Signal and Noise Generator

Signal and Noise Generator User's Guide

Preface

Signal and Noise Generator is an extension board for the Xplained Pro evaluation platform. It is designed to generate an analog signal with or without noise.
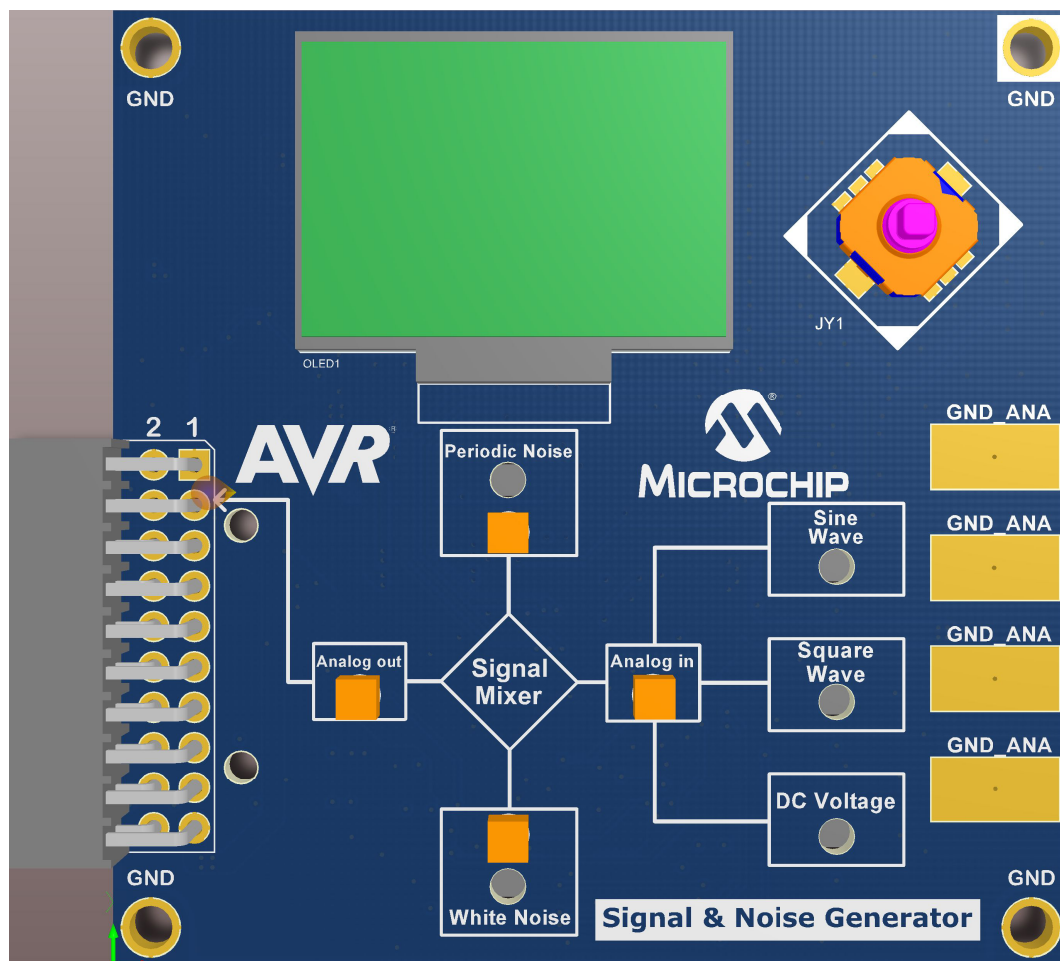

