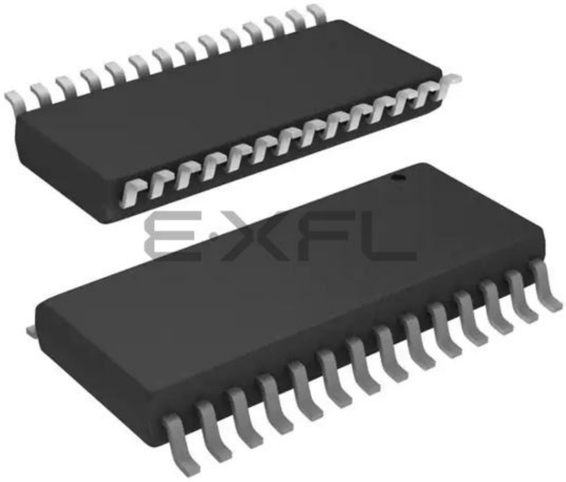

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What is "Embedded - Microcontrollers"?

"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	20MHz
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	0°C ~ 70°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-20-so

TIP #3 Read Three States From One Pin

To check state Z:

- Drive output pin high
- Set to Input
- Read 1
- Drive output pin low
- Set to Input
- Read 0

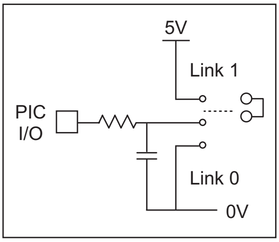
To check state 0:

- Read 0 on pin

To check state 1:

- Read 1 on pin

Figure 3-1



State	Link 0	Link 1
0	closed	open
1	open	closed
NC	open	open

Jumper has three possible states: not connected, Link 1 and Link 0. The capacitor will charge and discharge depending on the I/O output voltage allowing the “not connected” state. Software should check the “not connected” state first by driving I/O high, reading 1 and driving I/O low and reading 0. The “Link 1” and “Link 0” states are read directly.

TIP #4 Reading DIP Switches

The input of a timer can be used to test which switch(s) is closed. The input of Timer1 is held high with a pull-up resistor. Sequentially, each switch I/O is set to input and Timer1 is checked for an increment indicating the switch is closed.

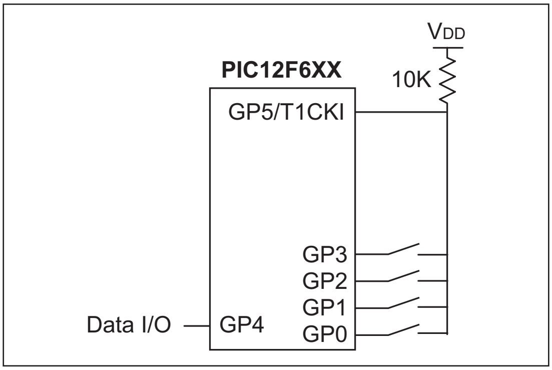
Example 4-1

```
        movlw    b'11111111'
        movwf    TRISIO
        movwf    DIP
        movlw    b'00000111'
        movwf    T1CON
        movlw    b'11111110'
        movwf    Mask
        clrf     GPIO
LOOP
        clrf     TMR1L
        movf     Mask,W
        movwf    TRISIO
        btfsc    TMR1L,0
        andwf    DIP,F
        bsf      STATUS,C
        rlf      Mask,F
        btfsc    Mask,4
        goto     Loop
        retlw    0
```

Each bit in the DP register represents its corresponding switch position. By setting Timer1 to FFFFh and enabling its interrupt, an increment will cause a rollover and generate an interrupt. This will simplify the software by eliminating the bit test on the TMR1L register.

Sequentially set each GPIO to an input and test for TMR1 increment (or 0 if standard I/O pin is used).

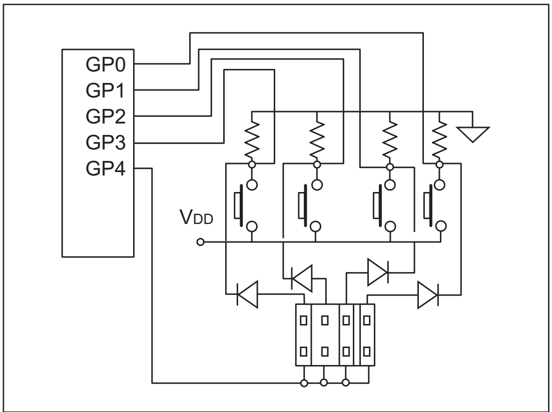
Figure 4-1



TIP #9 Decode Keys and ID Settings

Buttons and jumpers can share I/O's by using another I/O to select which one is read. Both buttons and jumpers are tied to a shared pull-down resistor. Therefore, they will read as '0' unless a button is pressed or a jumper is connected. Each input (GP3/2/1/0) shares a jumper and a button. To read the jumper settings, set GP4 to output high and each connected jumper will read as '1' on its assigned I/O or '0' if it's not connected. With GP4 output low, a pressed button will be read as '1' on its assigned I/O and '0' otherwise.

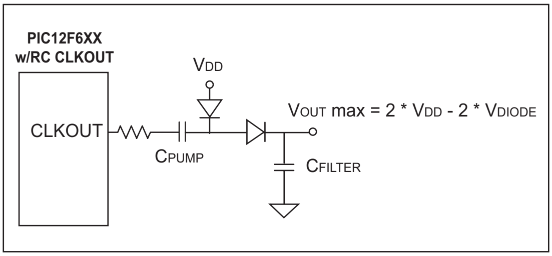
Figure 9-1



- When GP4 = 1 and no keys are pressed, read ID setting
- When GP4 = 0, read the switch buttons

TIP #10 Generating High Voltages

Figure 10-1



Voltages greater than V_{DD} can be generated using a toggling I/O. PIC MCUs CLKOUT/OSC2 pin toggles at one quarter the frequency of OSC1 when in external RC oscillator mode. When OSC2 is low, the V_{DD} diode is forward biased and conducts current, thereby charging C_{PUMP}. After OSC2 is high, the other diode is forward biased, moving the charge to C_{FILTER}. The result is a charge equal to twice the V_{DD} minus two diode drops. This can be used with a PWM, a toggling I/O or other toggling pin.

