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DESIGN AND IMPLEMENTATION OF A MICROCONTROLLER –BASED DIGITAL TIME AWARE OVEN TEMPERATURE CONTROLLER AND DISPLAY

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Abstract:

The objective of this research work is to design and implement a microcontroller – based digital time aware oven temperature controller and display. Various kinds of oven exist for various purposes: electrical, gas and manual types for either home use or industrial purposes. The research is achieved using the AT89C51 Microcontroller which compares the oven temperature with the preset temperature to determine when to turn ON or OFF the oven, the transistorized Relay which switches ON and OFF the oven depending on the logic signal sent by the microcontroller and the LM35 which is a temperature sensor that senses or determines the oven temperature. It works with the LM358 which amplifies the picked signal and the 555 timer which does the conversion (voltage to pulse width) and sends to the microcontroller for processing, it also has push buttons for setting the preset temperature and indicators showing the status of the oven. The accuracy of the microcontroller – based time aware oven temperature controller makes it more reliable as a particular temperature which a particular meal is expected to cook and be okay could be set.

Key Words: Digital Time Aware Oven, Temperature Controller, AT89C51 Microcontroller & Temperature Monitoring Circuit

1. Introduction:

A microcontroller based time aware oven is an automatic time control oven that monitors a preset time and regulates the oven temperature over the set time [2, 12]. If the temperature of the oven increases or reaches the set maximum, the heating element is automatically turned off, but when the temperature reduces, the heating element is also automatically turned on. This on and off activity takes place within the set time given to the controlling unit, say five minutes, and when the time runs out, the oven is automatically turned off. This is because the oven is a time conscious system. The research has an electric oven with a heating element as the heat source; it also has a microcontroller system. The system uses a temperature sensor LM35 to determine the ambient temperature surrounding the oven. An oven is an enclosed compartment for heating, baking or drying. It is most commonly used in cooking and pottery. Two common kinds of modern ovens are gas ovens and electric ovens. Ovens used in pottery are also known as kilns. An oven used for heating or for industrial processes is called a furnace or industrial oven [6, 10].

In cooking, the conventional oven is a kitchen appliance and is used for roasting and heating. Food normally cooked in this manner includes meat, casseroles and baked goods such as bread, cake and other desserts. In the past, cooking ovens were fueled by wood or coal. Modern ovens are fueled by gas or electricity. When an oven is contained in a complete stove, the burners on the top of the stove may use the same or different fuel than the oven [5, 7, 8].

Some ovens have a full logic system that can start and end the cooking process for you so you can simply set and forget [1, 3, 11]. To keep plates and food warm ready for serving, some ovens offer optional warming racks. If you want to enjoy roasts the low-fat way consider adding a rotisserie option to your new oven. A defrosting feature can help you thaw frozen food quickly.

2. Material and Methods:

The system uses a temperature sensor, LM35 that determines the ambient temperature, a microcontroller that acquires and analyzes data from the ADC, a heating element, display unit and a transistorized relay circuit. The system will monitor and regulate the ambient temperature with the preset temperature, the length of time the oven has been on with the present time, when the oven is turned on.

System Flow Diagram:

The system operates following series of stages which is highlighted in Figure 1. Initially, the system was in an idle mode, but once the user presets temperature and time using the push buttons, the start button is pressed and the system automatically turns on the heater and starts the time to decrement. As the system is running, it monitors the temperature sensor in relation to the preset temperature. If the oven temperature equals the preset temperature, the system turns off the heater but if less, it turns on the heater. As the system monitors temperature, it also monitors time and once the time has decremented to zero or equals the present time, the system turns off the heater and then stops and enters into an idle mode.

System Components:

The AT89C51 Microcontroller:

Microcontrollers are integrated circuits (Ics) which are mostly used for embedded and control systems. They are actually in the same category as the Microcomputer processor as they come with their own instruction set, registers and memory.

The AT89C51 is a low-power, high-performance Complimentary Metallic Oxide Semiconductor (CMOS) 8-bit microcontroller with 4Kbytes of Flash programmable and erasable read only memory (PEROM). The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.

