Design and Development of an Environmental Temperature Controller for Application to a Poultry Environment with an SMS Alert Feature using a Microcontroller: A Risk Reduction Approach

S. O. N. Okonye, U. M Asiwe

Department of Electrical and Electronics Engineering, School of Engineering Technology,
Delta State Polytechnic, Otefe-Oghara, Delta State, Nigeria

ABSTRACT

This work focus on design and development of an environmental temperature controller for application to a poultry environment with an sms alert feature: a risk reduction approach. The poultry farmer needs to be assured that his investment is secure against risks that are beyond his control. This risks have most of their origins in the variable temperature of the environment. The objective of the project is to control or regulate the temperature in the poultry environment to make for effective functioning of the biological activities taking place inside the bodies of the birds. This objective was realized using a microcontroller to help the farmer be able to regulate the temperature in the farm. In the case of abrupt temperature variation, is able to be aware via an sms alert feature and empowered to control it. Results obtained proved to be very helpful to poultry farmers.

KEYWORDS *Temperature, Microcontroller, Poultry Environment, SMS Alert, Risk*

1. BACKGROUND OF THE WORK

In recent times, the livestock sector of the industry has made tremendous adjustment to meeting the increased demands for inexpensive and safe supply of meat and eggs. In the past three years, the livestock sector has been growing at more than 5 percent per annum (Gerber, et al, 2006) and its share in world meat production increased from 15 percent three years ago to 30 percent currently (Gerber, et al, 2006). This growth has been accompanied by structural changes within the sector characterized by the emergence and growth of "land-independent" (industrial) farming establishments and the intensification and concentration of poultry operations (Kolominskas, et al, 2002). Pressure to lower production costs and increase supply has led to more efficient operations made possible through the shift to larger, specialized and move integrated facilities and through improvements in the use of animal genetics, optimized nutrition and new production technologies. The driving forms behind structural changes in poultry production are no different than those that affect other livestock commodities: Market pull, innovation and economics of scale. Innovation and economics of size that characterized the livestock sector has also served to separate animal production from the crop production. Large specialized facilities today focus on producing animals and most of their feeds (Ferket, et al, 2002)

1.1 LITERATURE SURVEY

In poultry and in general livestock farming, methods must be developed to reduce risk to a very low value so that profit can accrue to the farmer. Pannell *et al.* (2000) concluded that 'getting the big decisions right' is the key for farmers to achieve their objectives of staying in farming and increasing their wealth. By 'big decisions' they meant land purchases, machinery investment and resource improvements. In many areas of the world livestock production is closely linked to general economic development (Jahnke, 1983). Livestock diseases dramatically influence the pattern of livestock development in many regions, the effects being

manifested by premature death, reduced quantity, quality and value of livestock and livestock products, and denial of access to better markets (Morris and Meek, 1979). These diseases thrive in environments where the atmospheric temperature favours their growth and spread. This increases the risk of loosing hard earned investment.

Beal (1996) stated that it is to be expected that risk management strategies adopted by farm managers reflect their personal perceptions of risk.

The metabolic processes poultry in birds is temperature dependent. And if not controlled may lead to high mortality rates. This increases the risk factor involved for farmers. The risk environment of farmers is changing, in part due to increasing market liberalization, technology and industrialization of agriculture (Boehlje and Lins, 1998). These changes has led to new risks, and new risk management instruments being developed. It is the intention of this work to develop a method to help poultry farmers to reduce the risk involved in their operations and hence give them high returns for their investment.

2. SYSTEM ARCHITECTURE
The various sections contained in this system are as follows;
- power supply unit
- temperature sensor
- GSM transmitter
- Keypad
- Heat control
- Temperature control
- display
- microcontroller unit

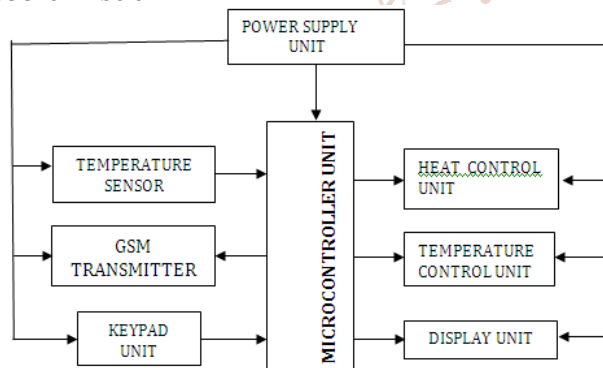The system architecture diagram for the complete system is as shown below:

Fig. 1: The System Architecture

2.1 POWER SUPPLY UNIT
This is the circuit that supplies power to the full system. The system obtains its power source from a 220voltas ac power supply source, to deliver a 5 volts output
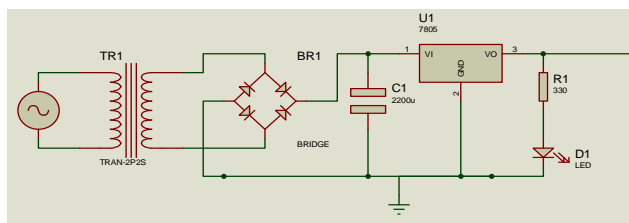
The circuit diagram is as shown below.

Fig.2: Power Supply Circuit

2.1.1 TRI:
This is the step down transformer. A transformer voltage of 12Vac or above is required. The current should be enough to supply the requirement of the circuit.

The transformer (T1) chosen is: 12Vac@300mA.

2.1.2 D1-D4:
These are the rectifier circuit. The diodes chosen must have a peak inverse voltage (PIV) that must be able to withstand twice the peak voltage (V_p) of the transformers output and a forward current (D_c) of 1.5 times the output current of the transformer.

$$V_p = \sqrt{2}\ V_{rms} \qquad 1$$

Where V_p is the peak voltage of the transformer output, V_{rms} is the actual output voltage from the transformer = 12Vac
$$V_p = \sqrt{2} \times 12 = 1.414 \times 12 = 16.97 Vac$$
$$D_{(piv)} = 2 \times V_p \qquad 2$$

Where $D_{(piv)}$ is the PIV of the rectifier diode
Therefore, $D_{(piv)} = 2 \times 16.97 = 33.94$.
And $D_c = 1.5 \times 300 \times 10^{-3} A = 0.45A$

Therefore the required diode must have a:
$$PIV \geq 33.94V \text{ and } D_c \geq 0.45A$$

From diode catalogue, the IN4007 has the following characteristics:
$$PIV = 50V \text{ and } D_C = 1A$$

Consequently, the diode chosen is the IN4007: D_1-D_4 = IN4007

2.1.3 C_1:
This is the filters capacitor. Electrolytic capacitors come with a capacitance and a voltage rating.

A. Voltage Rating
The voltage of the capacitor (V_c) must be able to withstand 150% of the output voltage from the diode.
$$V_C = 150\% \text{ of } V_{DP} \qquad 3$$

Where V_{DP} is the peak output voltage from the diodes
But V_{DP} is given as:
$$V_{DP} = V_p - V_D \qquad 4$$

Where V_p is the peak voltage of the transformer
V_D is the voltage drop of the diodes (0.7 X 2)
$$V_{DP} = 16.97 - 1.4 = 15.57V$$
$$V_c = 1.5 \times V_{DP}$$

V_c is the voltage rating of the capacitor
$$V_c = 1.5 \times 15.57 = 23.6V$$

B. Capacitance Rating:
The capacitance of the capacitor must be such that it could reduce the ripple voltage (V_R) to about 30% of the output peak voltage from the diodes.
$$V_R = 30\% \text{ of } V_{DP} \qquad 5$$

But V_{DP} is given as 15.57V
$$\therefore V_R = \frac{30}{100} \times 15.57 = 4.67V$$

From the ripple voltage equation, we could get the capacitance.

$$V_R = \frac{Imax}{2 \times f \times C1} \qquad\qquad 6$$

Where V_R is the ripple voltage

I_{max} is the maximum current from the diodes/transformers (300mA)
f is the frequency of supply (50Hz)
C is the capacitance of the capacitor in Farads.
$V_R = 4.67V$ (from eqn 5)

$$\therefore \qquad\qquad C_1 = \frac{Imax}{v_R \times 2 \times f} \qquad\qquad 7$$

Substituting,

$C_1 = \dfrac{500 \times 10^{-3}}{4.67 \times 2 \times 50}\; 1 = \dfrac{0.3}{467} = 6.42 \times 10^{-4}\,F = 642.4\mu F$

