

Low-Jitter Precision LVDS Oscillator

Features

- Low RMS Phase Jitter: <1 ps (typ.)
- High Stability: ± 10 ppm, ± 20 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
- Standby and Output Enable Functions
- Lead Free and RoHS-Compliant

Applications

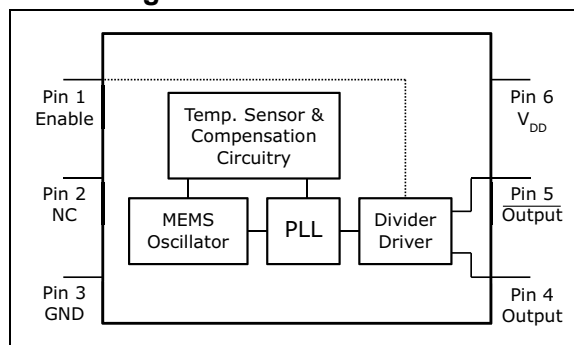
- Storage Area Networks
 - SATA, SAS, Fibre Channel
- Passive Optical Networks
 - EPON, 10G-EPON, GPON, 10G-PON
- HD/SD/SDI Video and Surveillance
- PCI Express Gen 1/Gen 2/Gen 3
- Display Port

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



DSC1103/23

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.
		—	—	± 20		
		—	—	± 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.

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.

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.
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.

DSC1103/23

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, $T = +25^{\circ}\text{C}$, $V_{\text{DD}} = 3.3\text{V}$.

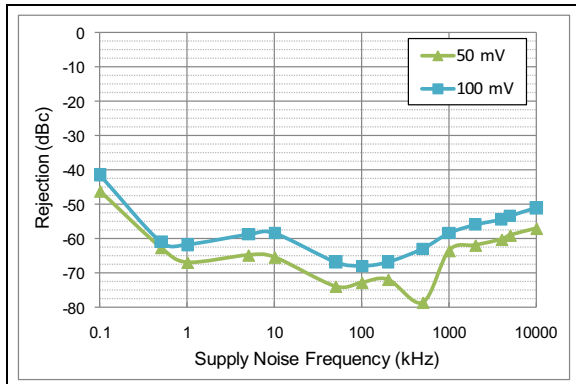


FIGURE 3-1: *Power Supply Rejection Ratio.*

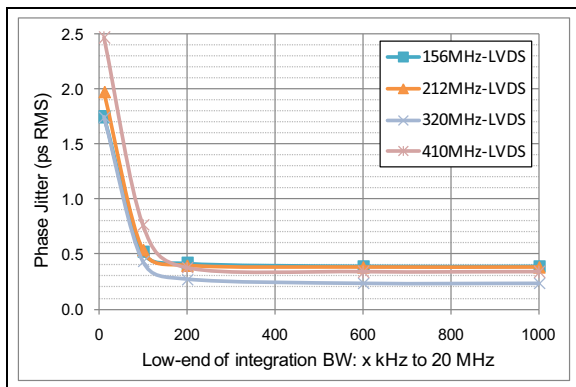


FIGURE 3-2: *Phase Jitter (Integrated Phase Noise).*

4.0 TERMINATION SCHEME

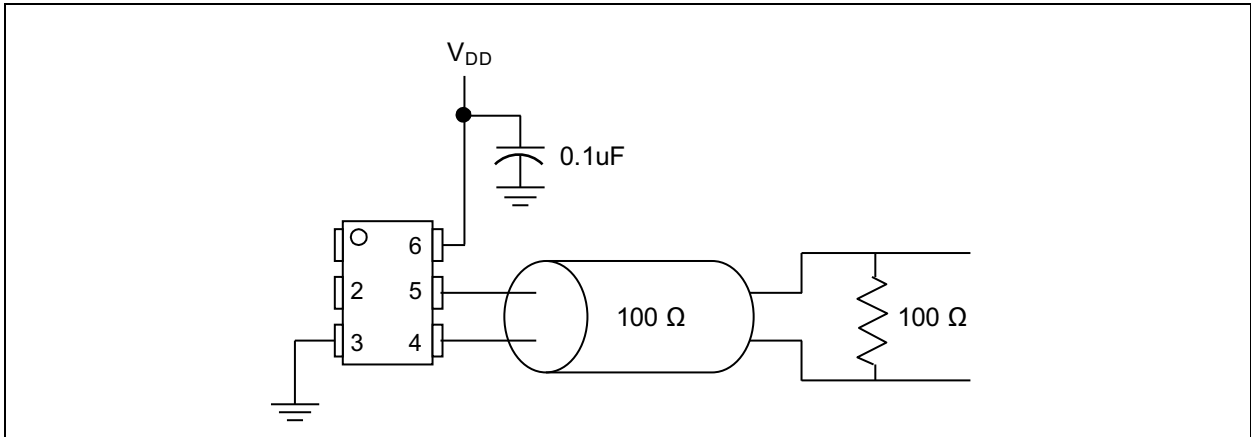


FIGURE 4-1: Typical Termination Scheme.

