

Using the Microchip Ultra Low-Power Wake-Up Module

Authors: Ruan Lourens
Jose Benevides
Jonathan Dillon
Microchip Technology Inc.

INTRODUCTION

This application note describes ways to reduce system current consumption with the use of the Ultra Low-power Wake-up (ULPWU) module. The PIC16F684 and PIC16F88X are examples of devices with this feature.

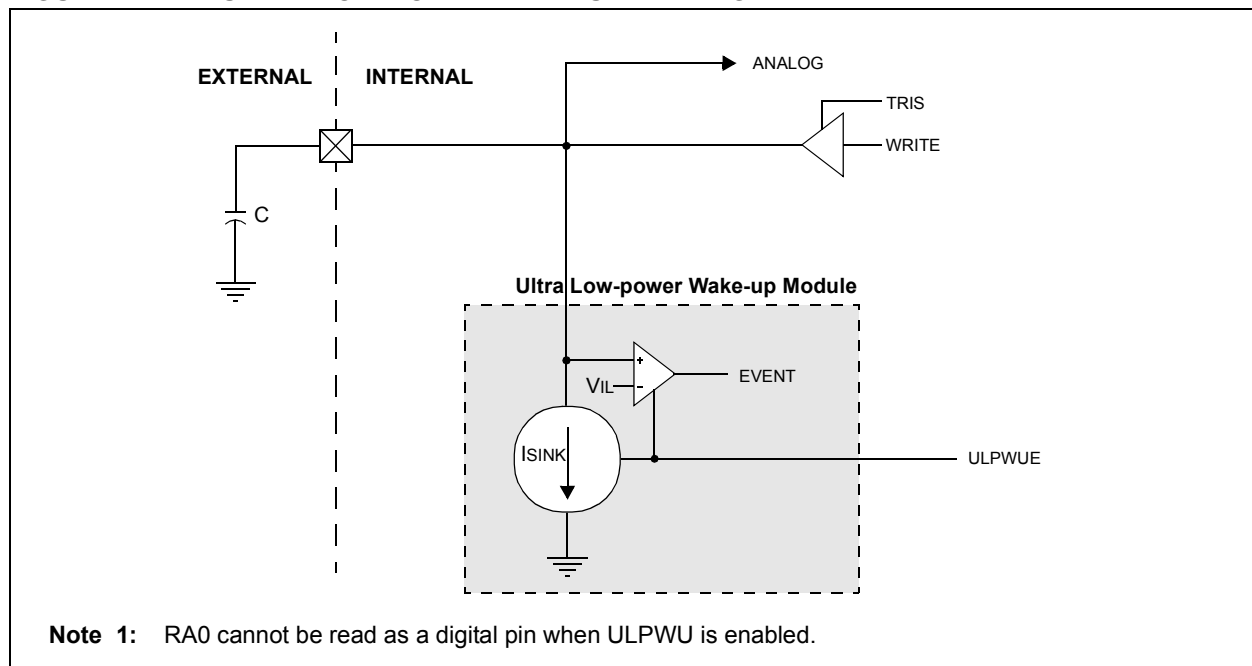
The primary use of this module is as an ULPWU timer, but its functionality can be expanded to function as a temperature sensor and/or a low-voltage detector. The main and expanded functions of this module are explained in this document.

Many low-power applications require that the microprocessor wake-up from a Sleep state on a periodic basis to check the status of some signal. It can then react based on a measurement of that signal and go back to Sleep until the next timed wake-up. This is a widely used method for reducing overall system

current consumption. These types of applications require a low-power periodic wake-up and can be accomplished by activating a low-power timer prior to placing the device in a Sleep mode. Upon rollover, the timer interrupt can then wake-up the part after some predefined period. A 32 kHz crystal timer used on one of the secondary clock sources is very popular if accuracy is required. Some parts also have dedicated internal low-power, low-frequency oscillators that can be used.

