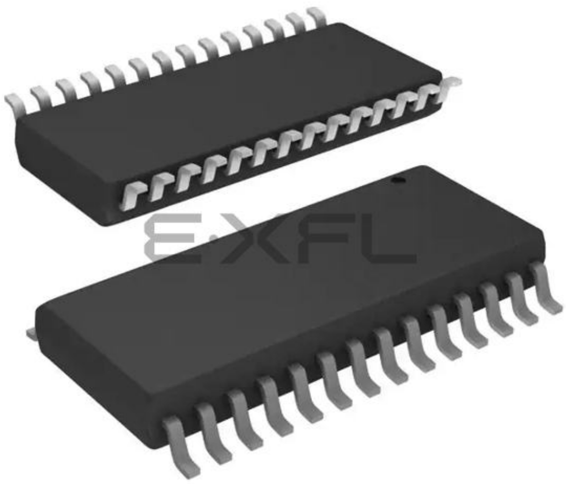

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"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	PIC
Core Size	8-Bit
Speed	4MHz
Connectivity	I²C, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	22
Program Memory Size	7KB (4K x 14)
Program Memory Type	OTP
EEPROM Size	-
RAM Size	192 x 8
Voltage - Supply (Vcc/Vdd)	4V ~ 5.5V
Data Converters	-
Oscillator Type	External
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	28-SOIC (0.295", 7.50mm Width)
Supplier Device Package	28-SOIC
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic16c63a-04i-so

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PIC® Microcontroller Comparator Tips 'n Tricks

PIC® Microcontroller DC Motor Control Tips 'n Tricks

LCD PIC® Microcontroller Tips 'n Tricks

Intelligent Power Supply Design Tips 'n Tricks

3V Tips 'n Tricks

TIP #9 Two-Speed Start-Up

Two-speed startup is a useful feature on some nanoWatt and all nanoWatt XLP devices which helps reduce power consumption by allowing the device to wake up and return to sleep faster. 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 an internal RC oscillator 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 below.

Example:

T_{CY} (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 #10 Clock Switching

Some nanoWatt devices and all nanoWatt XLP devices have multiple internal and external clock sources, as well as logic to allow switching between the available clock sources as the main system clock. This allows for significant power savings by choosing different clocks for different portions of code. For example, an application can use the slower internal oscillator when executing non-critical code and then switch to a fast high-accuracy oscillator for time or frequency sensitive code. Clock switching allows much more flexible applications than being stuck with a single clock source. Clock switching sequences vary by device family, so refer to device data sheets or Family Reference Manuals for the specific clock switching sequences.

TIP #11 Use Internal RC Oscillators

If frequency precision better than ±5% is not required, it is best to utilize the internal RC oscillators inside all nanoWatt and nanoWatt XLP devices. The internal RC oscillators have better frequency stability than external RC oscillators, and consume less power than external crystal oscillators. Additionally, the internal clock can be configured for many frequency ranges using the internal PLL module to increase frequency and the postscaler to reduce it. All these options can be configured in firmware.

Static Power Reduction Tips n' Tricks

The following tips and tricks will help reduce the power consumption of a device while it is asleep. These tips allow an application to stay asleep longer and to consume less current while sleeping.

TIP #16 Deep Sleep Mode

In Deep Sleep mode, the CPU and all peripherals except RTCC, DSWDT and LCD (on LCD devices) are not powered. Additionally, Deep Sleep powers down the Flash, SRAM, and voltage supervisory circuits. This allows Deep Sleep mode to have lower power consumption than any other operating mode. Typical Deep Sleep current is less than 50 nA on most devices. Four bytes of data are retained in the DSGPRx registers that can be used to save some critical data required for the application. While in Deep Sleep mode, the states of I/O pins and 32 kHz crystal oscillator (Timer1/SOSC) are maintained so that Deep Sleep mode does not interrupt the operation of the application. The RTCC interrupt, Ultra Low Power Wake-up, DSWDT time-out, External Interrupt 0 (INT0), MCLR or POR can wake-up the device from Deep Sleep. Upon wake-up the device resumes operation at the reset vector.

Deep Sleep allows for the lowest possible static power in a device. The trade-off is that the firmware must re-initialize after wake-up. Therefore, Deep Sleep is best used in applications that require long battery life and have long sleep times. Refer to the device datasheets and Family Reference Manuals for more information on Deep Sleep and how it is used.

TIP #17 Extended WDT and Deep Sleep WDT

A commonly used source to wake-up from Sleep or Deep Sleep is the Watchdog Timer (WDT) or Deep Sleep Watchdog Timer (DSWDT). The longer the PIC MCU stays in Sleep or Deep Sleep, the less power consumed. Therefore, it is appropriate to use as long a timeout period for the WDT as the application will allow.

The WDT runs in all modes except for Deep Sleep. In Deep Sleep, the DSWDT is used instead. The DSWDT uses less current and has a longer timeout period than the WDT. The timeout period for the WDT varies by device, but typically can vary from a few milliseconds to up to 2 minutes. The DSWDT time-out period can be programmed from 2.1ms to 25.7days

TIP #18 Low Power Timer1 Oscillator and RTCC

nanoWatt XLP microcontrollers all have a robust Timer1 oscillator (SOSC on PIC24) which draws less than 800 nA. nanoWatt technology devices offer a low power Timer1 oscillator which draws 2-3 uA. Some devices offer a selectable oscillator which can be used in either a low-power or high-drive strength mode to suit both low power or higher noise applications. 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. Timer1/SOSC wake-up options vary by device. Many nanoWatt XLP devices have a built-in hardware Real-Time Clock and Calendar (RTCC), which can be configured for wake-up periods from 1 second to many years.

