

# NL3S588

## USB 2.0-Capable Ultra-Low THD DPDT Switch

The NL3S588 is a single supply, bidirectional, double-pole/double-throw (DPDT) switch suitable for both hi-fidelity audio and high-speed data applications.

The NL3S588 features ultra-low distortion, high OFF-Isolation analog switches that can pass analog signals that are positive and negative with respect to ground. It is targeted at consumer and professional DC-coupled GND-referenced audio switching applications such as computer sound cards and home theater products.

The NL3S588 may also be used in high-speed differential data routing applications. Both channels are USB 2.0-compliant.

### Features

- DPDT Switch
- 3.3 V Single Supply Operation
- Available in 1.4 mm x 1.8 mm UQFN10
- This Device is Pb-Free, Halogen Free/BFR Free and RoHS Compliant

### Audio Capabilities

- 2  $V_{RMS}$  Signal Switching
- -116 dB THD+N into 20 k $\Omega$  Load at 2  $V_{RMS}$
- -112 dB THD+N into 32  $\Omega$  Load at 0.707  $V_{RMS}$
- Signal to Noise Ratio: > 125 dBV
- $\pm 0.004$  dB Insertion Loss at 1 kHz, 20 k $\Omega$  Load
- $\pm 0.0008$  dB Gain Variation 20 Hz to 20 kHz
- 112 dB Signal Muting into 20 k $\Omega$  Load
- 131 dB PSRR 20 Hz to 20 kHz

### High-Speed Data Capabilities

- Input Signal Range: 0 V to  $V_{DD}$
- $C_{ON}$ : 8.9 pF (Typ)
- Data Rate: USB 2.0-Compliant – up to 480 Mbps
- Bandwidth: 580 MHz

### Applications

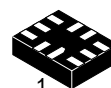
- Hi-Fi Audio Switching
- USB 2.0 High-Speed Data Switching
- USB 3.x Type C Switching



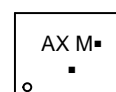
ON Semiconductor®

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### MARKING DIAGRAM



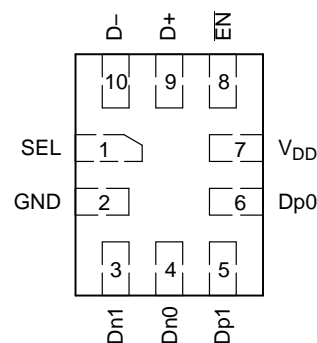
UQFN10  
MU SUFFIX  
CASE 488AT



AX = Device Code  
M = Date Code  
▪ = Pb-Free Device

(Note: Microdot may be in either location)

### PIN ASSIGNMENT



(Top View)

### ORDERING INFORMATION

Device	Package	Shipping†
NL3S588MUTBG	UQFN10 (Pb-Free)	3000 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

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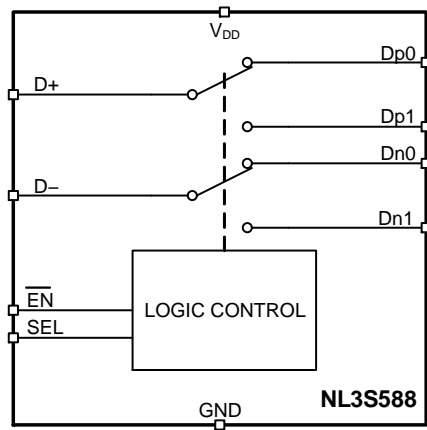


Figure 1. Block Diagram

## FUNCTION TABLE

INPUTS		Operating Mode
EN	SEL	
0	0	Dp0 connected to D+ / Dn0 connected to D-
0	1	Dp1 connected to D+ / Dn1 connected to D-
1	X	Shutdown (I/Os Disconnected)

NOTE: EN Logic "0"  $\leq 0.5$  V, Logic "1"  $\geq 1.4$  V or float.  
 SEL Logic "0"  $\leq 0.5$  V, Logic "1"  $\geq 1.4$  V.  
 X = Don't Care

## PIN DESCRIPTIONS

PIN NAME	PIN	DESCRIPTION
SEL	1	Channel Select
GND	2	Ground
Dn1	3	Normally-Open I/O
Dp1	5	
Dn0	4	Normally-Closed I/O
Dp0	6	
V <sub>DD</sub>	7	System power supply pin (+3 V to +3.6 V)
EN	8	Signal mute control pin
D+	9	Common I/O
D-	10	

**MAXIMUM RATINGS**

Symbol	Rating	Value	Unit
V <sub>DD</sub>	Positive 3 V DC Supply Voltage	-0.5 to +4.1	V
V <sub>IS</sub>	Analog Input/Output Voltage (D+, D-, Dpx, Dnx)	-3.1 to V <sub>DD</sub> + 0.5	V
V <sub>IN</sub>	Digital Input Voltage (EN, SEL)	-0.5 to V <sub>DD</sub> + 0.5	V
I <sub>IO</sub>	Switch Continuous Current (D+, D-, Dpx, Dnx)	±300	mA
I <sub>IO_PK</sub>	Switch Peak Current (D+, D-, Dpx, Dnx) (Pulsed 1 ms, 10% Duty Cycle, Max).	±500	mA
P <sub>D</sub>	Power Dissipation in Still Air	800	mW
T <sub>s</sub>	Storage Temperature	-65 to +150	°C
T <sub>L</sub>	Lead Temperature, 1 mm from Case for 10 seconds	260	°C
T <sub>J</sub>	Junction Bias Under Bias	150	°C
θ <sub>JA</sub>	Thermal Resistance	80	°C/W
T <sub>s</sub>	Storage Temperature	-65 to +150	°C
MSL	Moisture Sensitivity	Level 1	
F <sub>R</sub>	Flammability Rating Oxygen Index: 30% – 35%	UL94-V0 (0.125 in)	°C
ESD	ESD Protection Human Body Model Machine Model	3000 200	V
I <sub>L</sub>	Latch-up Current, Above V <sub>CC</sub> and below GND at 125°C (Note 1)	±300	mA

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Tested to EIA/JESD78.

