

Low-Jitter Precision LVDS Oscillator

Features

- Low RMS Phase Jitter: <1 ps (typ.)
- High Stability: ± 10 ppm, ± 25 ppm, ± 50 ppm
- Wide Temperature Range:
 - Ext. Industrial -40°C to $+105^{\circ}\text{C}$
 - Industrial -40°C to $+85^{\circ}\text{C}$
 - Ext. Commercial -20°C to $+70^{\circ}\text{C}$
- High Supply Noise Rejection: -50 dBc
- Wide Frequency Range:
 - 2.3 MHz – 460 MHz
- Small Industry Standard Footprints
 - 2.5 mm x 2.0 mm
 - 3.2 mm x 2.5 mm
 - 5.0 mm x 3.2 mm
 - 7.0 mm x 5.0 mm
- Excellent Shock and Vibration Immunity
 - Qualified to MIL-STD-883
- High Reliability
 - 20x better MTF than quartz-based devices
- Low Current Consumption
- Supply Range of 2.25V to 3.63V
- Standby and Output Enable Functions
- Lead Free and RoHS-Compliant

Applications

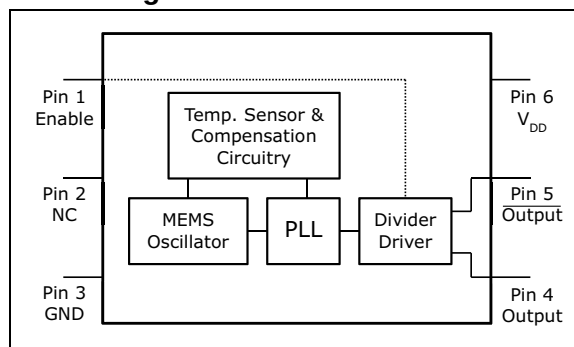
- Storage Area Networks
 - SATA, SAS, Fibre Channel
- Passive Optical Networks
 - EPON, 10G-EPON, GPON, 10G-PON
- HD/SD/SDI Video and Surveillance
- PCI Express Gen 1/Gen 2/Gen 3
- Display Port

General Description

The DSC1103 and DSC1123 series of high performance oscillators utilizes a proven silicon MEMS technology to provide excellent jitter and stability over a wide range of supply voltages and temperatures. By eliminating the need for quartz or SAW technology, MEMS oscillators significantly enhance reliability and accelerate product development, while meeting stringent clock performance criteria for a variety of communications, storage, and networking applications.

DSC1103 has a standby feature allowing it to completely power-down when EN pin is pulled low. For DSC1123, only the outputs are disabled when EN is low. Both oscillators are available in industry standard packages, including the smallest 2.5 mm x 2.0 mm, and are drop-in replacements for standard 6-pin LVDS crystal oscillators.

Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage	–0.3V to +4.0V
Input Voltage	–0.3V to $V_{DD}+0.3V$
ESD Protection (HBM)	4 kV
ESD Protection (MM)	400V
ESD Protection (CDM)	1.5 kV

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

Specifications: $V_{DD} = 3.3V$; $T_A = +25^{\circ}C$ unless otherwise specified.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Voltage (Note 1)	V_{DD}	2.25	—	3.63	V	—
Supply Current	I_{DD}	—	—	0.095	mA	DSC1103, EN pin low; all outputs disabled.
		—	20	22		DSC1123, EN pin low; all outputs disabled.
Frequency Stability	Δf	—	—	± 10	ppm	Includes frequency variations due to initial tolerance, temp., and power supply voltage.
		—	—	± 25		
		—	—	± 50		
Aging - First Year	Δf_{Y1}	—	—	± 5	ppm	One year at $+25^{\circ}C$
Aging - After First Year	Δf_{Y2+}	—	—	$< \pm 1$	ppm/yr	Year two and beyond at $+25^{\circ}C$
Start-up Time (Note 2)	t_{SU}	—	—	5	ms	$T = +25^{\circ}C$
Input Logic Levels	V_{IH}	$0.75 \times V_{DD}$	—	—	V	Input logic high
	V_{IL}	—	—	$0.25 \times V_{DD}$		Input logic low
Output Disable Time (Note 3)	t_{DA}	—	—	5	ns	—
Output Enable Time	t_{EN}	—	—	5	ms	DSC1103
		—	—	20	ns	DSC1123
Enable Pull-Up Resistor (Note 4)	R_{PU}	—	40	—	k Ω	Pull-up resistor exist.
LVDS Outputs						
Supply Current	I_{DD}	—	29	32	mA	Output enabled, $R_L = 100\Omega$
Output Offset Voltage	V_{OS}	1.125	—	1.4	V	$R = 100\Omega$ Differential
Delta Offset Voltage	ΔV_{OS}	—	—	50	mV	—
Peak-to-Peak Output Swing	V_{PP}	—	350	—	mV	Single-Ended

- Note 1:** V_{DD} pin should be filtered with a 0.1 μF capacitor.
Note 2: t_{SU} is time to 100 ppm stable output frequency after V_{DD} is applied and outputs are enabled.
Note 3: See the [Output Waveform](#) section and the [Test Circuit](#) for more information.
Note 4: Output is enabled if pad is floated or not connected.