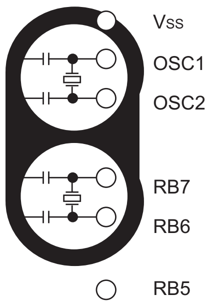
Some nanoWatt devices and all nanoWatt XLP devices can also use the Timer1/SOSC oscillator as the system clock source in place of the main oscillator on the OSC1/OSC2 pins. By reducing execution speed, total current consumption can be reduced.

TIP #19 Low Power Timer1 Oscillator Layout

Applications requiring very low power Timer1/SOSC oscillators on nanoWatt and nanoWatt XLP devices must take PCB layout into consideration. The very low power Timer1/SOSC oscillators on nanoWatt and nanoWatt XLP devices consume 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.

Figure 19-1: Guard Ring Around Oscillator Circuit and MCU Pins



TIP #20 Use LVD to Detect Low Battery

The Low Voltage Detect (LVD) interrupt present in many PIC MCUs is critical in battery based systems. It is necessary for two reasons. First, many devices cannot run full speed at the minimum operating voltage. In this case, the LVD interrupt indicates when the battery voltage is dropping so that the CPU clock can be slowed down to an appropriate speed, preventing code misexecution. Second, it allows the MCU to detect when the battery is nearing the end of its life, so that a low battery indication can be provided and a lower power state can be entered to maximize battery lifetime. The LVD allows these functions to be implemented without requiring the use of extra analog channels to measure the battery level.

TIP #21 Use Peripheral FIFO and DMA

Some devices have peripherals with DMA or FIFO buffers. These features are not just useful to improve performance; they can also be used to reduce power. Peripherals with just one buffer register require the CPU to stay operating in order to read from the buffer so it doesn't overflow. However, with a FIFO or DMA, the CPU can go to sleep or idle until the FIFO fills or DMA transfer completes. This allows the device to consume a lot less average current over the life of the application.

TIP #7 Periodic Interrupts

Generating interrupts at periodic intervals is a useful technique implemented in many applications. This technique allows the main loop code to run continuously, and then, at periodic intervals, jump to the interrupt service routine to execute specific tasks (i.e., read the ADC). Normally, a timer overflow interrupt is adequate for generating the periodic interrupt. However, sometimes it is necessary to interrupt at intervals that can not be achieved with a timer overflow interrupt. The CCP configured in Compare mode makes this possible by shortening the full 16-bit time period.

Example Problem:

A PIC16F684 running on its 8 MHz internal oscillator needs to be configured so that it updates a LCD exactly 5 times every second.

Step #1: Determine a Timer1 prescaler that allows an overflow at greater than 0.2 seconds

a) Timer1 overflows at: Tosc*4*65536* prescaler

b) For a prescaler of 1:1, Timer1 overflows in 32.8 ms.

c) A prescaler of 8 will cause an overflow at a time greater than 0.2 seconds.
8 x 32.8 ms = 0.25s

Step #2: Calculate CCPR1 (CCPR1L and CCPR1H) to shorten the time-out to exactly 0.2 seconds

a) CCPR1 = Interval Time/(TOSC*4*prescaler) = 0.2/(125 ns*4*8) = 5000 = 0xC350

b) Therefore, CCPR1L = 0x50, and CCPR1H = 0xC3

Step #3: Configuring CCP1CON

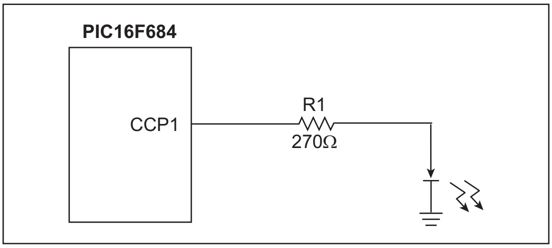
The CCP module should be configured in Trigger Special Event mode. This mode generates an interrupt when the Timer1 equals the value specified in CCPR1L and Timer1 is automatically cleared[1]. For this mode, CCP1CON = '`b00001011`'.

> **Note 1:** Trigger Special Event mode also starts an A/D conversion if the A/D module is enabled. If this functionality is not desired, the CCP module should be configured in "generate software interrupt-on-match only" mode (i.e., CCP1CON = `b`'`00001010`'). Timer 1 must also be cleared manually during the CCP interrupt.

TIP #18 Varying LED Intensity

The intensity of an LED can be varied by pulse-width modulating the voltage across the LED. A microcontroller typically drives an LED with the circuit shown in Figure 18-1. The purpose of R1 is to limit the LED current so that the LED runs in its specified current and voltage range, typically around 1.4 volts at 20 mA. Modulating the LED drive pin on the microcontroller will vary the average current seen by the LED and thus its intensity. As mentioned in Tip #13, LEDs and other light sources should be modulated at no less than 100 Hz in order to prevent noticeable flicker.

Figure 18-1: LED Drive

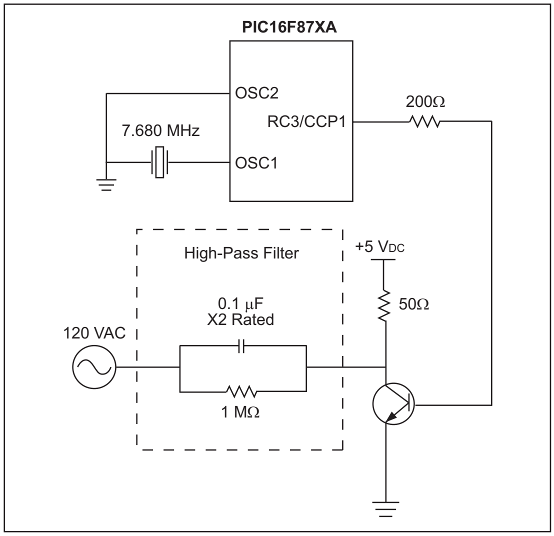


The CCP module, configured in PWM mode, is ideal for varying the intensity of an LED. Adjustments to the intensity of the LED are made by simply varying the duty cycle of the PWM signal driving the LED. This is accomplished by varying the CCPRxL register between 0 and 0xFF.

