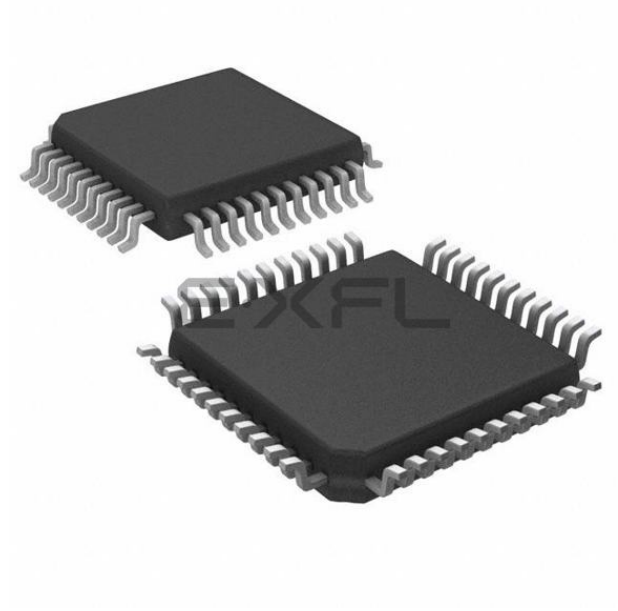

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"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable 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	20MHz
Connectivity	I²C, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	33
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	44-QFP
Supplier Device Package	44-MQFP (10x10)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic16c65b-20i-pq

CHAPTER 1
8-Pin Flash PIC® Microcontrollers 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. The 8-pin Flash PIC® microcontrollers (MCU) are used in an wide range of everyday products, from toothbrushes, hair dryers and rice cookers to industrial, automotive and medical products.

The PIC12F629/675 MCUs merge all the advantages of the PIC MCU architecture and the flexibility of Flash program memory into an 8-pin package. They provide the features and intelligence not previously available due to cost and board space limitations. Features include a 14-bit instruction set, small footprint package, a wide operating voltage of 2.0 to 5.5 volts, an internal programmable 4 MHz oscillator, on-board EEPROM data memory, on-chip voltage reference and up to 4 channels of 10-bit A/D. 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.

TIPS ‘N TRICKS WITH HARDWARE

The following series of Tips ’n Tricks can be applied to a variety of applications to help make the most of the 8-pin dynamics.

TIP #5 Scanning Many Keys With One Input

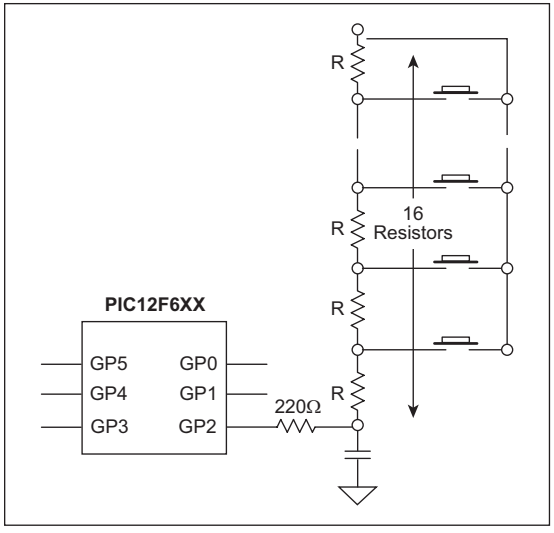
The time required to charge a capacitor depends on resistance between VDD and capacitor. When a button is pressed, VDD is supplied to a different point in the resistor ladder. The resistance between VDD and the capacitor is reduced, which reduces the charge time of the capacitor. A timer is used with a comparator or changing digital input to measure the capacitor charge time. The charge time is used to determine which button is pressed.

Software sequence:

1. Configure GP2 to output a low voltage to discharge capacitor through I/O resistor.
2. Configure GP2 as one comparator input and CVREF as the other.
3. Use a timer to measure when the comparator trips. If the time measured is greater than the maximum allowed time, then repeat; otherwise determine which button is pressed.

When a key is pressed, the voltage divider network changes the RC ramp rate.

Figure 5-1



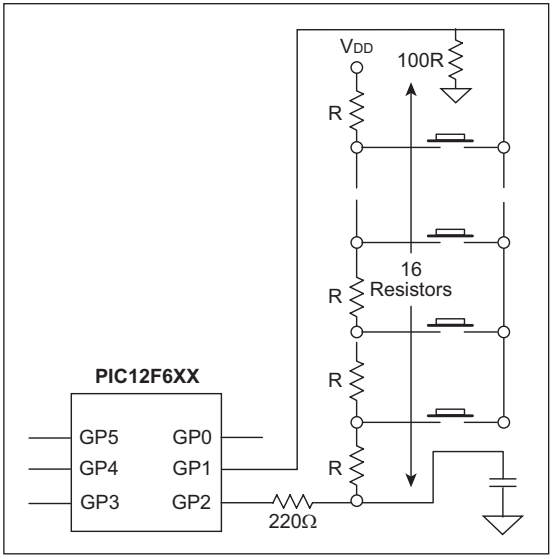
See AN512, "*Implementing Ohmmeter/ Temperature Sensor*" for code ideas.

TIP #6 Scanning Many Keys and Wake-up From Sleep

An additional I/O can be added to wake the part when a button is pressed. Prior to Sleep, configure GP1 as an input with interrupt-on-change enabled and GP2 to output high. The pull-down resistor holds GP1 low until a button is pressed. GP1 is then pulled high via GP2 and VDD generating an interrupt. After wake-up, GP2 is configured to output low to discharge the capacitor through the 220Ω resistor. GP1 is set to output high and GP2 is set to an input to measure the capacitor charge time.

- GP1 pin connected to key common
- Enable wake-up on port change
- Set GP1 as input and GP2 high prior to Sleep
- If key is pressed the PIC MCU wakes up, GP2 must be set low to discharge capacitor
- Set GP1 high upon wake-up to scan keystroke

Figure 6-1



Tip #13.3 Reading a Sensor With Higher Accuracy – A/D Method

NTC (Negative Temperature Coefficient) sensors have a non-linear response to temperature changes. As the temperature drops, the amount the resistance changes becomes less and less. Such sensors have a limited useful range because the resolution becomes smaller than the A/D resolution as the temperature drops. By changing the voltage divider of the RSEN, the temperature range can be expanded.

