RF Based Reservoir Heat Logging and Monitoring Using Matlab and Microcontroller

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Abstract – This research was developed to produce a prototype product of a RF based temperature monitoring system that allows that user to continuously monitor the temperature condition of a room. The enhancement from the existing system on the temperature monitoring that is proto type system allowed the data to be monitored anytime and anywhere from the internet .using an address based monitoring and control and it also logger the output.it can easy to see the output in graphical representation using MAT lab.

Index Terms – Temperature sensors, microcontrollers, PC monitor, Transducers, MAT lab coding.

1. INTRODUCTION

Efforts to understand and model environmental variables require data sets that track both temporal and spatial changes. Networks of recording instruments or instruments connected to commercially available data loggers can gather these data (e.g., Silliman and Booth, 1993), but the cost of such networks is typically several thousands to tens of thousands of dollars and may require the development of software to interface between the data logger and a host computer (e.g., Mukaro and Carelse, 1997). The high cost of these networks together with the risks of vandalism and theft associated with their deployment in remote locations prohibit their general use, even in studies that could clearly benefit from them. This note describes an inexpensive, easy-to-build, microprocessor-based, data logger system that is currently being adapted to a number of field applications (Dedrick, 1998). The low cost of this system coupled with the increasing availability and decreasing cost of a wide variety of compatible sensors should enable more researchers and educators to systematically gather temporal and spatial data without the necessity of a large budget.

Our system is based upon Microchip's PIC 16C73A microcontroller, and: (2) digitizes and records an analog voltage from a sensor at programmable sample periods of a few seconds to many hours, (3) stores over 4000 digital data values, (4) logs data for a number of weeks or more with a power supply of 4 AA alkaline batteries, (5) is readily adaptable for use with a variety of sensors, and (6) is inexpensive. Individual data loggers cost less than $20 per unit to build and can be assembled in less than an hour on a printed circuit board. In this note we describe the system, identify its unique qualities and provide an example of its use as a recording thermometer.

2. OVERVIEW OF THE DATA LOGGER SYSTEM

Our data logging system is composed of two separate units, a "logger" and a "reader" which work with a host computer (Fig. 1). The logger is 3 x 13 cm circuit board with an 8-bit microcontroller chip (PIC 16C73A, Microchip Technology, Inc.), a non-volatile serial EEPROM memory chip (24LC32A, Microchip Technology, Inc.), and supporting components (Fig. 2). Power is supplied by 4 AA or 4 C batteries. The logger converts an analog voltage signal from an external sensor into a digital value, and stores the digital value in the logger's EEPROM memory at user-supplied sample periods. The "reader" is a separate 5 x 7.5 cm circuit board with an identical microcontroller, a RS-232 transceiver interface chip (MAX232A, Microchip Technology), and supporting components (Fig. 3). Power is supplied by a 9 V battery regulated to 5 V (7805A regulator). The reader enables communication between the logger and a "host" PC-compatible computer using one cable to the logger and another cable to the RS-232 serial port of the host computer. The host computer runs a Windows-based program written by the authors that, through commands sent to the reader and relayed to the logger's memory chip, initializes the logger at the beginning of data collection and retrieves data once sampling is completed. Typically, a logger is connected to the reader for initialization, then disconnected from the reader, connected to the sensor and deployed in the field for data collection, and finally reconnected to the reader to download and store the data on the host computer.

Operation of the system depends upon coordinated software running on the host computer, reader and logger. The flow chart in Figure 4 shows how the software of the host, reader and logger function (vertical columns), as well as how all three programs are linked by software "handshakes" (links between columns). Ultimately, digitized sensor data are saved on the host computer as a character-delimited ("^"), ASCII text file. The sensor data in this file are uncalibrated numbers ranging between 0 and 255, reflecting the 8-bit resolution of the microcontroller's on-board analog to digital converter. This file also includes user-supplied comments about the deployment (e.g., field location), sensor and logger information (e.g., serial numbers), start time, start date, sample period, memory state, and sample times. This text file is readily imported into a spreadsheet for analysis. For example, most applications will require that the file's digital sensor data be converted to standardized units (temperature, stage height, pressure, etc.) by application of a calibration function. An example data file appears in Appendix 1.

3. FEATURES AND ADVANTAGES OF THE SYSTEM

Several aspects of the system deserve special note, particularly the use of the PIC 16C73A microcontroller, the use of the serial EEPROM chip for data storage, the separate reader and logger, the low cost of the system, the software design of the data download and initialization functions, and the adaptability of the logger to many different sensor types.

