

Introduction to Utility Metering Tutorial

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Preface

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Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXA", where "XXXXX" is the document number and "A" is the revision level of the document.

INTRODUCTION

This chapter contains general information that will be useful to know before using the Introduction to Utility Metering Tutorial. Items discussed in this chapter include:

- Document Layout
- The Microchip Web Site
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document provides an introduction to Utility Metering.

- Chapter 1. "Why Electronic Meters?"
- Chapter 2. "Types of Meters"
- Chapter 3. "Parts of a Meter"
- Chapter 4. "Microchip Solutions"
- Chapter 5. "Specifications"

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DOCUMENT REVISION HISTORY

Revision A (November 2005)

• Initial Release of this Document.



INTRODUCTION TO UTILITY METERING TUTORIAL

Chapter 1. Why Electronic Meters?

Electronic meters, as opposed to traditional mechanical and/or electromechanical solutions in use, offer several additional advantages of interest to the utility market including:

- · Improved reliability and ruggedness
- Improved accuracy
- Support of nonlinear and low-power factor loads
- · Ease of calibration
- Anti-tampering protection
- Automated meter reading
- Security
- Advanced billing (time-of-use, prepay, etc.)

Whether it is gas, water, heat or electricity being measured, some or all of these features apply and are making the electronic meter the solution of choice in both new (rapidly expanding) and existing (established) markets.

Implementing an electronic meter does not have to be a complex endeavor. This document will guide you through the many options and solutions available from Microchip Technology Inc.

Implementing an electronic energy meter, for example, can be as simple and inexpensive as using a single dedicated energy measurement IC (MCP3905) and a display/counter of choice. However, more advanced solutions are possible when adopting an 8 or 16-bit microcontroller (MCU), or even a 16-bit Digital Signal Controller (DSC).

In the following sections we will illustrate in greater detail the advantages listed above.

1.1 RELIABILITY AND RUGGEDNESS

The absence of moving parts is a clear advantage of the electronic solution (also referred to as a "solid state solution"), therefore, electronic meters can be designed to withstand higher levels of mechanical stress. Meters can be placed outdoors, exposed to the environment, in conditions and temperatures that can range with the seasons and, depending on the latitude, can reach extreme values. While it is true that electronic components are sensitive to temperature variations, these can be easily taken into account and compensated.

Finally, the high integration (reduced component count) and small packages typical of modern electronic devices make the electronic solution smaller and more reliable than the mechanical/electromechanical equivalent.

1.2 IMPROVED ACCURACY

Meters are classified in terms of the accuracy of their measurements.

It is typical, for example, for a mechanical energy meter to have an accuracy of better than 2%. By comparison, an average electronic meter may have an accuracy better than 0.8%, while some will offer accuracy specifications of 0.5% and even 0.2%, meeting for example, the more stringent American National Standard (ANSI) C12.20-2002 specifications.

The accuracy of MCU or DSC-based designs may be specified by software parameters that can be easily modified as requested by the application (upon installation) while maintaining a single common hardware platform. This allows for a streamlined production and economy of scale, both for the utility and meter manufacturer, as the same product can be deployed in different regions and simply updated in the field.

1.3 NONLINEAR LOADS AND LOW-POWER FACTORS (ENERGY METERS)

Most electromechanical energy meters are designed on the simple assumption that their load (the user application) is of a resistive nature (lights, heating elements and so on), but today, this is increasingly becoming a wrong assumption. The proportion of reactive (motors can account for up to 40% of total electricity usage) and nonlinear loads is constantly growing, posing a burden on the electricity suppliers. Traditional meters cannot adequately measure the energy consumption of systems with low-power factors. Electronic meters can easily provide indication of active/reactive power, and power factor instantaneous values, both alerting the user and providing the basis for a tariff system that takes power factor into consideration.

1.4 EASE OF CALIBRATION

As mentioned above, temperature variations can be easily compensated in electronic solutions, but similarly, any other mechanical/physical variation can be taken into account. Electronic meters can use several technologies to provide nonvolatile memories (EPROMs, EEPROMs, Flash, etc.) to store corrective/calibration parameters.

These parameters can be periodically reviewed and updated (in the field) as necessary to ensure that the required accuracy of the meter is maintained over time.

1.5 ANTI-TAMPERING PROTECTION

Electronic meters can use several, simple methods to detect tampering and theft.

Particularly in the case of energy meters, it is possible to detect a number of "typical" conditions. For example:

- · Asymmetrical loads (closing the loop with the ground to avoid metering)
- Temporary meter disconnect (or bypassed)
- Use of permanent magnets to saturate current transformers or stop the counter
- Vandalism

Upon detection of these attacks, the electronic meter can, in some cases, adopt specific "work arounds", or simply raise a flag, and if connected to a reading network (see **Section 1.6 "Automated Meter Reading**"), send an immediate alert to the utility company.

1.6 AUTOMATED METER READING

Considerable savings can be achieved by the utility companies by removing the need for a visual inspection of the meter at each billing term. The process is labor intensive, prone to (human) error and a source of inconvenience for the user when the meter is actually located inside the user premises. Several technologies are currently in use to achieve automated meter reading of electronic meters or to retrofit existing mechanical/electromechanical meters.

Electronic meters can read and communicate automatically through mechanisms such as:

- Infrared short-range infrared LED through the faceplate of the meter
- Radio Frequency (RF) short and long-range
- Data Modem via a telephone line
- Power Line Carrier (PLC) short to medium range
- Serial Port (RS-485)
- Broadband

Part of the advantage of automated reading can be obtained simply by communicating with a handheld device (via infrared, or RF, up to several hundred feet away). While this does not eliminate the need for an operator to visit each location, it insures that the readings are accurate and speeds up the process considerably.

In another scenario, in a multi-tenant building, multiple meters may be connected to an RS-485 network and read from a single point, again achieving gains in terms of speed and accuracy.

1.7 SECURITY

As the metering process automation increases, so does the need for secure communication technology. Privacy and integrity of the data being collected by the utilities is of great importance. Microchip solutions include advanced cryptographic algorithms, such as triple DES and AES (up to 256-bit keys) for data encryption, as well as low-cost proprietary solutions (KEELOQ[®] security ICs) for user authentication and access control.

1.8 ADVANCED BILLING

There are two fundamentally new billing technologies that are made possible by the implementation of electronic meters: time-of-use and prepay.

1.8.1 Time-of-Use

Time-of-use refers to different tariffs for the use of the same utility (e.g., electric energy) at different hours of the day or day of the week. This technology allows the utility companies to shape the demand in order to optimize the utilization of the available capacity throughout the day. Higher rates can be charged during the peak hours (and days of the week), encouraging the user to make a more rational (and ultimately efficient) use of the resources.

Electronic meters can incorporate inexpensive Real-Time Clock (RTC) and Calendar (RTCC) circuitry to keep track of utility usage in real time.

1.8.2 Prepay

Prepay technology is designed to reduce the financial cost of payment collection for the utilities. The user is allowed to purchase finite amounts of the service ahead of time and receives credits that are typically charged on smart or magnetic cards.

The meter in this case, coupled with a card reader, acts as a gate controlling the delivery of the service (gas, water, heat or electricity).