To select the higher temperature range, GP1 outputs '1' and GP2 is set as an input. For the lower range, GP2 outputs '1' and GP1 is configured as an input. The lower range will increase the amount the sensor voltage changes as the temperature drops to allow a larger usable sensor range.

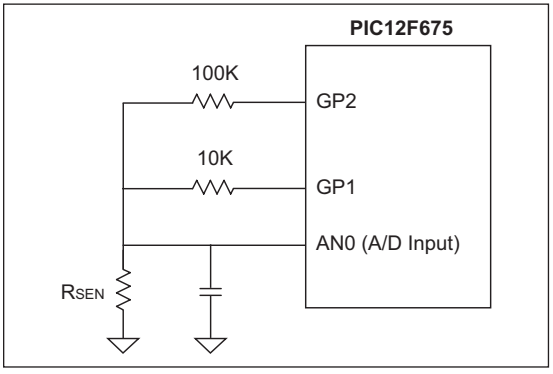
Summary:

High range: GP1 output '1' and GP2 input

Low range: GP1 input and GP2 output '1'

1. 10K and 100K resistors are used to set the range
2. VREF for A/D = VDD
3. Rth calculation is independent of VDD
4. Count = RSEN/(RSEN+RREF) x 255
5. Don't forget to allow acquisition time for the A/D

Figure 13-4

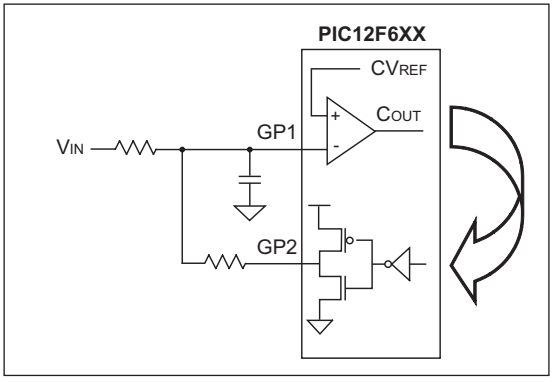


TIP #14 Delta-Sigma Converter

The charge on the capacitor on GP1 is maintained about equal to the CVREF by the MCU monitoring COUT and switching GP2 from Input mode or output low appropriately. A timer is used to sample the COUT bit on a periodic basis. Each time GP2 is driven low, a counter is incremented. This counter value corresponds to the input voltage.

To minimize the affects of external component tolerances, temperature, etc., the circuit can be calibrated. Apply a known voltage to the input and allow the microcontroller to count samples until the expected result is calculated. By taking the same number of samples for subsequent measurements, they become calibrated measurements.

Figure 14-1



1. GP1 average voltage = CVREF
2. Time base as sampling rate
3. At the end of each time base period:
   - If GP1 > CVREF, then GP2 Output Low
   - If GP1 < CVREF, then GP2 Output High
4. Accumulate the GP2 lows over many samples
5. Number of samples determines resolution

TIP #16 Optimizing Destinations

- Destination bit determines W for F for result
- Look at data movement and restructure

Example 16-1

Example: A + B → A

```
MOVF    A,W
ADDWF   B,W
MOVWF   A
```

3 instructions

```
MOVF    B,W
ADDWF   A,F
```

2 instructions

Careful use of the destination bits in instructions can save program memory. Here, register A and register B are summed and the result is put into the A register. A destination option is available for logic and arithmetic operations. In the first example, the result of the ADDWF instruction is placed in the working register. A MOVWF instruction is used to move the result from the working register to register A. In the second example, the ADDWF instruction uses the destination bit to place the result into the A register, saving an instruction.

TIP #17 Conditional Bit Set/Clear

- To move single bit of data from REGA to REGB
- Precondition REGB bit
- Test REGA bit and fix REGB if necessary

Example 17-1

```
BTFSS   REGA,2
BCF     REGB,5
BTFSC   REGA,2
BSF     REGB,5
```

4 instructions

```
BCF     REGB,5
BTFSC   REGA,2
BSF     REGB,5
```

3 instructions

One technique for moving one bit from the REGA register to REGB is to perform bit tests. In the first example, the bit in REGA is tested using a BTFSS instruction. If the bit is clear, the BCF instruction is executed and clears the REGB bit, and if the bit is set, the instruction is skipped.The second bit test determines if the bit is set, and if so, will execute the BSF and set the REGB bit, otherwise the instruction is skipped. This sequence requires four instructions.

A more efficient technique is to assume the bit in REGA is clear, and clear the REGB bit, and test if the REGA bit is clear. If so, the assumption was correct and the BSF instruction is skipped, otherwise the REGB bit is set. The sequence in the second example uses three instructions because one bit test was not needed.

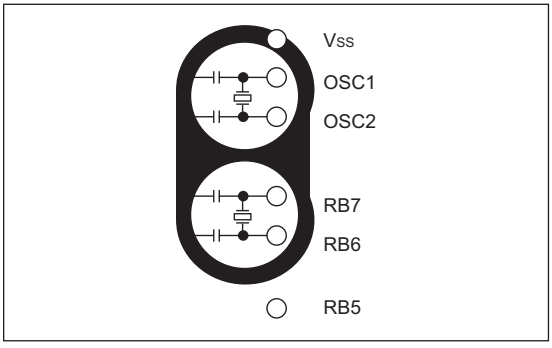
One important point is that the second example will create a two-cycle glitch if REGB is a port outputting a high. This is caused by the BCF and BTFSC instructions that will be executed regardless of the bit value in REGA.

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

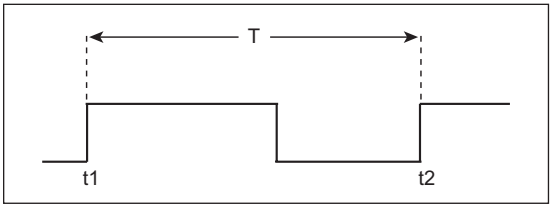
The Low Voltage Detect (LVD) interrupt present in many PIC MCUs is critical in battery based systems. It is necessary for two reasons. First, many devices cannot run full speed at the minimum operating voltage. In this case, the LVD interrupt indicates when the battery voltage is dropping so that the 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 #1 Measuring the Period of a Square Wave

Figure 1-1: Period



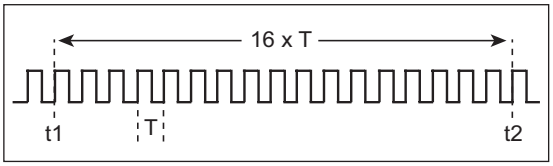
1. Configure control bits CCPxM3:CCPxM0 (CCPxCON<3:0>) to capture every rising edge of the waveform.
2. Configure the Timer1 prescaler so Timer1 with run T_{MAX}(1) without overflowing.
3. Enable the CCP interrupt (CCPxIE bit).
4. When a CCP interrupt occurs:
   a) Subtract saved captured time (t1) from captured time (t2) and store (use Timer1 interrupt flag as overflow indicator).
   b) Save captured time (t2).
   c) Clear Timer1 flag if set.