The PIC 16C73A, 8-bit, microcontroller (Microchip Technology, Inc) is well suited for an inexpensive data logger. It has a built-in analog-to-digital converter, hardware and software support for serial communication and EEPROM data storage, an internal programmable timer that can operate in the background but produce time-out interrupts, and very low power consumption. Our system uses two identical microcontrollers, one in the reader, another in the logger. The reader's microcontroller operates at a clock speed of 4 MHz to support 2400-baud serial communication with the host computer. By contrast, the logger's microcontroller operates at a slower clock speed of 32.768 kHz to simplify its timing functions and reduce its power consumption. We have measured the operating current of the logger to be less than 2 mA. Assuming a 4 AA alkaline battery pack and battery capacities of 2140 mAh (Glover, 1989), this provides a theoretical 44 day operating supply (currently, 15 days is our maximum field trial duration). Sample periods are user selected during initialization, and implemented by two internal, cascaded 8-bit counters that provide sample periods of 8 seconds to any multiple of 8 seconds up to approximately 6 days (8 seconds x 28 x 28). The PIC microcontroller costs less than $10, and is available from many different suppliers.

The use of a separate reader and logger is not necessary, but advantageous for several reasons. Segregating host communications functions into the reader: (1) reduces the number of components and complexity of the logger thus reducing the cost of each logger, (2) allows the logger to operate at the lower, power-saving clock frequency discussed above, (3) allows a single reader to service many loggers, significantly reducing the total cost in the typical situation where a project requires multiple measurement sites (many loggers). Excluding the housing, parts for the logger cost under $20, and for the reader cost under $35.

A serial EEPROM chip serves as the logger memory (24LC32A, Microchip Technology, Inc.). It is a low-cost and low-power storage solution designed to interface with the PIC microcontroller. This 4K EEPROM has 4096 memory locations, each capable of storing an 8-bit integer, i.e., a digital value from 0 to 255. More importantly, it provides non-volatile storage for the data logger. Even if the power source for the logger is removed for extended periods of time, the data remains in the EEPROM and can be retrieved. This chip requires only a "2-wire" interface with the microcontroller, a serial data line (SDA) and a serial clock line (SCL), which greatly simplifies the remaining circuitry and so the cost of the system. It also makes it possible for the reader and the logger to access the EEPROM independently so that when the logger is attached to the reader, the reader is storing and retrieving information directly to or from the logger's EEPROM, rather than relaying the data through the logger microcontroller. This simplifies the logger circuitry and the associated software.

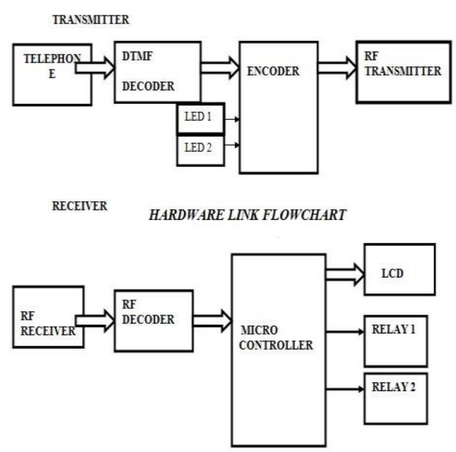

Figure1: Logger Circuit

Our software design combines data transfer and initialization functions so that the host computer always transfers data from the logger before initialization is permitted. This contrasts with the operation of generic data loggers in which data transfer and initialization may be separated. The operation of a generic data logger typically has three stages: initializing the logger with date and sampling information, deployment of the logger and an attached sensor [7], and retrieval of the logger and transfer of the data to the host computer. In our system, combined download and initialization functions reduce the risk of reinitializing a logger before the data from a previous deployment has been transferred. Thus the operation of our system has two stages: transfer of data followed by the option to reinitialize the logger for a new deployment.

Our system is adaptable to a wide and increasing array of sensors. To date, we have tested it with temperature, pressure and light intensity sensors, and details of the temperature application are described below. Virtually any sensor that produces an analog voltage signal from ground (Vss) to the positive supply (Vpp) can be connected to the logger. In our case, the approximate range is from 0 to 6 volts. The microcontroller's on-board analog-to-digital converter produces an 8-bit digital value equal to the ratio between the analog signal and a voltage reference (minimum reference voltage is 3 volts). Thus the system can provide a theoretical resolution of approximately 0.5% (1/256) of the reference voltage. Experiments with three different loggers tested at 25°C and 3°C over periods of two or three days indicate that the time-of-sample errors are less than 12 seconds per day.

To maximize sensor battery life, the microcontroller also provides a sensor "control line" logic output. In the temperature sensor design described below, this output is connected to a solid state relay (Aromot AVQ 210E) that toggles power on and off to the sensor. When the control line output is high (+Vss), power is connected to the sensor so it can warm up, stabilize, and then provide output to the logger microcontroller; when the control line is low (ground), power is disconnected from the sensor. Between samples, all PIC microcontroller connections to the logger are high-impedance inputs that are unaffected by voltage changes in the sensor circuit. An optional sensor LED illuminates when the control line is on.

