



## Design and Development of a Temperature Monitoring System Based on PIC Microcontroller and 1- Wire Communication Protocol

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**Abstract** Temperature monitoring and control are important in many control applications, for instance, industrial domains such as process heat, automotive, industrial places, storage or office buildings. This paper presents a temperature monitoring system based on 1-wire protocol communication and PIC microcontroller. The hardware implementation of the proposed temperature monitoring system uses the digital temperature sensor DS18B20, which has a unique 64-bit serial code identifier that allows multiple DS18B20s to function on the same 1-Wire bus. Therefore, one PIC microcontroller can be used to control many DS18B20s distributed over a large area. The experimental results show that the proposed system is performed well as expected.

**Key words:** Temperature monitoring, 1-wire protocol, DS18B20, PIC microcontroller

### تصميم وتنفيذ لنظام مراقبة لدرجة الحرارة باستخدام الحاكم الدقيق PIC وبروتوكول الاتصال بخط واحد

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**المخلص** مراقبة درجة الحرارة والتحكم فيها يعتبر مهم للعديد من تطبيقات التحكم، على سبيل المثال في المجالات الصناعية، وكمثال على ذلك عمليات التحكم بالحرارة ، السيارات، الأماكن الصناعية، أماكن التخزين أو مباني المكاتب. تقدم هذه الورقة نظام لمراقبة درجة الحرارة باستخدام بروتوكول الاتصال بخط واحد والمتحكم الدقيق نوع PIC. تم تنفيذ نظام مراقبة درجة الحرارة المقترح باستخدام متحسس درجة الحرارة الرقمي نوع DS18B20، حيث كل متحسس لديه رقم تسلسلي معرف ب 64 بت، وبالاستفادة من هذه الميزة يمكن توصيل عدة متحسسات من هذا النوع على خط اتصال واحد ، ويمكن لحاكم دقيق واحد التحكم في عدة متحسسات موزعة على مساحة واسعة لقياس درجة حرارة. النتائج التجريبية للنظام تبين أن النظام المقترح يعمل بشكل جيد كما هو متوقع.  
**الكلمات المفتاحية:** مراقبة درجة الحرارة، بروتوكول الاتصال بخط واحد، DS18B20، المتحكم الدقيق نوع PIC.

### 1. Introduction

Monitoring and maintaining temperatures is important in many control applications, for instance, industrial domains such as process heat, automotive, industrial places, storage or office buildings and the desired temperature achievement and consumption optimization are the most important concerns [1]. Temperature is measured using temperature sensors, that can be classified into two main broad categories. The first analog temperature sensors, in which the sensors produce an analog output voltage which is proportional to the temperature, and these sensors require analog-to-digital (A/D) converters. The second category includes digital temperature sensors, in which the sensors produce digital outputs and these sensors can directly be connected to microprocessors or microcontrollers without the need for A/D converters. Choosing these sensors is based on certain specifications factors include: repeatability accuracy, long term stability, interchangeability, ability to recover from condensation, resistance to physical and chemical contaminants and cost effectiveness. In recent years, several temperature monitoring systems have been proposed for various types of processes and they were implemented based on

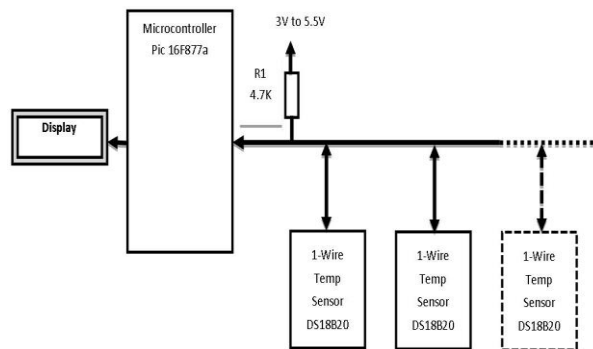
microcontrollers and microprocessor [2-4]. Authors in [5] proposed a system for monitoring the temperature and humidity based on the microcontroller and the analogue temperature sensor was used to measure the temperature. Authors [6, 7] proposed a microcontroller based system for monitoring server room temperature, the temperature is measured using analogue temperature sensor. A temperature control system for smart electric fan was proposed in [8] using analogue temperature sensor. In [9], author describes the design of a monitoring temperature system based on PIC microcontroller and analogue temperature sensor. Authors in [10] presented the design for monitoring the temperature based on microcontroller and GSM technique. the temperature is measured using analogue temperature sensor. Authors in [11] describe a design of an embedded system for the temperature controller in industrial and laboratories using analogue temperature sensor. Authors in [12] present an industrial temperature measuring and monitoring system. They used a digital temperature sensor and interfaced to the microcontroller via serial peripheral interface (SPI), which is an interface bus commonly used to