5.0 OUTPUT WAVEFORM

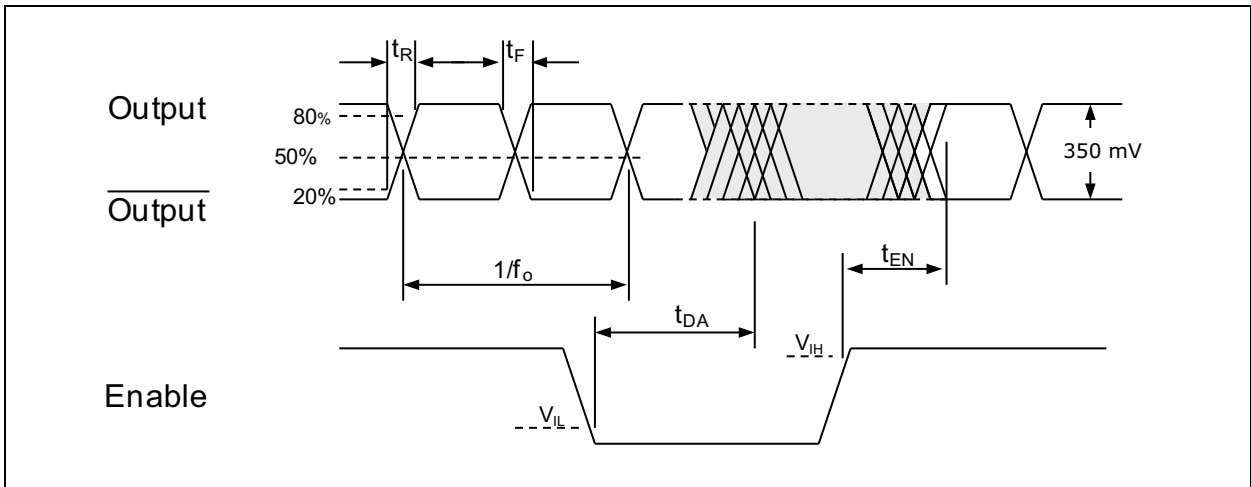


FIGURE 5-1: Output Waveform.

DSC1103/23

6.0 TEST CIRCUIT

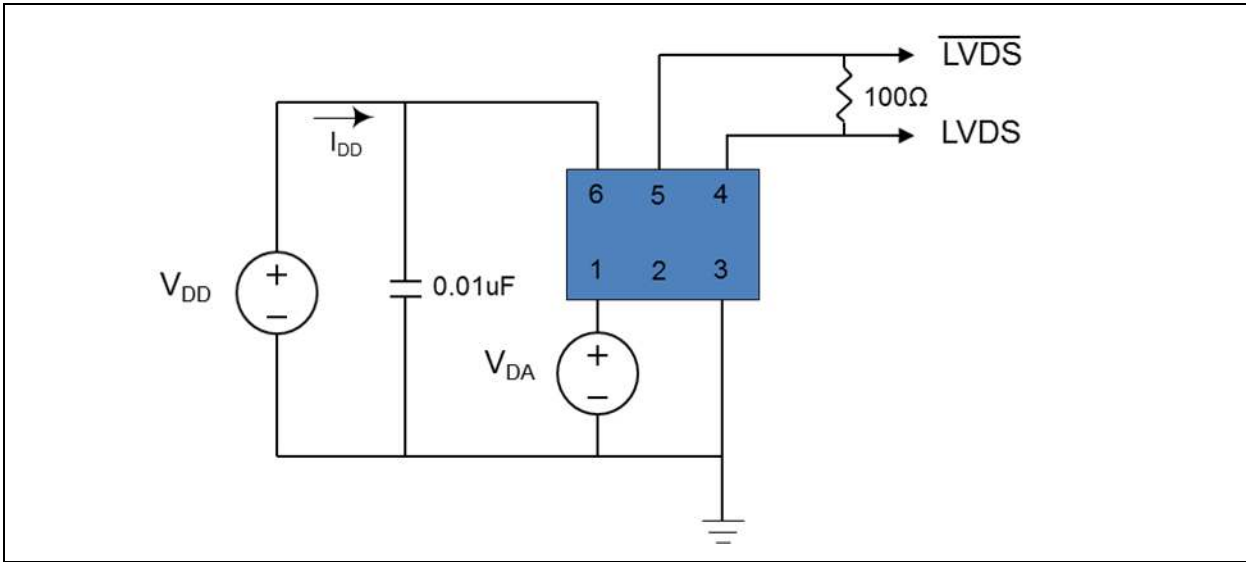


FIGURE 6-1: Test Circuit.