NOTES:



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Chapter 2. Types of Meters

2.1 GAS AND WATER

Gas and water meters use positive displacement flow meters. This means they measure the number of times a unit volume of the fluid moves through the meter. With each unit volume of fluid, a shaft or magnet is rotated one revolution. The revolutions can be easily converted to an electrical pulse train and counted by a microprocessor. Gas and water flow meters only differ in the mechanical design due to the differences in pressure and viscosity of the working fluids. Typically, a household gas meter is much larger than the water meter at the same household. Pulse counting can be accomplished on any digital input of a microcontroller, but it may be appropriate to attach the pulse input to an interrupt pin, or to a timer/counter pin, in an effort to minimize power by using Sleep mode as often as possible. Low power is a major concern with gas and water meters because electricity is generally not wired to the locations of these meters.

2.2 HEAT METERS

Heat is billed by the number of British Thermal Units (BTU) or Kilowatt Hours (kWh) that are delivered to a location. This is determined by measuring the flow of hot water through a radiator and by measuring the input and exit water temperature. Measuring the water flow has been discussed above. The new feature is the temperature sensing. Temperature sensing can be accomplished in a variety of ways. Generally the trade-off is between interfacing simplicity, linearity and operational range. The most common sensors used in heat metering are Resistance Temperature Detectors (RTD). RTDs are typically used for the temperature sensor pair, as they are easily matched and highly accurate, providing temperature measurements of tenths of a degree. These devices are relatively inexpensive, but must be linearized over the range they will be used. Linearization can be easily accomplished with software running in a microcontroller. Once the temperature and flow data has been collected, some mathematics must be performed to determine the amount of radiated heat used.

2.3 ELECTRICITY METERS

Traditional electricity meters provide a measurement of the number of kilowatt hours that have been consumed by a customer. To encourage more efficient use of electricity, utility companies would also like to measure the power factor of the load, and time of electricity consumption, among other things. Mechanical meters are good at measuring linear loads; however, many of the loads today are anything but linear. Light dimmers, refrigerators, washing machines and dryers and HVAC, to name a few, provide a significant nonlinear load to the meter. To build an electronic meter that can measure electricity requires a current sensor and a voltage sensor. Determining the power factor requires a more complicated measurement, but essentially the same two sensors. The number of sensors must match the number of electrical phases in the system. These sensors and supporting electronics have been integrated into specialized ICs that take much of the effort out of building an electricity meter and accurately measure the nonlinear component.

NOTES:



INTRODUCTION TO UTILITY METERING TUTORIAL

Chapter 3. Parts of a Meter

3.1 TIMEKEEPING

From the beginning, both the utility provider and customer must have a fair and equitable system, and accurate timekeeping is paramount for this requirement. For example, modern electricity meters are built to varying specifications and requirements. One category of power meters is required to log multi-rate energy usage, to track the energy consumed and the time of day so the power companies can bill correctly. Multi-rate meters must record this switching from one rate to another very accurately.

Looking at this from another perspective, keeping track of the electricity used, it is possible to determine where the greatest opportunity for energy savings lies. By keeping track of this usage for a period of time, high energy use areas can be identified. Therefore, employing some form of timekeeping in electronic meters is required.

Microchip offers a wide range of low-power 8 and 16-bit microcontrollers (MCUs) with hardware and software Real-Time Clock (RTC) support features. These features, combined with a conventional 32,768 Hz crystal connected to the device, yield an effective RTC in time-of-use metering. Periodic clock update/synchronization can be performed remotely should the need arise.

Table 4.5 in **Chapter 4.** "**Microchip Solutions**" provides a list of reference material which demonstrates Real-Time Clock implementations on Microchip's MCUs.

3.2 SENSOR

3.2.1 Gas and Water Meter Sensors

Gas and water meters measure the volume of fluid flowing through a pipe. They typically employ a mechanical method of measurement known as the "volumetric rotary piston principle", where the gas, or water, flowing through the meter drives a circular piston, or baffle, in an eccentric (not perfectly circular) path around a measuring chamber, with each revolution representing a known quantity of fluid. The movement of the turning chamber is translated to a turning shaft, or electrical pulse, which can then be measured by a mechanical dial or electronic controller.

Figure 3-1 illustrates the mechanics of a typical water meter.



FIGURE 3-1: WATER METER

3.2.2 Heat Meter Sensors

Heat meters are installed directly in the pipe system and therefore, permit an exact physical measurement of the heat. Heat consumption is calculated from the difference between supply and return temperature of the heat medium, as well as the flow rate. It is displayed in BTU or kWh.

Thus, two types of sensors are required in the system: a temperature sensor pair capable of indicating small differences in temperature; and a flow sensor capable of measuring water flow through the pipe.

Resistance Temperature Detectors (RTD) are typically used for the temperature sensor pair, as they are easily matched and highly accurate, providing temperature measurements of tenths of a degree.

3.2.3 Electricity Meter Sensors

Most electricity meters measure current (amperes) and voltage (volts) and calculate the product of these values to determine electrical power (watts). Power integrated over time then provides the energy that is used (typically expressed as watt hours or joules).

There are two common methods for sensing the amount of current flowing in a wire. The first method uses a shunt resistor to directly measure the amount of current, while the second method uses an isolation transformer that indirectly measures current through the secondary winding.

3.2.3.1 DIRECT CONNECTION VERSUS TRANSFORMER

Choosing to measure current or voltage directly, or through a transformer, is a major decision in the design of the analog front end. Low-cost meter designs will use direct connect methods for reduced cost with a few trade-offs. Direct connect type meters are connected directly to the power lines, typically using either a current sensing shunt resistor on the current input channel and/or a resistive voltage divider on the voltage input channel.

A direct connect meter scheme on both current and voltage input channels is shown in Figure 3-2. The meter has a hot ground where all AC measurement signals are biased. The MCP3905 device has an input structure allowing negative signals up to 1V below ground.



FIGURE 3-2: DIRECT CONNECT METER SCHEME

The current sensing shunt is a small piece of metal, typically made of manganese and copper, that is manufactured with a variety of mounting holes and wired connections. It acts as a simple resistor with the voltage drop across it proportional to the current flowing through it. Shunt resistances are typically between 100 $\mu\Omega$ and 500 m Ω . The shunt is ultimately limited by its own self-heating and is typically not used in meter designs with large maximum current requirements (IMAX > 100A).

With power dissipation requirements usually at 2W for single-phase residential meters, a direct connect meter using a current sensing shunt must have ultra-low resistivity to meet the power requirements. Using a meter specified for 80A maximum current as an example, the 250 $\mu\Omega$ would consume I² * R or 80² * 250e-6 or 1.6W. This leaves 400 mW for the remaining meter power (microcontroller, LCD, and so on).

The power consumption that the shunt brings to a meter design is poor compared to that of a Current Transformer (CT). Lower value shunts (< $250 \ \mu\Omega$) offer less power consumption, but the resulting VRMS signal going to the ADC can be difficult to measure using lower resolution ADCs and the inductance and resistance combination can require special compensation or calibration.

FIGURE 3-3: CURRENT SENSING SHUNTS



The Current Transformer (CT) is another choice for sensing current when designing an energy meter. This device offers isolation through transfer of current from the primary to the secondary core. The CT can handle higher currents than the shunt and also consumes less power.

The nonlinear phase response of the CTs can cause power or energy measurement errors at low currents and large power factors.

Advantage	Shunt	Current Transformer
Meter cost	Х	
Meter can handle higher currents (greater than 100A)		х
Meter power consumption		Х
Fewer accuracy issues (saturation, phase response at high-power factors)	X	

3.3 DISPLAYS

The most common types of displays used in metering applications are the Liquid Crystal Display (LCD) and the Light Emitting Diode (LED). These displays are preferred for their extremely low cost and power consumption requirements.