Table of Contents

1. Introduction

1.1 Features

- Xplained Pro Extension Features:
  - Follow existing latest version of Xplained Pro platform specification
  - PCB dimension: 60 mm x 60 mm (not including the connector)
  - One female standard 20-pin extension connector
  - ID chip
  - Four mounting holes with GND
  - Two test jig holes
  - Four rubber feet
  - Power measurement
- Power from Xplained Pro Standard Ext Header:
  - Boost to 5.25V for powering on-board microcontrollers (MCUs) and analog circuit
  - LDO to 3V for powering OLED
  - Level converter for I^2C interface to the external host MCU
  - Level converter for clock sync signal between external MCU and on-board MCUs
- Microcontrollers:
  - On-board ATtiny1617 to act as the board controller, signal generator and periodic noise generator
  - On board ATtiny416 to act as the white noise generator
- Analog Features:
  - 1-channel analog signal that can be switched between:
    - Sine Wave: 1 - 150 Hz frequency, 0.05 - 2.5V V_{PP}, 0 - 2.5V offset
    - Square Wave: 0.5 - 150 Hz frequency, 0.05 - 2.5V V_{PP}, 0 - 2.5V offset
    - DC Voltage: 0.05 - 2.5V
    - FSK: 5 - 150 kHz frequency, 0.05 - 2.5V V_{PP}, 0 - 2.5V offset
  - 1-channel periodic noise:
    - Periodic noise: 45 - 140 kHz, 0.05 - 2.5V V_{PP}
  - 1-channel white noise:
    - White noise: ~ 1 MHz bandwidth, 0.05 - 2V V_{PP}
  - One 4-channel electronic potentiometer used for signal or noise attenuation
  - Op amps for signal conditioning
  - Offset circuit
- One OLED Display 128x64
- User Interface:
  - Five status LEDs controlled by a board controller
  - 5-way joystick
  - Probe points for scope connections
- Programming and Debugging:
  - Two UPDI headers for the two MCUs respectively

1.2 Kit Overview

The Signal and Noise Generatoris an extension board that generates signal with or without noise for the Xplained Pro platform. The kit can be connected to any extension header on the Xplained Pro MCU Board.

