DOI: http://dx.doi.org/10.4314/star.v4i4.20
ISSN: 2226-7522 (Print) and 2305-3372 (Online)
Science, Technology and Arts Research Journal
Sci. Technol. Arts Res. J., Oct-Dec 2015, 4(4): 131-137
Journal Homepage: http://www.starjournal.org/

Original Research

Design and Implementation of Microcontroller based Automated Air Conditioning Control System for Refrigerator Truck

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Abstract

In order to transport temperature sensitive agricultural or factory products for the markets which demand high quality products, using special freight transportation like refrigerator truck facilities is mandatory. However, the currently available refrigerator trucks have no dynamically controlled system as expected to be. Therefore, the aim of this paper is to design, simulate and implement microcontroller based air conditioning controller to monitor and control the Refrigerator temperature by using a temperature sensor, LM35 and this sensor monitors the temperature of the refrigerator based on the predefined temperature value under the control of PIC016F877A microcontroller. The system displays the temperature and the status of the heater, compressor and fan as ON or OFF on the LCD. The input temperature in the range of –55 to +150°C is compared with the value stored by the user and if the temperature goes below the predefined point of temperature value, the heater and fan switch will be ON and compressor will be OFF; if temperature goes between predefined temperature value only fan switched ON, and when the predefined temperature value goes above, the fan and compressor only switched ON. A 24V of each three relays are interfaced with the microcontroller in order to make the respective fan, heater and compressor switched ON/OFF. The simulation result is checked for consistence and correctness with the result of physically implemented refrigerator truck controller.

Article Information

Article History:

Received : 25-08-2015

Revised : 10-11-2015

Accepted : 13-11-2015

Keywords:

Microcontroller

Air conditioning

Refrigerator Truck

Sensor

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INTRODUCTION

Air conditioning is the process of changing or modifying the properties of air in the specified area, in this case the refrigerator truck; the ultimate goal in air conditioning is to distribute the temperature to more comfortable conditions, typically with a target of distributing the conditioned air to improve thermal comfort and indoor air quality. Therefore, temperature controlling is a process in which change of temperature of a space or an object or both is detected so that the flow of heat energy into or out of the space is controlled and adjusted to achieve a better and desired temperature (Wikipedia, 2015).

The existing traditional and mostly affordable type of AC controlling system has lots of problem since it is manually manipulated. As a result of this it is prone for error. In addition to this, the measurement is not as such accurate and also the expected output is displayed using analog display system. Beside this almost all the currently existed refrigerator trucks are mostly complemented with cooling system. Therefore, this paper aimed to design, simulate and implement microcontroller based air conditioning controller for refrigerator truck by integrating both the heating and cooling element and come up with ON-OFF type closed loop controlling system which in turn has an impact in the development endeavor.

MATERIALS AND METHODS

Materials

The following hardware and software resources are used in order to design and implement microcontroller-based automated refrigerator truck AC controlling system.

Hardware Requirements

Microcontroller (PIC16F877A): It is the central part of the system that controls the entire system by processing the input and output signals. It continuously receive input temperature signal from the sensor and then process the information and decides based on the predefined set point of temperature condition.

Temperature Sensor: The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature with a gradient of 10mV/°C (Thein Thein Soe *et al*., 2014; Sooxma). This sensor is used to sense the refrigerator inside van temperature condition between -55 ^{o}C and 150 ^{o}C and then transmit to the microcontroller for further

processing (Tassou *et al*., 2006). The circuit connection for LM35 temperature sensor is also given in (Figure 1) (Thein Thein Soe *et al*., 2014).

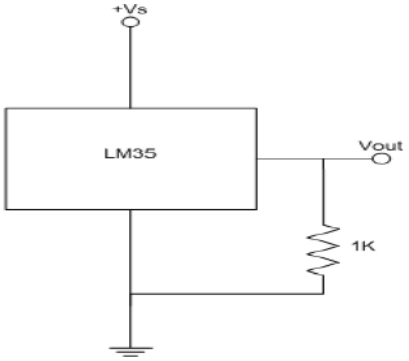

Figure 1: Circuit connection of LM35 sensor

Liquid Crystal Display (LCD): Microcontroller interfaced LCDs are mostly used in many applications. These days, LCD replaced most of the LEDs in system design because of low power consumption and flexible graphics display. This intelligent LCD module can show 160 different characters (Thein Soe *et al*., 2014). It displays every condition of the microcontroller output based on ASCII standard set of characters and mathematical symbols. It is indicated in (Figure 2).