The very low-cost of individual loggers allow our system to be adapted to situations that might require multiple input channels or data capacities of more than 4000 samples (4K) per deployment. Where multiple channels are required, one simply uses more loggers. At less than $20 per logger, this is a cost-effective solution. When more than 4000 samples are required during a deployment, one simply uses two or more loggers. This involves using multiple loggers with the same sample period but staggered start times to independently sample and record sensor output. Each logger records data from its own sensor for the full deployment period; the time- staggered data from each logger are then standardized (based on individual logger/sensor calibration curves), combined and sorted by time within any spreadsheet to produce a single data set with the desired temporal resolution. Again the low cost of individual loggers makes this option cost effective. An additional benefit of multiple loggers is full data coverage over the deployment period even if one logger or sensor malfunctions (though at an increased sample interval).

Though our system has many advantages, its effective use requires additional care and work on the part of the user. First, though the system will work with a wide-array of sensors, users must pay careful attention to the output of these sensors. The microcontroller's on-board analog-to-digital converter produces a number between 0 and 255 that is proportional to the ratio of the analog sensor voltage to a voltage reference. However, the minimum voltage reference is 3.0 V and the maximum is approximately 6 V. Sensors that produce voltages outside this range, or sensors that only produce a narrow range of voltages like pH and conductivity electrodes within this range (for example, 4.0 to 4.1 V) must be "conditioned" for use with the system. Coupling this type of sensor to the logger would require an amplifier circuit to boost the output of the sensor into the 0 to 5 V range. Furthermore, the user must establish a calibration between the analog-to-digital converter's digital values and the desired reference units (degree Celsius, pound per square inch, etc.). The calibration directly affects the accuracy and resolution of the final data. The user must also be concerned with changes in calibrations over the range in environmental conditions (temperature, pressure, humidity, etc.) that the sensor/logger may experience. Finally, users must be cautious about measuring rapidly fluctuating signals. The microcontroller's analog-to-digital converter takes an "instantaneous" sample of sensor output presumed to constant over a period of at least several milliseconds. Rapidly fluctuating signals may require an "averaging" or "peak hold" circuit to make reliable measurements appropriate to a particular investigation. Discussion of signal conditioning circuits appropriate to particular sensors and applications is beyond the scope of this short note. An accessible introduction to sensor, analog-to-digital conversion and signal conditioning is Carr, 1997.

4. RECORDING THERMOMETER APPLICATION

Figure 2 shows a schematic for a temperature sensor that can be connected to the data logger system to create a recording thermometer. In this example, the sensing element is a thermistor used in series with a fixed resistor to create a voltage divider. The resultant voltage output varies with temperature, and Figure 6 shows the calibrated output of our test run. The sensor circuit is powered by a separate 9 V battery regulated by a 7805A voltage regulator to provide a constant 5 V power supply. A regulated supply eliminates voltage drift that could result from decreasing battery output over the deployment period. Pin one of the solid state relay is connected to the sensor's "control line." This configuration switches current flow on and off through the sensing circuit. The sensor and circuitry as shown cost under $10 to construct.

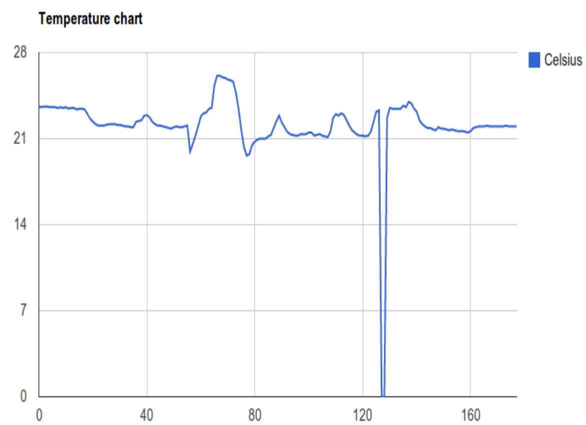

Figure 2: Temperature Sensor Chart

The sensor was deployed between the inner and storm window of our lab for approximately five days in the fall to monitor daily cycles in air temperature (Fig. 6). The daily cycle in temperature detected by the data logger is temporally consistent with observed daily and longer- term changes in outside air temperature over the deployment period. The plot also reveals higher resolution fluctuations that are probably related to the heating cycle of the room and periods of more direct sunlight through the window.

5. CONCLUSIONS

The data logger system is an inexpensive and simple solution to the collection of temporal and spatial field data for numerous research and educational endeavors. It can be integrated with a large array of available sensors. The schematics, circuit board layouts, parts list, suppliers, PIC and host software, and other associated items will be published on a Web site so that any educator or researcher could download sufficient information to construct her/his own data logger. In addition to the recording thermometer example described here, this Web site will also contain information on use of the logger as a pressure-based recording stream gauge. We welcome any and all suggestions.

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