The result obtained in step 4.a is the period (T).

Note 1: T_{MAX} is the maximum pulse period that will occur.

TIP #2 Measuring the Period of a Square Wave with Averaging

Figure 2-1: Period Measurement



1. Configure control bits CCPxM3:CCPxM0 (CCPxCON<3:0>) to capture every 16th rising edge of the waveform.
2. Configure the Timer1 prescaler so Timer1 will run 16 T_{MAX}(1) without overflowing.
3. Enable the CCP interrupt (CCPxIE bit).
4. When a CCP interrupt occurs:
   a) Subtract saved captured time (t1) from captured time (t2) and store (use Timer1 interrupt flag as overflow indicator).
   b) Save captured time (t2).
   c) Clear Timer1 flag if set.
   d) Shift value obtained in step 4.a right four times to divide by 16 – this result is the period (T).

Note 1: T_{MAX} is the maximum pulse period that will occur.

The following are the advantages of this method as opposed to measuring the periods individually.

- Fewer CCP interrupts to disrupt program flow
- Averaging provides excellent noise immunity

TIP #5 Measuring RPM Using an Encoder

Revolutions Per Minute (RPM), or how fast something turns, can be sensed in a variety of ways. Two of the most common sensors used to determine RPM are optical encoders and Hall effect sensors. Optical encoders detect the presence of light shining through a slotted wheel mounted to a turning shaft (see Figure 5-1.) As the shaft turns, the slots in the wheel pass by the eye of the optical encoder. Typically, an infrared source on the other side of the wheel emits light that is seen by the optical encoder through slots in the wheel. Hall effect sensors work by sensing the position of the magnets in an electric motor, or by sensing a permanent magnet mounted to a rotating object (see Figure 5-2). These sensors output one or more pulses per revolution (depending on the sensor).

Figure 5-1: Optical Encoder

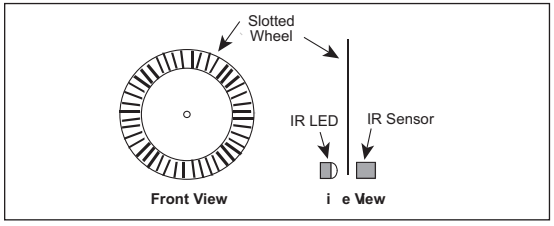
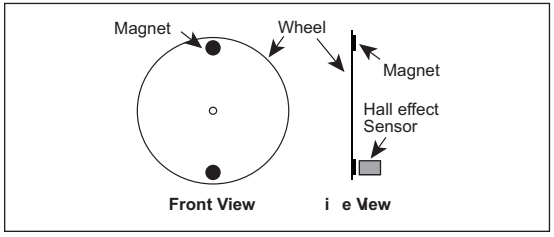


Figure 5-2: Hall Effect Sensor



In Figure 5-3 and Figure 5-4, the waveform is high when light is passing through a slot in the encoder wheel and shining on the optical sensor. In the case of a Hall effect sensor, the high corresponds to the time that the magnet is in front of the sensor. These figures show the difference in the waveforms for varying RPMs. Notice that as RPM increases, the period (T) and pulse width (W) becomes smaller. Both period and pulse width are proportional to RPM. However, since the period is the greater of the two intervals, it is good practice to measure the period so that the RPM reading from the sensor will have the best resolution. See Tip #1 for measuring period. The technique for measuring period with averaging described in Tip #2 is useful for measuring high RPMs.

Figure 5-3: Low RPM

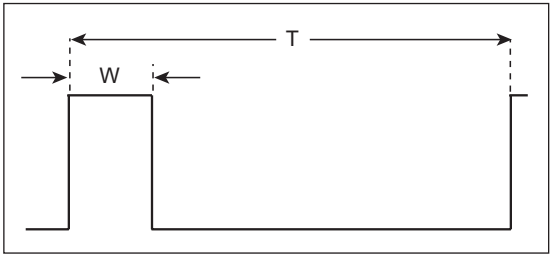
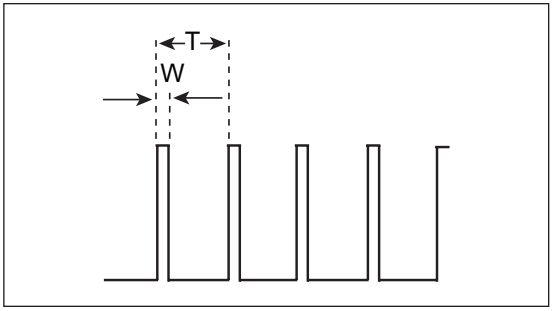


Figure 5-4: High RPM



TIP #8 Modulation Formats

The CCP module, configured in Compare mode, can be used to generate a variety of modulation formats. The following figures show four commonly used modulation formats:

