Ultrasonic Range Finder

Ultrasonic Range Finder with ATtiny817 Hardware User's Guide

Introduction

This user guide describes the hardware for the Ultrasonic Range Finder Field Engagement Board based on the ATtiny817, a high-performance tinyAVR® 8-bit microcontroller.

This board demonstrates complex functionality of core independent peripherals like the Configurable Custom Logic (CCL) peripheral for real-time or low-power applications.

For further information on firmware functionality, see the corresponding application note, AVR42779: Core Independent Ultrasonic Distance Measurement with ATtiny817. The latest firmware can be found at Atmel START.

Features

- Ultrasonic Transceiver used for Transmitting a Burst and Receiving the Reflection
- Measurable Distance Range from 0.7 to 4.0 Meters
- Temperature Sensor for Compensation of Calculations
- OLED Display with 128 x 64 Pixels

Table of Contents

1. Background

Ultrasonic distance measurement is a relatively low-cost, contactless range finding method with high accuracy. It uses sound waves with frequencies higher than the upper audible limit of human hearing (20kHz).

The principle of measurement is quite simple. The distance (*L*) can be calculated based on the ultrasound velocity (*c*) and the travel time (*t*) of ultrasonic waves, namely $L = (c * t) / 2$. The velocity is assumed to be constant, however, its actual value varies with air temperature. A compensation formula is $c = 331.3 + 0.606 * T$, where *T* is the air temperature. A typical ultrasound velocity in the air is 340m/s, so the formula for distance can be simplified to $L = 170 * t$, where *t* stands for the total travel time of the ultrasonic waves (the time between transmitting an ultrasonic burst and receiving its reflection).

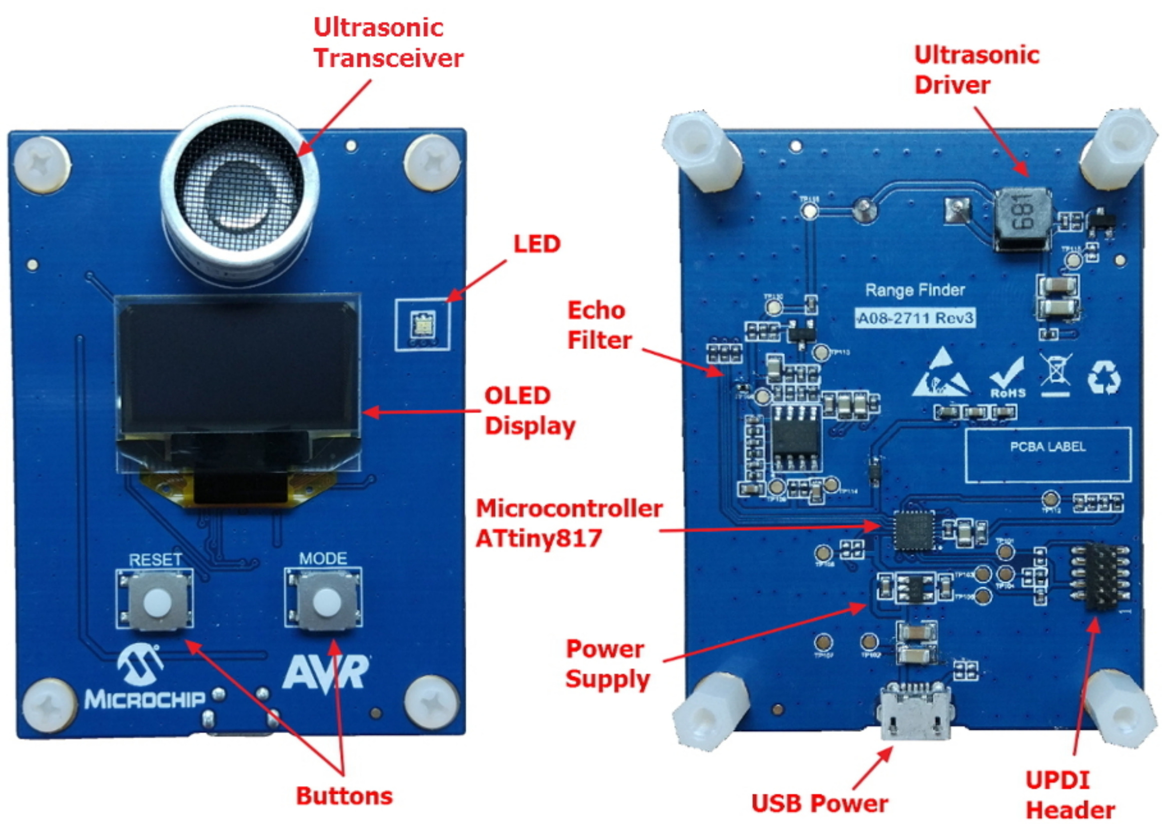
This document instructs the user on how to use the Ultrasonic Range Finder Field Engagement Board. The board uses core independent peripherals of ATtiny817 to measure the wave's travel time. The design focuses on reducing the MCU core usage and system power consumption for real-time or low-power applications.