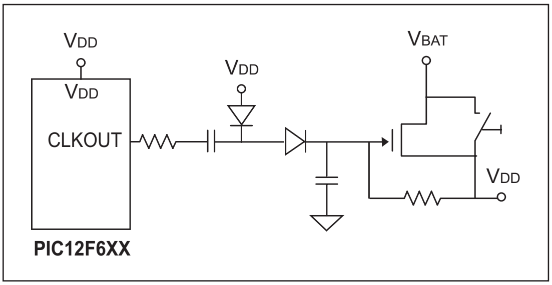
TIP #11 V_{DD} Self Starting Circuit

Building on the previous topic, the same charge pump can be used by the MCU to supply its own V_{DD}. Before the switch is pressed, V_{BAT} has power and the V_{DD} points are connected together but unpowered. When the button is pressed, power is supplied to V_{DD} and the MCUs CLKOUT (in external RC oscillator mode) begins toggle. The voltage generated by the charge pump turns on the FET allowing V_{DD} to remain powered. To power down the MCU, execute a Sleep instruction. This allows the MCU to switch off its power source via software.

Advantages:

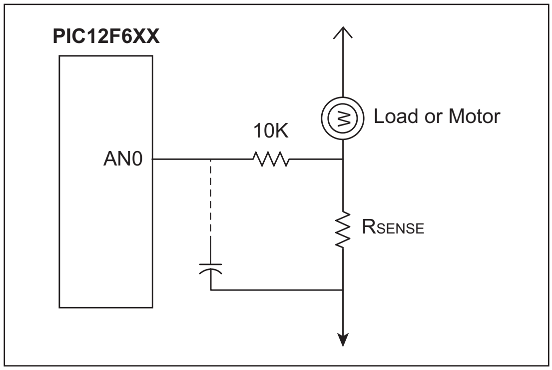
- PIC MCU leakage current nearly 0
- Low cost (uses n-channel FET)
- Reliable
- No additional I/O pins required

Figure 11-1



TIP #12 Using PIC® MCU A/D For Smart Current Limiter

Figure 12-1



- Detect current through low side sense resistor
- Optional peak filter capacitor
- Varying levels of overcurrent response can be realized in software

By adding a resistor (R_{SENSE}) in series with a motor, the A/D can be used to measure in-rush current, provide current limiting, over-current recovery or work as a smart circuit breaker. The 10K resistor limits the analog channel current and does not violate the source impedance limit of the A/D.

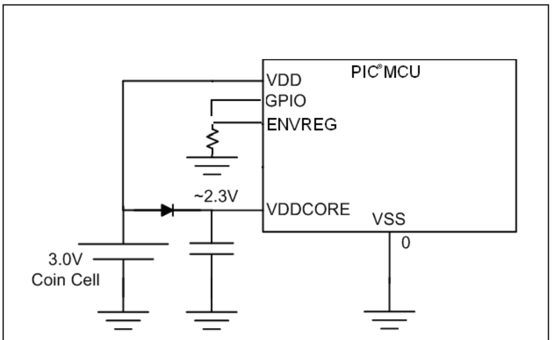
TIP #6 Use an External Source for CPU Core Voltage

Some PIC MCUs such as “J” type devices (ex. PIC18F87J90 or PIC24FJ64GA004) use separate power for CPU core. These devices have an internal voltage regulator that can be used to provide the core voltage. Alternatively, the core voltage can be provided externally by disabling the internal regulator. In some cases, it is more power efficient to use an external source for the core. This is because the internal regulator powers the core at the nominal voltage that allows full speed operation. However, if an application doesn’t require full speed, it is beneficial to use lower voltage to power the core. Disabling the internal regulator also turns off the BOR and LVD circuits, which saves power as well. The following examples show two different battery powered applications where it can be beneficial to disable the internal regulator.

Example 1: Constant Voltage Source

When using a regulated power source or a battery with a flat discharge curve, such as a lithium coin cell, the regulator can be disabled and the core powered directly from the battery through a diode. The diode provides the voltage drop necessary to power the core at the correct voltage. It may be necessary to use a zener diode with a higher forward voltage for applications using sleep mode, as the current consumed in sleep is too low to cause the full forward voltage drop which can result in applying a voltage too high for the core.

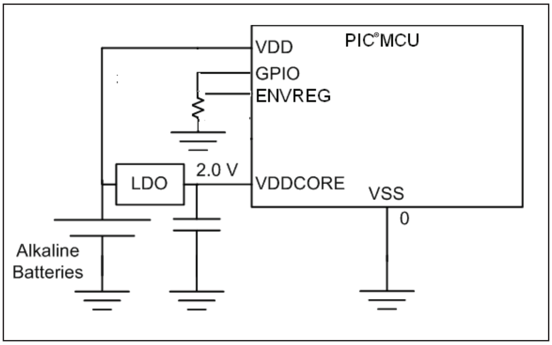
Figure 6-1:



Example 2: Non-Constant Voltage Source

If the source for VDD is not constant, a regulator will be required. It can be beneficial to use an external low quiescent current regulator, which can be selected to provide lower voltage to the core than the internal regulator. Additionally, devices such as the MCP1700, which consumes 1 uA quiescent current while asleep, require less power than the internal regulator.

