AN1244

PIC® Microcontroller Horn Driver

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INTRODUCTION

The use of a horn and horn driver is very common, particularly for safety critical products. Many semiconductor companies have implemented devices that were specifically designed for either the sole or primary purpose of serving as the horn driver. This application note discusses how the PIC® MCU can serve as the horn driver by merely using a couple of peripherals. This application note also discusses the implementation of those peripherals to serve as the horn driver.

HORN THEORY

Horns generally use a Piezo element, that when driven within a particular frequency range, vibrate and emanate a high pitch at a high dB level. Within that frequency range, there is a particular point of frequency that will cause the horn to emanate the highest dB level. Horn driver devices have served to find this particular drive frequency, and then drive the horn with that frequency to solicit the highest dB level. The horns generally have 3 leads, 2 for driving and 1 for feedback, that are used to electrically locate the highest dB level.

PIC MICROCONTROLLER IMPLEMENTATION

Working with the knowledge of the horn theory, the PIC MCU has peripheral resources within the device to provide horn driver services in a very simple manner. Externally, only a few simple and inexpensive components are needed to complete the circuit. The PIC MCU peripherals include the Enhanced CCP (ECCP) module in Pulse-Width Modulation (PWM) Half-Bridge mode to drive the 2 horn drive leads and a single ADC input to monitor the horn feedback after it has been conditioned. While the horn driver can be implemented across the PIC MCU product line of 8, 16 and 32-bit devices, the PIC16F886 will be used as the example device in the following discussion.

Horn characteristics are required to determine the defined parameters for the range of the PWM module.

For example:

A horn with a resonant frequency of 3.5 kHz ± 0.5 kHz; the PWM module generates a PWM frequency output from 3 kHz to 4 kHz with 50% duty cycle.

With a device that is running off of the internal oscillator at 8 MHz, the clock source to Timer2 that drives the PWM period generates 2M clocks per second. For a 3 kHz period, this is 667 clocks per cycle, and for a 4 kHz period, this is 500 clocks per cycle. Because Timer2 is an 8-bit timer, accepting only a maximum value of 255, these clocks per cycle must be divided down. A prescaler of divide-by-4, yielding 166 clocks per cycle for 3 kHz, and 125 clocks per cycle for 4 kHz, is required.

The PWM output driven by the ECCP module in Half-Bridge mode, with both the P1A and P1B outputs active-high, will step through the 125 through 166 clocks per cycle periods at a period rate, and as the Period register is loaded, the value will be divided-by-2 and loaded into the Duty Cycle register for a 50% duty cycle. This will become the new PWM period for measuring the feedback from the horn driver, and drives the transistor that raises the level that the horn lead sees, to 9V.

To properly monitor the feedback circuit from the horn driver, a simple peak detector circuit is inserted between the horn feedback wire and the PIC microcontroller ADC input. This assures a steady state is measured relative to the PWM period that is being driven. The resistor and capacitor values for this circuit should be selected to generate a stable and accurate charge value within the allowable time period for the charge to occur. The charging time constant in a series RC circuit is T = RC, where:

T = Time constant in seconds
R = Resistance in ohms
C = Capacitance in farads

The capacitor in an RC circuit does not charge at a linear rate, instead, at each time constant interval, the capacitor charges another 63.2% of the remaining level to the maximum voltage level (see Table 1).