$C_1 = 1000\mu F$ @35V (nearest preferred value)

2.1.4 U1:
This is the voltage regulator.
Regulator specifications I:
➤ Maximum input voltage = 30V
➤ Maximum output voltage = 5.5V
➤ Operating temperature = $0^0C- 150^0C$
For effective Voltage regulation, the minimum input voltage should be:

$$V_{min} = V_{out} + V_{ref} \qquad\qquad 8$$

V_{min} – Minimum input voltage
V_{out} – required output voltage: 5V
V_{ref} – Datasheet Stipulated reference voltage; 3V
$V_{min} = 5 + 3$
$V_{min} = 8V$

The output voltage after the capacitor is 15.57 volts. This is enough to supply the minimum input voltage (8 volts) Therefore, the voltage regulator could be comfortably used. The regulator chosen is : $U_1 = 7805$

2.1.5 C_2
is a transient capacitor. The rating is stipulated in the 78XX voltage regulator's data sheet as 0.1Uf. Hence, $C_2=0.1uF$
This capacitor helps for smoothening of the output from the voltage regulator. It is also to prevent spikes in the DC output voltage waveform in the event of transient disturbances. It is known as a buffer capacitor whose value is gotten from the data sheet of the regulator.

2.1.6 Current limiting resistor calculation:

$$R_1 = \frac{V_S - V_D}{I_D} \qquad\qquad 9$$

$$R_1 - \frac{5-2}{10 \times 10^{-3}} = 300\Omega$$

$R_1 = 330\Omega$ (nearest preferred value)

2.1.7 Light emitting diode characteristics:
Forward current of $10 \times 10^{-3}A$ to $20 \times 10^{-3}A$
Voltage drop of 2V

2.2 TEMPERATURE SENSOR UNIT
The temperature fan is controlled by the ambient temperature. This unit ensures that the ambient temperature is constantly being monitored and the fan will automatically turn on when the temperature is above a certain set reference and will also turn off if the temperature is below the set reference.

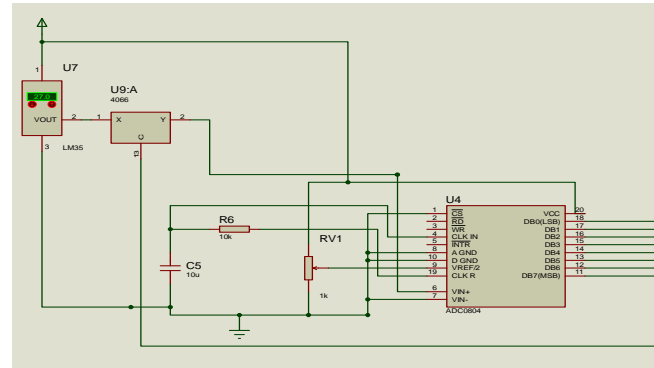The circuit diagram of this unit is divided into two sections

Fig. 3: The Temperature Control Fan Circuit

2.2.1 U7:
this is a temperature sensor and it has the following general description and features from the data sheet
General description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/4°C$ at room temperature and $\pm 3/4°C$ over a full -55 to $+150°C$ temperature range. Low cost is assured by trimming and calibration at the wafer level. 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 60 µA from its supply, it has very low self-heating, less than $0.1°C$ in still air. The LM35 is rated to operate over a $-55°$ to $+150°C$ temperature range, while the LM35C is rated for a $-40°$ to $+110°C$ range $(-10°$ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features
➤ Calibrated directly in ° Celsius (Centigrade)
➤ Linear + 10.0 mV/°C scale factor n 0.5°C accuracy guaranteeable (at +25°C)
➤ Rated for full $-55°$ to $+150°C$ range n Suitable for remote applications
➤ Low cost due to wafer-level trimming n Operates from 4 to 30 volts
➤ Less than 60 µA current drain
➤ Low self-heating, 0.08°C in still air
➤ Nonlinearity only $\pm 1/4°C$ typical
➤ Low impedance output, 0.1 Ω for 1 mA load