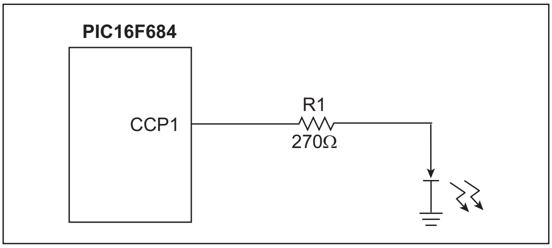
Figure 6-2:



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

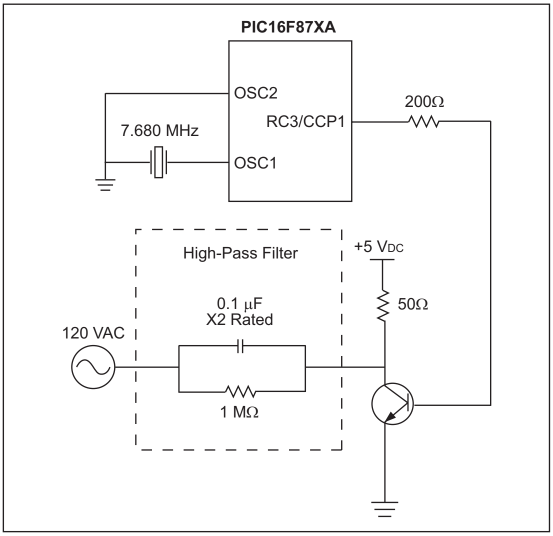


The CCP module, configured in PWM mode, is ideal for varying the intensity of an LED. Adjustments to the intensity of the LED are made by simply varying the duty cycle of the PWM signal driving the LED. This is accomplished by varying the CCPRxL register between 0 and 0xFF.

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.

CHAPTER 4
PIC® Microcontroller Comparator Tips ‘n Tricks

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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 PIC® microcontrollers (MCUs) are used in a wide range of everyday products from smoke detectors to industrial, automotive and medical products.

The PIC12F/16F Family of devices with on-chip voltage comparators merge all the advantages of the PIC MCU architecture and the flexibility of Flash program memory with the mixed signal nature of a voltage comparator. Together they form a low-cost hybrid digital/analog building block with the power and flexibility to work in an analog world.

The flexibility of Flash and an excellent development tool suite, including a low-cost In-Circuit Debugger, In-Circuit Serial Programming™ (ICSP™) 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 discrete voltage comparators or microcontrollers with on-chip voltage comparators.

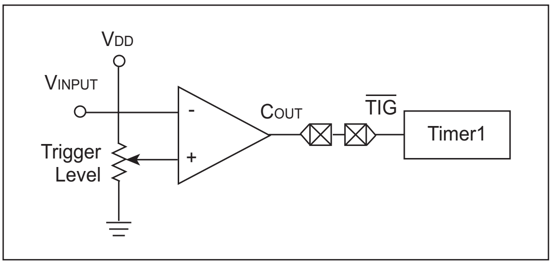
TIP #4 Pulse Width Measurement

To measure the high or low pulse width of an incoming analog signal, the comparator can be combined with Timer1 and the Timer1 Gate input option (see Figure 4-1). Timer1 Gate acts as a count enable for Timer1. If the input is low, Timer1 will count. If the $\overline{\text{T1G}}$ input is high, Timer1 does not count. Combining $\overline{\text{T1G}}$ with the comparator allows the designer to measure the time between a high-to-low output change and a low-to-high output change.

To make a measurement between a low-to-high and a high-to-low transition, the only change required is to set the CINV bit in the comparator CMCON register which inverts the comparator output.

Because the output of the comparator can change asynchronously with the Timer1 clock, only comparators with the ability to synchronize their output with the Timer1 clock should be used and their C2SYNC bits should be set.

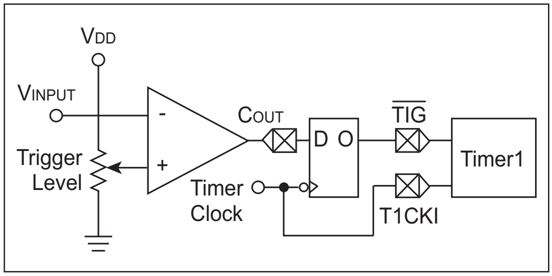
Figure 4-1: Comparator with Timer1 and $\overline{\text{T1G}}$



If the on-chip comparator does not have the ability to synchronize its output to the Timer1 clock, the output can be synchronized externally using a discrete D flip-flop (see Figure 4-2).

> **Note:** The flip-flop must be falling edge triggered to prevent a race condition.

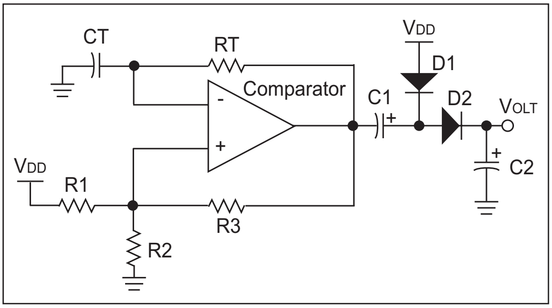
Figure 4-2: Externally Synchronized Comparator



TIP #10 Capacitive Voltage Doubler

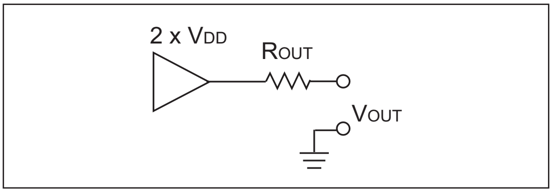
This tip takes the multi-vibrator described in Tip #8 and builds a capacitive voltage doubler around it (see Figure 10-1). The circuit works by alternately charging capacitor C1 through diode D1, and then charge balancing the energy in C1 with C2 through diode D2. At the start of the cycle, the output of the multi-vibrator is low and charge current flows from V_{DD} through D1 and into C1. When the output of the multi-vibrator goes high, D1 is reverse biased and the charge current stops. The voltage across C1 is added to the output voltage of the multi-vibrator, creating a voltage at the positive terminal of C1 which is 2 x V_{DD}. This voltage forward biases D2 and the charge in C1 is shared with C2. When the output of the multi-vibrator goes low again, the cycle starts over.