ELECTRICAL CHARACTERISTICS (CONTINUED)Specifications: $V_{DD} = 3.3V$; $T_A = +25^{\circ}C$ unless otherwise specified.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Output Transition Rise/Fall Time (Note 3)	t_R/t_F	—	200	—	ps	20% to 80% $R_L = 50\Omega$, $C_L = 2\text{ pF}$
Frequency	f_0	2.3	—	460	MHz	–20°C to +70°C & –40°C to +85°C
		3.3	—	460		–40°C to +105°C
Output Duty Cycle	SYM	48	—	52	%	Differential
Period Jitter	J_{PER}	—	2.5	—	ps _{RMS}	—
Integrated Phase Noise	J_{PH}	—	0.28	—	ps _{RMS}	200 kHz to 20 MHz @156.25 MHz
		—	0.4	—		100 kHz to 20 MHz @156.25 MHz
		—	1.7	2		12 kHz to 20 MHz @156.25 MHz

- Note 1:** V_{DD} pin should be filtered with a 0.1 μF capacitor.
- 2:** t_{SU} is time to 100 ppm stable output frequency after V_{DD} is applied and outputs are enabled.
- 3:** See the [Output Waveform](#) section and the [Test Circuit](#) for more information.
- 4:** Output is enabled if pad is floated or not connected.

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Operating Temperature Range	T_A	-20	—	+70	°C	Ordering Option E
	T_A	-40	—	+85	°C	Ordering Option I
	T_A	-40	—	+105	°C	Ordering Option L
Junction Temperature	T_J	—	—	+150	°C	—
Storage Temperature Range	T_S	-55	—	+150	°C	—
Soldering Temperature	—	—	—	+260	°C	40 sec. max.

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature, and the thermal resistance from junction to air (i.e., T_A , T_J , θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +150°C rating. Sustained junction temperatures above +150°C can impact the device reliability.

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 2-1](#).

TABLE 2-1: PIN FUNCTION TABLE

Pin Number 7x5 with Pad	Pin Number 7x5 w/o Pad	Pin Number 5x3.2	Pin Number 3.2x2.5	Pin Number 2x2.5	Pin Name	Description
1	1	1	1	1	EN	Enable
2	2	2	2	2	NC	Do not connect
3	3	3	3	3	GND	Ground
4	4	4	4	4	OUT	LVDS clock output +
5	5	5	5	5	OUT–	LVDS clock output –
6	6	6	6	6	VDD	Supply voltage
PAD	—	—	—	—	PAD	Tie to Ground

TABLE 2-2: OUTPUT ENABLE MODES

EN Pin	DSC1103	DSC1123
High	Outputs Active	Outputs Active
NC	Outputs Active	Outputs Active
Low	Standby	Outputs Disabled

3.0 NOMINAL PERFORMANCE PARAMETERS

Unless otherwise specified, T = +25°C, V_{DD} = 3.3V.

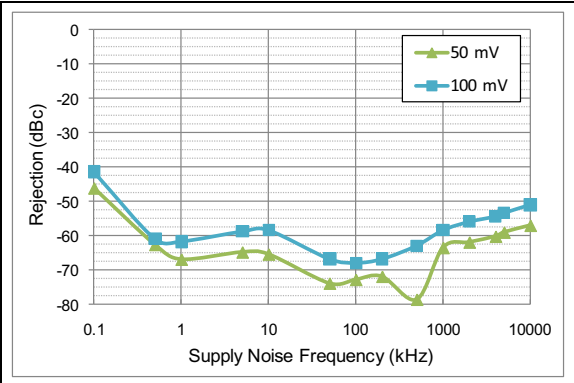


FIGURE 3-1: Power Supply Rejection Ratio.

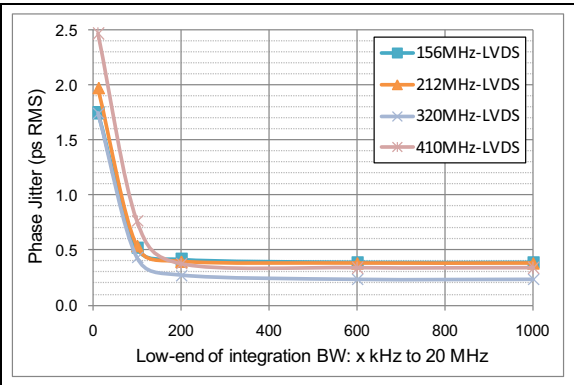


FIGURE 3-2: Phase Jitter (Integrated Phase Noise).

4.0 TERMINATION SCHEME

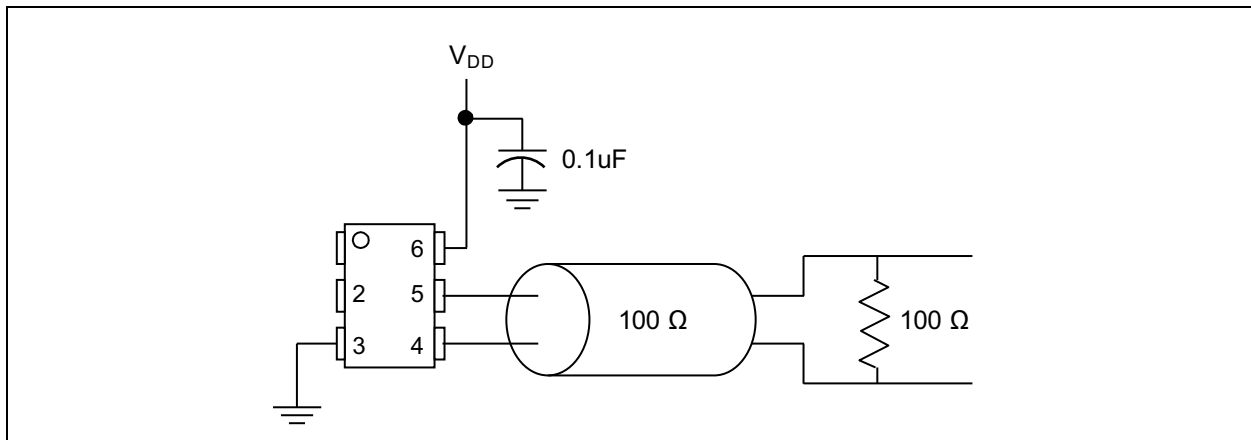


FIGURE 4-1: Typical Termination Scheme.