TIP #19 Generating X-10® Carrier Frequency

X-10 uses a piggybacked 120 kHz square wave (at 50% duty cycle) to transmit information over 60 Hz power lines. The CCP module, running in PWM mode, can accurately create the 120 kHz square wave, referred to as the carrier frequency. Figure 19-1 shows how the 120 kHz carrier frequency is piggybacked onto the sinusoidal 60 Hz power waveform.

Figure 19-1: Carrier Frequency With Sinusoidal Waveform



X-10 specifies the carrier frequency at 120 kHz (± 2 kHz). The system oscillator in Figure 18-1 is chosen to be 7.680 MHz, so that the CCP module can generate precisely 120 kHz. X-10 requires that the carrier frequency be turned on and off at different points on the 60 Hz power waveform. This is accomplished by configuring the TRIS register for the CCP1 pin as either an input (carrier frequency off) or an output (carrier frequency on). Refer to Application Note AN236 "*X-10 Home Automation Using the PIC16F877A*" for more details on X-10 and for source code for setting up the CCP module appropriately.

Example 20-1: Transmit Routine

```
TxRountine
  MOVLW  8         ;preload bit counter
                   ;with 8
  MOVWF  counter
  BCF    TxLine    ;line initially high,
                   ;toggle low for START
                   ;bit
TxLoop
  CALL   DelayTb   ;wait Tb (bit period)
  RRF    RxByte,f  ;rotate LSB first into
                   ;the Carry flag
  BTFSS  STATUS,C  ;Tx line state equals
                   ;state of Carry flag
  BCF    TxLine
  BTFSC  STATUS,C
  BSF    TxLine
  DECFSZ Counter,f ;Repeat 8 times
  GOTO   TxLoop
  CALL   Delay Tb  ;Delay Tb before
                   ;sending STOP bit
  BSF    TxLine    ;send STOP bit
```

Example 20-2: Receive Routine

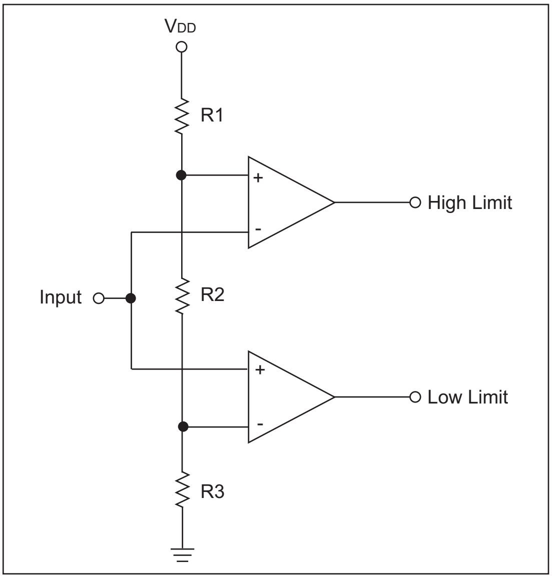
```
RxRoutine
  BTFSC  RxLine         ;wait for receive
                        ;line to go low
  GOTO   RxRoutine
  MOVLW  8              ;initialize bit
                        ;counter to 8
  MOVWF  Counter
  CALL   Delay1HalfTb;delay 1/2 Tb here
                        ;plus Tb in RxLoop
                        ;in order to sample
                        ;at the right time
RxLoop
  CALL   DelayTb        ;wait Tb (bit
                        ;period)
  BTFSS  RxLine         ;Carry flag state
                        ;equals Rx line
                        ;state
  BCF    STATUS,C
  BTFSC  RxLine
  BSF    STATUS,C
  BTFSC  RxLine
  BSF    STATUS,C
  RRF    RxByte,f       ;Rotate LSB first
                        ;into receive type
  DECFSZ Counter,f      ;Repeat 8 times
  GOTO   RxLoop
```


TIP #5 Window Comparison

When monitoring an external sensor, it is often convenient to be able to determine when the signal has moved outside a pre-established safe operating range of values or window of operation. This windowing provides the circuit with an alarm when the signal moves above or below safety limits, ignoring minor fluctuations inside the safe operating range.

To implement a window comparator, two voltage comparators and 3 resistors are required (see Figure 5-1).

Figure 5-1: Window Comparator



Resistors R1, R2 and R3 form a voltage divider which generates the high and low threshold voltages. The outputs HIGH LIMIT and LOW LIMIT are both active high, generating a logic one on the HIGH LIMIT output when the input voltage rises above the high threshold, and a logic one on the LOW LIMIT output when the input voltage falls below the low threshold.

To calculate values for R1, R2 and R3, find values that satisfy Equation 5-1 and Equation 5-2.

> **Note:** A continuous current will flow through R1, R2 and R3. To limit the power dissipation in the resistors, the total resistance of R1, R2 and R3 should be at least 1k. The total resistance of R1, R2 and R3 should also be kept less than 1 M to prevent offset voltages due to the input bias currents of the comparator.

Equation 5-1

$$V_{TH\text{-}HI} = \frac{V_{DD} * (R_3 + R_2)}{R1 + R2 + R3}$$

Equation 5-2

$$V_{TH\text{-}LO} = \frac{V_{DD} * R_3}{R1 + R2 + R3}$$

Example:

- V_{DD} = 5.0V, V_{TH} = 2.5V, V_{TL} = 2.0V
- R1 = 12k, R2 = 2.7k, R3 = 10k
- V_{TH} (actual) = 2.57V, V_{TL} (actual) = 2.02V

Adding Hysteresis:

To add hysteresis to the HIGH LIMIT comparator, follow the procedure outlined in Tip #3. Use the series combination of R2 and R3 as the resistor R2 in Tip #3.