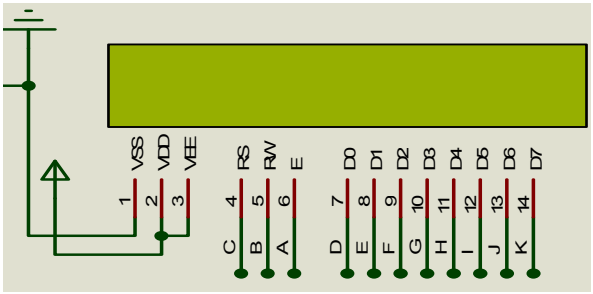

Figure 2: A 16 character x 2 lines LCD pin configuration

DC Power Supply: stable DC voltage is needed for consistent operation for the entire circuit. The microcontroller needs +5DC volt, the three relays each (24DC volt), and other component in the system also need stable DC voltage. As can be shown below a variable regulator can be set to produce +5v and +24v by varying the output in order to obtain the desired DC output (Figure 3).

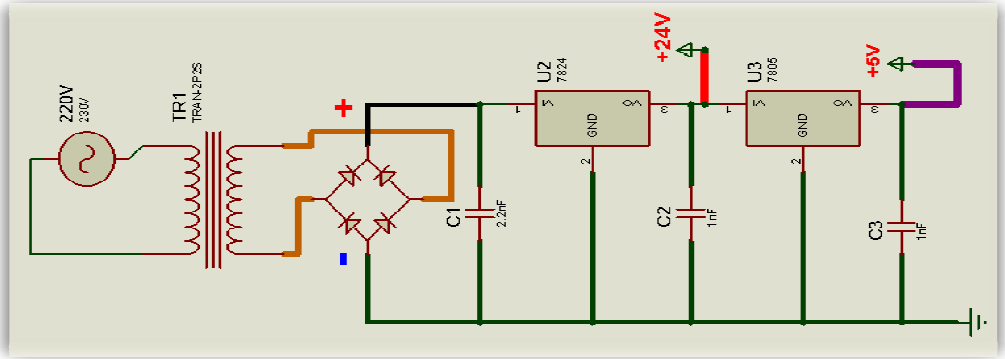

Figure 3: Power supply circuit for truck refrigerator controller

Relay: is an electrical switch that opens and closes under the control of the microcontroller. Permanently the relays gets positive DC volt from the power supply and opposite DC from the microcontroller in order to amplify the respective subsequent refrigerator truck electromechanical system.

Push Button: is used to RESET the system.

Other Components: semiconductor and basic electronics components such as diode, transistor, resistors and capacitors are also used during system design (Amos and James, 1959).

Software Requirement

There are different ways to program PIC16F877A microcontroller either using a highly level programming language like C or using an assembly language. In this project we used the procedural oriented language of (C) to program the microcontroller. The C programming language has a lot of advantage compared to other programming languages: It has many libraries that provide built-in functions and possibilities for user to define arbitrary functions. The compiler optimize the code for faster execution, easy to learn syntax and easily portable. Proteus 8 professional and MPLAB IDE v8.92 are also used.

Methodology

To design, simulate and implement the microcontroller based automatic air conditioning control system for refrigerator truck the following procedures are followed,

Identifying the Requirement

Identifying the Required Hardware

- Microcontroller (PIC16F877A), Resistor (10kΩ), Diode (normal p-n and LED), DC power supply (5V, 12V, and 24V), Switch, Transistor, Relay (24V), LCD (LM016L), Temperature Sensor (LM35), and capacitors (1nf x4, 2.2nf) are used

Identifying the required Software

- C-Programming language to program the microcontroller
- Proteus 8 professional for circuit designing and simulation
- MPLAB IDE v8.92 for code development environment

Designing and System Modeling

- In this step the system flow diagram is developed to design and integrate each component to form the required system and C code is written to run the entire system.

Simulating the System

- Integrating the circuit design with the C-program code.
- Based on each component specification interfacing with the microcontroller and then loading the program on proteus and on microcontroller.