7.0 RECOMMENDED BOARD LAYOUT

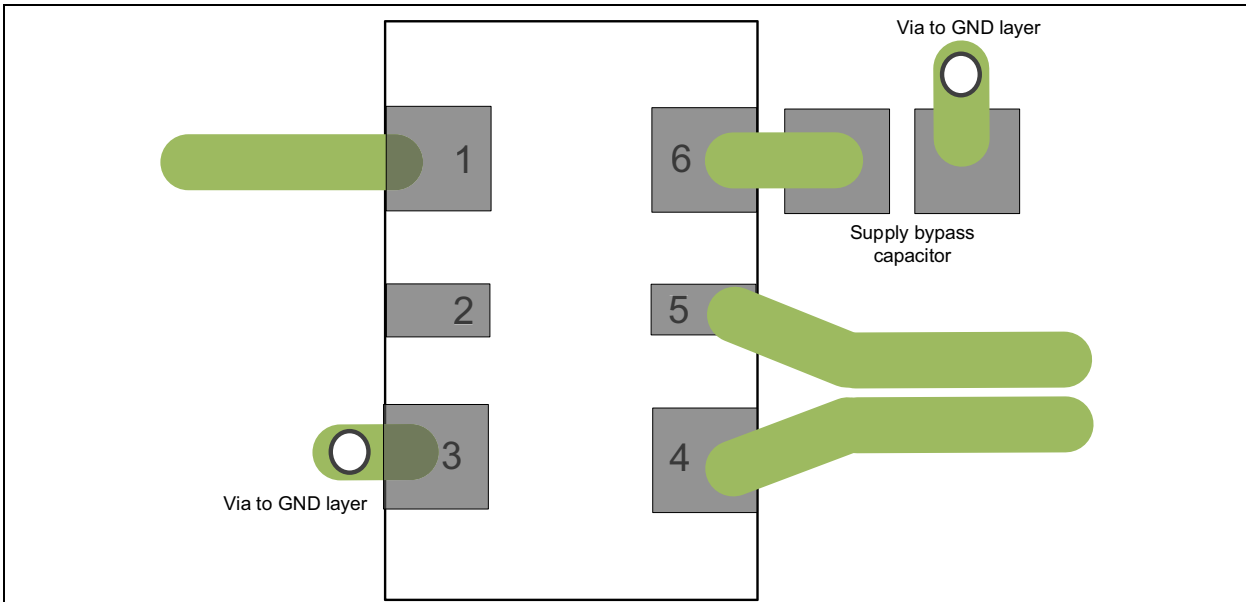
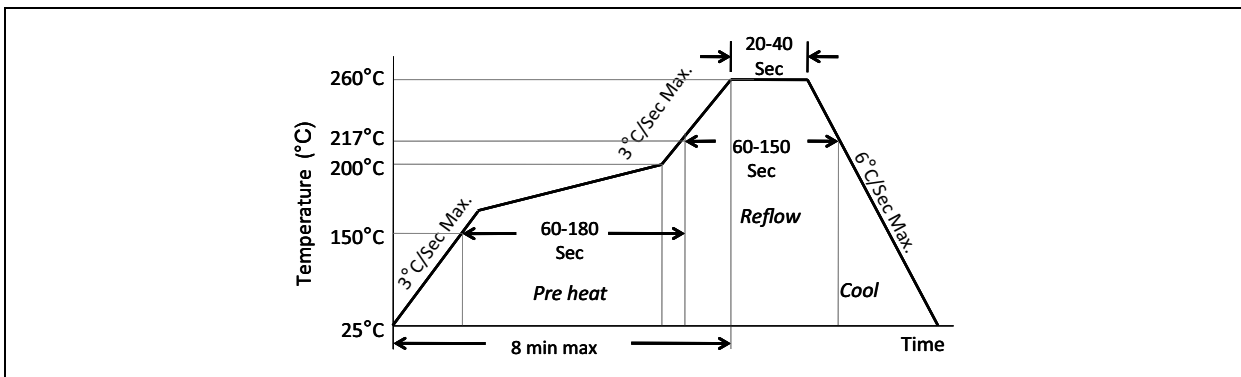


FIGURE 7-1: DSC1103/23 Recommended Board Layout.