To add hysteresis to the LOW LIMIT comparator, choose a suitable value for Req, 1k to 10 k , and place it between the circuit input and the non-inverting input of the LOW LIMIT comparator. Then calculate the needed feedback resistor using Equation 3-4 and Equation 3-5.

TIP #2 Brushless DC Motor Drive Circuits

A Brushless DC motor is a good example of simplified hardware increasing the control complexity. The motor cannot commutate the windings (switch the current flow), so the control circuit and software must control the current flow correctly to keep the motor turning smoothly. The circuit is a simple half-bridge on each of the three motor windings.

There are two basic commutation methods for Brushless DC motors; sensored and sensorless. Because it is critical to know the position of the motor so the correct winding can be energized, some method of detecting the rotor position is required. A motor with sensors will directly report the current position to the controller. Driving a sensored motor requires a look-up table. The current sensor position directly correlates to a commutation pattern for the bridge circuits.

Without sensors, another property of the motor must be sensed to find the position. A popular method for sensorless applications is to measure the back EMF voltage that is naturally generated by the motor magnets and windings. The induced voltage in the un-driven winding can be sensed and used to determine the current speed of the motor. Then, the next commutation pattern can be determined by a time delay from the previous pattern.

Sensorless motors are lower cost due to the lack of the sensors, but they are more complicated to drive. A sensorless motor performs very well in applications that don’t require the motor to start and stop. A sensor motor would be a better choice in applications that must periodically stop the motor.

Figure 2-1: 3 Phase Brushless DC Motor Control

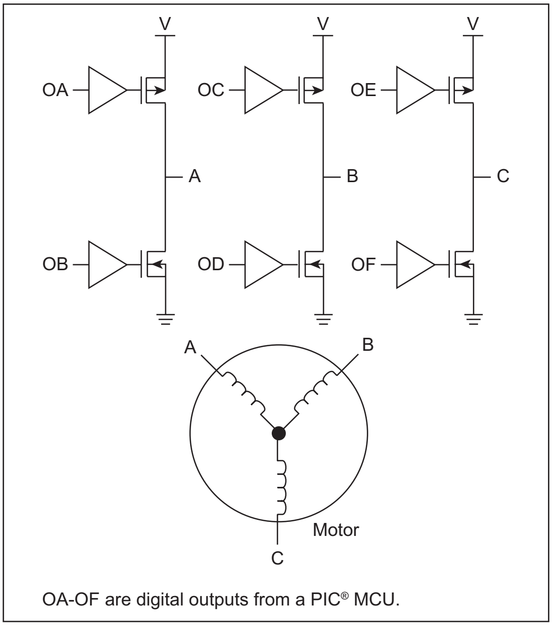


Figure 2-2: Back EMF Sensing (Sensorless Motor)

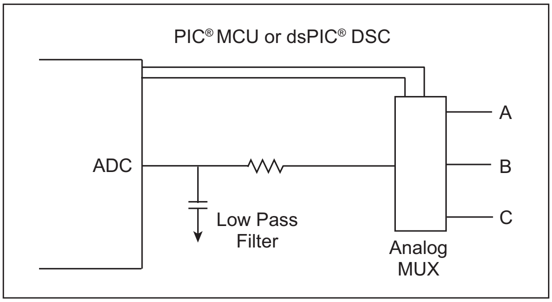
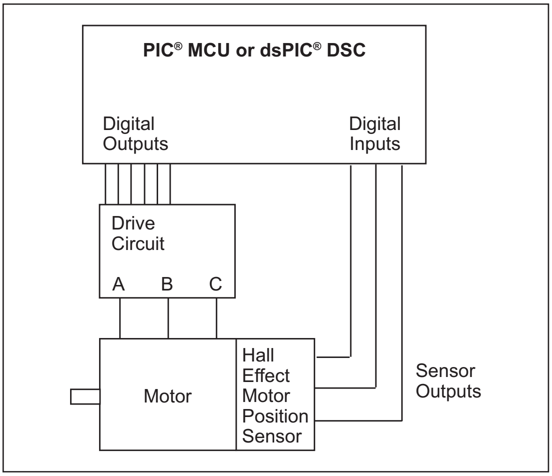


Figure 2-3: Quadrature Decoder (Sensor Motor)



Application notes describing Brushless DC Motor Control are listed below and can be found on the Microchip web site at: www.microchip.com.

- AN857, "*Brushless DC Motor Control Made Easy*" (DS00857)
- AN885, "*Brushless DC Motor Fundamentals*" (DS00885)
- AN899, "*Brushless DC Motor Control Using PIC18FXX31*" (DS00899)
- AN901, "*Using the dsPIC30F for Sensorless BLDC Control*" (DS00901)
- AN957, "*Sensored BLDC Motor Control Using dsPIC30F2010*" (DS00957)
- AN992, "*Sensorless BLDC Motor Control Using dsPIC30F2010*" (DS00992)
- AN1017, "*Sinusoidal Control of PMSM with dsPIC30F DSC*" (DS01017)
- GS005, "*Using the dsPIC30F Sensorless Motor Tuning Interface*" (DS93005)

TIP #3 Stepper Motor Drive Circuits

Stepper motors are similar to Brushless DC motors in that the control system must commutate the motor through the entire rotation cycle. Unlike the brushless motor, the position and speed of a stepping motor is predictable and does not require the use of sensors.

There are two basic types of stepper motors, although some motors are built to be used in either mode. The simplest stepper motor is the unipolar motor. This motor has four drive connections and one or two center tap wires that are tied to ground or Vsupply, depending on the implementation. Other motor types are the bipolar stepper and various combinations of unipolar and bipolar, as shown in Figure 3-1 and Figure 3-2. When each drive connection is energized, one coil is driven and the motor rotates one step. The process is repeated until all the windings have been energized. To increase the step rate, often the voltage is increased beyond the motors rated voltage. If the voltage is increased, some method of preventing an over current situation is required.