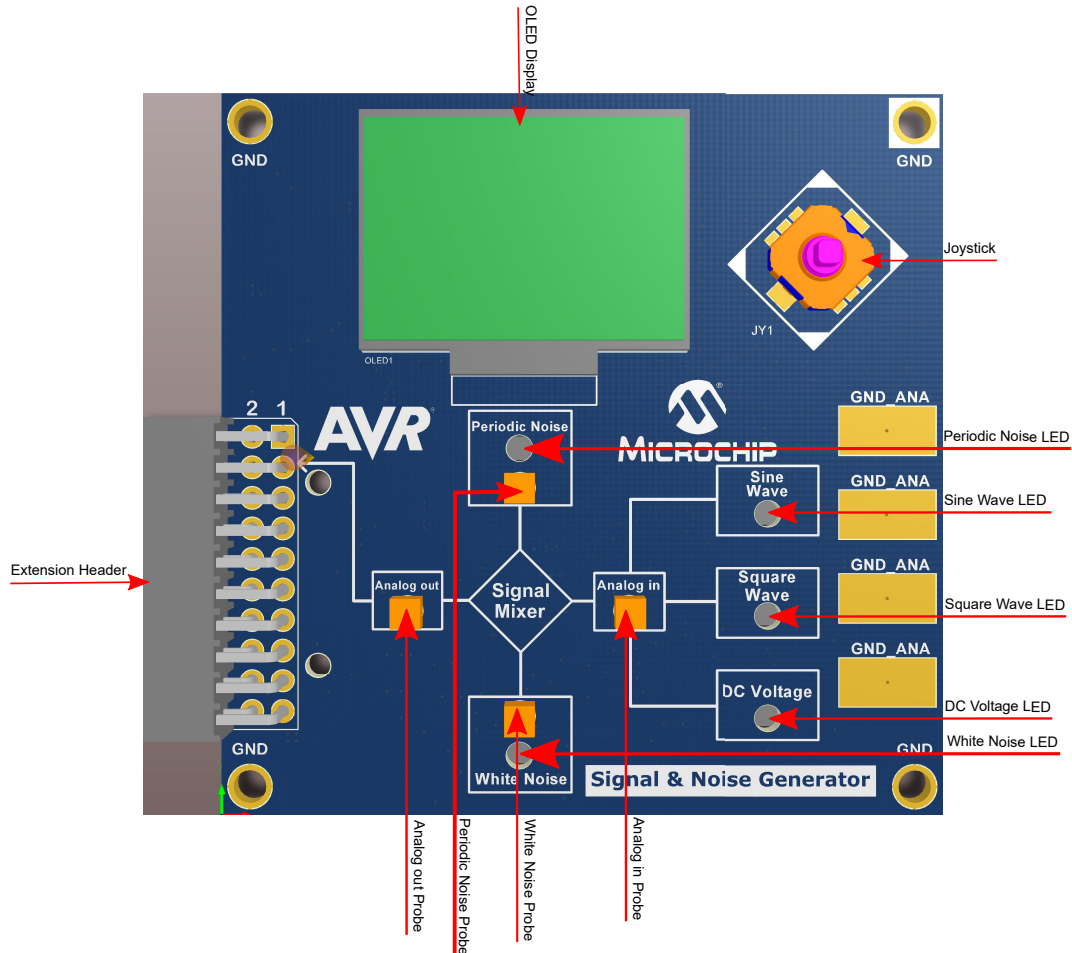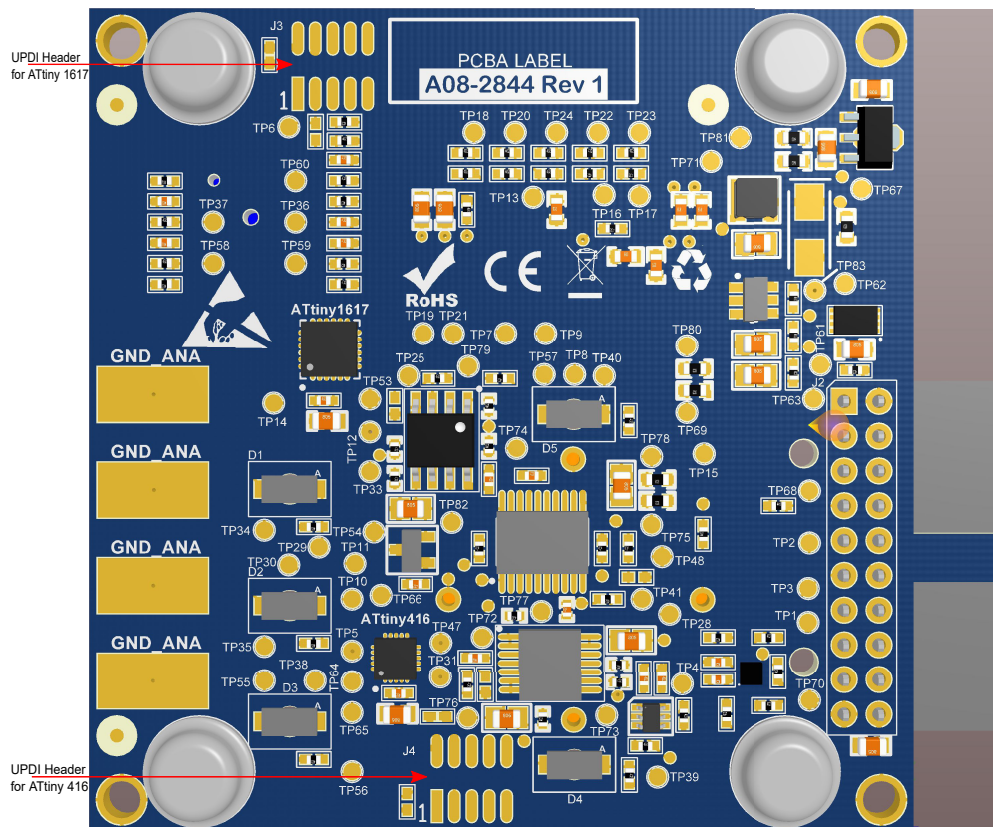**Figure 1-1. Signal and Noise Generator Front**

Figure 1-2. Signal and Noise Generator Back

2. Getting Started

2.1 Xplained Pro Quick Start

Steps to start exploring the Xplained Pro platform:

1. Download and install Atmel Studio.
2. Launch Atmel Studio.

When the Xplained Pro MCU kit is connected to the computer for the first time, the operating system installs the driver software automatically. This driver supports 32-bit and 64-bit versions of Microsoft® Windows® XP, Windows Vista®, Windows 7, Windows 8, Windows 10, and Windows Server 2012.

When the Xplained Pro MCU board is powered, the power LED (green) glows and the Atmel Studio automatically detects the specific Xplained Pro MCU and extension board(s) that are connected. The landing page of the kit in the Atmel Studio has an option to launch the Atmel Software Framework (ASF) and the Atmel START example application codes for the kit. The target device is programmed and debugged by the on-board embedded debugger and therefore no external programmer or debugger tool is required.