Figure 8-1: Pulse-width Modulation

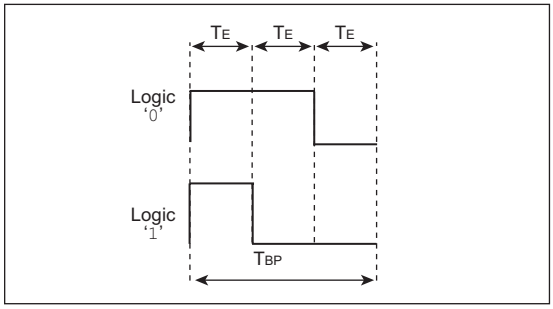


Figure 8-2: Manchester

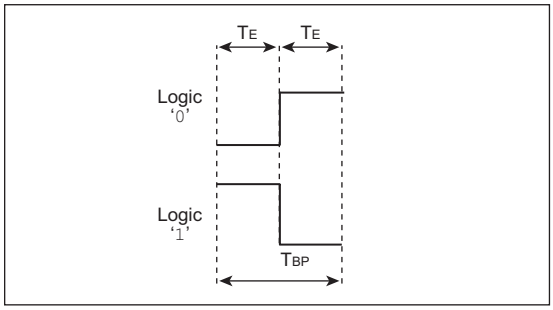


Figure 8-3: Pulse Position Modulation

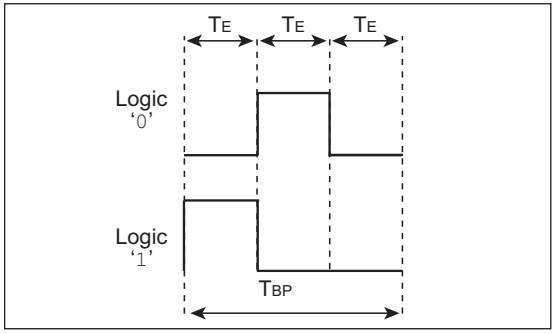
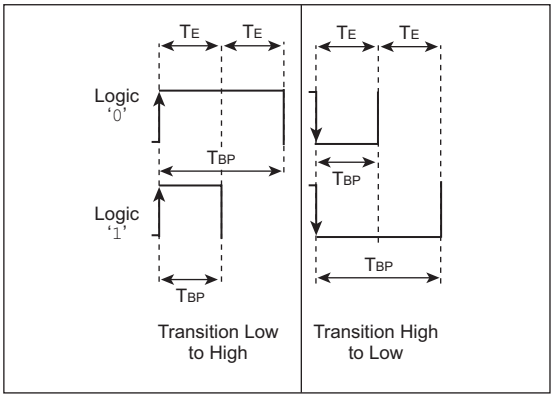


Figure 8-4: Variable Pulse-width Modulation



The figures show what a logic '0' or a logic '1' looks like for each modulation format. A transmission typically resembles an asynchronous serial transmission consisting of a Start bit, followed by 8 data bits, and a Stop bit.

T_E is the basic timing element in each modulation format and will vary based on the desired baud rate.

Trigger Special Event mode can be used to generate T_E, (the basic timing element). When the CCPx interrupt is generated, code in the ISR routine would implement the desired modulation format (additional modulation formats are also possible).

TIP #9 Generating the Time Tick for a RTOS

Real Time Operating Systems (RTOS) require a periodic interrupt to operate. This periodic interrupt, or "tick rate", is the basis for the scheduling system that RTOS's employ. For instance, if a 2 ms tick is used, the RTOS will schedule its tasks to be executed at multiples of the 2 ms. A RTOS also assigns a priority to each task, ensuring that the most critical tasks are executed first. Table 9-1 shows an example list of tasks, the priority of each task and the time interval that the tasks need to be executed.

Table 9-1: Tasks

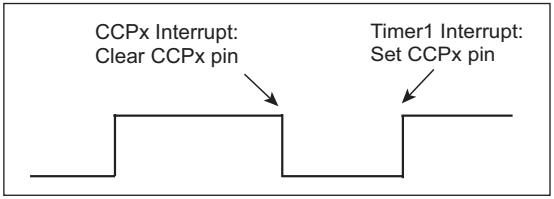
Task	Interval	Priority
Read ADC Input 1	20 ms	2
Read ADC Input 2	60 ms	1
Update LCD	24 ms	2
Update LED Array	36 ms	3
Read Switch	10 ms	1
Dump Data to Serial Port	240 ms	1

The techniques described in Tip #7 can be used to generate the 2 ms periodic interrupt using the CCP module configured in Compare mode.

Note: For more information on RTOSs and their use, see Application Note AN777 "*Multitasking on the PIC16F877 with the Salvo™ RTOS*".

TIP #10 16-Bit Resolution PWM

Figure 10-1: 16-Bit Resolution PWM



1. Configure CCPx to clear output (CCPx pin) on match in Compare mode (CCPxCON <CCPSM3:CCPxM0>).
2. Enable the Timer1 interrupt.
3. Set the period of the waveform via Timer1 prescaler (T1CON <5:4>).
4. Set the duty cycle of the waveform using CCPRxL and CCPRxH.
5. Set CCPx pin when servicing the Timer1 overflow interrupt(1).

Note 1: One hundred percent duty cycle is not achievable with this implementation due to the interrupt latency in servicing Timer1. The period is not affected because the interrupt latency will be the same from period to period as long as the Timer1 interrupt is serviced first in the ISR.

Timer1 has four configurable prescaler values. These are 1:1, 1:2, 1:4 and 1:8. The frequency possibilities of the PWM described above are determined by Equation 10-1.

Equation 10-1

$$F_{PWM} = F_{OSC}/(65536*4*prescaler)$$

For a microcontroller running on a 20 MHz oscillator (Fosc) this equates to frequencies of 76.3 Hz, 38.1 Hz, 19.1 Hz and 9.5 Hz for increasing prescaler values.

TIP #13 Deciding on PWM Frequency

In general, PWM frequency is application dependent although two general rules-of-thumb hold regarding frequency in all applications. They are:

1. As frequency increases, so does current requirement due to switching losses.
2. Capacitance and inductance of the load tend to limit the frequency response of a circuit.

In low-power applications, it is a good idea to use the minimum frequency possible to accomplish a task in order to limit switching losses. In circuits where capacitance and/or inductance are a factor, the PWM frequency should be chosen based on an analysis of the circuit.

Motor Control

PWM is used extensively in motor control due to the efficiency of switched drive systems as opposed to linear drives. An important consideration when choosing PWM frequency for a motor control application is the responsiveness of the motor to changes in PWM duty cycle. A motor will have a faster response to changes in duty cycle at higher frequencies. Another important consideration is the sound generated by the motor. Brushed DC motors will make an annoying whine when driven at frequencies within the audible frequency range (20 Hz-4 kHz.) In order to eliminate this whine, drive brushed DC motors at frequencies greater than 4 kHz. (Humans can hear frequencies at upwards of 20 kHz, however, the mechanics of the motor winding will typically attenuate motor whine above 4 kHz).