2.2.2 U4: this is the analogue to digital converter integrated circuit.

Pin No	Function	Name
1	Activates ADC; Active low	Chip select
2	Input pin; High to low pulse brings the data from internal registers to the output pins after conversion	Read
3	Input pin; Low to high pulse is given to start the conversion	Write
4	Clock Input pin; to give external clock.	Clock IN
5	Output pin; Goes low when conversion is complete	Interrupt
6	Analog non-inverting input	Vin(+)
7	Analog inverting Input; normally ground	Vin(-)
8	Ground(0V)	Analog Ground
9	Input pin; sets the reference voltage for analog input	Vref/2
10	Ground(0V)	Digital Ground
11		D7
12		D6
13		D5
14		D4
15		D3
16		D2
17		D1
18		D0
19	Used with Clock IN pin when internal clock source is used	Clock R

Table 1: A/D Converter Pin Functions

2.2.3 R6 and C5:
these are the discreet components of the CLK IN and the CLK R terminals. These terminals are for the use of the internal clock of the ADC

CLK IN is an input pin connected to an external clock source. To use the internal clock generator (also called self-clocking), CLK IN and CLK R pins are connected to a capacitor and a resistor, and the clock frequency is determined by

$$F = \frac{1}{1.1 \, RC} \qquad 10$$

As always, mathematically, when faced with two unknowns, we assume one and calculate for the other. Meanwhile the data sheet of the ADC 0804 stipulated the clocking frequency to be about 110 µs.

Therefore: $F = 110 \times 10^{-6}$, $R = 10 \times 10^{3}$

$$C = \frac{1}{1.1 \, RF} \qquad 11$$

$C = \frac{1}{1.1 \times 10 \times 10^{3} \times 10 \times 10^{-6}} = 150 \times 10^{-12} = 150\text{pF}$

2.2.4 RV1:
for the Vref/2 terminal of the ADC, It is used for the reference voltage. If this pin is open (not connected), the analog input voltage is in the range of 0 to 5 volts (the same

as the Vcc pin). If the analog input range needs to be 0 to 4 volts, Vref/2 is connected to 2 volts

Vref/2(V)	Vin(V)	Step Size (mV)
Not connected*	0 to 5	5/256=19.53
2.0	0 to 4	4/255=15.62
1.5	0 to 3	3/256=11.71
1.28	0 to 2.56	2.56/256=10
1.0	0 to 2	2/256=7.81
0.5	0 to 1	1/256=3.90

Step size is the smallest change can be discerned by an ADC

Table 2: Vref/2 Range of Values

For the case of connecting an LM35 to an ADC804. Since the ADC804 has 8-bit resolution with a maximum of 256 steps and the LM35 produces 10 mV for every degree of temperature change, we can condition Vin of the ADC804 to produce a Vout of 2560 mV full-scale output. Therefore, in order to produce the full scale V_{OUT} of 2.56 V for the ADC804, We need to set

$$\frac{V_{REF}}{2} = 1.28 \qquad 12$$

This makes V_{OUT} of the ADC804 correspond directly to the temperature as monitored by the LM35.

To this effect, we need RV1 to be a variable resistor. Therefore, RV1 = 10kΩ

2.3 GSM TRANSMITTER UNIT
This is the unit that the system uses to send sms to the user in the event that a change in the ambient temperature is detected. This circuit is built around a GSM MODEM.

The SIM900 GSM modem will be used and it will require the connection to the microcontroller via a TTL to RS converter, MX232. The circuit diagram is as shown below.
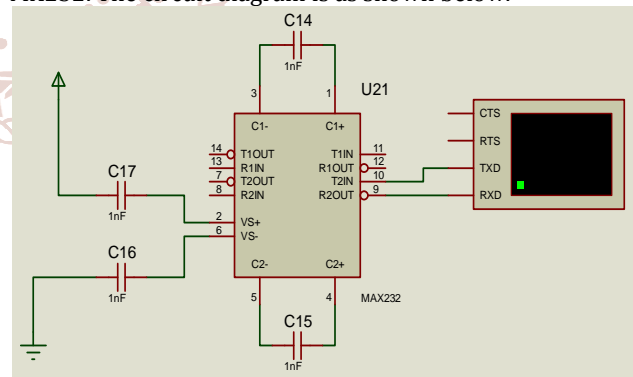

Fig. 4: GSM Transmitter Circuit

The connections for the MAX232 is as lifted off from the data sheet of the integrated circuit.