5.0 OUTPUT WAVEFORM

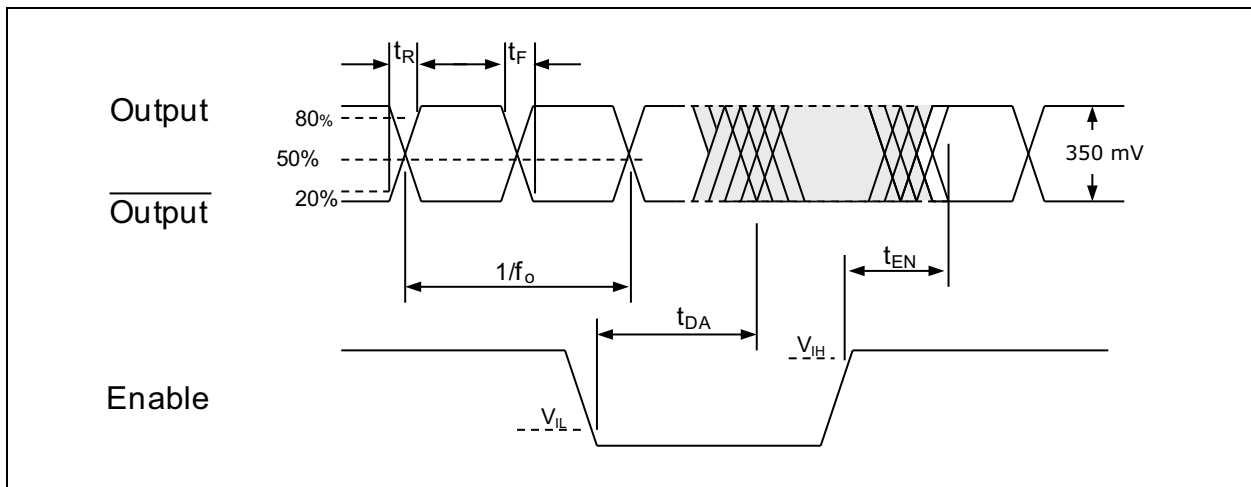


FIGURE 5-1: Output Waveform.

6.0 TEST CIRCUIT

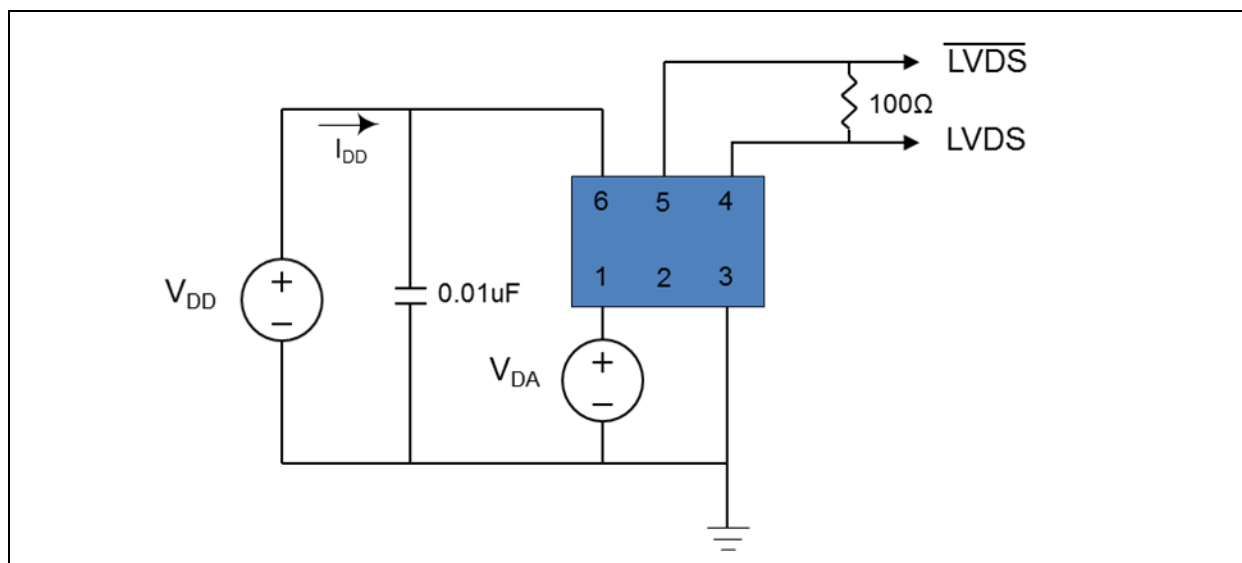
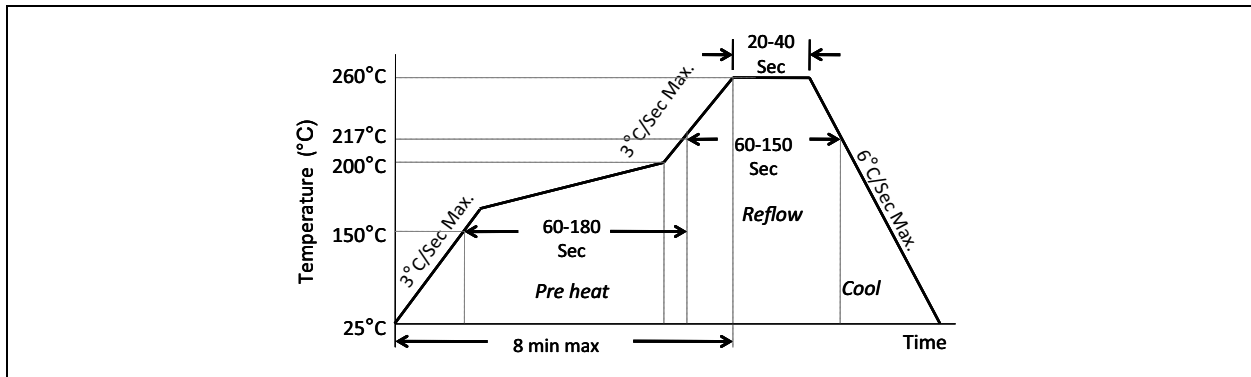


FIGURE 6-1: Test Circuit.

