

MICROCHIP

PICmicro[®]
Power Managed
Tips 'n Tricks

Featuring nanoWatt Technology

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Tips 'n Tricks

TIPS 'N TRICKS INTRODUCTION

Microchip continues to provide innovative products that are smaller, faster, easier to use and more reliable. The Flash-based PICmicro[®] microcontrollers (MCU) are used in a wide range of everyday products, from smoke detectors, hospital ID tags and pet containment systems, to industrial, automotive and medical products.

The PIC16F/18F Power Managed Family featuring *nanoWatt Technology* merge all of the advantages of the PICmicro MCU architecture and the flexibility of Flash program memory with several new power management features. The devices become a logical solution for intelligent small systems, or complex systems that require extended battery life and energy efficient operation.

The flexibility of Flash and an excellent development tool suite, including a low cost In-Circuit Debugger, In-Circuit Serial Programming[™] and MPLAB[®] ICE 2000 emulation, make these devices ideal for just about any embedded control application.

The following series of Tips 'n Tricks can be applied to a variety of applications to help make the most of the PIC16F/18F Power Managed Family featuring *nanoWatt Technology*.

TIPS 'N TRICKS WITH HARDWARE

Making the most out of supplied hardware can eliminate external components which in turn reduces overall cost. Here are some tips that can help make the most out of the *nanoWatt* Family.

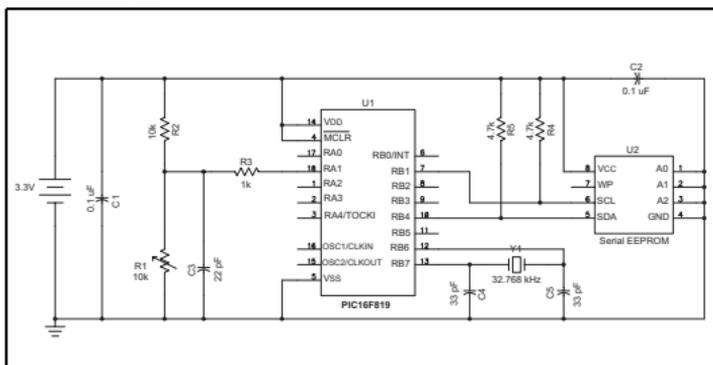
TIP #1 Switching Off External Circuits/ Duty Cycle

All the low power modes in the world won't help your application if you are unable to control the power used by circuits external to the microprocessor. Lighting an LED is equivalent to running most PICmicro[®] microcontrollers (MCUs) at 5V - 20 MHz. When you are designing your circuitry, decide what physical modes or states are required and partition the electronics to shutdown unneeded circuitry.

EXAMPLE:

The application is a long duration data recorder. It has a sensor, an EEPROM, a battery and a microprocessor. Every two seconds, it must take a sensor reading, scale the sensor data, store the scaled data in EEPROM and wait for the next sensor reading.

Solution 1:



TIP #2 Power Budgeting

Power budgeting is a technique that is critical to predicting current consumption and battery life.

Mode	Time in Mode (mS)	Current (mA)		Charge Current * Time (Amp * Sec)
		By Part	Total	
Sleeping	1989		0.001	1.989 e-6
CPU	Sleep	0.001		
Sensor	off	0.000		
EEPROM	off	0.000		
Sensor Warm-up	1		0.166	0.166 e-6
CPU	Sleep	0.001		
Sensor	on	0.165		
EEPROM	off	0.000		
Sensing	1		0.213	0.213 e-6
CPU	run	0.048		
Sensor	on	0.165		
EEPROM	off	0.000		
Scaling	1		0.048	0.048 e-6
CPU	run	0.048		
Sensor	off	0.000		
EEPROM	off	0.000		
Storing	8		2.048	16.384 e-6
CPU	run	0.048		
Sensor	off	0.000		
EEPROM	on	2.000		
Total Time (mS)	2000	Total Charge (Amp*Sec)		18.800 e-6

$$\begin{aligned}
 \text{Average Current (mA)} &= \frac{\text{Total Charge}}{\text{Total Time}} \\
 &= \frac{18.8 \text{ e-6}}{2000 \text{ e-3}} \quad \frac{\text{Amp*Sec}}{\text{Sec}} \\
 &= 0.009 \text{ mA} \\
 \text{Peak Current} &= 2.048 \text{ mA}
 \end{aligned}$$

Tips 'n Tricks

TIP #2 Power Budgeting (Cont.)