2. Overview

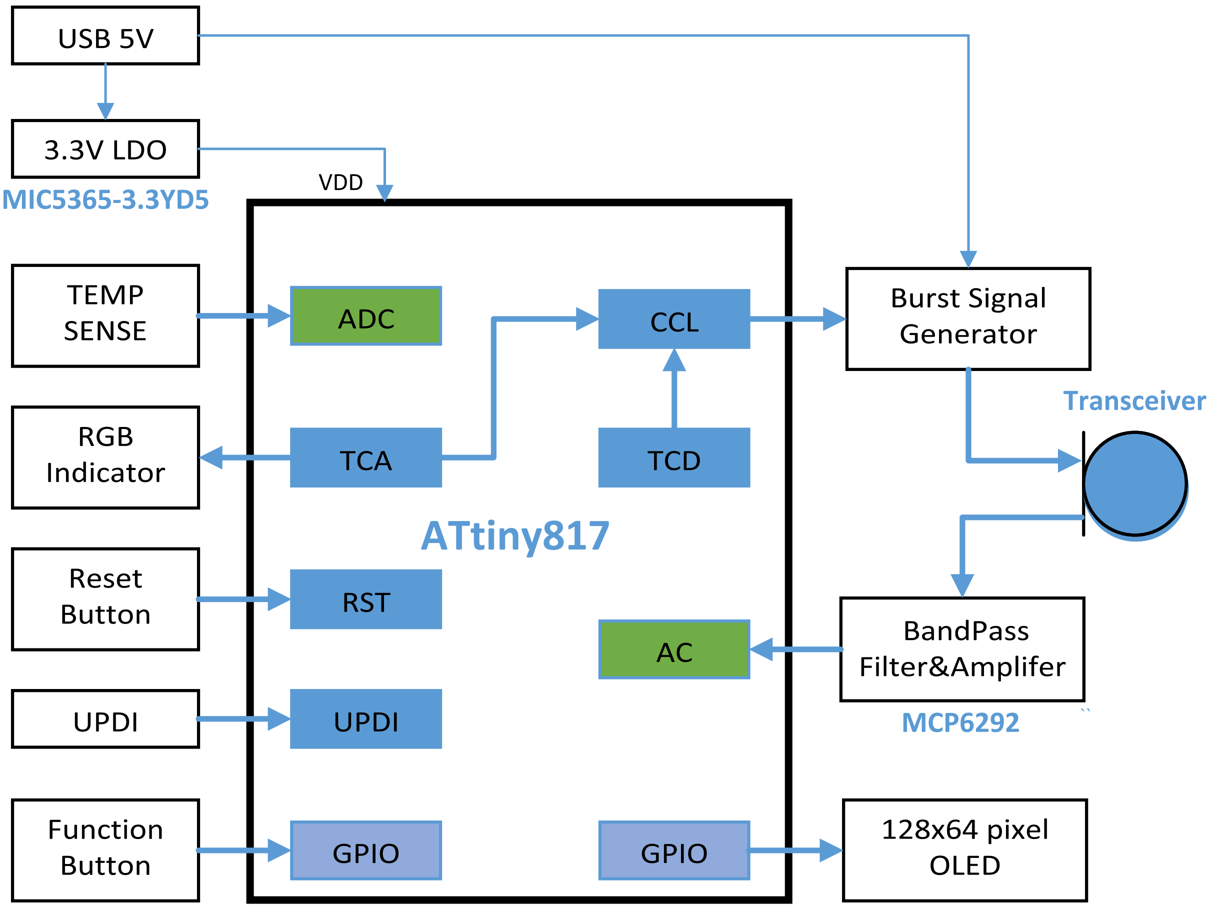
2.1 System Overview

The board carries the combined ultrasonic transceiver as the sensor for distance detection. The detected value is displayed on the OLED screen. Other LED and buttons are defined as the UI for the user.

Figure 2-1. Overview of the Ultrasonic Range Finder Board



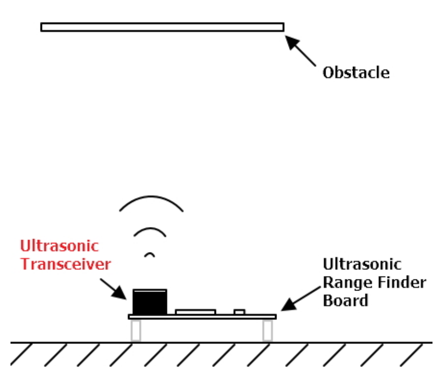
2.2 Block Diagram



2.3 Operation Guide

It is quite easy to understand the theory of the distance detection. The ultrasonic transceiver sends out the burst waveform and, while waiting for the feedback waveform which is reflected from the obstacle above it, the microcontroller calculates the travel time and translates it into the distance.

Figure 2-2. The Detect Theory of the Ultrasonic Range Finder Board



To use the Ultrasonic Range Finder Board, the user needs only to power-up the board with a micro-USB cable.

Figure 2-3. Power the Board

While powered, the OLED display will show the measured distance above the board. Changing the altitude of the obstacle also changes the displayed value.

The user must select the most suitable level to get the most precise result. The optional levels are show below:

- 40cm ~ 100cm(beta)
- 70cm ~ 250cm
- 100cm ~ 600cm
- 250cm ~ 1000cm

Press the MODE button to switch between these levels.

3. Hardware Details

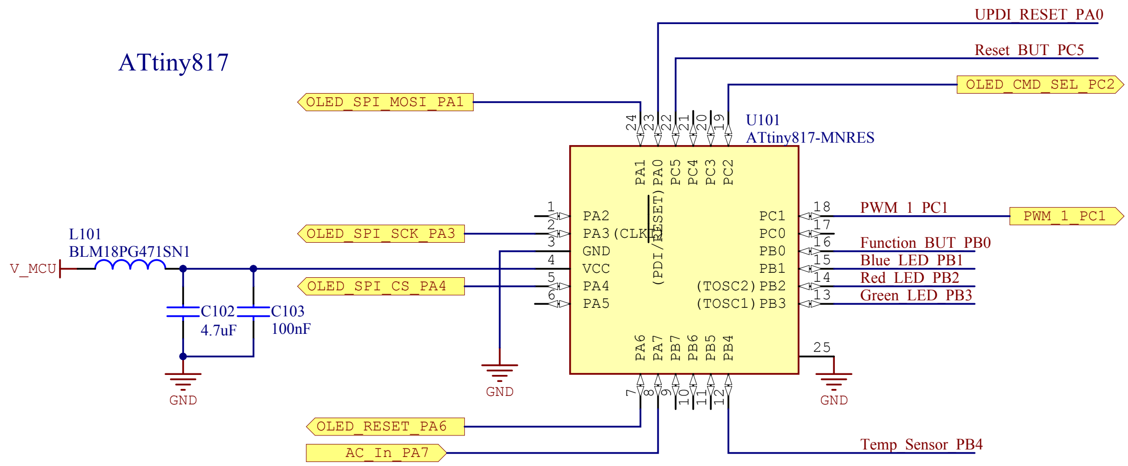
3.1 Microcontroller

ATtiny817 applies the latest technologies from Microchip with a flexible and low-power architecture including Event System and SleepWalking, accurate analog features, and advanced peripherals.