There are many ways to control the winding current, but the most popular is a chopper system that turns off current when it reaches an upper limit and enables the current flow a short time later. Current sensor systems are discussed in Tip #6. Some systems are built with a current chopper, but they do not detect the current, rather the system is designed to begin a fixed period chopping cycle after the motor has stepped to the next position. These are simpler systems to build, as they only require a change in the software.

TIP #6 Current Sensing

The torque of an electric motor can be monitored and controlled by keeping track of the current flowing through the motor. Torque is directly proportional to the current. Current can be sensed by measuring the voltage drop through a known value resistor or by measuring the magnetic field strength of a known value inductor. Current is generally sensed at one of two places, the supply side of the drive circuit (high side current sense) or the sink side of the drive circuit (low side current sense). Low side sensing is much simpler but the motor will no longer be grounded, causing a safety issue in some applications. High side current sensing generally requires a differential amplifier with a common mode voltage range within the voltage of the supply.

Figure 6-1: Resistive High Side Current Sensing

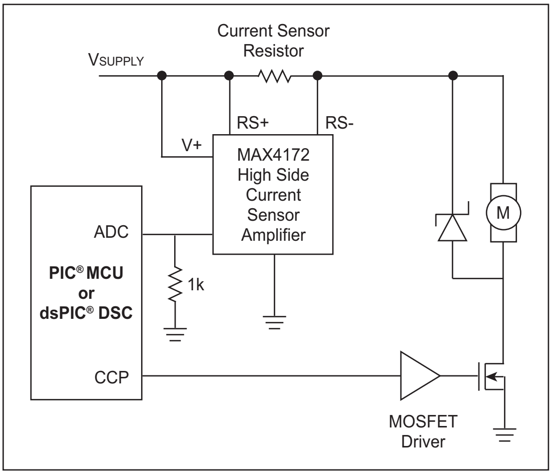
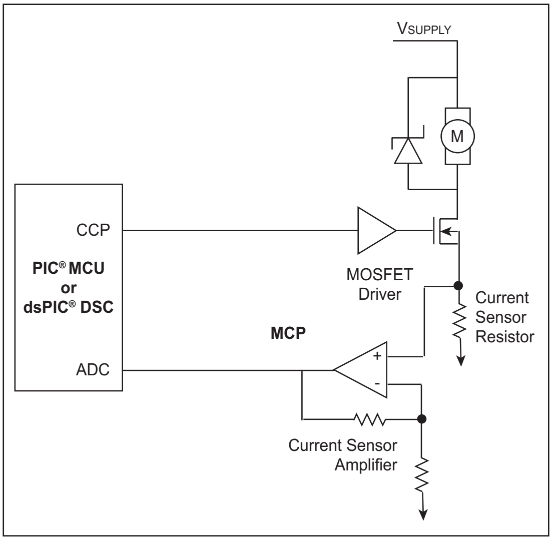
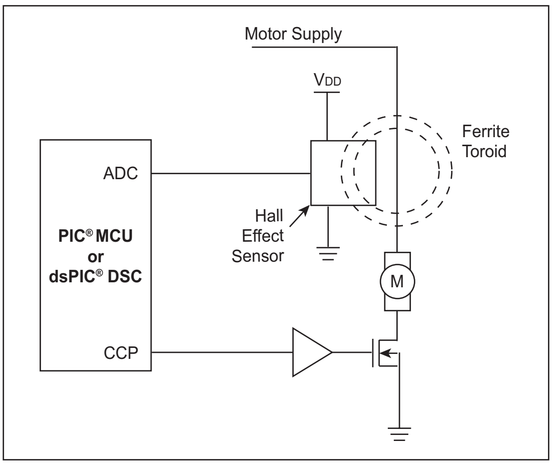


Figure 6-2: Resistive Low Side Current Sensing



Current measurement can also be accomplished using a Hall effect sensor to measure the magnetic field surrounding a current carrying wire. Naturally, this Hall effect sensor can be located on the high side or the low side of the load. The actual location of the sensor does not matter because the sensor does not rely upon the voltage on the wire. This is a non-intrusive method that can be used to measure motor current.

Figure 6-3: Magnetic Current Sensing



CHAPTER 6
LCD PIC® Microcontroller Tips 'n Tricks

Table Of Contents

TIPS 'N TRICKS INTRODUCTION

Using an LCD PIC® MCU for any embedded application can provide the benefits of system control and human interface via an LCD. Design practices for LCD applications can be further enhanced through the implementation of these suggested "Tips 'n Tricks".

This booklet describes many basic circuits and software building blocks commonly used for driving LCD displays. The booklet also provides references to Microchip application notes that describe many LCD concepts in more detail.

TIP #1 Typical Ordering Considerations and Procedures for Custom Liquid Displays

1. Consider what useful information needs to be displayed on the custom LCD and the combination of alphanumeric and custom icons that will be necessary.
2. Understand the environment in which the LCD will be required to operate. Operating voltage and temperature can heavily influence the contrast of the LCD and potentially limit the type of LCD that can be used.
3. Determine the number of segments necessary to achieve the desired display on the LCD and reference the PIC Microcontroller LCD matrix for the appropriate LCD PIC microcontroller.
4. Create a sketch/mechanical print and written description of the custom LCD and understand the pinout of the LCD. (Pinout definition is best left to the glass manufacturer due to the constraints of routing the common and segment electrodes in two dimensions.)
5. Send the proposed LCD sketch and description for a written quotation to at least 3 vendors to determine pricing, scheduling and quality concerns.
   a) Take into account total NRE cost, price per unit, as well as any setup fees.
   b) Allow a minimum of two weeks for formal mechanical drawings and pin assignments and revised counter drawings.
6. Request a minimal initial prototype LCD build to ensure proper LCD development and ensure proper functionality within the target application.
   a) Allow typically 4-6 weeks for initial LCD prototype delivery upon final approval of mechanical drawings and pin assignments.
7. Upon receipt of prototype LCD, confirm functionality before giving final approval and beginning production of LCD.

