International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)
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A LOW COST THERMOELECTRIC REFRIGERATOR

A.Manikandan[1],V.Nirmala[2]
[1,2]Assistant Professor/ECE
M.Kumarasamy College of Engineering, Karur
[1]mani85a@gmail.com,[2] nirmalaece@gmail.com

Abstract
We are proposed to design and construct thermoelectric refrigerator. The thermo electric cooler was equipped with on/off control .One liter of water was placed inside the cooler to test the performance of the device. We have tested the maximum performance of the device by cooling a sample down to 4 degrees Celsius. Temperature control was also tested by cooling one liter of water from room temperature down to 8 degrees Celsius.

Keywords: Thermoelectric, Microcontroller, LM35

1. Introduction

Now a day's everyone would need a refrigerator. In many cases, people cannot afford a regular-size refrigerator. Especially students staying in a hostel can neither afford it nor would like to carry such a big appliance along with them when they leave. Also, these refrigerators consume power to the tune of 500W, which is not allowed in most hostels. Presented here is a thermoelectric refrigerator that can be built with easily available off-the-shelf components for approximately 1200. The refrigerator consumes only around 60W of power. There is also a control system in the refrigerator that monitors and controls the temperature. The overall size is small, so it can be kept quite comfortably in a small hostel room.Thermo Electric Modules (TEMs) are effectively heat pumps that transfer heat from one side of the module to the other when a current is applied. This phenomenon is called the Peltier effect. The goal of this project is to utilize this phenomenon to build a temperature controlled environment free of vibration and meet all the project requirements.

2. Design Requirements

(i) Utilize Peltier effect to refrigerate and maintain a specified temperature

(ii) Use See beck effect to convert Temperature into Electricity

(iii) Perform temperature control in the range 5 to 25 degrees Celsius.

(iv) Maintain temperature accuracy within ± 0.2 C°

(v) Low Noise and Vibration Levels

2.1 Seebeck Effect: The Seebeck effect is the conversion of temperature differences directly into electricityin fig 1. It is named after German physicist Thomas Johann See beck in 1821 he discovered that a compass needle would be deflected by a closed loop formed by two metals joined in two places, with a temperature difference between the junctions. This was because the metals responded differently to the temperature difference, creating a current loop and a magnetic field.

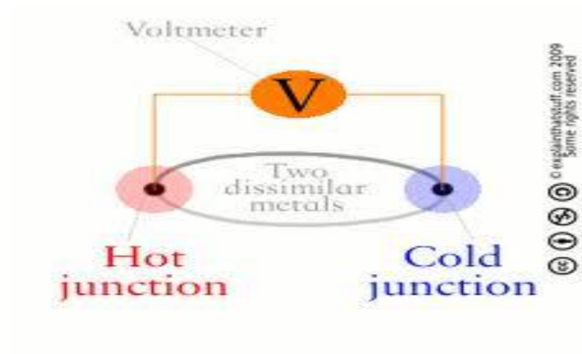

Fig.1 Seebeck Effect

2.2 Peltier Effect: Thermoelectric cooling, is a solid-state method of heat transfer through dissimilar semiconductor materials**.** It is also called "the Peltier Effect" after the French watchmaker who discovered the phenomenon in the early 19th century. Like their conventional refrigeration counterparts, thermoelectric cooling systems obey the basic laws of thermodynamics. However, the actual system for cooling is different.

In a conventional refrigeration system, the main working parts are the evaporator, condenser, and compressor. The evaporator surface is where the liquid refrigerant boils, changes to vapor, and absorbs heat energy. The compressor circulates the refrigerant and applies enough pressure to increase the temperature of the refrigerant above ambient level. The condenser helps discharge the absorbed heat into surrounding room air. The three main working parts in a thermoelectric refrigeration system are a cold junction, a heat sink, and a DC power source**.** Two dissimilar conductors replace the refrigerant in both liquid and vapor form.

The cold sink (evaporator surface) becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another, instead of energy absorption by the refrigerant as it changes from liquid to vapor.The DC powersource pumps the electrons from one semiconductor to another, and the heat sink (condenser) discharges the accumulated heat energy from the system.