As shown in the figure below, peripherals used in this design mainly include:

- Timers for PWM generation or masking
- CCL for programmable glue logic
- AC for echo signal receive
- ADC for temperature measurement
- SPI for OLED display
- GPIO for user interfaces
- UPDI for single-wire programming

Figure 3-1. Schematic for the Microcontroller



3.2 CCL

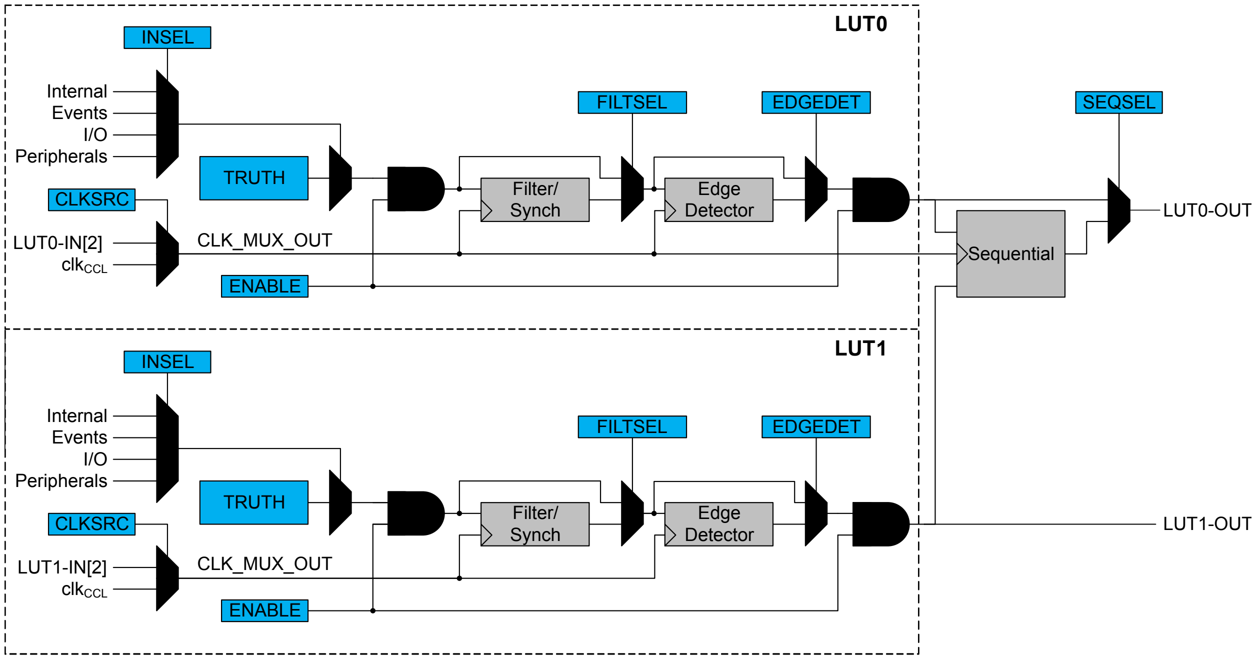
Configurable Custom Logic (CCL) is a programmable logic block that can use the device port pins, internal peripherals, and the internal Event System as both input and output channels.

As a Core Independent Peripheral (CIP), the CCL can serve as a programmable glue logic, which allows users to eliminate logic gates for simple glue logic functions on the PCB. This increases the reliability of the PCB by reducing its complexity, and also helps to keep the BOM down.

In ATtiny817, the CCL includes two programmable look-up tables (LUT). Each LUT consists of three inputs, a truth table, and as options, synchronizer, filter, and edge detector. Each LUT can generate an output as a user-programmable logic expression with three inputs. The inputs can be individually masked.

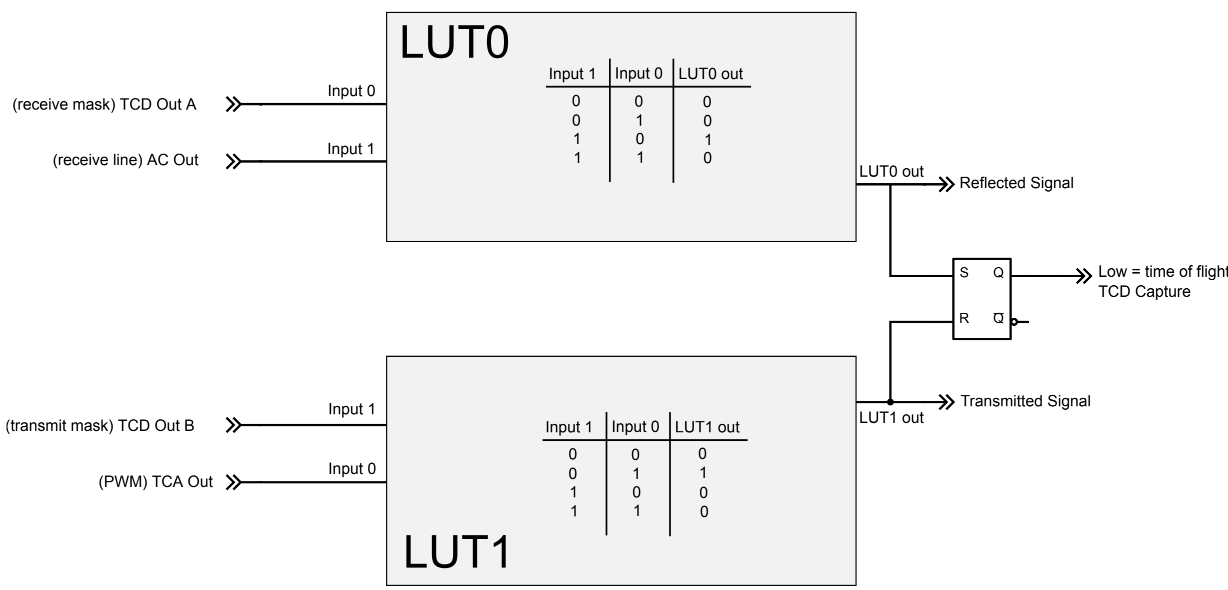
For more detail about this peripheral, refer to the latest data sheet of ATtiny817, available at http://www.microchip.com/.

Figure 3-2. Configurable Custom Logic Block Diagram



In this application, LUT1 is configured to generate a control signal to the ultrasonic transmitted pulses, while LUT0 is set to receive the reflected ultrasonic echo data. Mask signals from the Timer TCD can be used to avoid an overlap conflict between the transmitting period and the receiving period. Travel time can be measured by feeding both LUT outputs into a sequential control block, specifically an SR latch. The result is that the output of the latch indicates the travel time. See the figure below for more details.

