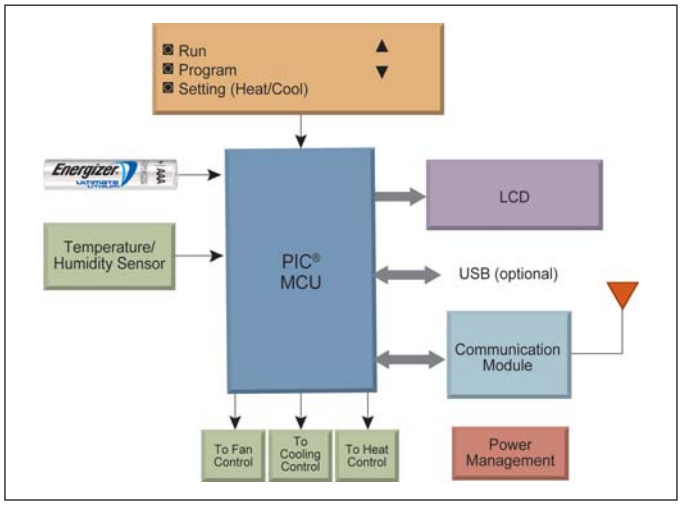
Low Power Case Study #3: Thermostat Case Study

Objective: Demonstrate the flexibility of the PIC® microcontroller platform for a range of thermostats from a low cost, segmented display to a fully featured graphical display with touch sensing.

Thermostat Platform Requirements:

- Must regulate the temperature of a system, room or building
- Requires accurate temperature measurement to 0.1°C
- Must wake every 120 seconds to take a temperature measurement
- Provides data to control the temperature via connection to an HVAC unit
- Display temperature in °C or °F, time and date information
- Maximize battery lifetime



Thermostat Application Examples

Feature	Model 1	Model 2	Model 3
	 Low Cost Entry Segmented Display with Mechanical or Capacitive Buttons	 Fully Featured Segmented Display with Touch Screen	 Graphical Display with Touch Screen
Display	• Display up to 64 segments • Show temperature, time • No contrast control	• Display up to 192 segments • Show temperature, date, day of week, time, heat/cool modes • Contrast control	• Graphical display • Show temperature, date, day of week, time, heat/cool modes
User Interface	Mechanical buttons or capacitive touch keys	Capacitive touch screen	Touch screen with resistive touch technology
Interface to Sensors	Direct interface to analog temp sensor	Integrated temp and humidity sensor	Serial I²C™ interface to temp and humidity sensor
Time Keeping	Software RTC	Integrated Real-Time Clock/Calendar	Real Time-Clock/Calendar with battery backup
Power Pro«le	• Must drive display in Sleep mode • Battery backup and option to operate from battery for 4 years	• Must drive display in Sleep mode • Battery backup and option to operate from battery for 4 years	• Sleeps when not in use to conserve power and wake-up upon touch • Battery backup must last 6 months
Power Consumption Requirements	• Average current around 50 µA req. for 2x AA batteries • Average current of 5 µA req. for CR2032	• Average current around 50 µA req. for 2x AA batteries • Average current of 5 µA req. for CR2032	• Average current around 500 µA required for 2x AA batteries
Communication	Wired	Wired	Wireless communication to HVAC

Low Power Case Study #3: Thermostat Case Study (continued)

Thermostat Application Examples (Continued)

Feature	Model 1	Model 2	Model 3
	 Low Cost Entry Segmented Display with Mechanical or Capacitive Buttons	 Fully Featured Segmented Display with Touch Screen	 Graphical Display with Touch Screen
Additional Features	Basic control features for setting temperature, fan on and auto mode	Code space for programmable set points for heating and cooling; programmable set and hold mode	Code space for programmable set points for heating and cooling; programmable set and hold mode; ZigBee® or WiFi® stack for wireless communication
Suggested PIC MCU and Microchip Solutions	• PIC16F1947 • MCP9700/1 temp sensor	• PIC18F87K90 • Sensing for touch, temperature and humidity done with integrated CTMU	• PIC24FJ256DA210 • AR1000 touch controller • MCP79410 RTCC • MCP9800/4 temp sensor I^2C I/F • MRF24WB0MA WiFi Module or • MRF24J40MA ZigBee Module • SST25VF032B external Flash

