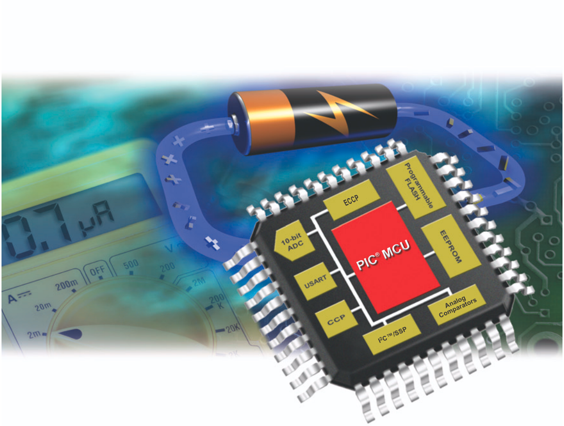

MICROCHIP

PICmicro® Power Managed Tips 'n Tricks

Featuring *nanoWatt Technology*

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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 an 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.

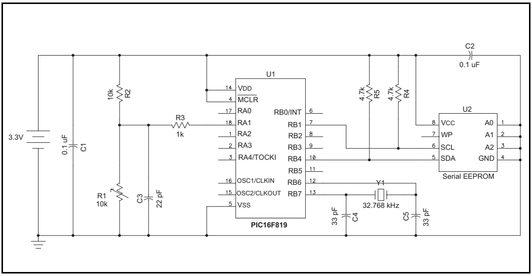
TIP #1 Switching Off External Circuits/ Duty Cycle

All the low power modes in the world will not 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 present 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 2 seconds, it must take a sensor reading, scale the sensor data, store the scaled data and wait for the next sensor reading.

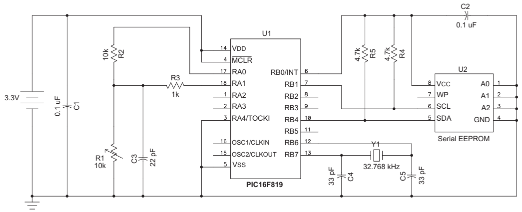
Solution 1:



TIP #1 Switching Off External Circuits/ Duty Cycle (Cont.)

The system shown above is very simple and clearly has all the parts identified in the requirements. Unfortunately it has a few problems in that the sensor, its bias circuit, and the EEPROM are powered all the time. To get the minimum current draw for this design, it would be advantageous to shutdown these circuits when they are not required. See Solution 2.

Solution 2:



In Solution 2, I/O pins are used to power the EEPROM and the sensor. Because the I/O pins can source 20 mA, there is no need to provide additional components to switch the power.

TIP #2 Power Budgeting

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

Operation Modes	Time in Mode (mS)	Current in Mode (uA)	uAmS in Mode	Description
Sleeping	**1989**	**1**	**1989**	**Waiting to read the data**
CPU		1		
Sensor		0		
EEPROM		0		
Sensor Warm-up	**1**	**166**	**166**	**Stabilizing the sensor**
CPU		1		
Sensor		165		
EEPROM		0		
Sensing	**1**	**213**	**213**	**Reading the sensor**
CPU		48		
Sensor		165		
EEPROM		0		
Scaling	**1**	**48**	**48**	**Scaling the sensor data**
CPU		48		
Sensor		0		
EEPROM		0		
Storing	**8**	**2048**	**16384**	**Writing 2 bytes (4 mS per byte)**
CPU		48		
Sensor		0		
EEPROM		2000		
uAmS			18800	
converting to mAH			5.2 µA	

TIP #2 POWER BUDGETING (CONT.)

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

Computing Battery Life			
Typical Coin Battery	Capacity mAH	Live (H)	Life (Years)
CR1212	18	3446808.511	393.47
CR1620	75	14361702.13	1639.46
CR2032	220	42127659.57	4809.09

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 two ways to wake-up a sleeping PICmicro MCU:

1. Receive an interrupt
2. Wait for the watchdog timer

The new *nanoWatt* PIC16F/18F devices have a low current watchdog timer (WDT) that draws 2-3 μA. Additionally, the PIC18F device can also 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, have an extended watchdog timer that allows the watchdog period to be stretched up to 2 minutes.