Testing the System

- After loading the code on the Proteus and integration of the circuit design with the code the system was tested for its correctness and performance.

Physical Implementation and Experimentation

- After simulation and simulation testing, all components are tested for proper functionality and then soldered together to get system circuit.

Testing the Physical Implementation

- In this step, injecting the code to the microcontroller was performed and then testing was conducted to confirm the simulation result by physically implemented system.

System Design and Simulation

The system design basically consists of microcontroller as a central processor of the entire control operation. The temperature sensor gives the analog output voltage based on the temperature of the refrigerator truck room. This analog voltage is feed to the ADC (built-in inside the microcontroller). The ADC then converts the analog input voltage from the temperature sensor into equivalent binary bits. The converted binary data from the ADC is applied to microcontroller and then the microcontroller reads binary data from ADC. Finally, the microcontroller converts it to suitable form and performs different operations based on the value of temperature read from ADC. The LCD is used to display the data given by microcontroller. Microcontroller can turn on the relay(s) based on the condition defined during initialization (set value). The system functional diagram for refrigerator truck controller is given in (Figure 4).

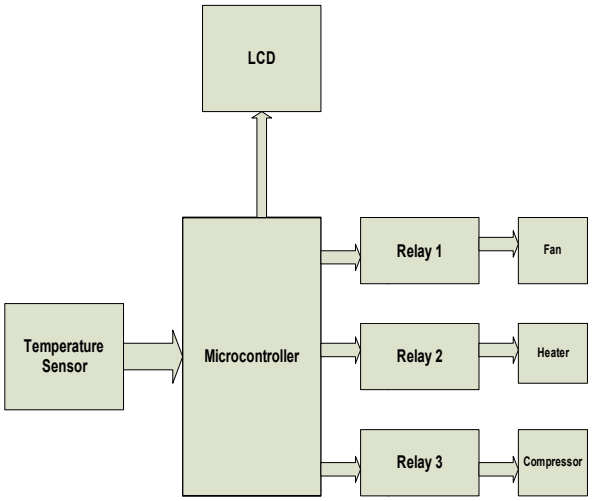

Figure 4: Functional block diagram for refrigerator truck controller

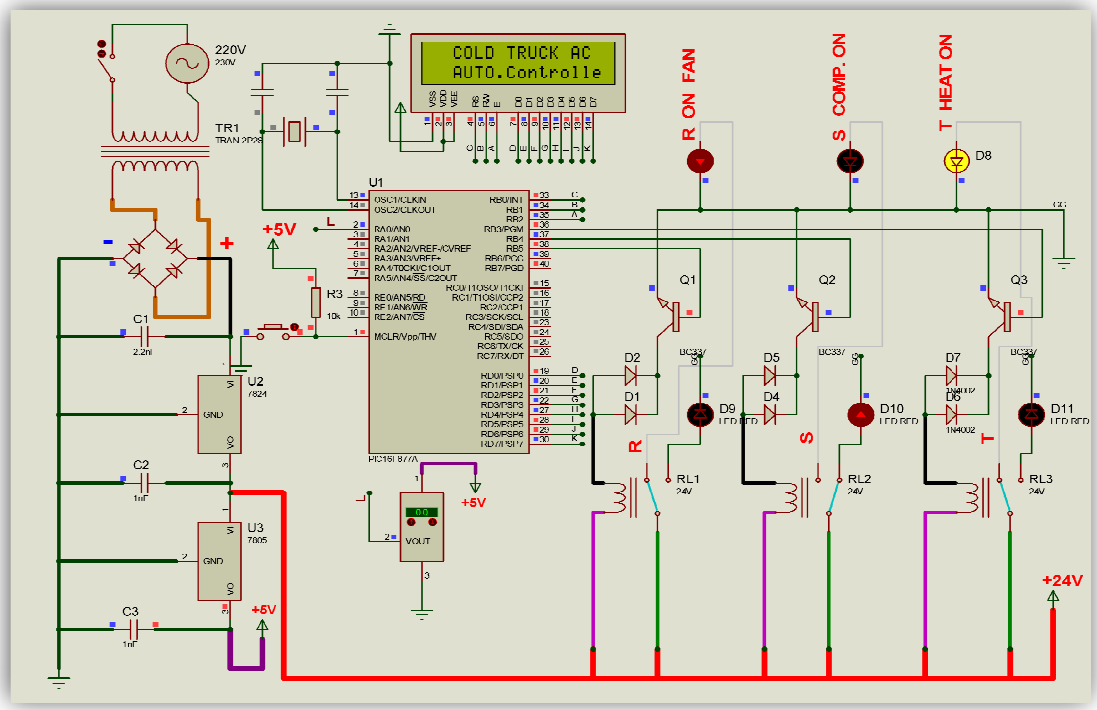

Figure 5: Circuit Diagram for truck refrigerator controller result after RESET

The PIC16F877A microcontroller receives information signal through LM35 sensor from external environment (level of temperature). The sensor checks the environment in every five seconds. The microcontroller processes the digital signal and then transmits command to the respective relays based on the conditions

predefined set value. If the checked set point of temperature is below 2°C, the microcontroller commands relay one and relay three turned ON- to make the fan and heater switched ON respectively; and relay two switched OFF- to make the compressor turned OFF. If the checked temperature is between 2°C and 6°C, the microcontroller directs relay two and three switched OFF (compressor and heater) and relay one switched ON. If the temperature condition is greater or equal to 6°C, the microcontroller commands relay one (fan) and relay two (compressor) switched ON and relay three (heater) switched OFF. Relay one (fan) always switched ON to make the air diffused or balanced throughout the van of cold truck. Whether each respective relays functions or not, that is enables the fan, compressor, and heaters switched ON is observed through the LEDs which are connected to the fun, compressor, and heater. Also if each respective LED's are switched ON, the respective relays are function properly, and the push button is used to RESET and the system starts again.

System Flow Diagram

The following flow chart illustrates the flow of operations of the overall automatic AC controller system for refrigerator truck. A C-programming code is employed to run the entire system.