LED and Light Bulbs

PWM is also used in LED and light dimmer applications. Flicker may be noticeable with rates below 50 Hz. Therefore, it is generally a good rule to pulse-width modulate LEDs and light bulbs at 100 Hz or higher.

TIP #14 Unidirectional Brushed DC Motor Control Using CCP

Figure 14-1: Brushed DC (BDC) Motor Control Circuit

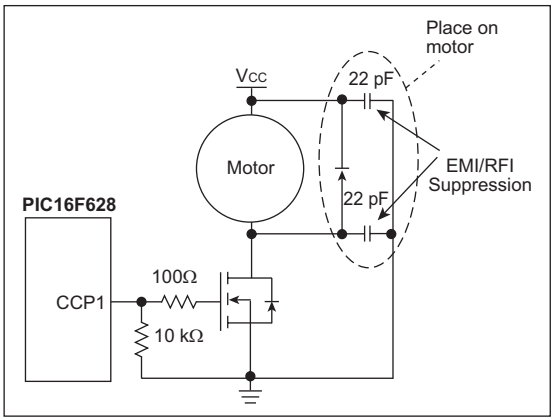


Figure 14-1 shows a unidirectional speed controller circuit for a brushed DC motor. Motor speed is proportional to the duty cycle of the PWM output on the CCP1 pin. The following steps show how to configure the PIC16F628 to generate a 20 kHz PWM with 50% duty cycle. The microcontroller is running on a 20 MHz crystal.

Step #1: Choose Timer2 Prescaler

a) F_{PWM} = Fosc/((PR2+1)*4*prescaler) = 19531 Hz for PR2 = 255 and prescaler of 1

b) This frequency is lower than 20 kHz, therefore a prescaler of 1 is adequate.

Step #2: Calculate PR2

PR2 = Fosc/(F_{PWM}*4*prescaler) – 1 = 249

Step #3: Determine CCPR1L and CCP1CON<5:4>

a) CCPR1L:CCP1CON<5:4> = DutyCycle*0x3FF = 0x1FF

b) CCPR1L = 0x1FF >> 2 = 0x7F, CCP1CON<5:4> = 3

Step #4: Configure CCP1CON

The CCP module is configured in PWM mode with the Least Significant bits of the duty cycle set, therefore, CCP1CON = '`b001111000`'.

CHAPTER 4
PIC® Microcontroller Comparator 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. 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 #11 PWM Generator

This tip shows how the multi-vibrator (ramp wave) can be used to generate a voltage controlled PWM signal. The ramp wave multi-vibrator operates as described in Tip #9, generating a positive going ramp wave. A second comparator compares the instantaneous voltage of the ramp wave with the incoming voltage to generate the PWM output (see Figure 11-2).

When the ramp starts, it is below the input voltage, and the output of the second comparator is pulled high starting the PWM pulse. The output remains high until the ramp wave voltage exceeds the input, then the output of the second comparator goes low ending the PWM pulse. The output of the second comparator remains low for the remainder of the ramp waveform. When the ramp waveform returns to zero at the start of the next cycle, the second comparator output goes high again and the cycle starts over.

Figure 11-1: PWM Wave Forms

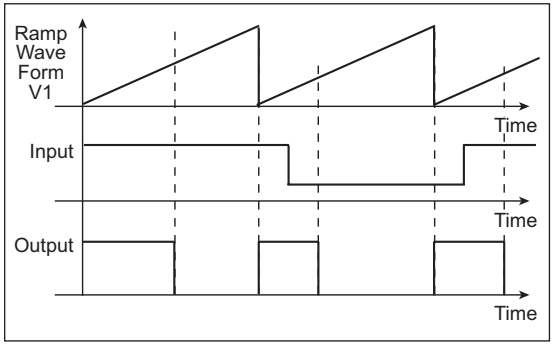
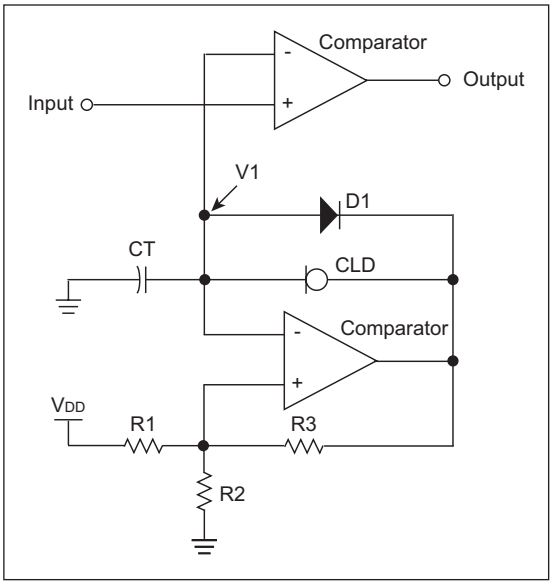


Figure 11-2: PWM Circuit



To design a PWM generator, start with the design of a ramp wave multi-vibrator using the design procedure from Tip #9. Choose high and low threshold voltages for the multi-vibrators hysteresis feedback that are slightly above and below the desired PWM control voltages.

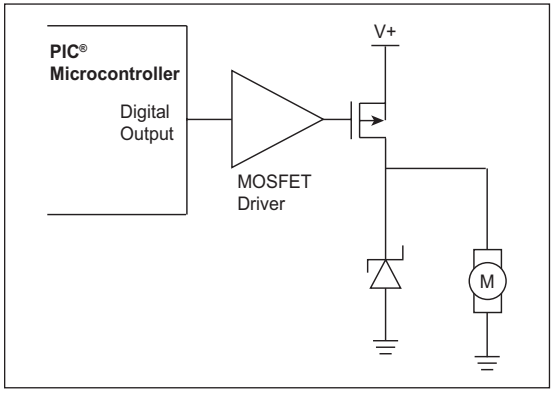
Note: The PWM control voltage will produce a 0% duty cycle for inputs below the low threshold of the multi-vibrator. A control voltage greater than the high threshold voltage will produce a 100% duty cycle output.

Using the example values from Tip #9 will result in a minimum pulse width at an input voltage of 1.7V and a maximum at an input of 3.2V.

