AN988

Interfacing the MCP9800 I²C™ Digital Temperature Sensor to a PICmicro® Microcontroller

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INTRODUCTION

The MCP9800 is a digital CMOS silicon temperature sensor that provides an accurate digital temperature measurement. Data is converted from an internal diode temperature-sensing element to a digital format that can be directly interfaced to a PICmicro® microcontroller unit (MCU). The MCP9800 sensor offers many system-level advantages, including the integration of the sensor and signal-conditioning circuitry in a small Integrated Circuit (IC) package. The MCP9800 also has a One-shot Conversion mode that performs a single temperature measurement and then goes into power-saving Shutdown mode. The One-shot Conversion mode makes this sensor a good choice for power-critical, portable applications.

The MCP9800 digital temperature sensor is especially suited for embedded systems due to its I²C™ interface, which serves to provide an industry standard method of interface to a microcontroller. This application note will discuss system integration, firmware implementation and Printed Circuit Board (PCB) layout techniques for using the MCP9800 in an embedded system.

The techniques for integrating the MCP9800 into an embedded systems environment will be demonstrated by using the PICkit™ 1 Flash Starter Kit and a MCP9800 PICtail™ daughter board. The MCP9800 PICtail daughter board plugs into the PICkit 1 Flash Starter Kit expansion header J3, as shown in Figure 1. The MCP9800 demonstration is designed to measure and display temperature using the on-board 7-segment LED display.

Gerber files for the PCB, source code and a hex file to program a PIC16F684 are included in the companion zip file, 00059R1.zip.

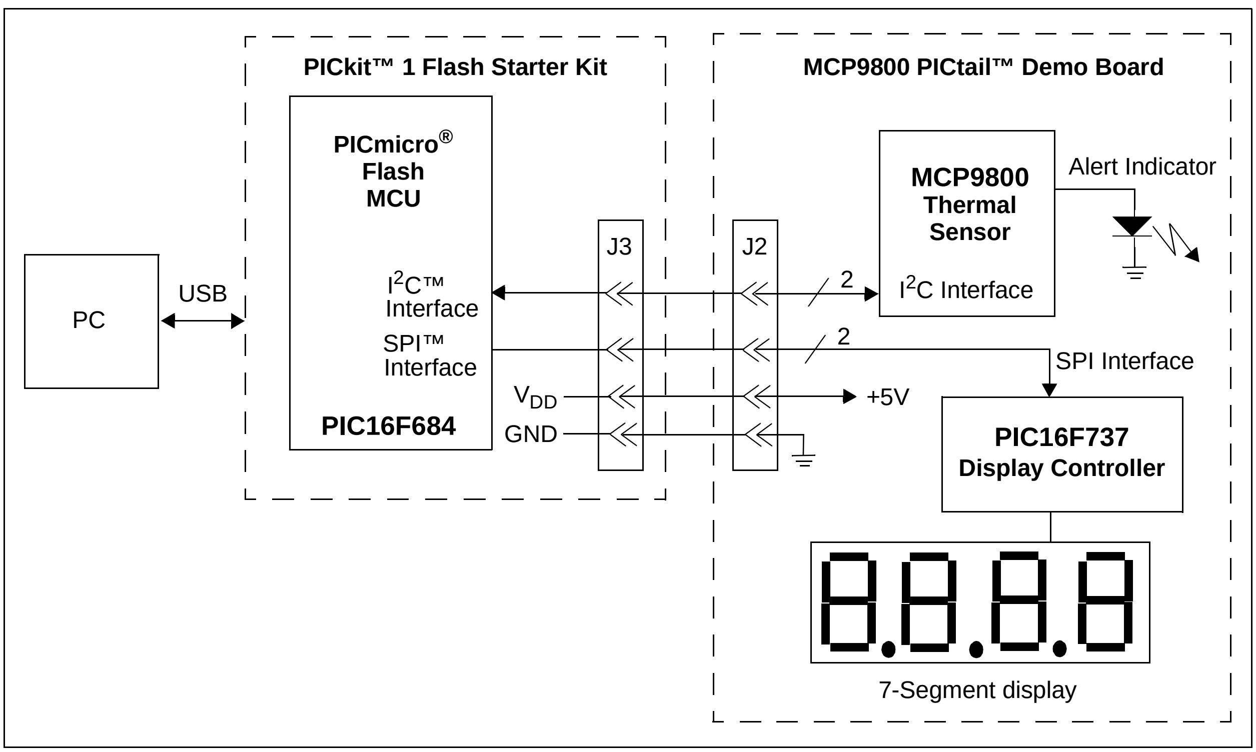

FIGURE 1: *Block Diagram of the MCP9800 Digital Temperature Sensor Demonstration.*