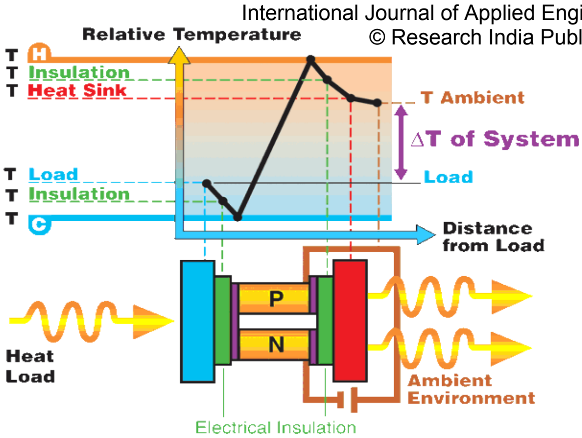

Fig. 2 Peltier Effect

3 Hardware Components:

3.1 Thermoelectric Module: Actual cooling is done by thermoelectric module TEC1-12706. It works on the principle of Seebeck effect: when current is passed through two dissimilar metal junctions, one junction gets heated while the other junction cools down. The module is 40×40×3.6mm insize. Although it operates over 4V-16V, recommended operating voltage is12V. Depending on temperature of hot side, TEC1-12706 is capable of transferring 50-60W of heat. Outer construction of this module is ceramic and the metal junctions are inside along two surfaces.

Fig.3 Thermo electric Module

3.2 ATMEGA85: It has 8 Kb of Flash program memory (10,000 Write/Erase cycles durability), 512 Bytes of EEPROM (100,000 Write/Erase Cycles). 1Kbyte Internal SRAM 23 I/ line can be obtained from three ports; namely Port B, Port C and Port D.Two External Interrupt source, located at port D. 19 different interrupt vectors supporting 19 events generated by internal peripherals. Three Internal Timers are available, two 8 bit, one 16 bit, offering various operating modes and supporting internal or external clocking.

3.3 LM35: The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^{o}C).You can measure temperature more accurately than a using a thermistor. The sensor circuitry is sealed and not subject to oxidation, etc.The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

4 Circuit Diagram

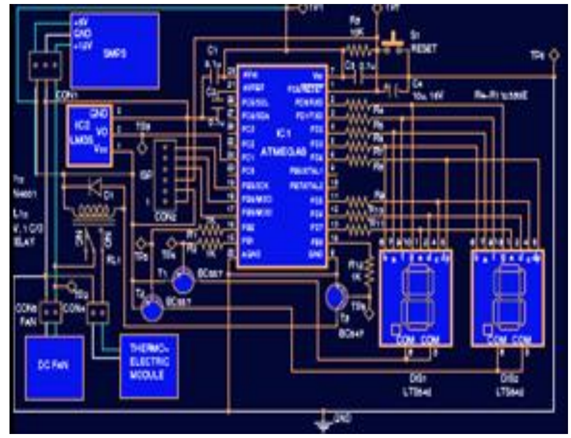

Fig 4. Circuit Diaram

Fig. 4 shows the circuit diagram of the thermoelectric refrigerator. The circuit is built around microcontroller ATmega8 (IC1), temperature sensor LM35 (IC2), thermoelectric module TEC1-12706 (connected at CON4), desktop computer's SMPS (connected at CON1), DC fan (connected at CON3), 7-segment displays (DIS1 and DIS2) and relay (RL1). The complete circuit is powered by desktop computer's SMPS. 12V and 5V outputs from the SMPS are connected at CON1. 5V supply is used to power microcontroller IC1 and rest of the circuit, while 12V is used for the DC fan and thermoelectric module.