TIP #1 Brushed DC Motor Drive Circuits

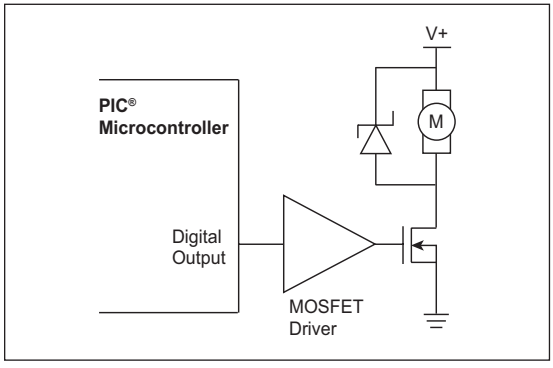
All motors require drive circuitry which controls the current flow through the motor windings. This includes the direction and magnitude of the current flow. The simplest type of motor, to drive, is the Brushed DC motor. Drive circuits for this type of motor are shown below.

Figure 1-1: High Side Drive



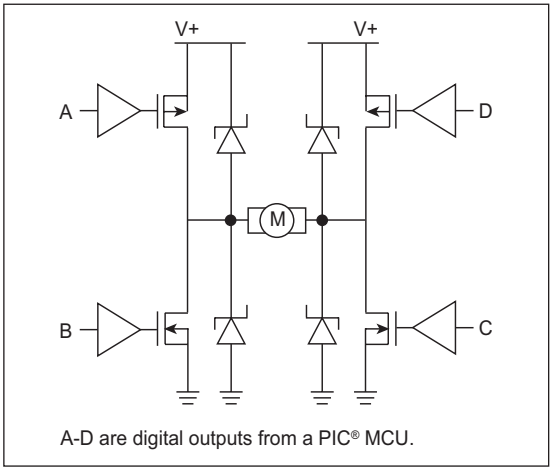
This drive can control a Brushed DC motor in one direction. This drive is often used in safety critical applications because a short circuit at the motor terminals cannot turn the motor on.

Figure 1-2: Low Side Drive



This is the lowest cost drive technique because of the MOSFET drive simplicity. Most applications can simply use an output pin from the PIC® microcontroller to turn the MOSFET on.

Figure 1-3: H-Bridge Drive



The H-Bridge derived its name from the common way the circuit is drawn. This is the only solid state way to operate a motor in both directions.

Application notes that drive Brushed DC motors are listed below and can be found on the Microchip web site at: www.microchip.com.

- AN847, “*RC Model Aircraft Motor Control*” (DS00847)
- AN893, “*Low-cost Bidirectional Brushed DC Motor Control Using the PIC16F684*” (DS00893)
- AN905, “*Brushed DC Motor Fundamentals*” (DS00905)

Application Note References

- AN532, “*Servo Control of a DC Brush Motor*” (DS00532)
- AN696, “*PIC18CXXX/PIC16CXXX DC Servomotor*” (DS00696)
- AN718, “*Brush-DC Servomotor Implementation using PIC17C756A*” (DS00718)
- AN822, “*Stepper Motor Microstepping with the PIC18C452*” (DS00822)
- AN843, “*Speed Control of 3-Phase Induction Motor Using PIC18 Microcontrollers*” (DS00843)
- AN847, “*RC Model Aircraft Motor Control*” (DS00847)
- AN857, “*Brushless DC Motor Control Made Easy*” (DS00857)
- AN885, “*Brushless DC (BLDC) Motor Fundamentals*” (DS00885)
- AN899, “*Brushless DC Motor Control Using the PIC18FXX31*” (DS00899)
- AN893, “*Low-cost Bidirectional Brushed DC Motor Control Using the PIC16F684*” (DS00893)
- AN894, “*Motor Control Sensor Feedback Circuits*” (DS00894)
- AN898, “*Determining MOSFET Driver Needs for Motor Drive Applications*” (DS00898)
- AN901, “*Using the dsPIC30F for Sensorless BLDC Control*” (DS00901)
- AN905, “*Brushed DC Motor Fundamentals*” (DS00905)
- AN906, “*Stepper Motor Control Using the PIC16F684*” (DS00906)
- AN907, “*Stepper Motor Fundamentals*” (DS00907)
- AN1017, “*Sinusoidal Control of PMSM Motors with dsPIC30F DSC*” (DS01017)
- GS001, “*Getting Started with BLDC Motors and dsPIC30F Devices*” (DS93001)

Application notes can be found on the Microchip web site at www.microchip.com.

Motor Control Development Tools

- PICDEM™ MC Development Board (DM183011)

  Used to evaluate the PIC18FXX31 8-bit microcontroller family.
- PICDEM™ MCLV Development Board (DM183021)
- dsPIC30F Motor Control Development System (DM300020)

  Used to evaluate the dsPIC30F 16-bit Digital Signal Controller family.
- Motor Control (MC) Graphical User Interface (GUI)

  The MC-GUI allows user to configure the motor and a wide range of system parameters for a selected motor type.

  The MC-GUI is free an can be downloaded at www.microchip.com

  Visit the Motor Control Design Center at: www.microchip.com/motor for additional design resources.

TIP #10 How to Update LCD Data Through Firmware

To update the LCD, the content of the LCDDATA registers is modified to turn on, or off, each pixel on the LCD display. The application firmware will usually modify buffer variables that are created to correspond with elements on the display, such as character positions, bar graph, battery display, etc.

When the application calls for a display update, the values stored in the buffer variables must be converted to the correct setting of the pixel bits, located in the LCDDATA registers.

For Type-A waveforms, the LCD Data registers may be written any time without ill effect. However, for Type-B waveforms, the LCD Data registers can only be written every other LCD frame in order to ensure that the two frames of the Type-B waveform are compliments of one another. Otherwise, a DC bias can be presented to the LCD.

The LCD Data registers should only be written when a write is allowed, which is indicated by the WA bit in the LCDCON register being set.

On the PIC16C926 parts, there is no WA bit. The writing of the pixel data can be coordinated on an LCD interrupt. The LCD interrupt is only generated when a multiplexed (not static) Type-B waveform is selected.

TIP #11 Blinking LCD

Information can be displayed in more than one way with an LCD panel. For example, how can the user's attention be drawn to a particular portion of the LCD panel? One way that does not require any additional segments is to create a blinking effect.

Look at a common clock application. The ":" between the hours and minutes is commonly made to blink once a second (on for half a second, off for half a second). This shows that the clock is counting in absence of the ticking sound or second hand that accompanies the usual analog face clock. It serves an important purpose of letting the user know that the clock is operating.