> **Note:** Be sure to maintain good records by keeping copies of all materials transferred between both parties, such as initial sketches, drawings, pinouts, etc.

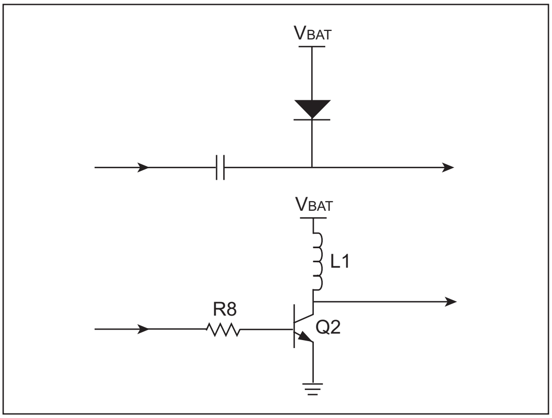
TIP #2 LCD PIC® MCU Segment/ Pixel Table

Table 2-1: Segment Matrix Table

Multiplex Commons	Maximum Number of Segments/Pixels					Bias
	PIC16F913/ 916	PIC16F914/ 917	PIC16F946	PIC18F6X90 (PIC18F6XJ90)	PIC18F8X90 (PIC18F8XJ90)	
Static (COM0)	15	24	42	32/ (33)	48	Static
1/2 (COM1: COM0)	30	48	84	64/ (66)	96	1/2 or 1/3
1/3 (COM2: COM0)	45	72	126	96/ (99)	144	1/2 or 1/3
1/4 (COM3: COM0)	60	96	168	128/ (132)	192	1/3

This Segment Matrix table shows that Microchip's 80-pin LCD devices can drive up to 4 commons and 48 segments (192 pixels), 64-pin devices can drive up to 33 segments (132 pixels), 40/44 pin devices can drive up to 24 segments (96 pixels) and 28-pin devices can drive 15 segments (60 segments).

Figure 5-2: Two Types of Boost Converter

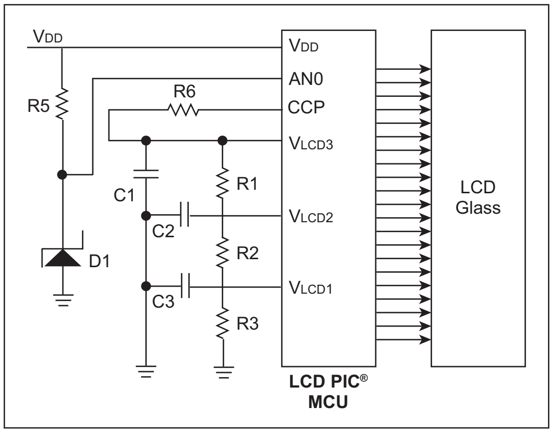


The two methods of producing a boost converter are shown above. The first circuit is simply a switched capacitor type circuit. The second circuit is a standard inductor boost circuit. These circuits work by raising V_{DD}. This allows the voltage at V_{LCD} to exceed V_{DD}.

TIP #6: Software Controlled Contrast with PWM for LCD Contrast Control

In the previous contrast control circuits, the voltage output was set by a fixed reference. In some cases, the contrast must be variable to account for different operating conditions. The CCP module, available in the LCD controller devices, allows a PWM signal to be used for contrast control. In Figure 6-1, you see the buck contrast circuit modified by connecting the input to RA6 to a CCP pin. The resistor divider created by R4 and R5 in the previous design are no longer required. An input to the ADC is used to provide feedback but this can be considered optional. If the ADC feedback is used, notice that it is used to monitor the V_{DD} supply. The PWM will then be used to compensate for variations in the supply voltage.

Figure 6-1: Software Controlled Voltage Generator



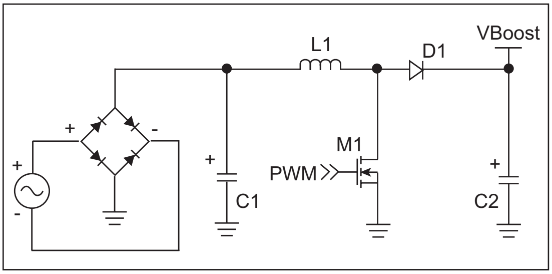
TIP #7 Using a PIC® Microcontroller for Power Factor Correction

In AC power systems, the term Power Factor (PF) is used to describe the fraction of power actually used by a load compared to the total apparent power supplied.

Power Factor Correction (PFC) is used to increase the efficiency of power delivery by maximizing the PF.

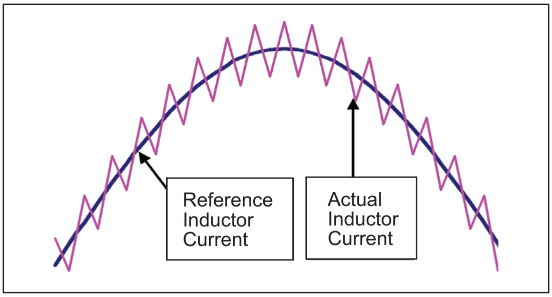
The basis for most Active PFC circuits is a boost circuit, shown in Figure 7-1.

Figure 7-1: Typical Power Factor Correction Boost Supply



The AC voltage is rectified and boosted to voltages as high as 400 VDC. The unique feature of the PFC circuit is that the inductor current is regulated to maintain a certain PF. A sine wave reference current is generated that is in phase with the line voltage. The magnitude of the sine wave is inversely proportional to the voltage at VBoost. Once the sine wave reference is established, the inductor current is regulated to follow it, as shown in Figure 7-2.