Figure 3-3. CCL Logic Application



The pin selection for CCL in this design is shown in the table below.

Table 3-1. Configurable Custom Logic Pin Description

Pin Name	Function	Selected Pin in MCU
LUT1-OUT	Output for transmitted signal	PC1

For more details about the firmware algorithm and configuration, refer to the firmware user guide available at http://www.microchip.com/.

3.3 Ultrasonic Transceiver

The ultrasonic ceramic transceiver can be used for transmitting or receiving ultrasonic waves. It is manufactured by MULTICOMP with part number MCUSD16A40S12RO. See the table below for technical parameters.

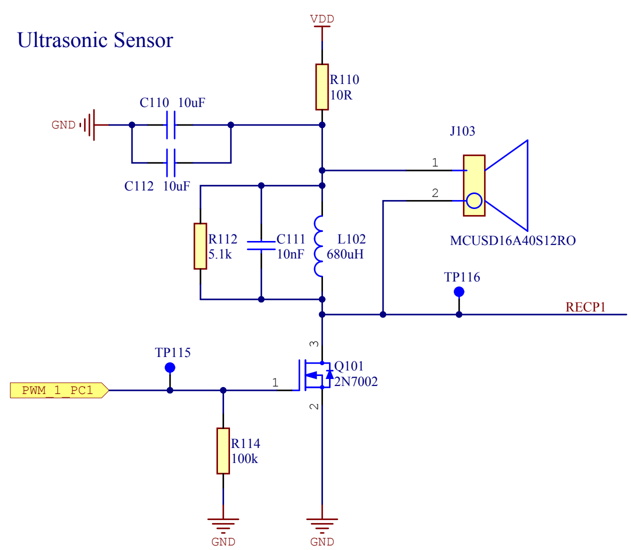
Table 3-2. Technical Parameters

Parameters	Value
Center frequency	40kHz ±1kHz
Output sound pressure at 40kHz	Min.110dB, while 0dB = 0.0002μbar
Sensitivity at 40kHz	Min.-65dB/V/μbar
Capacitance	2,500pF, ±25% at 1kHz
Directivity	50°
Operating temperature range	-35°C to +85°C
Detectable range	0.7 to 18m

3.4 Ultrasonic Transmit

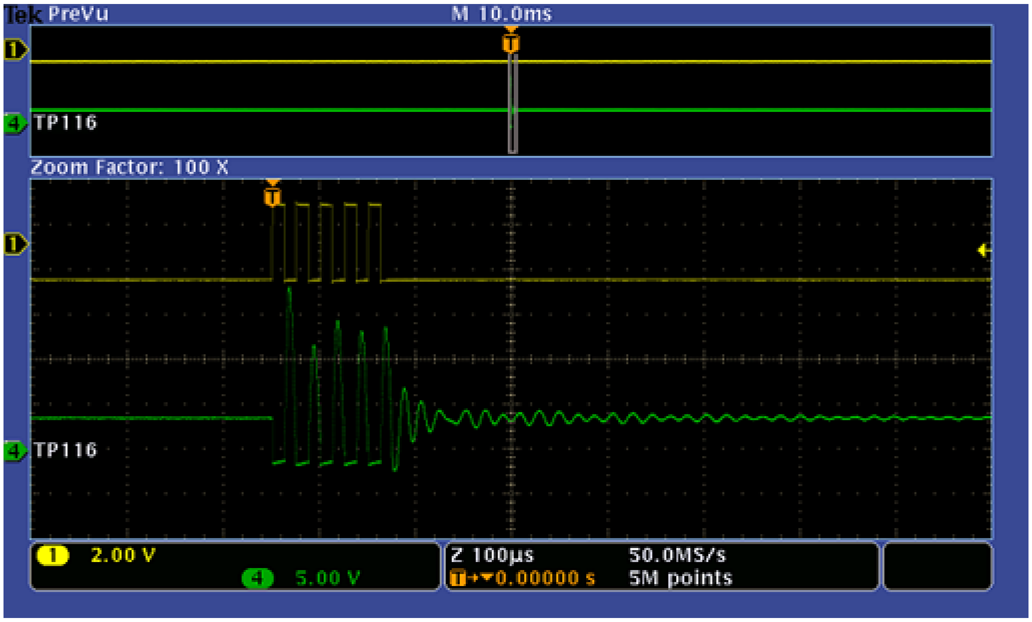
The 16-bit Timer TCA from ATtiny817 will sort out PWM pulses with a frequency of 40kHz. After passing the CCL and TCD logic mask process, the PWM pulses can switch the ultrasonic transceiver via a MOSFET to generate bursted ultrasonic waves. The ultrasonic waves will then propagate in the air until encountering any obstacles and reflecting back.

Figure 3-4. Ultrasonic Burst Circuit



The PWM pulses drive the burst circuit shown above to generate waves with amplitude close to 20Vpp. See the measured PWM pulses in yellow and ultrasonic waves in green in the figure below.

Figure 3-5. PWM Pulses vs. Bursted Ultrasonic Waves



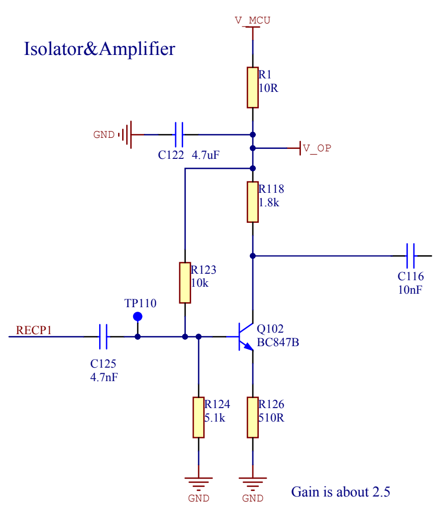
The signal amplitude is given by the PWM. The PWM's duty cycle is set to 50%. The MCUSD16A40S12RO ultrasonic transducer emits ultrasonic waves into the air.

3.5 Echo Process

The transmitted ultrasonic waves will propagate in the air until meeting obstacles and reflecting back. Once reflected back to the transceiver, the echo signal will be amplified and filtered in the isolator and pre-amplifier circuit. The signal will then be digitized by the AC with the threshold set up in the firmware. For detailed algorithm, read the firmware user guide available at http://start.atmel.com.