If there is a power outage, then it is common for the entire clock display to blink. This gives the user of the clock an immediate indication that the clock is no longer showing the correct time.

When the user sets the time, then blinking is commonly used to show that a new mode has been entered, such as blinking the hours to identify that the hours are being set, or blinking the minutes to show that the minutes are being set. In a simple clock, blinking is used for several different purposes. Without blinking effects, the common digital clock would not be nearly as user friendly.

The two digital I/O pins that are used are RB0 and RB5, but any two digital I/O pins could work. The two analog pins used are AN0 and AN1.

To read the keypad, follow the steps below:

1. First, make RB0 an output high and RB5 an input (to present a high impedance).
2. Perform two successive A/D conversions, first on AN0, then on AN1.
3. Save the conversion results to their respective variables; for example, `RB0_AN0_Result` and `RB0_AN1_Result`.
4. Next, make RB5 an output high and RB0 an input (to present a high impedance).
5. Perform two successive A/D conversions, first on AN0, then on AN1.
6. Save the conversion results to their respective variables; for example, `RB5_AN0_Result` and `RB5_AN1_Result`.
7. There are now 4 variables that represent a key press in each quadrant of the 4 x 4 keypad:
   - `RB0_AN0_Result` denotes key press of 1, 2, 4 or 5
   - `RB0_AN1_Result` denotes key press of 7, 8, A or 0
   - `RB5_AN0_Result` denotes key press of 3, C, 6 or D
   - `RB5_AN1_Result` denotes key press of 9, E, B or F
8. Finally, check each value against the matching column of Table 12-1. If it is within ±10% of a value, then it can be taken to indicate that the corresponding key has been pressed.

Table 12-1: Keypad Values

Value ±10%	RB0_AN0	RB0_AN1	RB5_AN0	RB5_AN1
<V_{DD}/10	–	–	–	–
V_{DD}/5.2	2	8	C	E
V_{DD}/4.2	1	7	3	9
V_{DD}/3	5	0	D	F
V_{DD}/2	4	A	6	B

9. This loop should be repeated about once every 20 ms or so.

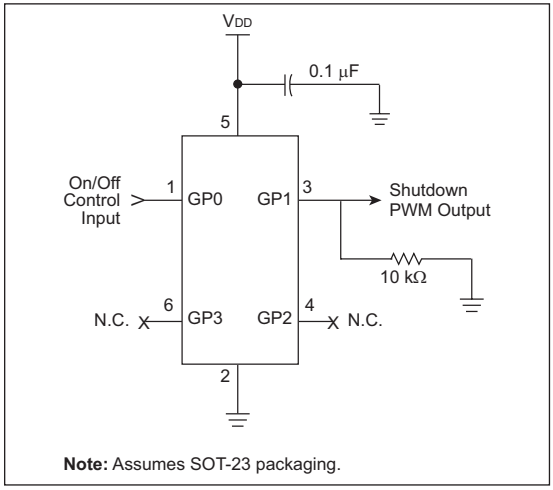
Don't forget a debounce routine. For example, require the above steps (with 20 ms delay between) to return the same key value twice in a row for that key to be considered pressed. Also, require a no key press to be returned at least twice before looking for the next key press.

When keys within the same quadrant are pressed simultaneously, voltages other than the four valid levels shown in the table may be generated. These levels can either be ignored, or if you want to use simultaneous key presses to enable certain functions, you can add decoding for those levels as well.

TIP #1 Soft-Start Using a PIC10F200

Almost all power supply controllers are equipped with shutdown inputs that can be used to disable the MOSFET driver outputs. Using Pulse-Width Modulation (PWM), the amount of time the power supply is allowed to operate can be slowly incremented to allow the output voltage to slowly rise from 0% to 100%.

Figure 1-1: Soft-Start Circuit Schematic



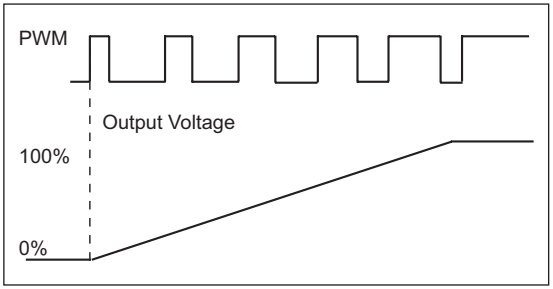
Note: Assumes SOT-23 packaging.

This technique is called soft-start and is used to prevent the large inrush currents that are associated with the start-up of a switching power supply.

GP0 on the PIC MCU is used to enable or disable the soft-start. Once enabled, the on-time of the PWM signal driving the shutdown output will increase each cycle until the power supply is fully on.

During the PIC MCU Power-on Reset, the PWM output (GP1) is initially in a high-impedance state. A pull-down resistor on the PWM output ensures the power supply will not unexpectedly begin operating.

Figure 1-2: Timing Diagram



It is important to note that this type of soft-start controller can only be used for switching regulators that respond very quickly to changes on their shutdown pins (such as those that do cycle-by-cycle limiting). Some linear regulators have active-low shutdown inputs, however, these regulators do not respond fast enough to changes on their shutdown pins in order to perform soft-start.

Example software is provided for the PIC10F200 which was taken from TB081. Please refer to TB081, “*Soft-Start Controller For Switching Power Supplies*” (DS91081) for more information.

TIP #8 Transformerless Power Supplies

When using a microcontroller in a line-powered application, such as the IR remote control actuated AC switch described in Tip #9, the cost of building a transformer-based AC/DC converter can be significant. However, there are transformerless alternatives which are described below.

Capacitive Transformerless Power Supply

Figure 8-1: Capacitive Power Supply

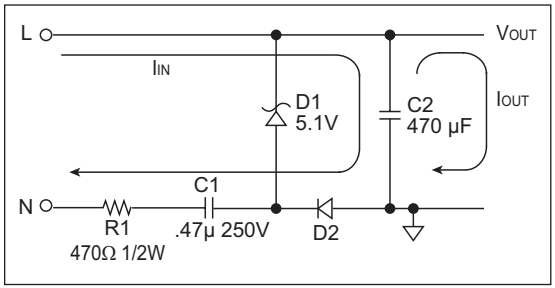


Figure 8-1 shows the basics for a capacitive power supply. The Zener diode is reverse-biased to create the desired voltage. The current drawn by the Zener is limited by R1 and the impedance of C1.

