

10.3Gbps Thunderbolt™ Port and DisplayPort™ Switch

Check for Samples: [HD3SS0001](#)

FEATURES

- **Compatible with Thunderbolt™ Technology Electrical Standards and DisplayPort™ 1.2a**
- **Wide –3dB Differential Bandwidth of Over 10GHz on 10G Path**
- **Supports DP and DP++ Configurations**
- **Handles HPD (5V tolerant) and Cable Detect**
- **Supports AUX and DDC MUX**
- **Excellent Dynamic Characteristics (on 10G path, typical values at 5GHz):**
 - Crosstalk = –35dB
 - Off-Isolation = –24dB
 - Insertion Loss = –1.5dB
 - Return Loss = –20dB
 - Intra-pair Skew Added < 4ps
- **Single 3.3V Power Supply**
- **Small 3x3mm 24-Pin QFN Package**
- **Low Power Consumption**
 - 3.3mW Typical Active Power
 - 80 μ W Typical Detect Mode

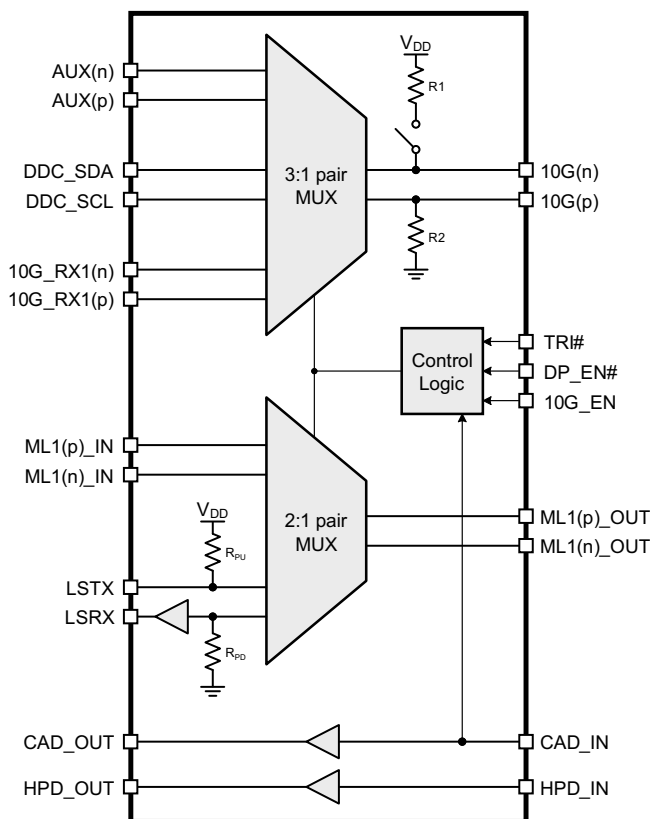
DESCRIPTION

The HD3SS0001 is a high-speed passive-switch device with integrated buffers and resistors, designed to support Thunderbolt™ technology, DisplayPort, and Dual Mode DisplayPort. The 10G path supports a high 10GHz bandwidth and excellent loss characteristics, while the DisplayPort path supports 5.4Gbps.

The integrated 3-pairs to 1-pair multiplexer (3:1 MUX) switches between DDC, AUX, and 10.3Gbps signals. The integrated 2-pairs to 1-pair multiplexer (2:1 MUX) switches between the Thunderbolt™ technology Low Speed UART transmit/receive pair and DisplayPort Main Link 1.

The MUXs are controlled by 4 input pins: TRI#, DP_EN#, 10G_EN, and CAD_IN (cable detect from the connector). The HD3SS0001 is packaged in a small 3x3mm 24-pin QFN, operates from a single 3.3V supply, and supports an ambient temperature range of –40°C to 85°C.

FUNCTIONAL DIAGRAM



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

Thunderbolt is a trademark of Intel Corp.