LCD and XLP MCU System Integration

Microchip provides a large selection of 8- and 16-bit microcontrollers with XLP Technology for designers. The PIC16F1947 and PIC18F87K90 are both ideal for use in low power thermostats. These products are both members of the XLP family – designed for battery-powered and low power applications that feature a LCD driver can run in Sleep mode, providing the lowest power consumption. PIC MCUs with XLP Technology offer on-the-fly clock switching. By reducing the clock frequency when full performance is not required, significant power savings can be achieved. In addition, the instruction set efficiency of Microchip XLP MCUs often allows the code to run at lower frequency saving battery power. Reduced stand-by and active currents on the XLP LCD MCUs can enable battery life up to 20 years.

Model 1: Low Cost Thermostat – PIC16F1947 Unique Features

The low-cost entry level thermostat requirements are met by the PIC16F1947 microcontroller for measurement and control. This MCU features a 32 kHz crystal with T1OSC for a low cost RTC for time keeping. With up to 28 KB Flash and 8 MIPS performance there is plenty of memory and bandwidth to implement the necessary control and user interface from the mechanical buttons. The integrated 10-bit ADC interfaces directly to the MCP9701 temperature sensing chip.

Since this thermostat must operate from battery backup for 4 years, the XLP (eXtreme Low Power) MCU provides low sleep currents to extend battery life and is capable of driving the display while sleeping. For safety and reliability, the low battery detection and voltage measurements can be done with the integrated 10-bit ADC and VREF. The ADC can also be used to implement capacitive touch keys using the Capacitive Voltage Divider (CVD) method.

For scalability within the thermostat products various displays, the PIC16F19XX family is available in 28 to 64 pin options depending on the number of segments that need to be driven (up to 184 pixels on the 64 pin version). Typically the LCD displays temperature, mode and time information directly driven from the LCD controller integrated into the MCU. Multiple LCD glass types are supported in order to enable a single LCD platform without needing separate LCD driver chips. Minimizing system cost, internal resistor reference voltages will reduce the need for external components.

Low Power Case Study #3: Thermostat Case Study (continued)

Model 2: Cost Effective, Fully-Featured Thermostat – PIC18F87K90 Unique Features

In addition to the requirements for the entry level thermostat, this model has a larger display which requires a LCD driver that can drive more segments to show temperature, date, day of week, time and heat/cool modes. The PIC18F87K90 MCU has an integrated LCD controller capable of driving up to 192 segments with integrated resistor network for biasing the LCD, saving cost and reducing current consumption. To compensate for various lighting conditions, the integrated contrast control is used for optimal viewing.

For displaying date and time information, the thermostat can use the MCU's hardware RTCC module which is designed for applications where accurate time must be maintained for an extended period with minimum intervention from the CPU. The module is optimized for low-power usage in order to provide extended battery life while keeping track of time. The RTCC module provides hours, minutes, seconds with half second period as well as calendar function with weekday, date, month and year. With up to 128 KB Flash, there is plenty of code space for programmable set points for heating and cooling as well as programmable set and hold modes. A single layer ITO can be used for adding touch screen capability over the segmented display.

The PIC18F87K90 has an integrated CTMU or Charge Time Measurement Unit which is used for capacitive touch sensing when used with the ADC. The CTMU is also used with the 12-bit ADC to provide the resolution required for temperature and humidity measurement, thereby eliminating the need for an external ADC or sensors.

Multiple Enhanced Input Capture/Output Compare/PWM modules can drive simultaneous functions such as RGB LEDs, buzzers, motors etc. and time multiple external events simultaneously for control and feedback.