Advantages:

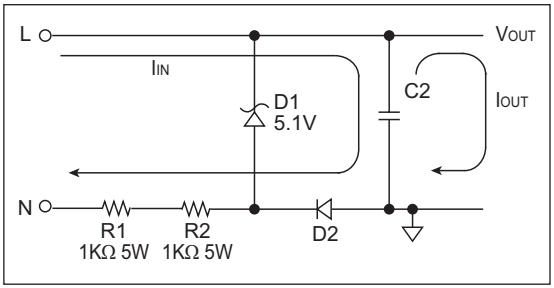
- Significantly smaller than a transformer-based power supply
- Lower cost than a transformer-based or switcher-based power supply
- Power supply is more efficient than a resistive transformerless power supply

Disadvantages:

- Not isolated from the AC line voltage which introduces safety issues
- Higher cost than a resistive power supply because X2 rated capacitors are required

Resistive Power Supply

Figure 8-2: Resistive Power Supply



The resistive power supply works in a similar manner to the capacitive power supply by using a reversed-biased Zener diode to produce the desired voltage. However, R1 is much larger and is the only current limiting element.

Advantages:

- Significantly smaller than a transformer-based power supply
- Lower cost than a transformer-based power supply
- Lower cost than a capacitive power supply

Disadvantages:

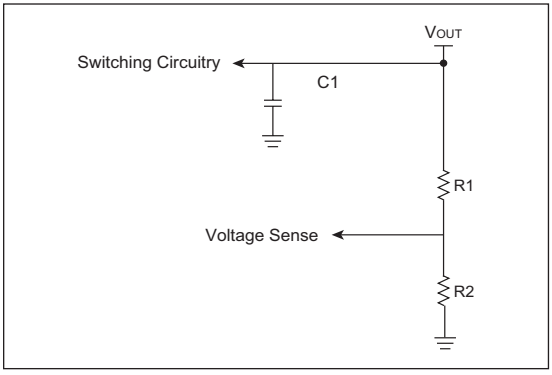
- Not isolated from the AC line voltage which introduces safety issues
- Power supply is less energy efficient than a capacitive power supply
- More energy is dissipated as heat in R1

More information on either of these solutions, including equations used for calculating circuit parameters, can be found in AN954, “*Transformerless Power Supplies: Resistive and Capacitive*” (DS00954) or in TB008, “*Transformerless Power Supply*” (DS91008).

TIP #21 Using Output Voltage Monitoring to Create a Self-Calibration Function

A PIC microcontroller can be used to create a switching power supply controlled by a PID loop (as described in Tip #16). This type of power supply senses its output voltage digitally, compares that voltage to the desired reference voltage and makes duty cycle changes accordingly. Without calibration, it is sensitive to component tolerances.

Figure 21-1: Typical Power Supply Output Stage



The output stage of many power supplies is similar to Figure 21-1. R1 and R2 are used to set the ratio of the voltage that is sensed and compared to the reference.

A simple means of calibrating this type of power supply is as follows:

1. Supply a known reference voltage to the output of the supply.
2. Place the supply in Calibration mode and allow it to sense that reference voltage.

By providing the supply with the output voltage that it is to produce, it can then sense the voltage across the resistor divider and store the sensed value. Regardless of resistor tolerances, the sensed value will always correspond to the proper output value for that particular supply.

Futhermore, this setup could be combined with Tip #20 to calibrate at several temperatures.

This setup could also be used to create a programmable power supply by changing the supplied reference and the resistor divider for voltage feedback.

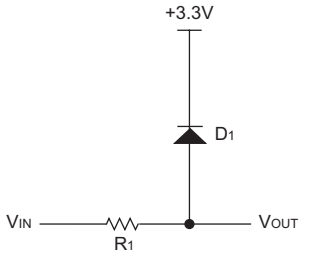
TIP #17 5V → 3V Analog Limiter

When moving a 5V signal down to a 3.3V system, it is sometimes possible to use the attenuation as gain. If the desired signal is less than 5V, then attaching that signal to a 3.3V ADC will result in larger conversion values. The danger is when the signal runs to the 5V rail. A method is therefore required to control the out-of-range voltages while leaving the in-range voltages unaffected. Three ways to accomplish this will be discussed here.

1. Using a diode to clamp the overvoltage to the 3.3V supply.
2. Using a Zener diode to clamp the voltage to any desired limit.
3. Using an op amp with a diode to perform a precision clamp.

The simplest method to perform the overvoltage clamp is identical to the simple method of interfacing a 5V digital signal to the 3.3V digital signals. A resistor and a diode are used to direct excess current into the 3.3V supply. The resistor must be sized to protect the diode and the 3.3V supply while not adversely affecting the analog performance. If the impedance of the 3.3V supply is too low, then this type of clamp can cause the 3.3V supply voltage to increase. Even if the 3.3V supply has a good low-impedance, this type of clamp will allow the input signal to add noise to the 3.3V supply when the diode is conducting and if the frequency is high enough, even when the diode is not conducting due to the parasitic capacitance across the diode.

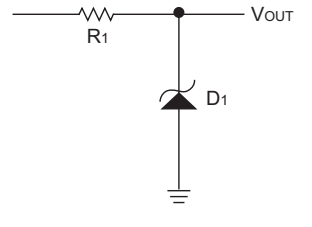
Figure 17-1: Diode Clamp



$V_{OUT} = 3.3V + V_F$ if $V_{IN} > 3.3V + V_F$
$V_{OUT} = V_{IN}$ if $V_{IN} \leq 3.3V + V_F$
V_F is the forward drop of the diode.

To prevent the input signal from affecting the supply or to make the input more robust to larger transients, a variation is to use a Zener diode. The Zener diode is slower than the fast signal diode typically used in the first circuit. However, they are generally more robust and do not rely on the characteristics of the power supply to perform the clamping. The amount of clamping they provide is dependant upon the current through the diode. This is set by the value of R1. R1 may not be required if the output impedance of the V_{IN} source is sufficiently large.

Figure 17-2: Zener Clamp



$V_{OUT} = V_{BR}$ if $V_{IN} > V_{BR}$
$V_{OUT} = V_{IN}$ if $V_{IN} \leq V_{BR}$
V_{BR} is the reverse breakdown voltage of the Zener diode.