Both display types are available in seven-segment, alphanumeric and matrix format (see Figure 3-4).

The following sections briefly discuss these displays types and present selected PICmicro[®] microcontrollers that best interface with them.





3.3.1 LED

LEDs are relatively efficient light sources, as they produce a significant amount of light when directly polarized (at relatively low voltages: 1.2-1.6V), and a current of a few milliamperes is applied.

PICmicro MCUs feature a very powerful I/O pin driver structure capable (when configured as an output) of sourcing up to 25mA (drive high) and sinking an equal amount (drive low).

This allows the PICmicro devices to efficiently control LED displays by directly driving the necessary voltages and currents required by the most inexpensive and widely used types.

Since PICmicro MCUs are CMOS devices, their I/O structures can be paired and grouped to allow even higher currents to be controlled, up to a limit of 100 mA per port and a total of 200 mA per device. These are typical values applicable to most PICmicro devices (refer to the specific device data sheet for actual values).

Each I/O pin can also be configured as an input, and as such, presents an extremely high impedance (typically in the range of several megaohm).

Technical brief, *TB029 "Complementary LED Drive*", presents an interesting application of the I/O driver flexibility, illustrating how it is possible to drive multiple LEDs with a minimum number of I/O pins. To reduce I/O count, LEDs are multiplexed in a matrix.

FIGURE 3-5: EXAMPLE OF LED PLACEMENT RESULTING IN 12 LEDS FOR 4 PINS



The complementary LED drive method listed in TB029 illustrates how to increase the number of LEDs while using fewer I/O. Application note, *AN234 "Hardware Techniques for PICmicro® Microcontrollers"*, looks at different ways of driving multiple LEDs. Application note, *AN529 "Multiplexing LED Drive and a 4x4 Keypad Sampling"*, describes a method to sample a 4x4 keypad matrix while directly driving four, seven-segment LEDs. See Table 4-5 in **Chapter 4. "Microchip Solutions"** for these and additional resources.

3.3.2 LCD

LCD displays utilize two sheets of polarizing material with a liquid crystal solution between them. A voltage applied across the liquid crystal causes the individual molecules to change their alignment so that light cannot pass through them. Each crystal, therefore, is like a shutter, either allowing light to pass through or blocking it.

Each LCD segment can represent a segment in a seven-segment configuration similar to an LED display, an individual pixel in a matrix, or a complete icon in a custom designed display.

3.3.2.1 LCD DISPLAY TYPES

Because of the chemical properties of the liquid crystals, it is necessary to periodically alternate the polarity of the voltage applied across each segment. The presence of a DC component can damage the material and therefore, quickly render the display unusable.

The multiplexing schemes illustrated for the LED displays cannot be applied to an LCD display, where more complex techniques must be employed to ensure long life and good contrast of the display.

For this reason, it is common to employ dedicated LCD controllers and/or microcontroller peripherals to support LCD displays with varying multiplexing schemes (number of background connections) and therefore, varying total segment count capabilities. Table 3-2 shows examples of multiplexing schemes supported by PICmicro devices.

Multiplay Commons	Maximum Number of Segments									
	PIC16F913/916	PIC16F914/917	PIC16F946	PIC18F6X90	PIC18F8X90	Dids				
Static (COM0)	15	24	42	32	48	Static				
1/2 (COM1:COM0)	30	48	84	64	96	1/2 or 1/3				
1/3 (COM2:COM0)	45	72	126	96	144	1/2 or 1/3				
1/4 (COM3:COM0)	60	96	168	128	192	1/3				

TABLE 3-2: LCD SEGMENT MATRIX

For the larger displays (200-400 total segments or more), complete display modules (alphanumeric or graphic) are commonly made available, where the actual segment driving functionality is taken care of by on-board (or on-glass) dedicated circuitry and the connection for an embedded controller is offered as a parallel or serial port with a standardized communication protocol. See application note, *AN587 "Interfacing PICmicro® MCUs to an LCD Module"* for a description of an efficient PICmicro interface to a common LCD module.

Finally, the largest display panels (128 x 128 segments, most QVGA, VGA and higher) not only incorporate one or more controllers on-board, but also interface through a serial protocol that allows continuous refresh of each line of pixels similar to a TV signal.

It is uncommon for metering applications to make use of such complex and expensive devices, and in the following sections, we will focus on the previous two types of LCD displays.

3.3.2.2 MICROCHIP LCD SOLUTIONS

Microchip's offering of PICmicro devices with on-chip LCD driver peripherals consist of two major families of devices:

- PIC16F913/914/916/917/946 for low-cost and small to medium size displays
- PIC18F6390/6490/8390/8490 for larger displays and higher performance applications

Both are based on Flash technology and offer nanoWatt power management features; however, the number and complexity of additional peripherals offered, as well as the performance offered by the two families of devices, can vary considerably as illustrated by Table 3-3.

	Product Specifications for Selected PIC [®] Microcontrollers with Integrated LCD Module											
Device	Flash Program Memory Bytes	EEPROM Data Memory Bytes	Data RAM Bytes	I/O	Analog (10-bit)	Comparators	Serial USART/ I ² C™/ SPI™	CCP/ PWM	LCD Segments	TMR 8-bit/ 8/16-bit/ 16-bit	Pins	
PIC16F913	7168	256	256	25	5	2	I ² C/SPI AUSART	1	4x15 (60)	2-8 bit 1-16 bit 1-WDT	28PDIP 28SOIC 28SSOP 28QFN	
PIC16F914	7168	256	256	36	8	2	I ² C/SPI AUSART	2	4x24 (96)	2-8 bit 1-16 bit 1-WDT	40PDIP 44TQFP 44QFN	
PIC16F916	14336	256	352	25	5	2	I ² C/SPI AUSART	1	4x15 (60)	2-8 bit 1-16 bit 1-WDT	28PDIP 28SOIC 28SSOP 28QFN	
PIC16F917	14336	256	352	36	8	2	I ² C/SPI AUSART	2	4x24 (96)	2-8 bit 1-16 bit 1-WDT	40PDIP 44TQFP 44QFN	
PIC16F946	14336	256	336	53	8	2	I ² C/SPI AUSART	2	4x46(168)	2-8 bit 1-16 bit 1-WDT	64TQFP	
PIC18F6390	8192	_	768	50	12	2	I ² C/SPI EUSART AUSART	2	4x32 (128)	3-16 bit 1-8 bit 1-WDT	64TQFP	
PIC18F6490	16384	_	768	50	12	2	I ² C/SPI EUSART AUSART	2	4x32 (128)	3-16 bit 1-8 bit 1-WDT	64TQFP	
PIC18F8390	8192	-	768	66	12	2	I ² C/SPI EUSART AUSART	2	4x48 (192)	3-16 bit 1-8 bit 1-WDT	80TQFP	
PIC18F8490	16384	—	768	66	12	2	I ² C/SPI EUSART AUSART	2	4x48 (192)	3-16 bit 1-8 bit 1-WDT	80TQFP	

TABLE 3-3: LCD PIC[®] MICROCONTROLLERS

3.3.2.3 MID-RANGE LCD SOLUTIONS

The PIC16F913/914/916/917/946 LCD devices provide a strong balance between price and LCD pixel count. The PIC16F913/914/916/917/946 feature set includes:

- 60-96 LCD segments
- 7/14 Kbytes Flash program memory
- 256 bytes EEPROM data memory
- Low-power nanoWatt Technology
- 35 easy-to-learn instructions
- 32 kHz to 8 MHz internal oscillator for flexible clock system, fail safe clock
- Integrated analog peripherals, such as A/D converters and comparators
- I²C[™]/SPI[™]/AUSART serial communications
- 5-8 channel, 10-bit A/D converter

See Chapter 4. "Microchip Solutions" for additional information.