The following example shows the power budget for Solution 2 in Tip #1.

Computing Battery Life

Assuming an average current = .009 mA

(Based on Previous Power Budget)

Battery	Capacity	Life			
	(mAHr)	Hours	Days	Months	Years
CR1212	18	2000	83	2.8	0.23
CR1620	75	8333	347	11.6	0.96
CR2032	220	24444	1019	34.0	2.83

After completing a power budget, it is very easy to determine the battery size required to meet the application requirements. If too much power is consumed, it is very easy to determine where additional effort needs to be placed to reduce the power consumption.

TIP #3 WDT Alternative Wake-ups

Most applications control the power of the microprocessor by periodically going to Sleep. There are three ways to wake-up a sleeping PICmicro MCU:

1. Receive an interrupt
2. Wait for the Watchdog Timer
3. Use an Ultra Low-Power Wake-Up (ULPWU) peripheral

The new *nanoWatt* PIC16F/18F devices have a low current Watchdog Timer (WDT) that draws 2-3 μA . Additionally, the same devices can dynamically turn on/off the WDT for even more current savings.

TIP #4 Stretched Dog

The Watchdog Timer (WDT) is commonly used for waking up a sleeping PICmicro MCU. The longer the PICmicro MCU stays asleep, the less power most applications will take. Therefore, it is appropriate to have a watchdog time-out duration that is long enough for your application. If the application requires data samples once per minute, then the Watchdog Timer should wake-up the PICmicro MCU once per minute. Newer PICmicro devices, such as the PIC18F1320 and PIC16F684, have an extended Watchdog Timer that allows the watchdog period to be stretched up to two minutes.

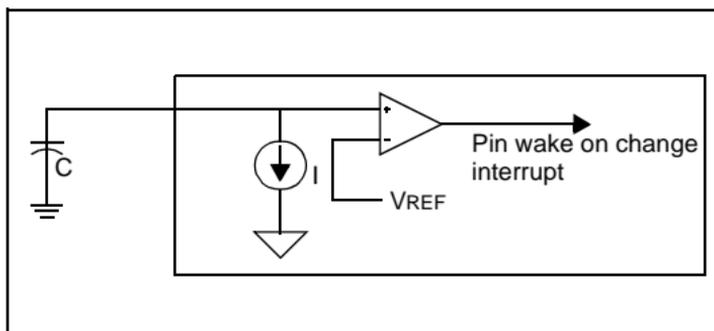
TIP #5 Low Power Timer1 Oscillator

nanoWatt devices also offer a robust low power Timer1 oscillator which draws 2-3 μA . The Timer1 counter and oscillator can be used to generate interrupts for periodic wakes from Sleep and other power managed modes, and can be used as the basis for a real-time clock. The normal two second Timer1 overflow (using a 32.786 kHz watch crystal) can be extended to 16 seconds by selecting the 1:8 prescaler.

Some *nanoWatt* devices can also use the Timer1 oscillator as the system clock source in place of the main oscillator on the OSC1/OSC2 pins. By reducing execution speed, total current consumption can be reduced.

TIP #6 Ultra Low-Power Wake-Up

Newer devices have a modification to PORTA that creates an Ultra Low-Power Wake-Up (ULPWU) peripheral. A small current sink and a comparator have been added that allows an external capacitor to be used as a wake-up timer.



If the accuracy of the Watchdog Timer is not required, this peripheral can save a lot of current.