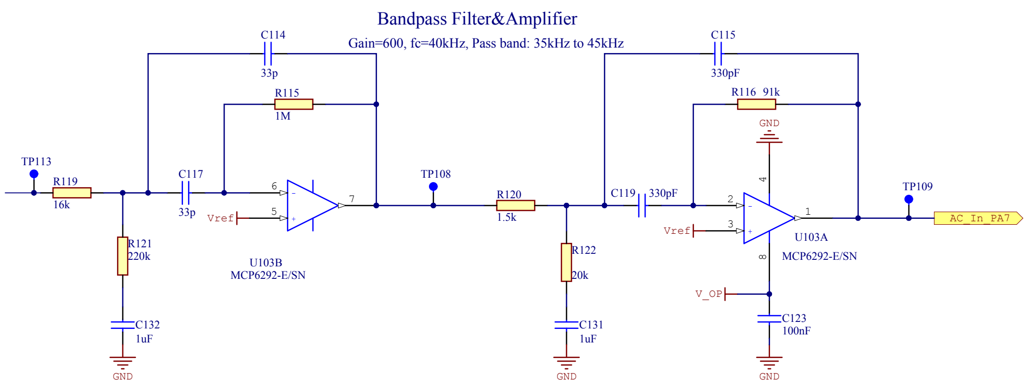
The echo process circuit mainly includes two parts; a pre-amplifier based on BJT and a 2-stages 4-order band pass filter.

Figure 3-6. Isolator and Pre-amplifier



As shown in the figure above, the gain for the pre-amplifier based on BJT is approximately 2.5. This circuit also protects the system from high-voltage impacts from the bursted transceiver.

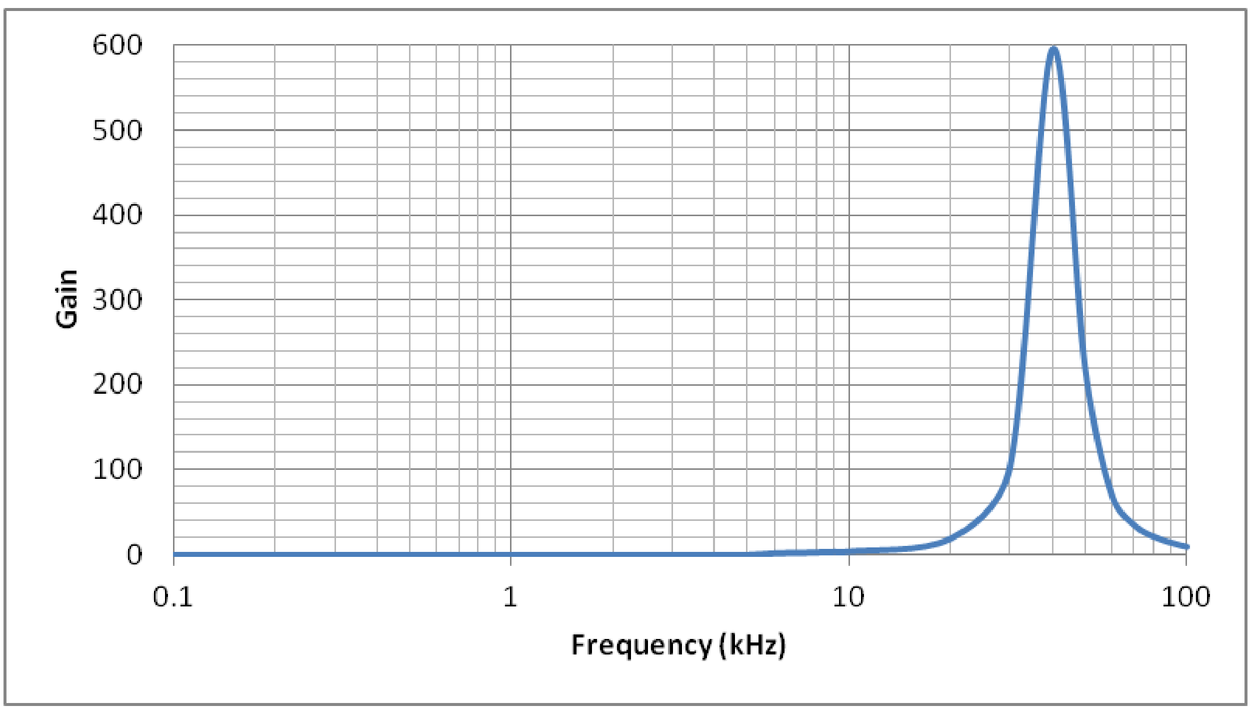
Figure 3-7. Echo Band Pass Filter and Amplifier



As shown in the figure above, this filter is a 2-stages 4-order band pass filter with over 600V/V voltage gain. The center frequency is designed to be 40kHz with 10kHz pass-band bandwidth. Also, a DC voltage reference (Vref = 1.65V) is used to provide an offset voltage for the filter to make the signal amplitude as large as possible.