Some of the features of the AT89C51 microcontroller include: 4Kbytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. In addition, the AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning [4,9]. The Power-down Mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

The Power Control Unit

Virtually every piece of electronic equipment, e.g., computers and their peripherals, calculators, TV and hi-fi equipment, and instruments, is powered from a DC power source, be it a battery or a DC power supply. Most of this equipment requires not only DC voltage but voltage that is also well filtered and regulated.

There are three types of electronic power conversion devices in use today which are classified as follows according to their input and output voltages:

- ✓ The AC/DC power supply
- ✓ DC/DC converter
- ✓ The DC/AC inverter

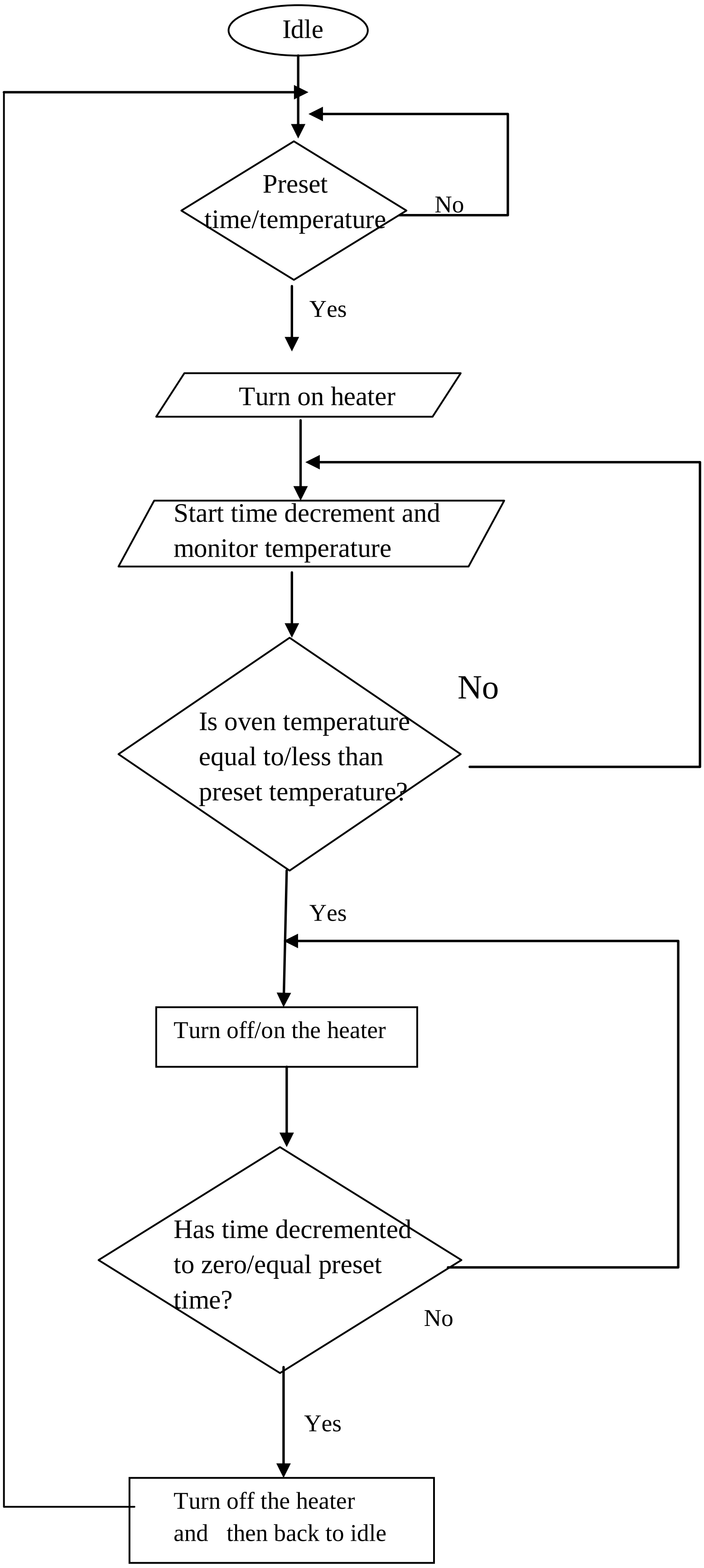

Figure 1: System Flow Diagram

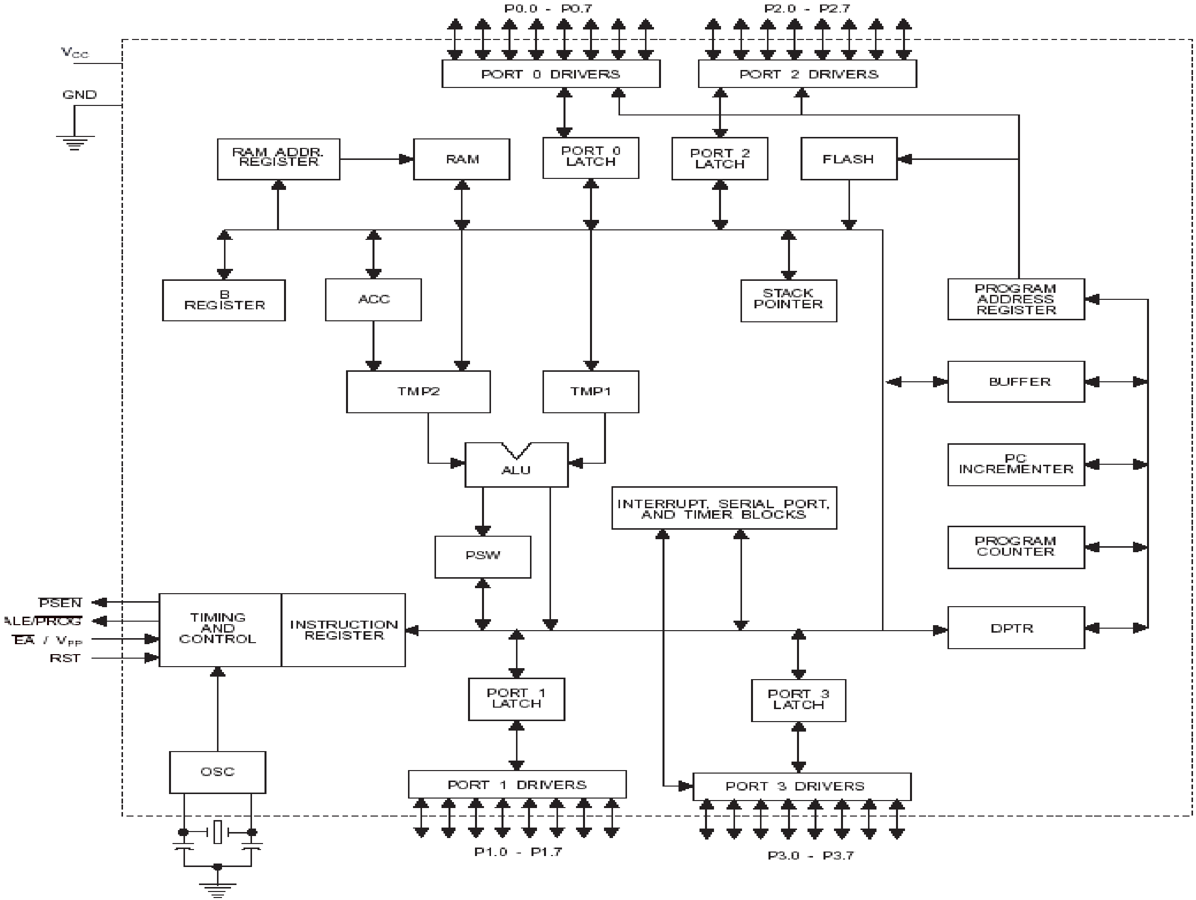

Figure 2: Block Diagram of the Microcontroller

Pin Description:

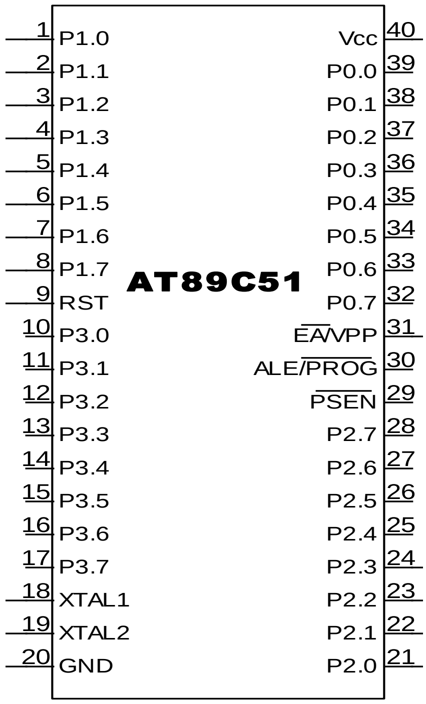

Figure 3: Pin Configuration of the AT89C51

Each has its own area of use but for our design the Alternating current to Direct current is utilized. A power supply converting AC line voltage to DC power must perform the following functions at high efficiency and at low cost:

- ✓ Voltage transformation: Supply the correct DC voltage level(s).
- ✓ Rectification: Convert the incoming AC line voltage to DC voltage.
- ✓ Filtering: Smooth the ripple of the rectified voltage.
- ✓ Regulation: Control the output voltage level to a constant value irrespective of line, load and temperature changes.
- ✓ Isolation: Separate electrically the output from the input voltage source.
- ✓ Protection: Prevent damaging voltage surges from reaching the output and also provide back-up power or shut down during a brown-out.

An ideal power supply would be characterized by supplying a smooth and constant output voltage regardless of variations in line voltage, load current or ambient temperature at 100% conversion efficiency.

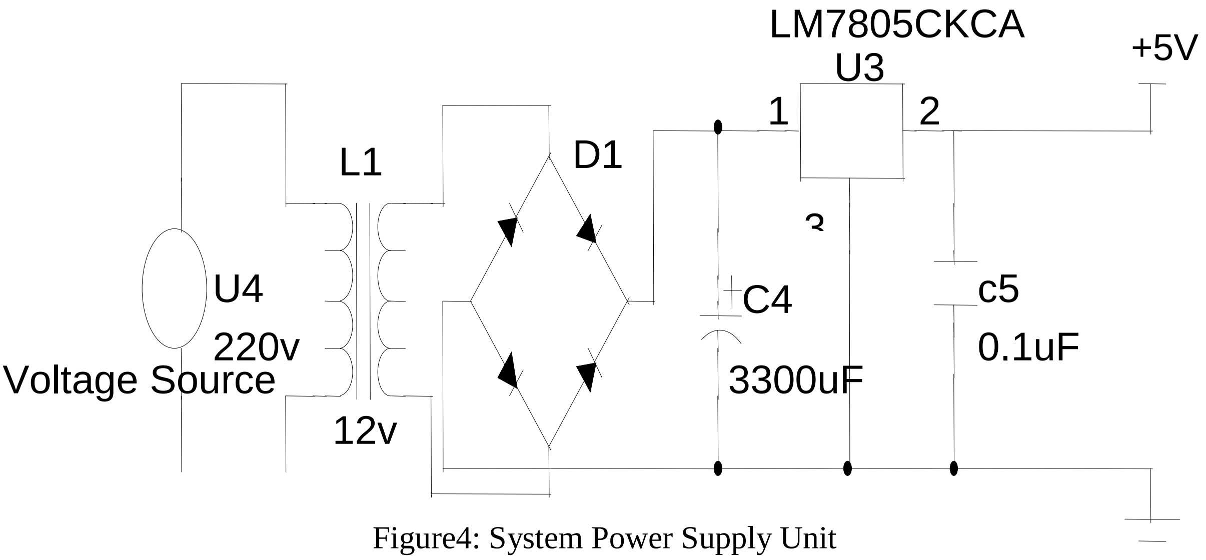

Figure4: System Power Supply Unit

The figure 4 above illustrates two common linear power supply circuits in current use. Both circuits employ full-wave rectification to reduce ripple voltage to capacitor C4. The bridge rectifier circuit, D1 has a simple transformer but current must flow through two diodes. In order to achieve the voltage levels required for the design, the Transformer L1 steps down the 220volt AC and converts it into 12v DC which is passed through a bridge diode for rectification to occur. The voltage is then filtered using the 3300Uf C4 which simply removes ripples.