**RECOMMENDED OPERATING CONDITIONS**

Symbol	Parameter	Min	Max	Unit
V <sub>DD</sub>	Positive DC Supply Voltage	3.0	3.6	V
V <sub>S</sub>	Switch Input / Output Voltage (D+, D-, Dpx, Dnx)	-2.9	V <sub>DD</sub>	V
V <sub>IN</sub>	Digital Select Input Voltage (EN, SEL)	GND	V <sub>DD</sub>	V
T <sub>A</sub>	Operating Temperature Range	-40	+85	°C

**DC ELECTRICAL CHARACTERISTICS** (Voltages referenced to GND): V<sub>DD</sub> = +3.0 V to +3.6 V, GND = 0 V, V<sub>S</sub> = 2 V<sub>RMS</sub>, R<sub>LOAD</sub> = 20 kΩ, f = 1 kHz, V<sub>SELH</sub> = V<sub>ENH</sub> = 1.4 V, V<sub>SELL</sub> = V<sub>ENL</sub> = 0.5 V, (Note 2), Unless otherwise specified.

Parameter	Test Conditions	Supply (V)	Temp (°C)	Min (Notes 3, 4)	Typ	Max (Notes 3, 4)	Units
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**ANALOG SWITCH CHARACTERISTICS**

Analog Signal Range, V <sub>ANALOG</sub>		3.3	Full	-	2	-	V <sub>RMS</sub>
ON-Resistance, r <sub>ON</sub>	I <sub>D+</sub> or I <sub>D-</sub> = 80mA, V <sub>Dpx</sub> or V <sub>Dnx</sub> = -2.828 V to +2.828 V (See Figure 5)	3.3	25	-	2.1	-	Ω
			Full	-	2.5	-	
r <sub>ON</sub> Matching Between Channels, Δr <sub>ON</sub>	I <sub>D+</sub> or I <sub>D-</sub> = 80mA, V <sub>Dpx</sub> or V <sub>Dnx</sub> = Voltage at max r <sub>ON</sub> over -2.828 V to +2.828 V (Note 7)	3.3	25	-	0.046	-	Ω
			Full	-	0.23	-	
r <sub>ON</sub> Flatness, r <sub>FLAT(ON)</sub>	I <sub>D+</sub> or I <sub>D-</sub> = 80mA, V <sub>Dpx</sub> or V <sub>Dnx</sub> = -2.828 V, 0V, +2.828 V (Note 5)	3.3	25	-	0.047	0.05	Ω
			Full	-	0.092	-	

- V<sub>IN</sub> = input voltage to perform proper function.
- The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.
- Flatness is defined as the difference between maximum and minimum value of ON-resistance at the specified analog signal voltage points.
- Limits established by characterization and are not production tested.
- r<sub>ON</sub> matching between channels is calculated by subtracting the channel with the highest max r<sub>ON</sub> value from the channel with lowest max r<sub>ON</sub> value.
- Crosstalk is inversely proportional to source impedance.

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**DC ELECTRICAL CHARACTERISTICS** (Voltages referenced to GND):  $V_{DD} = +3.0$  V to  $+3.6$  V,  $GND = 0$  V,  $V_S = 2$  V<sub>RMS</sub>,  $R_{LOAD} = 20$  k $\Omega$ ,  $f = 1$  kHz,  $V_{SELH} = V_{ENH} = 1.4$  V,  $V_{SELL} = V_{ENL} = 0.5$  V, (Note 2), Unless otherwise specified.

Parameter	Test Conditions	Supply (V)	Temp (°C)	Min (Notes 3, 4)	Typ	Max (Notes 3, 4)	Units
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## ANALOG SWITCH CHARACTERISTICS

D+, D-, Dpx, Dnx Pull-down Resistance	$V_{Dpx}$ or $V_{Dnx} = -2.83$ V, $2.83$ V, $V_{D+}$ or $V_{D-} = -2.83$ V, $2.83$ V, $V_{EN} = 3.6$ V, measure current, calculate resistance.	3.6	25	225	300	375	k $\Omega$
			Full	-	345	-	

## DYNAMIC CHARACTERISTICS

THD+N	$V_S = 2$ V <sub>RMS</sub> , $f = 1$ kHz, A-weighted filter, $R_{LOAD} = 20$ k $\Omega$	3.3	25	-	< -116	-	dB
	$V_S = 1.9$ V <sub>RMS</sub> , $f = 1$ kHz, A-weighted filter, $R_{LOAD} = 20$ k $\Omega$		25	-	< -116	-	
	$V_S = 1.8$ V <sub>RMS</sub> , $f = 1$ kHz, A-weighted filter, $R_{LOAD} = 20$ k $\Omega$		25	-	< -116	-	
	$V_S = 0.707$ V <sub>RMS</sub> , $f = 1$ kHz, A-weighted filter, $R_{LOAD} = 32$ $\Omega$		25	-	< -112	-	
SNR	$f = 20$ Hz to $20$ kHz, A-weighted filter, inputs grounded, $R_{LOAD} = 20$ k $\Omega$ or $32$ $\Omega$	3.3	25	-	> 125	-	dBV
Insertion Loss, $G_{ON}$	$f = 1$ kHz, $R_{LOAD} = 20$ k $\Omega$	3.3	25	-	$\pm 0.004$	-	dB
Gain vs Frequency, $G_f$	$f = 20$ Hz to $20$ kHz, $R_{LOAD} = 20$ k $\Omega$ , reference to $G_{ON}$ at $1$ kHz	3.3	25	-	$\pm 0.0008$	-	dB
Stereo Channel Imbalance $Dp0$ and $Dn0$ , $Dp1$ and $Dn1$	$f = 20$ Hz to $20$ kHz, $R_{LOAD} = 20$ k $\Omega$	3.3	25	-	$\pm 0.0001$	-	dB
OFF-Isolation (Disabling)	$f = 20$ Hz to $22$ kHz, $D+ = D- = 2$ V <sub>RMS</sub> , $R_{LOAD} = 20$ k $\Omega$ , $SEL = "X"$	3.3	25	-	112	-	dB
	$f = 20$ Hz to $22$ kHz, $V_{D+}$ or $V_{D-} = 0.7$ V <sub>RMS</sub> , $R_{LOAD} = 32$ $\Omega$		25	-	129	-	
Crosstalk (Channel-to-Channel)	$R_L = 20$ k $\Omega$ , $f = 20$ Hz to $20$ kHz, $V_S = 2$ V <sub>RMS</sub> , signal source impedance = $20$ $\Omega$ , (Note 8)	3.3	25	-	102	-	dB
	$R_L = 32$ $\Omega$ , $f = 20$ Hz to $20$ kHz, $V_S = 0.7$ V <sub>RMS</sub> , signal source impedance = $20$ $\Omega$ , (Note 8)		25	-	129	-	
PSRR	$f = 1$ kHz, $V_S = 100$ mV <sub>RMS</sub> , inputs grounded	3.3	25	-	131	-	dB
	$f = 20$ kHz, $V_S = 100$ mV <sub>RMS</sub> , inputs grounded		25	-	133	-	
Bandwidth, -3 dB	$R_{LOAD} = 50$ $\Omega$	3.3	25	-	580	-	MHz
ON to Disable Time, $T_{TRANS-OM}$		3.3	25	-	250	-	ns
Disable to ON Time, $T_{TRANS-MO}$	$V_{IS} = 1.5$ V	3.3	25	-	1680	-	$\mu$ s
Turn-ON Time, $t_{ON}$	$V_{Dpx}$ or $V_{Dnx} = 1.5$ V, $V_{EN} = 0$ V, $R_L = 32$ $\Omega$ (See Figure 2)	3.3	25	-	14	-	$\mu$ s
Turn-OFF Time, $t_{OFF}$	$V_{Dpx}$ or $V_{Dnx} = 1.5$ V, $V_{EN} = 0$ V, $R_L = 32$ $\Omega$ (See Figure 2)	3.3	25	-	95	-	ns