One solution for a lower current periodic wake-up timer is a simple RC timer that can be charged prior to Sleep and left to slowly discharge. A change in state event can be used to wake the part when the RC voltage reaches the digital input threshold voltage. This sounds ideal, but the problem is that a normal digital-input structure consumes high-crowbar currents when a slowly changing voltage is applied to it. The digital-input structure will consume a few hundred micro amps when driven by an analog voltage that is not close to the rail voltages (V_{SS} and V_{DD}). To combat these high-crowbar currents, Microchip has introduced an ULPWU module, which provides an analog input that can be used to implement a RC timer. The basic module block diagram is shown in Figure 1.

FIGURE 1: ULTRA LOW-POWER WAKE-UP PIN DIAGRAM⁽¹⁾



The module operates as a low-power analog comparator that compares the voltage on the external capacitor C to a reference V_{IL} . The module generates an event output when the analog comparator changes state. The change in state event can generate an interrupt-on-change. The module provides a very weak current source to discharge the external capacitor in a controlled manner. The code in Example 1 for PIC16F684 initializes the module, charges the capacitor, enables the module, and then goes to Sleep, waiting for an interrupt-on-change.

EXAMPLE 1: ULPWU CODE FOR THE PIC16F684

```
BANKSEL PORTA      ;Bank 0
BSF    PORTA, 0     ;Set RA0 data latch
MOVLW  H'7'         ;Turn off
MOVWF  CMCON0       ;comparators
BANKSEL ANSEL       ;Bank 1
BCF    ANSEL, 0     ;RA0 to digital I/O
BCF    TRISA, 0     ;Output high to
CALL   CapDelay     ;charge capacitor
BSF    PCON, ULPWUE ;Enable ULP Wake-Up
BSF    IOCA, 0      ;Select RA0 IOC
BSF    TRISA, 0     ;RA0 to input
MOVLW  B'10001000' ;Enable interrupt
MOVWF  INTCON       ;and clear flag
SLEEP                    ;Wait for IOC
NOP
```

The code in Example 2 for PIC16F88X devices charges the external capacitor, sets up the module and goes to Sleep, waiting for the ULPWU interrupt. The interrupt is level triggered and, if global interrupts are enabled, the Interrupt Service Routine (ISR) must disable either the ULPWU interrupt enable or the ULPWU module to clear the ULPWU interrupt flag and charge the external cap.

EXAMPLE 2: ULPWU CODE FOR THE PIC16F88X

```
BANKSEL PORTA      ;
BSF    PORTA, 0     ;Set RA0 data latch
BANKSEL ANSEL       ;
BCF    ANSEL, 0     ;RA0 to digital I/O
BANKSEL TRISA       ;
BCF    TRISA, 0     ;Output high to
CALL   CapDelay     ;charge capacitor
BANKSEL PIR2        ;
BCF    PIR2, ULPWUIF ;Clear flag
BANKSEL PCON        ;
BSF    PCON, ULPWUE ;Enable ULP Wake-up
BSF    TRISA, 0     ;RA0 to input
BSF    PIE2, ULPWUIE ;Enable interrupt
MOVLW  B'11000000' ;Enable peripheral
                    ;interrupt
MOVWF  INTCON       ;
SLEEP                    ;Wait for interrupt
NOP
```

The trip voltage V_{IL} and the sink current I_{SINK} are basically independent of V_{DD} , but are sensitive to temperature and process variations. Data for the module is given in Table 1.

From the data in Table 1, it becomes clear that the variation in module parameters would limit the overall accuracy of the timer, when used as in Figure 1. The wake-up period can vary by as much as 30% between modules. For a large number of applications, it is acceptable to have a large variation in the wake-up period and thus, the module's accuracy is acceptable.

TABLE 1: MODULE DATA*

		V_{IL} (Vdc)	I_{SINK} (nA)
-40°C	Min	0.58	104
	Typ	0.69	113
	Max	0.81	131
25°C	Min	0.48	121
	Typ	0.58	135
	Max	0.69	158
85°C	Min	0.38	130
	Typ	0.48	145
	Max	0.58	169
125°C	Min	0.30	142
	Typ	0.40	157
	Max	0.49	183

* Example data not characterized or tested

The module, when enabled, will add between 75 nA and 160 nA to the microprocessor's Sleep current, depending on process variations, temperature and voltage. The total expected Sleep current with the ULPWU module enabled should be only a few hundred nA for the PIC16F684 and PIC16F88X devices, since the Sleep current is typically 1 nA with all peripherals disabled.