2.2 Design Documentation and Relevant Links

The following list contains links to the most relevant documents and software for the Signal and Noise Generator.

- Xplained products – Xplained evaluation kits are a series of easy-to-use evaluation kits for microcontrollers and other products. For low pin-count devices, the Xplained Nano series provides a minimalistic solution with access to all I/O pins of the target microcontroller. Xplained Mini kits are for medium pin-count devices and adds Arduino Uno compatible header footprint and a prototyping area. Xplained Pro kits are for medium to high pin-count devices, and feature advanced debugging and standardized extensions for peripheral functions. All these kits have on board programmers/ debuggers which creates a set of low-cost boards for evaluation and demonstration of features and capabilities of different products.
- Atmel Studio – Atmel Studio presents Free Atmel IDE for development of C/C++ and assembler code for microcontrollers and relevant documentation.
- Microchip sample store – Microchip sample store where you can order samples of devices.
- EDBG User Guide – User guide with more information about the on-board Embedded Debugger.
- IAR Embedded Workbench ® for ARM ® – This is a commercial C/C++ compiler available for ARM®. On their website there is also a 30-day evaluation version, available as a code-size limited kick-start version. The code-size limit is 16 KB for devices with M0, M0+, and M1 cores and 32 KB for devices with other cores.
- Data Visualizer – Data Visualizer is a program used for processing and visualizing data. Data Visualizer can receive data from various sources such as the Embedded Debugger Data Gateway Interface found on Xplained Pro boards and COM ports.

3. Xplained Pro

Xplained Pro is an evaluation platform which contains a series of microcontroller boards (evaluation kits) and extension boards. Atmel Studio is used to program and debug the microcontrollers on these boards. Atmel Studio includes Advanced Software Framework (ASF) and Atmel START, which has drivers and demo code, and Data Visualizer, which supports data streaming and advanced debugging. Xplained Pro evaluation kits can be connected to a wide range of Xplained Pro extension boards through standardized headers and connectors. Xplained Pro extension boards have identification (ID) chips to uniquely identify which boards are connected to the Xplained Pro evaluation kits.

3.1 Hardware Identification System

All Xplained Pro extension boards come with an identification chip (ATSHA204A CryptoAuthentication™ chip) to uniquely identify the boards that are connected to the Xplained Pro evaluation kit. This chip contains information that identifies the extension with its name and some extra data. When an Xplained Pro extension is connected to an Xplained Pro evaluation kit, the information is read and sent to the Atmel Studio. The following table shows the data fields stored in the ID chip with example content.

Table 3-1. Xplained Pro ID Chip Content

Data Field	Data Type	Example Content
Manufacturer	ASCII string	Microchip'\0'
Product name	ASCII string	Segment LCD1 Xplained Pro'\0'
Product revision	ASCII string	02'\0'
Product serial number	ASCII string	1774020200000010'\0'
Minimum voltage [mV]	uint16_t	3000
Maximum voltage [mV]	uint16_t	3600
Maximum current [mA]	uint16_t	30

3.2 Xplained Pro Headers and Connectors

3.2.1 Xplained Pro Standard Extension Header

All Xplained Pro kits have many dual-row, 20-pin, 100-mil extension headers. The Xplained Pro MCU boards have male headers, while the Xplained Pro extensions have their female counterparts. The following table provides the pin description of all the connected pins.

> **Info:** Not all pins are always connected on all extension headers.

The extension headers can be used to connect a variety of Xplained Pro extensions to Xplained Pro MCU boards or to access the pins of the target microcontroller on the Xplained Pro boards.