MCP9800 FUNCTIONAL DESCRIPTION

The MCP9800 consists of an internal diode temperature sensor, a user selectable 9-12-bit sigma delta Analog-to-Digital Converter (ADC), digital registers and a I^2C communication port. Figure 2 provides a simplified block diagram of the MCP9800. A schematic of the MCP9800 to PICmicro MCU interface is shown in Figure 3.

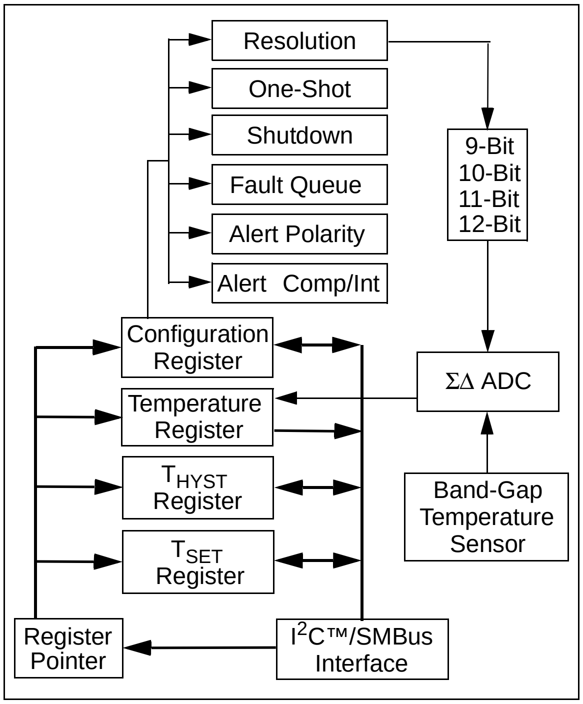

FIGURE 2: Functional Block Diagram.

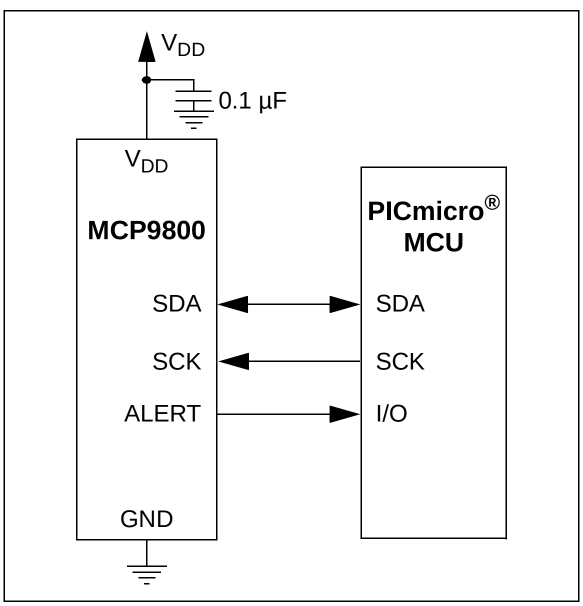

FIGURE 3: MCP9800 to PICmicro® MCU Interface.

Temperature Data Format

Temperature data is represented by a 9-12-bit two's complement word with a resolution of 0.15°C per bit to 0.0025°C per bit. The temperature data is stored in the temperature registers in a two's complement format, as shown in Table 1.