3.3.2.4 HIGH-PERFORMANCE LCD SOLUTION

Microchip's high-performance PIC18F6390/6490/8390/8490 LCD microcontrollers offer greater memory density and higher pin counts to meet the demands of more complex LCD applications. The PIC18F6390/6490/8390/8490 LCD microcontrollers provide greater pixel count, higher performance and a generous feature set. Available with 64 and 80-pin package options, the standard feature set includes:

- 128-192 LCD segments
- 8/16 Kbytes Flash program memory
- Low-Power nanoWatt Technology
- · Advanced instruction set optimized for code efficiency and performance
- 32 kHz to 32 MHz internal oscillator for flexible clock system, fail-safe clock
- · Integrated analog peripherals, such as A/D converters and comparators
- I²C[™]/SPI[™]/AUSART/EUSART serial communications
- 12 channel, 10-bit A/D converter

For LCD applications requiring high segment count and high performance, the PIC18F6390/6490/8390/8490 LCD microcontrollers offer the best in class. See **Chapter 4. "Microchip Solutions**" for additional information.

3.3.2.5 DEVELOPMENT TOOLS SUPPORTING LCD PIC MICROCONTROLLERS

The PICDEM[™] LCD board (DM163028) demonstrates the main features of the 28, 40, 64 and 80-pin LCD Flash PIC microcontrollers. It is populated with the PIC18F8490. Other devices are supported via a transition socket. A sample LCD glass display is included for custom prototyping.



FIGURE 3-6: PICDEM™ LCD DEMONSTRATION BOARD

Visit the Microchip web site (www.microchip.com/lcd) for complete information on LCD-specific emulation and development products.

3.4 COMMUNICATIONS

Communications are often used in electronic meters to configure parameters in the meter and transfer stored data to a host. The methods are either wired (telephone, power line, etc.) or wireless (IrDA[®], cellular, etc.). This section will take a brief look at some of the technologies for communicating with meters.

Once you have a communications port, the designer needs to protect the contents of the meter. The communications software should have several levels of security. For example, first, the software should have reasonable means to allow only authorized personal the ability to read the contents. Second, the meter should have several levels of access. For instance, one level allows the meter to be read, the second level allows the meter to be read and cleared, the third level allows configuring parameters inside the meter, and so on.

Microchip has many encryption routines available to facilitate secure communications over an exposed link. The application notes include: *AN583 "Implementation of the Data Encryption Standard Using PIC17C42"* (DES), *AN821 "Advanced Encryption Standard Using the PIC16XXX"* (AES) and AN953 *"Data Encryption Routines for the PIC18"* (AES, XTEA, SKIPJACK, pseudo-random XOR). There are also asymmetric (SW300055) and symmetric (SW300050) libraries for the dsPIC[®] DSC products. Refer to Table 4.5 in **Chapter 4. "Microchip Solutions"** for information on these and other technical resources.

3.4.1 Wired

3.4.1.1 TELEPHONE

The telephone line is probably the most widely deployed "network" on earth. It is most commonly used with energy meters because the entry point into the house for the telephone line is most often near the energy meter itself. Water meters are more likely to be located near the street and gas meters are typically on the opposite side of the house from the energy meter and would therefore, require some additional infrastructure to use the telephone line.

Telephone lines require a modem to communicate. Embedded modems exist with baud rates from 1200 to 56K. The interface between the microcontroller and the embedded modem is a simple serial port and some status and control lines. The embedded modem will typically communicate with a standard AT command set which is easy to implement in the microcontroller. Companies such as TDK Semiconductor, Xecom, Zoom and Wintec offer modem modules and discrete modem ICs for use in embedded systems.

At first glance, the telephone line seems to be a good solution. However, the wide deployment of modems in metering requires local access numbers for the modem to dial out. The property owner may not appreciate long distance phone calls made by the meter. It also requires infrastructure to be in place to handle these incoming phone calls and communicate with the meters. Another requirement is that the modem must be able to detect if another handset becomes active and terminate the phone call. This is important for emergency dialing.

Microchip offers a couple of resources for telephone communications. The application note, *AN731 "Embedding PICmicro[®] Microcontrollers in the Internet"*, shows the connection of a microcontroller to an embedded modem (V.21 to V.23). Microchip also offers a soft modem design using the dsPIC30F family of devices. It offers various protocols and baud rates from V.21 to V.42.

Introduction to Utility Metering Tutorial

The dsPICDEM.net[™] Development Board (Figure 3-7) provides a basic platform for developing and evaluating Internet connectivity based on soft modem solutions that use dsPIC30F6014 16-bit digital signal controllers.



FIGURE 3-7: dsPICDEM.net[™] DEVELOPMENT BOARD

3.4.1.2 POWER LINE

This technology uses AC power lines as the communication medium. The power line communication module is typically located in the energy meter to facilitate the connection to the high-voltage AC power lines. This technology should not be confused with X-10[®]. X-10 is designed to operate within a home, not for communication outside the home. The main challenge is for the data to pass through transformers that are used to convert the extremely high voltage present on power lines (kilovolts) down to the 240 VAC that is delivered to your house. These transformers act like a filter and the technology to transmit data through them is not trivial and requires a spread spectrum or similar type of communication method. Air conditioners and refrigerators generate quite a lot of noise on the power lines and the modem must be able to transfer data reliably in this environment.

Power line communications require infrastructure to be in place to collect the incoming data from houses, typically upstream from the transformers. These collection "stations" will then typically communicate via telephone lines back to a data storage facility. Power line modems are not yet mainstream because of the technological hurdles, but companies such as AMRTech, Hunt Technologies and DCSI/TWACS offer solutions.

3.4.1.3 OTHER WIRED TECHNOLOGIES

Other wired technologies are present, such as cable modems and Ethernet, but have not yet found their way into metering, primarily because they require the property owner to subscribe to a service and additional wiring to be added to the building. When this technology is feasible for metering, Microchip will be prepared with several stand-alone and integrated hardware Ethernet solutions and a free TCP/IP stack to help customers develop applications. WiFi also falls into this category as it will need a wired Ethernet counterpart to connect and transfer data.

3.4.2 Wireless

3.4.2.1 ZigBee™/IEEE 802.15.4 (SHORT RANGE WIRELESS)

ZigBee is the next up and coming wireless standard. Designed for slower data rates (typically 20-40 kbps) and short distances (<100 meters), ZigBee is well suited for connecting the energy, gas and water meters together. The ZigBee protocol stack uses IEEE 802.15.4 wireless transceivers that are now becoming widely available from Chipcon, Atmel, Freescale, ZMD and Microchip. IEEE 802.15.4 has three frequency bands, allowing operation in all regions of the world: 2.4 GHz for worldwide applications, 868 MHz for Europe and 915 MHz for the Americas.

A ZigBee enabled meter would require the IEEE 802.15.4 transceiver and a microcontroller running a ZigBee protocol stack. Microchip offers a 2.4 GHz transceiver and a free ZigBee protocol stack. Refer to application note, *AN965 "Microchip Stack for the ZigBee*[™] *Protocol"* for additional information.

