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EGG INCUBATOR CONTROL SYSTEM WITH SHORT MESSAGE SERVICE (SMS) FAULT ANALYSIS ALERT

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ABSTRACT:
The egg incubator system with temperature sensor can measure the state of the incubator and automatically change to the suitable condition for the egg. The health of the egg is very important for the development of embryo. The status condition in the incubator system will appear on the liquid crystal display (LCD) screen. To make sure all part of egg was heated by lamp, direct current (DC) motor was used to rotate iron rod at the bottom side and automatically change the position of egg. The entire element is controlled using programmable integrated circuit (PIC) – a type of microcontroller that can process a data from sensor and will execute the control element to change the condition of the incubator system. The heater is interfaced with the controller through the optocoupler. The optocoupler isolates the microcontroller from the alternating current (AC) power, thereby preventing any possible flow back of the AC into the control circuit. The software intelligent agent was embedded into 8051 family of micro controllers, emulating the attention commands of mobile cell phone using window HyperTerminal and microcontroller and thus translate attention commands to assembly language, having machine cycle of 1.085s,R=10K,C=10µF, t=2.17µs,transistor collector current, Ic=800mA and emitter forward current gain, hfe gives 200.The SMS mobile cell phone using AT89C51 microcontroller in the prototype self diagnostic systems, will not only control the temperature of an incubator but also detect and analyze faults in the system. The programme used in this work is user friendly since the incubator system can move to other places.

Keywords: Microcontroller, Optocoupler, Programmable Integrated Circuit (PIC) and Window HyperTerminal
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INTRODUCTION

The ancient Egyptians and Chinese both devised incubators to hatch chicks from eggs without the mother hen sitting on the eggs. This enabled hens to continue laying eggs. The Egyptian incubators were large rooms heated by fires; attendants turned the eggs at regular intervals so they would warm evenly. Some Chinese incubators were warmed by fire, others by rotting manure. The Italian inventor, Jean Baptiste Porta drew on the ancient Egyptians

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designs to build his 1588 egg incubator, but was forced to abandon his work by the inquisition. Dutch inventor, Cornelius Drebbel also invented an incubator to hatch eggs.

Knowledge about egg incubation was revived and introduced throughout Europe by the inventive Frenchman Rene-Antoine Ferchault de Reaumur (1683-1757) around 1750. Reaumur's device was by a wood stove; temperature was monitored by a thermometer, also invented by Reaumur, which gave rise to the temperature scale named after the inventor. The success of Reaumur's incubator and Louis (1710) enjoyed helping the chicks hatch andboosted commercial production of foodstuffs at the beginning of the industrial era.After Reaumur's death, the incubator was further developed by Abbe Jean-Antoine Nollet (1700-1770) and later by Abbe Copineau, who used alcohol lamps as a source of heat (http://search.datasheetcatalog.net/key/LM35, retrieved on 02/04/11.Ibid. Roger Seymour, p.109. Ibid, Roger Seymour,p.110.http://Incubator%20Summary%20%20%20BookRags.com.htm).

Today's incubators are electrically heated and turn the eggs automatically. The large ones may hold up to 75,000 eggs. With the innovations associated therein, faults in the incubation system could be detected through the software intelligent agent (SIA), embedded into the Integrated circuit (ATMEL89C51) microcontroller. From Barr. and Feigenbaum, (1981); Rocks and Mazur, (1993) contributions the SIA, monitors the fan that brings about good air circulation in the incubator, the heater which heats up the incubator, the sensor- analog to digital converter(ADC), that converts the analog temperature to digital value. When the agent detects fault(s), it uses the case based reasoning built into the controller to diagnose the cause of the fault and hence the possible solution can be predicted. Ram, (2008), worked on microcontroller that could send the cause of the fault and the possible solution to the liquid crystal display (LCD) interfaced to it and at the same time copy the same information to the mobile number of the maintenance personnel, thus turning ON the buzzer alarm. Depending on the nature of the fault, Einar et al.,(1997); Hunt, (1996); Trevor,(2000) and http://search.datasheetcatalog.net/key/LIGHT+EMITTING+DIODE retrieved on 02/04/11.http://www.datasheetcatalog.com/datasheets_pdf/E/M/X/- /EMX-300.shtml,retrieved http://search.datasheetcatalog.net/key/LIQUID+CRYSTAL+DISPLAY+, retrieve on 02/04/11), found out that the controller might decide to shut down the entire system irrespective of the case based reasoning.

For incubator bird chicks to survive, they demand a precise temperature of 91^{o}F. If the chicks must survive, the temperature must not vary more than one degree on either side of 91^{o}F. Scientists differ on the mechanism they think the bird uses to measure the temperature. Some think the bird's thermometer is in its beak while others believe the tongue can distinguish 91^{o}F and a few tenths of a percent above and below 91^{o}F. For the bird to keep the eggs at 91^{o}F, the male digs down into the nest and checks the temperature. On hot days, he may pile extra sand on top of the nest to shield it from the sun. He may even rearrange the entire pile of rotting leaves and grasses several times a day. Paul and Winfield (2002),on their research found out that in the cooler days, the male megapode (which means big feet) will push material off the top of the nest to permit more sunlight to penetrate the decaying organic material. Or, to keep the humidity at 99.5% around the eggs, he may dig conical holes toward the eggs to get more moisture deeper into the nest.

In view of high-tech associated with this work, the following elements were considered:

Monitoring: The temperature of the incubator is monitored through the temperature sensor connected to microcontroller via analog to digital converter (ADC).

Control: The microcontroller uses the control program embedded into it to actuate the heater and air-circulation fan. Temperature is maintained within a defined limit by switching ON or OFF the heater.

Fault analysis and alert: Intelligence is built into the controller using rule based reasoning. In order to build the required intelligence into the controller, by simulating the components under normal and fault conditions using proteus professional. The analysis arising from the simulation was then translated into case-based reasoning program. The alert is in three levels: SMS alert, buzzer alarm and liquid crystal display (LCD) .Each time a fault occurs, alert is sent to the mobile phone numbers of the maintenance personnel. The alert describes the nature of the fault and the possible solution. The same information sent to the maintenance personnel is also displayed on the liquid crystal display (LCD). Depending on the nature of the fault, the system might refuse to start or shut down if already in operation. Buzzer alarm, alerts the operators of the immediate faults, as shown in block diagram overview of Figure 1.