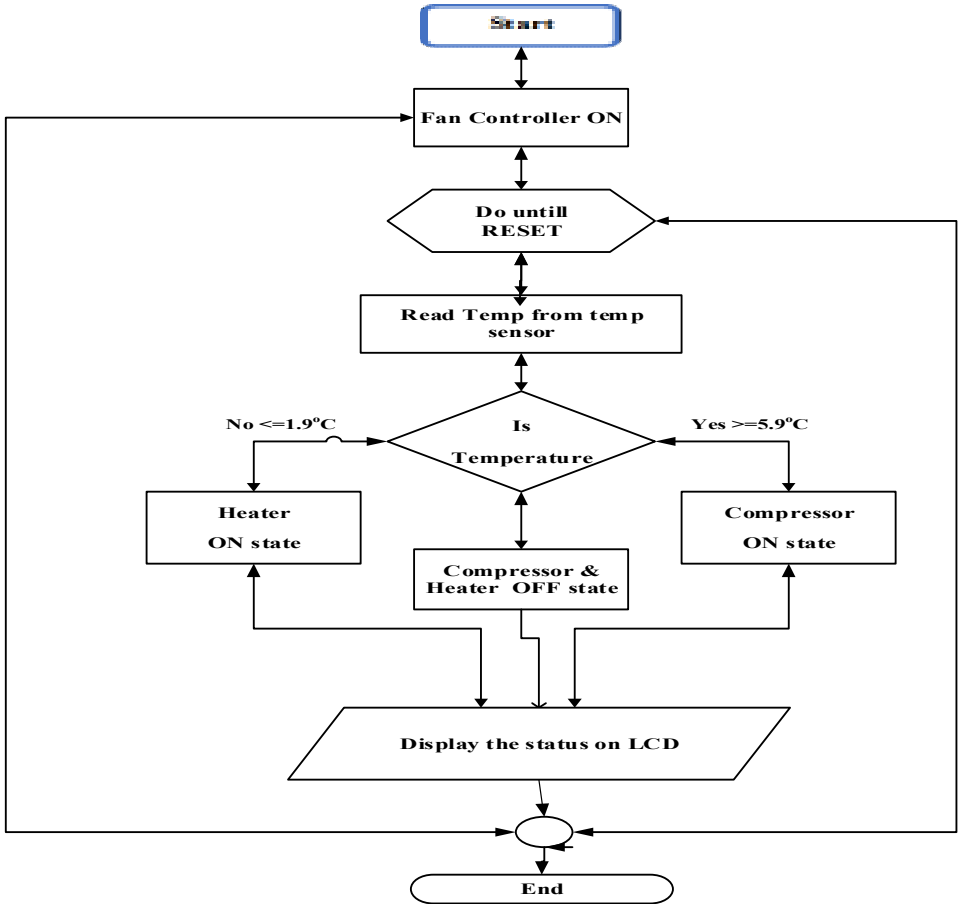

Figure 6: System flow diagram for refrigerator truck controller

RESULT AND DISCUSSION

The sensor, LM35, checks the environment in every five seconds to collect information from the external environment so that microcontroller uses this information for generating commands to send to relays depending on the predefined conditions. Whether each respective relays connected to fan, compressor, and heaters are properly functioning or not are controlled through the LEDs which are connected to the fan, compressor, and heater. That means, if each respective LED's are switched ON, the respective relays are working properly. The simulation of the system is performed based on the following conditions,

Condition 1: If the sensor finds temperature below 1.9°c, the microcontroller commands relay one and relay three to be turned ON so that the fan and heater switch ON; and relay two switch OFF so as to make the compressor will turn OFF.

Below in (Figure 7), the sensor reads truck temperature of (T°c = 0.8) as displayed in LCD. As the result, the microcontroller commands the respective relays to turn ON so as to ON the fan and heater as indicated on the LCD and the respective LEDs (the red and yellow) has also switched ON.

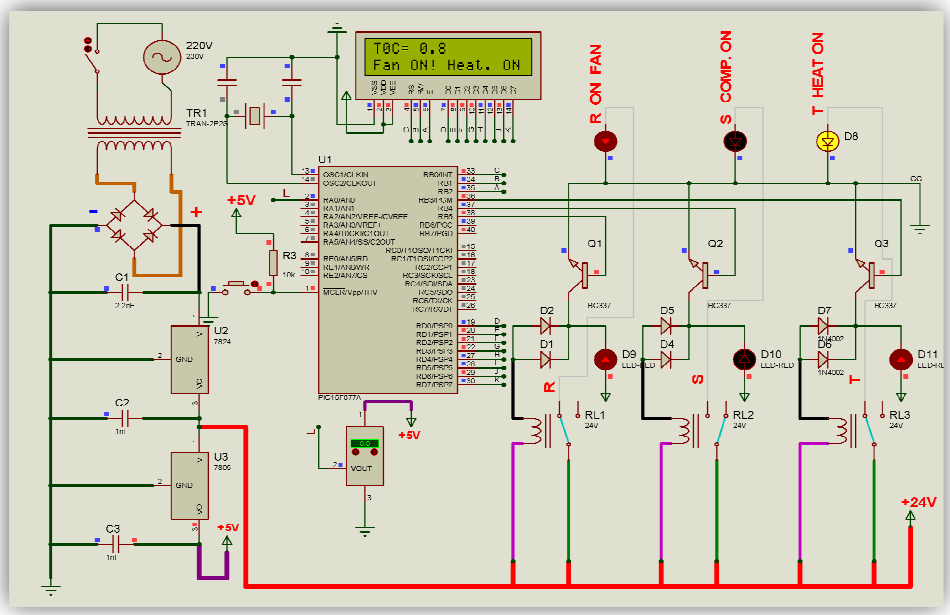

Figure 7: Refrigerator Truck Controller result when temperature is below 1.9° C

Condition 2: If the sensor senses a temperature between 2 and 5.9 °C, the microcontroller directs relay two and three to be switched OFF (compressor and heater) and relay one switched ON.

The sensor finds a temperature of 2.30°C as displayed on the LCD and microcontroller commands the fan to be turned ON (red LED) and the other two LEDs are to be switched OFF state (compressor and heater). This is shown below in (Figure 8).