The GSM modem outputs an RS signal and the max232 converts it to TTL signals which will be readable by the microcontroller.

2.4 KEYPAD UNIT
This is the circuit that the system uses to set the reference temperature of the environment. The fan gets triggered when the set temperature is exceeded while the heater turns on when the set temperature drops. The circuit diagram is as shown below
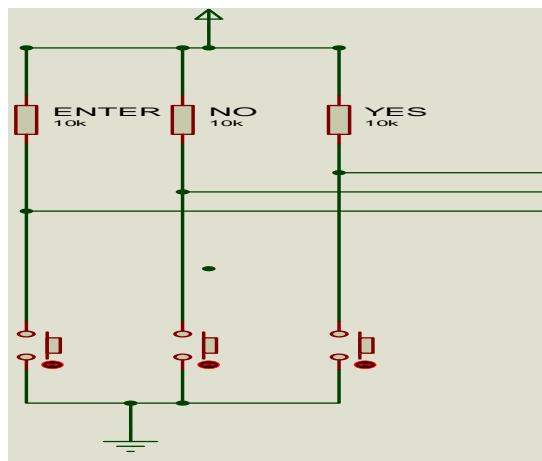
Fig. 5: Key Pad Circuit

R: these are pull up resistors. Pull up resistors are always given a range of values from

$$470\Omega \text{ to } 22k\Omega$$

For the sake of this design, the value chosen for the pull up resistors values are

$$R = 10k\Omega \text{ each}$$

2.5 HEAT CONTROL UNIT

This is the circuit that the system uses to control the heater in the system. The heater responds to the program instructions by the microcontroller and gets turned on when the set reference temperature gets above the ambient temperature. The circuit diagram is as shown below
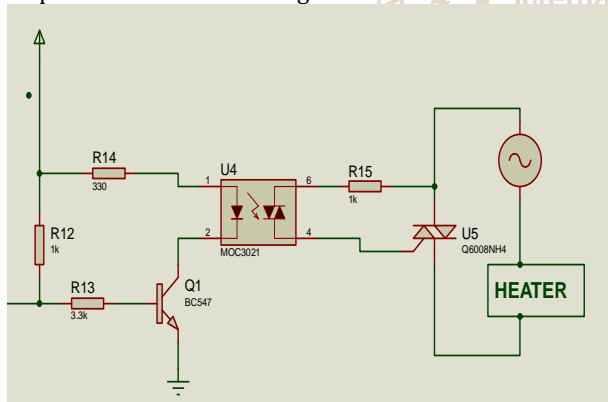

Fig. 6: Heat Control Unit Circuit

The control part of the heater actually turns it off or on. This is basically a switch that is built around a static relay using a triac fired by another triac based opto-isolator. An NPN transistor is used to control the low voltage side of the isolator from signals transmitted from a microcontroller terminal.

R_{12} = a pull up resistor. This is a resistor that is basically used to set a terminal temporarily high. The value is usually from a range of : 470Ω to $10,000\Omega$

For this circuit, the value of $1,000\Omega$ (nearest preferred value).

R_{14} = this is a current limiting resistor for the light emitting diode inside the low voltage side of the Optoisolator. The formula to calculate the value of current limiting resistors is given thus

$$R_{14} = \frac{V_S - V_D}{I_D} \qquad\qquad 13$$

From the MOC3021 datasheet, the following characteristics of the low voltage side light emitting diode is given as

Forward current, I_D = 10 mA and Voltage drop V_D = 2V, while the supply voltage for the system is V_S = 5V

$$R_{14} = \frac{5-2}{10 \times 10^{-3}} = 300\Omega$$

$$R_{14} = 330\Omega \text{ (nearest preferred value)}$$

R_{13} = this is the biasing resistor for the NPN transistor. For the transistor to work in the saturation mode, we use the equation

$$R_B = 10 \times R_C \qquad\qquad 14$$

Where R_B is base resistor R_{13}, and R_C is collector resistor R_{14} (330Ω)

Substituting

$$R_B = 10 \times 330\Omega = R_{13} = 3300\Omega$$

R_{15} = snubber resistor for the triac on inductive loads. Datasheet stipulates the collective resistance to 1kΩ Therefore R_{15} = 1,000Ω