8.0 SOLDER REFLOW PROFILE



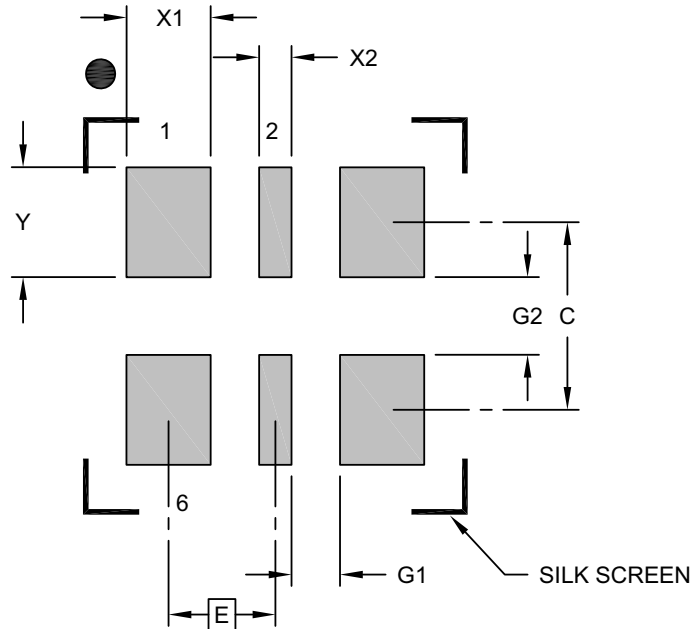
MSL 1 @ 260°C refer to JSTD-020C	
Ramp-Up Rate (200°C to Peak Temp)	3°C/sec. max.
Preheat Time 150°C to 200°C	60-180 sec.
Time Maintained above 217°C	60-150 sec.
Peak Temperature	255°C to 260°C
Time within 5°C of Actual Peak	20-40 sec.
Ramp-Down Rate	6°C/sec. max.
Time 25°C to Peak Temperature	8 minutes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

9.0 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		

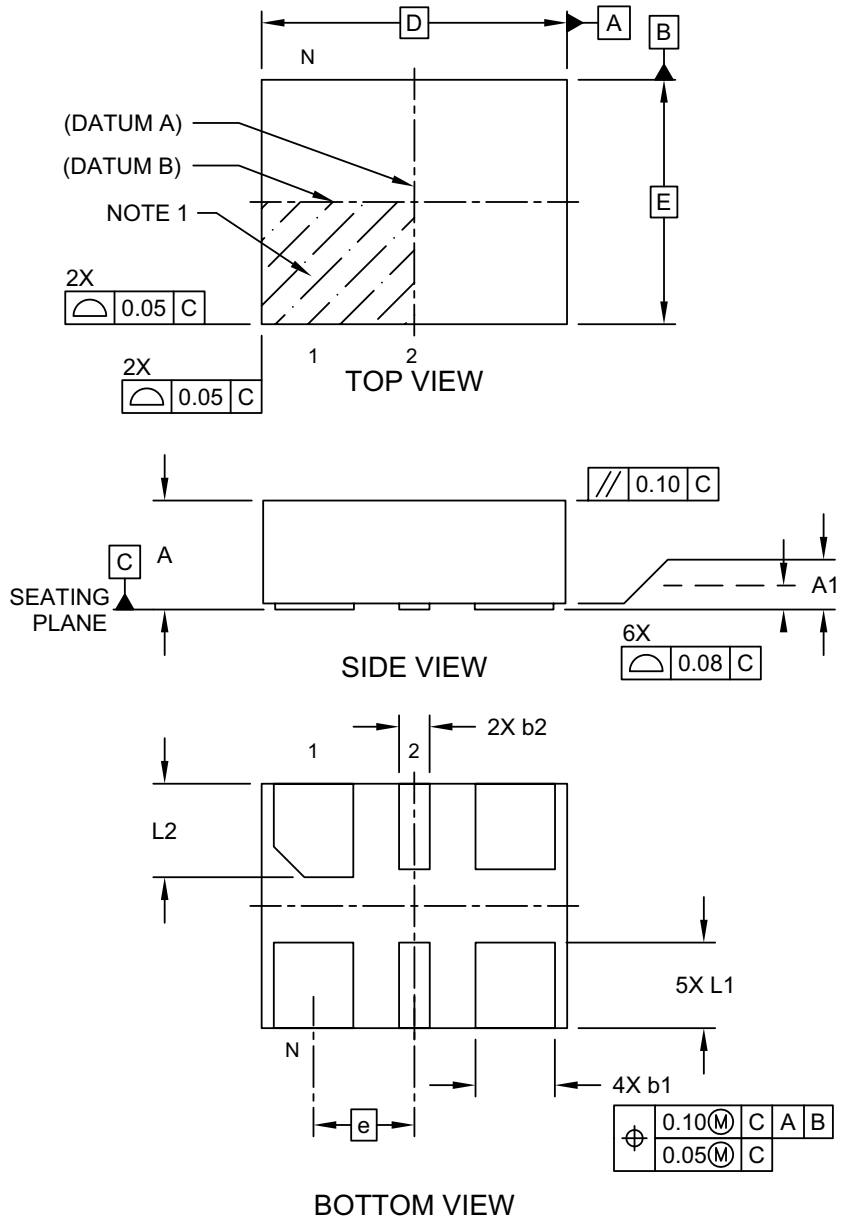
Notes:

- 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]

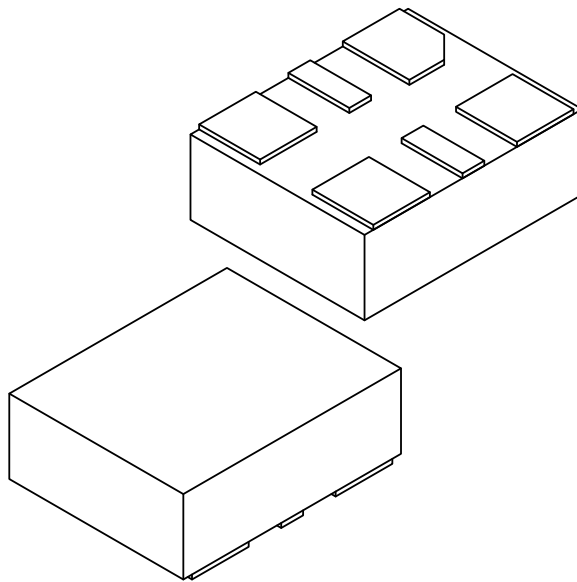
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



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:

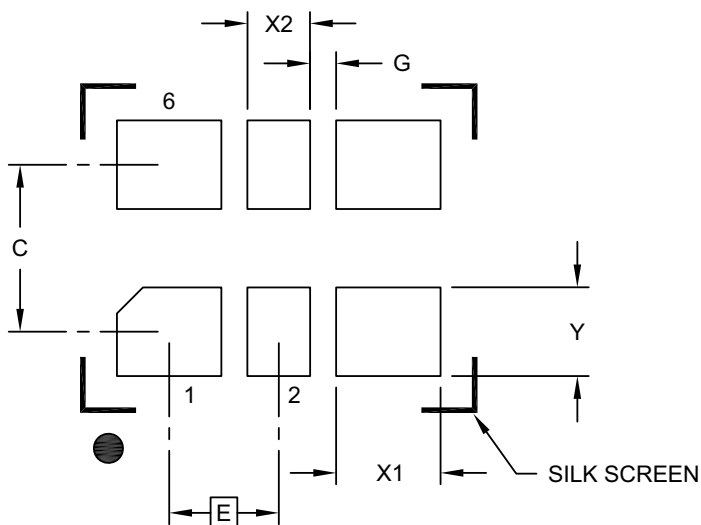
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated
- Dimensioning and tolerancing per ASME Y14.5M
 - BSC: Basic Dimension. Theoretically exact value shown without tolerances.
 - REF: Reference Dimension, usually without tolerance, for information 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

Dimension Limits	Units	MILLIMETERS		
		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

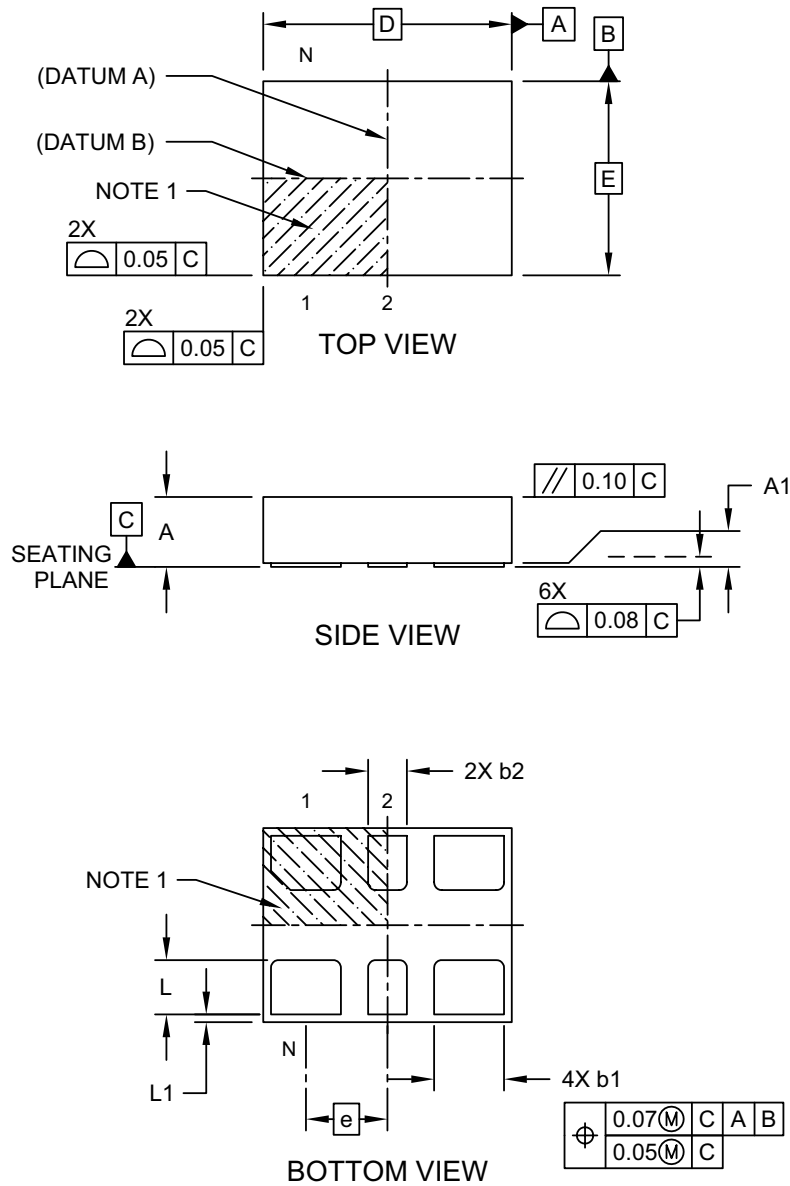
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-3007A