7.0 SOLDER REFLOW PROFILE



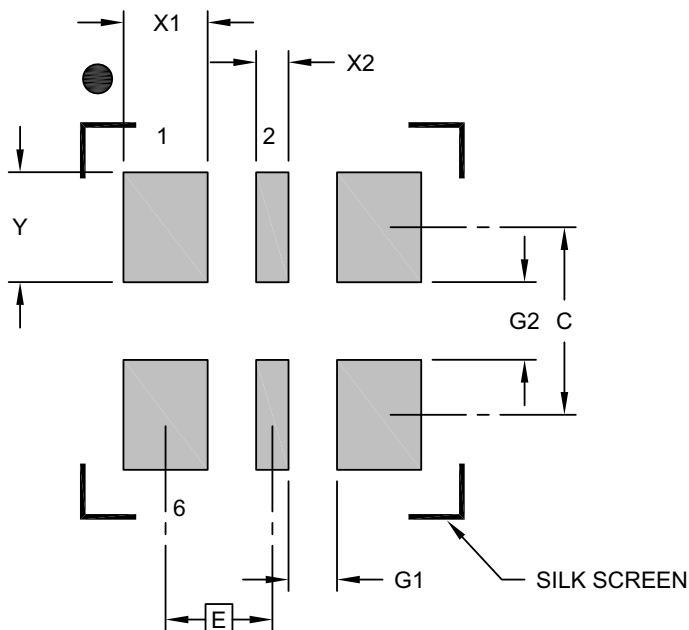
MSL 1 @ 260°C refer to JSTD-020C	
Ramp-Up Rate (200°C to Peak Temp)	3°C/sec. max.
Preheat Time 150°C to 200°C	60-180 sec.
Time Maintained above 217°C	60-150 sec.
Peak Temperature	255°C to 260°C
Time within 5°C of Actual Peak	20-40 sec.
Ramp-Down Rate	6°C/sec. max.
Time 25°C to Peak Temperature	8 minutes max.

8.0 PACKAGE MARKING INFORMATION

6-Lead VDFN 2.5 mm x 2.0 mm Package Outline and Recommended Land Pattern

6-Lead Very Thin Dual Flatpack No-Leads (J7A) - 2.5x2.0 mm Body [VDFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	0.825 BSC		
Contact Pad Width (X4)	X1			0.65
Contact Pad Width (X2)	X2			0.25
Contact Pad Length (X6)	Y			0.85
Contact Pad Spacing	C		1.45	
Space Between Contacts (X4)	G1	0.38		
Space Between Contacts (X3)	G2	0.60		

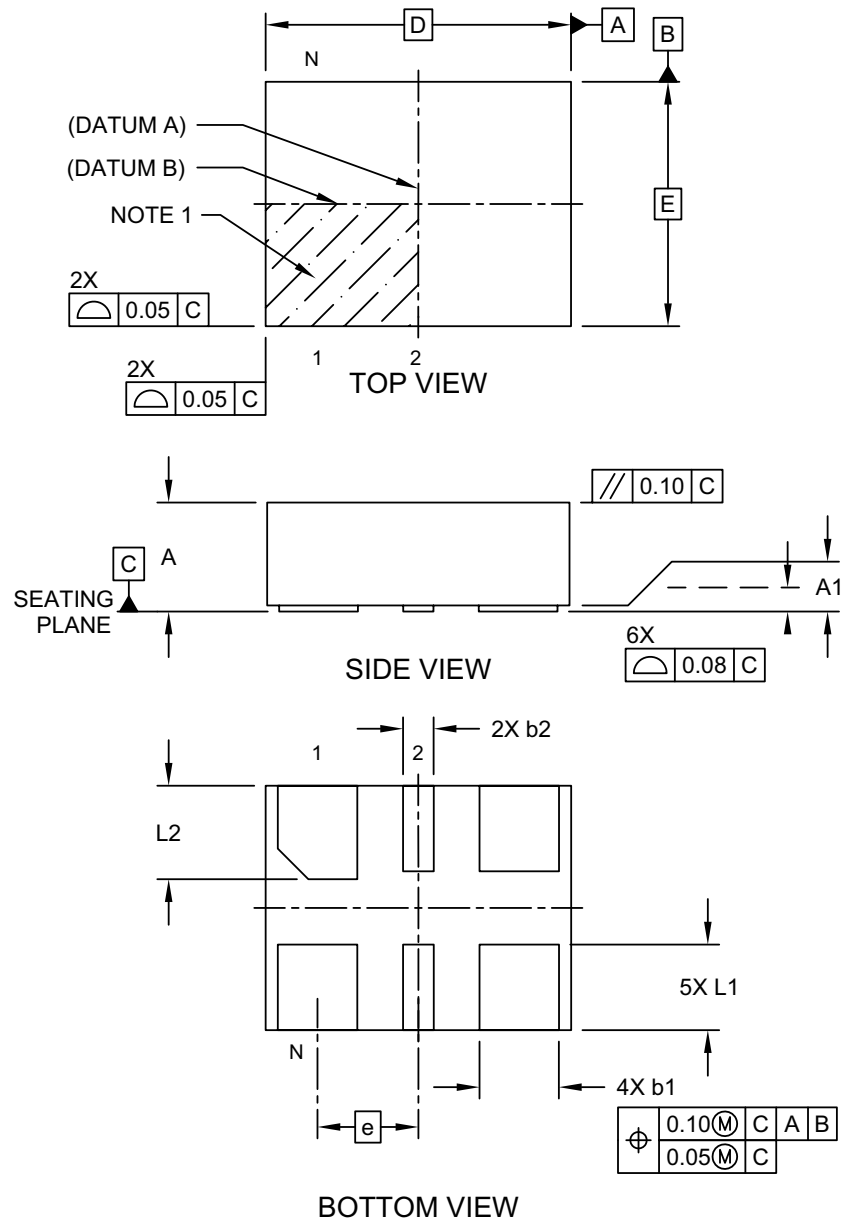
Notes:

- Dimensioning and tolerancing per ASME Y14.5M
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
- For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-3005A

6-Lead Very Thin Dual Flatpack No-Leads (J7A) - 2.5x2.0 mm Body [VDFN]

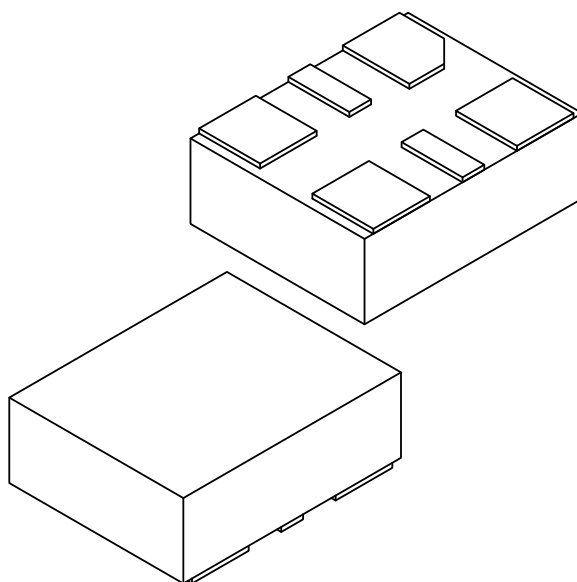
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-1005A Sheet 1 of 2

6-Lead Very Thin Dual Flatpack No-Leads (J7A) - 2.5x2.0 mm Body [VDFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N	6		
Pitch	e	0.825 BSC		
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Overall Length	D	2.50 BSC		
Overall Width	E	2.00 BSC		
Terminal Width	b1	0.60	0.65	0.70
Terminal Width	b2	0.20	0.25	0.30
Terminal Length	L1	0.60	0.70	0.80
Terminal Length	L2	0.665	0.765	0.865

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

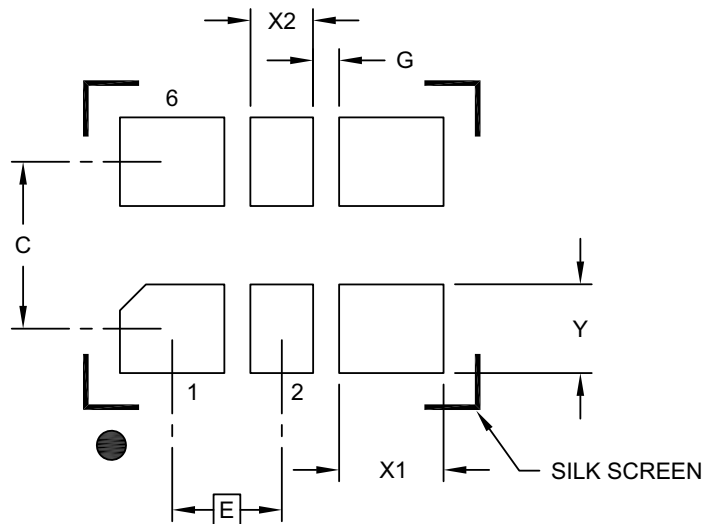
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-1005A Sheet 2 of 2

6-Lead VDFN 3.2 mm x 2.5 mm Package Outline and Recommended Land Pattern

6-Lead Very Thin Plastic Dual Flatpack No-Lead (H5A) - 3.2x2.5 mm Body [VDFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	1.05 BSC		
Contact Pad Spacing	C		1.60	
Contact Pad Width (X4)	X1			1.00
Contact Pad Width (X2)	X2			0.60
Contact Pad Length (X6)	Y			0.85
Space Between Contacts (X4)	G1	0.25		

Notes:

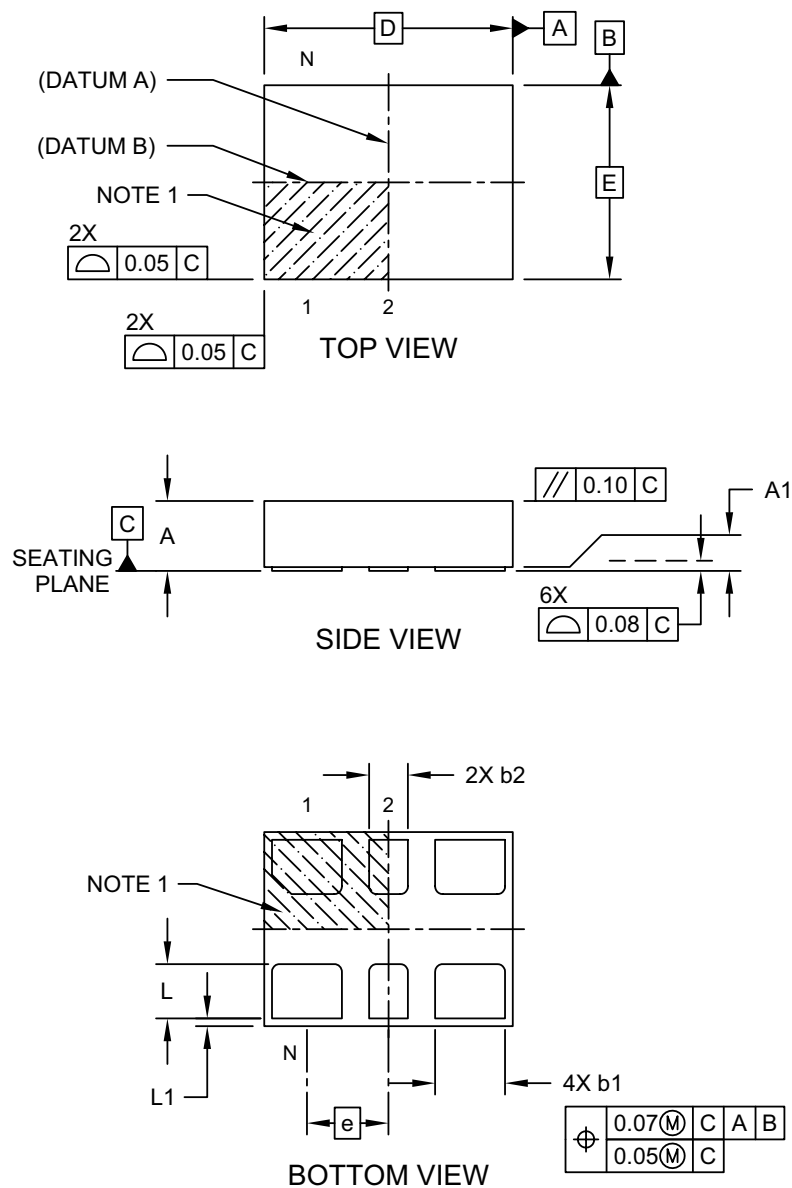
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-3007A

6-Lead Very Thin Plastic Dual Flatpack No-Lead (H5A) - 3.2x2.5 mm Body [VDFN]

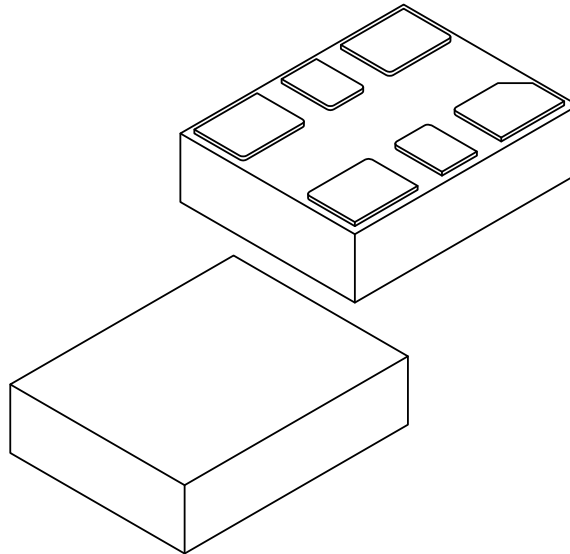
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-1007A Sheet 1 of 2

6-Lead Very Thin Plastic Dual Flatpack No-Lead (H5A) - 3.2x2.5 mm Body [VDFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N	6		
Pitch	e	1.05 BSC		
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Overall Length	D	3.20 BSC		
Overall Width	E	2.50 BSC		
Terminal Width	b1	0.85	0.90	0.95
Terminal Width	b2	0.45	0.50	0.55
Terminal Length	L	0.65	0.70	0.75
Terminal Pullback	L1	0.10 REF		

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

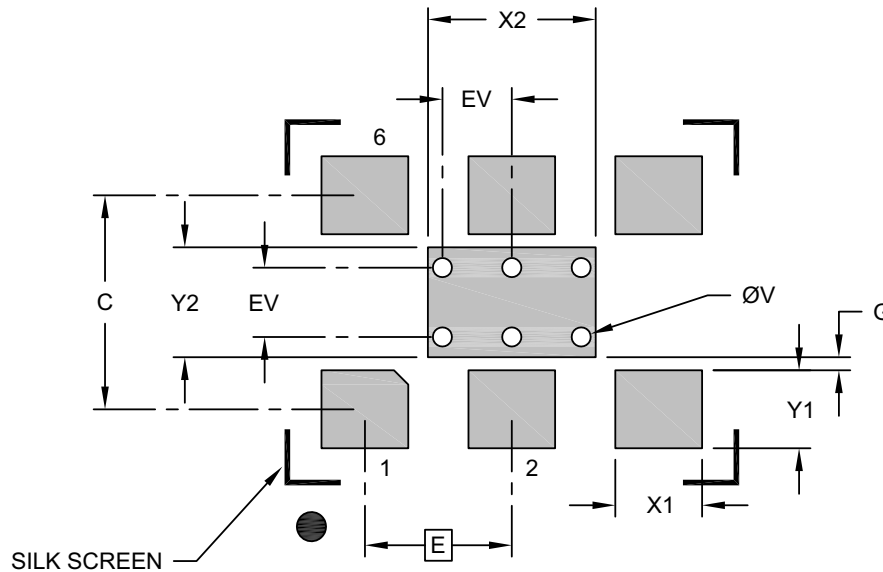
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-1007A Sheet 2 of 2