2.6 TEMPERATURE CONTROL FAN

This is the unit that the system uses to indirectly control the temperature of the environment by powering a temperature controllable fan. This fan will be activated by the microcontroller to turn on each time the temperature of the environment exceeds the set reference temperature and turn off each time it doesn't. The circuit diagram for the unit is as shown below.
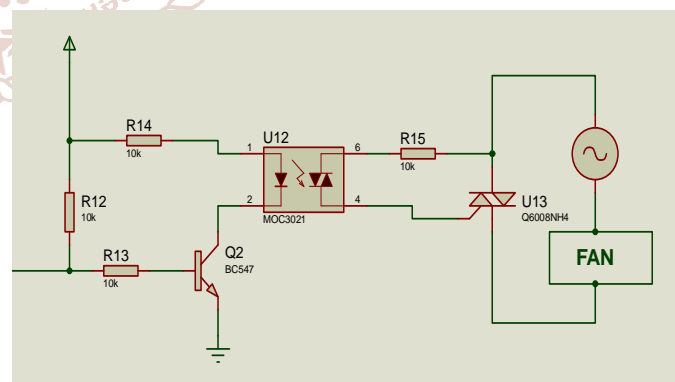

Fig. 7: Temperature Control Fan Circuit

R_{12} = a pull up resistor. This is a resistor that is basically used to set a terminal temporarily high. The value is usually from a range of: 470Ω to $10,000\Omega$

For this circuit, the value of $1,000\Omega$ was used.

R_{14} = this is a current limiting resistor for the light emitting diode inside the low voltage side of the Optoisolator. The formula to calculate the value of current limiting resistors is given thus

$$R_{14} = \frac{V_S - V_D}{I_D}$$

From the MOC3021 datasheet, the following characteristics of the low voltage side light emitting diode is given as

Forward current, I_D = 10 mA and Voltage drop V_D = 2V

While the supply voltage for the system is V_s = 5V

$$R_{14} = \frac{5 - 2}{10 \times 10^{-3}} = R_{14} = 300\Omega$$

R_{14} = 330Ω (nearest preferred value)

R_{13} = this is the biasing resistor for the NPN transistor. For the transistor to work in the saturation mode, we use the equation

$$R_B = 10 \times R_C$$

Where R_B is base resistor

R_{13}, and R_C is collector resistor R_{14} (330Ω)

Substituting:

$$R_B = 10 \times 330\Omega = R_{14} = 3300\Omega$$

R_{15} = snubber resistor for the triac on inductive loads

Datasheet stipulates the collective resistance to 1kΩ

Therefore R_{15} = 1,000Ω

2.7 DISPLAY UNIT

This is the unit that the system uses to inform the user on the status and progress of the complete circuit. It serves as an interface between the circuit and the user. It displays the current and set temperature of the ambient and the general surroundings. It enables the user to set the desired temperature and guides the user on the progress of the temperature of the system. The circuit diagram is as shown below
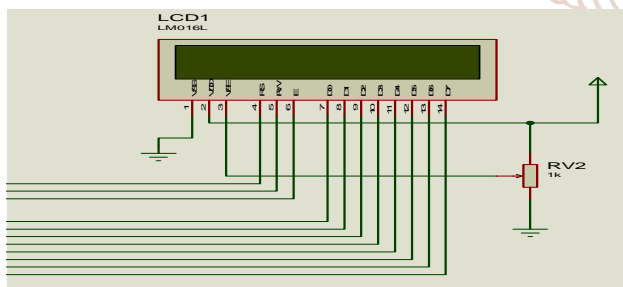

Fig. 8: Display Unit Circuit

The LCD is 16 x 2 screen display. This means that it can display 16 alphanumeric characters on 2 lines.