The PICDEM[™] Z demonstration kit is an easy-to-use ZigBee technology wireless communication protocol development and demonstration platform. The demonstration kit includes the ZigBee protocol stack and two PICDEM Z boards, each with an RF daughter card. The demonstration board is also equipped with a 6-pin modular connector to interface directly with Microchip's MPLAB[®] ICD 2 in-circuit debugger (DV164005). With MPLAB ICD 2, the developer can reprogram or modify the PIC18 MCU Flash memory and develop and debug application code, all on the same platform. Microchip MPLAB IDE software is available for download on the Microchip web site at no charge.



FIGURE 3-8: PICDEM[™] Z MOTHERBOARD AND RF CARD CONNECTION

3.4.2.2 Z-WAVE[®]

Z-Wave is a proprietary protocol developed by Zensys[™], operating at a data rate of 9.6 kbps and a frequency of 868 MHz or 908 MHz. Z-Wave has been widely accepted in home control applications such as lighting, appliance and HVAC control. It is similar in features to ZigBee and would be ideal for connecting water, gas and energy meters together. There are currently no embedded modules other than those developed by Zensys. They also offer single chip devices as well.

3.4.2.3 INFRARED (SHORT RANGE WIRELESS)

The other wireless technology that is often overlooked is infrared. Infrared is currently used in many energy meters to configure and transfer data. It follows several standards. ANSI C12.18 is the standard that sets the physical dimensions of the connector housing. The IEC 62056 specifications provide the protocol and tables for the infrared communications. The application note, *AN243 "Fundamentals of the Infrared Physical Layer"*, provides a good description of the physics behind infrared communications.

This type of infrared port is used today in meter reading. The meter reader walks up to the energy meter, places the probe on the connector and then reads out the stored data inside. The device is usually some type of handheld PDA, or similar device, running custom software to read the data. One example is GE's MeterMate[™] software.

Figure 3-9 shows a probe that connects a PC or PDA to the energy meter connector. This connector is held against the meter as shown by the dashed lines.



FIGURE 3-9: ENERGY METER CONNECTOR PROBE

3.4.2.4 PROPRIETARY SHORT RANGE WIRELESS

The market is currently flooded with a plethora of short range wireless devices. These devices cover the 314, 433, 868 and 915 MHz frequency bands and bit rates up to 100 kbps. Companies such as Chipcon, Micrel and Microchip offer stand-alone transceivers and integrated solutions (transceiver plus microcontroller). The challenge with these types of designs is that the protocol stack is left up to the designer to create. This turns a potentially simple application into two applications: the main application and the RF protocol. Fortunately, some manufacturers have developed simple protocols to reduce the engineering effort.

3.4.2.5 GSM/GPRS/CDMA CELLULAR WIRELESS

Another viable technology for metering is GSM/GPRS/CDMA modems. These are ideal for remote metering applications. For instance, a water pump used to irrigate crops may need both a water meter and an energy meter. Because of the remote nature of the pump, a cellular-based modem may be needed to relay the information to a monitoring station. It is impractical to send a person to read the meter because of the long distance and travel time to reach the site. This easily offsets the initial cost of the modem hardware. Typically, a utility company will have many of these types of meters and will be able to negotiate a discount on the monthly service charges for the modem.

Embedded cellular modems will most often have a simple serial interface and will use the standard AT command set for configuring and making phone calls. Companies such as Motorola, Sierra Wireless and Falcom, among others, all manufacture GSM/GPRS and CDMA-based modems for embedded systems.

3.5 LOW POWER

Another very important part of any metering application is proper low-power management and system robustness in the event that the application loses it primary source of energy. To better understand these various requirements, the primary energy source for the metering system must be identified. Utility meters are typically powered in one of two ways: from an AC outlet, which is normally the case for electrical power meters, or by a DC power source, such as a small battery, as is the case for water meters where access to an AC mains outlet is not always available or deemed safe.

Next, we will look at each of these two cases in more detail as well as consider some of Microchip's key device features that are well suited for these types of applications. Keep in mind that almost the exact same device features used in AC regulated source applications can also be used in unregulated DC source applications.

3.5.1 Meters Powered by an AC Regulated Source

AC powered meters have an almost unlimited pool of energy (typically limited to a maximum of 2 watts) available from a standard utility outlet. For utility meters powered from AC mains, smart power management is more an issue of managing the integrity of the overall system when the metering unit loses it primary source of energy. The user might still be using gas even if the AC mains is turned off temporarily, or the unit was busy storing critical information in nonvolatile memory, or downloading information to the utility company when the unit lost power.

AC regulated metering systems use either a transformer or a transformerless power supply. To reduce the cost and size of the application, it is sometimes desirable to provide a power supply to a meter through a simple reactive/resistive partition transformerless circuit. This can be particularly desirable when the meter is already connected to the AC mains (as in the case of energy meters). However, in this arrangement, the amount of current supplied by the typical circuit (see Figure 3-10) can be fairly limited to avoid the use of large (bulky power) components. Proper power management can help reduce the average power consumption of the applications, therefore, reducing the size and weight of the power supply components.

FIGURE 3-10: CAPACITIVE POWER SUPPLY WITH SAFETY CONSIDERATIONS



To compensate for the loss of the AC mains, the design engineer normally adds some type of backup power system to the metering design. This backup system can either be a large capacitor, a supercapacitor or even a small, lithium backup battery. Under these conditions, the power consumption of the whole system, and particularly that of the microcontroller, becomes more crucial.

Some typical challenges the design engineer is faced with are:

- · How long should the system stay active under these conditions?
- What is the standby current of the complete system?
- What is the active current of the system?
- How to optimize power consumption, quickly adapting the device performance (clock speed) to the application demand?
- Reliable operation from an unregulated battery power
- · Reliable operation in a transformerless power supply system
- Increased reliability by integrating Brown-out Reset, Watchdog Timer and Fail-Safe Clock Monitor circuits

Better dynamic optimization of the power consumption of the microcontroller in the metering application can be crucial as the workload varies considerably as different tasks are executed. In the typical metering example, shown in Figure 3-11, we see the following tasks:

- Real-Time Clock update a very light task that can be scheduled to happen regularly once every second.
- A counter increment another example of a very light task that can be triggered by an interrupt as a pulse from the metering mechanism is received (output of the MCP3905 in an energy meter, or pulse from the liquid/gas displacement measuring mechanism in a gas/water meter).
- Occasionally the MCU can be called to perform a more computationally intensive kind of activity. For example, for communicating via IrDA[®] or RS-485 for automated meter reading, or simply to update the display or perform some other billing/logging related function.

All new PICmicro microcontrollers (both in the PIC16 and PIC18 families) offer Microchip's nanoWatt power management technology. This technology has a particularly compelling set of useful features for utility metering designs as they address both critical power consumption and robustness issues. In fact, nanoWatt devices not only offer among the industry's lowest power consumption figures and operate over a very wide voltage range, they also offer an extremely flexible set of smart power management features.



FIGURE 3-11: nanoWatt POWER MANAGEMENT

nanoWatt technology devices offer up to seven operating modes, giving meter designers the ability to quickly switch to the most appropriate clock source at each point in time. In the example above, an optimal power management strategy might utilize the following scheme:

- Keep the MCU in Sleep mode to reduce the power consumption during quiet periods
- Leave the timer used by the RTC function active and operating (using the secondary oscillator at 32 kHz as shown in Figure 3-12)

FIGURE 3-12: TMR1 OSCILLATOR USE FOR RTC



- Periodically wake-up to execute any light task at low speed (reusing the same secondary oscillator already running for a fast and efficient wake-up)
- Upon detecting that a more advanced functionality is required, the primary oscillator can be turned on to execute the most intensive tasks (trading faster execution times for short bursts of higher power consumption)

Now, given the power consumption figures (see Figure 3-13), it is possible to compute the estimated average power consumption of the application by weighing each task with the percentage of time the MCU spends executing it and the power consumption of the chosen mode of operation. Combining that with the fact that most PICmicro devices with nanoWatt technology include up to nine selectable oscillator options (including four Crystal modes, two External Clock modes, two External RC Oscillator modes and an internal oscillator block that provides multiple clock frequencies under software control), the flexibility offered by this technology is almost unlimited.