Figure 10-1: Capacitive Voltage Doubler



Note: The output voltage of a capacitive double is unregulated and will sag with increasing load current. Typically, the output is modeled as a voltage source with a series resistance (see Figure 10-2).

Figure 10-2: Equivalent Output Model



To design a voltage doubler, first determine the maximum tolerable output resistance based on the required output current and the minimum tolerable output voltage. Remember that the output current will be limited to one half of the output capability of the comparator. Then choose a transfer capacitance and switching frequency using Equation 10-1.

Equation 10-1

$$R_{OUT} = \frac{1}{F_{SWITCH} * C1}$$

Note: R_{OUT} will be slightly higher due to the dynamic resistance of the diodes. The equivalent series resistance or ESR, of the capacitors and the output resistance of the comparator. See the TC7660 data sheet for a more complete description.

Once the switching frequency is determined, design a square-wave multi-vibrator as described in Tip #8.

Finally, select diodes D1 and D2 for their current rating and set C2 equal to C1.

Example:

From Tip #8, the values are modified for a F_{OSC} of 4.8 kHz.

- C1 and C2 = 10 μF
- R_{OUT} = 21

CHAPTER 5
DC Motor Control Tips 'n Tricks

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TIPS 'N TRICKS INTRODUCTION

Every motor control circuit can be divided into the drive electronics and the controlling software. These two pieces can be fairly simple or extremely complicated depending upon the motor type, the system requirements and the hardware/software complexity trade-off. Generally, higher performance systems require more complicated hardware. This booklet describes many basic circuits and software building blocks commonly used to control motors. The booklet also provides references to Microchip application notes that describe many motor control concepts in more detail. The application notes can be found on the Microchip web site at www.microchip.com.

Additional motor control design information can be found at the Motor Control Design Center (www.microchip.com/motor).

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

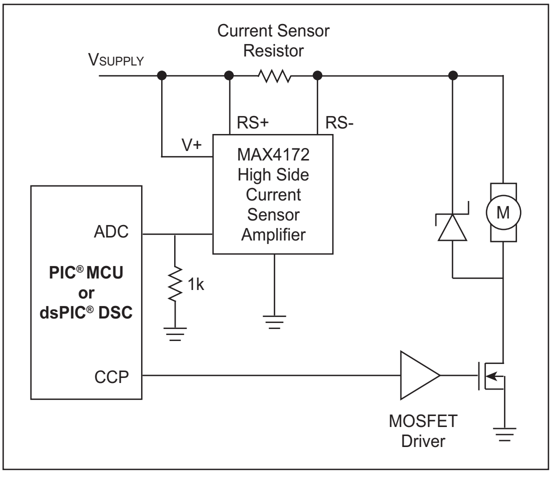
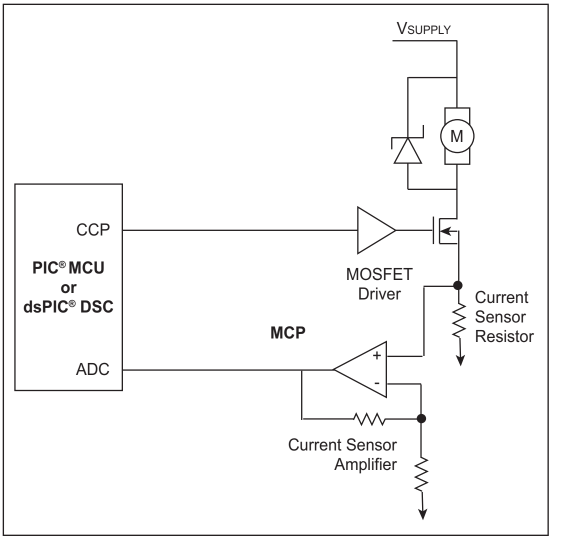
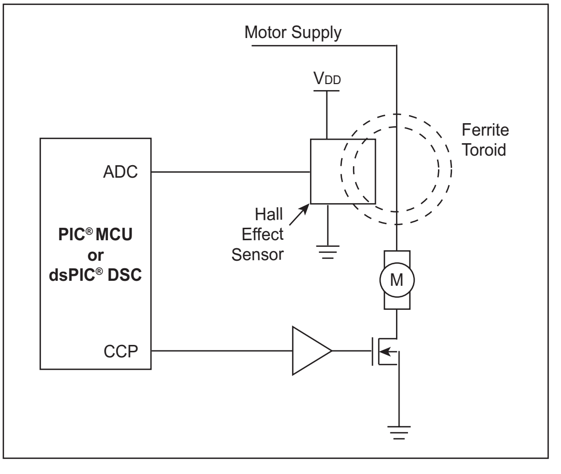