Table 3-2. Xplained Pro Standard Extension Header

Pin Number	Pin Name	Description
1	ID	Pin to communicate with the ID chip on an extension board.
2	GND	Ground
3	ADC(+)	Analog-to-Digital Converter; alternatively, a pin for the positive terminal of a differential ADC.
4	ADC(-)	Analog-to-Digital Converter; alternatively, a pin for the negative terminal of a differential ADC.
5	GPIO1	General purpose I/O pin.
6	GPIO2	General purpose I/O pin.
7	PWM(+)	Pulse width modulation; alternatively, a pin for the positive part of a differential PWM.
8	PWM(-)	Pulse width modulation; alternatively, a pin for the negative part of a differential PWM.
9	IRQ/GPIO	Interrupt request pin and/or general purpose I/O pin.
10	SPI_SS_B/ GPIO	Slave select pin for Serial Peripheral Interface (SPI) and/or general purpose I/O pin.
11	I^2C_SDA	Data pin for I^2C interface. Always connected, bus type.
12	I^2C_SCL	Clock pin for I^2C interface. Always connected, bus type.
13	UART_RX	Receiver pin of target device UART.
14	UART_TX	Transmitter pin of target device UART.
15	SPI_SS_A	Slave select for SPI. This pin should preferably not be connected to anything else.
16	SPI_MOSI	SPI master out slave in pin. Always connected, bus type.
17	SPI_MISO	SPI master in slave out pin. Always connected, bus type.
18	SPI_SCK	SPI clock pin. Always connected, bus type.
19	GND	Ground pin for extension boards.
20	VCC	Power pin for extension boards.

4. Hardware Users Guide

4.1 ID Chip Content

Signal and Noise Generatorcan be connected to several Xplained Pro MCU boards. An Xplained Pro MCU board that does not have 3.3V as primary target voltage will read all ID devices on connected extensions to check if they support the target voltage before enabling it to the extension headers. The table below shows the static content written in the ID chip.

Table 4-1. Signal and Noise Generator ID Chip Content

Data Field	Content
Product name	Signal and Noise Generator
Minimum operation voltage	3.1V
Maximum operation voltage	5.25V
Maximum current	150 mA

Related Links

3.1 Hardware Identification System

4.2 Headers

4.2.1 Extension Header

Signal and Noise Generator implements one Xplained Pro Standard Extension Header. This header makes it possible to connect the board to an Xplained Pro MCU board. The pin-out definition for the extension header can be seen in the table below.

Table 4-2. Signal and Noise Generator Extension Header

Pin on EXT1	Function	Description
1	ID	Communication line to the ID chip
2	GND	Ground
3	Analog_out	Output of the analog signal mixed with noise
4	Analog_signal	Output of the original analog signal
5	NC	Not Connected
6	NC	Not Connected
7	Sync_clock	Clock sync signal
8	NC	Not Connected
9	NC	Not Connected
10	NC	Not Connected
11	TWI_SDA	I^2C SDA

Pin on EXT1	Function	Description
12	TWI_SCL	I^{2}C SCL
13	NC	Not Connected
14	NC	Not Connected
15	NC	Not Connected
16	NC	Not Connected
17	NC	Not Connected
18	NC	Not Connected
19	GND	Ground
20	VCC	Target supply voltage

Related Links

3.2.1 Xplained Pro Standard Extension Header

4.2.2 Current Measurement

The 0Ω resistor *R69* can be removed to measure the current consumed by Signal and Noise Generator by soldering in wires for an ammeter. The 0Ω resistors *R60*, *R62* and *R67* can be removed to measure the current consumed by individual power rails *VCC_MCU_P5V0*, *VCC_ANA_P5V0* and *VCC_OLED_P3V0* respectively by soldering in wires for an ammeter.

4.2.3 Programming and Debugging Headers

Two UPDI headers (J3 and J4) are used for programming and debugging the two on-board MCUs (ATtiny1617 and ATtiny416), which are not mounted on the board.

Table 4-3. UPDI header for ATtiny1617 (J3)

Pin on UPDI header	Pin on ATtiny1617-MNR	Function
1	-	Not Connected
2	3	GND
3	23	UPDI
4	4	VCC
5	-	Not Connected
6	-	Not Connected
7	-	Not Connected
8	-	Not Connected
9	-	Not Connected
10	-	Not Connected

Table 4-4. UPDI header for ATtiny416 (J4)

Pin on UPDI header	Pin on ATtiny416-MNR	Function
1	-	Not Connected
2	3	GND
3	19	UPDI
4	4	VCC
5	-	Not Connected
6	-	Not Connected
7	-	Not Connected
8	-	Not Connected
9	-	Not Connected
10	-	Not Connected

4.3   Functional Decription

The Signal and Noise Generator can be configured to generate various analog signals such as DC, sine waves, square waves and FSK. It can also be configured to add both white and periodic noise to the generated analog signal output. The extension board is illustrated in Figure 1-1 and Figure 1-2.