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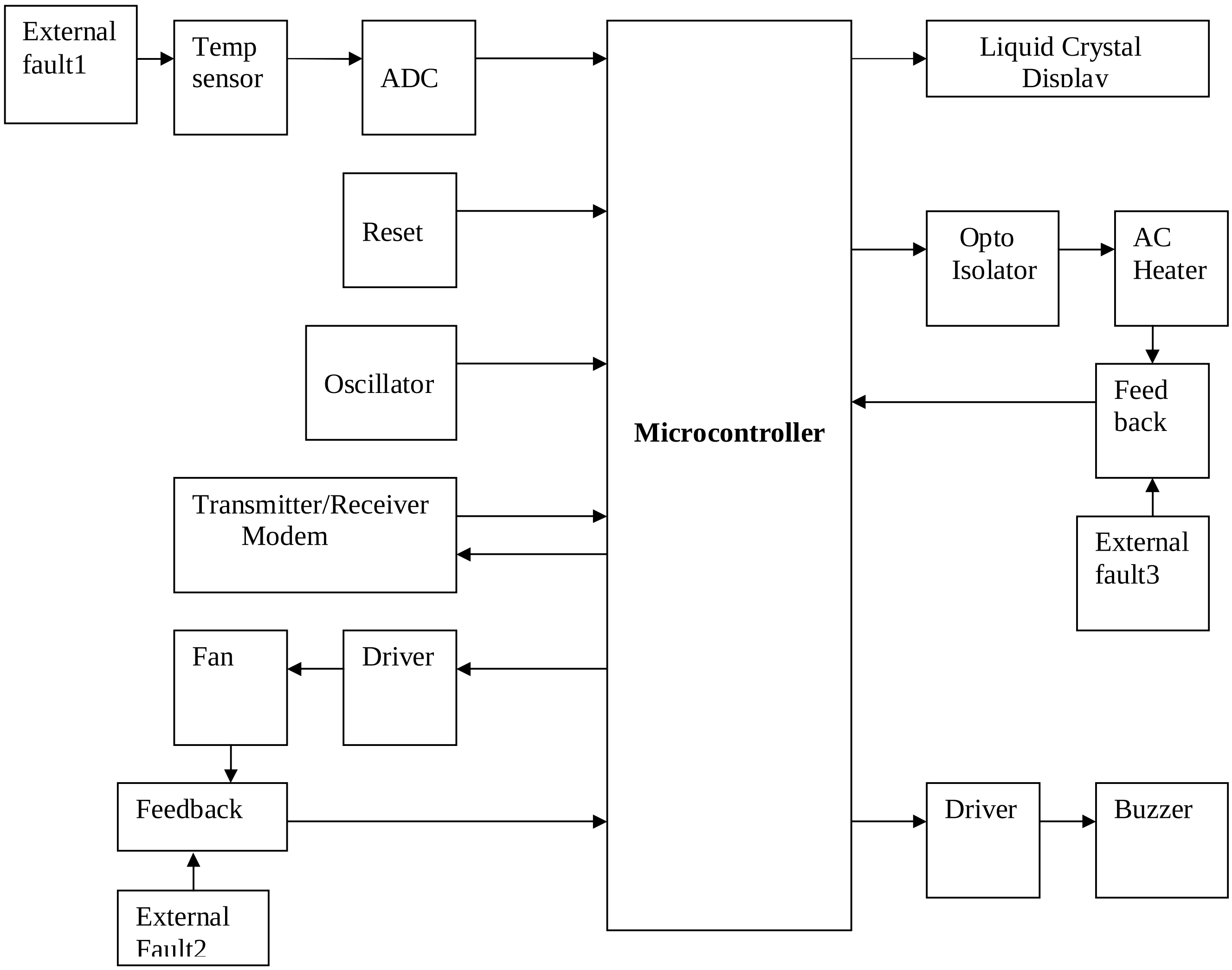


Figure 1:The block diagram overview of the project

Design methodology and system analysis:

The following were considered in this work:

1. The processes that would be involved and the necessary technology required.
2. The availability of materials/components required for implementation.

Clearly this work involves control, intelligent faults analysis, and full duplex serial communication processes.

The technology used in implementing SMS is that of Global System Mobile Communication (GSM) which entails the use of attention (AT) command to write to the memory of a mobile cell phone. AT command is a set of instructions made up of the American Standard Code for Information Interchange (ASCII) strings with predefined functions which every mobile cell phone should understand, depending on the phone manufacturer. Half duplex serial communication requires transmitter and receiver, transmitting and receiving at an agreed protocol, especially the baud rate.

Thus,it becomes obvious that Gate-Oriented design which involves equation-to-gate conversion, map simplification, output function synthesis and next-state function synthesis, flip-flops, state assignment and hazards cannot be used to implement this work. Even Read Only Memory (ROM) Centered Design where ROM is used to implement control process is not the most economical as ROM does not have serial communication capability. And it will certainly be cumbersome to build intelligence into ROM.

One possible way to implement this system is to use a computer, i.e. interface the system to a computer and then use high level language to develop the intelligent fault analysis program and serial communication program. The bottle neck with this method besides the cost is that the computer has to be on as long as the incubator is on. The microcontroller-based implementation was chosen due to the following reasons.

1. Since AT command is a string of ASCII characters, it can easily be emulated using microcontroller.
2. It supports a set of baud rates which are compatible with most mobile cell phones.
3. Microcontroller supports multi-level programming. In other words, its memory can be mapped into various sections. Each sub-routine can then be assigned a particular section of the memory, with one central programming calling each sub-routine when necessary. In this work for example, there are three major sub-routines: Intelligent, i.e. fault analysis, serial communication, and control subroutines.
4. Microcontroller also has interrupt capability, That is to say that it can suspend whatever action it's executing whenever an events of higher priority occurs and attend to that event after which it goes back to what it was doing.
5. **Microcontroller** can run at external clock speed of 24MHz. With this, any fault can be detected within microseconds.

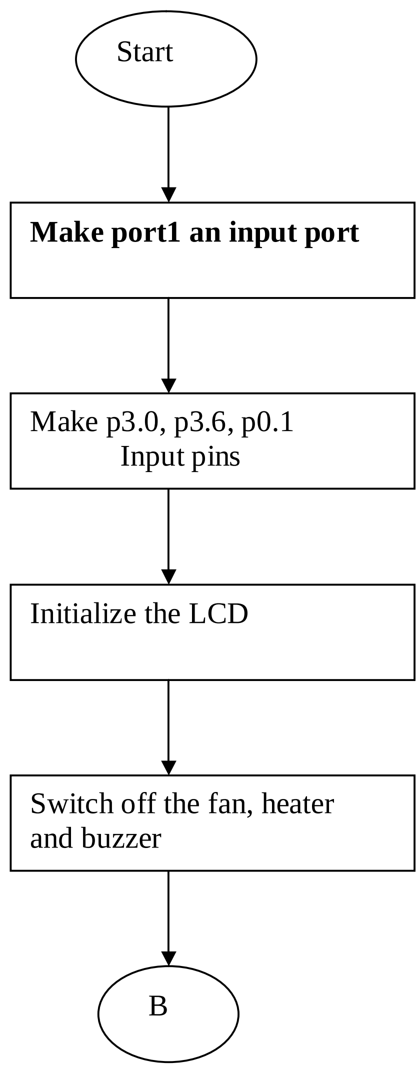
Structural Analysis and Design Method:

The structure of design and implementation of self diagnostic intelligent incubator control system is that of a prototype that could be demonstrated in a laboratory.