DisplayPort is a trademark of VESA Standards Association.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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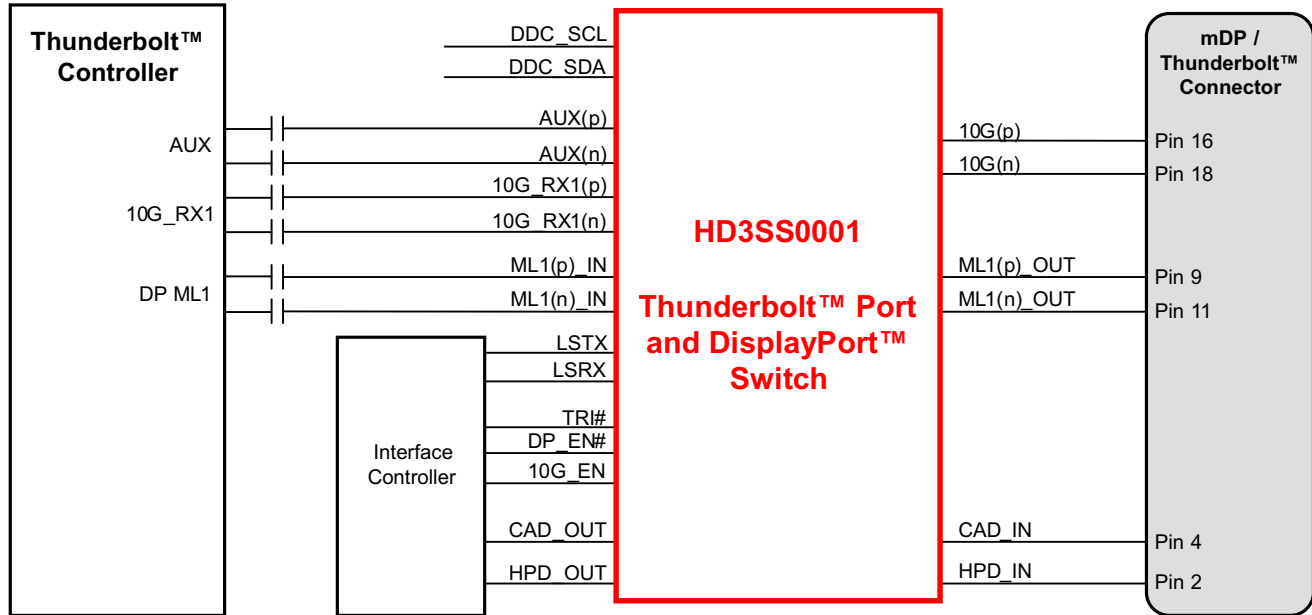
HD3SS0001