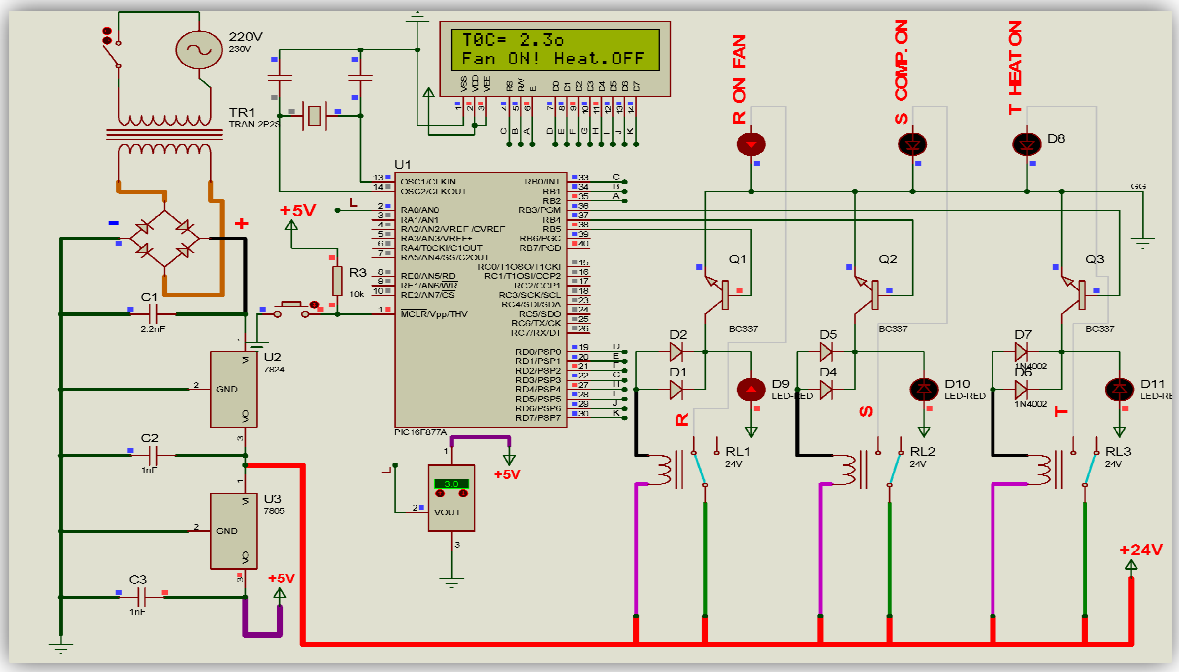

Figure 8: Refrigerator truck controller result when temperature is between 2°C and 5.9°C

Condition 3: If the sensor reads a temperature greater or equal to 6 °C, the microcontroller commands relay one (fan) and relay two (compressor) to be switched ON and relay three (heater) to be switched OFF. Relay one (fan) always switched ON to make the air diffused or balanced throughout the van of cold truck.

If the sensor reads a truck temperature of 6.5°C as displayed on the LCD, the microcontroller commands the fan and compressor to be turned ON (red and yellow LED) and this is depicted in figure 9.