Example using a 10-bit data:

Temperature	=	41.5°C
MSb Temperature Register	=	`00101001b`
	=	$2^5 + 2^3 + 2^0$
	=	32 + 8 + 1 = 41
LSb Temperature Register	=	`10000000b` = 2^{-1}
	=	0.5

TABLE 1: TEMPERATURE REGISTER

D7	D6	D5	D4	D3	D2	D1	D0	Address/ Register
Sign	2^6	2^5	2^4	2^3	2^3	2^1	2^0	02H Temp. MSb
2^{-1}	2^{-2}	0	0	0	0	0	0	01H Temp. LSb

Refer to the MCP9800 data sheet, "2-Wire Accuracy Temperature Sensor" (DS21909), for more information regarding the serial interface.

REGISTERS

The MCP9800 family has four registers that are user-accessible. These registers are specified as the ambient temperature register, the Temperature Limit-set (T_{SET}) register, the Temperature Hysteresis (T_{HYST}) register and device Configuration registers.

The Ambient Temperature register is a read-only register and is used to access the ambient temperature data. The data from the ADC is loaded in parallel in the register. The T_{SET} and T_{HYST} registers are read/write registers that provide user-programmable temperature limits. If the ambient temperature drifts beyond the programmed limits, the MCP9800 outputs an alert signal using the ALERT pin (refer to **"ALERT Output Configuration"**). The device Configuration register provides access for the user to configure the MCP9800's various features. These registers are described in further detail in the following sections.

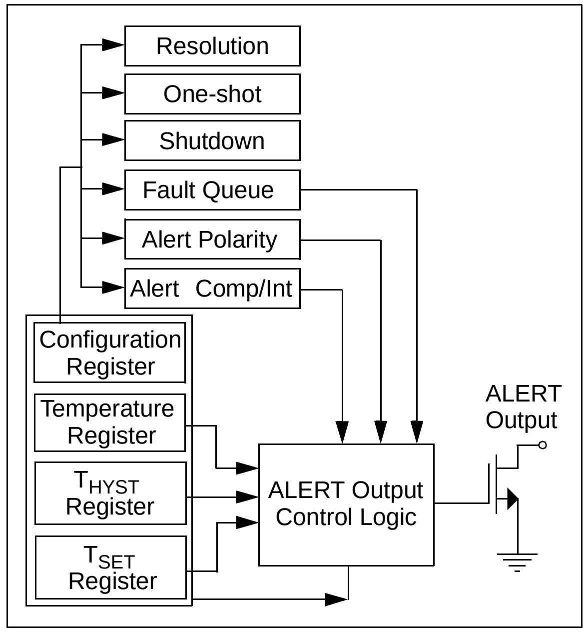

FIGURE 4: *Register Block Diagram.*

The registers are accessed by sending a register pointer to the MCP9800 using the SPI™ interface. This is an 8-bit pointer. However, the two Least Significant bits (LSb) are used as pointers and all other bits need to be cleared <0>. This device has additional registers that are reserved for test and calibration. If these registers are accessed, the device may not perform according to specification. Refer to the MCP9800 data sheet for detailed information.

APPLICATIONS INFORMATION

The MCP9800 does not require any additional components in order to measure temperature, though it is recommended that a decoupling capacitor (a high-frequency ceramic capacitor should be used) of 0.1 µF to 1 µF be provided between the V_{DD} and GND pins. The capacitor should be located as close as possible to the IC power pins in order to provide effective noise protection to the sensor.

The MCP9800 measures temperature by monitoring the voltage of a diode located on the IC die. The IC pins of the MCP9800 provide a low-impedance thermal path between the die and the PCB, allowing the MCP9800 to effectively monitor the temperature of the PCB. The thermal path between the ambient air is not as efficient because the plastic IC housing package functions as a thermal insulator. Thus, the ambient air temperature (assuming that a large temperature gradient exists between the air and PCB) has only a small effect on the temperature measured by the MCP9800.

A potential for self-heating errors can exist if the MCP9800 I^2C interface communication lines are heavily loaded. Typically, the self-heating error is negligible because of the relatively small current consumption of the MCP9800. A temperature accuracy error will result from self-heating if the I^2C communication pins sink/source the maximum current specified for the MCP9800. Therefore, to maximize the temperature accuracy, the output loading of the I^2C inteface signals should be minimized.