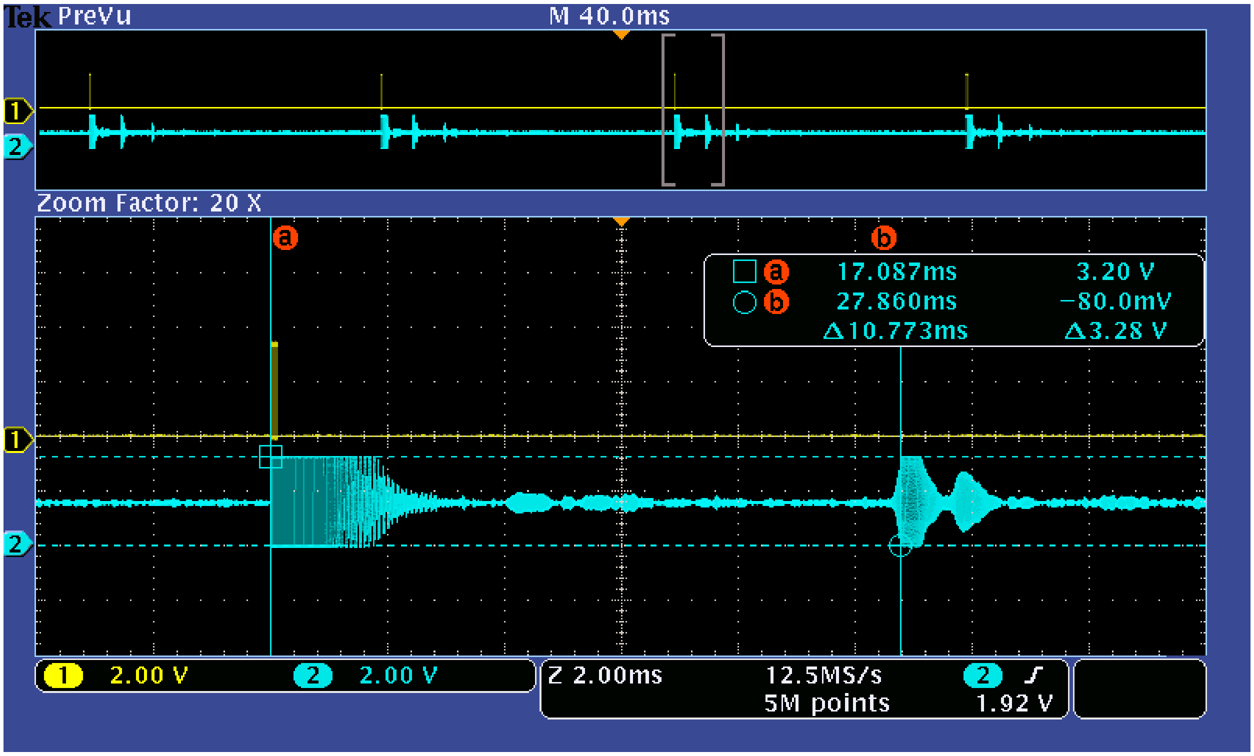
A curve based on measured data for the band pass filter is shown in the figure below. The component tolerances in the design are E24 (5%) for resistors and E12 (10%) for capacitors.

Figure 3-8. Gain vs. Frequency Curve for the Band Pass Filter



An oscilloscope screen of the ultrasonic echo signal is shown in the figure below.

Figure 3-9. Measured Ultrasonic Echo Waves

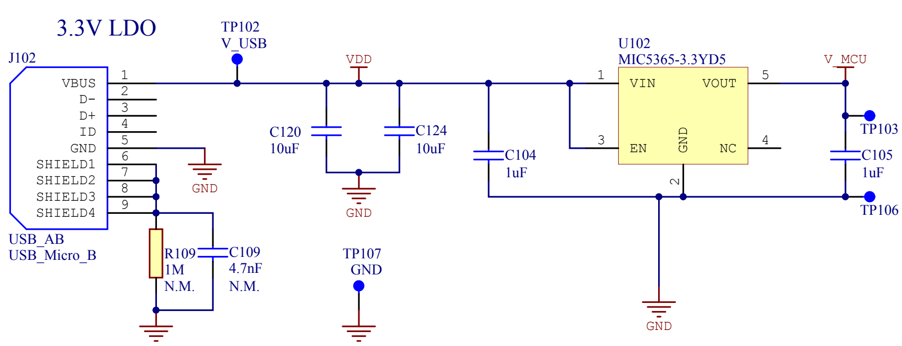


3.6 Power Supply

The +5V system power is from the USB interface.

Only the ultrasonic transceiver is supplied directly by the +5V, namely the VDD. All other circuits in the system are supplied by 3.3V, named V_MCU from an LDO.

Figure 3-10. Power Supply for the System



As shown in the image above, R109 and C109 can be mounted to enhance the ESD protection performance.

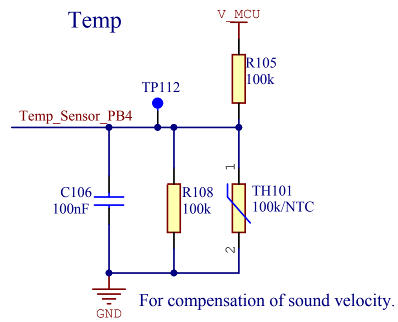
Note: Parts marked with "N.M" should not be mounted by default.

3.7 Temperature Test

The principle of the ultrasonic distance measurement depends on the velocity of the ultrasonic wave in the air. The velocity of the ultrasonic wave in the air is influenced by the air temperature. In strict

applications, consider the temperature factor in the distance calculation to achieve a more accurate result.

Figure 3-11. NTC Measurement



As shown in the figure above, a low-cost NTC resistor is used in this design. See the tables below for more details about the resistor.

Table 3-3. NTC Resistor Pin Map

Part Name	Manufacturer Part Number	Signal Name	Pin in MCU
NTC resistor	NCP15WF104F03RC	Temp	PB4

The table below shows the accurate relationship between the temperature, NTC resistance, and voltage at the NTC resistor.

Table 3-4. Detail Parameters for the NTC

Temperature [°C]	Resistance [kΩ]	Rtemp=Rth*R108/(Rth+R108) [kΩ]	Vtemp=3.3*Rtemp/(Rtemp +R105) [V]
-40	4397.119	97.77635415	1.631448664
-35	3088.599	96.8638264	1.623714387
-30	2197.225	95.64692183	1.613288055
-25	1581.881	94.05427613	1.599444843
-20	1151.037	92.0066313	1.58130936
-15	846.579	89.4356414	1.557983569
-10	628.988	86.28235307	1.528495644
-5	471.632	82.50622778	1.491842525
0	357.012	78.11873649	1.447303274
5	272.5	73.15436242	1.394186047
10	209.71	67.71173033	1.332337992
15	162.651	61.92666314	1.262040385
20	127.08	55.96265633	1.184108877
25	100	50	1.1