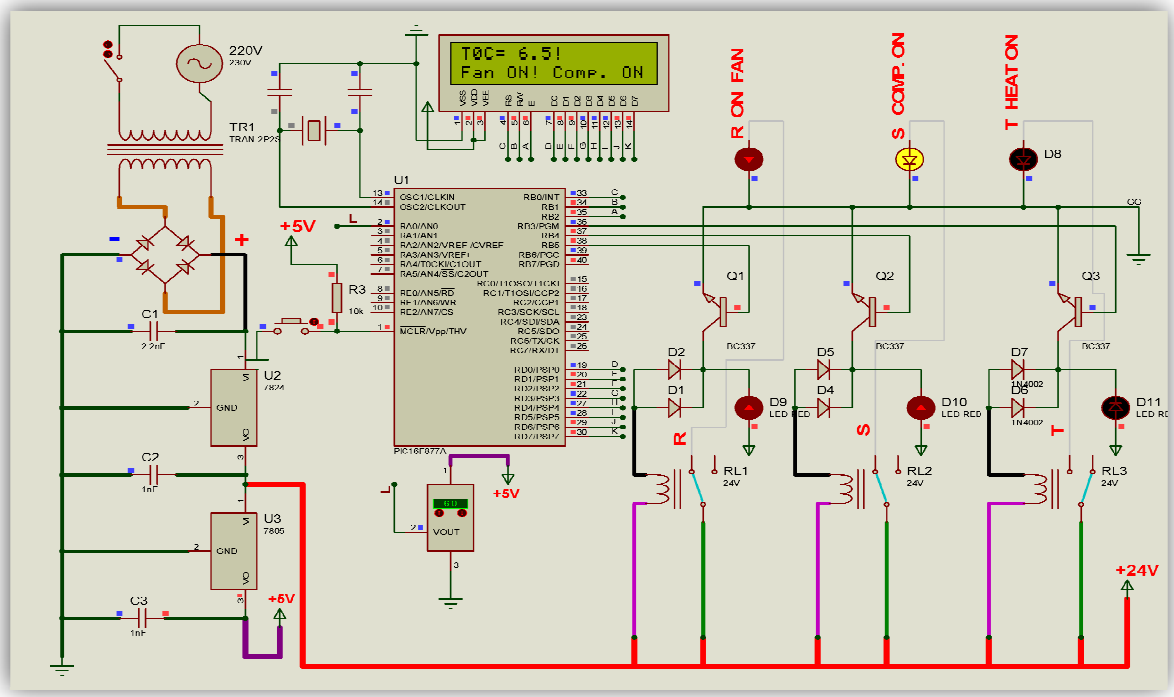

Figure 9: Refrigerator truck controller result when temperature is above 6°C

Condition 4: Reset Condition, when the refrigerator truck reaches its target destination, the entire system will be rested through re-setted button so that the system starts again. That means, the microcontroller command the LCD to display the readiness of the system with the default temperature (T °C = 0.00) and the status of fan and heater to be on the ON state as it is indicated in figure 10.