MCP9800 PICtail™ DAUGHTER BOARD

The MCP9800 PICtail daughter board is plugged into the PICkit 1 Flash Starter Kit via expansion header J3. Figure 5 shows the MCP9800 PICtail daughter board plugged into the PICkit 1 Flash Starter Kit. For more information on the PICkit 1 Flash Starter Kit, refer to the "PICkit™ 1 Flash Starter Kit User's Guide" (DS40051).

The MCP9800 PICtail daughter board consists of a MCP9800 temperature sensor and a bypass capacitor. The bypass capacitor (C_1) is used to provide noise immunity on the +5 VDC power supply. In addition, this demo board has a 7-segment LED temperature display circuit. Figure 6 shows a schematic of the board.

Refer to the "MCP9800 Thermal Sensor PICtail™ Demo Board User's Guide" (DS51528) for further details.

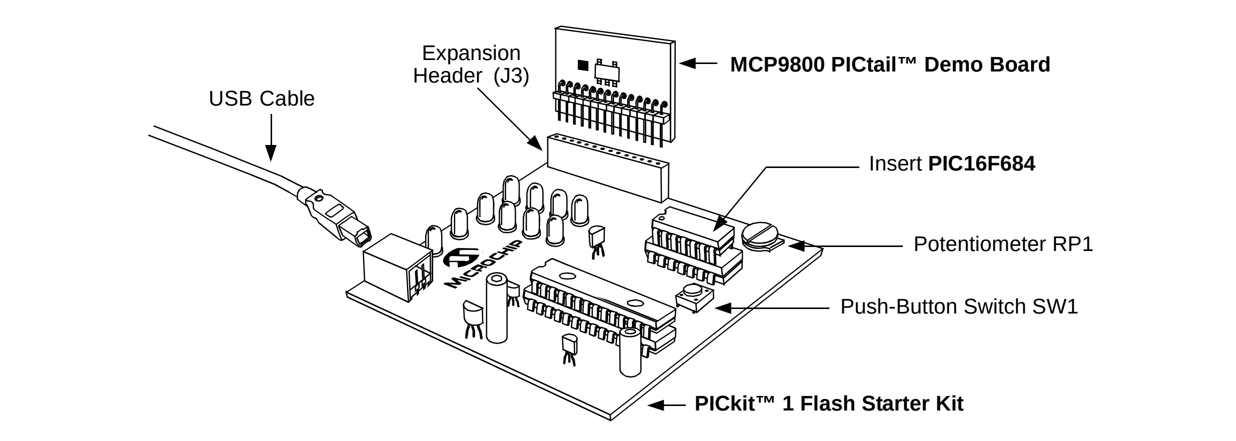

FIGURE 5: *MCP9800 PICtail™ Daughter Board and PICkit™ 1 Flash Starter Kit.*

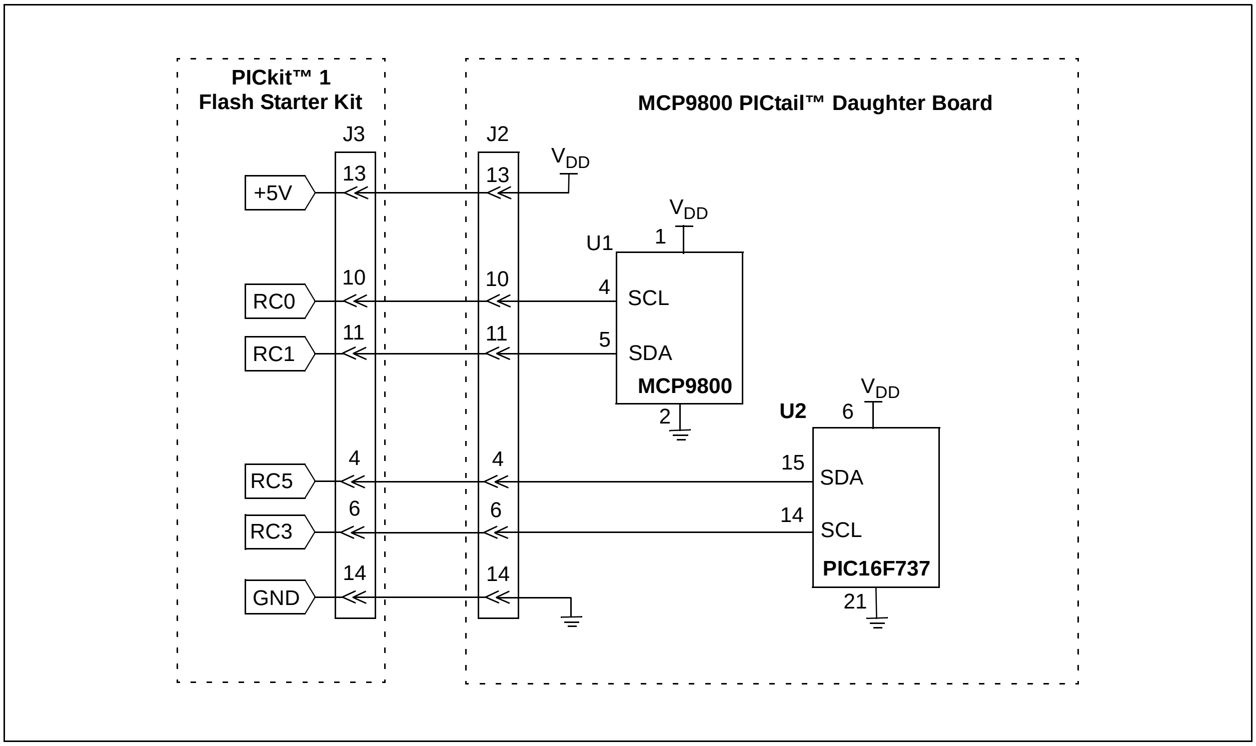

FIGURE 6: *MCP9800 PICtail™ Daughter Board Schematic.*

MCP9800 INTERFACE FIRMWARE

A block diagram of the firmware flow is shown in the Figure 7.