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

TYPICAL APPLICATION

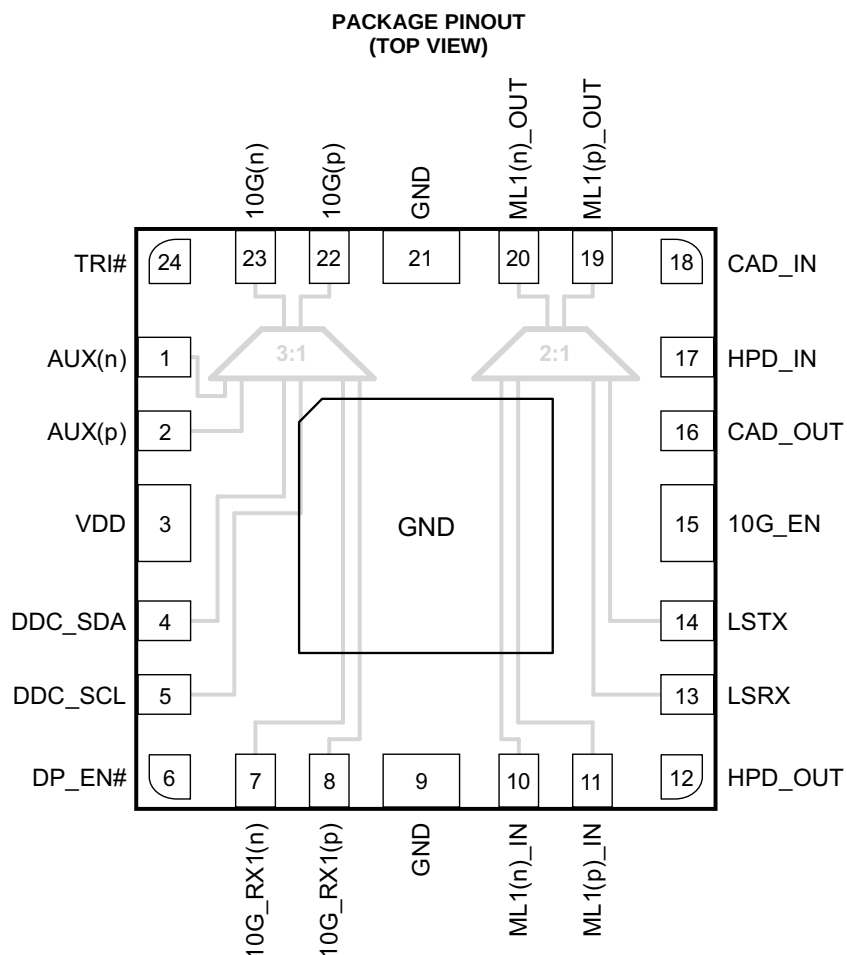


TRUTH TABLE

MODE	LOGICAL INPUT TO SET ⁽¹⁾				EFFECT		
	TRI#	DP_EN#	10G_EN	CAD_IN	2:1 MUX SELECTION ⁽²⁾	3:1 MUX SELECTION ⁽²⁾	PULL-UP RESISTOR on 10G(n)
Thunderbolt™ Protocol	1	1	1	X	LS	10G	Disconnected
	0	1	1	X	LS	Tri-stated	Disconnected
DisplayPort	1	0	0	0	ML	AUX	Connected
	0	0	0	0	Tri-Stated	Tri-stated	Connected
TMDS	1	0	0	1	ML	DDC	Connected
	0	0	0	1	Tri-Stated	Tri-stated	Connected
Detect Mode	X	1	0	X	LS	Tri-Stated	Connected
[Invalid]	X	0	1	X	Tri-Stated	Tri-Stated	Disconnected

(1) "X" = Don't Care.

(2) MUX Selection names are abbreviated.



MUX PIN MAPPING⁽¹⁾

CONTROLLER-SIDE PIN	Connector-Side Pin
AUX(n)	10G(n)
DDC_SDA	
10G_RX1(n)	
AUX(p)	10G(p)
DDC_SCL	
10G_RX1(p)	
ML1(p)_IN	ML1(p)_OUT
LSTX	
ML1(n)_IN	ML1(n)_OUT
LSRX	

(1) NOTE: The HD3SS0001 can tolerate polarity inversions for the differential signals denoted by the (p) and (n) terminology, to ease potential board routing issues. LSTX/LSRX cannot be swapped, since LSRX is buffered and therefore unidirectional. Also, note that the integrated pullup on 10G(n) and the integrated pulldown on 10G(p) cannot be swapped.

PIN FUNCTIONS

PIN		I/O	SYSTEM SIDE	DESCRIPTION
NO.	NAME			
11	ML1(p)_IN	I	Controller	DisplayPort MainLink1(p) input
10	ML1(n)_IN			DisplayPort MainLink1(n) input
24	TRI#			Tri-State control (see TRUTH TABLE)
6	DP_EN#			DisplayPort Enable, active-low (see TRUTH TABLE)
15	10G_EN			10.3Gbps Mode Enable (see TRUTH TABLE)
18	CAD_IN		Connector	Cable Detect
17	HPD_IN			Hot Plug Detect
2	AUX(p)	I/O	Controller	AUX Positive Signal
1	AUX(n)			AUX Negative Signal
5	DDC_SCL			DDC Clock
4	DDC_SDA			DDC Data
14	LSTX			UART TX Signal
13	LSRX			UART RX Signal
22	10G(p)		Connector	10G_RX1(p) or AUX(p) or DDC_SCL, with pull-down
23	10G(n)			10G_RX1(n) or AUX(n) or DDC_SDA, with pull-up
19	ML1(p)_OUT			DisplayPort MainLink1(p) output or LSTX
20	ML1(n)_OUT			DisplayPort MainLink1(n) output or LSRX
8	10G_RX1(p)	O	Controller	10.3Gbps Positive Signal
7	10G_RX1(n)			10.3Gbps Negative Signal
16	CAD_OUT			Cable Detect
12	HPD_OUT			Hot Plug Detect
3	V _{DD}	Power Supply		Power supply
9, 21, Center Pad	GND			Reference ground

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Over operating free-air temperature range (unless otherwise noted)

		VALUE		UNIT
		MIN	MAX	
Supply voltage range ⁽²⁾	V _{DD}	−0.5	4	V
Voltage range	Differential I/O	−0.5	4	V
	Control pin/buffers	−0.5	V _{DD} +0.5	
Electrostatic discharge	Human body model ⁽³⁾		±1,500	V
	Charged-device model ⁽⁴⁾		±500	
Continuous power dissipation		See Power Characteristics		

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values, except differential voltages, are with respect to network ground terminal.
- (3) Tested in accordance with JEDEC/ESDA JS-001-2011
- (4) Tested in accordance with JEDEC JESD22 C101-E

THERMAL INFORMATION

over operating free-air temperature range (unless otherwise noted)