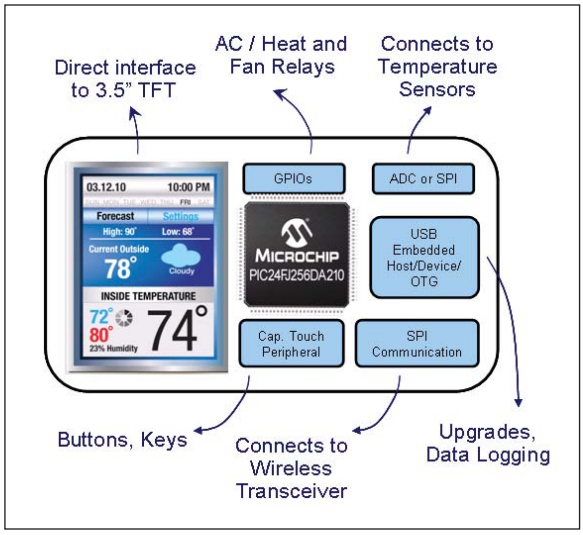
This thermostat must operate from battery backup option for up to 4 years with average current of 50 µA for 2 AA batteries of 5 µA for CR2032 coin cell. The PIC18F87K90 has extremely low power consumption with LCD currents down to 300 nA, RTCC currents down to 700 nA and Sleep mode down to 20 nA.

Model 3: Next Generation Fancy Thermostat – PIC24F with Graphical Display

The user interface is the most important feature on the graphical thermostat. For customers who want to buy a thermostat that is extremely modern, colorful and easy to use, adding a graphical display will help differentiate this line of thermostats. It's easy to add color graphical display for high end thermostats by using the PIC24FJ256DA210 with integrated hardware graphical acceleration. This MCU has direct interface to STN, TFT and OLED displays and includes color look-up table for 256 16-bit colors.

External memory can be used if more than the integrated 96 KB RAM is needed. For many graphical thermostats looking for 24-bit color, the SST25VF032B external Flash can be used.

To easily implement the control screens on the display, use Microchip's free graphics library and graphical designer tool to develop the code to drive the display showing temperature, date, day of week, time and heat/cool modes as well as the touch screen buttons. The PIC24FJ256DA210 has a I^2C™ interface that connects to the MCP9800 or MCP9804 temperature sensor for highest accuracy. For battery backup and lowest power, an external RTCC chip such as the MCP79410 can be used.



To conserve power, the thermostat display goes blank and sleeps when not in use. The screen also has touch screen capability for analog resistive on-screen menus. The AR1000 touch controller is used to implement the resistive touch screen capability, with the ability to wake-up on touch.

Many next generation thermostats also provide wireless connectivity, such as Wi-Fi® or ZigBee®, to communicate to other devices in the home. The PIC24FJ256DA210 has up to 256 KB of Flash which is plenty of code space for Microchip's free ZigBee stack as well as the programmable set points for heating and cooling, graphics library for the various control screens and control. The MCU also includes USB connectivity which can be helpful for remote field diagnostics.

Low Power Case Study #3: Thermostat Case Study (continued)

Wireless Connectivity

Wireless command and control communication is becoming a standard for Smart Energy thermostat applications. Microchip offers IEEE 802.15.4/ZigBee, IEEE 802.11 Wi-Fi and a broad range of sub-GHz RF-ICs for low-power RF communication. Thermostats can now communicate to HVAC, home automation, and the internet for a number of climate and energy saving usage modes.

Wi-Fi connectivity is achieved by using Microchip's agency certified Wi-Fi modules and the free TCP-IP stack running on the low-cost, low-power PIC18 and PIC24 MCUs. The MRF24WB0MA Wi-Fi module is designed to allow our customers to significantly increase the value of their systems by reducing the design effort, power consumption, system design requirements and system cost to add Wi-Fi.

The MRF24J40MA 2.4 GHz IEEE 802.15.4 transceiver module is FCC, IC and ETSI agency certified. The PIC MCU runs the free ZigBee or MiWi communication protocol stacks for communication to a ZigBee Smart Energy network or proprietary Home Automation network.

The MRF89XA family of sub-GZ band RF transceivers modules operate from 863-870 MHz and 902-928 MHz in the ISM band and are optimized for low power. Sub-GHz wireless networks are also used in many home automation and proprietary energy communication systems.

Conclusions

A thermostat platform is an application where PIC microcontrollers provide improved battery lifetimes, increased integration, and an enhanced user interface. Additional goals like long battery life, reliability, low cost, reduced size and ease of manufacturing are easily achieved using PIC MCUs. Eliminate external components and accelerate design timelines by utilizing the code and tool compatible migration from low end to fully featured thermostat designs.

