# 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<sub>RMS</sub> Signal Switching
- -116 dB THD+N into 20 k $\Omega$  Load at 2 V<sub>RMS</sub>
- -112 dB THD+N into  $32 \Omega$  Load at 0.707 V<sub>RMS</sub>
- Signal to Noise Ratio: > 125 dBV
- $\pm 0.004$  dB Insertion Loss at 1 kHz, 20 k $\Omega$  Load
- ±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<sub>DD</sub>
- C<sub>ON</sub>: 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®**

www.onsemi.com



= Pb-Free Device

(Note: Microdot may be in either location)



#### ORDERING INFORMATION

Device	Package	Shipping <sup>†</sup>		
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.





#### FUNCTION TABLE

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

NOTE:  $\overline{\text{EN}}$  Logic "0"  $\leq$  0.5 V, Logic "1"  $\geq$  1.4 V or float. SEL Logic "0"  $\leq$  0.5V, 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
VIS	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>	(Pulsed 1 ms, 10% Duty Cycle, Max).		±500	mA
PD	Power Dissipation in Still Air		800	mW
Τ <sub>s</sub>	Storage Temperature		-65 to +150	°C
ΤL	Lead Temperature, 1 mm from Case for 10 seconds		260	°C
TJ	Junction Bias Under Bias		150	°C
$\theta_{JA}$	Thermal Resistance		80	°C/W
Τ <sub>s</sub>	Storage Temperature		-65 to +150	°C
MSL	Moisture Sensitivity		Level 1	
F <sub>R</sub>	Flammability Rating Oxygen Ind	ex: 30% – 35%	UL94–V0 (0.125 in)	°C
ESD		an Body Model Machine Model	3000 200	V
١L	Latch-up Current, Above V <sub>CC</sub> and below GND at 125°C (Net Contemporate Contemporated C	ote 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
VS	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): $V_{DD} = +3.0 \text{ V}$ to +3.6 V, GND = 0 V, $V_S = 2 \text{ V}_{RMS}$ , $R_{LOAD} = 20 \text{ k}\Omega$ , f = 1 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)	Тур	Max (Notes 3, 4)	Units
ANALOG SWITCH CHARA	ANALOG SWITCH CHARACTERISTICS						
Analog Signal Range, V <sub>ANALOG</sub>		3.3	Full	-	2	-	V <sub>RMS</sub>
ON-Resistance, $r_{ON}$ $I_{D+}$ or $I_{D-} = 80mA$ , $V_{Dpx}$ or $V_{Dnx} = 1000$	3.3	25	-	2.1	-	Ω	
	-2.828 V to +2.828 V (See Figure 5)		Full	-	2.5	-	
r <sub>ON</sub> Matching Between	$I_{D+}$ or $I_{D-}$ = 80mA, $V_{Dpx}$ or $V_{Dnx}$ = Voltage at max $r_{ON}$ over -2.828 V	3.3	25	-	0.046	-	Ω
Channels, Zron	hannels, $\Delta r_{ON}$ Voltage at max $r_{ON}$ over -2.828 V to +2.828 V (Note 7)		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
	-2.828 v, 0v, +2.828 v (Note 5)		Full	-	0.092	-	

2.  $V_{IN}$  = input voltage to perform proper function.

3. 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.

5. Flatness is defined as the difference between maximum and minimum value of ON-resistance at the specified analog signal voltage points.

6. Limits established by characterization and are not production tested.

7. 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.