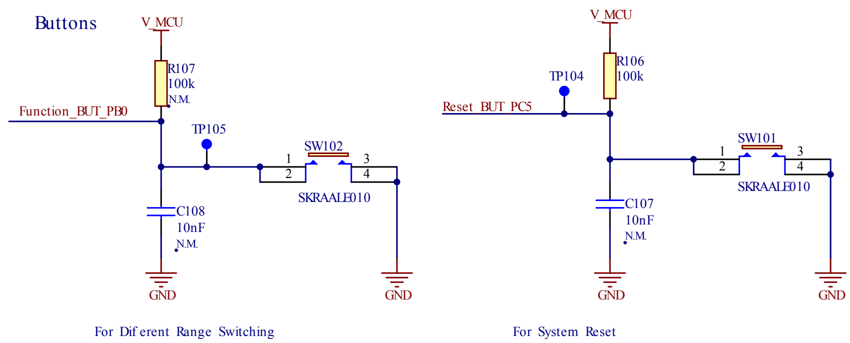
Temperature [°C]	Resistance [kΩ]	Rtemp=Rth*R108/(Rth+R108) [kΩ]	Vtemp=3.3*Rtemp/(Rtemp +R105) [V]
30	79.222	44.20327862	1.01156382
35	63.167	38.71309762	0.920988893
40	50.677	33.63287031	0.830547692
45	40.904	29.02969398	0.742449177
50	33.195	24.92210669	0.658353867
55	27.091	21.31622223	0.579836168
60	22.224	18.18300825	0.507720425
65	18.323	15.48557761	0.442500329
70	15.184	13.18238644	0.384351988
75	12.635	11.21764993	0.332845055
80	10.566	9.556283125	0.287849619
85	8.873	8.149862684	0.248678511
90	7.481	6.96029996	0.214743133
95	6.337	5.959355634	0.185598275
100	5.384	5.108934943	0.160400116
105	4.594	4.392221351	0.138844928
110	3.934	3.785094387	0.120352653
115	3.38	3.269491198	0.104477332
120	2.916	2.833378678	0.09092524
125	2.522	2.459959814	0.079229656

3.8 User Interface

The user interface consists mainly of three parts; User buttons for control, OLED for display, and LED for status indication.

3.8.1 Buttons

Figure 3-12. User Buttons



The MODE function button is defined in the firmware for different range switching.

The RESET button is not applied in the firmware in this design, it is open for the user to use freely.

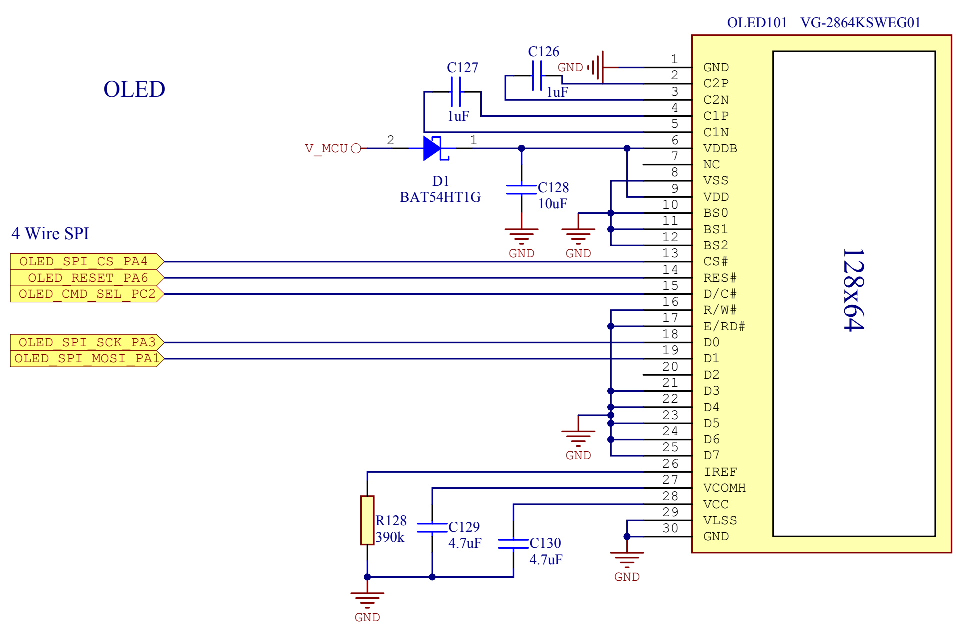
Note: Parts marked with "N.M" should not be mounted by default.

Table 3-5. Buttons Pin Map

Signal Name	Pin in MCU
Function_BUT_PB0	PB0
Reset_BUT_PC5	PC5

3.8.2 OLED

Figure 3-13. OLED Display



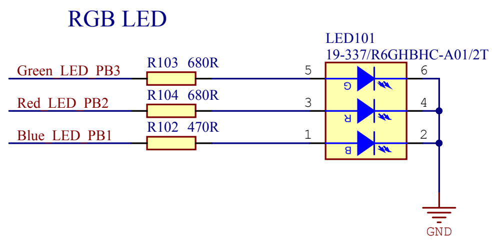
The OLED with 128 x 64 pixels is used to display the measured result via the SPI interface. The pin usage can be found in the table below.

Table 3-6. OLED Pin Map

Part Name	Manufacturer Part Number	Net Name	Pin in MCU
OLED Display Module with 128x64 pixels	VG-2864KSWEG01	OLED_SPI_CS_PA4	PA4
		OLED_RESET_PA6	PA6
		OLED_CMD_SEL_PC2	PC2
		OLED_SPI_SCK_PA3	PA3
		OLED_SPI_MOSI_PA1	PA1

3.8.3 LED

Figure 3-14. RGB LED for Status Indication



The RGB LED is controlled independently by three GPIOs from the microcontroller to show or mix red, green, and blue lighting colors. Theoretically, the user can generate almost all colors by mixing the three basic colors with duty control.

The indication function is not applied in this design, it is open for users to program the GPIOs to change the color of the RGB LED to indicate the measured distance.

The detailed GPIO pin definition is shown in the table below.

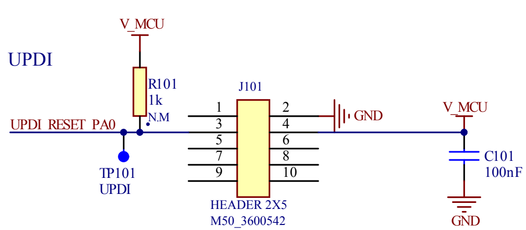
Table 3-7. RGB LED Pin Map

Part Name	Manufacturer Part Number	Signal Name	Pin in MCU
RGB LED	19-337/R6GHBHC-A01/2T	Green_LED_PB3	PB3
		Red_LED_PB2	PB2
		Blue_LED_PB1	PB1

3.9 Programming

Unified Program and Debug Interface (UPDI) is a Microchip proprietary interface for external programming and on-chip debugging.

Figure 3-15. UPDI Programming Interface



The pin definition is shown in the table below.