Figure 6-2: Resistive Low Side Current Sensing



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



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

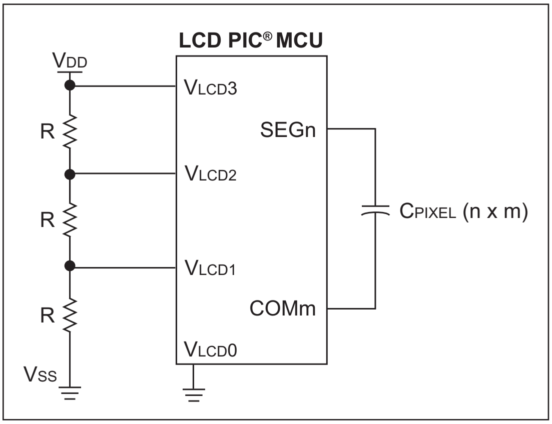
Multiplex Commons	Maximum Number of Segments/Pixels					Bias
	PIC16F913/ 916	PIC16F914/ 917	PIC16F946	PIC18F6X90 (PIC18F6XJ90)	PIC18F8X90 (PIC18F8XJ90)	
Static (COM0)	15	24	42	32/ (33)	48	Static
1/2 (COM1: COM0)	30	48	84	64/ (66)	96	1/2 or 1/3
1/3 (COM2: COM0)	45	72	126	96/ (99)	144	1/2 or 1/3
1/4 (COM3: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

TIP #3 Resistor Ladder for Low Current

Bias voltages are generated by using an external resistor ladder. Since the resistor ladder is connected between V_{DD} and V_{SS}, there will be current flow through the resistor ladder in inverse proportion to the resistance. In other words, the higher the resistance, the less current will flow through the resistor ladder. If we use 10K resistors and V_{DD} = 5V, the resistor ladder will continuously draw 166 μA. That is a lot of current for some battery-powered applications.

Figure 3-1: Resistor Ladder

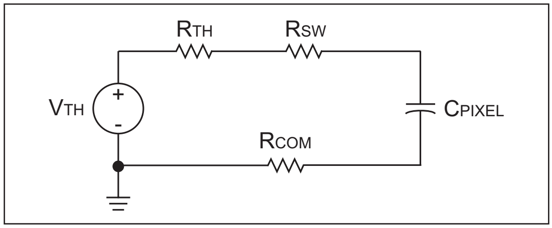


How do we maximize the resistance without adversely effecting the quality of the display? Some basic circuit analysis helps us determine how much we can increase the size of the resistors in the ladder.

The LCD module is basically an analog multiplexer that alternately connects the LCD voltages to the various segment and common pins that connect across the LCD pixels. The LCD pixels can be modeled as a capacitor. Each tap point on the resistor ladder can be modeled as a Thevenin equivalent circuit. The Thevenin resistance is 0 for $V_{LCD}3$ and $V_{LCD}0$, so we look at the two cases where it is non-zero, $V_{LCD}2$ and $V_{LCD}1$.

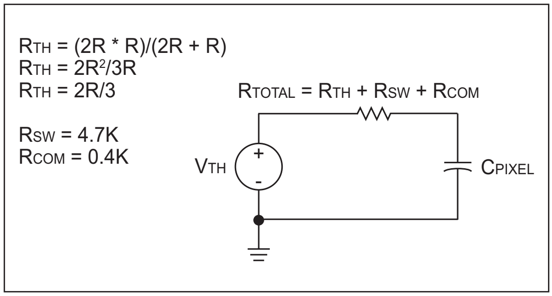
The circuit can be simplified as shown in Figure 3-2. R_{SW} is the resistance of the segment multiplex switch; R_{COM} is the resistance of the common multiplex switch.

Figure 3-2: Simplified LCD Circuit



The Thevenin voltage is equal to either 2/3 V_{DD}, or 1/3 V_{DD}, for the cases where the Thevenin resistance is non-zero. The Thevenin resistance is equal to the parallel resistance of the upper and lower parts of the resistor ladder.

Figure 3-3: LCD Circuit Resistance Estimate



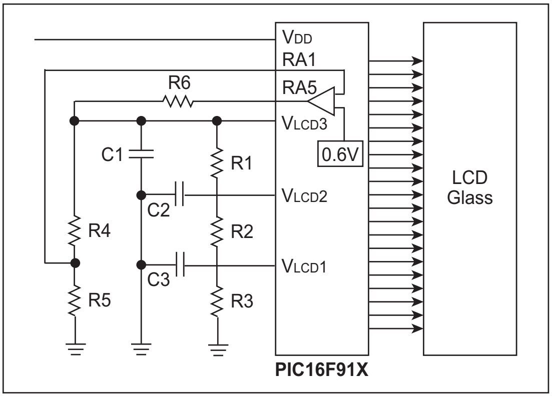
As you can see, we can model the drive of a single pixel as an RC circuit, where the voltage switches from 0V to $V_{LCD}2$, for example. For LCD PIC microcontrollers, we can estimate the resistance of the segment and common switching circuits as about 4.7K and 0.4K, respectively.

We can see that the time for the voltage across the pixel to change from 0 to V_{TH} will depend on the capacitance of the pixel and the total resistance, of which the resistor ladder Thevenin resistance forms the most significant part.

TIP #4: Contrast Control with a Buck Regulator

Contrast control in any of the LCD PIC MCUs is accomplished by controlling the voltages applied to the V_{LCD} voltage inputs. The simplest contrast voltage generator is to place a resistor divider across the three pins. This circuit is shown in the data sheet. The resistor ladder method is good for many applications, but the resistor ladder does not work in an application where the contrast must remain constant over a range of V_{DD}s. The solution is to use a voltage regulator. The voltage regulator can be external to the device, or it can be built using a comparator internal to the LCD PIC microcontroller.