The average system current consumption will be higher due to the energy required to charge the capacitor and the energy consumed to execute code between Sleep periods. The time between Sleep periods and active duty cycle of use will largely dictate the overall current consumption. A typical smoke detector or Tire Pressure Monitoring (TPM) system with sub 1 μ A current consumption can be achieved.

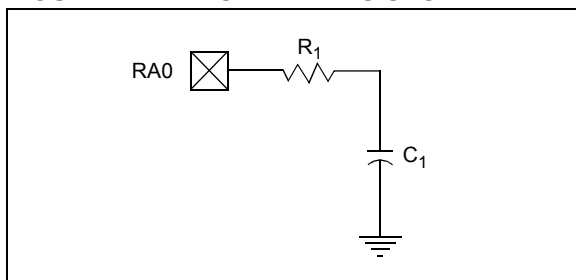
MODULE APPLICATIONS

The ULPWU module's accuracy and functionality can be improved by using it as a programmable timer or using some additional external components. This includes a programmable low-voltage detect and/or a temperature sensor. The following sections will briefly explain these functions.

Basic Timer

Although the operation of the basic wake-up timer has been discussed, there are more aspects to consider. Figure 2 shows the addition of a series resistor when compared to Figure 1. The resistor R_1 is added if C_1 is larger than 50 pF. This is done to reduce the peak current drawn from RA0 while charging C_1 . For larger capacitors, Equation 1 gives the peak charge current drawn from RA0. The maximum allowable current drawn from pin 1 is 25 mA. A resistor of 200 ohm is sufficient for 5-volt supply voltages and large capacitors.

FIGURE 2: SERIAL RESISTOR



EQUATION 1:

$$I_{PEAK} = \frac{V_{DD}}{R_1} \text{ for } C_1 \gg 50 \text{ pF}$$

I_{PEAK} = peak charge current

Equation 2 gives the discharge period. V_O is the initial capacitor voltage and will be the same as V_{DD} , if the capacitor is allowed to fully charge prior to starting the discharge process.

EQUATION 2:

$$T_{DISCHARGE} = \frac{(V_O - V_{IL}) \cdot C}{I_{SINK} + I_{LEAKAGE}}$$

$T_{DISCHARGE}$ = discharge period

V_O = initial capacitor voltage

V_{IL} = trip voltage

I_{SINK} = sink current

$I_{LEAKAGE}$ = capacitors internal leakage current

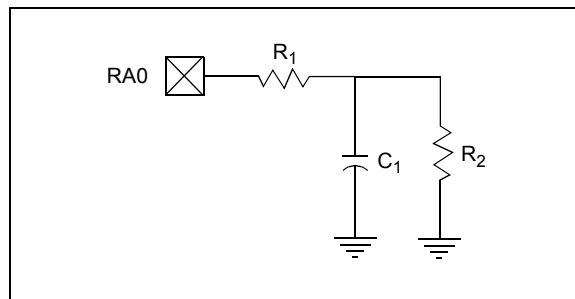
The discharge period is about 30 ms for a 1 nF capacitor, a V_O of 5 VDC with a current sink of 140 nA, and V_{IL} of 0.6 VDC. The internal current sink is fairly constant with voltage, assuming the voltage on the capacitor is V_{IL} or more. This results in a near linear voltage discharge of the capacitor over time. Keep in mind that the weak current sink is equivalent to very high-impedance of several tens of mega ohms. Such a high-impedance discharge system is very sensitive. Care must be given to layout, the influence of moisture, and the capacitor's self-discharge impedance.

To minimize noise and moisture effects, it is advisable to keep trace lengths short by placing the discharge capacitor close to the AN0 pin. Also, note that capacitors have some internal leakage that will shorten the discharge period. Different capacitors have different self-discharge characteristics that will become important, especially if long discharge periods are required. Some electrolytic capacitors have fairly high self-discharge rates that are temperature sensitive.