send data between microcontrollers and small peripherals such as sensors. Disadvantages of using SPI are that, it requires more signal lines (wires) for interfacing devices with microcontroller than other communications methods such as 1-wire protocol communication. In addition; the communications must be well-defined in advance. As mentioned early, the exiting methods [5-11] have developed for the measurement of the temperature uses the analogue temperature sensors, that are required an analogue to digital converter (ADC) and therefore, extra cost is required using such these sensors. Moreover; the more sensors connected to the system, required the more hardware for interface. Zhu and Bai [13] proposed a method for monitoring the temperature of electric cable interface in order to avoid occurrences of the electric hazards effectively. The method is based on AT89C51 Microcontroller and the 1-wire digital DS18B20 temperature sensor. The information can be send in or out from DS18B20 through the single bus connection. This paper present, a temperature monitoring system based on 1-wire protocol communication and PIC microcontroller. In comparison, with existing approaches, the proposed system possesses the following advantages: (i) the proposed temperature monitoring system requires one data line and ground to connect and transfer that between sensors and microcontroller. In contrast to other serial communication protocols such as I<sup>2</sup>C or SPI that are required more than one data line for interfacing with microcontroller. (ii) to measure the temperature, the proposed system uses the digital temperature sensor, which does not required an analogue to digital converter (ADC). By contrast, methods in mentioned early [5-11] are implemented using the analogue temperature sensors that are required an analogue to digital converter (ADC) and therefore, extra cost is required using such these sensors. (iii) based on the fact that many 1-Wire Devices such as sensors, memory can be connected via one line data and ground and each 1-Wire slave device has a unique, unalterable, factory-programmed, 64-bit ID, which serves as a device address on the 1-Wire bus in order to identify the device type and functionality [14]. As result, the required hardware for interfacing the sensors is reduced in proposed monitoring temperature system. The rest of this paper is structured as follows. Section 2 covers the details of the proposed temperature monitoring system. Section 3 presents experimental results. Conclusions are drawn in Section 4.

**2. Proposed temperature monitoring system**

The block diagram shown in figure 1 provides an overview of the proposed temperature monitoring system, which consists of PIC microcontroller (16f877a), digital temperature sensors (DS18B20) and the display unit to display the measured

temperature. As illustrated in the block diagram shown in figure 1, a single-wire bus is used for communication between the microcontroller and the temperature sensor. Each DS18B20 has a unique 64-bit serial code identifier, which allows multiple DS18B20s to function on the same 1-Wire bus. Therefore, one PIC microcontroller can be used to control many DS18B20s distributed over a large area. The number of devices that can be addressed on one bus is virtually unlimited [15]. Applications that can benefit from this feature include temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.



**Fig.1:**Block diagram of the proposed temperature monitoring system

**2.1 Overview of the 1-Wire communication protocol**

The 1-wire communication protocol is designed by Dallas Semiconductor Corp. and it is typically used to communicate with small inexpensive devices such as digital thermometers and weather instruments. The Characteristics of the 1 wire can summarize as follows: (i) it uses only one wire for signaling and power, (ii) allows interaction with many Maxim/Dallas Semiconductor parts, (iii) the architecture of the 1-Wire communication protocol uses a pull-up resistor to pull voltage off the data line at the master side, (iv) master and slave devices can be receivers and transmitters, but transfer only one direction at a time (half duplex). The master device initiates and controls all 1-Wire operations. (v) It is a bit-oriented operation with data read and write, Least Significant bit (LSb) first, and is transferred in time slots. More information about the wire communication protocol can be found in [16, 17].

**2.2 Interfacing the DS18B20 digital thermometer Sensor to the PIC microcontroller**

The DS18B20 digital thermometer sensor can be connected to PIC microcontroller over a 1-Wire bus, which is required only one data line (and ground) for communication with PIC microcontroller. It provides 9-bit to 12-bit Celsius temperature measurements and the sensor can measure temperatures from -55°C to +125°C (-

67°F to +257°F) with  $\pm 0.5^{\circ}\text{C}$  Accuracy from  $-10^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

As shown in figures 2 and 3, the sensor can be powered by either derive power directly from the 1-Wire bus, or by using an external supply on VDD pin. The later method is used in the proposed temperature monitoring system. The advantage of this method is that the MOSFET pull-up is not required, and the 1-Wire bus is free to carry other traffic during the temperature conversion time. A detailed description of DS18B20 digital thermometer sensor can be found in [15].

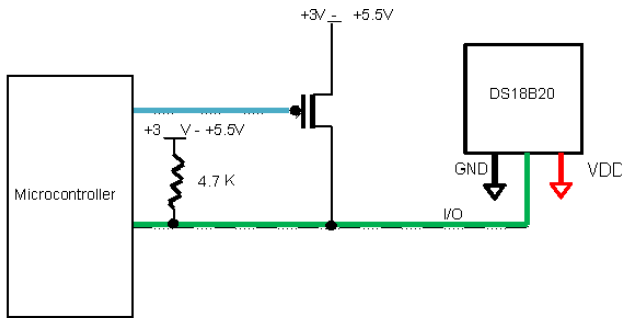


Fig. 2: Derive power directly from the 1-Wire bus

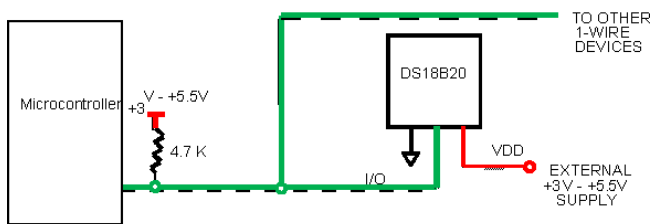


Fig. 3: Derive power using an external supply on VDD pin.