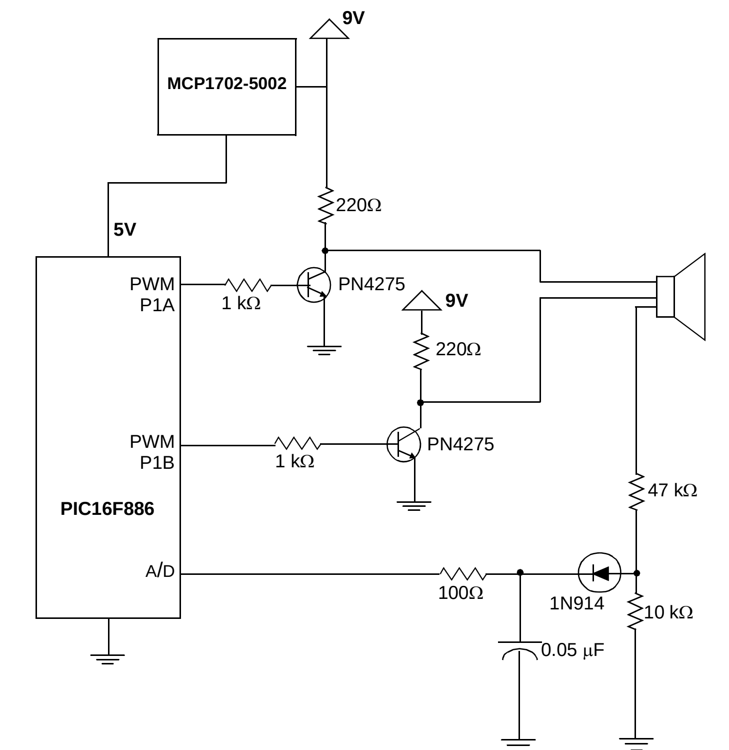
TABLE 1: RC CHARGE

Time Intervals (T)	Voltage Level
0	0
1	0.632 of source voltage
2	0.865 of source voltage
3	0.950 of source voltage
4	0.981 of source voltage
5	0.992 of source voltage

A Thevenin equivalent circuit for the peak voltage detector can be developed to determine the charging time constant for the feedback circuit. For a steady voltage source, this would allow for a calculable charging time number. Due to the non-steady feedback from the piezo, this can be difficult; therefore, measurement and analysis with an oscilloscope would be a suitable method for revealing the charging pattern for the peak detector. Measuring the final charged voltage, and contrasting to the calculated voltage levels determined from Table 1, provides the actual time constant in the circuit. From this time constant, the charge time software delay can be calculated. The software must provide enough delay to allow for an appropriate charge time based on the circuit design. This is essential to compare the dB level generated by each PWM output.

To ensure that the measurement is accurate at the ADC, at the beginning of the new PWM period, the ADC input is flipped to a low output for a delay to discharge the peak detector circuit measurement capacitor. The ADC low output is flipped back to an ADC input, allowing the capacitor to charge up for a voltage measurement reading. See Figure 1 for a typical horn driver.

FIGURE 1: PIC® MICROCONTROLLER HORN DRIVER



To simplify the software and reduce program memory, the maximum dB level scan can simply look for the highest sample conversion and its PWM period increment, dynamically saving the highest found as it performs the scan. During the process of finding the PWM period with the highest feedback dB level, the PWM is configured with the individual steps in the range, and the feedback is sampled with the A/D converter.

For example:

To support a range of 125 to 166 represents 42 PWM periods and sampled ADC values, one for each step in the range.

While stepping through the PWM range searching for the highest ADC value, the most current high value and its position into the range are tracked and stored. After completing the search through the range, the PWM period that generated the highest dB level of feedback from the horn is known. This is then loaded into the PWM generation registers with the duty cycle that is half of that, and the PWM generator is left to continue driving the horn.

The feedback can periodically be monitored, or the PWM occasionally altered, to assure that the highest dB feedback value is generated should the temperature or some other variant affect the highest dB level.

PIC MICROCONTROLLER DEVICE REQUIREMENTS

To support the horn driver function, memory requirements are minimal. As it is written in C, compiled with the HI-TECH 9.60 PICC™ C compiler, and prototyped with the PICDEM™ 2+, this demo code for the PIC16F886 requires less than 120 program words and 6 RAM locations. Considering that the RAM is only needed during horn generation scan, this RAM could be overlaid and used for other application functions. With about 120 program words, the device is initialized, the horn feedback is scanned for the maximum dB level and then the horn is driven. The majority of the code scans for the highest dB level and once that is determined, the PWM generator runs free.