THERMAL METRIC ⁽¹⁾		HD3SS0001	UNITS
		24-PIN VQFN (RLL)	
θ_{JA}	Junction-to-ambient thermal resistance	41.5	°C/W
θ_{JCTop}	Junction-to-case (top) thermal resistance	43.1	
θ_{JCBot}	Junction-to-case (bottom) thermal resistance	6.3	
θ_{JB}	Junction-to-board thermal resistance	11.2	
Ψ_{JT}	Junction-to-top characterization parameter	1.2	
Ψ_{JB}	Junction-to-board characterization parameter	11.2	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

POWER CHARACTERISTICS

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX ⁽¹⁾	UNIT
I_{DD}	Supply Current in Active Mode	Outputs Floating		1.0	1.3	mA
I_{DETECT}	Supply Current in Detect Mode	DP_EN# = 1, 10G_EN = 0		26	50	μA
P_D	Power Dissipation in Active Mode			3.3	4.7	mW
P_{Detect}	Power Dissipation in Detect Mode			80	150	μW

(1) The maximum ratings are simulated for $V_{DD} = 3.6V$.

RECOMMENDED OPERATING CONDITIONS

Typical values for all parameters are at $V_{DD} = 3.3V$ and $T_A = 25^{\circ}C$. (Temperature limits are specified by design)

PARAMETER	NOTES/CONDITIONS	MIN	TYP	MAX	UNIT
V_{DD}	Supply voltage	3.0	3.3	3.6 ⁽¹⁾	V
T_A	Operating free-air temperature	–40		85	$^{\circ}C$
V_{IH}	Input high voltage CAD_IN, HPD_IN ⁽²⁾ , TRI#, DP_EN#, and 10G_EN ML1(n)_OUT (when 2:1 MUX selects LS)	2.0		V_{DD}	V
		2.0		V_{DD}	
V_{IL}	Input low voltage CAD_IN, HPD_IN ⁽²⁾ , TRI#, DP_EN#, and 10G_EN ML1(n)_OUT (when 2:1 MUX selects LS)	–0.1		0.8	V
		–0.1		0.8	
V_{OH}	Output high voltage CAD_OUT, HPD_OUT LSRX (when 2:1 MUX selects LS)	2.7		V_{DD}	V
		2.7		V_{DD} ⁽¹⁾	
V_{OL}	Output low voltage CAD_OUT, HPD_OUT LSRX (when 2:1 MUX selects LS)	0.0		0.1	V
		0.0		0.1	
I_{IH}	High-level input current TRI#, DP_EN#, 10G_EN, CAD_IN, and HPD_IN; $V_{DD} = 3.6V$, $V_{IN} = V_{DD}$ ML1(n)_OUT; $V_{DD} = 3.6V$; $V_{IN} = V_{DD}$ (when 2:1 MUX selects LS)			5	μA
				3.75	
I_{IL}	Low-level input current TRI#, DP_EN#, 10G_EN, CAD_IN, and HPD_IN; $V_{DD} = 3.6V$, $V_{IN} = GND$ ML1(n)_OUT; $V_{DD} = 3.6V$, $V_{IN} = GND$ (when 2:1 MUX selects LS)			100	nA
				100	
V_{I/O_Diff}	Differential I/O voltage AUX(p)/AUX(n), 10G_RX1(p)/10G_RX1(n), ML1(p)_IN/ML1(n)_IN, 10G(p)/10G(n), and ML1(p)_OUT/ML1(n)_OUT when MUX's are connected to Differential Signals.	0		1.8	Vpp
V_{I/O_CM}	Common mode I/O voltage AUX(p)/AUX(n), 10G_RX1(p)/10G_RX1(n), ML1(p)_IN/ML1(n)_IN, 10G(p)/10G(n), and ML1(p)_OUT/ML1(n)_OUT when MUX's are connected to Differential Signals.	0		2.0	V

(1) V_{DD} range supports 3.0V to 3.6V, but for Thunderbolt products it is anticipated that the V_{DD} must be maintained at less than or equal to 3.4V to ensure that the V_{OH} on the LSRx do not exceed 3.4V.

(2) HPD_IN is 5V tolerant.