It is an embedded system in the sense that the software controlling the system is embedded in the controller. The inputs to the system are the temperature signal from the sensor, transmitter/receiver and feedback from outputactuators. (http://wataniya.yahoo.com/smshistory.html,2003;http://www.developershome.com/sms/, 2002, retrieved on 12/10/10).

Theoutput devices include the buzzer alarm, liquid crystal display (LCD), fan and electric heater.

The software is in three levels: The intelligent fault analysis subroutine, serial communication sub routine and temperature control sub routine. The Initialization Flow Charts are as shown below:



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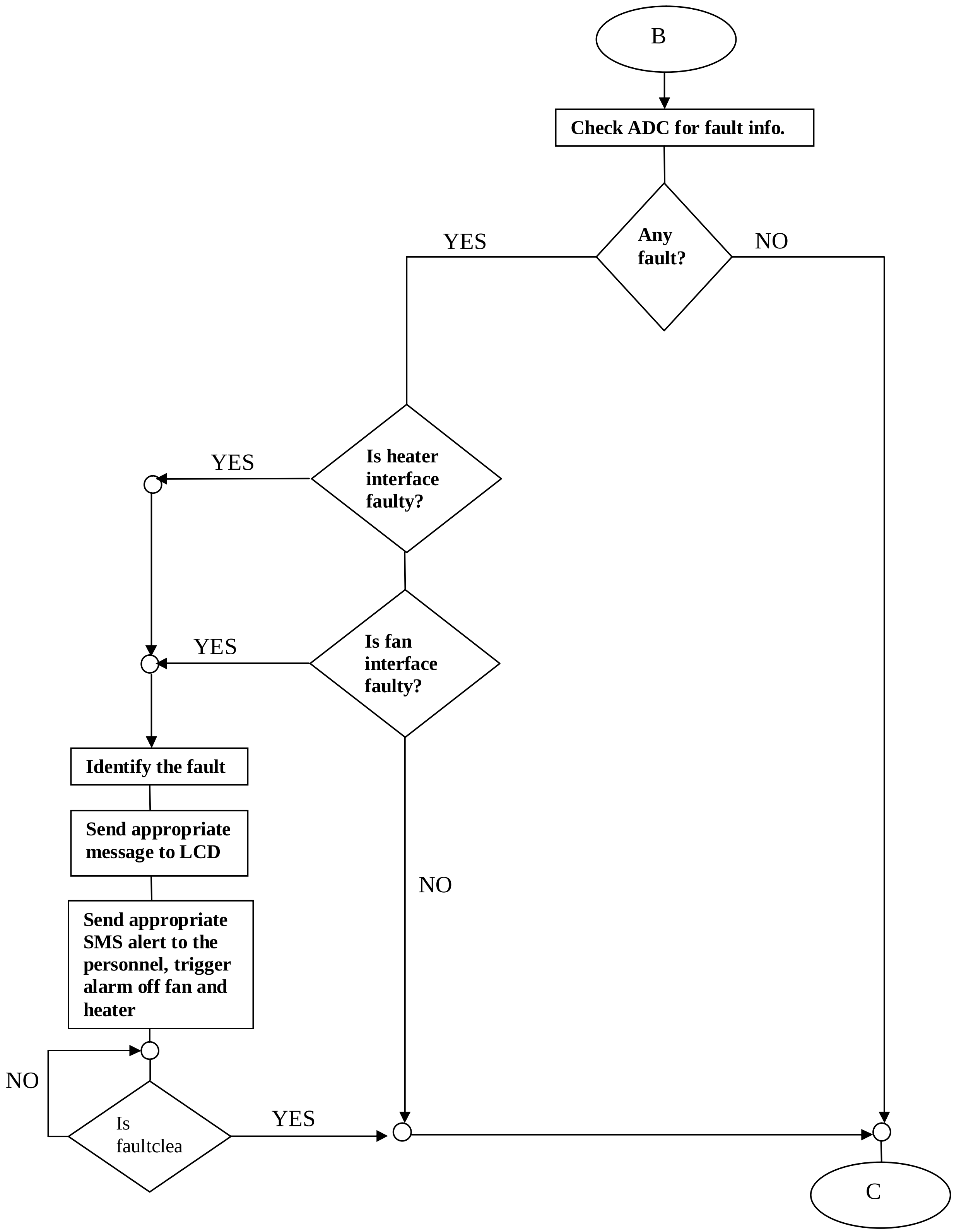