FIGURE 3-13: POWER MANAGEMENT EXAMPLE



3.5.2 Meters Powered by a DC Unregulated Source

DC-powered meters, such as a water or gas utility meter, normally run off of a small unregulated battery source. In these types of systems, the standby, or inactive current of the system, becomes a very critical part to the overall system power budget. PICmicro devices with nanoWatt technology features, such as low standby current, fast oscillator start-up modes and various software controlled oscillator modes, help to optimize the maximum performance when needed but also help to reduce current consumption. In most battery-powered applications, the robustness of the complete system also relies on how the microcontroller handles low-voltage, unregulated battery supplies, as well as any noise induced events.

The large operating voltage range (typically from 2.0V to 5.5V) of PICmicro devices with nanoWatt technology allows a number of simplifications in the meter design, and offers the possibility for a further extended battery life of battery operated applications. In fact, it is possible to eliminate the voltage regulator, gaining precious extra margin on battery voltage, and extending the battery use to a deeper level of discharge. Microchip also offers various stand-alone analog devices that can be used for supervisory or smart battery management in the systems.

Increased reliability is crucial in all metering applications, but even more so in unregulated power supply units. There are three key circuits that are integrated in all Microchip nanoWatt devices, in addition to the more traditional Watchdog Timer, that are designed to offer a superior level of reliability:

- **Brown-out Reset (BOR)**: This programmable device option is used to generate a Reset of the MCU when the power supply falls below a threshold value, preventing the device from operating erroneously outside the specified voltage range of the device.
- Low-Voltage Detect (LVD): This programmable device option can alert the MCU by generating an interrupt when the power supply level falls below a predetermined value (typically set slightly higher than the BOR). This can be used to anticipate the intervention of the Brown-out Reset circuit and save critical operating parameters in nonvolatile memory for safe recovery later.
- Fail-Safe Clock Monitor (FSCM): This is the most advanced feature of the three. Not to be confused with the Watchdog Timer, the Fail-Safe Clock Monitor is composed of an additional circuit that verifies the correct functioning of an external clock source. Should it detect that, for any reason, the external clock source failed, the MCU clock will be promptly switched to an internal oscillator that will allow the MCU to continue operating, bringing the application to a "safe" failure mode (storing critical parameters in nonvolatile memory for example) and alerting the user.

3.6 CALIBRATION

3.6.1 Gas and Water Meter Calibration

The mechanism for measuring the amount of gas or water flowing through a meter is mechanical in nature; that is, it measures a known quantity of water or gas through mechanical means, as discussed in **Section 3.2.1** "**Gas and Water Meter Sensors**". A meter design may implement a method to adjust for minor variations in this mechanism.

If the human interface is implemented as an electronic display, a microcontroller can be used to compensate for small variations in the measuring mechanism provided that those variations are predictable and consistent.

Most countries have a standards document that specifies the accuracy requirements for residential and commercial meters. An independent laboratory can test the accuracy of a meter under controlled conditions.

3.6.2 Heat Meter Calibration

The calibration of a heat meter requires determining the accuracy of three components of the system: flow sensor, temperature sensor pair and energy calculator, each of which has maximal permissible errors as specified in international standards EN1434-1 Heat Energy Meters and OIML R75-1 Heat Meters.

EN1434-1 indicates a maximum error of about 2% for the flow meter (*Ef*), 0.5% for the temperature sensors (*Et*, measured as differential temperature between the two sensors), and 0.5% for the energy calculation (*Ec*). The total error is then Et = Ef + Et + Ec.

Manufacturers of temperature sensors and flow sensors offer products that have been tested and calibrated to meet EN1434-1, and will indicate this information in their product data sheets.

As a system, calibration of these subunits can be a challenge, and is often carried out by an independent laboratory with equipment that has been specifically designed for these types of measurements.

3.6.3 Electricity Meter Calibration

Electricity meters require calibration due to variation in voltage references, sensor tolerances or other system gain errors. When measuring AC power only, a single-point calibration can be used. This single-point meter calibration removes any gain errors in the system due to shunt tolerances, VREF tolerances or any other error.

The most basic and trusted method of energy meter calibration uses a resistor divider network with "calibration shorts" (Figure 3-14) on the Printed Circuit Board (PCB) to short circuit resistors in the chain.

The network has a series of weighted resistors with shorting jumpers for each. In addition, there are two extra 330K resistors in front of the calibration network. These two resistors will always be present and are part of a scheme to maintain a 3 dB point for phase matching.

The resistors shown in Figure 3-14 are on the back side of the PCB. A soldering iron can be used to quickly test each resistor and calibrate the meter.



To calibrate the meter, test each resistor once for a frequency that is either too high or too low than the expected calibration frequency. As an example, Network 2 shown in Figure 3-15, will begin on the high frequency and calibrate downwards towards the slower frequency, speeding up the calibration process.

The calibration resistors (RC1 to RCN) are binary weighted around the meter-specific calibration range. A typical calibration network for a 1% accuracy would have ten resistors, the smallest resistor being 1% of the total calibration chain (RC1 to RCN) for 10-bit resolution.

It is important to note that the resistor network populating the cutoff frequency or -3 dB point must match the other channels. The anti-aliasing filter must stay the same regardless of how many calibration shorts are closed. This is ensured by dominating the total chain resistance with either one or two dominated by the two largest resistors, marked RF1 and RF2 in the circuit. The exact value of the cutoff frequency is a trade-off between low phase delay in the signal pass band and high noise attenuation around the sampling frequency.





FIGURE 3-14: CALIBRATION SHORTS FOR RESISTOR NETWORK

3.6.3.1 PARASITIC INDUCTANCE CALIBRATION

For shunt values less than 250 $\mu\Omega$, parasitic inductances can cause problems in the anti-aliasing network and require calibration or compensation.

The anti-aliasing filter design of the analog front end is intended to keep any noise near our sampling frequency (1 MHz) attenuated below our accuracy threshold (40 dB). The most prevalent noise in this bandwidth comes from AM radio, or other RF signals, coupled through the power transmission lines. When a shunt is directly connected to this input network, the frequency response of the shunt must be included in the analysis of the input network.

A second RC low-pass filter is used to cancel the effects of the shunt inductance. Note that there is now only -10 dB of attenuation above the zero frequency, caused by the shunt (Figure 3-16), which is around 10 kHz. The exact frequency of the pole and the values of the RC for specific shunt inductance and resistances can be calculated using a prepared Microsoft[®] Excel spreadsheet available at www.microchip.com/meter design.