- $V_{IN}$  = input voltage to perform proper function.
- The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Parameters with MIN and/or MAX limits are 100% tested at  $+25^\circ\text{C}$ , unless otherwise specified. Temperature limits established by characterization and are not production tested.
- Flatness is defined as the difference between maximum and minimum value of ON-resistance at the specified analog signal voltage points.
- Limits established by characterization and are not production tested.
- $r_{ON}$  matching between channels is calculated by subtracting the channel with the highest max  $r_{ON}$  value from the channel with lowest max  $r_{ON}$  value.
- Crosstalk is inversely proportional to source impedance.

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**DC ELECTRICAL CHARACTERISTICS** (Voltages referenced to GND):  $V_{DD} = +3.0\text{ V to }+3.6\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_S = 2\text{ V}_{RMS}$ ,  $R_{LOAD} = 20\text{ k}\Omega$ ,  $f = 1\text{ kHz}$ ,  $V_{SELH} = V_{ENH} = 1.4\text{ V}$ ,  $V_{SELL} = V_{ENL} = 0.5\text{ V}$ , (Note 2), Unless otherwise specified.

Parameter	Test Conditions	Supply (V)	Temp (°C)	Min (Notes 3, 4)	Typ	Max (Notes 3, 4)	Units
<b>DYNAMIC CHARACTERISTICS</b>							
Break-Before-Make Time Delay, $t_D$	$V_{Dpx}$ or $V_{Dnx} = 1.5\text{ V}$ , $V_{EN} = 0\text{ V}$ , $R_L = 32\ \Omega$ (See Figure 3)	3.6	25	–	10	–	$\mu\text{s}$
OFF-Isolation	$R_L = 50\ \Omega$ , $f = 1\text{ MHz}$ , $V_{D+}$ or $V_{D-} = 1\text{ V}_{RMS}$ (See Figure 4)	3.3	25	–	70	–	dB
Crosstalk (Channel-to-Channel)	$R_L = 50\ \Omega$ , $f = 1\text{ MHz}$ , $V_{D+}$ or $V_{D-} = 1\text{ V}_{RMS}$ (See Figure 4)	3.3	25	–	89	–	dB
Dpx, Dnx OFF Capacitance, $C_{OFF}$	$f = 1\text{ MHz}$ , $V_{Dpx}$ or $V_{Dnx} = V_{D+}$ or $V_{D-} = 0\text{ V}$ (See Figure 7)	3.3	25	–	2.7	–	pF
D+, D- ON Capacitance, $C_{COM(ON)}$	$f = 1\text{ MHz}$ , $V_{Dpx}$ or $V_{Dnx} = V_{COM} = 0\text{ V}$ (See Figure 7)	3.3	25	–	8.9	–	pF
Differential Insertion Loss, $D_{IL}$	$f = 10\text{ MHz}$	3.3	25	–	-0.22	–	dB
	$f = 800\text{ MHz}$	3.3	25	–	-3.3	–	
Differential OFF-Isolation, $D_{ISO}$	$f = 10\text{ MHz}$	3.3	25	–	-44	–	dB
	$f = 800\text{ MHz}$	3.3	25	–	-16	–	
Differential Crosstalk, $D_{CTK}$	$f = 10\text{ MHz}$	3.3	25	–	-44	–	dB
	$f = 800\text{ MHz}$	3.3	25	–	-16	–	

## POWER SUPPLY CHARACTERISTICS

Power Supply Range, $V_{DD}$		3.3	Full	3	–	3.6	V
Positive Supply Current, $I_+$	$V_{EN} = 0\text{ V}$ , $V_{SEL} = 0\text{ V}$ or $V_{DD}$	3.6	25	–	54	65	$\mu\text{A}$
			Full	–	59	–	
	$V_{EN} = V_{DD}$ , $V_{SEL} = 0\text{ V}$ or $V_{DD}$	3.6	25	–	14	40	$\mu\text{A}$
			Full	–	15	–	
	$V_{EN} = 0\text{ V}$ , $V_{SEL} = 1.8\text{ V}$	3.6	25	–	55	65	$\mu\text{A}$
Full			–	58	–		

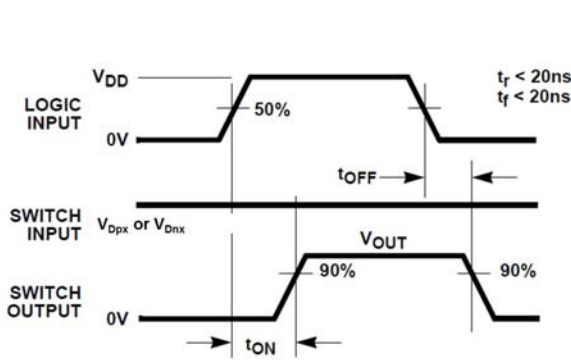
- $V_{IN}$  = input voltage to perform proper function.
- The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.
- Flatness is defined as the difference between maximum and minimum value of ON-resistance at the specified analog signal voltage points.
- Limits established by characterization and are not production tested.
- $r_{ON}$  matching between channels is calculated by subtracting the channel with the highest max  $r_{ON}$  value from the channel with lowest max  $r_{ON}$  value.
- Crosstalk is inversely proportional to source impedance.