TIP #7 Low Energy Power Supplies

Designing the power supply for a low power device can be very tricky. There are many factors to consider including:

1. Voltage/Current Requirements
2. Battery Chemistry
3. Battery Performance
4. Battery Capacity
5. Battery Size/Weight
6. Battery Cost

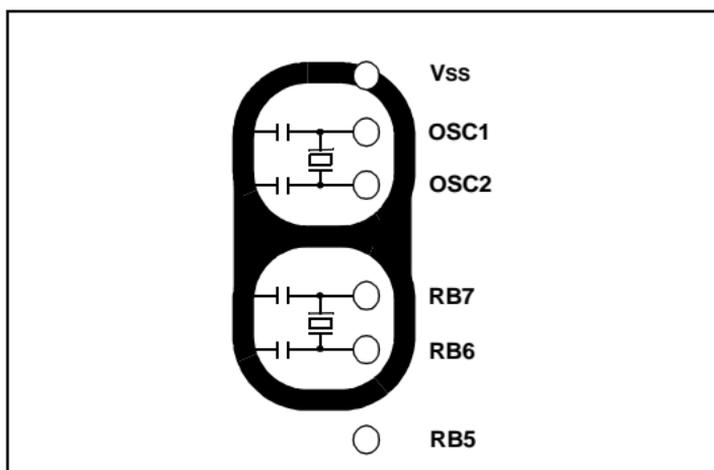
Batteries come in all shapes, sizes and chemistries. High capacity batteries typically have a higher internal resistance, so they are less useful for high current applications. Batteries good for high current generally have lower capacity or greater weight than a similarly sized high resistance battery. Primary batteries (discharge only) also have much higher capacity than secondary batteries (rechargeable).

If VDD must be kept constant, a battery chemistry with a flat discharge voltage may be used - two examples include LiMg (primary) and NiMH (secondary). If better control of a supply voltage is needed, a voltage regulator may be used.

TIP #8 Low Power Timer1

Applications requiring Timer1 to have a clock crystal connected to its T1OSO and T1OSI pins must take PCB layout into consideration. The new low power Timer1 consumes very little current, and this sometimes makes the oscillator circuit sensitive to neighboring circuits. The oscillator circuit (crystal and capacitors) should be located as close as possible to the microcontroller.

No circuits should be passing through the oscillator circuit boundaries. If it is unavoidable to have high-speed circuits near the oscillator circuit, a guard ring should be placed around the oscillator circuit and microcontroller pins similar to the figure below. Placing a ground plane under the oscillator components also helps to prevent interaction with high speed circuits.



TIPS 'N TRICKS WITH SOFTWARE

To reduce costs, designers need to make the most of the available program memory in MCUs. Since program memory is typically a large portion of the MCU cost, optimizing the code helps to avoid buying more memory than needed. Here are some ideas that can help reduce code size.

TIP #9 Configuring Port Pins

All PICmicro MCUs have bidirectional I/O pins. Some of these pins have analog input capabilities. It is very important to pay attention to the signals applied to these pins so the least amount of power will be consumed.

Unused Port Pins:

If a port pin is unused, it may be left unconnected but configured as an output pin driving to either state (high or low), or it may be configured as an input with an external resistor (about 10k Ohm) pulling it to VDD or VSS. If configured as an input, only the pin input leakage current will be drawn through the pin (the same current would flow if the pin was connected directly to VDD or VSS). Both options allow the pin to be used later for either input or output without significant hardware modifications.

Analog Inputs:

A digital input pin consumes the least amount of power when the input voltage is near VDD or VSS. If the input voltage is near the midpoint between VDD and VSS, the transistors inside the digital input buffer are biased in a linear region and they will consume a significant amount of current. If such a pin can be configured as an analog input, the digital buffer is turned off, reducing both the pin current as well as the total controller current.

TIP #9 Configuring Port Pins (Cont.)

Analog inputs have a very high-impedance so they consume very little current. They will consume less current than a digital input if the applied voltage would normally be centered between V_{DD} and V_{SS} . Sometimes it is appropriate and possible to configure digital inputs as analog inputs when the digital input must go to a low power state.