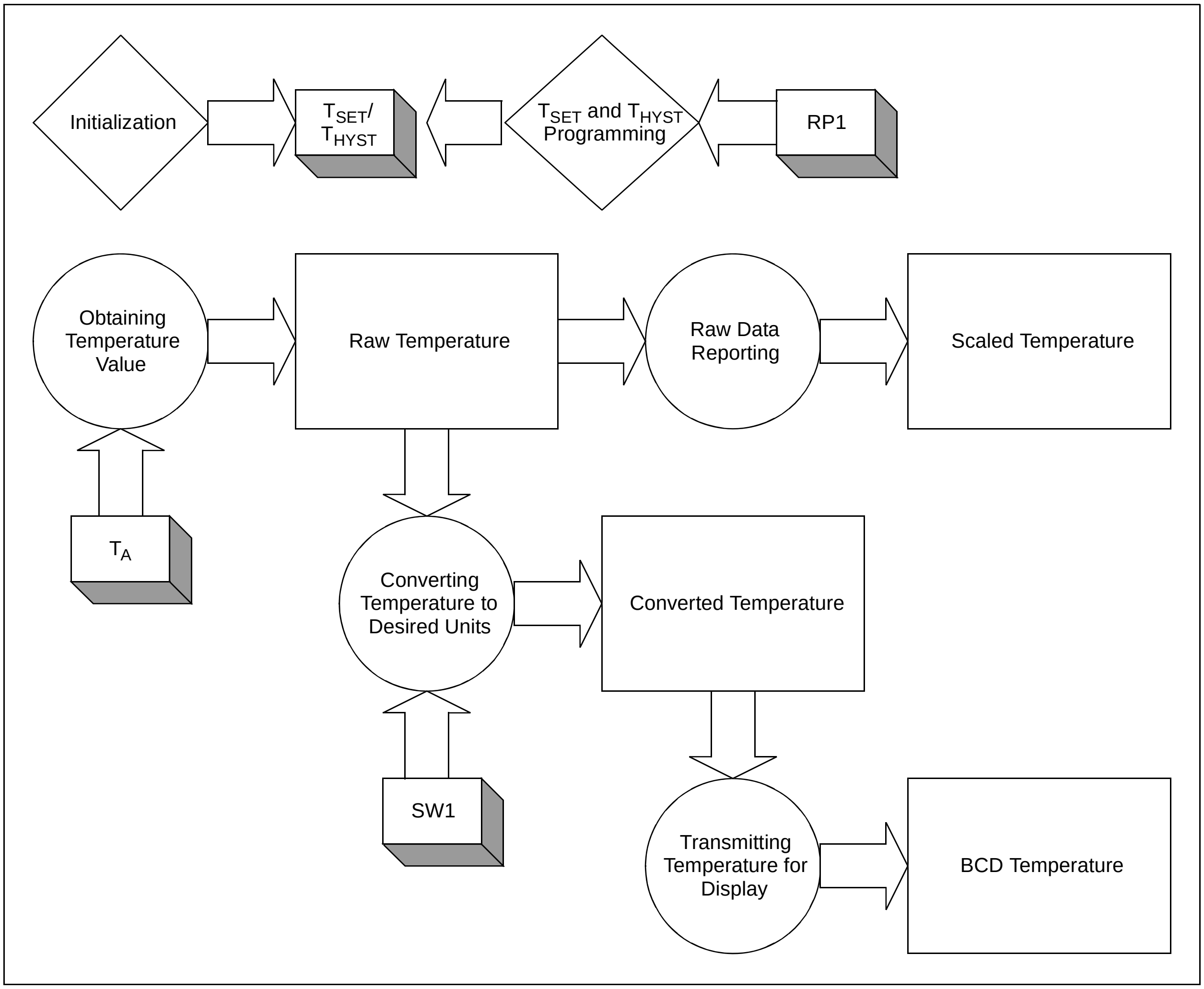

FIGURE 7: *Block Diagram of the Firmware.*

Initially, the position of the RP1 potentiometer is determined using an ADC. This data is used to set the ALERT output limit and hysteresis. Temperature data is then obtained from the MCP9800. If the PC requests temperature data, the raw temperature data is transmitted using the USB cable. Refer to the "MCP9800 Thermal Sensor PICtail™ Demo Board User's Guide" (DS51528), for further detail. The SW1 switch position is determined to select the measurement unit as degree Celsius or Fahrenheit. Once the unit conversion is completed, data is transmitted for display using the 7-segment display.

Figure 8 shows the flow diagram that describes the temperature unit conversion.