**DC ELECTRICAL CHARACTERISTICS – Digital Section** (Voltages referenced to GND):  $V_{DD} = +3.0\text{ V to }+3.6\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_S = 2\text{ V}_{RMS}$ ,  $R_{LOAD} = 20\text{ k}\Omega$ ,  $f = 1\text{ kHz}$ ,  $V_{SELH} = V_{ENH} = 1.4\text{ V}$ ,  $V_{SELL} = V_{ENL} = 0.5\text{ V}$ , (Note 9), Unless otherwise specified.

Parameter	Test Conditions	Supply (V)	Temp (°C)	Min (Notes 10, 11)	Typ	Max (Notes 10, 11)	Units
<b>DIGITAL INPUT CHARACTERISTICS</b>							
Input Voltage Low, $V_{SELL}$ , $V_{ENL}$		3.3	Full	–	–	0.5	V
Input Voltage High, $V_{SELH}$ , $V_{ENH}$		3.3	Full	1.4	–	–	V
Input Current, $I_{SELH}$ , $I_{SELL}$	$V_{EN} = 0\text{ V}$ , $V_{SEL} = 0\text{ V}$ or $V_{DD}$	3.6	Full	-0.5	0.01	0.5	$\mu\text{A}$
Input Current, $I_{ENL}$	$V_{SEL} = V_{DD}$ , $V_{EN} = 0\text{ V}$	3.6	Full	-1.3	-0.7	0.3	$\mu\text{A}$
Input Current, $I_{ENH}$	$V_{SEL} = 0\text{ V}$ , $V_{EN} = V_{DD}$	3.6	Full	-0.5	0.01	0.5	$\mu\text{A}$

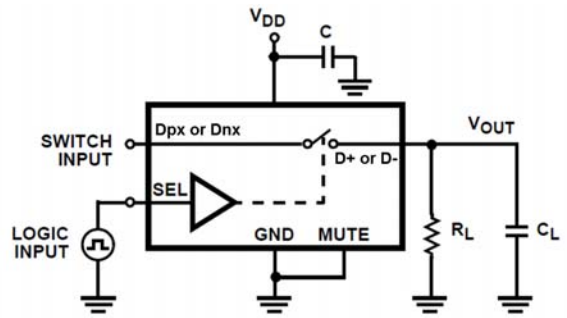
- $V_{IN}$  = input voltage to perform proper function.
- The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.

TEST CIRCUITS AND WAVEFORMS



Logic input waveform is inverted for switches that have the opposite logic sense.

Measurement Points

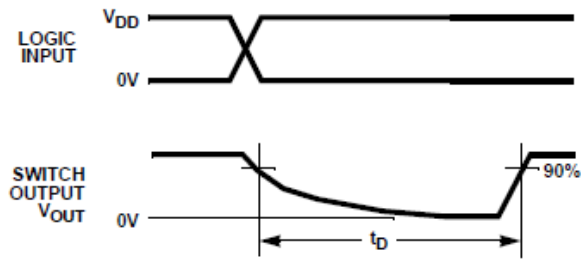


Repeat test for all switches.  $C_L$  includes fixture and stray capacitance.

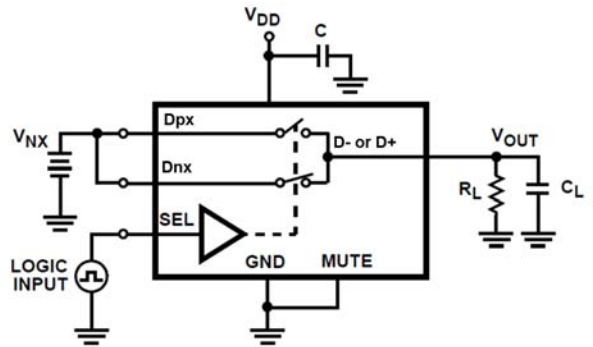
$$V_{OUT} = V_{(Dpx \text{ or } Dnx)} \frac{R_L}{R_L + r_{ON}}$$

Test Circuit

Figure 2. Switching Times



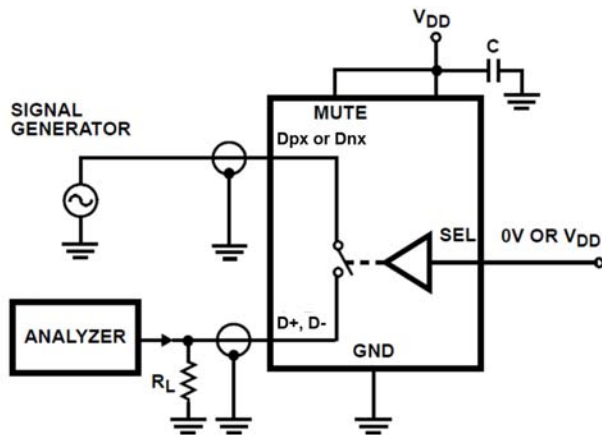
Measurement Points



Repeat test for all switches.  $C_L$  includes fixture and stray capacitance.

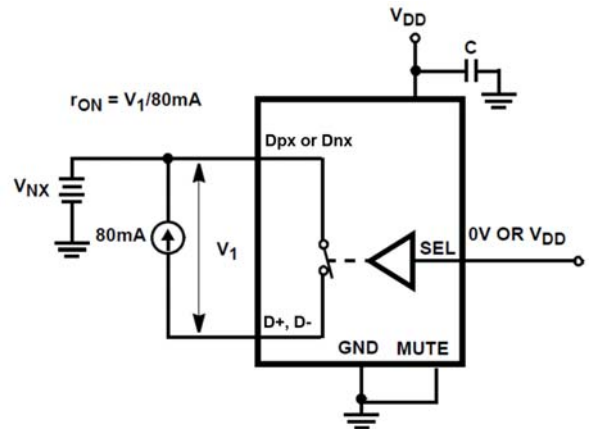
Test Circuit

Figure 3. Break-Before-Make Time



Signal direction through switch is reversed, worst case values are recorded. Repeat test for all switches.