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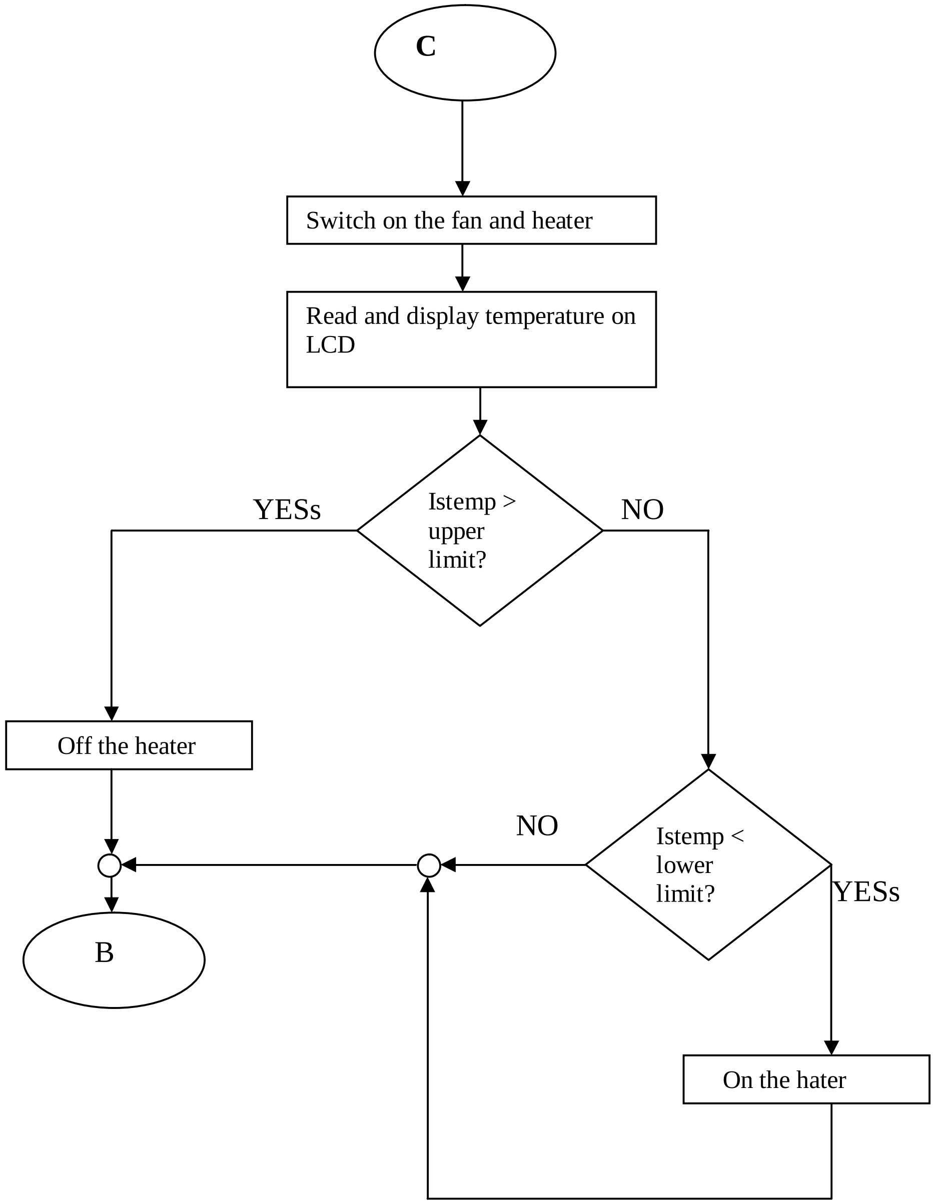

A. Initialization subroutine
B. Serial communication subroutine
C. Monitoring subroutine.

Design Method:

Each section of the work is developed and tested before the final coupling. The glass used is Perspex glass, which was used for transparency. It can withstand a temperature of 100^oC, likewise the black casing,(Leo, 1995).

Features of MY-X7 Sagem phone series that make them suitable for emulation using microcontroller.

1. The serial port is compatible with transistor-transistor logic (TTL) levels. Thus there is no need for voltage level conversion between the phone and controller.
2. The serial transmit pin has dual function of transmitting data and charging of the phone.
3. A voltage of 5-7V and current of 300mA at transmit pin will cause the phone to start charging while the pin sees a voltage of 5Vand current of about20mA as data.
4. The phone has its Attention Command (AT) for sending SMS enabled.
5. There are two modes of SMS: PDU and text modes. In text mode, one can easily write to the phone in American Standard Code of Information Interchange (ASCII) format.
6. The baud rate can be manually set.
7. It has USB-to-serial cable for connection to the computer. The cable, one can understand the AT command of the phone using Hyper Terminal program.
8. One can check the state of the battery using AT command.

Design of Case base reasoning sub routine for fault analysis:

To be able to build intelligence required to actualize this work into the microcontroller, one must understand how relays, transistors, ADC, optocoupler, temperature sensor (LM35), diodes work under normal conditions. This is because failure of any of these components used in the circuit design directly affects the system.

Investigation of how LM35 and ADC0804 work under normal and abnormal conditions:

Below is the screen shot of the schematics used to investigate how LM35 and ADC0804 work under normal and abnormal conditions. The software (Figure 2), used for simulation is proteus professional. The values of the components used are not arbitrary.

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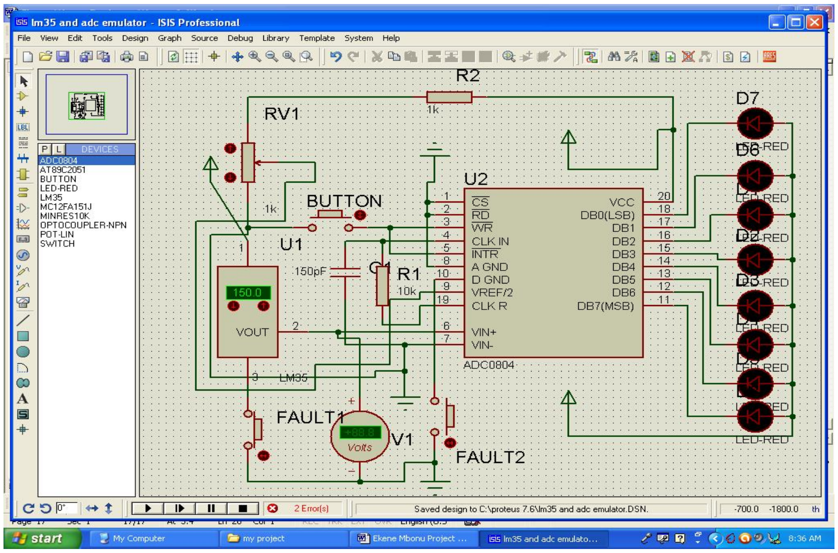

Figure 2: Investigation of how LM35 and ADC0804 work under normal and abnormal conditions
(Mazidi and Mazidi, 2000)

LM35 has a linear output with accuracy of 10mV/C. Its temperature range is from -55ºC to 150ºC. The temperature output is supplied to the input of the ADC0804 (VIN+). A voltmeter, V1 is also connected across the sensor output to measure the analog to digital converter (ADC), as shown inTable 1, forthe result of the simulation.

If ADC0804 has no output,then,there is no power to it. Else,the chip is bad since is most unlikely that the capacitor, C1 and resistor, R1 used in determining the clock value for the analog digital converter (ADC) will go bad (little or no power is dissipated on them). Likewise the investigation of how relay and optocoupler work under normal and abnormal conditions, is shown in Figure 3.