Actual cooling is done by thermoelectric module TEC1-12706. It works on the principle of Seebeck effect: when current is passed through two dissimilar metal junctions, one junction gets heated while the other junction cools down. The module is 40×40×3.6mm in size. Although it operates over 4V-16V, recommended operating voltage is 12V. Depending on temperature of hot side, TEC1-12706 is capable of transferring 50-60W of heat. Outer construction of this module is ceramic and the metal j u n c t i o n s are inside along two s u r f a c e As shown in Fig. 4, the side on which model number is printed is the hot side and the other one is cold side. Polarity of voltage is very important; red wire should be connected to 12V and black to ground. If the polarity is reversed, hot and cold sides get reversed as well. Heat produced on the hot side must be dissipated, otherwise the module will heat up beyond limit. We can make use of any heat-sink such as the one used for CPU in a computer. Temperature of hot side has direct effect on how much heat the module can suck from the cold side. Here we have mounted the DC fan over the heat-sink to dissipate heat more efficiently.

Today, there are already a few systems that have some promise for portable use, but they cannot handle product labeling. For example, portable bar code readers designed to help blind peo-ple identify different products in an extensive product database can enable users who are blind to access information about these products through speech and braille. But a big limitation is that it is very hard for blind users to find the position of the bar code and to correctly point the bar code reader at the bar code.

Some reading-assistive systems such as pen scanners might be employed in these and similar situations. Such sys-tems integrate OCR software to offer the function of scanning and recognition of text and some have integrated voice output. However, these systems are generally designed for and perform best with document images with simple backgrounds, standard fonts, a small range of font sizes, and well-organized characters rather than commercial product boxes with multiple decorative patterns. Most state-of-the-art OCR software cannot directly handle scene images with complex backgrounds.

Mobile accurately reads black print on a white background, but has problems recognizing colored text or text on a colored background. It cannot read text with complex backgrounds, text printed on cylinders with warped or incomplete images (such as soup cans or medicine bottles). Furthermore, these systems require a blind user to manually localize areas of interest and text regions on the objects in most cases.

Although a number of reading assistants have been designed specifically for the visually impaired, to our knowledge, no exist-ing reading assistant can read text from the kinds of challenging patterns and backgrounds found on many everyday commercial products. As shown in Fig. 1, such text information can appear in multiple scales, fonts, colors, and orientations. To assist blind persons to read text from these kinds of hand-held objects, we have conceived of a camera-based assistive text reading frame-work to track the object of interest within the camera view and extract print text information from the object. Our proposed algorithm can effectively handle complex background and mul-tiple patterns, and extract text information from both hand-held objects and nearby signage, as shown in Fig. 2.

In assistive reading systems for blind persons, it is very challenging for users to position the object of interest within the center of the camera's view. As of now, there are still no acceptable solutions.

Microcontroller: ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture with throughputs approaching 1MIPS per megahertz. ATmega8 comes with the 8 kilobytes of in-system programmable Flash, 512 bytes of EEPROM, 1 kilobyte of SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, three flexible timers/counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented two-wire serial interface, a 6-channel ADC (eight channels in TQFP and QFN/MLF packages) with 10-bit accuracy, a programmable watchdog timer with internal oscillator and an SPI serial port. microcontroller IC1 runs at a clock frequency of 8MHz using an internalsucks heat from the water inside the refrigerator box and keeps cooling it down. The temperature of water is sensed through temperature sensor IC2 which is interfaced to the microcontroller's ADC pin 24. When the temperature reaches 9°C or above, relay RL1 gets energized and switches on the thermoelectric module. When the temperature reaches 5°C or below, the relay is reenergized and the thermoelectric module is switched off. Port pins PD0 through PD7 of IC1 reconnected to pins g, f, a, b, dp, c, d and e of 7-segment displays, DIS1 and DIS2. Port pins PB1 and PB2 of IC1 drive the base of transistors T1 and T2 for switching on 7-segment displays, DIS1 and DIS2, respectively. The 7-segment displays show the temperature sensed by IC2.