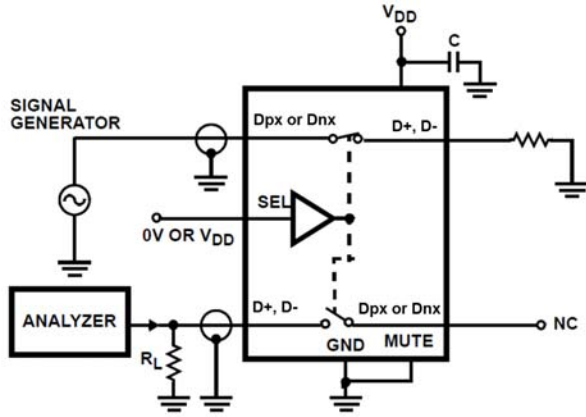
Figure 4. Off-Isolation Test Circuit



Repeat test for all switches.

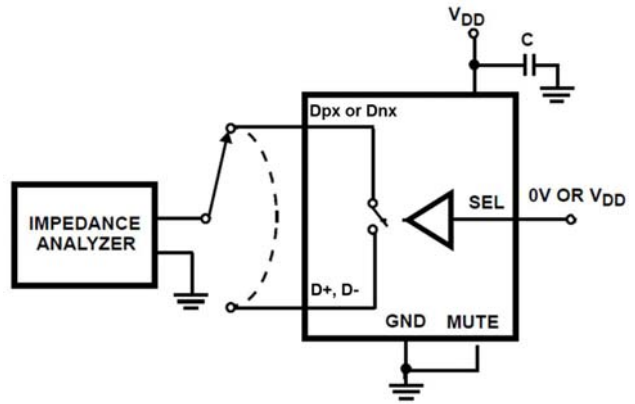
Figure 5.  $r_{ON}$  Test Circuit

TEST CIRCUITS AND WAVEFORMS



Signal direction through switch is reversed, worst case values are recorded. Repeat test for all switches.

Figure 6. Crosstalk Test Circuit



Repeat test for all switches.

Figure 7. Capacitance Test Circuit

TYPICAL PERFORMANCE CURVES:

$T_A = +25^\circ\text{C}$ , Unless Otherwise Specified

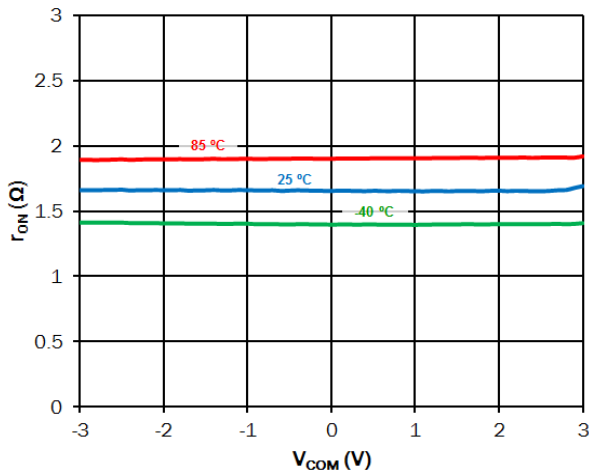


Figure 8. On-Resistance vs. Switch Voltage

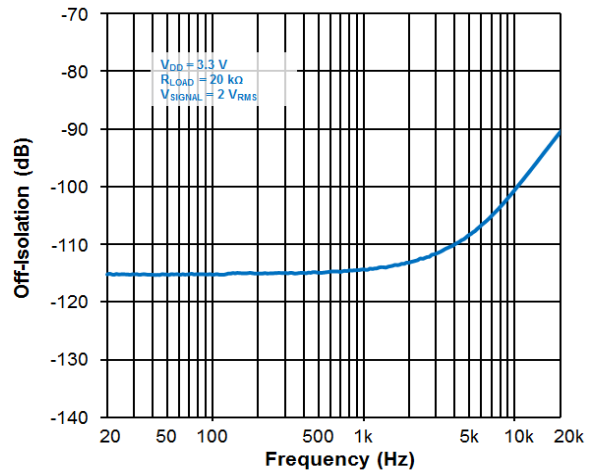


Figure 9. Off-Isolation, 2  $V_{RMS}$  Signal, 20  $k\Omega$  Load

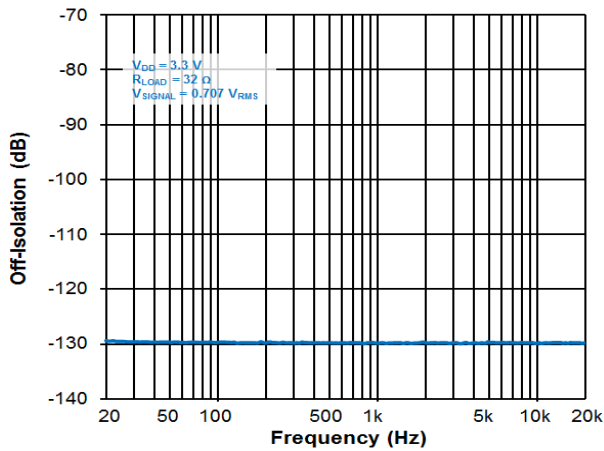


Figure 10. Off-Isolation, 0.707  $V_{RMS}$  Signal, 32  $k\Omega$  Load

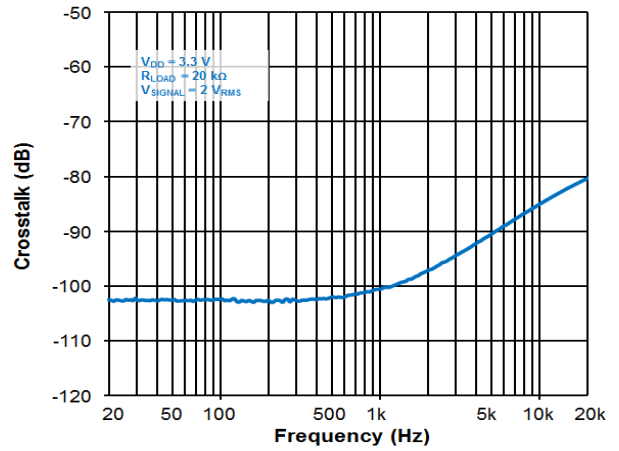


Figure 11. Channel-to-Channel Crosstalk

TYPICAL PERFORMANCE CURVES:

T<sub>A</sub> = +25°C, Unless Otherwise Specified

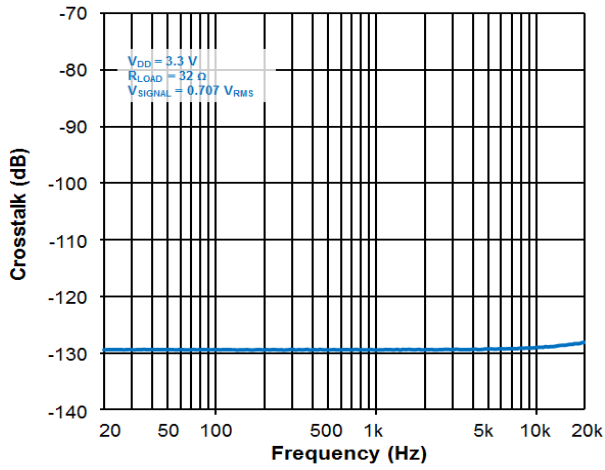


Figure 12. Channel-to-Channel Crosstalk

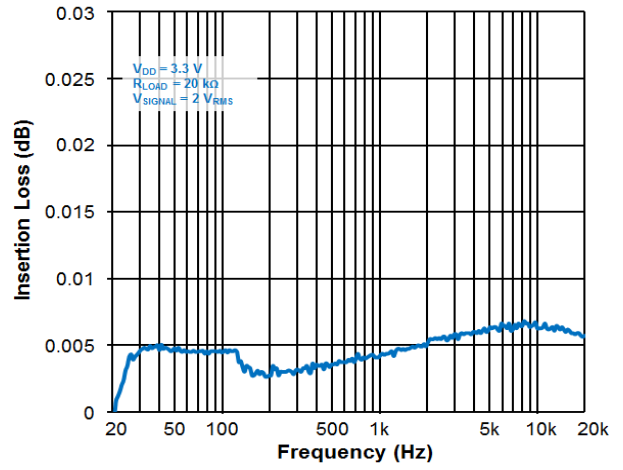


Figure 13. Insertion Loss vs. Frequency

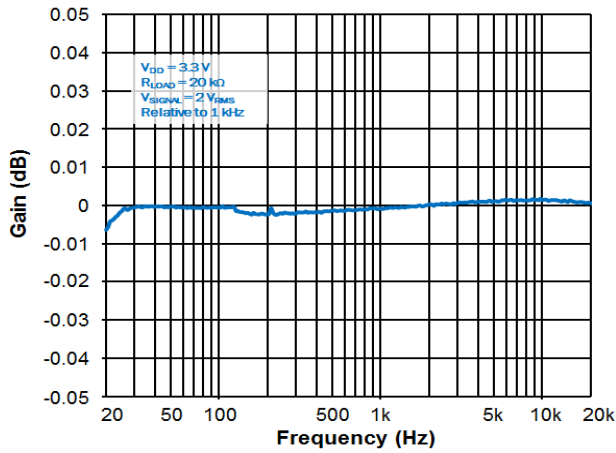


Figure 14. Gain vs. Frequency

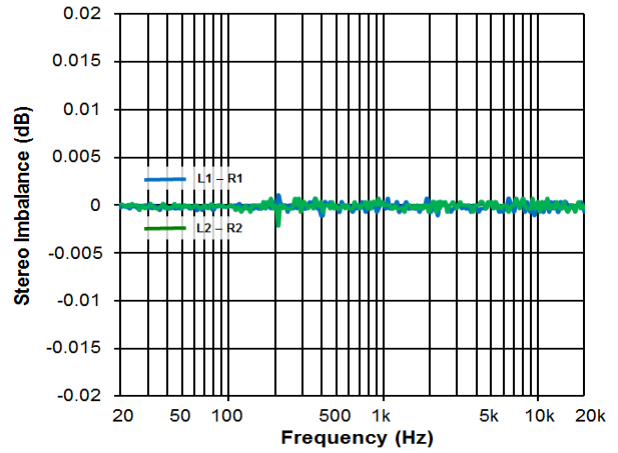


Figure 15. Stereo Imbalance vs. Frequency

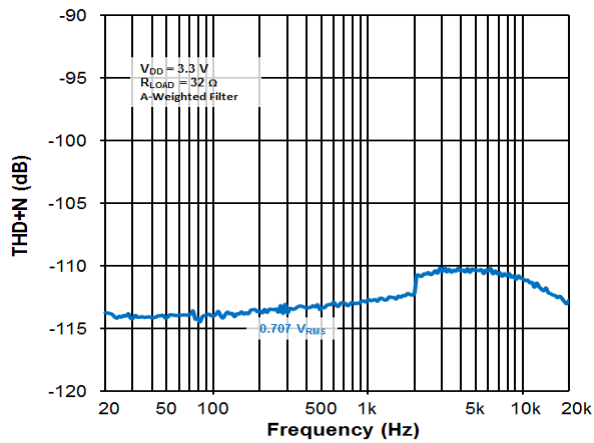


Figure 16. THD+N vs. Signal Levels vs. Frequency

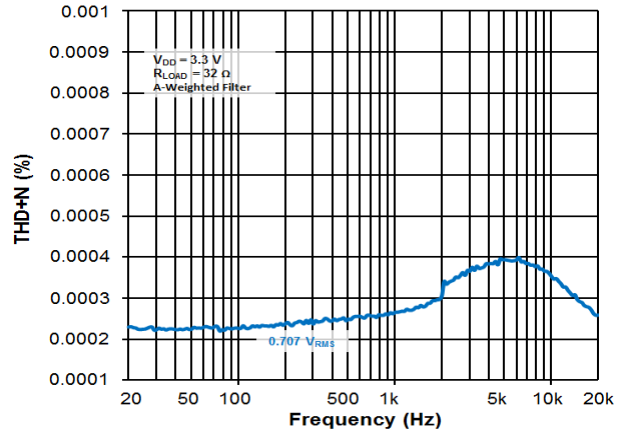


Figure 17. THD+N vs. Signal Levels vs. Frequency



TYPICAL PERFORMANCE CURVES:

T<sub>A</sub> = +25°C, Unless Otherwise Specified

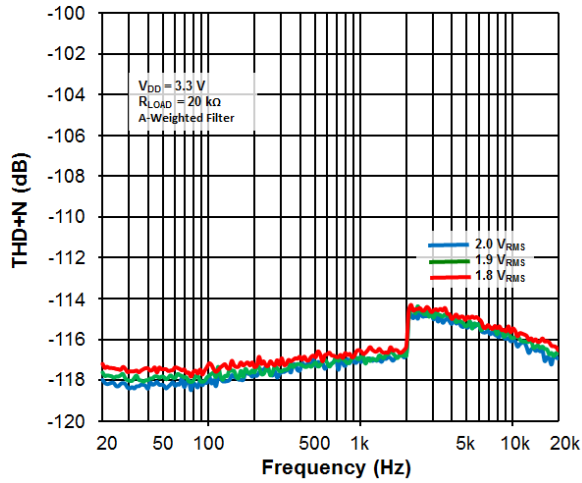


Figure 18. THD+N vs. Signal Levels vs. Frequency

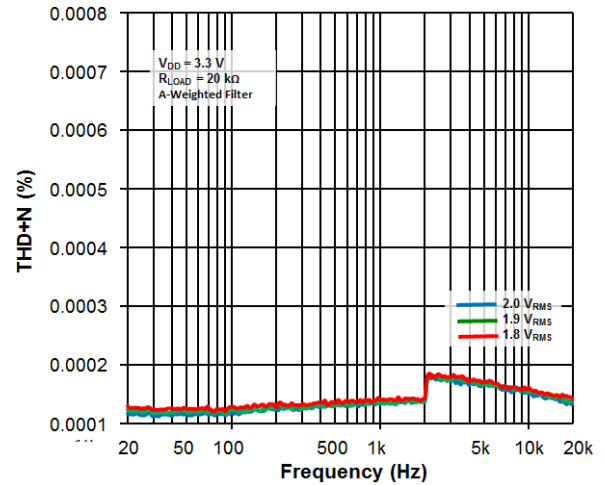


Figure 19. THD+N vs. Signal Levels vs. Frequency

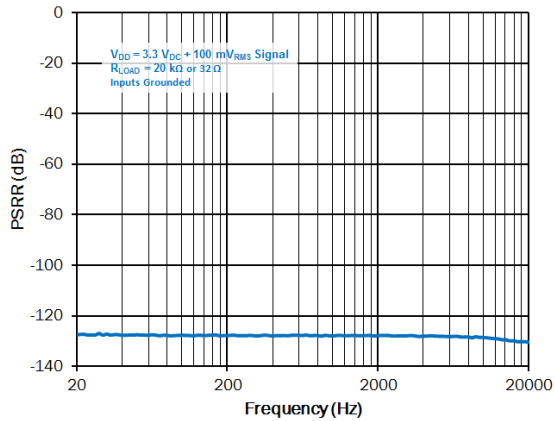


Figure 20. PSRR vs. Frequency

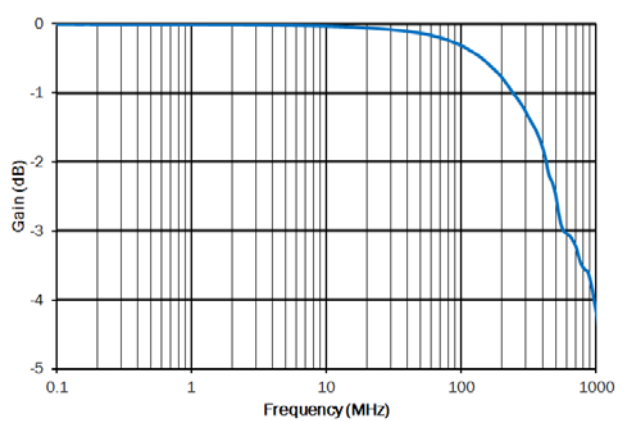


Figure 21. Frequency Response

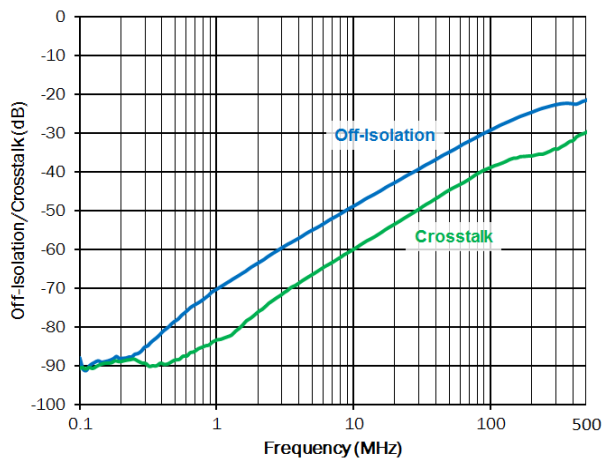


Figure 22. Crosstalk and Off-Isolation

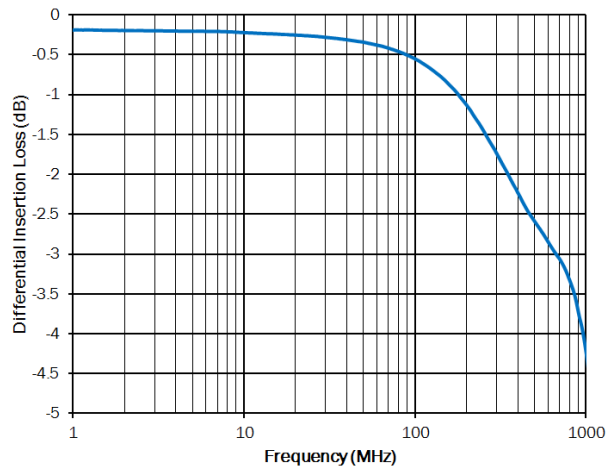


Figure 23. Differential Crosstalk

# NL3S588

## TYPICAL PERFORMANCE CURVES:

$T_A = +25^\circ\text{C}$ , Unless Otherwise Specified

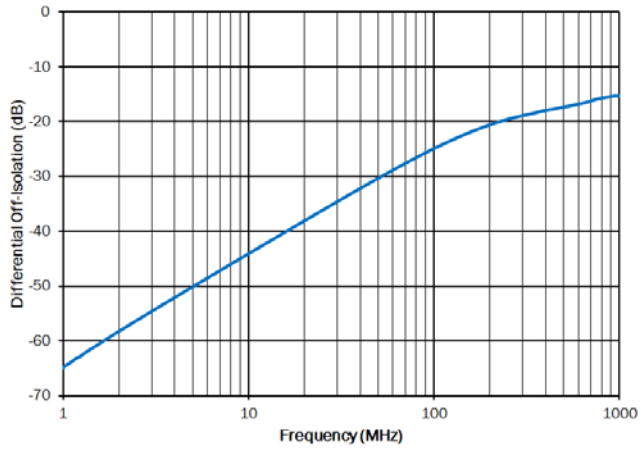


Figure 24. Differential Off-Isolation

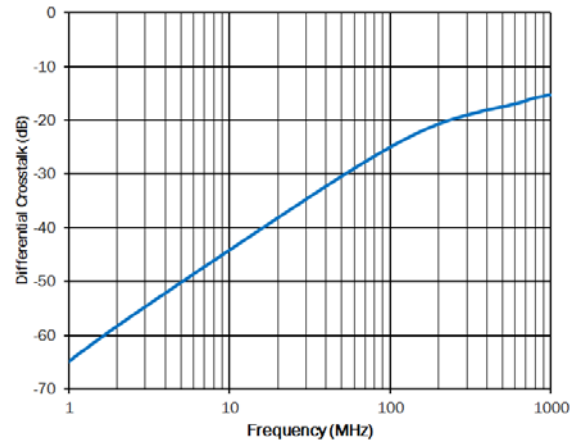


Figure 25. Differential Crosstalk

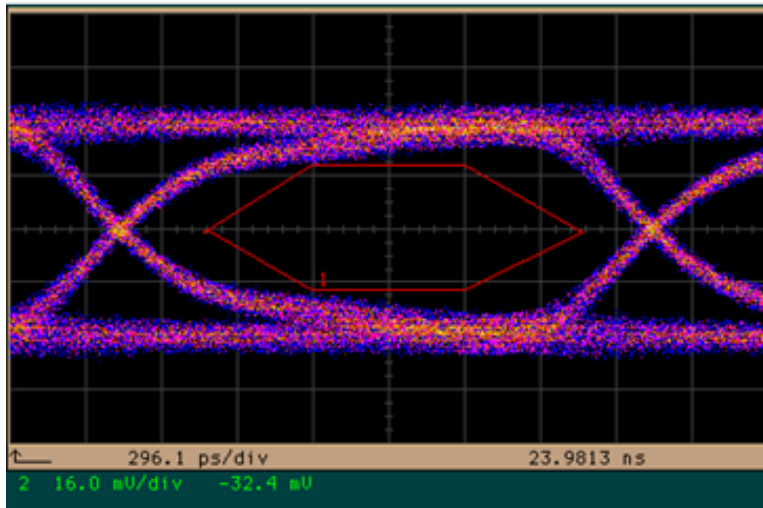