ELECTRICAL CHARACTERISTICS

(under recommended operation conditions)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Thunderbolt™ Technology 10.3Gbps Link: 10G_RX1(p), 10G_RX1(n)⁽¹⁾					
R_L	Differential Return Loss $f = 5.0\text{ GHz}$		–20		dB
I_L	Differential Insertion Loss $f = 5.0\text{ GHz}$		–1.5		dB
O_{IRR}	Differential Off Isolation $f = 5.0\text{ GHz}$ (see Figure 3)		–24		dB
X_{TALK}	Differential Crosstalk $f = 5.0\text{ GHz}$		–35		dB
BW	Bandwidth	–3 dB	10		GHz
t_{PD}	Propagation Delay(from input to output) R_{sc} and $R_L = 50\ \Omega$ (see Figure 2)			200	ps
T_{SKEW}	Intra-Pair Skew Added R_{sc} and $R_L = 50\ \Omega$ (see Figure 2)			4	ps
C_{ON}	Outputs ON Capacitance $V_I = 0\text{ V}$, Outputs Open, Switch ON		1.5		pF
C_{OFF}	Outputs OFF Capacitance $V_I = 0\text{ V}$, Outputs Open Switch OFF		1		pF
R_{ON}	Output ON resistance $V_{DD} = 3.3\text{ V}$, $I_O = -15\ \mu A$		7.5		Ω
ΔR_{ON}	On resistance match between pairs of the same channel $V_{DD} = 3.3V$; $I_O = -15\ \mu A$			1	Ω
T_{ON}	Control Line Change to MUX Output Switched See Figure 1			400	μs
T_{OFF}				10	

(1) These values apply for CAD_IN tri-stated, unless otherwise noted.

ELECTRICAL CHARACTERISTICS (continued)

(under recommended operation conditions)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
DisplayPort Link: ML1(p)_IN, ML1(n)_IN						
R _L	Differential Return Loss	f = 2.7 GHz		–16		dB
I _L	Differential Insertion Loss	f = 2.7 GHz; V _{CM} = 0 V		–0.8		dB
O _{IRR}	Differential Off-Isolation	f = 2.7 GHz (see Figure 3)		–20		dB
X _{TALK}	Differential Crosstalk	f = 2.7 GHz		–35		dB
BW	Differential Bandwidth	–3 dB		7		GHz
t _{PD}	Propagation Delay(from input to output)	R _{SC} and R _L = 50 Ω (see Figure 2)			200	ps
T _{SKEW}	Intra-pair Skew Added	R _{SC} and R _L = 50 Ω (see Figure 2)			4	ps
C _{ON}	Outputs ON Capacitance	V _I = 0 V; Outputs Open; Switch ON		1.5		pF
C _{OFF}	Outputs OFF Capacitance	V _I = 0 V; Outputs Open; Switch OFF		1		pF
R _{ON}	Output ON resistance	V _{DD} = 3.3 V; I _O = –15 mA; V _{CM} = 0.5 V to 1.5 V; CAD_IN = 0 V		6	8	Ω
ΔR _{ON}	On resistance match between pairs of the same channel	V _{DD} = 3.3 V; I _O = -15 mA; V _{CM} = 0.5 V to 1.5 V			1	Ω
T _{ON}	Control Line Change to MUX Output Switched	See Figure 1			400	μs
T _{OFF}					10	
Thunderbolt™ Technology Low Speed UART : LSTX						
C _{ON}	Outputs ON capacitance	V _I = 0 V , Outputs Open, Switch ON		8		pF
C _{OFF}	Outputs OFF capacitance	V _I = 0 V, Outputs Open, Switch OFF		3		pF
R _{ON}	Output ON resistance	V _{DD} = 3 V, V _{CM} = 0 V to 3 V, I _O = –1 mA CAD_IN = 0 V		12	19	Ω
t _{PD}	Propagation Delay	LSTX to ML1(p)_OUT		200		ps
DisplayPort: AUX(p), AUX(n)						
C _{ON}	Outputs ON Capacitance	V _I = 0 V; Outputs Open; Switch ON		6		pF
C _{OFF}	Outputs OFF Capacitance	V _I = 0 V; Outputs Open; Switch OFF		3		pF
R _{ON}	Output ON resistance	V _{DD} = 3.3V; I _O = –10 mA; AUX(p) = 0.3 V; AUX(n) = 3.0 V; CAD_IN = 0 V		12		Ω
ΔR _{ON}	On resistance match between pairs of the same channel	V _{DD} = 3.3 V; I _O = –10 mA; V _{CM} = 0.5 V to 1.5 V			1	Ω
T _{ON}	Control line change to Mux output switched	See Figure 2			40	ms
T _{OFF}					10	μs
Thunderbolt Technology Low Speed UART : LSRX						
C _{ON}	Outputs capacitance			3		pF
Z _O	Output impedance	V _{DD} = 3.3 V		60		Ω
t _{PD}	Propagation delay	ML1(n)_OUT to LSRX		3.2		ns
t _r	Rise Time	V _{DD} = 3 V		3		ns
t _f	Fall Time	V _{DD} = 3 V		3		ns
T _{ON}	Control line change to MUX Output Switched	See Figure 1			400	μs
T _{OFF}					10	μs