Digital Outputs:

There is no additional current consumed by a digital output pin other than the current going through the pin to power the external circuit. Pay close attention to the external circuits to minimize their current consumption.

TIP #10 I/O Initialization

Although the following practice may seem routine, PORT I/O initialization is often overlooked. On a POR (Power-on Reset), the PORT registers (for example) have an unknown value. If the TRISB registers are configured before the PORTB registers are set or cleared, output pins could generate glitch pulses during port initialization. The instruction sequence below is an example of how I/O initialization should be handled.

Example: Clear PORTB and configure all PORTB I/O as outputs:

```
BANKSEL  PORTB  ;bank 0
CLRF     PORTB  ;clear PORTB
BANKSEL  TRISB  ;bank 1
CLRF     TRISB  ;configure for outputs
```

TIP #11 Two-Speed Start-Up

This feature is new to the PIC[®] Microcontroller Family and is available on some of the *nanoWatt Technology* devices. Using the internal oscillator, the user can execute code while waiting for the Oscillator Start-up (OST) timer to expire (LP, XT or HS Modes). This feature (called “Two-Speed Start-up”) is enabled using the IESO configuration bit. A Two-Speed Start-up will clock the device from the INTRC (32 kHz) until the OST has expired. Switching to a faster internal oscillator frequency during start-up is also possible using the OSCCON register. The example below shows several stages on how this can be achieved. The number of frequency changes is dependent upon the designer’s discretion. Assume a 20 MHz crystal (HS Mode) in the PIC16F example found on the following page.

Tips 'n Tricks

TIP #11 Two-Speed Start-Up (Cont.)

Tcy

(Instruction Time)

Instruction

ORG 0x05 ;RESET vector

125 μ s @ 32 kHz BSF STATUS,RP0 ;bank1

125 μ s @ 32 kHz BSF OSCCON,IRCF2 ;switch to 1 MHz

4 μ s @ 1 MHz BSF OSCCON,IRCF1 ;switch to 4 MHz

1 μ s @ 4 MHz BSF OSCCON,IRCF0 ;switch to 8 MHz

500 ns application code

500 ns application code

...

.. ...

(eventually OST Expires, 20 MHz crystal clocks the device)

200 ns application code

...

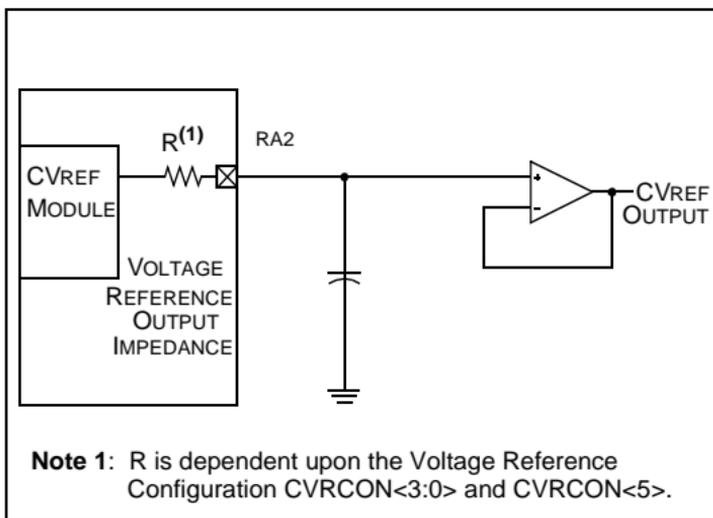
.. ...

TIP #12 How To Use A Comparator Reference As A D/A

The voltage reference module normally used to set a reference for the comparators may be used as a simple D/A output with limited drive capability on pin RA2.

Set the CVROE bit (CVRCON<6>), and configure the pin as an analog input.

Due to the limited current drive capability, an external buffer must be used on the voltage reference output for external connections to VREF. See example below:



TIP #13 How To Detect A Loss of Crystal/ Resonator Oscillator

The Fail-Safe Clock Monitor feature can be used to detect the loss of a crystal/resonator oscillator or other external clock source. When loss is detected, an internal clock source will provide system clocks, allowing for either a graceful shutdown or a “limp-along” mode if shutdown is not needed.