Table 3-8. UPDI Interface Pin Map

Net Name	Pin in MCU
UPDI_RESET_PA0	PA0

The interface supports single-wire programming. For a detailed description, refer to the UPDI section of the latest ATtiny817 data sheet.

4. Default Firmware

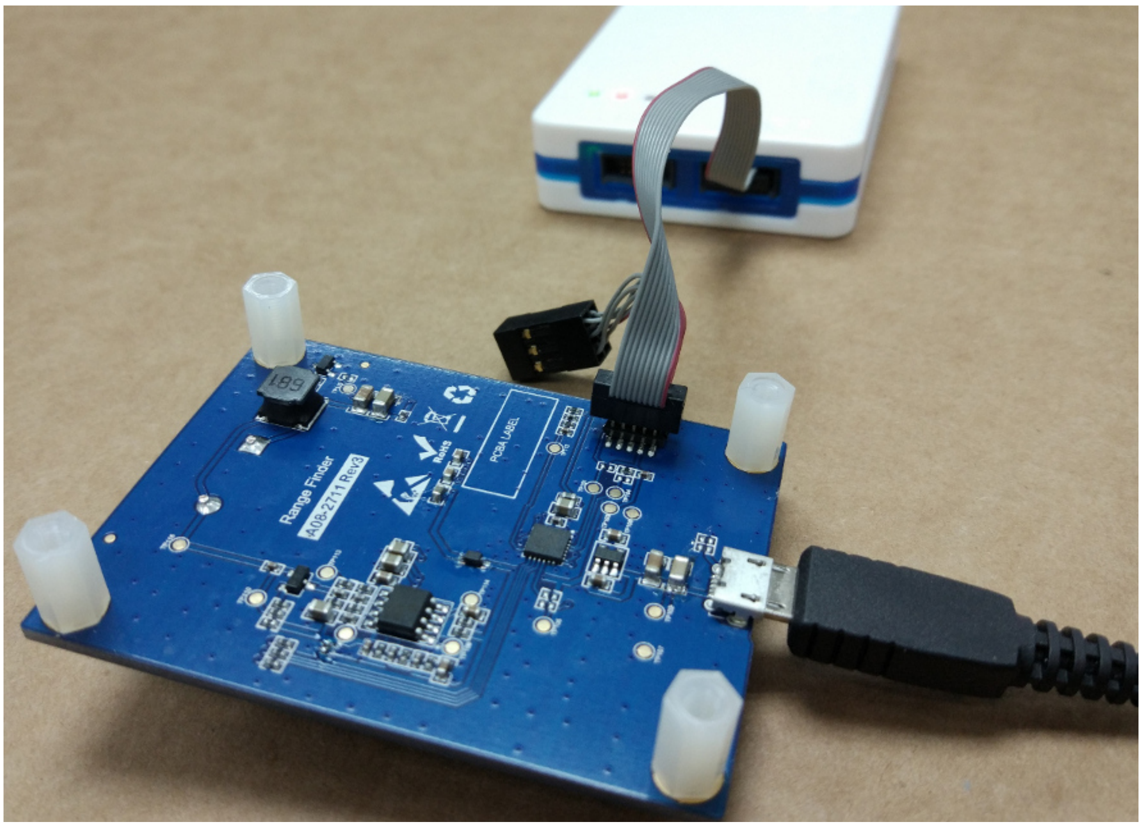
A default firmware is preprogrammed in the ATtiny817 microcontroller. It is open to the user for reprogramming.

4.1 Firmware Programming

The default firmware is available in the enclosed package named 'ATTINY817_CIP_UltrasoundSens.elf'

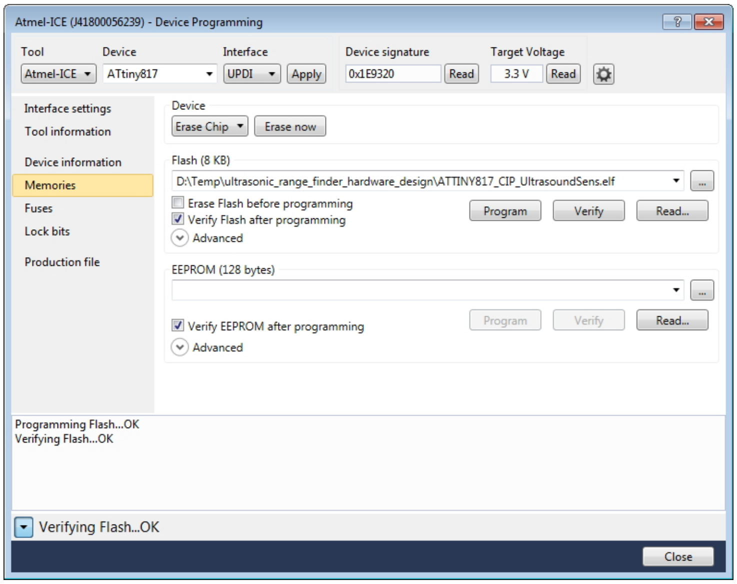
Atmel Studio and Atmel ICE will help the user in programming the device. The UPDI header is defined as the connecter between the board and Atmel ICE.

Figure 4-1. Connection of the Board and Programmer



The programming interface of Atmel Studio is shown in the figure below:

Figure 4-2. Programming Interface in Atmel Studio



5. Revision History

Doc. Rev.	Date	Comments
A	08/2017	Initial document release. Microchip DS40001902A replaces Atmel 42792A.

6. Object of Declaration

EU Declaration of Conformity for Ultrasonic Range Finder Field Engagement Board

This declaration of conformity is issued by the manufacturer.

The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.

This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.

For information regarding the exclusive, limited warranties applicable to Microchip products, please see Microchip’s standard terms and conditions of sale, which are printed on our sales documentation and available at www.microchip.com.

Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA.

Rodger Richey
Director of Development Tools

4/4/17
Date

The Microchip Web Site

Microchip provides online support via our web site at http://www.microchip.com/. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

Customer Change Notification Service

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at http://www.microchip.com/. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or Field Application Engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://www.microchip.com/support

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.

- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip’s code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Legal Notice

Trademarks

ISBN: 978-1-5224-2105-4

Quality Management System Certified by DNV

ISO/TS 16949

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-3326-8000
Fax: 86-21-3326-8021

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

France - Saint Cloud
Tel: 33-1-30-60-70-00

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra’anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7289-7561

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820