The low memory requirements combined with the low peripheral resources' requirements of the PWM and single ADC input, allow for the selection of a PIC MCU in all packages and memory options to support the remainder of the application needs. The small 8-pin 12F615 device is sufficient to operate as a horn driver, leaving three I/O for other uses, and the high-voltage 12HV615 can be used allowing for a single 9V supply if needed.

Horn Driver Circuit Power

For applications that would use the horn driver in battery circuits, current drawn from the supply is important. A typical 9V battery has a rating of 500 mA hours, reflecting its life supplying power to the application. Table 2 provides the current budget required for driving the horn.

TABLE 2: PIC® MCU HORN DRIVER CURRENT CONSUMPTION

	Current at 5V	Current at 3V
HFINTOSC mode F_{OSC} = 4 MHz	1.13 mA	640 μA
Power-Down Base Current (I_{PD})	0.35 μA	0.15 μA
WDT Current	3.0 μA	2.0 μA
MCP1702	2.0 μA	2.0 μA

Referencing electrical specifications for devices such as the PIC16F886, and using the internal high frequency oscillator to clock the device at 4 MHz, uses a typical supply current of 640 μA at 3V, and when the horn is being driven, an additional 82 mA of supply current is being driven to the horn through the horn terminal resistors in this example. This means that the 9V battery can drive the horn at a decaying rate, for 500 mAh/82.640 mA = 6 hours, when the horn driving circuit is active.

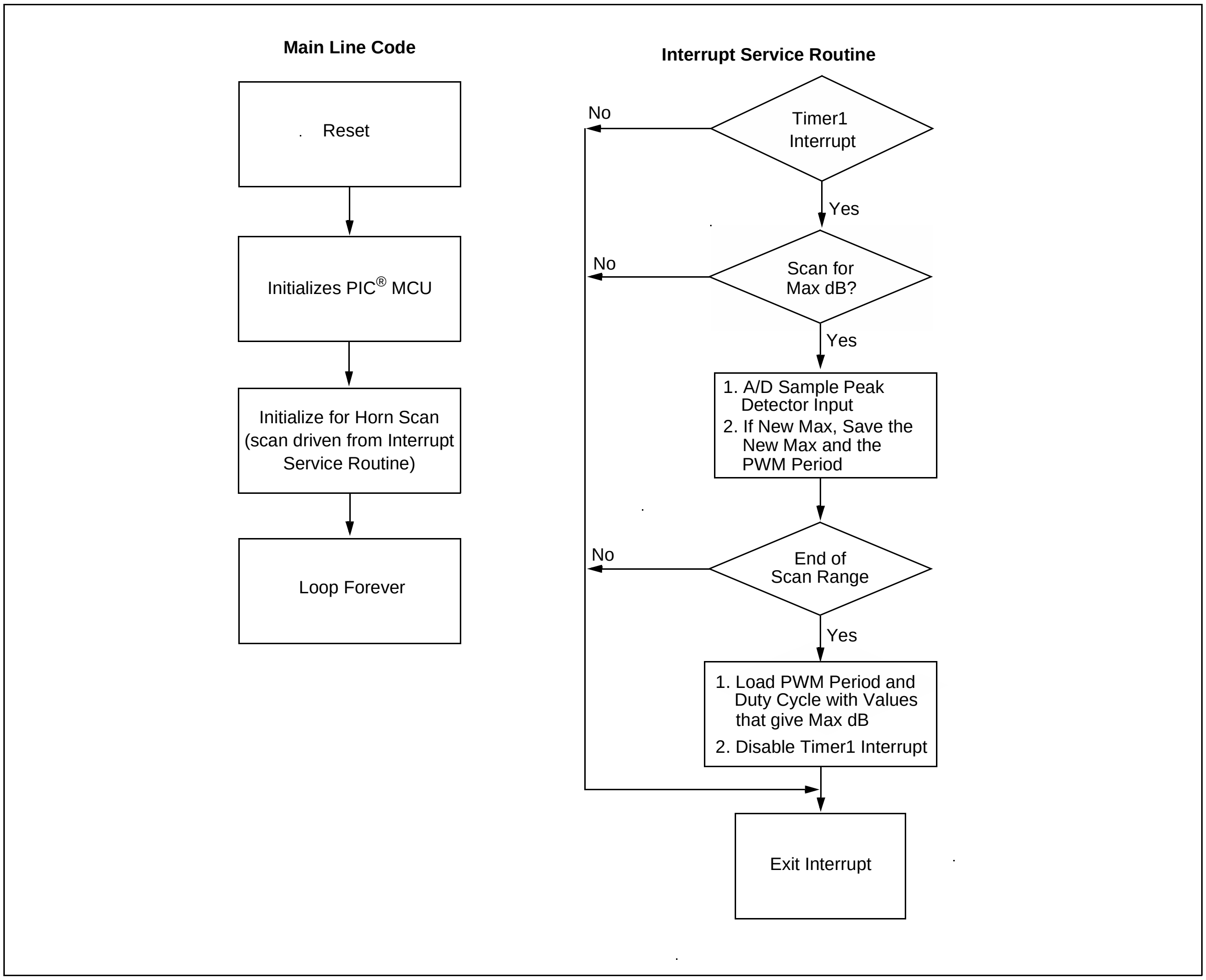
Just as important is how long the system can be active and waiting to drive the horn. Generally, the horn driver application can exist in a Power-Down mode with all peripherals disabled. Only periodically does the application use the Watchdog Timer (WDT) to wake-up from Sleep to check a sensor input and determine if the alarm should be driven with only a few instructions. Because the device is running on the internal fast oscillator, in just a few clock cycles, the device is awake and running, and typically, only a few instructions are required to determine if the horn should be sounded.

