BME11
The Second TSME International Conference on Mechanical Engineering
19-21 October, 2011, Krabi

Vaccine Storage Temperature Monitoring and Alert System

Thawan Sucharitakul and Nitipat Phantkankam

Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University,
Chiang Mai, Thailand 50200
Corresponding Author: Tel: 053 944 146, Fax: 053 944 145,
E-mail: pnitipat@hotmail.com

Abstract

This paper describes the development of a low cost vaccine storage temperature monitoring and alert system. The system has to be cheap and can alert assigned personnel in the case of power failure or malfunctions especially during the off-hours. The first prototype of the vaccine storage temperature monitoring and alert system was built from off-the-shelf components to prove that the system concept can work successfully. The prototype consists of a digital thermostat for a sensor which is connected to a microcontroller board that sends a short telephone massage to responsible personnel via a general packet radio service (GPRS) module when the storage temperature is out of safe range. The system is powered by an uninterruptible power supply (UPS) and plugged in to the power grid. The first prototype is too expensive for remote hospitals (12,000 Thai Baht or 400 US dollar) but proves that the concept can work. The final system uses high-precision digital thermometer integrated circuit (Dallas Semiconductor DS18S20) as the temperature probe and then weather proofed with plastic tubing and acetic silicone sealant. The probe is read by an 8-bit microcontroller that can use wide tolerance power supply (Atmel AT89LP4052) and the microcontroller is used to drive four small relays (Fujitsu FTR-C1CA003G-01) through darlington drivers (Toshiba ULN2803AP-G). The relay contacts are then wired directly to the keyboard contact of a low cost cellular telephone (Nokia 1208). The power supply of the whole system is a telephone battery plugged in to a wall charger. The system can send a SMS to a telephone when the storage temperature is getting out of safe range, when the power grid fails or when the temperature probe did not response to the controller read command. The firmware for the controller is written in assembly language for compactness and is 1,047 byte long. In this configuration, the user needs to store the destination phone number and the massage in the telephone before operation. The system cost including assembly is 2,500 Thai Baht or less than 100 US dollar. With appropriate sensors and firmware programs, this type of system can be used to monitor many kinds of mechanical systems or processes at a very low cost.

Key words: Vaccines, Temperature, Microcontroller, Cellular Telephone

1. Introduction

Vaccines used in rural hospitals in Thailand are stored in domestic type refrigerators equipped with uncalibrated thermostats which are purchased from the lowest bidder. These refrigerators operate in the ambient temperature as low as 10 ^{o}C at night and as high as 38 ^{o}C in the afternoon and are plugged in to the power grid that is not always reliable. While these refrigerators can keep food reasonably fresh for household consumption, it is difficult to assure that the stored vaccine can be maintained between the recommended 2 to 8 ^{o}C to retain its full potency when it is administered to local children [1]. Unfortunately, there is no cheap and easy way to identify compromised vaccine and continuous monitoring system is needed.

2. System Requirement

While purpose-built refrigerator designed specifically for vaccine storage is available commercially, the cost of acquiring one is beyond the budget scope of local hospitals. A low cost system is needed to continuously monitor the stored vaccine temperature and alert assigned personnel in the case of power failure, storage temperature going out of recommended storage range, or malfunctions especially during the off-hours. The desired method of sending the alert is via cellular telephone short message service (SMS) because the massage can reach the assign person's phone almost immediately or as soon as the phone is in the network coverage in case the person has been out of coverage range.

3. System Description

The vaccine temperature monitoring and alert system is composed of a low-cost cellular telephone connected to a microcontroller system via the keyboard using small signal relays. The microcontroller is then connected to a digital temperature probe to continuously monitor the vaccine temperature and send out an SMS via the telephone when the temperature is out of the recommended storage range. The contact of a relay with 220 volt alternating current coil is also connected to the controller to signal the power outage condition. The whole system is powered by the telephone battery connected to a charger.

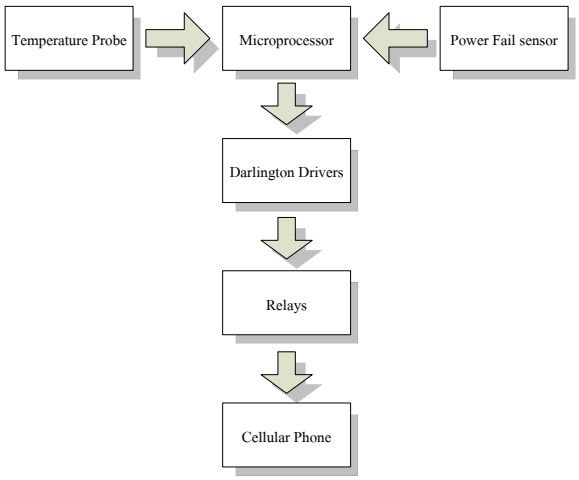

Fig1. System Block Diagram

4. Temperature Probe

The temperature probe is built around a Dallas Semiconductor DS18S20 high-precision digital thermometer in the TO-92 package [2]. This device is selected because the output is digital which provide good noise immunity, requires only 3 wires for connection (power, signal, and ground), can operate with wide range of power supply, can inform the controller in case of device failure, have $\pm$0.5^{o}C accuracy