Figure 26. USB 2.0 High-Speed Eye Diagram

# MECHANICAL CASE OUTLINE

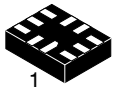
## PACKAGE DIMENSIONS

ON Semiconductor®

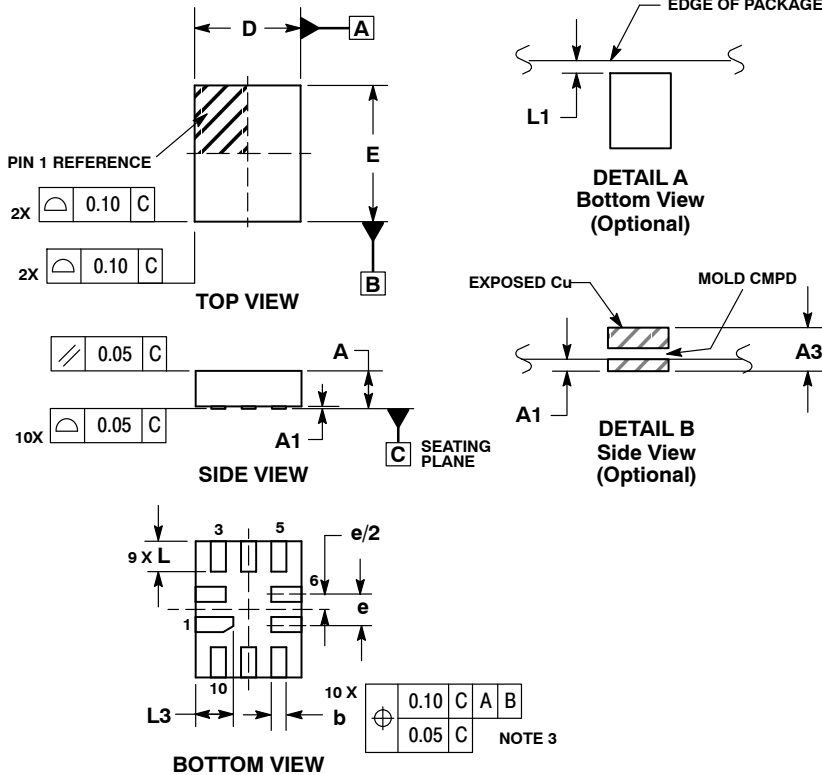


### UQFN10 1.4x1.8, 0.4P CASE 488AT-01 ISSUE A

DATE 01 AUG 2007

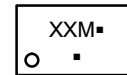


SCALE 5:1



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  2. CONTROLLING DIMENSION: MILLIMETERS
  3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM FROM TERMINAL.
  4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

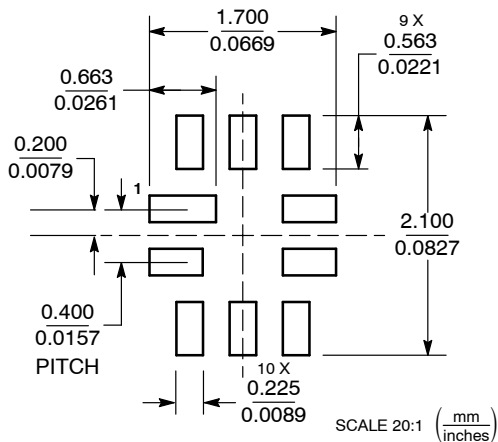
### GENERIC MARKING DIAGRAM\*



- XX = Specific Device Code
  - M = Date Code
  - = Pb-Free Package
- (Note: Microdot may be in either location)

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present.

### MOUNTING FOOTPRINT



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