6-Lead VDFN 7.0 mm x 5.0 mm Package Outline and Recommended Land Pattern

6-Lead Very Thin Plastic Quad Flat, No Lead Package (H8A) - 7x5 mm Body [VDFN] With 2.8x1.8 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	2.54 BSC		
Optional Center Pad Width	X2			2.90
Optional Center Pad Length	Y2			1.90
Contact Pad Spacing	C		3.70	
Contact Pad Width (X6)	X1			1.50
Contact Pad Length (X6)	Y1			1.35
Contact Pad to Center Pad (X2)	G	0.20		
Thermal Via Diameter (X6)	V		0.33	
Thermal Via Pitch	EV		1.20	

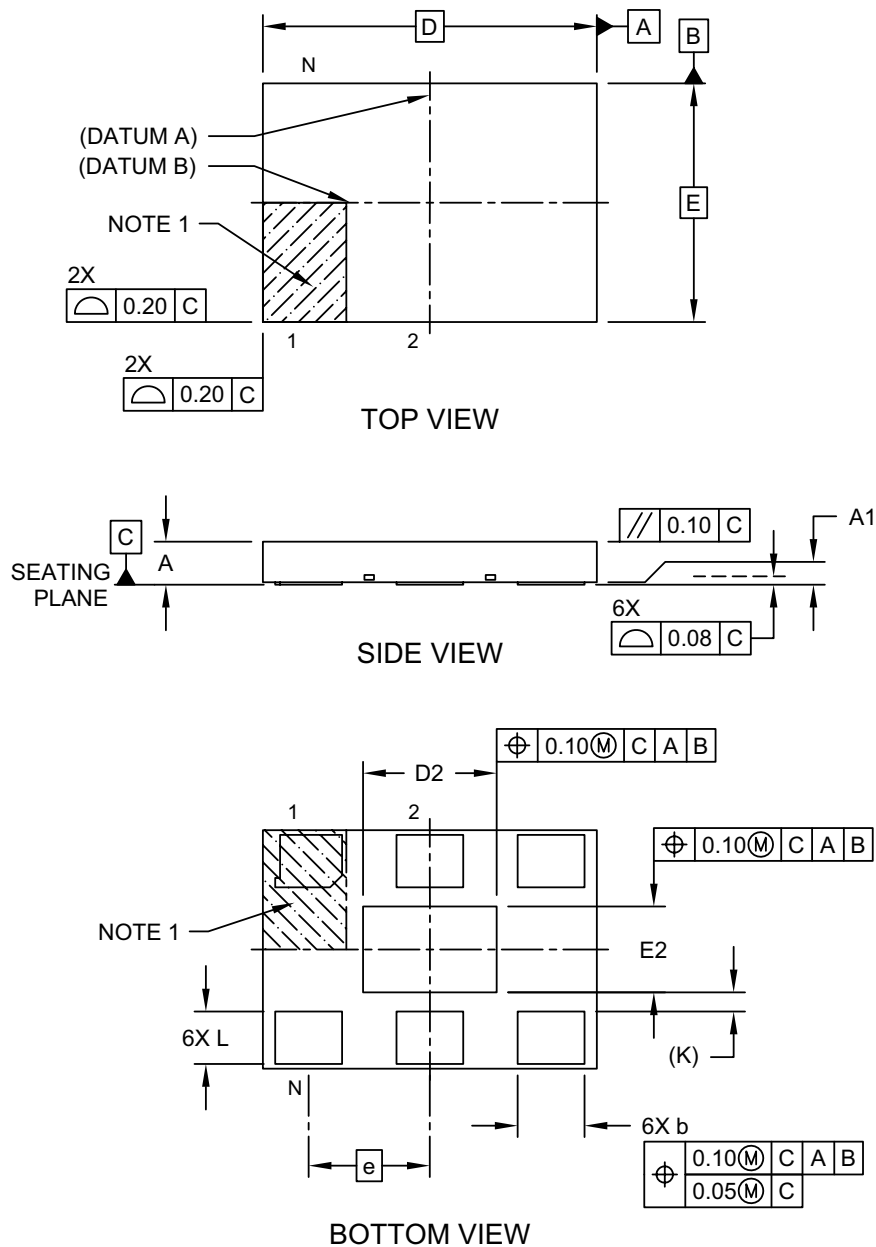
Notes:

- Dimensioning and tolerancing per ASME Y14.5M
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
- For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-3010A

6-Lead Very Thin Plastic Quad Flat, No Lead Package (H8A) - 7x5 mm Body [VDFN] With 2.8x1.8 mm Exposed Pad

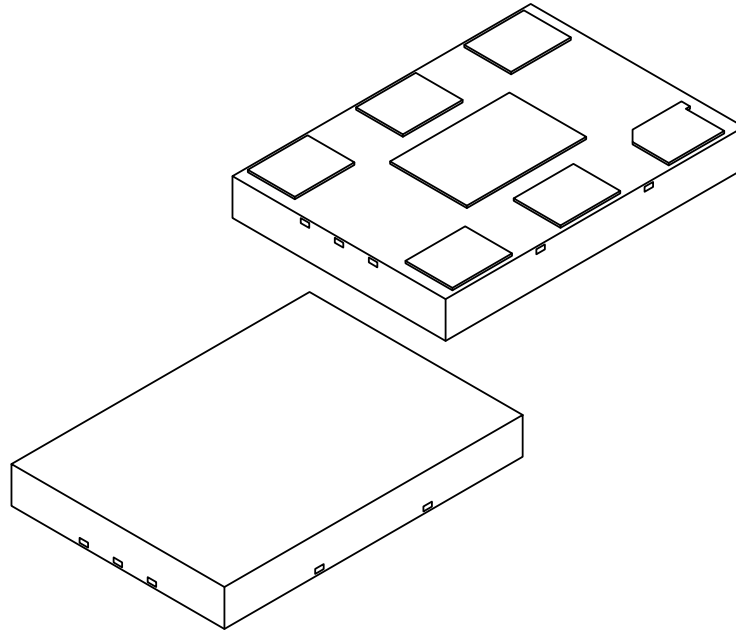
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-1010A Sheet 1 of 2