ELECTRICAL CHARACTERISTICS (continued)

(under recommended operation conditions)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
DisplayPort : DDC_SCL, DDC_SDA						
C _{ON}	Outputs ON capacitance	V _I = 0 V, Outputs Open, Switch ON		9		pF
C _{OFF}	Outputs OFF capacitance	V _I = 0 V, Outputs Open, Switch OFF		3		pF
R _{ON}	Output ON resistance	V _{DD} = 3.3 V, I _O = −10 mA, V _{CM} = 0.4 V, CAD_IN = 3.3 V		80	150	Ω
T _{ON}	Control line change to MUX output switched	See Figure 1			400	μs
T _{OFF}					10	
UART and 10G MUX Outputs : LSTX/LSRX/10G(p)/10G(n)						
R1	Integrated Pullup Resistance	10G(n) pin when in DP, TMDS, or Detect Mode		87	105	kΩ
R2	Integrated Pulldown Resistance	10G(p) pin when in DP, TMDS, or Detect Mode, or VDD = 0V		87	105	kΩ
R _{PU}	Integrated pullup resistance	LSTX		8.7		kΩ
R _{PD}	Integrated pulldown resistance	LSRX		1.2		MΩ

TEST DIAGRAMS

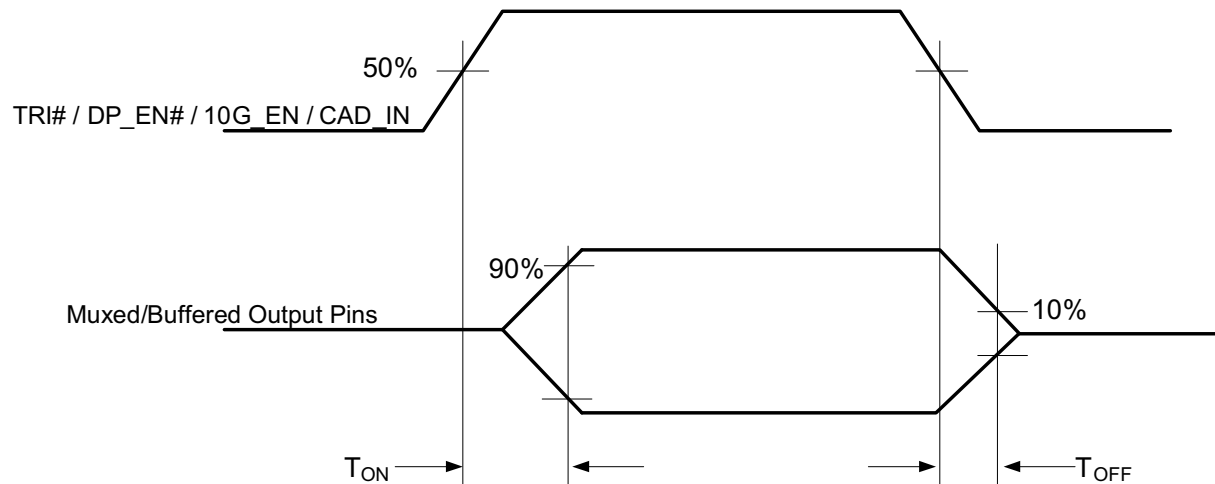
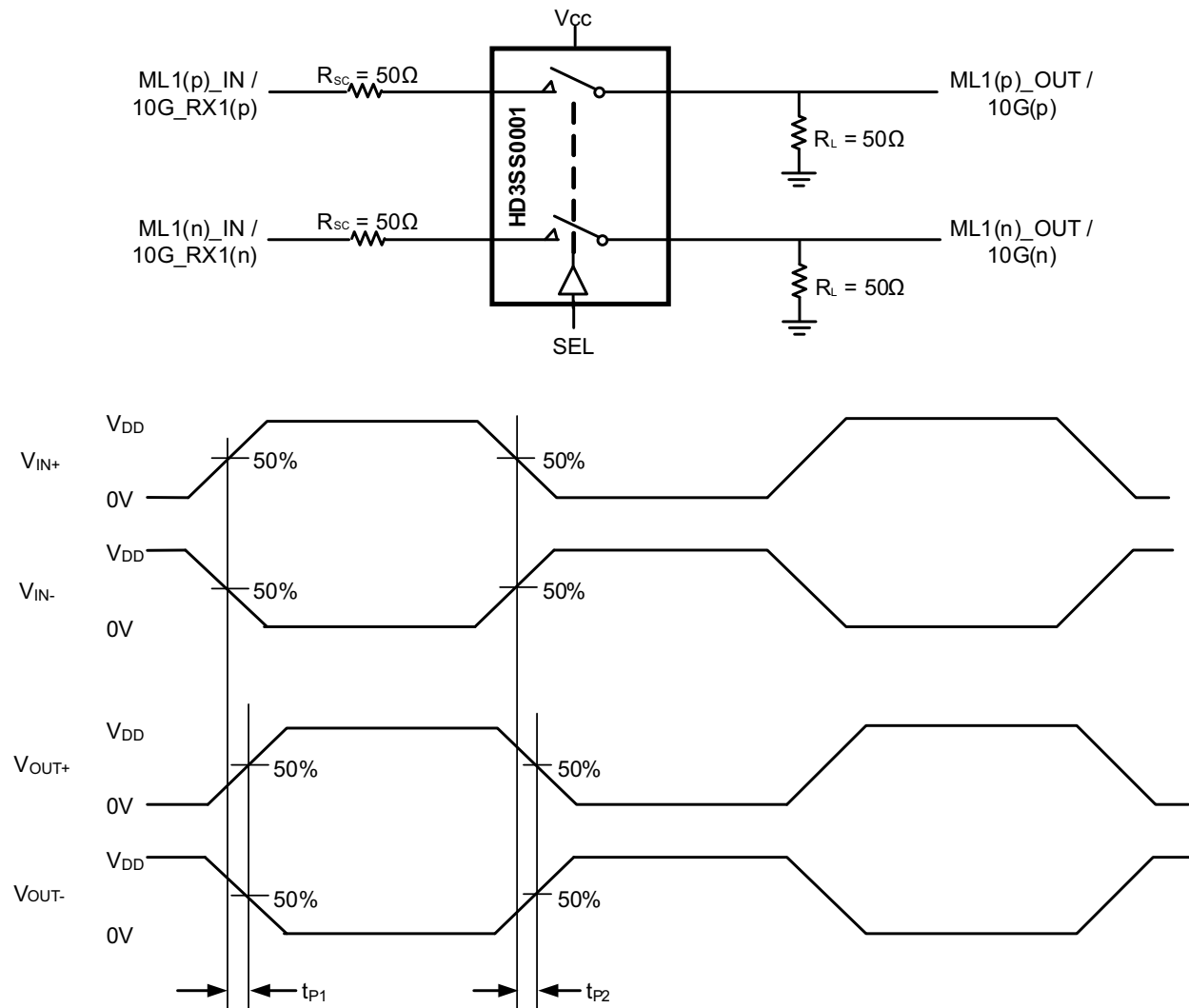