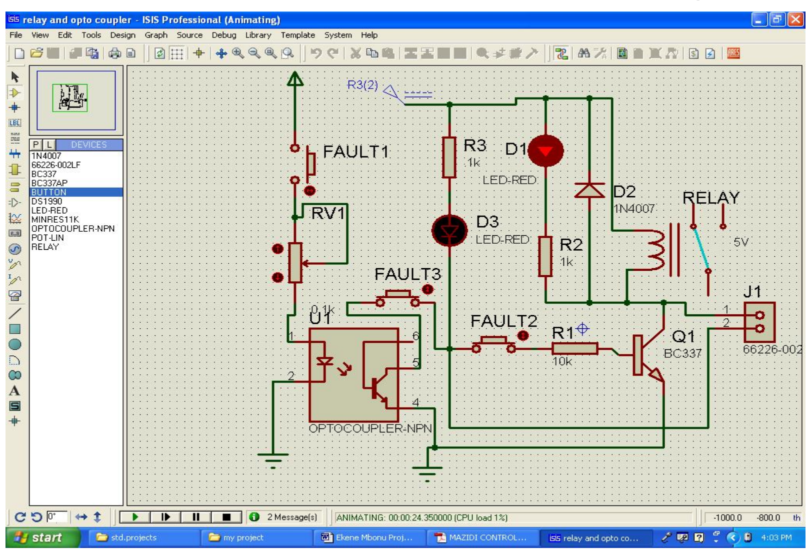

Figure 3: Investigation of how relay and optocoupler work under normal and fault conditions

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From Figure 1, the block diagram overview of this work, the optocoupler will isolate the microcontroller from the AC heater.J1 is the feedback to the micro controller.

Temperature interface to the microcontroller:

Figure 4 shows how to interface the temperature sensor LM35 to the microcontroller AT89C51.

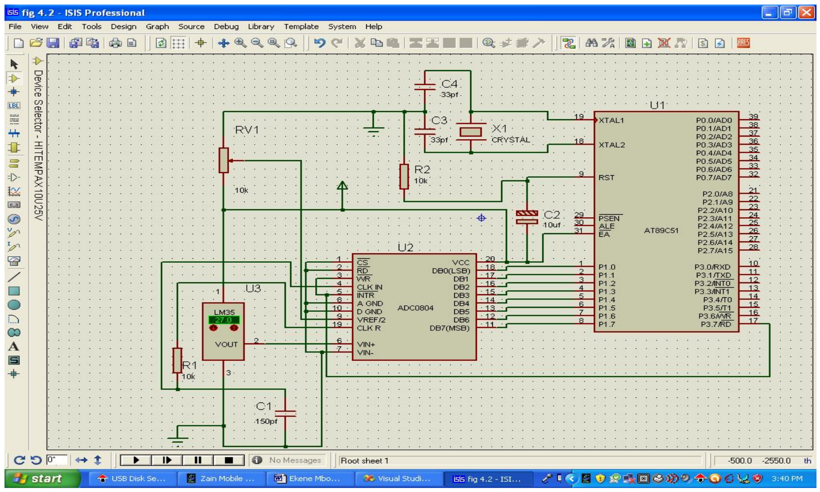

Figure 4: Temperature Interface to the Microcontroller

External reset:

Pin 9 (see Figure 4) is the RESET pin. It is an input and is active high (normally low). Upon applying a high pulse to this pin, the microcontroller will reset and terminate all activities. This is often referred to as a power on reset. In order for the RESET input to be effective, it must have a minimum of duration of 2 machines cycles. Interface of the Liquid Crystal Display (LCD) to the controller is shown in Figure 5,while interface of AC heater to the controller with feedback is shown in Figure 6.

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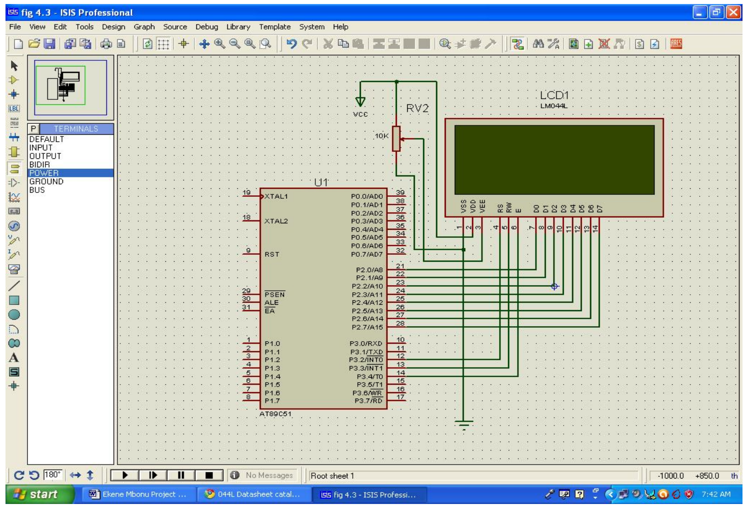

Figure 5: The LCD interface

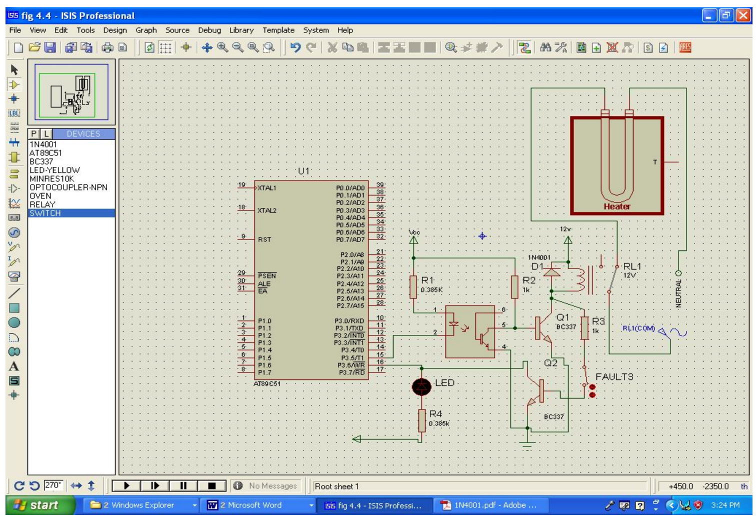

Figure 6: Interfacing AC heater to the controller with feedback

The heater is interfaced to the controller through the optocoupler. The optocoupler isolates the microcontroller from the A.C. power, thereby preventing any possible flowback of the AC into the control circuit.