Figure 4-1: Voltage Generator with Resistor Divider



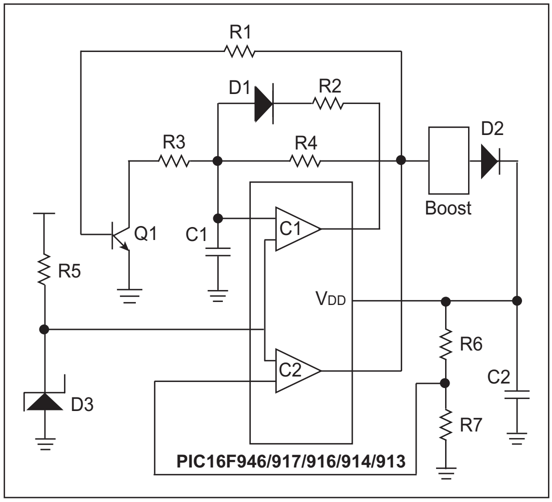
The PIC16F946/917/916/914/913 devices have a special Comparator mode that provides a fixed 0.6V reference. The circuit shown in Figure 4-1 makes use of this reference to provide a regulated contrast voltage. In this circuit, R1, R2 and R3 provide the contrast control voltages. The voltage on $V_{LCD}3$ is compared to the internal voltage reference by dividing the voltage at $V_{LCD}3$ at R4 and R5 and applying the reduced voltage to the internal comparator. When the voltage at $V_{LCD}3$ is close to the desired voltage, the output of the comparator will begin to oscillate. The oscillations are filtered into a DC voltage by R6 and C1. C2 and C3 are simply small bypass capacitors to ensure that the voltages at $V_{LCD}1$ and $V_{LCD}2$ are steady.

TIP #5: Contrast Control Using a Boost Regulator

In LCD Tip #4, a buck converter was created using a comparator. This circuit works great when V_{DD} is greater than the LCD voltage. The PIC microcontroller can operate all the way down to 2.0V, whereas most low-voltage LCD glass only operates down to 3V. In a battery application, it is important to stay operational as long as possible. Therefore, a boost converter is required to boost 2.0V up to 3.0V for the LCD.

The figure below shows one circuit for doing this.

Figure 5-1: Boost Converter



In this circuit, both comparators are used. The voltage setpoint is determined by the value of Zenier diode D3 and the voltage at R6:R7. The rest of the circuit creates a simple multivibrator to stimulate a boost circuit. The boost circuit can be inductor or capacitor-based. When the output voltage is too low, the multivibrator oscillates and causes charge to build up in C2. As the voltage at C2 increases, the multivibrator will begin to operate sporadically to maintain the desired voltage at C2.

CHAPTER 7
Intelligent Power Supply Design Tips 'n Tricks

Table Of Contents

TIPS 'N TRICKS INTRODUCTION

Microchip continues to provide innovative products that are smaller, faster, easier-to-use and more reliable. PIC® microcontrollers (MCUs) are used in a wide range of everyday products from washing machines, garage door openers and television remotes to industrial, automotive and medical products.

While some designs such as Switch Mode Power Supplies (SMPS) are traditionally implemented using a purely analog control scheme, these designs can benefit from the configurability and intelligence that can only be realized by adding a microcontroller.

This document showcases several examples in which a PIC microcontroller may be used to increase the functionality of a design with a minimal increase in cost.

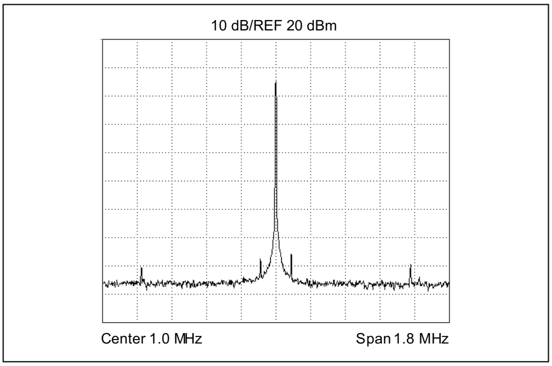
Several of the tips provide working software examples or reference other documents for more information. The software and referenced documents can be found on the Microchip web site at www.microchip.com/tipsntricks.

TIP #4 Creating a Dithered PWM Clock

In order to meet emissions requirements as mandated by the FCC and other regulatory organizations, the switching frequency of a power supply can be varied. Switching at a fixed frequency produces energy at that frequency. By varying the switching frequency, the energy is spread out over a wider range and the resulting magnitude of the emitted energy at each individual frequency is lower.

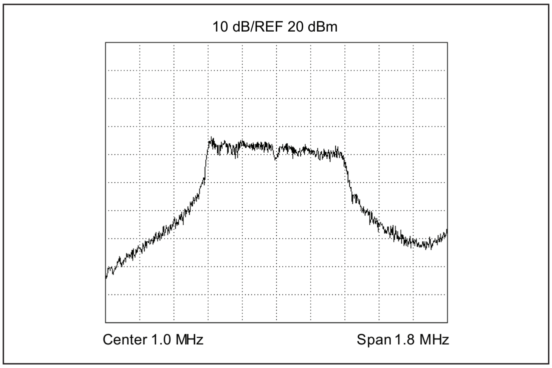
The PIC10F200 has an internal 4 MHz oscillator. A scaled version of oscillator can be output on a pin (Fosc/4). The scaled output is 1/4 of the oscillator frequency (1 MHz) and will always have a 50% duty cycle. Figure 4-1 shows a spectrum analyzer shot of the output of the Fosc/4 output.

Figure 4-1: Spectrum of Clock Output Before Dithering



The PIC10F200 provides an Oscillator Calibration (OSCCAL) register that is used to calibrate the frequency of the oscillator. By varying the value of the OSCCAL setting, the frequency of the clock output can be varied. A pseudo-random sequence was used to vary the OSCCAL setting, allowing frequencies from approximately 600 kHz to 1.2 MHz. The resulting spectrum is shown in Figure 4-2.

Figure 4-2: Spectrum of Clock Output After Dithering



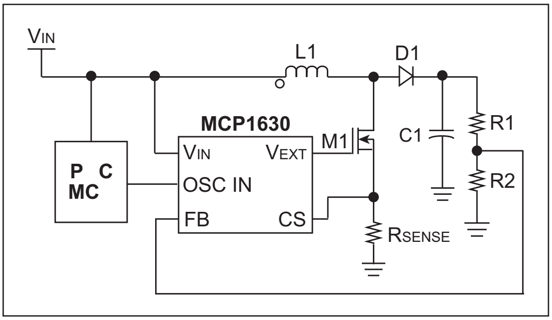
By spreading the energy over a wider range of frequencies, a drop of more than 20 dB is achieved.