Figure 1. Control Line Change to Switched Signals



$$t_{PD} = \text{Max}(t_{p1}, t_{p2})$$

$t_{SK(O)}$ = Difference between t_{PD} for any two pairs of outputs

$t_{SK(b-b)}$ = Difference between t_{P1} and t_{P2} of same pair

Figure 2. Propagation Delay and Skew

HD3SS0001

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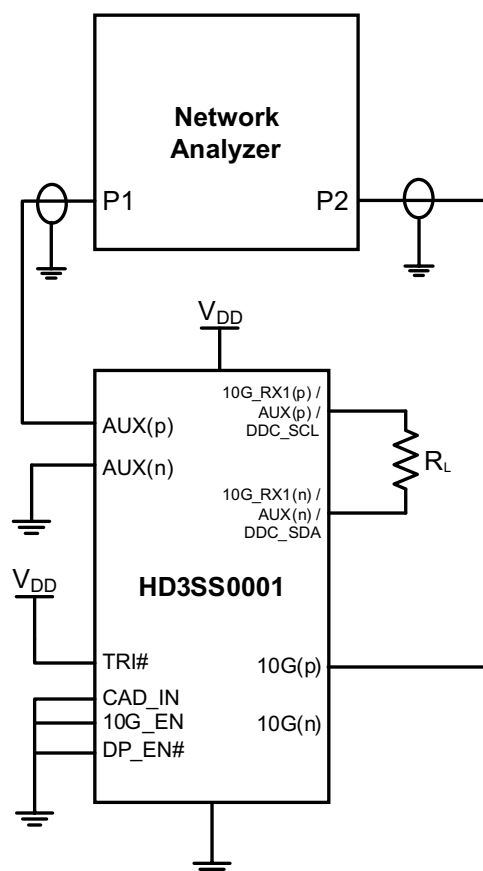