### 2.3 The implementation of the proposed temperature monitoring system

The implementation of the proposed temperature monitoring system is divided into two stages: The first stage covers the hardware implementation and the second covers the software implementation. In the hardware implementation, RE2 pin of the PIC 16f877a is used as input pin for connecting and controlling the DS18B20 digital thermometer sensor as shown in figure 4. The display unit of the proposed system is consist of two seven segments and connected to PIC microcontroller via PORTC and PORTD for display the results of the measurements.

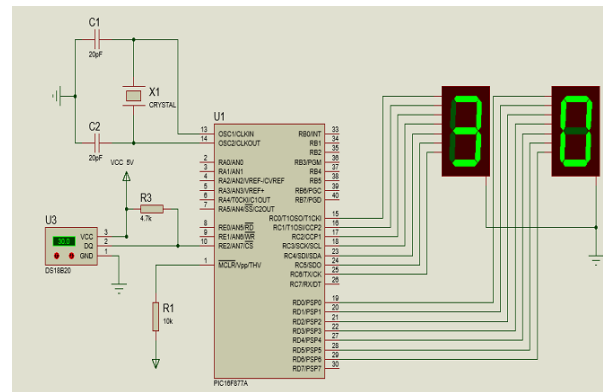


Fig. 4: the schematic circuit of the proposed system

The software implementation of the proposed system is divided into three functions, the first is the Initialization function, which aims to initiate the RE2 pin of the PIC 16f877a as input pin in order to connect the sensor and PORTC and PORTD as output ports to connect the two seven segments display. The second is the measurement function, which aims to initiate and control the DS18B20 sensor. and the third is display function, which aims to display the results of the temperature measurements. The flowchart of software design is illustrated in figure 5. The implementation of the proposed system is shown in Figure 6.

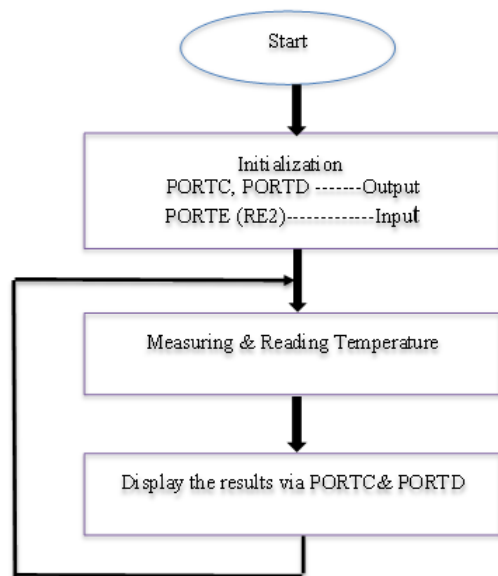


Fig. 5: flowchart of the software design

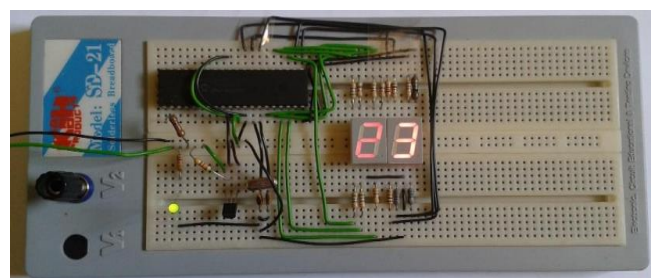


Fig. 6: the implementation of the proposed system

### 3. Experimental results

To test and evaluate the accuracy of the proposed temperature monitoring systems, a digital thermometer and Mercury thermometer shown in figure 7 were used to conduct an experiment to compare and gauge the performance of the proposed temperature monitoring system. The measurement process was done to gauge the room temperature and done at different times of day. The results of the experiments are summarized in table I , in which shows, the proposed system is able to measure the temperature correctly.

**Table I results of measuring temperatures using different sensors**

Time	Digital thermometer C°	Mercury thermometer C°	Proposed system C°
10 am	29.1	29.2	29
11 am	29.2	29.5	29
12 am	30.4	30.3	30
2 pm	30	30.6	30
4 pm	30	30.1	30
7 pm	28.5	28.4	28
8 pm	28.5	28.3	28
9 pm	27	27.2	27



**Fig. 7:**a digital thermometer and mercury thermometer

### 4. Conclusion

This paper presents the design and implementation of a temperature monitoring system based on Pic microcontroller and the DS18B20 digital thermometer sensor, which is connected to PIC microcontroller over a 1-Wire communication protocol that requires only one data line for communication. Experimental results show that the proposed system succeeds in measuring the temperature.

Further improvements can be done by adding more features to the proposed system such as a wireless connection to interface with PC in order to transmit and save the temperature data.

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