TIP #5 Low Energy Power Supplies

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

1. Battery Capacity
2. Internal Battery Resistance
3. Battery Size
4. Battery Cost
5. Battery Weight
6. Voltage Regulator minimum regulation voltage
7. Voltage Regulator quiescent current

Batteries come in all shapes, sizes and chemistry. A small, high capacity battery typically has a higher internal resistance, so it is less useful for high current applications. Batteries good for high current generally have lower capacity and higher weight than a similar sized high resistance battery. Examples are NiCd and NiMh. The NiMh battery is low in weight, high in capacity and small in size. However, it has a much higher internal resistance than the NiCd. Rapid discharge of the NiMh will seriously decrease the life. The high internal resistance will not affect most low current applications, but if the application requires a burst of current, it is possible for the voltage to sag and the PICmicro MCU could reset. Think of a RF transponder. Most of the time it is sitting idle, but upon demand, it must produce a powerful radio burst.

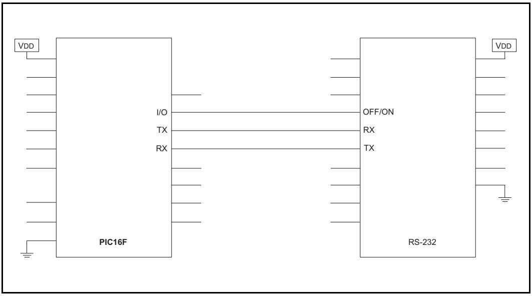
TIP #5 Low Energy Power Supplies (Cont.)

If V_{DD} must be kept constant or the battery voltage is too large, a voltage regulator may be used in the application. If you add a voltage regulator, you increase the current consumption by the quiescent current of the regulator (the current used by the regulator to regulate).

TIP #6 I/O Device Control

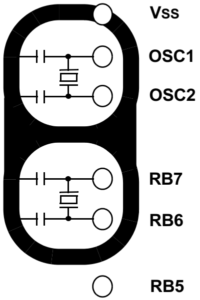
When power consumption is crucial in an application, designers look for ways of saving as much power as possible. The first obvious way is to put the microcontroller to SLEEP when there is no need for it to be running. Another solution is to clock the device at a lower frequency to consume less current. If there are other ICs on the PCB, it is possible to use an I/O pin to turn them off and on when they are not needed. Some of these ICs have a control pin dedicated for this (see example below). What if there is no dedicated control pin? The I/O pin can be tied to the VDD pin of the devices. There are limitations to this. The device can not draw more than the rated source current of the microcontroller I/O pin and must have a VDD requirement equal to the microcontrollers VDD.

An alternative would be to tie an output pin to control a switch, which controls power to other devices.



TIP #7 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, therefore making it's oscillator circuit sensitive to neighboring circuits. To start, the oscillator circuit (including crystal and capacitors) should be located as close as possible to the microcontroller. Other than VDD and VSS, no other circuits should be passing through the oscillator boundaries. If it is unavoidable to have high-speed circuits around the oscillator circuit, then a guard ring should be placed around the oscillator circuit and microcontroller pins similar to the figure below. It would also help to have the oscillator circuit placed over a ground plane.



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 #8 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 device is operating from internal RC (INTRC), External RC* (EXTRC) or External Resistor** (ER) modes. It 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. If the bit is clear, the low speed oscillator is used. If the bit is set, then the oscillator configured by the CONFIG bits is used.

* EXTRC mode only available on A parts.

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

TIP #9 Config Port

All PICmicro MCUs have bi-directional 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.

Digital Inputs:

A digital input pin consumes the least amount of power when the input voltage is near V_{DD} or V_{SS}. If the input voltage is near the midpoint between V_{DD} and V_{SS}, the transistors inside the PICmicro MCU are biased in a linear region and they will consume a significant amount of current. This current drain is most likely to occur if the application uses pin overloading tricks such as using a charging capacitor to read multiple switches or driving many LED's from a few I/O pins. Sometimes it may be better to reconfigure inputs to outputs to hold a known condition and minimize current.

