INTRODUCTION

Object ranging is essential in many types of systems. One of the most popular ranging techniques is ultrasonic ranging. Ultrasonic ranging is used in a wide variety of applications including:

- Auto focus cameras
- Motion detection
- Robotics guidance
- Proximity sensing
- Object ranging

This application note describes a method of interfacing PIC16CXX microcontrollers to the Polaroid 6500 Ranging Module. This implementation uses a minimum of microcontroller resources, a CCP module and two I/O pins. The two major components of the system are:

- Microcontroller
- Polaroid 6500 Ranging Module

The microcontroller performs the intelligence and arithmetic functions for ultrasonic ranging, while the Polaroid 6500 Ranging Module performs the ultrasonic signal transmissions and echo detection.

FIGURE 1: RANGING MODULE INTERFACE

THEORY OF OPERATION

Ultrasonic ranging entails transmitting a sound wave and measuring the time that it takes for the sound wave to reflect off of an object and back to the origin. The reflection time is proportional to the distance that the object is from the source. In this implementation, the sound wave is transmitted and received from the same transducer. Therefore, a blanking interval is required between signal transmission and reception to eliminate false echoes (i.e., a transmitted signal being detected as its own echo).

CIRCUIT CONFIGURATION

In this implementation, a PIC16C74 is connected to the ranging module as shown in Figure 1. The RE0 and RE1 I/O pins are configured as digital outputs and are tied to INIT and BINH, respectively. The CCP1 pin is configured as a digital input and is tied to ECHO through a pull-up resistor. The pull-up resistor is needed since the ECHO signal is an open-collector output. The CCP1 pin is configured for capture mode (CCP1CON). Figure 2 shows the timing relationship for VDD and the three signal lines (INIT, BINH, and ECHO).

Note: The ranging module requires 5.0 milliseconds to stabilize during power-up.
The PIC16C74 is configured to use one of its internal timers, Timer1, in capture mode to measure the time between signal transmission and echo detection. The resolution of the timer is determined by the microcontroller clock frequency. For this application, a 4 MHz external oscillator was used, giving a resolution of 1 ms per bit. The PIC16C74 initiates a ranging cycle by first clearing Timer1. Timer1 is then enabled and INIT is immediately asserted on the ranging module. When INIT is asserted, the ranging module transmits a series of 16 pulses on the transducer at 49.4 kHz. The transmitted pulses reflect off the object and are received back at the transducer.

The transducer is used for both transmitting and receiving sound waves. A blanking interval is needed to ensure that the transmitted signal has decayed on the transducer, in order not to receive false echoes. In normal operation, the ranging module has a blanking interval of 2.38 milliseconds, which corresponds to a minimum detection distance of approximately 17 inches. However, the BINH (blank inhibit) signal can be manipulated to reduce the blanking time on the transducer to allow for object ranging as close as 6 inches.

In this implementation, the PIC16C74 asserts the BINH signal approximately 0.9 milliseconds after signal transmission. This enables the transducer to receive reflections off objects at a distance of 6 inches. The ranging module asserts the ECHO signal when a valid reflection has been detected. The PIC16C74 then calculates object distance based on the Timer1 value, microcontroller clock speed, and the velocity of sound in the atmosphere. The basic equation for calculating distance is given below:

\[
\text{Distance (inches)} = \frac{\text{TECHO time}}{147.9 \text{ microseconds}}
\]

**DESIGN CONSIDERATIONS**

There are several design considerations which must be taken into account and are listed below.

The absolute measuring distance supported by the ranging module is 6 inches to 35 feet with an accuracy of +/- 1%.

The distance output from the ranging module can be averaged over time to filter distance calculations.

In some applications, the gain of the receiver amplifier may be too low or too high and may need to be adjusted. For example, if the transducer is mounted in a cylinder, the gain may need to be lowered to reduce false echoes within the cylinder. In this case, R1 (refer to the Polaroid Ultrasonic Ranging System manual) may be replaced with a 20 kΩ potentiometer to tweak the gain of the receiver amplifier to reduce false echoes.

In order for the Polaroid 6500 ranging module to operate properly, the power supply must be capable of handling high current transients (2.5 A) during the

---

**Note:** The minimum high and low time for INIT is 100 milliseconds, as seen in Figure 2.
transmit pulse. The instantaneous drain on the power supply can be mitigated by installing a storage capacitor across the power lines at the ranging module. A value of 500 microfarads is recommended.

A 200 millisecond interval is recommended between ranging cycles (Figure 2) to allow the transducer to clear.

The ECHO line requires a pull-up resistor (4.7 kΩ was used in this application).

There must be a common ground between the PIC16C74 circuitry and the ranging module.

Some applications may not need the resources of the higher end PIC16CXX devices. It is still possible to do this application using a device that does not contain a CCP module (for ECHO timing). The capture function can be implemented in firmware. The effect of a firmware implementation is that the resolution of the ECHO time would be 3 Tcy cycles versus 1 Tcy cycle for the CCP module. Also, the firmware implementation would not allow other tasks to be performed while the capture function was occurring.