Figure 7-2: Desired and Actual Inductor Currents



A PIC MCU has several features that allow it to perform power factor correction.

- The PIC MCUs CCP module can be used to generate a PWM signal that, once filtered, can be used to generate the sine wave reference signal.
- The PIC Analog-to-Digital (A/D) converter can be used to sense VBoost and the reference sine wave can be adjusted in software.
- The interrupt-on-change feature of the PIC MCU input pins can be used to allow the PIC MCU to synchronize the sine wave reference to the line voltage by detecting the zero crossings.
- The on-chip comparators can be used for driving the boost MOSFET(s) using the PWM sine wave reference as one input and the actual inductor current as another.

TIP #14 Brushless DC Fan Speed Control

There are several methods to control the speed of a DC brushless fan. The type of fan, allowable power consumption and the type of control desired are all factors in choosing the appropriate type.

Figure 14-1: Low-Side PWM Drive

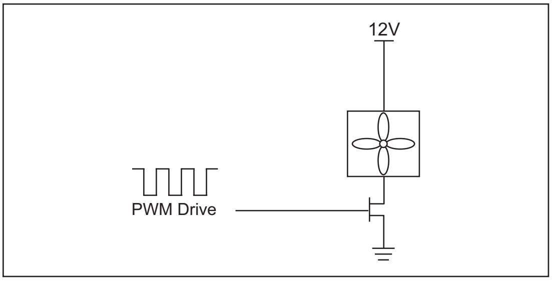
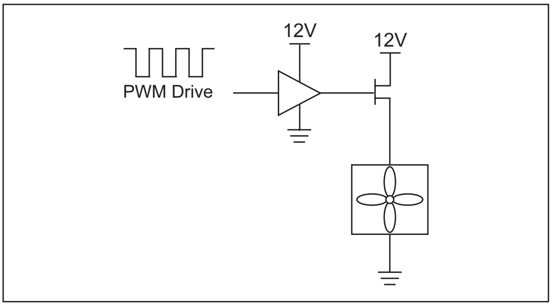


Figure 14-2: High-Side PWM Drive



Method 1 – Pulse-Width Modulation

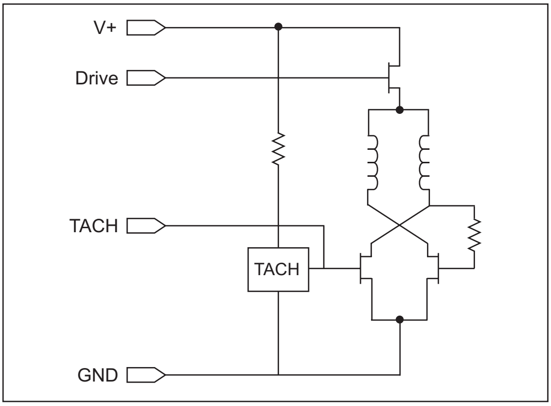
As shown in Figure 14-1 and Figure 14-2, a simple PWM drive may be used to switch a two-wire fan on and off. While it is possible to use the circuit in Figure 14-1 without a high-side MOSFET driver, some manufacturers state that switching on the low side of the fan will void the warranty.

Because of this, it is necessary to switch the high side of the fan in order to control the speed. The simplest type of speed control is ‘on’ or ‘off’. However, if a higher degree of control is desired, PWM can be used to vary the speed of the fan.

For 3-wire fans, the tachometer output will not be accurate if PWM is used. The sensor providing the tachometer output on 3-wire fans is powered from the same supply as the fan coils, thus using a PWM to control fan speed will render the fan’s tachometer inaccurate.

One solution is to use a 4-wire fan which includes both the tachometer output and a drive input. Figure 14-3 shows a diagram of a 4-wire fan.

Figure 14-3: Typical 4-Wire Fan



A 4-wire fan allows speed to be controlled using PWM via the Drive line. Since power to the tachometer sensor is not interrupted, it will continue to output the correct speed.

TIPS 'N TRICKS INTRODUCTION

Overview - the 3.3 Volt to 5 Volt Connection

One of the by-products of our ever increasing need for processing speed is the steady reduction in the size of the transistors used to build microcontrollers. Up-integration at cheaper cost also drives the need for smaller geometries. With reduced size comes a reduction in the transistor breakdown voltage, and ultimately, a reduction in the supply voltage when the breakdown voltage falls below the supply voltage. So, as speeds increase and complexity mounts, it is an inevitable consequence that the supply voltages would drop from 5V to 3.3V, or even 1.8V for high density devices.

Microchip microcontrollers have reached a sufficient level of speed and complexity that they too are making the transition to sub-5V supply voltages. The challenge is that most of the interface circuitry is still designed for 5V supplies. This means that, as designers, we now face the task of interfacing 3.3V and 5V systems. Further, the task includes not only logic level translation, but also powering the 3.3V systems and translating analog signals across the 3.3V/5V barrier.

This Tips 'n Tricks book addresses these challenges with a collection of power supply building blocks, digital level translation blocks and even analog translation blocks. Throughout the book, multiple options are presented for each of the transitions, spanning the range from all-in-one interface devices, to low-cost discrete solutions. In short, all the blocks a designer is likely to need for handling the 3.3V challenge, whether the driving force is complexity, cost or size.

Additional information can be found on the Microchip web site at www.microchip.com/3volts.

> **Note:** The tips 'n tricks presented here assume a 3.3V supply. However, the techniques work equally well for other supply voltages with the appropriate modifications.

Power Supplies

One of the first 3.3V challenges is generating the 3.3V supply voltage. Given that we are discussing interfacing 5V systems to 3.3V systems, we can assume that we have a stable 5 V_{DC} supply. This section will present voltage regulator solutions designed for the 5V to 3.3V transition. A design with only modest current requirements may use a simple linear regulator. Higher current needs may dictate a switching regulator solution. Cost sensitive applications may need the simplicity of a discrete diode regulator. Examples from each of these areas are included here, with the necessary support information to adapt to a wide variety of end applications.