FIGURE 3-16: CALIBRATING OUT ANTI-ALIASING FILTER PROBLEMS CAUSED BY PARASITIC SHUNT INDUCTANCE



INTRODUCTION TO UTILITY METERING TUTORIAL

Chapter 4. Microchip Solutions

4.1 GAS



TABLE 4-1: RECOMMENDED DEVICES

	Flash	Data Memory			10 1-14	Capture	MS	SSP	Time	
Device	Program (bytes)	RAM (bytes)	EEPROM (bytes)	I/O	ADC	Compare PWM	SPI™	MI ² C	8/16-bit	Segments
PIC18F8490	16,384	768		66	12	2	1	1	1/3	4x48 (192)
PIC18F6490	16,384	768	_	50	12	2	1	1	1/3	4x32 (128)
PIC16F946	14,336	336	256	53	8	2	1		2/1	4x42 (168)
PIC16F917	14,336	352	256	36	8	1	1		2/1	4x24 (96)
PIC16F916	14,336	352	256	25	5	2	1		2/1	4x15 (60)
PIC16F877A	14,336	368	256	33	8	2	1		1/2	-
PIC16F876A	14,336	368	256	22	5	2	1		2/1	-
PIC16F77	14,336	368	-	33	8x8 bits	2	1	Ι	2/1	
PIC16F76	14,336	368	_	22	5x8 bits	2	1		2/1	
PIC16F72	3,584	128	—	22	5x8 bits	1	1	-	2/1	_
PIC16F648A	7,168	256	256	16	_	1	_	_	2/1	_

Display: AY0438

Op Amps: MCP6141, MCP601 Digital Potentiometers: MCP4021 Voltage Supervisors: MCP131, MCP100 Serial EEPROMs: Product Portfolio

4.2 WATER



TABLE 4-2: RECOMMENDED DEVICES

Flash		Data	Memory		10 1-11	Capture	MSSP		Timoro	
Device	Program (bytes)	RAM (bytes)	EEPROM (bytes)	I/O	ADC	Compare PWM	SPI™	MI ² C	8/16-bit	Segments
PIC18F8490	16,384	768	_	66	12	2	1	1	1/3	4x48 (192)
PIC18F6490	16,384	768		50	12	2	1	1	1/3	4x32 (128)
PIC16F946	14,336	336	256	53	8	2	1		2/1	4x42 (168)
PIC16F917	14,336	352	256	36	8	1	1		2/1	4x24 (96)
PIC16F916	14,336	352	256	25	5	2	1		2/1	4x15 (60)
PIC16F877A	14,336	368	256	33	8	2	1		1/2	
PIC16F876A	14,336	368	256	22	5	2	1		2/1	
PIC16F77	14,336	368		33	8x8 bits	2	1		2/1	_
PIC16F76	14,336	368	-	22	5x8 bits	2	1	_	2/1	_
PIC16F72	3,584	128	_	22	5x8 bits	1	1		2/1	
PIC16F648A	7,168	256	256	16	-	1	_		2/1	_

Display: AY0438

Op Amps: MCP6141, MCP601 Digital Potentiometers: MCP4021 Voltage Supervisors: MCP131, MCP100 Serial EEPROMs: Product Portfolio

4.3 **HEAT**



TABLE 4-3: RECOMMENDED DEVICES

	Flash		Data Memory		10 54	Capture	М	SSP	Timore	
Device	Program (bytes)	RAM (bytes)	EEPROM (bytes)	I/O	ADC	Compare PWM	SPI™	MI ² C	8/16-bit	Segments
PIC18F8490	16,384	768	-	66	12	2	1	1	1/3	4x48 (192)
PIC18F6490	16,384	768	_	50	12	2	1	1	1/3	4x32 (128)
PIC16F946	14,336	336	256	53	8	2	1	_	2/1	4x42 (168)
PIC16F917	14,336	352	256	36	8	1	1	_	2/1	4x24 (96)
PIC16F916	14,336	352	256	25	5	2	1		2/1	4x15 (60)
PIC16F877A	14,336	368	256	33	8	2	1	_	1/2	-
PIC16F876A	14,336	368	256	22	5	2	1		2/1	—
PIC16F77	14,336	368	_	33	8x8 bits	2	1	_	2/1	
PIC16F76	14,336	368	-	22	5x8 bits	2	1	_	2/1	
PIC16F72	3,584	128	—	22	5x8 bits	1	1	_	2/1	—
PIC16F648A	7,168	256	256	16	_	1	—	_	2/1	_

Display: AY0438 Interface: MCP2122, MCP2120 Op Amps: MCP6141, MCP601, MCP6021 ADCs: MCP3304, MCP3208, MCP3008 Digital Potentiometers: MCP42010, MCP4021 Voltage Supervisors: MCP131, MCP100 Serial EEPROMs: Product Portfolio

4.4 ELECTRICITY



TABLE 4-4: RECOMMENDED DEVICES

Flash		Data	Memory		10-bit	Capture	MSSP		Timoro	
Device	Program (bytes)	RAM (bytes)	EEPROM (bytes)	I/O	ADC	Compare PWM	SPI™	MI ² C	8/16-bit	Segments
PIC18F8490	16,384	768	_	66	12	2	1	1	1/3	4x48 (192)
PIC18F6490	16,384	768	_	50	12	2	1	1	1/3	4x32 (128)
PIC16F946	14,336	336	256	53	8	2	1	_	2/1	4x42 (168)
PIC16F917	14,336	352	256	36	8	1	1	_	2/1	4x24 (96)
PIC16F916	14,336	352	256	25	5	2	1	_	2/1	4x15 (60)
PIC16F877A	14,336	368	256	33	8	2	1	—	1/2	_
PIC16F876A	14,336	368	256	22	5	2	1	—	2/1	
PIC16F77	14,336	368	-	33	8x8 bits	2	1	_	2/1	—
PIC16F76	14,336	368	-	22	5x8 bits	2	1	_	2/1	—
PIC16F72	3,584	128	_	22	5x8 bits	1	1	—	2/1	_
PIC16F648A	7,168	256	256	16	-	1	_	_	2/1	

Digital Signal Controller: dsPIC30F3012 Energy Measurement ICs: MCP3906, MCP3905 Interface: MCP2122, MCP2120 Display: AY0438 Op Amps: MCP6141, MCP601, MCP6021 Programmable Gain Amplifiers: MCP6S28 ADCs: MCP3304, MCP3208, MCP3008 Digital Potentiometers: MCP42010, MCP4021 DACs: MCP4821 Voltage Supervisors: MCP131, MCP100 Temperature Sensors: TCN75, TCN75A, TC77