Example software is provided for the PIC10F200 that performs the pseudo-random sequence generation and loads the OSCCAL register.

TIP #5 Using a PIC® Microcontroller as a Clock Source for a SMPS PWM Generator

A PIC MCU can be used as the clock source for a PWM generator, such as the MCP1630.

Figure 5-1: PIC MCU and MCP1630 Example Boost Application



The MCP1630 begins its cycle when its clock/oscillator source transitions from high-to-low, causing its PWM output to go high state. The PWM pulse can be terminated in any of three ways:

1. The sensed current in the magnetic device reaches 1/3 of the error amplifier output.
2. The voltage at the Feedback (FB) pin is higher than the reference voltage (V_{REF}).
3. The clock/oscillator source transitions from low-to-high.

The switching frequency of the MCP1630 can be adjusted by changing the frequency of the clock source. The maximum on-timer of the MCP1630 PWM can be adjusted by changing the duty cycle of the clock source.

The PIC MCU has several options for providing this clock source:

- The Fosc/4 pin can be enabled. This will produce a 50% duty cycle square wave that is 1/4th of the oscillator frequency. Tip #4 provides both example software and information on clock dithering using the FOSC/4 output.
- For PIC MCUs equipped with a Capture/Compare/PWM (CCP) or Enhanced CCP (ECCP) module, a variable frequency, variable duty cycle signal can be created with little software overhead. This PWM signal is entirely under software control and allows advanced features, such as soft-start, to be implemented using software.
- For smaller parts that do not have a CCP or ECCP module, a software PWM can be created. Tips #1 and #2 use software PWM for soft-start and provide software examples.

TIP #12 Using Auto-Shutdown CCP

PWM Auto-Shutdown

Several of Microchip’s PIC MCUs, such as the PIC16F684, PIC16F685 and PIC16F690, have a PWM auto-shutdown feature. When auto-shutdown is enabled, an event can terminate the current PWM pulse and prevent subsequent pulses unless the event is cleared. The ECCP can be setup to automatically start generating pulses again once the event clears.

Figure 12-1: PWM Auto-Shutdown Timing

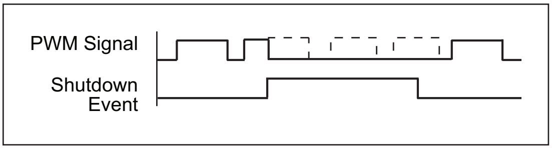
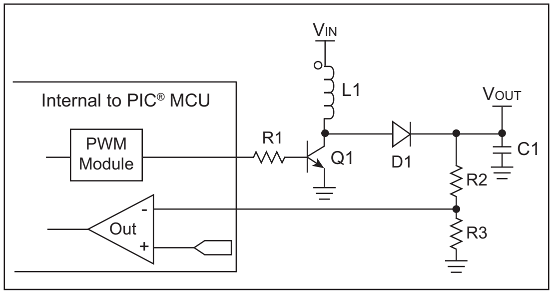


Figure 12-1 shows an example timing for the PWM auto-shutdown. When the shutdown event occurs, the current pulse is immediately terminated. In this example, the next two pulses are also terminated because the shutdown event had not been cleared by the beginning of the pulse period. After the event has cleared, pulses are allowed to resume, but only at the beginning of a pulse period.

Using Auto-Shutdown to Create a Boost Supply

By using the auto-shutdown feature, a very simple SMPS can be created. Figure 12-2 shows an example boost power supply.

Figure 12-2: Boost Power Supply



This power supply configuration has several unique features:

1. The switching frequency is determined by the PWM frequency and, therefore, can be changed at any time.
2. The maximum on-time is determined by the PWM duty cycle and, therefore, can be changed any time. This provides a very easy way to implement soft-start.
3. On PIC MCUs that have a programmable reference module, the output voltage can be configured and changed at any time.

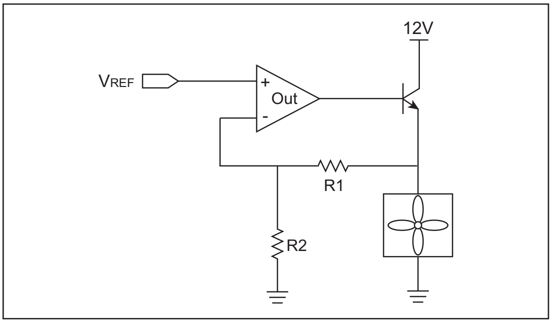
The topology can also be re-arranged to create other types of power supplies.

Example software is provided for the PIC16F685 (but can be adapted to any PIC MCU with the ECCP module). The software configures the PWM and comparator modules as shown in Figure 12-2.

Method 2 – Linear Control

When using PWM, the voltage will vary between a maximum and a minimum, however, is it also possible to use a linear method to control fan speed, as shown in Figure 14-4.

Figure 14-4: Linear Control Drive



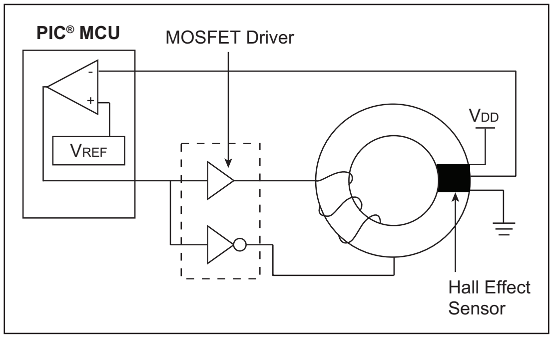
The voltage applied at the non-inverting terminal of the op amp is used to vary the voltage across the op amp. The non-inverting terminal voltage can be produced by a Digital-to-Analog Converter (DAC) or by the method shown in Tip #11.

