0.1µF; t = RC; R = t/C

Hence, $R = \frac{1x10^{-3}}{0.1x10^{-6}} = 10k\Omega$

For this design, a resistor in the order of 10kΩ was chosen to serve this purpose and C = 0.1µF.

Led Seven Segment Display

The Para-light, C-561R common cathode LED seven segment display was used for the display stage. The seven segments are made up of LED's with a forward voltage drop of 2.2V and a current of 10mA (forward current I_f). Therefore, the limiting resistor R_L can be calculated as follows;

$$nI_f = \frac{V_{cc} - Vdrop}{R_L}$$

Where

R_L = Limiting Resistance

I_f = Forward current

N = number of segments

Vcc = +5v, Vdrop = 2.2V

Hence

$$R_L = \frac{V_{cc} - Vdrop}{nI_F} = \frac{5 - 2.2}{7x10x10^{-3}} = 40\Omega$$

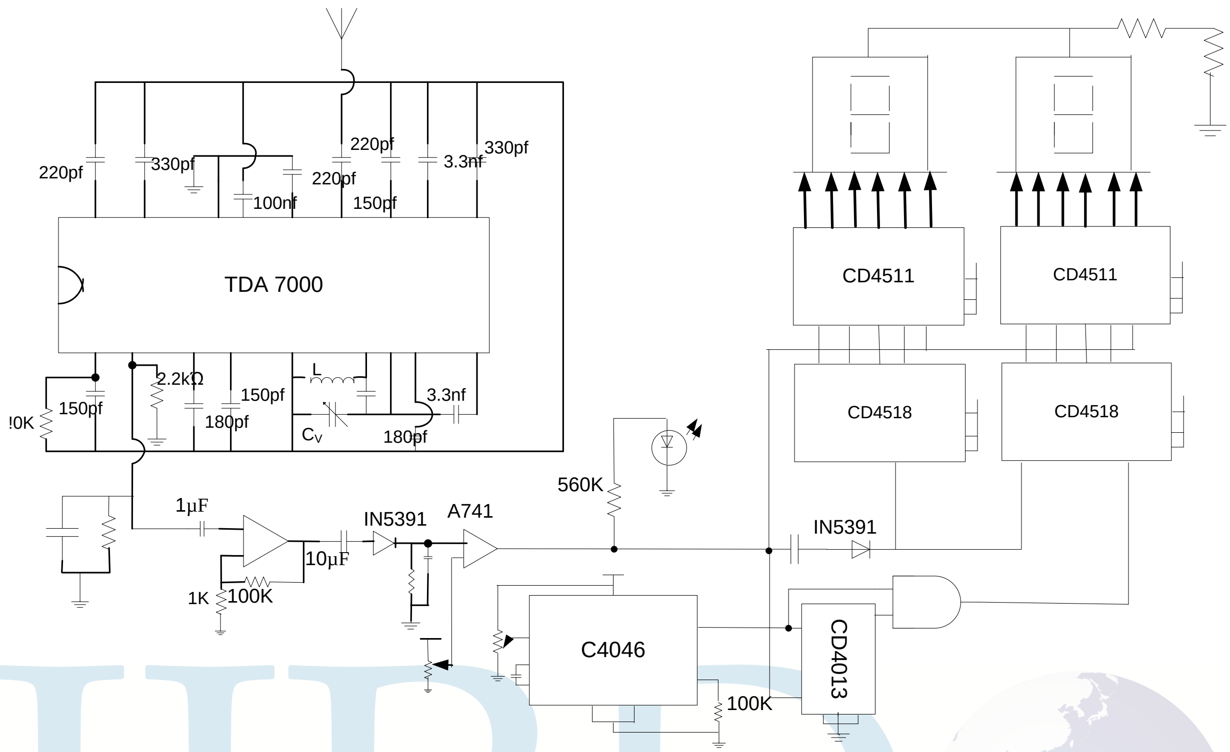

Fig 7. The full Circuit diagram of the Receiver/ Display Unit

Results Analysis and Discussions

Having completed work on the various units of the system, testing analysis was carried out. The temperature read-out value from the display segment was adjusted by varying the oscillator so that the pulse read-out was reading the same temperature value of the environment at the receiving end. This was made possible by the use of a mercury-in-glass thermometer, which gave the same readings with that of the displayed values. Holding the temperature sensor (LM 335) with bare hand in order to test the unit, produced a rise in temperature up to 36^{0}C (which is approximately the normal body temperature range) and remained at this value. However, when the temperature sensor was left alone, it was observed that the displayed value dropped to that of the room temperature.