DSC1103/23

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

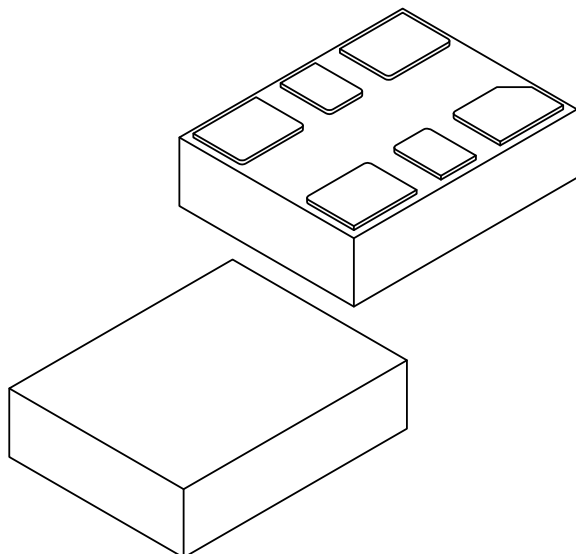
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



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

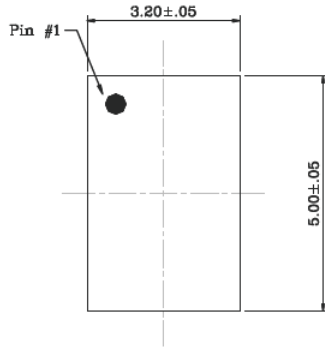
DSC1103/23

6-Lead CDFN 5.0 mm x 3.2 mm Package Outline and Recommended Land Pattern

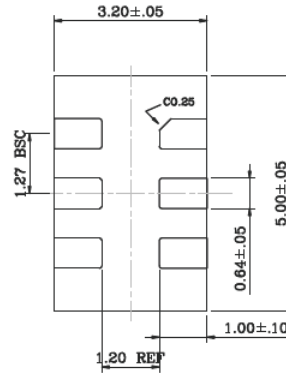
TITLE

6 LEAD CDFN 5.0x3.2mm COL PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	UNIT
CDFN5032-6LD-PL-1	MM



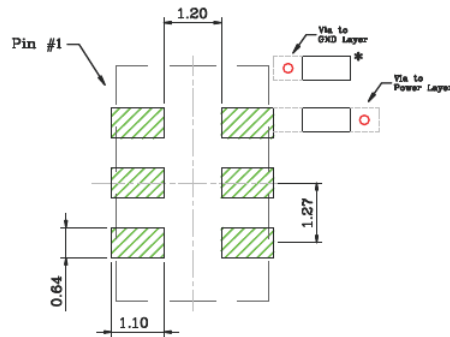
Top View



Bottom View



Side View



Recommended Land Pattern

NOTE:

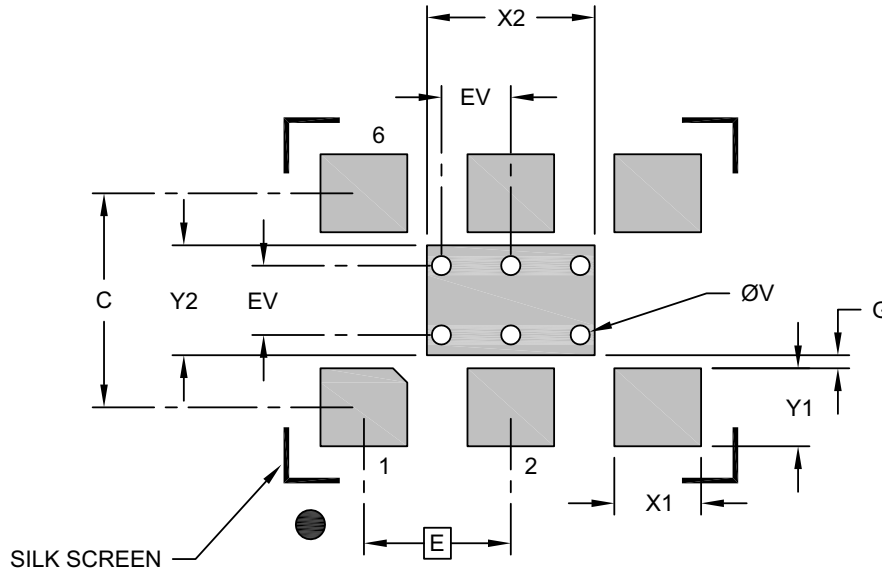
1. * Power Supply Decoupling Capacitor is required in Recommended Land Pattern.
2. Green shaded rectangles in Recommended Land Pattern are solder stencil opening.
3. Red circles in Recommended Land Pattern are thermal VIA.

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

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

Dimension Limits	Units	MILLIMETERS		
		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:

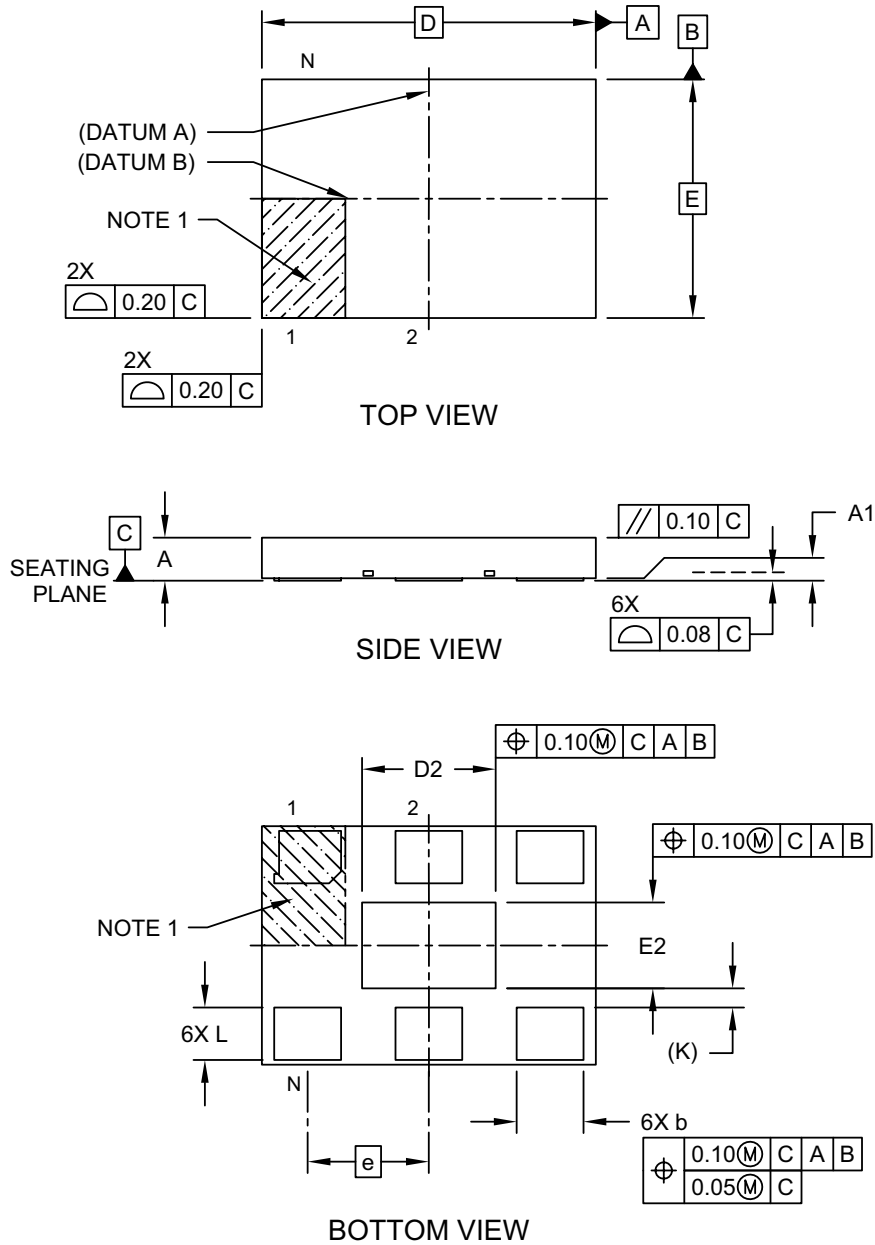
- Dimensioning and tolerancing per ASME Y14.5M
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
- For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-3010A