When using this method, care must be taken to ensure that the fan voltage is not too low or the fan will stop spinning. One advantage this method has over PWM is that the tachometer output will function properly on 3-wire fans. The disadvantage, however, is that it often offers less speed control. For example, a 12V fan will not spin below 8V, so a range of only 4V is available for speed control. A 5V fan will not spin below 4V and so the control range is only 1V, which is often unacceptable. Another disadvantage is the power consumption of the circuit. The transistor will dissipate more power than the PWM method.

TIP #15 High Current Delta-Sigma Based Current Measurement Using a Slotted Ferrite and Hall Effect Device

Many current sensors rely on ferrite cores. Non-linearity in the ferrite can lead to inaccurate results, especially at high currents. One way to avoid the non-linearities is to keep the net flux in the ferrite near zero. Consider the circuit in Figure 15-1.

Figure 15-1: Hall Effect Current Measurement Schematic



The Hall effect sensor output is proportional to the current being measured. When I_{IN} = 0 amps, the output of the sensor will be $V_{DD}/2$. A current passing through the sensor in one direction will increase the output of the sensor, and a current in the other direction will decrease the output of the sensor.

The output of the comparator is used to drive a coil of wire wound around the ferrite core. This coil of wire will be used to create flux in the opposite direction as the flux imposed in the core.

TIP #4 Powering 3.3V Systems From 5V Using Switching Regulators

A buck switching regulator, shown in Figure 4-1, is an inductor-based converter used to step-down an input voltage source to a lower magnitude output voltage. The regulation of the output is achieved by controlling the ON time of MOSFET Q1. Since the MOSFET is either in a lower or high resistive state (ON or OFF, respectively), a high source voltage can be converted to a lower output voltage very efficiently.

The relationship between the input and output voltage can be established by balancing the volt-time of the inductor during both states of Q1.

Equation 4-1

$$(V_S - V_O) * t_{on} = V_o * (T - t_{on})$$
$$\text{Where: } T \equiv t_{on}/\text{Duty\_Cycle}$$

It therefore follows that for MOSFET Q1:

Equation 4-2

$$\text{Duty\_Cycle}_{Q1} = V_O/V_S$$

When choosing an inductor value, a good starting point is to select a value to produce a maximum peak-to-peak ripple current in the inductor equal to ten percent of the maximum load current.

Equation 4-3

$$V = L * (di/dt)$$
$$L = (V_S - V_O) * (t_{on}/I_o * 0.10)$$

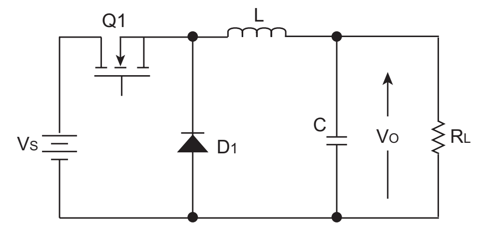
When choosing an output capacitor value, a good starting point is to set the LC filter characteristic impedance equal to the load resistance. This produces an acceptable voltage overshoot when operating at full load and having the load abruptly removed.

Equation 4-4

$$Z_o \equiv \sqrt{L/C}$$
$$C = L/R^2 = (I_O^2 * L)/V_O^2$$

When choosing a diode for D1, choose a device with a sufficient current rating to handle the inductor current during the discharge part of the pulse cycle (I_L).

Figure 4-1: Buck Regulator



Digital Interfacing

When interfacing two devices that operate at different voltages, it is imperative to know the output and input thresholds of both devices. Once these values are known, a technique can be selected for interfacing the devices based on the other requirements of your application. Table 4-1 contains the output and input thresholds that will be used throughout this document. When designing an interface, make sure to reference your manufacturers data sheet for the actual threshold levels.

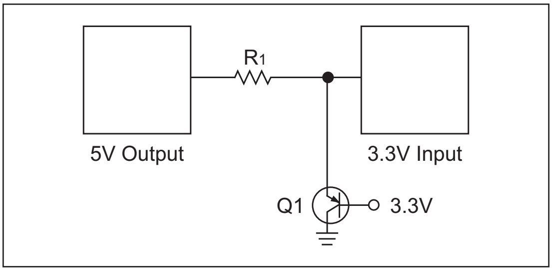
Table 4-1: Input/Output Thresholds

	V_{OH} min	V_{OL} max	V_{IH} min	V_{IL} max
5V TTL	2.4V	0.5V	2.0V	0.8V
3.3V LVTTL	2.4V	0.4V	2.0V	0.8V
5V CMOS	4.7V (Vcc-0.3V)	0.5V	3.5V (0.7xVcc)	1.5V (0.3xVcc)
3.3V LVCMOS	3.0V (Vcc-0.3V)	0.5V	2.3V (0.7xVcc)	1.0V (0.3xVcc)

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

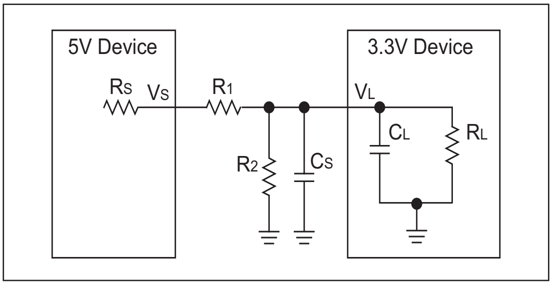


The base-emitter junction of Q1 performs the same function as the diode in a diode clamp circuit. The difference is that only a small percentage of the emitter current flows out of the base of the transistor to the 3.3V rail, the bulk of the current is routed to the collector where it passes harmlessly 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.