Use of External Components

For harsh noise and moisture conditions, the stability of the ULPWU module can be improved by adding an additional discharge resistor R_2 , as in Figure 3. The voltage discharge on C_1 , due to R_2 , will follow Equation 3, if the current through R_2 is large compared to the discharge current I_{SINK} . Thus, the discharge period can be derived as in Equation 4.

FIGURE 3: DISCHARGE RESISTOR



EQUATION 3:

$$V(T) = V_O \cdot e^{\left(\frac{-T}{C_1 R_2}\right)}$$

$V(T)$ = voltage across capacitor

V_O = initial capacitor voltage

T = time

EQUATION 4:

$$T_{DISCHARGE} = C_1 R_2 \ln \left(\frac{V_O}{V_{IL}} \right)$$

$T_{DISCHARGE}$ = charge period

V_O = initial capacitor voltage

V_{IL} = trip voltage

Calibrated Timer

The following section explains how the accuracy of the basic timer can be improved by controlling the charge period. The discharge period for both implementations shown in Figures 2 and 3 are dependent on V_O , C_1 , V_{IL} and I_{SINK} or R_2 . These parameters depend on process variations, temperature effects, usage and more. A software calibrated Sleep timer will compensate for some of these variations by controlling V_O . Timing the charge period of C_1 through R_1 allows control over the voltage on C_1 at the start of the Sleep period V_O . The discharge period $T_{DISCHARGE}$ is timed against the main clock source while the part is awake, then the charge period can be adjusted based on the $T_{DISCHARGE}$ error. This process is repeated until the desired accuracy is obtained. Repeat the calibration process after a fixed amount of normal Sleep periods, to maintain accuracy over time.

Pay close attention to the residual charge across C_1 at the start of the charge period. There may be charge left in C_1 , depending on V_{IL} and whether or not the ULPWU module was disabled, and whether RA0 turned into an analog input, digital input or digital output. One approach is to fully discharge C_1 before starting the charge process. This approach increases accuracy, but will increase the overall current consumption.

The final capacitor voltage V_O , when charging C_1 through R_1 , is given by Equation 5. The residual voltage across C_1 at the beginning of the charge period is represented by V_{RES} and the charge period is T_{CHARGE} .

EQUATION 5:

$$V_O = V_{RES} + (V_{DD} - V_{RES}) \left[1 - e^{\frac{-T_{CHARGE}}{C_1 R_1}} \right]$$

T_{CHARGE} = charge period

V_O = final capacitor voltage

V_{RES} = residual voltage

Temperature Sensor

This section explains how to implement a temperature sensor that gives a reading relative to the standard temperature at which calibration was completed. The module parameters V_{IL} and I_{SINK} are dependent on temperature and process variations. The process dependent component must be identified in order to calculate the temperature from later measurements of V_{IL} and I_{SINK} . The process variation can be measured when the device is first turned on under controlled conditions such as at final product testing. These standard measured values can be stored in EEPROM and used for future reference.

To measure V_{IL} , sample the voltage across C_1 with the A/D converter after the output of the ULPWU module changes the status of bit '0' on PORTA. The sampled voltage will be referenced to the A/D converter reference, which can be V_{DD} or an external voltage reference. V_{IL} has a negative temperature coefficient and is approximately $-1.25 \text{ mV}/^\circ\text{C}$. V_{IL} is calculated by using the method described in **Section "Use of External Components"**.

The sink current I_{SINK} is measured under standard conditions by using Equation 2 and has a positive temperature coefficient of approx. $140 \text{ pA}/^\circ\text{C}$. The discharge time $T_{DISCHARGE}$ is a function of V_O , V_{IL} and temperature. Under standard conditions, V_O and temperature are controlled and V_{IL} is measured. From this, calculate the standard process dependent value for I_{SINK} .

Note: The accuracy of the measurements is dependent on V_O , which can be V_{DD} , and the source for the A/D converter, which may or may not be V_{DD} . The method described in **Section "Use of External Components"** to calculate V_{IL} without an A/D is also dependent on a known value for V_O or V_{DD} .

Equations 7 and 8 are used to calculate temperature variation from the standard temperature using the measured or calculated values for I_{SINK} and V_{IL} .