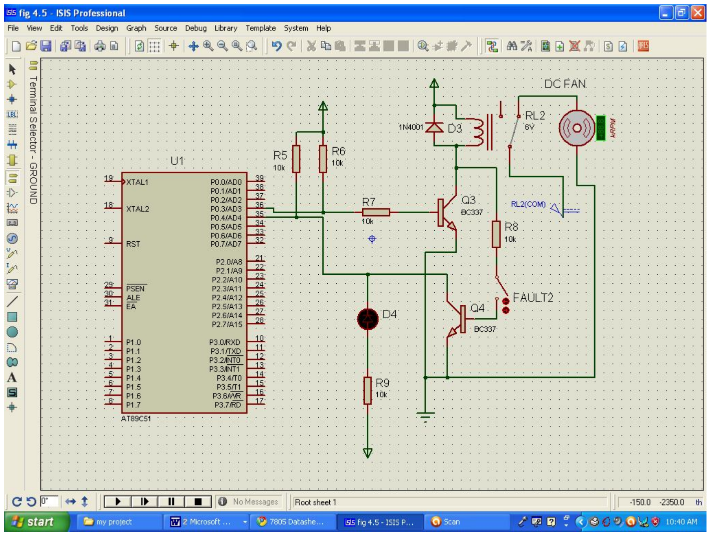

Figure 7: Interfacing DC fan to microcontroller with feedback

The DC fan requires 5V to function. The relay used here is 5V so that the power consumption will be reduced to the minimum.

The feedback loop sends a low to the controller each time the relay is in the off condition. This is visible by the light emitting diode (LED) indicator, D4. D4 requires at least 5mA to come on to the Buzzer Alarm (Figure 8)

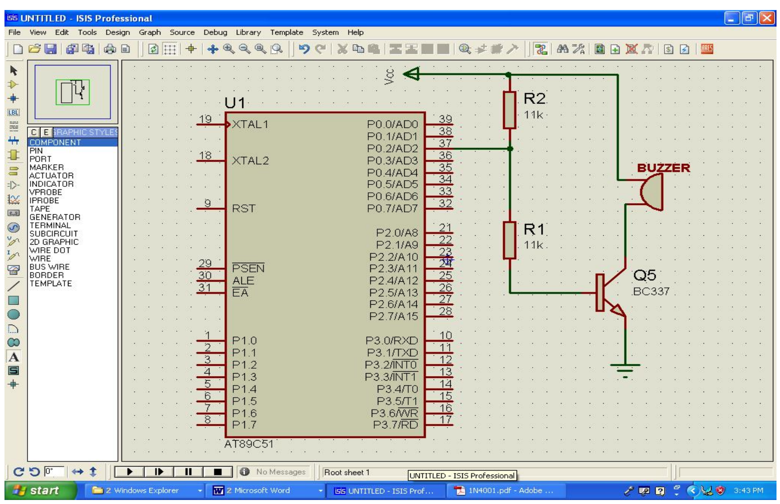

Figure 8:Interfacing the buzzer alarm to microcontroller

The Power Supply:

The block diagram of the power supply is shown in figure 9 while the shematic is shown in Figure 10.

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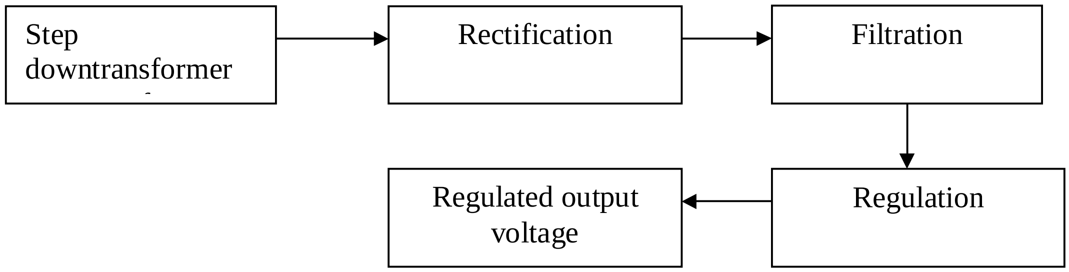

Figure 9:Block diagram of the power supply

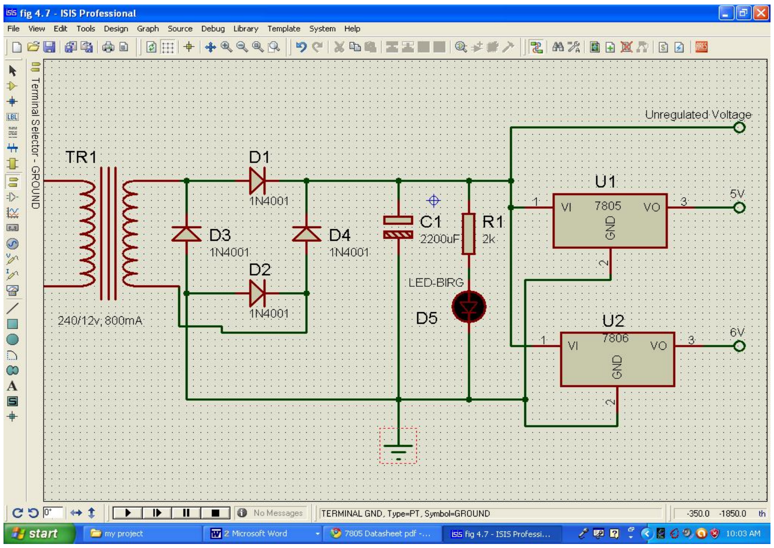

Figure 10: Power supply schematic

System Design:

The voltage charge in an RC circuit is given by:

$Vc = V (1 - e^{-t/RC})$ (1)

Where RC = time constant

t = 2 machines cycles

So, V = Vcc = 5V

Vc = voltage across C2 which is usually less than Vcc because of discharging action of the capacitor.

Machine cycle = 1/value of crystal/12MHz

1/machine cycle = $11.0592 \times 10^6 / 12 \times 10^6$ = 921.6 KHz

Machine cycle = 1/921.6 KHz = 1.085 sec

2machiunes = 2 x 1.085 = 2.17μs

From (1) $Vc/V = 1 - e^{-t/Rc}$ (2)

$e^{-t/Rc} = (1 - Vc/V)$ (3)

$\ln e^{-t/Rc} = \ln (1 - Vc/V)$ (4)

$c = -t/R(1 - Vc/V)$ (5)

Let R = 10k, then c = 10µf, t = 2.17µs

Choice of the Optocoupler 4N35:

This optocoupler is cheap and available.

Input LED forward voltage = 1.15 (typical).

Input LED forwards current = 10mA.

Now Vcc = 10mA (R1) + 1.15

Vcc = 5V

5-1.15/10 x 10^-3 = R1

R1 = 3.35 x 10^2/10 = 3.85 x 10^2

R1 = 385Ω.

Collector current of the optocoupler, Ic = 150mA, continuous.