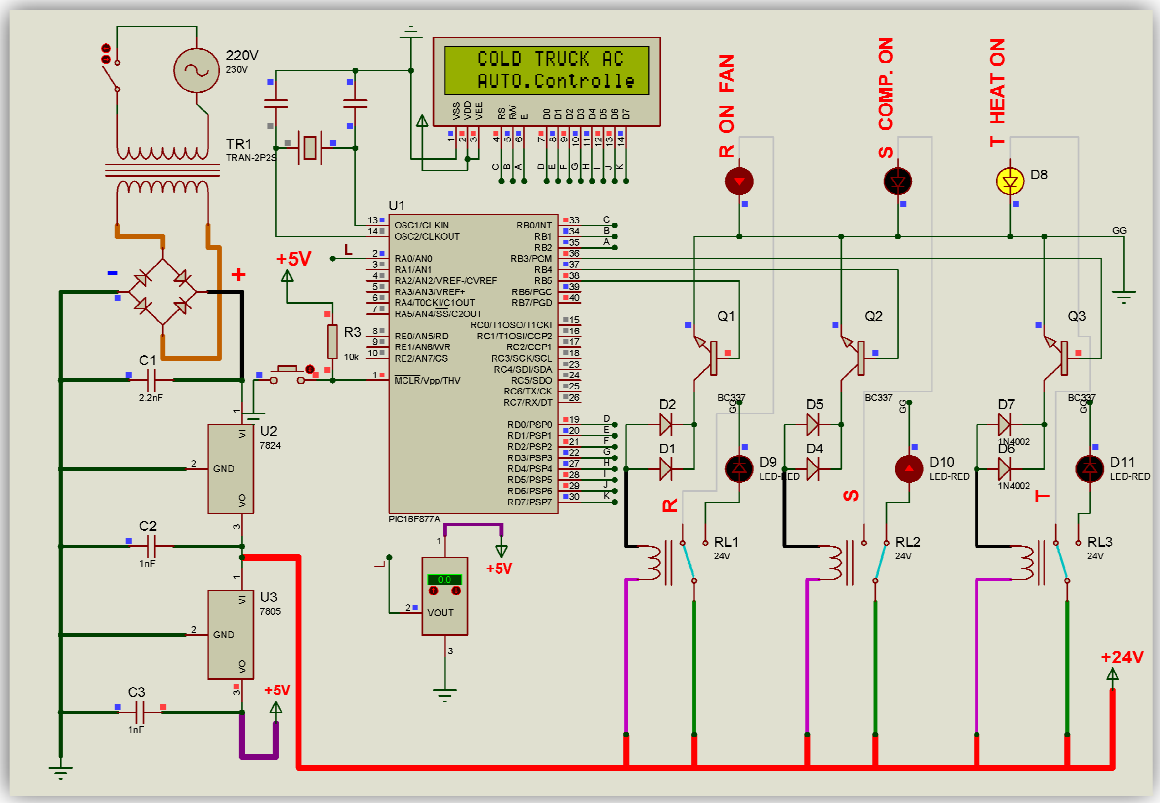

Figure 10: Refrigerator truck controller result after RESET

Physical Implementation

Once the simulation results are justified for its proper operation of the system, the physical implementation of the system is performed as indicated in Figure 11. After soldering each component based on the circuit design, the resulting automated digital control board as it's shown in figure below, the microcontroller is interfaced with the LCD and the relays through diodes and then transistors and also with external crystal oscillator, DC voltage source, and analog temperature sensor to get the desired output.

The PIC16F877A microcontroller accepts external signal as an input +5V DC, 16MHz Clock frequency through pin OSC1 (CLKIN) and analog temperature through port-A (RA0/AN0) in order to produce output signal through port B and D, i.e., the LCD is connected to the PIC pin RB0 –RB2 and RD0 – RD7; the three transistors are also connected to the PIC via pin RB3 – RB5.

The status of each condition is then displayed through the LCD based on ASCII standard. On the other hand, the output of the microcontroller which directs the respective fan, compressor, and heater in order to regulate the van air condition of the truck. This output is checked in our digital board by assigning three LEDs for each respective fan, compressor, and heater. The digital controlling board has also reserved socket (Plug) to connect with the refrigerator truck's electrical and mechanical controlling units, i.e., fan, compressor, and heater controlling boards.