Microchip XLP MCUs enable:

- Extremely low power consumption
- Large memory LCD MCUs supporting RF stack integration
- On-chip segmented LCD drivers and hardware real-time clock with calendar
- Battery friendly operation down to 1.8V or even 0.6V for single cell battery
- Modularity and flexibility to enable new features through implementation of control algorithms in MCU
- Wireless connectivity to control and monitor thermostats from a remote location

Featured Microcontrollers for Thermostat Applications

Device	Pins	Flash	Display	XLP	Voltage	Other Key Features
PIC32MX6XX	64-100	256-512 KB	Graphical	No	2.3-3.6	USB, 64-128 KB RAM, Ethernet MAC
PIC24FJ256DA210	64-100	128-256 KB	Graphical	No	2.2-3.6	Hardware graphics acceleration, USB
PIC18F87K90	64-80	32-128 KB	Segmented up to 192 pixels	Yes	1.8-5.5V	24 ch, 12-bit ADC, CTMU, RTCC, EEPROM
PIC16F1947	28-64	14-28 KB	Segmented up to 184 pixels	Yes	1.8-5.5V	10-bit ADC, EEPROM

Other Featured Products for Thermostat Applications

Device	Key Features
MCP9701 Temperature Sensor	– Linear Active Thermistor™ ICs are sensors whose output voltage is directly proportional to measured temperature. – Accurately measure temperature from -40°C to +125°C – Output is calibrated to a slope of 19.53 mV/°C and has a DC offset of 400 mV
MCP9800 Temperature Sensor	A digital temperature sensor capable of reading temperatures from -55°C to +125°C. Temperature data is measured from an integrated temperature sensor and converted to digital word with a user selectable 9 to 12-bit Sigma Delta Analog-to-Digital Converter.

Low Power Case Study #3: Thermostat Case Study (continued)

Other Featured Products for Thermostat Applications (Continued)

Device	Key Features
MCP79410 Low Power RTCC	– I²C™ Compatible Real-Time Clock/Calendar (RTCC) – Includes a battery switch over circuit for backup power, a timestamp to log power failures and digital trimming for accuracy – Time is tracked in either a 12-hour or 24-hour format with an AM/PM indicator and timing to the second, minute, hour, day of the week, day, month and year – Non-volatile memory with a Unique ID in a locked section of EEPROM that can be unlocked and programmed by the end user
MRF89XA Sub-GHz ISM Band RF Transceivers	The MRF89XA is a single chip, multi-channel FSK/OOK transceiver capable of operating in the 863-870 MHz and 902-928 MHz license-free ISM frequency bands, as well as the 950-960 MHz frequency band. The low-cost MRF89XA is optimized for very low power consumption (3 mA in Receiver mode). Its highly integrated architecture allows for minimum external component count while still maintaining design flexibility.
MRF24J40MA 2.4 GHz Wireless Transceiver Module	– 2.4 GHz IEEE 802.15.4 power radio transceiver module intended for longer range applications integrated PCB antenna, matching circuitry and supports the ZigBee®, MiWi™ and MiWi P2P protocols. – The MRF24J40MA Module connects to hundreds of PIC® microcontrollers via a 4-wire SPI interface. – Integrated PA and LNA – Integrated PCB Antenna – Surface Mountable – FCC, IC, ETSI certified
MRF24WB0MA Wi-Fi Module	– IEEE 802.11b compliant wireless solution compatible with b/g/n routers – Supports infrastructure and Ad hoc networks – MRF24WB0MA small footprint module integrated antenna, MAC, Baseband, RF and power amplifier – MRF24WB0MA/B module is FCC, IC, Wi-Fi certified, and ROHS, CE and ETSI compliant, providing considerable cost savings and quick time-to-market. – License Free TCP/IP stack supporting standard suite of internet protocols – Compatible with PIC18, PIC24 and PIC32 microcontrollers and dsPIC® digital signal controllers – Supports WEP, WPA and WPA2 security protocols on module
MCP2200 USB-to-UART Bridge	– USB-to-UART serial converter – Easily add USB connectivity to any MCU with a UART interface – Integrated USB termination resistors

MICROCHIP

www.microchip.com/XLP

DS41446A