Also Vcc = IcR2

5/150 x 10^-3.

R2 = 5 x 10^3/150

R2 = 33Ω

This is the minimum value of R2. This value can be increased and the device will still work perfectly especially when it is required to bias a transistor (in this case BC337) when the optocoupler is off. Thus, R2 can be taken and increased to a value that can bias the transistor.

Choice of 240V/10A Relay:

The heater rating is 100w, 220V. But power = I x V.

100/220 = 0.45A.

Thus the relay meets the current and voltage requirement of the load (heater).

Choice of Transistor BC337:

The resistance of relay coil = 400Ω (given).

Current I, through the coil = 12/400 = 30MA.

The transistor BC337 can handle this current very well (its hfe = 200 typical).

Now when the optocoupler is off, from kickoff's voltage law:

$Vcc - I_bR_2 - Vbe = 0$ (6)

For silicon transistors, Vbe = 0.7V

$5 - 0.7 = I_bR_2$, $4.3 = I_bR_2$.

But $I_b = I_c/hfe$ (7)

Where I_c = transistor collector current=800mA

And emitter forward current gain, hfe = 200

$I_b = 0.8/200 = 0.004A$

$R_2 = 4.3/I_b = 4.3/0.004$

R_2=1kΩ

Choice of the Freewheel Diode, 1N4001:

The free wheel diode D1 protects the transistor from inductive click of the relay. The peak inverse voltage of 1N4001 = 50V, its forward current is 1ampere. These are well above 30mA and 12V.Thus Vcc = IR implies, R = 5/ (5 x 10^-3) = 1kΩ.

Based on the systems design, the component parts were assembled and tested for its reliability as shown in Figure 11.

System Specification:

The digital ICs used in the design and implementation of microcontroller based self diagnostic incubator control system with fault analysis alert using short message service (SMS) are ADC0804 and AT89C51 microcontroller. The voltage requirement for both of them is +5V. This +5V is supplied to each of ICs from the power supply circuit with a 7805 regulator IC. For the 12V D.C relay that is used in the output interface, the voltage required to switch it, +12V and this is tapped from the unregulated voltage of the power supply. The alternative to this way is to connect another 12 volts regulator at the input of the unregulated voltage to get exactly 12 volts. 220AC/100watts electric bulb whose power is provided by the mains is used as incubator heater. Other components used are BC337 (transistor), 4N35 (optocoupler), buzzer alarm, LM35 (temperature sensor).MY-X7 Sagem mobile phone (transmitter/receiver). Each of them requires +5V D.C to function. The step-down transformer that is used for the power supply is 240V A.C to 12V A.C with the current rating of 800mA. The system’s main features are summarized in Table 5.

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Software Subsystem Testing

The software testing was divided into three major modules: the input, output and serial communication modules.

- **a)** The output module was first developed and tested to make sure that data are being displayed properly, and that the relays, fan, and heater were properly switched. The feedback loop was also tested and confirmed okay.
- **b)** The input module was developed to reading temperature value from LM35 through ADC0804.
- **c)** The serial communication protocol between the controller and the phone was developed and tested.
- **d)** Finally, the entire software was put together by way of integrating all the modules in a main control loop and tested for conformity with the main control algorithm.

Conclusion:

A standard prototype of the microcontroller based self diagnostic incubator control system with fault analysis alert using SMS and attention command(AT) was demonstrated. This approach can be applied to many other control/ monitoring systems.

The process of developing and embedding intelligent agents into 8051 family of microcontrollers was clearly shown. This will be of great help to systems developers.

TTLor CMOS ensures that the chips are compatible, if not appropriate drivers should be used.

Much loss is incurred whenever an incubator develops faults especially where the expatriate is not locally available. It is therefore necessary to build self diagnostic intelligent agents into such systems to aid maintenance personnel in fault analysis and management. This work shows the way to building such intelligent system.

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Table 1: The result of Investigation of how LM35 and ADC0804 work under normal and fault conditions

Temp (ºC)	**V1 (Volt)**	**FAULT1 SWITCH**	**FAULT2 SWITCH**	**ADC Value In binary**	**ADC Value In decimal**	**Inference**
0	0.00	Closed	Closed	00000000	00000000	No fault detected
0	Erratic	Open	Closed	00001110	14	On no power to Sensor, ADC outputs 14v instead of 0volt
1	Erratic	Open	Closed	11111111	255	On no power to Sensor, ADC outputs 255V instead of 1V.
2	Erratic	Open	Closed	11111111	255	On no power to Sensor, ADC outputs 255V instead of 2V.
10	Erratic	Open	Closed	11111111	255	On no power to Sensor, ADC outputs 255V instead of 10V
-55	Erratic	Open	Closed	11111111	255	On no power to Sensor, ADC outputs 255V instead of 10V
Any Other Value	Erratic	Open	Closed	1111111	255	On no power to Sensor, ADC outputs 255V. the exception iat (degree temp.
Any Value	No Result	Closed	Open	Simulation Fails	Simulation Fails	In absence of power To ADC, there will be no output

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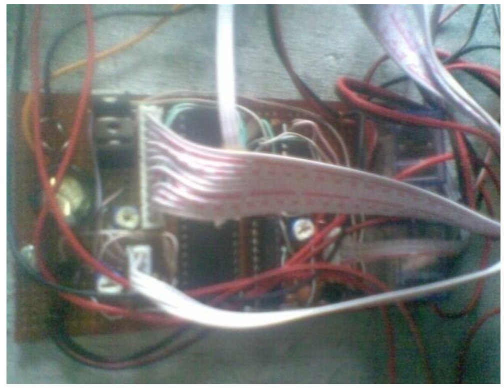
APPENDICES



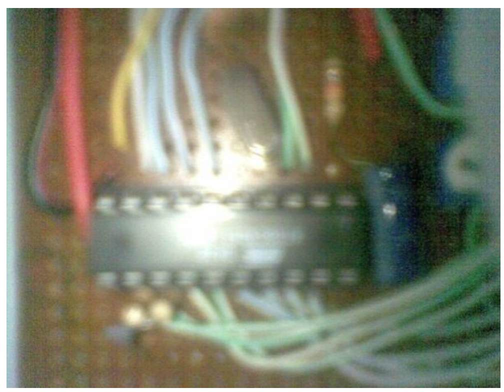


Table 5:System's main features

ITEM	CONTENT
Controller IC	AT89C51 microcontroller
Input sensor	LM35
Display Type	4x20 LCD(text)
Dedicated input lines	9
Dedicated output lines	16
Control lines	3
Feedback lines	2
Input mode	Analog
Output mode	Digital(3-5V)
Text Format	Alphanumeric
Operating temperature	34-37°C
Storage temperature	20-80°C
Power supply	11-20V D.C/220V A.C
Transmitter modem	MY-X7 Sagem phone
Heater	220Va.c/100W electric bulb
Power extension	Yes, one

The Hardware Subsystems Design:

The hardware subsystem is made up of the input interface, the output interface, the feedback loops and the control system. The schematic block
Diagram of the hardware subsystem is shown in figure 4.2 below.