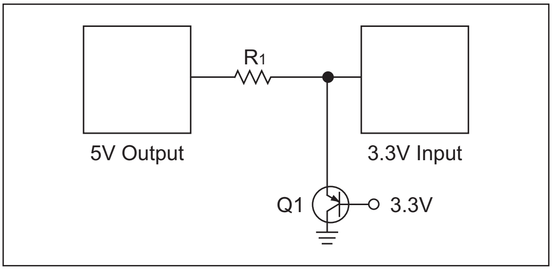
Table 1: Power Supply Comparisons

Method	V_{REG}	I_Q	Eff.	Size	Cost	Transient Response
Zener Shun Reg.	10% Typ	5 mA	60%	Sm	Low	Poor
Series Linear Reg.	0.4% Typ	1 µA to 100 µA	60%	Sm	Med	Excellent
Switching Buck Reg.	0.4% Typ	30 µA to 2 mA	93%	Med to Lrg	High	Good

TIP #11 5V → 3.3V Active Clamp

One problem with using a diode clamp is that it injects current onto the 3.3V power supply. In designs with a high current 5V outputs, and lightly loaded 3.3V power supply rails, this injected current can float the 3.3V supply voltage above 3.3V. To prevent this problem, a transistor can be substituted which routes the excess output drive current to ground instead of the 3.3V supply. Figure 11-1 shows the resulting circuit.

Figure 11-1: Transistor Clamp

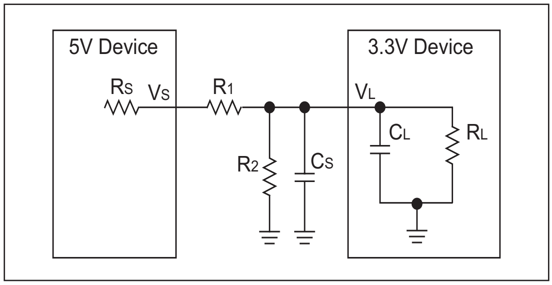


The base-emitter junction of Q1 performs the same function as the diode in a diode clamp circuit. The difference is that only a small percentage of the emitter current flows out of the base of the transistor to the 3.3V rail, the bulk of the current is routed to the collector where it passes harmlessly to ground. The ratio of base current to collector current is dictated by the current gain of the transistor, typically 10-400, depending upon which transistor is used.

TIP #12 5V → 3.3V Resistor Divider

A simple resistor divider can be used to reduce the output of a 5V device to levels appropriate for a 3.3V device input. An equivalent circuit of this interface is shown in Figure 12-1.

Figure 12-1: Resistive Interface Equivalent Circuit



Typically, the source resistance, Rs, is very small (less than 10Ω) so its affect on R1 will be negligible provided that R1 is chosen to be much larger than Rs. At the receive end, the load resistance, R_L, is very large (greater than 500 kΩ) so its affect on R2 will be negligible provided that R2 is chosen to be much less than R_L.

There is a trade-off between power dissipation and transition times. To keep the power requirements of the interface circuit at a minimum, the series resistance of R1 and R2 should be as large as possible. However, the load capacitance, which is the combination of the stray capacitance, Cs, and the 3.3V device input capacitance, C_L, can adversely affect the rise and fall times of the input signal. Rise and fall times can be unacceptably long if R1 and R2 are too large.

Neglecting the affects of R_S and R_L, the formula for determining the values for R1 and R2 is given by Equation 12-1.

Equation 12-1: Divider Values

$$\frac{V_S}{R_1 + R_2} = \frac{V_L}{R_2} \quad \text{; General relationship}$$

$$R_1 = \frac{(V_S - V_L) \cdot R_2}{V_L} \quad \text{; Solving for } R_1$$

$$R_1 = 0.515 \cdot R_2 \quad \text{; Substituting voltages}$$

The formula for determining the rise and fall times is given in Equation 12-2. For circuit analysis, the Thevenin equivalent is used to determine the applied voltage, V_A, and the series resistance, R. The Thevenin equivalent is defined as the open circuit voltage divided by the short circuit current. The Thevenin equivalent, R, is determined to be 0.66*R1 and the Thevenin equivalent, V_A, is determined to be 0.66*V_S for the circuit shown in Figure 12-2 according to the limitations imposed by Equation 12-2.

Equation 12-2: Rise/Fall Time

$$t = -\left[R \cdot C \cdot \ln\left(\frac{V_F - V_A}{V_I - V_A}\right)\right]$$

Where:

- t = Rise or Fall time
- R = 0.66*R_1
- C = C_S+C_L
- V_I = Initial voltage on C (V_L)
- V_F = Final voltage on C (V_L)
- V_A = Applied voltage (0.66*V_S)

As an example, suppose the following conditions exist:

- Stray capacitance = 30 pF
- Load capacitance = 5 pF
- Maximum rise time from 0.3V to 3V ≤ 1 μS
- Applied source voltage Vs = 5V

The calculation to determine the *maximum* resistances is shown in Equation 12-3.

Equation 12-3: Example Calculation

Solve Equation 12-2 for *R*:

$$R = -\left[\frac{t}{C \cdot \ln\left(\frac{V_F - V_A}{V_I - V_A}\right)}\right]$$

Substitute values:

$$R = -\left[\frac{10 \cdot 10^{-7}}{35 \cdot 10^{-12} \cdot \ln\left(\frac{3 - (0.66 \cdot 5)}{0.3 - (0.66 \cdot 5)}\right)}\right]$$

Thevenin equivalent maximum R:

$R = 12408$

Solve for maximum R1 and R2:

$R1 = 0.66 \cdot R$ $\qquad R2 = \frac{R1}{0.515}$

$R1 = 8190$ $\qquad R2 = 15902$