Just set the FCMEN bit in the configuration word (CONFIG1H<6>). A higher “limp-along” speed can be selected by setting some of the IRCF bits (OSCCON<6:4>) before or after the loss occurs.

TIP #14 Enabling IDLE Modes

The PIC18F *nanoWatt* Family of devices feature multiple IDLE modes that can be used to reduce overall power consumption. By setting the IDLE bit (OSCCON<7>) and executing a `SLEEP` instruction, you can turn off the CPU and allow the peripherals to keep running. In these states, power consumption can be reduced by as much as 96%.

TIP #15 How To Eliminate An External Crystal, Resonator, or RC Timing Network

If a precision frequency clock is not required, use the internal clock source. It has better frequency stability than external RC oscillators, and does away with the external crystal, resonator, or RC timing network.

The internal clock source can also generate one of several frequencies for use by the controller, allowing for reducing current demand by reducing the system frequency. When higher speed is required, it can be selected as needed under program control.

TIPS 'N TRICKS FOR HARDWARE/ SOFTWARE COMBINED

This section combines both hardware and software tips to help reduce external component count and reduce code size.

TIP #16 Clock Switching PIC16F Dual Clock

The PIC16F62X Family of devices is equipped with a second low speed internal oscillator. This oscillator is available when the configured clock source is one of internal RC (INTRC), External RC* (EXTRC) or External Resistor** (ER) modes. The internal oscillator can be used to operate the microcontroller at low speeds for reduced power consumption. The actual speed of this oscillator is not calibrated, so expect 20%-40% variability in the oscillator frequency.

To change oscillators, simply toggle bit 3 (OSCF) in the PCON register. When OSCF is clear, the low speed oscillator is used. When OSCF is set, the oscillator selected by the CONFIG bits is used.

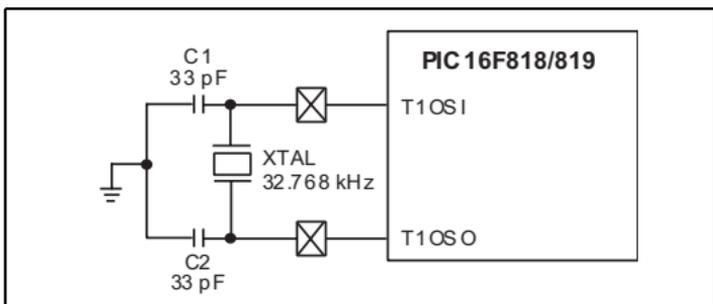
* EXTRC mode only available on A parts.

** ER mode only available on the non-A parts.

Newer devices have a multi-speed internal clock. They can switch from 8 MHz down to 31 kHz in 8 steps. The speed is selected using the OSCCON register.

TIP #17 Calibration

An internal RC oscillator calibrated from the factory may require further calibration as the temperature or VDD change. Timer1 can be used to calibrate the internal oscillator by connecting a 32.768 kHz clock crystal. Refer to AN244, “*Internal RC Oscillator Calibration*” for the complete application details.



The calibration is based on the measured frequency of the internal RC oscillator. For example, if the frequency selected is 4 MHz, we know that the instruction time is $1 \mu\text{s}$ ($F_{\text{OSC}}/4$) and Timer1 has a period of $30.5 \mu\text{s}$ ($1/32.768 \text{ kHz}$). This means within one Timer1 period, the core can execute 30.5 instructions. If the Timer1 registers TMR1H:TMR1L are preloaded with a known value, we can calculate the number of instructions that will be executed upon a Timer1 overflow.

TIP #17 Calibration (Cont.)

This calculated number is then compared against the number of instructions executed by the core. With the result, we can determine if re-calibration is necessary, and if the frequency must be increased or decreased. Tuning uses the OSCTUNE register, which has a $\pm 12\%$ tuning range in 0.8% steps.

Visit the low power design center at www.microchip.com for additional design resources.

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