4.5 **RESOURCES**

TABLE 4-5: RELATED APPLICATION NOTES AND TECHNICAL BRIEFS

Category	Document Number	Title
Communications	AN242	Designing an FCC Approved ASK rfPIC™ Transmitter
	AN554	Software Implementation of I ² C [™] Bus Master
	AN710	Antenna Circuit Design for RFID Applications
	AN734	Using the PICmicro [®] SSP for Slave I ² C™ Communication
	AN735	Using the PICmicro [®] MSSP Module for Master I ² C™ Communications
	AN774	Asynchronous Communications with the PICmicro [®] USART
	AN833	The Microchip TCP/IP Stack
	AN860	rfRXD0420 ASK Receiver Reference Design
	AN868	Designing Loop Antennas for the rfPIC12F675
	AN870	An SNMP Agent for the Microchip TCP/IP Stack
	AN965	Microchip Stack for the ZigBee™ Protocol
	AN979	Interfacing I ² C [™] Serial EEPROMs to PIC18 Devices
	TB069	rfPIC12F675 Transmitter Module
	TB070	rfRXD0420 Receiver Module
Display	AN234	Hardware Techniques for PICmicro [®] Microcontrollers
	AN529	Multiplexing LED Drive and a 4x4 Keypad Sampling
	AN557	Four-Channel Digital Voltmeter with Display and Keyboard
	AN563	Using PIC16C5X Microcontrollers as LCD Drivers
	AN582	Low-Power Real-Time Clock
	AN587	Interfacing PICmicro [®] MCUs to an LCD Module
	AN649	Yet Another Clock Featuring the PIC16C924
	AN658	LCD Fundamentals Using PIC16C92X Microcontrollers
	AN785	Simplify A/D Converter Interface with Software (TC7135)
	AN874	Buck Configuration High-Power LED Driver
	AN948	Efficiently Powering Nine White LEDs with the MCP1650
	TB029	Complementary LED Drive
	TB060	Drive High Intensity White LEDs Efficiently Using the PIC16C781
	TB062	High Power IR LED Driver Using the PIC16C781/782
Math	AN526	PIC16C5X/PIC16CXXX Math Utility Routines
	AN544	Math Utility Routines
	AN575	IEEE 754 Compliant Floating Point Routines
	AN617	Fixed Point Routines
	AN660	Floating Point Math Functions
	AN670	Floating Point to ASCII Conversion
	AN730	CRC Generating and Checking
	TB040	Fast Integer Square Root

Category	Document Number	Title
Miscellaneous	AN606	Low-Power Design Using PICmicro [®] Microcontrollers
	AN682	Using Single Supply Operational Amplifiers in Embedded Systems
	AN686	Understanding and Using Supervisory Circuits
	AN700	Make a Delta-Sigma Converter Using a Microcontroller's Analog Comparator Module
	AN722	Operational Amplifier Topologies and DC Specifications
	AN730	CRC Generating and Checking
	AN823	Analog Design in a Digital World Using Mixed Signal Controllers
	AN826	Crystal Oscillator Basics and Crystal Selection for rfPIC [®] and PICmicro [®] Devices
	AN849	Basic PICmicro [®] Oscillator Design
	AN851	A Flash Bootloader for PIC16 and PIC18 Devices
	AN866	Designing Operational Amplifier Oscillator Circuits For Sensor Applications
	AN943	Practical PICmicro [®] Oscillator Analysis and Design
	AN949	Making Your Oscillator Work
	AN954	Transformerless Power Supplies: Resistive and Capacitive
	TB008	Transformerless Power Supply
Timekeeping	AN582	Low-Power Real-Time Clock
	AN590	A Clock Design Using the PIC16C54 for LED Displays and Switch Inputs
	AN615	Clock Design Using Low Power/Cost Techniques
	AN649	Yet Another Clock Featuring the PIC16C924
	CE004	Real-Time Clock on the dsPIC30F
	TB028	Technique to Calculate Day of Week
Security	AN583	Implementation of the Data Encryption Standard Using PIC17C42
	AN714	Wireless Home Security Implementing KEELOQ® and the PICmicro® Microcontroller
	AN821	Advanced Encryption Standard Using the PIC16XXX
	AN953	Data Encryption Routines for the PIC18
Serial EEPROM	AN690	I ² C™ Memory Auto-Detect
	AN709	System Level Design Considerations When Using I ² C™ Serial EEPROM Devices
	AN974	Interfacing I ² C [™] Serial EEPROMs to PICmicro [®] Microcontrollers
	AN976	Using the MSSP Module to Interface I ² C [™] Serial EEPROMs with PIC16 Devices
	AN979	Interfacing I ² C [™] Serial EEPROMs to PIC18 Devices
	AN989	Using the MSSP Module to Interface I ² C [™] Serial EEPROMs with PIC18 Devices
	AN991	Using the C18 Compiler and the MSSP to Interface I ² C [™] EEPROMs with PIC18 Devices
	AN997	Using the C18 Compiler to Interface I ² C [™] Serial EEPROMs with PIC18 Devices

TABLE 4-5: RELATED APPLICATION NOTES AND TECHNICAL BRIEFS (CONTINUED)

4.6 WEB SEMINARS

Archived versions of Microchip's web seminars shown in the table below are available for download and viewing. These web seminars (and many more) can be accessed from the Microchip web site: **www.microchip.com** > **Support** > **WebSeminars** > **Archived WebSeminars**. The files are a zipped (compressed) version of a Microsoft[®] Windows[®] Media file. To view one of the files, first download (save) the file to your computer, unzip it and then view it using the Microsoft Media Player.

Category	Title
Analog	Amplify Sensor Signals Using the PGA
Analog	Select the Right Operation Amplifier for Your Filtering Circuits
Analog	Smaller Packages = Bigger Thermal Challenges
Analog	Techniques That Reduce System Noise in ADC Circuits
Applications	EMC Part 1: Introduction to Electromagnetic Compatibility (EMC)
Applications	EMC Part 2: What is Electrostatic Discharge (ESD)?
Applications	EMC Part 3: What are Electrical Fast Transients (EFT)?
Connectivity	Microchip's ENC28J60, World's Smallest Ethernet Controller
Development Tools	Introduction to Microchip's Development Tools
Products	The LCD PIC Microcontrollers, PIC18F8490/6490, with 16 Kbytes of Flash in 64 and 80-pin Packages

TABLE 4-6: ARCHIVED WEB SEMINARS

NOTES:



INTRODUCTION TO UTILITY METERING TUTORIAL

Chapter 5. Specifications

There are many different specifications used around the world for metering. Many of them are derived from IEC or ANSI specifications. Some are physical or mechanical, others are operational. When beginning a meter development, the designer should consult the local, regional or national regulatory agency responsible for metering to determine which specifications should be followed when designing the meter and any electronics inside.

The following sections list some potential specifications referenced by the regulatory agencies.

5.1 WATER

- ANSI C700 Cold-Water Meters Displacement Type, Bronze Main Case
- ANSI C707 Encoder-Type Remote-Registration Systems for Cold-Water Meters
- BSR/AWWA C7AA-200x Automatic Meter Reading Simple Interface for Cold-Water Meters

5.2 **HEAT**

- EN 1434-4 Heat Meters Pattern Approval Tests
- OIML R75-1 Heat Meters Part 1: General Requirements

5.3 ELECTRICITY

- ANSI C12.20-2002 For Electricity Meters 0.2 and 0.5 Accuracy Classes
- AS1284.5/IEC61036 Alternating Current Static Watt-Hour Meters for Active Energy (Classes 1 and 2)
- AS1284.9/IEC60687 Alternating Current Static Watt-Hour Meters for Active Energy (Classes 0.2 and 0.5)
- IEC61268 Alternating Current Static Var-Hour Meters for Reactive Energy (Classes 2 and 3)
- IEC1107 Data Exchange for Meter Reading, Tariff and Load Control Direct Local Data Exchange
- IEC62056-31 Electricity Metering Data Exchange for Meter Reading, Tariff and Load Control Part 31: Use of Local Area Networks on Twisted Pair with Carrier Signalling
- IEC62056-42 Electricity Metering Data Exchange for Meter Reading, Tariff and Load Control Part 42: Physical Layer Services and Procedures for Connection-Oriented Asynchronous Data Exchange
- IEC62053-11 Electricity Metering Equipment (a.c.) Particular Requirements Part 11: Electromechanical Meters for Active Energy (classes 0, 5, 1 and 2)
- IEC62053-21– Electricity Metering Equipment (a.c.) Particular Requirements Part 21: Static Meters for Active Energy (classes 1 and 2)

NOTES:



INTRODUCTION TO UTILITY METERING TUTORIAL

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