Therefore, very little time is required to service the sensor, and if the Sleep period based on the WDT is 1/2 second to 1 second, the amount of supply current required by the application code becomes negligible.

In Power-Down mode, the supply current is typically 0.35 μA at 5V, and the WDT is 3.0 μA at 5V for a total of 3.35 μA in power-down. Using the MCP1702 LDO regulator to supply 5V to the device adds an additional 2.0 μA of quiescent current. Without including normal battery leakage that varies among manufacturers, this means that the 9V battery can manage the horn driver circuit for approximately 500 mAh/5.34 μA = 93633 hours or 3901 days or 10.7 years.

If the design were to use the MCP1702 and run the PIC microcontroller at 3.0V, the Sleep current would be 0.15 μA and the WDT current would be 2.0 μA. With the MCP1702 quiescent current of 2 μA, the battery life in Sleep mode becomes 500 mAh/4.15 μA = 120482 hours or 13.75 years without accounting for normal battery leakage. See Figure 2 for horn driver flowchart.

FIGURE 2: HORN DRIVER FLOWCHART



HornDriver.c

```
#include <pic.h>
__CONFIG (WDTDIS & MCLREN & UNPROTECT & BOREN & INTIO & LVPDIS & DEBUGEN);

//unsigned char HornPeriod, MaxHornPeriod, x;

#define         MAXPERIOD 125
#define         MINPERIOD 166

unsigned char   HornPeriod, HornDBmax, HornPeriodMaxDB;

void main(void)
{
unsigned char temp;

   /* Bank 3 variables */
   ANSEL=0x03;                     // RA0 & RA1 is analog
   ANSELH=0x00;
/* Bank 1 variables */
   OSCCON=0x70;                    // IntOsc = 8Mhz

   TRISA=0xff;
   TRISB=0x00;                     // RB2 controls PWM transistor
   TRISC=0x00;                     // RC2 controls PWM transistor

   PR2 = MAXPERIOD;                // As specified in Timer 2 range below

   ADCON1=0;
   TMR1IE=1;
```

