EMBEDDED TEMPERATURE AND VOLTAGE MONITORING SYSTEM

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Abstract

Applications that involve the use of a videoscope have grown dramatically during the past decade and now encompass a wide range of industries. In some cases, videoscopes are used for inspection and/or observation in confined spaces where the human eye cannot reach. Such systems are capable of recording either live video or capturing still pictures. Most employ either a complementary metal-oxide-semiconductor or charge-couple device image sensor located directly on the tip of an insertion tube along with a light source for illumination. A typical probe ranges in diameter from 5 mm to 10 mm and can operate over a cable up to 50 ft in length.

This paper discusses the design and implementation of a low-cost embedded voltage and temperature monitoring system for use in an inspection videoscope. The purpose of the temperature sensor is to help ensure a safe operating temperature range and warn of potential image sensor damage. In addition, battery voltage is monitored to alert an operator when it drops below a preset threshold. Low battery and high temperature alerts were implemented using sensors coupled to a microcontroller with outputs fed to a liquid crystal display. Light emitting diode and audible alarms were included to complement the display.

Introduction

This paper describes the design and implementation of an embedded temperature control and battery level monitoring system for a videoscope. The design is based on a low-cost microcontroller with high random access memory (RAM) and program memory for software. The system remotely senses and monitors battery and temperature conditions at the insertion tube tip and continuously displays the current levels on a liquid crystal display (LCD). In addition, audible and visual alarms are triggered at temperature readings of 150° F and 180° F and battery levels of 11V and 10V. The software permits the threshold values to be changed and allows the user to modify the temperature scale between Celsius and Fahrenheit.

Background

A typical inspection videoscope cable ranges from 5 mm to 10 mm in diameter and in lengths of up to 50 ft. Several integral features include: insertion probe section, articulated tip, articulation controls (up, down, left, and right), lighting bundle, high intensity external light source, and a cable interface the video outputs to a console containing a liquid crystal display (LCD). An external media recording device such as computer hard disk or compact flash card can capture either live video or still pictures.

Videoscopes are often used for inspection and/or observation in confined spaces where the human eye cannot reach. In addition, a charge-coupled device (CCD) image sensor is located...
directly in the tip of the insertion tube along with a light source to illuminate the inspection area for a wide range of applications. The CCD chip enables the system to convert images into electrical signals to later be processed and displayed on a monitor. A video image is relayed from the distal tip and focusable lens assembly back to the display via internal wiring.

During the past decade, advances in videoscope technology have made an enormous leap in the optical portion of the system. Videoscopes deliver higher resolution images than a fiberscope and are now comparable to that of a high-end video camcorder. Figure 1 shows a picture of a typical videoscope console and inspection cable with an articulating control.

Figure 2 shows a picture of the circuit board located inside the tube tip enclosure. The video CCD is located at the forward end and positioned at the focal point of a lens (not shown). To maintain a small size, the electronics consists of a few components necessary for the CCD chip and a current driver that ensures the analog video output arrives at the console with an acceptable signal-to-noise ratio.
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Potential Improvements
An example videoscope application is to inspect an internal combustion engine while it is still hot. However, the temperature inside the engine may damage the imaging sensor and electronics at the end of the insertion tube. Current videoscopes do not measure the ambient temperature to determine if a safe working environment is present; therefore, there is a need for this feature if it can be provided at a sufficiently low cost. In addition, external electrical power is not always available in the field. In such cases, the operator must keep track of time to ensure that all of the images are captured before battery power runs out. A battery monitoring feature could keep the operator informed of the remaining battery life, allowing the operator to better “time manage” the task at hand and prioritize the inspection process. In this project, a breadboard temperature and voltage monitoring system suitable for use in a videoscope was designed and built.

System Design
The overall design contains three main elements: (1) temperature sensor to be located in the tube tip, (2) microcontroller located in the console and (3) operator display/alerting devices. The primary constraints are:

- +12 VDC power source
- Temperature response of <100ms
- Operating range: 0°F to 180°F
- Maximum tube tip diameter: 0.6mm
- Insertion cable length up to 15m
- Selectable temperature scale: Celsius (C) and Fahrenheit (F)

The system is designed using a low-cost microcontroller (µC) responsible for all incoming data from the temperature sensor and the battery source. The analog data is then processed by an...
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Integrated analog-to-digital converter (ADC) in the µC and gets translated to a numeric format by means of software pre-loaded on the µC memory. The µC then outputs the actual temperature and battery level for display on a small LCD. Depending on the data obtained, the µC verifies that the current battery and temperature values have not reached or exceeded the thresholds (150° F, 180° F and 11V, 10V, respectively). If either reaches a preset threshold, the µC will execute an alarm command and display warning signs on the LCD. In addition, an audible alarm generates a beeping sound. The frequency of the sound is changed if the second threshold is reached. Yellow and red LEDs are also turned on to indicate the warning level. A single pole double throw (SPDT) switch is included to select between Celsius and Fahrenheit temperature scales.