6-Lead Very Thin Plastic Quad Flat, No Lead Package (H8A) - 7x5 mm Body [VDFN] With 2.8x1.8 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N	6		
Pitch	e	2.54		
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Overall Length	D	7.00 BSC		
Exposed Pad Length	D2	2.70	2.80	2.90
Overall Width	E	5.00 BSC		
Exposed Pad Width	E2	1.70	1.80	1.90
Terminal Width	b	1.35	1.40	1.45
Terminal Length	L	1.00	1.10	1.20
Terminal-to-Exposed-Pad	K	0.20 REF		

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

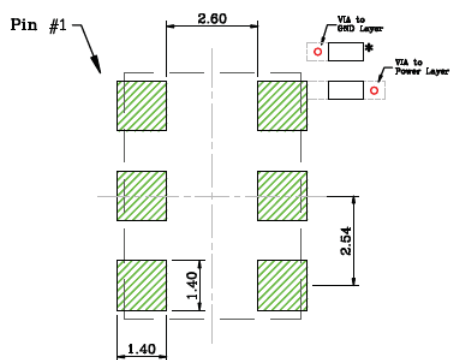
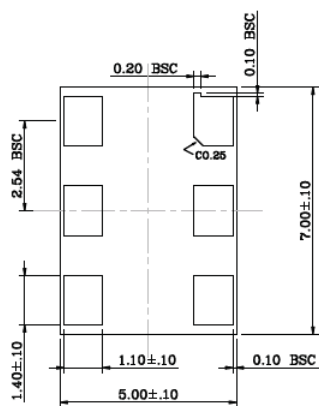
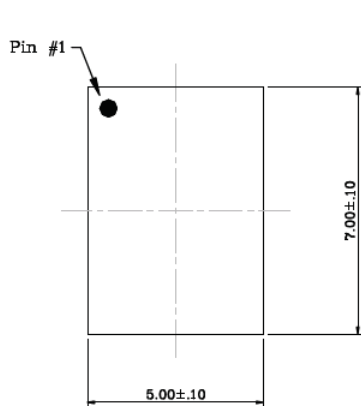
Microchip Technology Drawing C04-1010A Sheet 2 of 2

6-Lead CDFN 7.0 mm x 5.0 mm Package Outline and Recommended Land Pattern

TITLE

6 LEAD CDFN 7.0x5.0mm COL PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	CDFN75-6LD-PL-1	UNIT	MM
-----------	-----------------	------	----



NOTE:

- * Power Supply Decoupling Capacitor is required in Recommended Land Pattern.
- Green shaded rectangles in Recommended Land Pattern are solder stencil opening.
- Red circles in Recommended Land Pattern are thermal VIA.

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>.

APPENDIX A: REVISION HISTORY

Revision A (March 2017)

- Converted Micrel data sheet DSC1103/23 to Microchip DS20005745A.
- Minor text changes throughout.
- Updated [Package Marking Information](#) to MCHP-standard drawings where available.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

<u>PART NO.</u>	X	3	X	X	X	—	xxx,xxx	X
Device (First 2 Digits)	Enable Modes	Device (Last Digit)	Package	Temp. Range	Stability	Frequency		Packing
Device: DSC11x3: Low-Jitter Precision LVDS Oscillator								
Enable Modes: 0 = Enable/Standby 2 = Enable/Disable								
Package: A = 7.0 mm x 5.0 mm VDFN B = 5.0 mm x 3.2 mm CDFN C = 3.2 mm x 2.5 mm VDFN D = 2.5 mm x 2.0 mm VDFN N = 7.0 mm x 5.0 mm CDFN (no center pad)								
Temperature Range: E = -20°C to +70°C I = -40°C to +85°C L = -40°C to +105°C								
Stability: 1 = ±50 ppm 2 = ±25 ppm 5 = ±10 ppm								
Frequency Code: xxx,xxx = 2.3 MHz to 460 MHz (user-defined)								
Packing: T = 1,000/Reel (blank) = 100/Tube								

Examples:

- DSC1103AE1-125.0000: Low-Jitter Precision LVDS Oscillator, Enable/Standby, 7x5 VDFN, -20°C to +70°C, ±50 ppm, 125 MHz, 100/Tube
- DSC1123BI2-400.0000T: Low-Jitter Precision LVDS Oscillator, Enable/Disable, 5x3.2 CDFN, -40°C to +85°C, ±25 ppm, 400 MHz, 1,000/Reel
- DSC1103CL5-074.2500: Low-Jitter Precision LVDS Oscillator, Enable/Standby, 3.2x2.5 VDFN, -40°C to +105°C, ±10 ppm, 74.25 MHz, 100/Tube
- DSC1123DE1-082.5000T: Low-Jitter Precision LVDS Oscillator, Enable/Disable, 2.5x2.0 VDFN, -20°C to +70°C, ±50 ppm, 82.5 MHz, 1,000/Reel
- DSC1103NI2-056.0000: Low-Jitter Precision LVDS Oscillator, Enable/Standby, 7x5 CDFN (no center pad), -40°C to +85°C, ±25 ppm, 56 MHz, 100/Tube

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

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.

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.

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.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949 ==

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Helder, JukeBlox, KEELOQ, KEELOQ logo, Klear, 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, KlearNet, KlearNet 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.

© 2017, Microchip Technology Incorporated, All Rights Reserved.
ISBN: 978-1-5224-1546-6

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