Further test carried out yielded the following results as shown in Table 1.

Table 1. Comparison of temperature readings and percentage error

Test number	Temperature of mercury-in glass	Temperature at receiver unit (^{0}C)	Percentage error (%)

	thermometer (^{0}C)		
1	30	30	0.000
2	31	31	0.000
3	32	32	0.000
4	33	33	0.000
5	34	34	0.000
6	35	35	0.000
7	36	36	0.000
8	37	37	0.000
9	38	38	0.000
10	40	40	0.000
11	45	45	0.000
12	48	48	0.000
13	50	50	0.000
14	54	54	0.000
15	57	57	0.000
16	60	59	1.667
17	62	61	1.667
18	65	63	3.077
19	68	66	3.077
20	70	67	4.286

From Table 1., we can deduce that the displayed values from the receiver unit varies from that measured with the mercury-in-glass thermometer by an average of about ± 2.5^{0}C for temperature above 50^{0}C and about 100% accuracy was achieved for temperature ranging from 30^{0}C to 57^{0}C.

The design and construction of "REMOTE TEMPERATURE SENSOR" involves the use of an IC temperature sensor (LM 335) to realize digital modulation of temperature signal (which is first converted to pulse) implemented using the Amplitude Shift Keying (ASK). As a result, the transmitter is switched 'ON" and "OFF" by the digital signals to be conveyed. This signal is demodulated at the receiving end and the temperature of the remote location is then displayed in digital read-out form thus, the temperature of an object or environment can be monitored from a completely different location.

This system can be used to monitor, the temperature of an object or environment, provided that the temperature does not vary too widely. The obvious advantage of this system is CONVENIENCE. In other words, it makes accessible the displayed signal in digital read-out form of the sensed temperature at any point in time to the management/authority concerned for necessary measures in normalizing/regulating the temperature of the environment under control. This would in turn contribute to increased durability (useful life), efficiency and reliability of the system in use. This system can be used to monitor temperature in most medium and large-scale industries (in for example the breweries and manufacturing companies), electronic industries (for example computer firms, telecommunication industries e.t.c) as well as financial institutions (like the banks). It can also be used in hospitals to monitor the temperature of patients (which typically varies over a few degrees Celsius) by ensuring high degree of sensitivity. Apart from the aforementioned areas of application of this system, it can also be useful in the agricultural sector, in for example monitoring the temperature of a poultry farm (where temperature is a critical factor), and in monitoring the temperature of agricultural storages apparatus like silos.

Conclusion

The importance of the designed and constructed Remote Temperature Sensor using Amplitude Shift Keying (ASK) cannot be over emphasized. However, the purpose of the design and construction was basically to address and ameliorate (alleviate) some of the problems confronting small, medium and large-scale industries in tackling the problem of heat variation. This system therefore, can sense and transmit temperature variation at any point in time (where the transmitter units is located) and be monitored from a complete remote location (where the receiver unit is located) in digital read-out display form.

This system is able to monitor the temperature of a remote location up to two meters away. About 100% accuracy was achieved for temperature ranging from 30 to 57^0C and an average of about $+2.5^0$C accuracy was achieved for temperature above 57^0C.

Recommendations

Prior to further modifications and improvement, the following recommendations can be made as regards this project.

i. The transmission of the temperature signals should be designed to use Frequency Shift Keying (FSK) or Phase Shift Keying (PSK). These methods of digital modulation are more resistant to noise and hence give more accurate result and wider range than the Amplitude Shift Keying (ASK) which was employed in the project.
ii. The modulated temperature signal at the receiver could be connected or networked to computer(s) for proper monitoring of the variation in temperature instead of using the seven segment digital display unit only.
iii. The range (both temperature and distance) and the accuracy of the system should be improved upon by opting for more sophisticated and more standard components which will in turn increase the efficiency of the system.
iv. The digital display segment of the system should be designed in such a way that the displayed values are in decimal form.

Finally, one must remember that "the engineer is under obligation to consider the sociological, economical and spiritual effects of engineering and operations in order to aid his fellowmen to adjust wisely their modes of living, their industrial, commercial, governmental procedures and their educational processes so as to enjoy the greatest possible benefit from the progress achieved through our accumulated knowledge of the universe which is applied through engineering. The engineer's greatest obligation is to discover and conserve natural resources of materials and forces, including the human and to create means of utilizing these resources with minimal cost and waste and with maximum useful result".

According to the words of Alfred Douglas Film, a renowned scientist I quote "for a better and favorable technological improvement in our nation, all hands must be on deck and we need to pill all our resources and knowledge together and work for a common goal"

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