RV2: is a resistor to set the contrast of the display. A 1kΩ variable resistor is the usual value used

2.8 MICROCONTROLLER UNIT

The microcontroller unit circuit is the heart of the project. This is where the program for the control part of the project is written and burned using assembly language and a universal programmer, respectively. The circuit diagram is as shown below
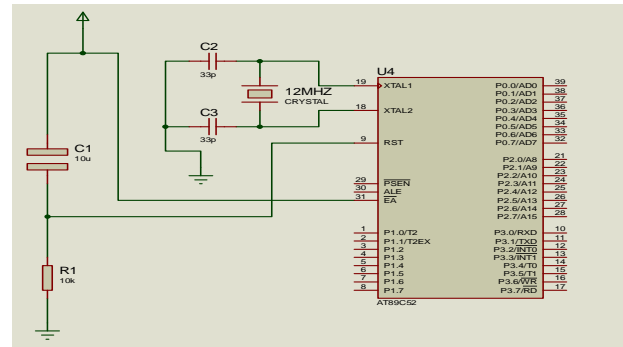

Fig.9: Microcontroller Unit Circuit

The 8052 microcontroller hardware circuit is usually a very flexible one and all the surrounding components are given a recommended range of values, by the datasheet but the actual values can be chosen by the programmer.

The ranges of values given for the 8052 microcontroller hardware are as follows

➤ Reset capacitor: 4.7µF to 10µF
➤ Reset resistor: 8.2KΩ to 15 KΩ
➤ Crystal oscillator: 4MHz to 32MHz
➤ Crystal capacitors: 27pF to 47pF

For the programming of the adiabatic temperature environment for a poultry with sms alert, the chosen values are as follows

➤ Reset capacitor (C_1): 10µF
➤ Reset resistor (R_1): 10 KΩ
➤ Crystal oscillator (X_1): 12MHz
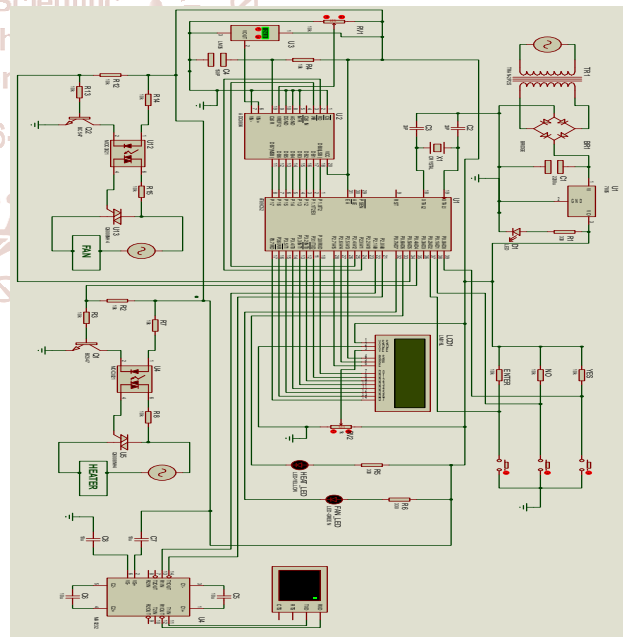➤ Crystal capacitors (C_2 & C_3): 33pF

Fig. 10: The System Complete Circuit Diagram

3. MODE OF OPERATION

The operation of the environmental temperature controlled system for a poultry environment functions in such a way that the user is prompted to manually set the reference temperature of the poultry environment by the use of the keypads made up of push buttons connected to pull up resistors designated as YES, NO and ENTER. The set reference will be displayed on the screen, then the system will activate the temperature controlled system depending on the set temperature of the environment. If the

temperature of the environment is higher than the set temperature, the system activates the temperature controlling fan by sending a high signal to transistor Q2, which will activate the low voltage side of the integrated circuit U12, which will in turn activate the fan via triacU13.

On the other hand, when the set temperature is lower that the temperature of the environment, the system will activate the heater. The heater works in virtually the same way as the temperature controlled fan however, using transistor Q1 and integrated circuit U4. The screen displays the set temperature and the current temperature of the system.

Meanwhile each time a temperature change is being performed; the system sends a text message to the user via the MAX232 integrated circuit. This IC is an RS to TTL converter which is interfacing the GSM MODEM (sim900). With this MODEM, the user gets an sms each time the garden changes. The complete system operates on a 5 VDC power supply obtained from a 220vac power source.

4. CONCLUSION

The problem of poultry farming arising from not being able to manage the temperature changes have resulted in many poultry farmers incurring huge financial losses. This paper has taken a close look at this problem and has proposed a dynamic solution using digital hardware and software. This proposed system works efficiently over the present conventional methods of manual observation before action and will help in reducing to a minimum the financial losses and risk farmers are made to incur.

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