between -10°C and +85°C, and available in easy to water proof package. The sensor is assembled in to a waterproof probe by first soldering it to a 3 conductor 28 AWG insulated flat cable approximately 2 meters long. This type of cable is only 0.9 mm thick and can fit between the refrigerator door and the refrigerator body without causing major leakage of cooled air. The sensor terminals are insulated with heat shrink tubing, placed inside a 30 mm section of plastic drinking straw and then sealed with general purpose silicone sealant.

5. Microprocessor

The microprocessor used in this system has to operate using the phone battery and low power consumption and compactness is the first priority. Atmel AT89LP4052 is chosen for this application [3]. The microprocessor only requires external parts such as a crystal oscillator and three small capacitors to operate. 4 kilobytes of flash memory is available to store the operating program and only 256 byte of random access memory is available with this microprocessor. With such limited resources, the control program is written in assembly language for compactness [4].

6. Cellular Phone Modifications

To keep the cost low, a Nokia 1208 cellular phone is chosen. The phone can be purchased in Thailand complete with battery and a charger for less than 30 US dollar. After some experimenting, it was found that once the outgoing massage and phone number are stored in the phone memory, the SMS can be sent to the stored number using only four keys on the telephone. Once the phone is disassembled, it was found that a pair of conductors on the keyboard printed circuit board can be short circuited to simulate the key operation. Ten conductors cable is needed to wire the four keys as well as the battery power from the phone.

7. Phone Interface

To enable the microprocessor to send an SMS from the phone, the controller drives four small signal relays (Fujitsu FTR-C1CA003G-01) through a set of darlington drivers with integral surpression diodes (SGS-Thomson Microelectronics ULN2803AP).

8. AC Power Sensor

The grid power failure is something not out of ordinary in the remote areas of Thailand. When power fails, it is necessary to pack the vaccine box with ice to keep it safe until power is restored. A relay with 220 volt alternating current coil is used as the power failure sensor. The coil is wired directly to the power outlet and the relay contact is wired to one of the port pins of the microprocessor so the controller can sense power failure and send an appropriate massage to the responsible person.

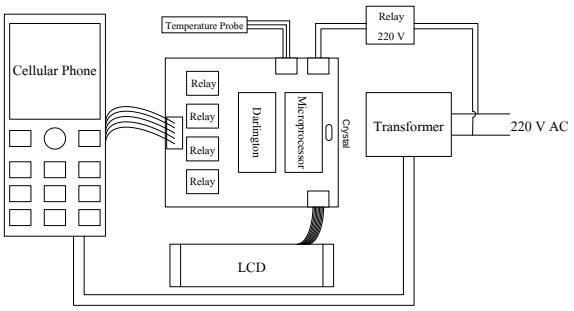

Fig2. Assembly

9. Alert Massages

A SMS massage is sent from the system when the vaccine temperature is getting too high (7.5°C or more) or too low (2.5°C or less), the power fails, or when the probe do not response to read command from the microprocessor [5].

10. Encountered Problems

When the cellular phone has received a SMS, the key sequence to send an SMS from the phone no longer operates properly. All SMS can be barred from the number being used by calling the cellular phone company and the problem was solved.

11. Conclusion

The system cost including assembly is 2,500 Thai Baht or less than 100 US dollar. Calibrations of temperature probe after assembly is not required because the probe communicates with the system using digital lines and there is no signal attenuation during transmission. The probe accuracy is guaranteed by the manufacturer that the sensing error will be no greater than 0.5 degree Celsius [2]. With appropriate sensors and firmware programs, this type of system can be used to monitor many kinds of mechanical systems or processes at a very low cost.

12. Acknowledgement

We would like to sincerely thank Dr.Wipat Sariddeechikool the director of Chiang Dao Hospital for bringing this project to our attention and test the system in the real world environment. We are also grateful for financial and prototype development support provided by the Consulting Center for Machine Design and Development for SMEs (C2MD2) of the Faculty of Engineering, Chiang Mai University, Thailand.

13. References

[1] Australian Government Department of Health and Aging, National Vaccine Storage Guidelines Strive for 5, Commonwealth of Australia 2005.

[2] WWW.maxim-ic.com, DS18S20 High-Precision 1-Wire Digital Thermometer.

[3] WWW.atmel.com

[4] Intel Cooperation, 8-Bit Embeded Controller Handbook, Intel Cooperation 1989.

[5] WWW.maxim-ic.com, Application Note 162 Interfacing the DS18x20/DS1822 1-Wire Temperature Sensor in a Micro-controller Environment.