Voltage Regulator (also called a "regulator") has only three legs and appears to be a comparatively simple device but it is actually a very complex integrated circuit [8]. A regulator converts varying input voltage and produces a constant "regulated" output voltage. Voltage regulators are available in a variety of outputs, typically 5 volts, 9 volts and 12 volts. The last two digits in the name indicate the output voltage.

Symbol for a Voltage Regulator. This device looks like a Transistor, but it is actually a complex Integrated Circuit.

A LM7805 Regulator

Figure 5: 7805 Voltage Regulator

After rectification we have full 12v on the positive end and to obtain the 5v required to drive the microcontroller a voltage regulator (LM7805) is connected to the circuit. This particular type of voltage regulator ensures that only 5v passes through to the other side. Hence, the above power supply design of the system can operate on +5v and +12v as well as 0v level.

Temperature Monitoring Circuit:

The circuit was implemented using LM35, 555 timer and LM358 IC. This circuit provides the physical connection of the temperature-sensing module, which will be connected to the system. This module uses LM35 as the temperature sensor; the sensor gives the equivalent temperature input as a voltage output of about 10mv per degree centigrade. LM358 (operational amplifier) is configured as a non-inverting voltage amplifier, to amplify the output from LM35. Finally the output from LM358 is converted to a digital form using a 555 timer, which is suitable for microcontroller input.

The LM35:

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 ±1/4°C at room temperature and ±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 Ma 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:

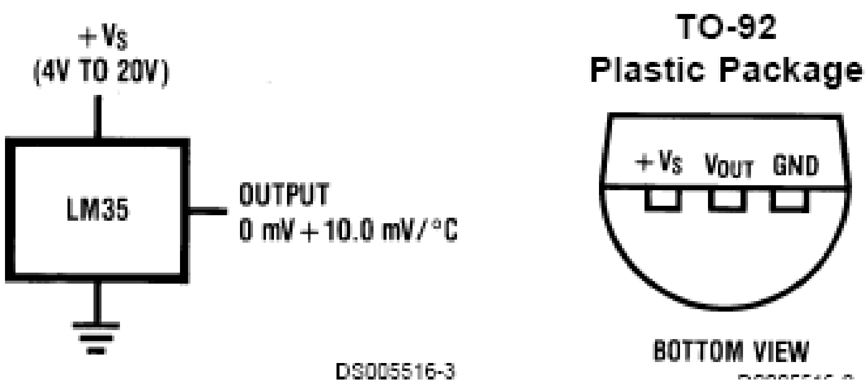

Figure 6: Basic centigrade temperature sensor

- ✓ Calibrated directly in ° Celsius (Centigrade)
- ✓ Linear + 10.0 Mv/°C scale factor
- ✓ 0.5°C accuracy guarantee able (at +25°C)
- ✓ Rated for full −55° to +150°C range
- ✓ Suitable for remote applications

- ✓ Low cost due to wafer-level trimming
- ✓ Operates from 4 to 30 volts
- ✓ Less than 60 Ma current drain
- ✓ Low self-heating, 0.08°C in still air
- ✓ Nonlinearity only ±1/4°C typical
- ✓ Low impedance output, 0.1 W for 1 Ma load

3. System Testing and Integration:

After the design and implementation phase, the system built has to be tested for durability, efficiency, and effectiveness and also ascertain if there is need to modify this design.