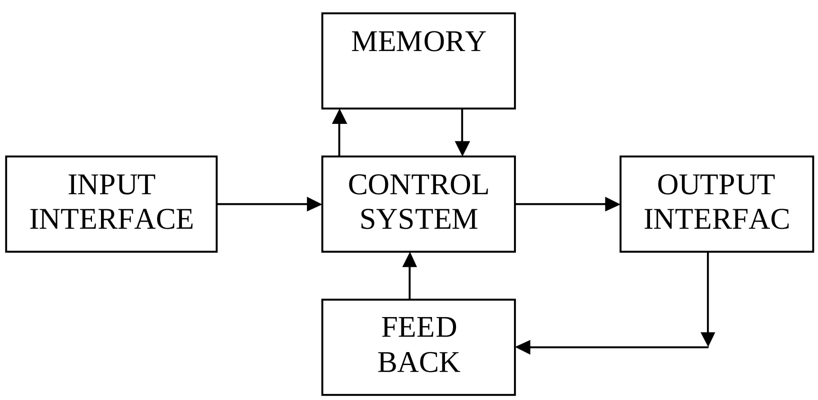


Figure 4.1: The schematic block diagram of the hardware subsystem

4.3 THE SOFTWARE SUBSYSTEM

Here the control algorithm for the system is represented using flow chart.

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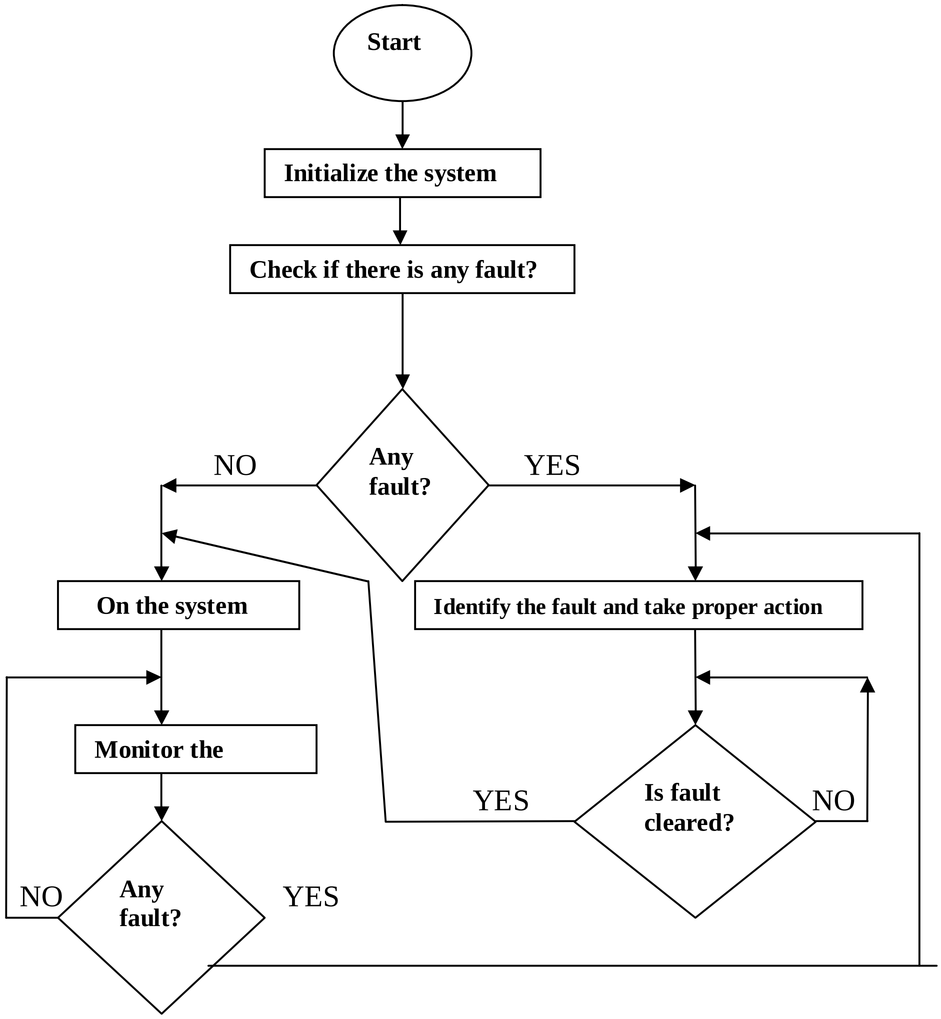

Figure 4.9:The main flow chart

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Sample codes for Initialization of The System

```
org  00h                    ;  Begin the program from origin
main
call init_LCD               ; initialze the LCD
call init_ports             ; Initialze the input/output ports of the controller
jmp end_                    ; end of initalization
init_lcd:mov a,#38h         ;  make LCD 5 x 7  matrix
call wr_instr               ; send instruction to LCD
mov a,#0ch                  ; display on, cursor off
call wr_instr               ; send instruction to LCD
mov a,#06h                  ; Increment cursor
call wr_instr               ; send instruction to LCD
mov a,#01h                  ; clear display screen
call wr_instr               ; send instruction to LCD
ret                          ; return to the main program
setb p3.6                   ; make p3.6 an input port
 setb p0.1                  ; make p0.1 an input port
 mov p1,#0ffh               ; make p1 an input port
ret                          ;return to the main program
init_ports:                   end_: end
```

Sample Codes for Serial Communication between the Phone and the Controller.

```
org 00h                                    ; Begin the program from origin
start:          mov scon,#50h              ;configure the serial port mode
                mov TMOD,#20h              ;setting the serial port to receive data
                mov TH1, #-3               ;setting the baud rate to 9,600
                setb TR1                   ;enable timer1
send_sms1:      CALL ONESEC                ; wait for one second
                CALL INIT_SMS              ; initialize the phone
                CALL ONESEC                ; wait for one second
                CALL SEND_PHONE_NUM        ; loads personnel phone num.
                CALL ONESEC                ; wait for one second
                CALL SEND_MESSAGE; send appropriate message
End
```