8. Crosstalk is inversely proportional to source impedance.

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 k $\Omega$ , 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)	<b>Min</b> (Notes 3, 4)	Тур	Max (Notes 3, 4)	Units
ANALOG SWITCH CHARAC	TERISTICS						
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,	3.6	25	225	300	375	kΩ
	calculate resistance.		Full	-	345	-	
DYNAMIC CHARACTERIST	CS						
THD+N	$V_S$ = 2 $V_{RMS},$ f = 1 kHz, A–weighted filter, $R_{LOAD}$ = 20 $k\Omega$	3.3	25	-	< -116	-	dB
	$V_S$ = 1.9 $V_{RMS},$ f = 1 kHz, A–weighted filter, $R_{LOAD}$ = 20 $k\Omega$	-	25	-	< -116	-	
	$V_S$ = 1.8 $V_{RMS}$ , f = 1 kHz, A–weighted filter, R <sub>LOAD</sub> = 20 k $\Omega$		25	-	< -116	-	
	$V_{S}$ = 0.707 $V_{RMS}$ , f = 1 kHz, A–weighted filter, R <sub>LOAD</sub> = 32 $\Omega$		25	-	< -112	-	
SNR	f = 20 Hz to 20 kHz, A–weighted filter, inputs grounded, $R_{LOAD}$ = 20 kΩ or 32 Ω	3.3	25	_	> 125	-	dBV
Insertion Loss, G <sub>ON</sub>	f = 1 kHz, $R_{LOAD}$ = 20 k $\Omega$	3.3	25	-	±0.004	-	dB
Gain vs Frequency, G <sub>f</sub>	f = 20 Hz to 20 kHz, $R_{LOAD}$ = 20 kΩ, reference to $G_{ON}$ at 1 kHz	3.3	25	-	±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	-	±0.0001	-	dB
OFF–Isolation (Disabling)	f = 20 Hz to 22 kHz, D+ = D- = 2 V <sub>RMS</sub> , R <sub>LOAD</sub> = 20 kΩ, = 3.3 V, SEL = "X"	3.3	25	_	112	-	dB
	f = 20 Hz to 22 kHz, V <sub>D+</sub> or V <sub>D-</sub> = 0.7 V <sub>RMS</sub> , R <sub>LOAD</sub> = 32 $\Omega$		25	-	129	-	
Crosstalk (Channel–to– Channel)	$ \begin{array}{l} R_L = 20 \; k\Omega,  f = 20 \; Hz \; to \; 20 \; kHz, \\ V_S = 2 \; V_{RMS},  signal \; source \; imped- \\ ance = 20 \; \Omega,  (Note \; 8) \end{array} $	3.3	25	_	102	-	dB
	$ \begin{array}{l} R_{L} = 32 \; \Omega, \; f = 20 \; Hz \; to \; 20 \; kHz, \; V_{S} \\ = 0.7 \; V_{RMS}, \; \text{signal source imped-} \\ \text{ance} = 20 \; \Omega, \; (\text{Note 8}) \end{array} $		25	_	129	-	
PSRR	$f = 1 \text{ kHz}, V_S = 100 \text{ mV}_{RMS}$ , inputs grounded	3.3	25	-	131	-	dB
	$f = 20 \text{ kHz}, V_S = 100 \text{ mV}_{RMS}$ , inputs grounded		25	-	133	-	
Bandwidth, -3 dB	$R_{LOAD} = 50 \ \Omega$	3.3	25	-	580	-	MHz
ON to Disable Time, T <sub>TRANS-OM</sub>		3.3	25	-	250	-	ns
Disable to ON Time, T <sub>TRANS-MO</sub>	V <sub>IS</sub> = 1.5 V	3.3	25	-	1680	-	μs
Turn–ON Time, t <sub>ON</sub>	$V_{Dpx}$ or $V_{Dnx}$ = 1.5 V, $V_{EN}$ = 0 V, R <sub>L</sub> = 32 $\Omega$ (See Figure 2)	3.3	25	-	14	-	μS
Turn–OFF Time, t <sub>OFF</sub>	$V_{Dpx}$ or $V_{Dnx}$ = 1.5 V, $V_{EN}$ = 0 V, R <sub>L</sub> = 32 $\Omega$ (See Figure 2)	3.3	25	-	95	-	ns

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 charac-

terization and are not production tested.

5. 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. 8. Crosstalk is inversely proportional to source impedance.