HornDriver.c (Continued)

```
    /* Bank 0 variables */
    PORTA=0;
    PORTC=0;
    ADCON0=5;                   //Select the feedback on RA1

    T1CON=0x00;                 // Timer 1 used to periodically sample
                                // the horn feedback amplitude

    /* Timer 2 is used to drive the horn.
     * Using 8Mhz IntOsc, the clock to Timer 2 is 2Mhz
     * To achieve 3.5kHz +-500Hz is 3kHz-4kHz
     * 2MHz/3kHz=667, to get value less than 256 must /4, = 166
     * 2MHz/4kHz=500, to be consistent with above, /4, = 125
     * => Period runs from 125 to 166, duty cycle is half that
     * => Duty runs from 62.5 to 83, shift right Period value

     * => Period of 125 measures 4.0kHz on the scope
     * => Period of 145 measures 3.5kHz on the scope
     * => Period of 166 measures 3.0kHz on the scope
     */
    HornDBmax=0;
    HornPeriod = MAXPERIOD;
    CCPR1L = HornPeriod>>1;    // load 50 % duty cycle

    /* For this example, the MAXPERIOD happens to be odd,
     * so CCP1CON = 0xAC.  If it was even, then CCP1CON = 0x8C
     * just like the ISR
     */
    CCP1CON = 0xAC;

    T2CON = 0x1;
    TMR2ON = 1;                 // Start PWM output

    /* Timer 1 reload value, don't make the time too short
     * or the proper charge on the peak detector won't have
     * accumulated.  Set here and in the ISR
     * No prescale, 8MHz/4 = 2Mhz clock
     * 0xc000 = 16384 * 0.5uS = 8.192mS
     */

    TMR1L=0x00;                 // Set up Timer 1 for scan dB period
    TMR1H=0xc0;
    TMR1IF=0;
    TMR1ON=1;

    PEIE=1;                     // enable peripheral interrupts
    GIE=1;                      // turn on interrupts

    // Stay here while horn searches for max dB and runs forever
    while(1);
}
```

HornDriver.c (Continued)

```
void interrupt isr(void){

   if(TMR1IF){

         GODONE=1;                  // Start A/D sampling of dB feedback
         while(GODONE);             // wait for A/D to finish

         // Discharge the Horn Feedback input
         TRISA1=0;

         if (ADRESH > HornDBmax)
         {
            HornDBmax = ADRESH;
            HornPeriodMaxDB = HornPeriod;
         }

         HornPeriod++;
         PR2 = HornPeriod;          // load period into PWM
         CCPR1L = HornPeriod>>1;    // load 50 % duty cycle

         if(HornPeriod>MINPERIOD)
         {
            PR2 = HornPeriodMaxDB;
            CCPR1L = PR2>>1;

            TMR1IE=0;               // finish scanning dB feedback
         }
         if(PR2 & 0x01)
            CCP1CON = 0xAc;         // odd period, so add 2 to duty LSbs
         else
            CCP1CON = 0x8C;         // even period, so use 00 as duty LSbs

         // Shut off horn discharge
         TRISA1=1;

         /* Timer 1 reload value, don't make the time too short
          * or the proper charge on the peak detector won't have
          * accumulated.  Set here and in the ISR
          * No prescale, 8MHz/4 = 2Mhz clock
          * 0xc000 = 16384 * 0.5uS = 8.192mS
          */
         TMR1ON=0;
         TMR1L=0x00;
         TMR1H=0xc0;
         TMR1IF=0;
         TMR1ON=1;
   }
}
```

CONCLUSION

Many different methods and techniques exist for providing the circuitry required to drive a Piezo horn. This application note provides a description for driving a horn using the peripheral circuitry that is incorporated within a PIC MCU with only a few, low-cost external circuit elements. Using the low-power features of the PIC MCU and Microchip LDO regulator allows the approach to remain in a Standby mode for extended periods of time.

REFERENCES

- http://www.microchip.com

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