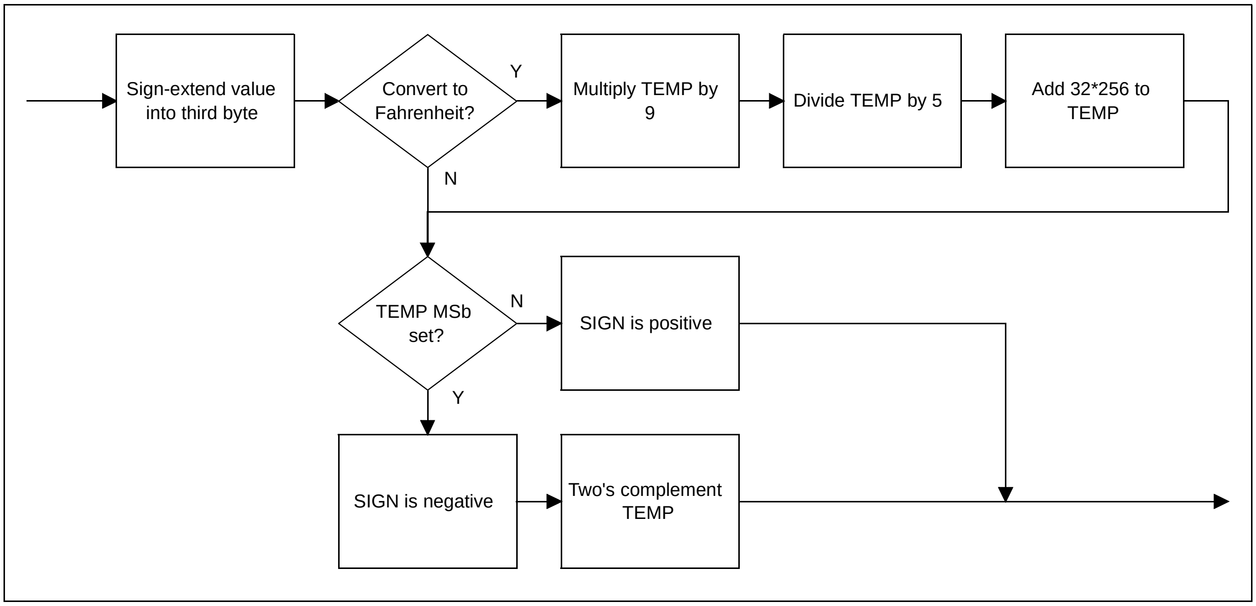

FIGURE 8: *Temperature Unit Conversion Flow Diagram.*

The temperature data from the MCP9800 is checked for positive or negative reading. If the temperature is below 0°C, the reading is converted to the two's compliment. Then, based on the position of the SW1 switch, the unit-conversion is followed as shown above.

The SPI interface is used to transmit the temperature data to the 7-segment display driver PICmicro MCU (PIC16F72). This PICmicro MCU receives temperature data from the PICkit 1 Flash Starter Kit and displays it on the 7-segment display. The display requires refreshing, therefore, this MCU continuously displays the received temperature data. The flow diagram is shown in Figure 9.

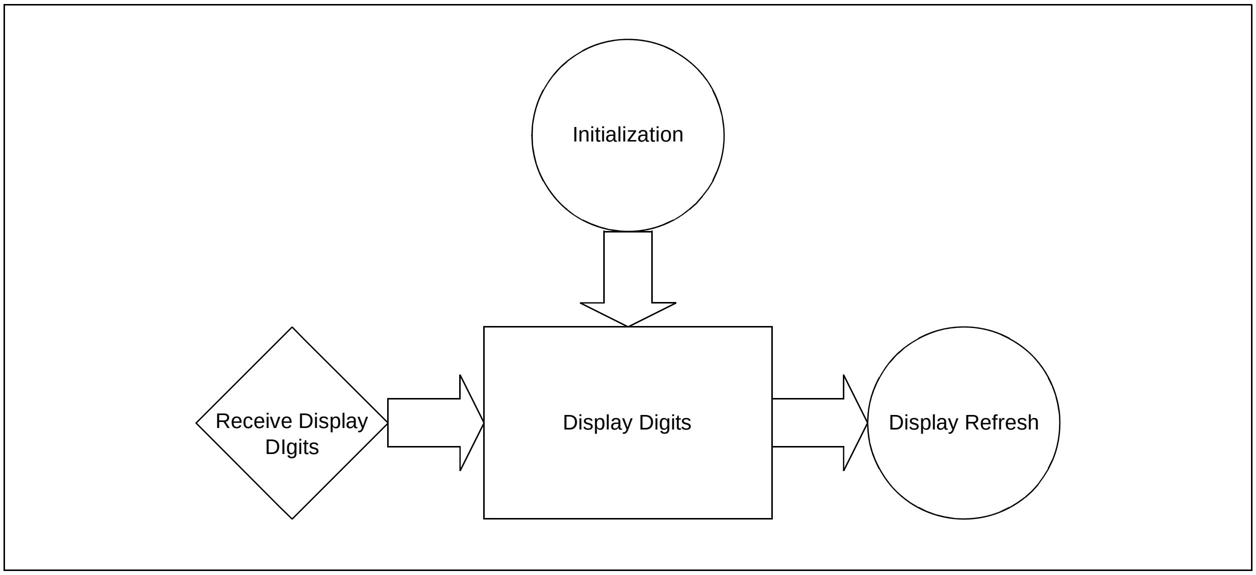

FIGURE 9: *Display Flow Diagram.*

The SPI interface routine protocol for the 7-segment display driver is designed to function as a generic tool to display any data. The protocol is described in the "MCP9800 Thermal Sensor PICtail™ Demo Board User's Guide" (DS51528). The flow diagram in Figure 10 shows the firmware structure for the serial interface.