Temperature Sensing
The Maxim MAX6612 is a low-power precision analog output temperature sensor and its tiny 5-pin SC70 package makes it ideal for this application [2]. It has a high output voltage to temperature sensitivity and provides good noise immunity. The output voltage varies linearly with the die temperature at a slope of 19mV/°C, and there is a 400mV offset at 0°C for measurement below zero.

Microcontroller
A PIC-18F4680 microcontroller was selected as the brains of the system [3]. It is low cost, comes with free software development tools, and has serial programming capability with flash memory. The primary function of the PIC is to process the analog signals from the MAX6612 and the battery via two 8-bit analog-to-digital converters. A software routine continuously monitors both results to determine if a preset threshold has been reached or exceeded. If not, the current temperature and battery level are displayed on the LCD. If so, a series of visual and audible alarms are triggered.

Liquid Crystal Display
A 16 character by 2 line LCD is used to display the real time battery voltage and temperature within the tube tip [4]. The LCD comes with a built in driver and controller (Hitachi HD4470) which simplifies the interface to the microcontroller.

Microcontroller Software
A C-compiler provided by Custom Computer Services (CCS), Inc. was used on the project [5]. It is simple, user friendly, and supports a wide range of PIC microcontrollers. It contains over 300 built-in functions and produces efficient and highly optimized code. An ICD-U40 was used for targeting the microcontroller flash memory and comes with a plug-and-play universal serial bus (USB) for connection to a personal computer [6].

The program developed for this project consists of four sections: headers, main routine, LCD driver, and a command file that contains critical system operations such as temperature, voltage,
print, and warning commands. Each section is represented in a “#include < (file name)>” statement in the headers file, commonly used for forward declarations of classes, subroutines, variables, and other identifiers.

The main routine is where execution begins and operates at a high level the functionality compared to other parts of the program. After the user sets the SPDT switch for the desired temperature scale, the appropriate calculation be it Fahrenheit or Celsius is enabled. At this point a “while(TRUE)” statement creates a loop that never stops unless an interrupt occurs or power is lost. The program loop reads the analog inputs and makes the appropriate temperature calculation. During each loop, checks for thresholds and execution of alarm commands occur.

**Temperature and Voltage Reads**
This portion of the program takes the analog input from the temperature sensor and digitized it into an 8-bit number. The digital value is then processed by the temperature sensor transfer function. The voltage command takes the analog input from the battery which ranges from 0V-12V. Since the maximum voltage input is 5V, a voltage divider is used to convert the range to 0V-5V after which the program computes a digital output that represents the current battery voltage.

**Print and LCD Commands**
The print command helps determine what is displayed on the LCD. During normal system operation, current temperature and voltage are displayed on the first and second rows, respectively. Warning commands are executed if any of the thresholds are met or exceeded. These commands deliver three types of warnings to the user. First, a text message appears on the LCD warning the user of the condition. Second, a visual alarm is activated by turning ON and OFF an LED. The color of the LED changes from yellow to red as the alarm becomes more severe. Third, a buzzer is sounded in case the user does not notice LCD or LED indicators. The LCD driver uses synchronous serial data to load a serial-in/parallel-out shift register with the data bits and reset information.

**Prototype Results**
Two fabrications of the system were performed during the project. First, a breadboard was constructed to validate operation. Afterwards, a printed circuit layout was done on Orcad and a board were fabricated using CircuitCam Board Master and a ProtoMat S100 [7]. Both sides of the board were used for traces, but all components were mounted on one side. The trace width was set to 20mils except where the +5V and +12V supplies connect where it was 40mils. The boards outside dimensions were 3.135” (W) x 3.097” (H) and 30mils in thickness. The assembled and functional system is shown in Fig. 3 indicating normal operation for both temperature and battery voltage.
The prototype was tested to confirm that it would react to four alarm conditions involving one or more of the following actions: warning message displayed, red/yellow LED turned on or off and/or a buzzer activated. The LCD messages alternate between warning messages and current readings. The LED and buzzer have a built-in time delay so the user could distinguish between a mild and severe alarm set to 500ms and 200ms, respectively. When each of the following operating conditions was presented, the appropriate display and/or warning events were occurred:

- Temperature < 150° F → Normal
- 150° F ≤ Temperature < 180° F → Mild Alarm
- Temperature ≥ 180° F → Severe Alarm
- Battery Level > 11V → Normal
- 11V ≥ Battery Level > 10V → Mild Alarm
- Battery Level ≤ 10V → Severe Alarm

**Conclusion**

Integrating a battery and temperature monitoring system was successfully demonstrated in this project. These features would add value to current inspection videoscopes by allowing an operator to better manage battery life and also prevent probe overexposure to high temperatures. The PIC18F4680 microcontroller and the Maxim MAX6612 temperature sensor turned out to be
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good choices for the design. Both were inexpensive, easy to use and provided the necessary accuracy. Future work might include a preventive shut-down routine such as a 20-second countdown display. Also, the 16x2 LCD could be replaced by displaying the same information on the main console screen where the CCD images are shown.

References