Refer to Appendix A for general ranging module specifications.
APPENDIX A: POLAROID MODULE SPECIFICATIONS

Note: This appendix contains general specifications from the Polaroid Ultrasonic Ranging System Manual. Please refer to the current Polaroid Ultrasonic Ranging System Manual for current information regarding ranging module design considerations.

DESIGN CONSIDERATIONS IN ULTRASONICS

Range: (with user custom designed processing electronics)

Farther
a) Use an acoustic horn to “focus” the sound (narrowing the beamwidth).
b) Use two transducers – 1 receiver and 1 transmitter – facing each other.
c) Lower the transmitting frequency (which will decrease the attenuation in air).

Closer
a) Use a shorter transmit signal (such as four cycles).
a) Use two transducers – one to transmit, one to receive (eliminates waiting for damping time).

Resolution
a) Above all, know the target and range well, and design a system with them in mind.
b) Use a higher transmit frequency.
c) Look at phase differences of a given cycle of the transmitted signal and received echo (as opposed to using and integration technique).
d) Increase the clock frequency of the timer.

Accuracy: (again, you must have a well defined target)

Temperature Compensate
a) Use a second small target, as a reference, at a known distance in the ranging path (such as a 1/4" rod several feet away), process both echoes, then normalize the second distance with respect to the first, since t1/d1 = t2/d2.
b) Incorporate a temperature sensing integrated circuit to drive a VCO to do the distance interval clocking.
c) To increase sensitivity of detection circuit change the value of C4 from 3300 pF to 1000 pF on the 6500 Series Ranging Module.

Beam Width:
Increase
a) Use an acoustic lens (to disperse the signal).
b) Decrease the transmitting frequency.
c) Use several transducers to span an area.

Decrease
a) Use an acoustic horn (to focus the sound).
b) Increase the transmitting frequency.

TABLE 1: RECOMMENDED OPERATING CONDITIONS

<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage, VCC</td>
<td>4.5</td>
<td>6.8</td>
<td>V</td>
</tr>
<tr>
<td>High-level input voltage, Vih</td>
<td>BINH, INIT</td>
<td>2.1</td>
<td>V</td>
</tr>
<tr>
<td>Low-level input voltage, Vil</td>
<td>BINH, INIT</td>
<td>0.6</td>
<td>V</td>
</tr>
<tr>
<td>ECHO and OSC output voltage</td>
<td></td>
<td>6.8</td>
<td>V</td>
</tr>
<tr>
<td>Delay time, power up to INIT high</td>
<td></td>
<td>5</td>
<td>ms</td>
</tr>
<tr>
<td>Recycle period</td>
<td>80</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>Operating free-air temperature, Ta</td>
<td></td>
<td>0</td>
<td>40°C</td>
</tr>
</tbody>
</table>
### TABLE 2: ELECTRICAL CHARACTERISTICS OVER RECOMMENDED RANGES OF SUPPLY VOLTAGE AND OPERATING FREE-AIR TEMPERATURE (UNLESS OTHERWISE NOTED)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input current</td>
<td>BINH, INIT</td>
<td>V1 = 2.1V</td>
<td>1 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-level output current, I_{OH}</td>
<td>ECHO, OSC</td>
<td>V_{OH} = 5.5V</td>
<td>100 μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-level output voltage, V_{OL}</td>
<td>ECHO, OSC</td>
<td>I_{OL} = 1.6 mA</td>
<td>0.4 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transducer bias voltage</td>
<td>TA = 25°C</td>
<td>200 V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transducer output voltage (peak-to-peak)</td>
<td>TA = 25°C</td>
<td>400 V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of cycles for XDCR output to reach 400V</td>
<td>C= 500 pF</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal blanking interval</td>
<td></td>
<td>2.38* ms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency during 16-pulse transmit period</td>
<td>OSC output</td>
<td>49.4* kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XMIT output</td>
<td>49.4* kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency after 16 pulse transmit period</td>
<td>OSC output</td>
<td>93.3* kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XMIT output</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply current, I_{CC}</td>
<td>During transmit period</td>
<td>2000 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>After transmit period</td>
<td>100 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These typical values apply for a 420 kHz ceramic resonator.
APPENDIX B: FIRMWARE LISTING