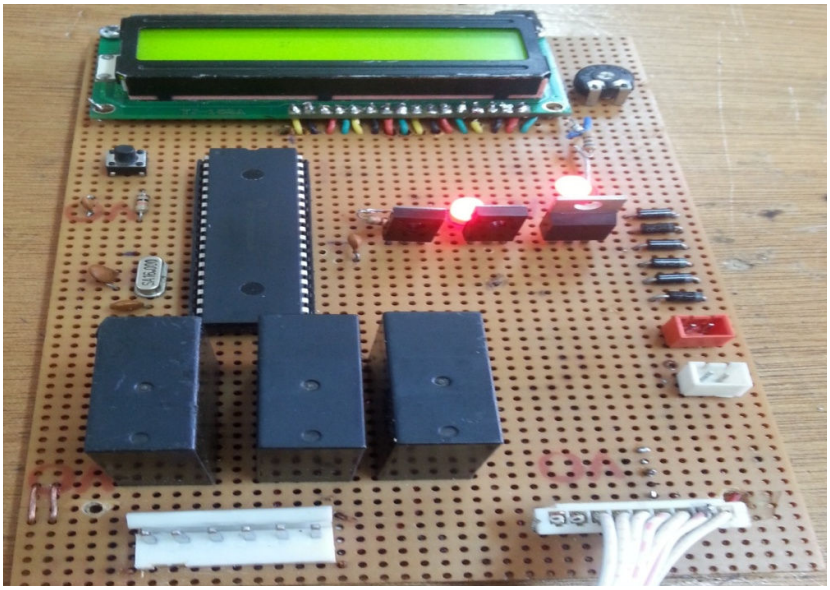

Figure 11: Physical implementation of the system

CONCLUSIONS

Refrigerator truck has an aluminum shielded van which is used to transport easily perishable and temperature sensitive materials from place to place. In order to make the temperature balanced and stable, most of the refrigerator trucks, starting from their invention till present have mainly cooling related controlling mechanism.

By using easily affordable electronics components PIC16F877A chip, LCD, relays, transistors, capacitors, resistors, diodes, and power supply and suitable programming code written in C programming language; an automated digital controller for refrigerator truck is designed, simulated and implemented. The controller controls the air condition of the truck's van by processing the three states predefined using temperature range, i.e., below 2 ^{o}C, between 2 and 6 ^{o}C and above 6 ^{o}C and then directs the respective fan, heater and compressor to turn ON/OFF. In this project the simulation result is confirmed with the physical implementation result for its correctness. However, this digital controlling system is properly working and useful when implemented as it is; it might also be possible to manage remotely by using remote sensing, communication and other relevant technologies.

Conflict of Interest

Authors declared no conflict of interest.

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