Note 1: The result is dependent on V_{DD} or V_O . The temperature dependency of V_{IL} is linear with temperature, but I_{SINK} has a significant second order term that is not shown. The second order term for I_{SINK} can be ignored if the temperature deviation is relatively small.

2: The data is preliminary and will be updated after full characterization is completed. The values $I_{STANDARD}$ and $V_{STANDARD}$ are the process dependent values for I_{SINK} and V_{IL} , as measured under standard conditions and stored in EEPROM.

EQUATION 6:

$$\Delta T \approx \frac{V_{IL} - V_{STANDARD}}{-1.25 \times 10^{-3}}$$

ΔT = temperature deviation
 $V_{STANDARD}$ = standard voltage
 V_{IL} = trip voltage

EQUATION 7:

$$\Delta T \approx \frac{I_{SINK} - I_{STANDARD}}{140 \times 10^{-12}}$$

ΔT = temperature deviation
 I_{SINK} = sink current
 $V_{STANDARD}$ = standard voltage

EQUATION 8:

$$V_{DD} \approx V_O = V_{IL} + \frac{T_{DISCHARGE} \cdot I_{SINK}}{C_1}$$

V_O = total capacitor voltage
 V_{IL} = trip voltage
 I_{SINK} = sink current
 $T_{DISCHARGE}$ = discharge period

Programmable Low-voltage Detect

V_{DD} can be calculated using the ULPWU module in two basic ways; both methods are temperature dependent and based on the standard values for V_{IL} and I_{SINK} , as discussed in **Section "Temperature Sensor"**. The method is fairly accurate for applications where the system is subjected to small temperature variations. Refer to **Section "Temperature Sensing and Programmable Low-voltage Detect"** for applications where both V_{DD} and temperature need to be measured across a large range.

INTERNAL CURRENT SINK DISCHARGE METHOD

This method uses the setup as in Figure 2 by measuring $T_{DISCHARGE}$, while keeping the part active and measuring it against the main clock source. Before measuring $T_{DISCHARGE}$, make sure that C_1 is fully charged to V_{DD} by allowing a long enough charge period. Then, use Equation 9 to calculate V_O or V_{DD} .

EQUATION 9:

$$V_O = (T_{discharge} \cdot \frac{I_{sink}}{C_1}) + V_{il}$$

V_O = Total Capacitor Voltage
 V_{IL} = Trip Voltage
 $T_{DISCHARGE}$ = Discharge Period
 I_{SINK} = Sink Current

The accuracy of the calculated V_{DD} is dependent on V_{IL} , $T_{DISCHARGE}$, C_1 and I_{SINK} . Interestingly, V_{IL} has a negative temperature coefficient while I_{SINK} has a positive temperature coefficient, which reduces the temperature dependency.

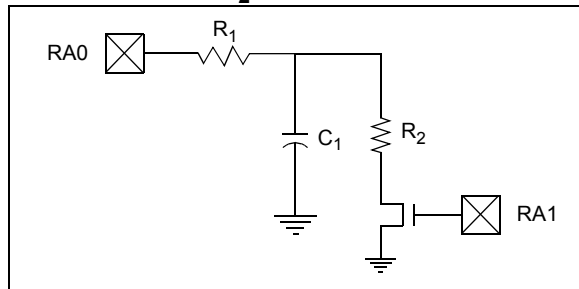
It is still possible to use this method if R_2 is required, as shown in Figure 3. V_O or V_{DD} is now calculated using Equation 10, as most of the discharge is through R_2 . Using this method, R_2 is more accurate and, for the most part, independent of temperature and process variations.

Connecting R_2 through an I/O controlled MOSFET provides a means for disconnecting R_2 from ground, as shown in Figure 4. The additional I/O enables the MOSFET when R_2 is needed.

EQUATION 10:

$$V_O = V_{IL} \cdot e^{\frac{-T_{DISCHARGE}}{C_1 R_2}}$$

FIGURE 4: R_2 TO I/O



VIL CHARGE METHOD

This method uses the same setup as illustrated in Figure 3. This method is applicable if R_1 is much smaller than R_2 . Again, the capacitor fully charges to V_{DD} and the $T_{DISCHARGE}$ is measured while the part is still active. Equation 9 can be used to calculate V_O or V_{DD} , but note that the result is a multiple of V_{IL} , which is temperature sensitive.