MPASM 01.02 Released     XDCR.ASM   11-14-1994 9:29:15
LOC  OBJECT CODE     LINE SOURCE TEXT
VALUE

0001 ; XDCR.ASM
0002 ;
0003 ; This routine continually executes ranging cycles in the
0004 ; following order:
0005 ;
0006 ; 1) Timers and Flags are cleared
0007 ; 2) Ranging Cycle Executes
0008 ; 3) Distance is Calculated (to 0.5 inch)
0009 ; 4) HW is re-initialized for next cycle
0010 ;
0011 ; The processor uses a 4MHz oscillator, so all timing
0012 ; calculations are referenced to that. The calculated
0013 ; distance is a 16-bit result in the ACCbHI:ACCbLO registers.
0014 ;
0015
0016 LIST P=16C74, F=INHX8M
0017 ;
0018 ;******************
0019 ; Bank 0 Registers
0020 ;******************
0021 ;
0022 clrf    T1CON
0023 ; Set to capture on every rising edge
0024 movlw   0x05
0025 movwf   CCP1CON
0026 clrf    PORT_A
0027 clrf    PORT_B
0028 clrf    PORT_C
0029 clrf    PORT_D
0030 clrf    PORT_E
0031 ;******************
0032 ; Bank 1 Registers
0033 ;******************
0034 bsf     STATUS,RP0
0035 ; Port A is Digital, Port E is Digital
0036 movlw   0x07
0037 movwf   ADCON1
0038 clrf    TRIS_A
0039 clrf    TRIS_B
0040 clrf    TRIS_C
0041 clrf    TRIS_D
0042 clrf    TRIS_E
0043 ; TMR1 is off, Prescaler is 1 for a capture timeout of 65 msec
0044 ; Set to capture on every rising edge
0045 clrf    T1CON
0046 clrf    PIR1
0047 ; Clear the Ports
0048 ; Clear the Ports
0049 ; Bank 1 Registers
0050 ; Bank 1 Registers
0051 ; Port A is Digital, Port E is Digital
0052 ; Configure CCP1 (RC2) as an input, and all other ports
0053 ; as Outputs, (RE0 = INIT, RE1 = BINH)
0054 ; Configuration
0055 ; Configuration
0056 clrf    TRIS_A
0057 clrf    TRIS_B
0058 movlw   0x04
0059 movwf   TRIS_C
0060 clrf    TRIS_D
0061 clrf    TRIS_E
0062 bcf     STATUS,RP0
0063 Xdcr
0064 ; Initialize Timers and Flags
0065 ; Initialize Timers and Flags
0066 ;
0067 bcf     T1CON,0
0068 clrf    PIR1
0069 ; Clear Timer1 Overflow Flag & Timer1 Capture Flag

Please check the Microchip BBS for the latest version of the source code. For BBS access information,
see Section 6, Microchip Bulletin Board Service information, page 6-3.
0014 018E 0069 clrf TMR1L ; Clear TMR1L
0015 018F 0070 clrf TMR1H ; Clear TMR1H
0016 0195 0071 clrf CCPR1L ; Clear CCPR1L
0017 0196 0072 clrf CCPR1H ; Clear CCPR1H
0018 1409 0073 bsf PORT_E,0 ; Set INIT High on Ranging Module
0019 1410 0074 bsf T1CON,0 ; Enable TMR1
001A 21F3 0075 call DEL_9 ; Delay 0.9 msec for transducer to stabilize
001B 1489 0076 bsf PORT_E,1 ; Enable Transducer to Receive (BINH)
001C 0077 chk_t1
001D 018C 0078 btfss PIR1,2 ; Check for Capture
001E 2822 0079 goto chk_done ; Jump if Capture
001F 1C0C 0080 btfss PIR1,0 ; Check for TMR1 Overflow
0020 281C 0081 goto chk_t1 ; Loop if nothing happened
0021 1010 0082 bcf T1CON,0 ; Turn off TMR1
0022 0083 chk_done
0085 ; Calculate distance to 0.5 inch resolution
0087 ;
0088 bcf T1CON,0 ; Turn off TMR1
0089 movf CCPR1L,W ; Move LSB into W
0090 movwf ACCbLO ; Move LSB into ACCbLO
0091 movf CCPR1H,W ; Move MSB into ACCbLO
0092 movwf ACCbHI ; Move MSB into ACCbHI
0093 movlw 0x4A ; Move 75usec/0.50in into W
0094 movwf ACCaLO ; Move LSB into ACCaLO
0095 clrf ACCaHI ; Clear MSB (ACCaHI)
0096 call D_divF ; Call 16-bit/8-bit routine
0097 ; which is described in
0098 ; Application Note 544
0099 movlw 0x25 ; Check remainder to see if
0100 subwf ACCcLO,W ; we should round up...
0101 btfsc STATUS,CARRY ; If Remainder < (0.5 * Divisor), skip
0102 incf ACCbLO,F ; Round up
0103 btfss STATUS,Z ; Check low byte for wrap around
0104 incf ACCbHI,F ; If LSB wrapped, increment high byte
0105 btfss STATUS,Z ; Check high byte for wrap around
0106 goto done ; High byte didn't wrap
0107 ovr_flo
0108 clrf ACCbLO
0109 clrf ACCbHI
0110 done
0111 call DEL_100 ; Wait 100 msec before clearing HW.
0112 bcf PORT_E,0 ; Disable INIT
0113 bcf PORT_E,1 ; Disable BINH
0114 call DEL_100 ; Wait 100 msec before enabling HW.
0115 goto Xdcr
0116
0117 MEMORY USAGE MAP ('X' = Used, ' ' = Unused)
0118 0000 : XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX----
0119 0040 : ---------------- ---------------- ---------------- ----------------
0120 All other memory blocks unused.
0121
Errors : 0
Warnings : 0
Messages : 0