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. Pay special attention to any bias circuits or pull-up/down circuits that may be required.

TIP #9 Config Port (Cont.)

Analog inputs:

Analog inputs are 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.

Pay attention to the behavior of the pins and determine what the pin I/O state must be when entering and leaving each Power mode. The wrong choice for one pin can cause a significant power increase and destroy the life of the application.

TIP #10 I/O Initialization

Although the following practice may seem routine, PORT I/O initialization is overlooked many times. On a POR (Power-on Reset), the PORT registers (Ex. PORTB) have an unknown value. If the TRIS registers (Ex. TRISB) are configured before the PORT registers are set or cleared, unexpected code behavior can result. 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, it allows the user to execute code while waiting for the Oscillator Start-up (OST) timer to expire (LP, XT or HS Modes). This feature is enabled through the IESO configuration bit. By the default setting of the OSCCON register, 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 can optimize this feature. 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 PIC18F example found on the following page.

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

Tcy (Instruction Time)	Instruction		
	org	0x05	;RESET vector
125 μs @ 32 kHz	bsf	STATUS,RP0	;bank1
125 μs @ 32 kHz	bsf	OSCCON,IRCF2	;switch to 1 MHz
4 μs @ 1 MHz	bsf	OSCCON,IRCF1	;switch to 4 MHz
1 μs @ 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)

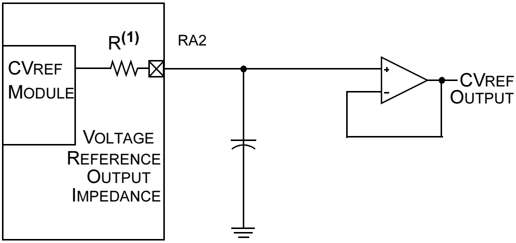
200 ns	application code
…	….
..	…

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:



Note 1: R is dependent upon the Voltage Reference Configuration CVRCON<3:0> and CVRCON<5>.

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 as low as 4% of full power operation requirements

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 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.

TIP #16 ADC Register ANSEL

Many of the PIC16 devices with an ADC module have a register called ADCON1, which is responsible for configuring the A/D channels for digital or analog I/O operation. A new register called ANSEL (Analog Select) has been added to the ADC and can be found on *nanoWatt* devices. The ANSEL register is located in Bank 1 and makes analog/digital selection easier than previous ADC modules. As standard, on a power-up, the I/O pins multiplexed for analog operation are configured as analog. A "1" will configure the corresponding I/O pin as analog and a "0" for digital.

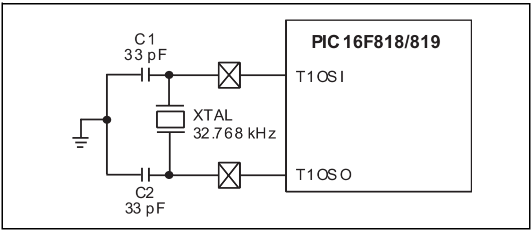
```
banksel  ANSEL
movlw    0x0F
movwf    ANSEL
Result:
         AN0 = Analog
         AN1 = Analog
         AN2 = Analog
         AN3 = Analog
         AN4 = Digital
         AN5 = Digital
         AN6 = Digital
```


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 #17 Calibration

An Internal RC Oscillator calibrated from the factory may require further calibration when subjected to a wide operating temperature. Timer1 can be used to calibrate the internal oscillator by connecting a 32.768 kHz clock crystal. Refer to AN244 for the complete application details.



The calibration is based on measured frequency of the Internal RC Oscillator. For example, if the frequency selected is 4 MHz, we know that the instruction time is 1 μs (4/4 MHz) and Timer1 has a period of 30.5 μs (1/32768). This means within one Timer1 period, the core can execute 30.5 instructions. Next, if the Timer1 registers TMR1H:TMR1L are preloaded with a known value, we could 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 calibration is necessary, and if calibration is needed, then we can determine if the frequency must be increased or decreased. Tuning is done through the OSCTUNE register, which has a +/-12% tuning range.

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