TEMPERATURE SENSING AND PROGRAMMABLE LOW-VOLTAGE DETECT

Section “Temperature Sensor” of this application note explains a simple method to measure temperature. Clearly, the accuracy of the result is dependent on knowing the V_{DD} and the process dependent variation of the variable. Similarly, **Section “Programmable Low-voltage Detect”** explains how to calculate V_{DD} , but the result depends on temperature and the process variation.

The accuracy of measuring the interdependent values V_{DD} and temperature is greatly improved by knowing the standard values $I_{STANDARD}$ and $V_{STANDARD}$, as explained in **Section “Temperature Sensor”**. The deviation of the measured unit from the standard value can then be used in an iterative process to calculate V_{DD} and temperature. The following sequence can be followed (see Figure 5):

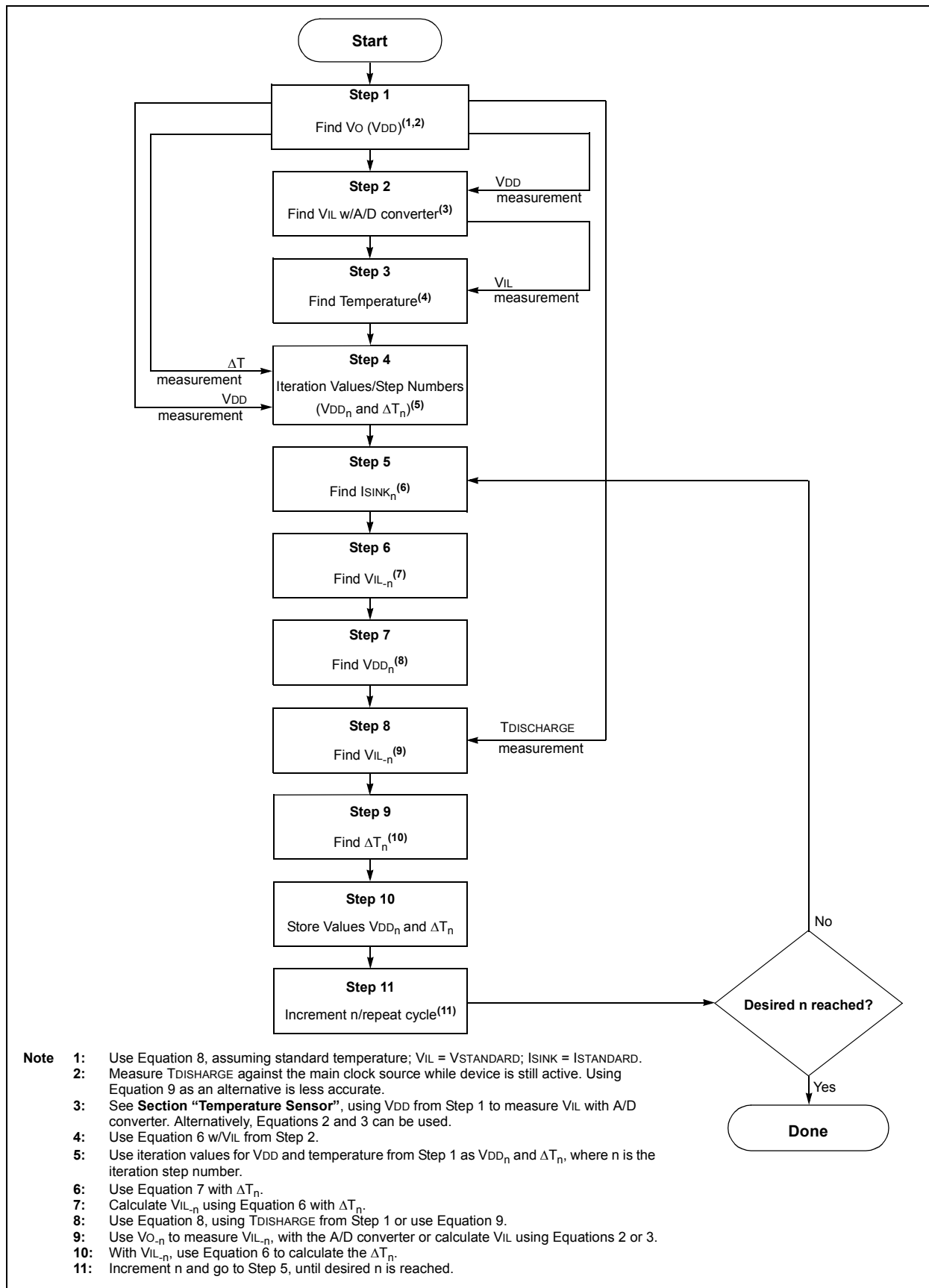
1. Calculate V_O or V_{DD} using Equation 8, assuming standard temperature, $V_{IL} = V_{STANDARD}$ and $I_{SINK} = I_{STANDARD}$. The discharge period $T_{DISCHARGE}$ is measured against the main clock source, while the device is still active. Alternatively, using Equation 9 is less accurate.
2. Use the resulting V_{DD} to measure V_{IL} with the A/D converter, as explained in **Section “Temperature Sensor”**. Alternatively, V_{IL} can be calculated using Equations 2 or 3.
3. Use the resulting V_{IL} to calculate the temperature with Equation 6.
4. Save the Step 1 iteration values for V_{DD} and temperature in V_{DD}_n and ΔT_n , where n is the iteration step number.
5. Calculate I_{SINK}_n using Equation 7 with ΔT_n .
6. Calculate V_{IL}_n using Equation 6 with ΔT_n .