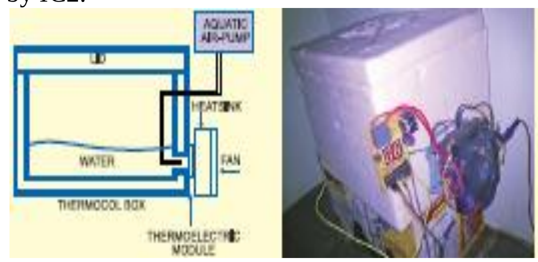

Fig.5 Model of Refrigerator

Software: The software program is written in 'C' programming language and compiled using AVR Studio. The program is burnt in the microcontroller using a suitable programmer.

Construction and testing: An actual-size, single-side PCB for the thermoelectric refrigerator circuit is shown in Fig. 4 and its component layout in Fig. 5. Assemble the circuit on the PCB to minimise any assemblyerrors. Use IC base for microcontrollerIC1. Once the PCB is assembled, power it on with the SMPS as shown in Fig.2. The DC fan should immediately start rotating. Check the voltage levels at various test points as shown in test point table to ensure the circuit is working as required.

Mechanical construction: The mechanical construction is the most critical part of this project. The overall body of the refrigerator is a thermocol box as shown in Fig. 1. This type of box is easily available in the market. Water is used as a coolant because it holds temperature for longer time than air can. An opening is created near the bottom of the box on one side which should be a little bigger in dimensionthan the thermoelectric module. An aluminium sheet is mounted over the opening from outside as shown in Fig. 6. Ensure that the sheet is firmly fixed and there is no leakage. Use a silicone sealant or an adhesive to firmly fix the thermoelectric module over the aluminium sheet. The adhesive should not come between the sheet and the module. Now we need to mount a heat-sink over the thermoelectric module to dissipate heat from the hot side. Way of mounting the heat-sink will depend on the type of heat-sink you could obtain. In our case, we used a spare CPU heat-sink which already had a nicebase clip as shown in Fig. 7. The base clip was screwed and glued to the box. Then, the heat-sink was fitted on the base clip with its holding assembly.

We also had the fan attached to the heat-sink. The refrigerator should be kept in a well-ventilated place enablingthe fan to blow good amount of air on the heat-sink. Let the adhesive dry properly. For silicone, it takes about 40-50 minutes. Pour in a small amount of water inside the box and see if there is any leakage. In case of leakage, try putting more silicone to fill in the voids. Water level should be equal to the height of opening, so that maximum water comes into contact with the cold side of TEC module. Water is a good conductor of heat only when it is in liquid form. Once it turns into ice, it will indeed block transfer of the heat. As said above, cold side can go well below 0°C and water near the opening will turn into ice in an hour or two.

Once that happens, remaining water in the box will not get any colder. Hence we have to stop formation of ice near the opening. Simple way of doing it is by using an aquatic air-pump. Pipe coming out from the air-pump is inserted in a box through a small hole at the top. The opening of the pipe from where the air blows out is facing the cold side of thermoelectric module as shown in Fig.1. In this way, air bubbles do not let ice to form at the opening. Effectively, it creates a motion or water current and helps all of the water to reach the same temperature. As there is water at the bottom, overall humidity inside the box goes high. Hence food items such as vegetables should be preferably stored in airtight containers or bags, as excessive moisture can ruin them. At least once a week, you should unplug the refrigerator and change water inside the box after cleaning it thoroughly.

CONCLUSION

Thermoelectric refrigerators are greatly needed, particularly for developing countries, where long life, low maintenance and clean environment are needed. In this aspect thermoelectrics cannot be challenged in spite of the fact that it has some disadvantages like low coefficient of performance and high cost. These contentious issues are the frontal factors hampering the large scale commercialization of thermoelectric cooling devices.The solution to above problems can only be resolved with the development of new techniques. There is a lot of scope for developing materials specefically suited for TE cooling purpose and these can greatly improve the C.O.P. of these devices. Development of new methods to improve efficiency catering to changes in the basic design of the thermoelectric set up like better heat transfer, miniaturization etc. can give very effective enhancement in the overall performance of thermoelectric refrigerators. Finally, there is a general need for more studies that combine several techniques, exploiting the best of each and using these practically.

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