4.3.1   LEDs

There are five LEDs on this board:

- D1 ON indicates the current generated signal is sine wave.
- D2 ON indicates the current generated signal is square wave.
- D3 ON indicates the current generated signal is DC voltage.
- D1, D2 and D3 all OFF indicates the current generated signal is FSK.
- D4 ON indicates white noise is mixed to the current signal.
- D5 ON indicates periodic noise is mixed to the current signal.

4.3.2   Joystick

The joystick *JY1* is used to navigate the menu system and have 5 operations:

- ↑
- ↓
- →
- ←
- Push down

4.3.3   OLED Display

The OLED display will show a menu for signal and noise configuration. This menu can be accessed to enable the available signal and noise sources, and adjust properties such as frequency, attenuation and signal level.

4.3.4 Signal & Noise Generator Oscilloscope Probe Points

The board has four oscilloscope probe points for measuring the original analog signal, white noise, periodic noise and the analog signal mixed with noise.

4.4 Usage

4.4.1 Power Supply

The Signal and Noise Generator can be powered up by connecting it to a Xplained Pro board.

4.4.2 Signal and Noise Generator Operation

After the kit is powered up, the joystick can be operated to generate signal and noise according to the menu system displayed on the OLED. There are three types of menu options in the menu system and the effect of joystick operation on the different menu options will be described as below:

One menu option starts with □:
- ↑↓ selects between the different menu options.
- ← returns from current menu.
- **Push down** → enables a signal /noise.

One menu option starts with > :
- ↑↓ selects between the different menu options.
- ← returns from current menu.
- **Push down** → enters a menu.

One menu option includes a slider:
- ↑→ increases Amplitude/Frequency/Offset of a signal/noise or DC level of DC signal.
- ↓← decreases Amplitude/Frequency/Offset of a signal/noise or DC level of DC signal.
- **Push down** returns from current menu.

The top menu will be displayed after powering up. The top menu options are > **Signal Sources** and > **Noise Sources**. All of the menu options are described as below:

- > Signal Sources
  - □Sine Enable
  - □Square Wave Enable
  - □DC Enable
  - □FSK Enable
  - > Sine Wave
    - > Sine Amplitude
      - Sine Amplitude Slider
    - > Sine Frequency
      - Sine Frequency Slider
    - > Sine Offset
      - Sine Offset Slider
  - > Square Wave
    - > Square Amplitude
      - Square Amplitude Slider

- • > Square Frequency
  - – Square Frequency Slider
- • > Square Offset
  - – Square Offset Slider
- – > DC
  - • > DC Level
    - – DC Level Slider
- – > FSK
  - • > FSK Amplitude
    - – FSK Amplitude Slider
  - • > FSK Sample Frequency
    - – FSK Sample Frequency Slider
  - • > FSK Offset
    - – FSK Offset Slider
- • > Noise Sources
  - – □Periodic Noise Enable
  - – □Random Noise Enable
  - – > Periodic Noise
    - • > Periodic Noise Amplitude
      - – Periodic Noise Amplitude slider
    - • > Periodic Noise Frequency
      - – Periodic Noise Frequency Slider
  - – > Random Noise
    - • > Random Noise Amplitude
      - – Random Noise Amplitude Slider

According to the joystick operations and menu system described above, the signal or noise will be easily generated.

5. Hardware Revision History and Known Issues

5.1 Identifying Product ID and Revision

The revision and product identifier of the Xplained Pro boards can be found in two ways: either through Atmel Studio or by looking at the sticker on the bottom side of the PCB.

When an Xplained Pro MCU board is connected to a computer with Atmel Studio running, an information window with the serial number is shown. The first six digits of the serial number contain the product identifier and revision. Information about connected Xplained Pro extension boards is also shown in the window.

The same information can be found on the sticker on the bottom side of the PCB. Most kits have stickers that have the identifier and revision printed in plain text as A09-nnnn/rr, where nnnn is the identifier and rr is the revision. Boards with limited space have a sticker with only a data matrix code, which contains a serial number string.

The serial number string has the following format:

"nnnnrrssssssssss"

n = product identifier

r = revision

s = serial number

The product identifier for the Signal and Noise Generator is A09-3090.

5.2 Hardware Revision

Revision 2 is the initially released revision for the market.