DSC1103/23

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

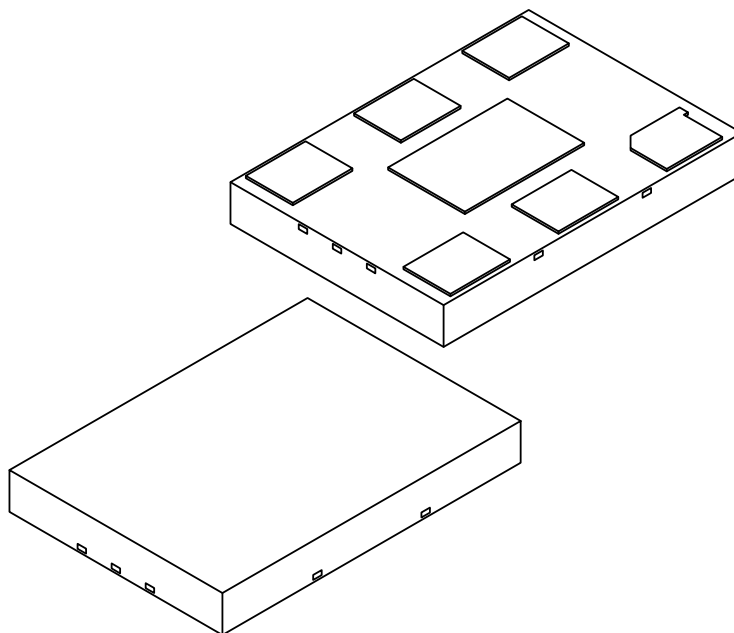
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



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:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated
- 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

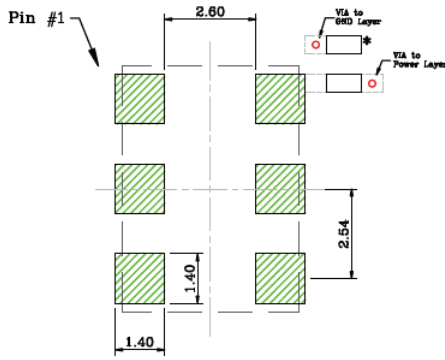
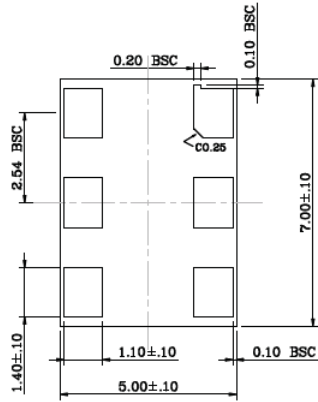
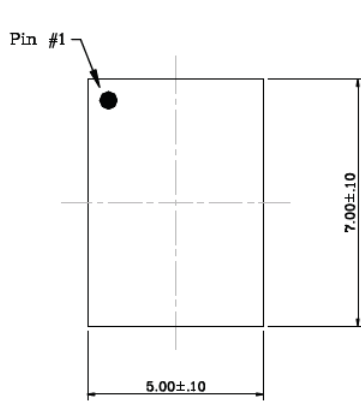
DSC1103/23

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.

Revision B (October 2018)

- Added ± 20 ppm stability references throughout document.
- Added [Section 7.0, Recommended Board Layout](#).

DSC1103/23

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	X	3	X	X	X	— xxx,xxxx	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				
	3	=	±20 ppm				
	5	=	±10 ppm				
Frequency Code:	xxx,xxxx	=	2.3 MHz to 460 MHz (user-defined)				
Packing:	T	=	1,000/Reel				
	(blank)	=	100/Tube				

Examples:	
a) DSC1103AE1-125.0000:	Low-Jitter Precision LVDS Oscillator, Enable/Standby, 7x5 VDFN, -20°C to +70°C, ±50 ppm, 125 MHz, 100/Tube
b) 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
c) 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
d) 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
e) 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, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, Klear, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, 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, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, memBrain, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICtail, PowerSmart, PureSilicon, QMatrix, 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.

© 2017-2018, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-3790-1



MICROCHIP

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

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

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

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

China - Hong Kong SAR
Tel: 852-2943-5100

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

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

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

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

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

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

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

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

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

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

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

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

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

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

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

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

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

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

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

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: 47-7288-4388

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