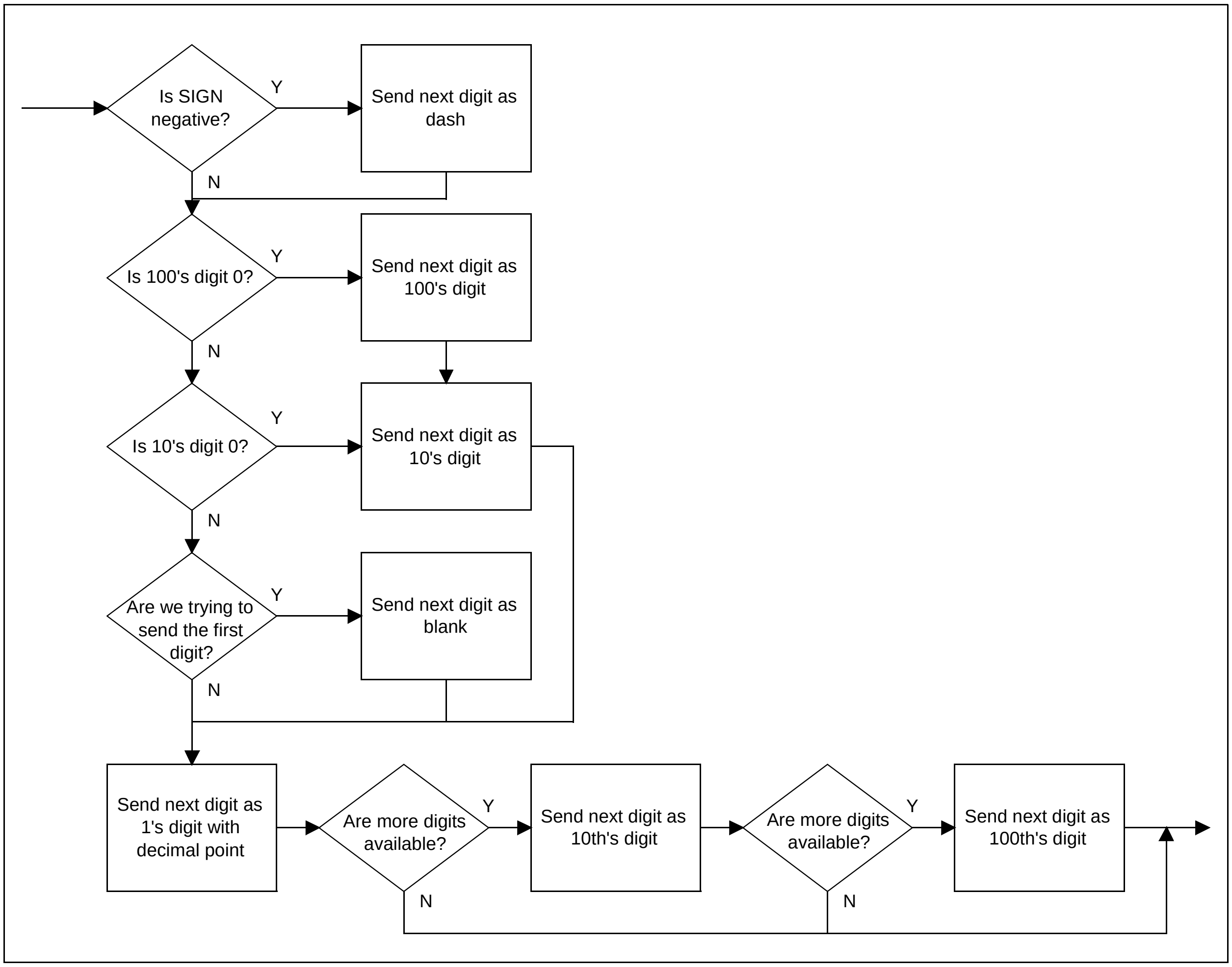

FIGURE 10: *Firmware Structure for the Serial Interface.*

CONCLUSION

The MCP9800 digital temperature sensor PICtail™ daughter board demonstrates the ease of integrating a digital output IC temperature sensor to a PICmicro® microcontroller. The MCP9800 is a CMOS silicon digital temperature sensor that provides many system-level advantages, including the integration of the sensor and the signal-conditioning circuitry in a small IC package. This provides for easy system integration and minimizes the required PCB space, component count and design time.

BIBLIOGRAPHY

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4. “MCP9800 Thermal Sensor PICtail™ Demo Board User’s Guide”, DS51528, Microchip Technology Inc., 2005.

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