7. Calculate V_{DD}_n with Equation 8, using the discharge period $T_{DISCHARGE}$ from the Step 1, or use Equation 9.
8. Use V_{O}_n to measure V_{IL}_n , with the A/D converter, or calculate V_{IL} using Equations 2 or 3.
9. With V_{IL}_n , use Equation 6 to calculate the temperature ΔT_n .
10. Store the values for V_{DD}_n and ΔT_n .
11. Increment n and go to Step 5, until desired n is reached.

The accuracy of the process can be evaluated by using the alternative methods for specific iterations. In addition, use the EEPROM write time as a temperature sensor for improving the accuracy of Step 1. The EEPROM write time is dependent on temperature and the variation from a standard-measured time can be used to calculate temperature.

CONCLUSION

The ULPWU module is a flexible module with unmatched current consumption that enables the designer to implement not only a wake-up timer, but also a low-cost PLVD (Programmable Low-voltage Detect) and temperature sensing functions. The module is especially attractive in lithium and other battery applications where very low Sleep currents are required.

FIGURE 5: CALCULATING V_{DD} AND TEMPERATURE BLOCK DIAGRAM

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, Accuron, dsPIC, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PRO MATE, rPIC and SmartShunt are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Linear Active Thermistor, MXDEV, MXLAB, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, In-Circuit Serial Programming, ICSP, ICEPIC, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, PICkit, PICDEM, PICDEM.net, PICtail, PIC³² logo, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rLAB, Select Mode, Total Endurance, UNI/O, WiperLock and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2008, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949:2002 ==

Microchip received ISO/TS-16949:2002 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.



WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office

2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://support.microchip.com>
Web Address:
www.microchip.com

Atlanta

Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Boston

Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago

Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas

Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit

Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo

Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles

Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

Santa Clara

Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto

Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office

Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney

Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing

Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu

Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Hong Kong SAR

Tel: 852-2401-1200
Fax: 852-2401-3431

China - Nanjing

Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao

Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai

Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang

Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen

Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Wuhan

Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xiamen

Tel: 86-592-2388138
Fax: 86-592-2388130

China - Xian

Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Zhuhai

Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore

Tel: 91-80-4182-8400
Fax: 91-80-4182-8422

India - New Delhi

Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune

Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Yokohama

Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Daegu

Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul

Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur

Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang

Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila

Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore

Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu

Tel: 886-3-572-9526
Fax: 886-3-572-6459

Taiwan - Kaohsiung

Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan - Taipei

Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Thailand - Bangkok

Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels

Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen

Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris

Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Munich

Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan

Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen

Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid

Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham

Tel: 44-118-921-5869
Fax: 44-118-921-5820