Test Plan:

This section entails an overall system testing of the integrated design of the voltage measurement device. The testing and integration is done to ensure that the design is functioning properly as expected thereby enabling one or even intended users for which the research was targeted for, appreciate its implementation and equally approaches used in the design and integration of the various modules of the research.
However, this involves checks made to ensure that all the various units and subsystems function adequately. Also there has to be a good interface existing between the input/output unit subsystems. Hence the test plan for the system testing and integration would be discussed as follows:

- ✓ Testing the Units which make up the full system in Isolation
- ✓ Integration test for the entire system
- ✓ Overall system check to obtain both expected and actual results

Module test is the process of testing each unit that makes up the control system of the Oven temperature controller and display system such as the Microcontroller Unit, Power Supply Unit and the LCD Unit. Testing for the following modules would be discussed on the power supply unit testing only.

Power Supply Unit Testing:

The power supply unit like we know supplies voltages to the entire system depending on the voltage needed by the system. Since the maximum voltage that can be applied or functional with the microcontroller chip is +5V. This power supply unit will consist of an initial step-down transformer rating of (220/240V, 12V) which is then converted to DC voltage, since a typical voltage measurement device works with DC voltages. Now, on powering-up the system after further connections were made on the board, an LED was used in conducting the test. The LED came ON to indicate the flow of current into the system, showing also that the exact voltage supply was applied to the system.

Following the confirmation came a testing with a digital meter of the voltage output at the output of the voltage regulator IC 7805 to regulate the voltage output as specified for the microcontroller. Hence the power supply unit was tested and confirmed OK with regards to voltage measurements for the voltage measurement device design.

Integration Testing:

This involves the interfacing of different modules to test if it would communicate. Integration test is normally carried out to test if modules integrated can achieve a high output performance. In the course of this research, the integration test would be carried out for the display unit output interface of the research design. The integration test was carried out as thus:

Test Data:

When the totality of the modules was integrated together, the system was created and all modules and sections responded to as specified in the design through the power supply delivering into the system designed.

This test was carried out on the voltage measurement device design after the integration test; hence the expected test and actual test was carried out. And it was observed that the expected test result corresponds with the actual test result after the testing.

Table 1: Showing Expected and Actual Result

Circuit Under Test	Test Data	Expected Test Result	Actual Test Result
Ac input voltage	Voltage	220Vac, 12V	210Vac, 11.4V
Regulated Dc voltage	Voltage	5V	4.72V
Clock pulse generator (oscillator circuit).	Frequency	Square wave one shot	As expected.

Performance Evaluation:

From the Table 1, the range between the expected values and actual values can be tolerated. As a result of this the drift in expected value has no critical effect on the system design, since the resultant current range was not exceeded. Also the operational voltage range was not exceeded.

System Packaging:

Taking the dimensions of the printed circuit board to be 24cm by 12cm by 7.2cm packaging was carried out. A wooden box was constructed that would contain the printed circuit board. On the wooden box provision was made for the display interface, a switch for AC to DC voltage selections, LED indicators and a power supply cord from the primary coil wire was stretched outside the box to enable its connection to a power socket that supplies power to the circuit for testing.

Finally, a wooden package was used owing to its advantages over other materials which initially considered because of its; durability, resistance to rust, availability, cheapness and adjustability. With the wooden pack, it allowed for the positioning and easy screwing of various switches and control knobs.

4. Conclusion:

Going through the planning, flow process, design, system testing and integration had really been a tough one; but on the whole it has been a chance to show case a little bit of craftsmanship. This system was fully implemented and the design functioned accurately.

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Appendix A:

System Component Listing:

- ✓ Micro-controller AT89C51
- ✓ 240 – 12Vac Transformer
- ✓ Bridge Rectifier
- ✓ 7805-voltage regulator
- ✓ Capacitor (30pf, 10µf, 3300µf, 0.1µf)
- ✓ Resistor (2.2kΩ, 10kΩ, 4.7kΩ,220Ω, 2kΩ)
- ✓ LM35 (temperature sensor)
- ✓ Push buttons
- ✓ LM358 (Op Amp)
- ✓ NPN Transistor (C945)
- ✓ Light Emitting Diode
- ✓ Liquid Crystal Display
- ✓ Vero board
- ✓ Crystal oscillator (16MHz)
- ✓ Heating element
- ✓ Connecting wires
- ✓ Electric plug
- ✓ Plywood
- ✓ Relay
- ✓ 555 timer
- ✓ IC sockets