5.3 Known Issues

No known issues.

6. Document Revision History

Doc. rev.	Date	Comment
A	05/2018	Initial document release.

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

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, KeeLoq logo, Kleer, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, RightTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, CryptoAuthentication, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PureSilicon, QMatrix, RightTouch logo, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

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	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
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	**Australia - Sydney** Tel: 61-2-9868-6733 **China - Beijing** Tel: 86-10-8569-7000 **China - Chengdu** Tel: 86-28-8665-5511 **China - Chongqing** Tel: 86-23-8980-9588 **China - Dongguan** Tel: 86-769-8702-9880	**India - Bangalore** Tel: 91-80-3090-4444 **India - New Delhi** Tel: 91-11-4160-8631 **India - Pune** Tel: 91-20-4121-0141 **Japan - Osaka** Tel: 81-6-6152-7160 **Japan - Tokyo** Tel: 81-3-6880- 3770	**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
Atlanta Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455	**China - Guangzhou** Tel: 86-20-8755-8029 **China - Hangzhou** Tel: 86-571-8792-8115	**Korea - Daegu** Tel: 82-53-744-4301 **Korea - Seoul** Tel: 82-2-554-7200	**Germany - Garching** Tel: 49-8931-9700 **Germany - Haan** Tel: 49-2129-3766400
Austin, TX Tel: 512-257-3370	**China - Hong Kong SAR** Tel: 852-2943-5100	**Malaysia - Kuala Lumpur** Tel: 60-3-7651-7906	**Germany - Heilbronn** Tel: 49-7131-67-3636
Boston Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088	**China - Nanjing** Tel: 86-25-8473-2460 **China - Qingdao** Tel: 86-532-8502-7355	**Malaysia - Penang** Tel: 60-4-227-8870 **Philippines - Manila** Tel: 63-2-634-9065	**Germany - Karlsruhe** Tel: 49-721-625370 **Germany - Munich** Tel: 49-89-627-144-0 Fax: 49-89-627-144-44
Chicago Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075	**China - Shanghai** Tel: 86-21-3326-8000 **China - Shenyang** Tel: 86-24-2334-2829	**Singapore** Tel: 65-6334-8870 **Taiwan - Hsin Chu** Tel: 886-3-577-8366	**Germany - Rosenheim** Tel: 49-8031-354-560 **Israel - Ra'anana** Tel: 972-9-744-7705
Dallas Addison, TX Tel: 972-818-7423 Fax: 972-818-2924	**China - Shenzhen** Tel: 86-755-8864-2200 **China - Suzhou** Tel: 86-186-6233-1526	**Taiwan - Kaohsiung** Tel: 886-7-213-7830 **Taiwan - Taipei** Tel: 886-2-2508-8600	**Italy - Milan** Tel: 39-0331-742611 Fax: 39-0331-466781
Detroit Novi, MI Tel: 248-848-4000	**China - Wuhan** Tel: 86-27-5980-5300	**Thailand - Bangkok** Tel: 66-2-694-1351	**Italy - Padova** Tel: 39-049-7625286
Houston, TX Tel: 281-894-5983	**China - Xian** Tel: 86-29-8833-7252	**Vietnam - Ho Chi Minh** Tel: 84-28-5448-2100	**Netherlands - Drunen** Tel: 31-416-690399 Fax: 31-416-690340
Indianapolis Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380	**China - Xiamen** Tel: 86-592-2388138 **China - Zhuhai** Tel: 86-756-3210040		**Norway - Trondheim** Tel: 47-7289-7561 **Poland - Warsaw** Tel: 48-22-3325737
Los Angeles Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800			**Romania - Bucharest** Tel: 40-21-407-87-50 **Spain - Madrid** Tel: 34-91-708-08-90 Fax: 34-91-708-08-91
Raleigh, NC Tel: 919-844-7510			**Sweden - Gothenberg** Tel: 46-31-704-60-40
New York, NY Tel: 631-435-6000			**Sweden - Stockholm** Tel: 46-8-5090-4654
San Jose, CA Tel: 408-735-9110 Tel: 408-436-4270			**UK - Wokingham** Tel: 44-118-921-5800 Fax: 44-118-921-5820
Canada - Toronto Tel: 905-695-1980 Fax: 905-695-2078			