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

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 k $\Omega$ , 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.

#### POWER SUPPLY CHARACTERISTICS

Power Supply Range, V <sub>DD</sub>		3.3	Full	3	-	3.6	V
Positive Supply	$V_{EN} = 0 V$ , $V_{SEL} = 0 V$ or $V_{DD}$	3.6	25	-	54	65	μΑ
Current, I+			Full	-	59	-	
	$V_{EN} = V_{DD}, V_{SEL} = 0 V \text{ or } V_{DD}$	3.6	25	-	14	40	μA
			Full	-	15	-	
	V <sub>EN</sub> = 0 V, V <sub>SEL</sub> = 1.8 V	3.6	25	-	55	65	μΑ
			Full	-	58	-	

2.  $V_{IN}$  = 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.

5. Flatness is defined as the difference between maximum and minimum value of ON-resistance at the specified analog signal voltage points.

6. Limits established by characterization and are not production tested.

7. ron matching between channels is calculated by subtracting the channel with the highest max ron value from the channel with lowest max r<sub>ON</sub> value.

8. Crosstalk is inversely proportional to source impedance.

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

Parameter	Test Conditions	Supply (V)	Temp (°C)	<b>Min</b> (Notes 10, 11)	Тур	<b>Max</b> (Notes 10, 11)	Units
DIGITAL INPUT CHARACT	ERISTICS						
Input Voltage Low, V <sub>SELL</sub> , V <sub>ENL</sub>		3.3	Full	-	-	0.5	V
Input Voltage High, V <sub>SELH</sub> , V <sub>ENH</sub>		3.3	Full	1.4	-	-	V
Input Current, I <sub>SELH</sub> , I <sub>SELL</sub>	$V_{EN}$ = 0 V, $V_{SEL}$ = 0 V or $V_{DD}$	3.6	Full	-0.5	0.01	0.5	μA
Input Current, I <sub>ENL</sub>	$V_{SEL} = V_{DD}, V_{EN} = 0 V$	3.6	Full	-1.3	-0.7	0.3	μA
Input Current, I <sub>ENH</sub>	$V_{SEL}$ = 0 V, $V_{EN}$ = $V_{DD}$	3.6	Full	-0.5	0.01	0.5	μA

9.  $V_{IN}$  = input voltage to perform proper function.

10. The algebraic convention, whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet. 11. Parameters with MIN and/or MAX limits are 100% tested at +25<sup>[2]</sup>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<sub>L</sub> includes fixture and stray capacitance.  $V_{OUT} = V_{(Dpx \text{ or } Dnx)} \frac{R_L}{R_L + rON}$ 

Test Circuit





Repeat test for all switches. CL includes fixture and stray capacitance.

Measurement Points

Test Circuit

VDD



**Figure 2. Switching Times** 



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.

ron = V1/80mA



#### **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°C, Unless Otherwise Specified



Figure 8. On-Resistance vs. Switch Voltage







Figure 9. Off–Isolation, 2 V\_{RMS} Signal, 20 k  $\Omega$  Load





#### TYPICAL PERFORMANCE CURVES:

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



Figure 12. Channel-to-Channel Crosstalk







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



Figure 13. Insertion Loss vs. Frequency



Figure 15. Stereo Imbalance vs. Frequency



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

#### **TYPICAL PERFORMANCE CURVES:**

 $T_A$  = +25°C, Unless Otherwise Specified



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



Figure 20. PSRR vs. Frequency



Figure 22. Crosstalk and Off–Isolation



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



Figure 21. Frequency Response



Figure 23. Differential Crosstalk

## TYPICAL PERFORMANCE CURVES:

 $T_A$  = +25°C, Unless Otherwise Specified



Figure 24. Differential Off–Isolation

Figure 25. Differential Crosstalk



Figure 26. USB 2.0 High–Speed Eye Diagram

#### PACKAGE DIMENSIONS



and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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