Figure 3. Off-Isolation Measurement Setup

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
HD3SS0001RLLR	ACTIVE	VQFN	RLL	24	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	3SS001	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
HD3SS0001RLLR	VQFN	RLL	24	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS

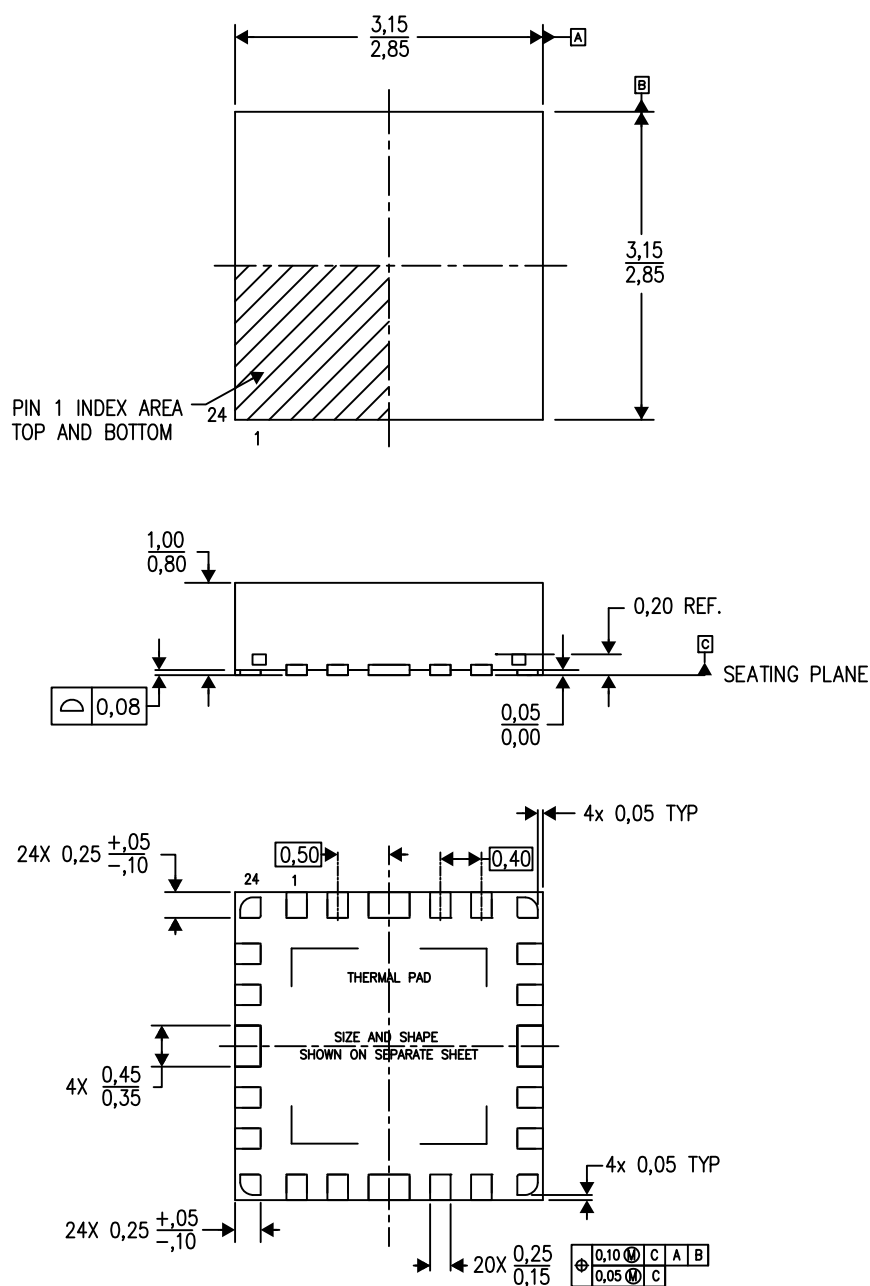


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
HD3SS0001RLLR	VQFN	RLL	24	3000	367.0	367.0	35.0

RLL (S-PVQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



4214704/C 08/13

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - Quad Flatpack, No-leads (QFN) package configuration.
 - The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

THERMAL PAD MECHANICAL DATA

RLL (S-PVQFN-N24)

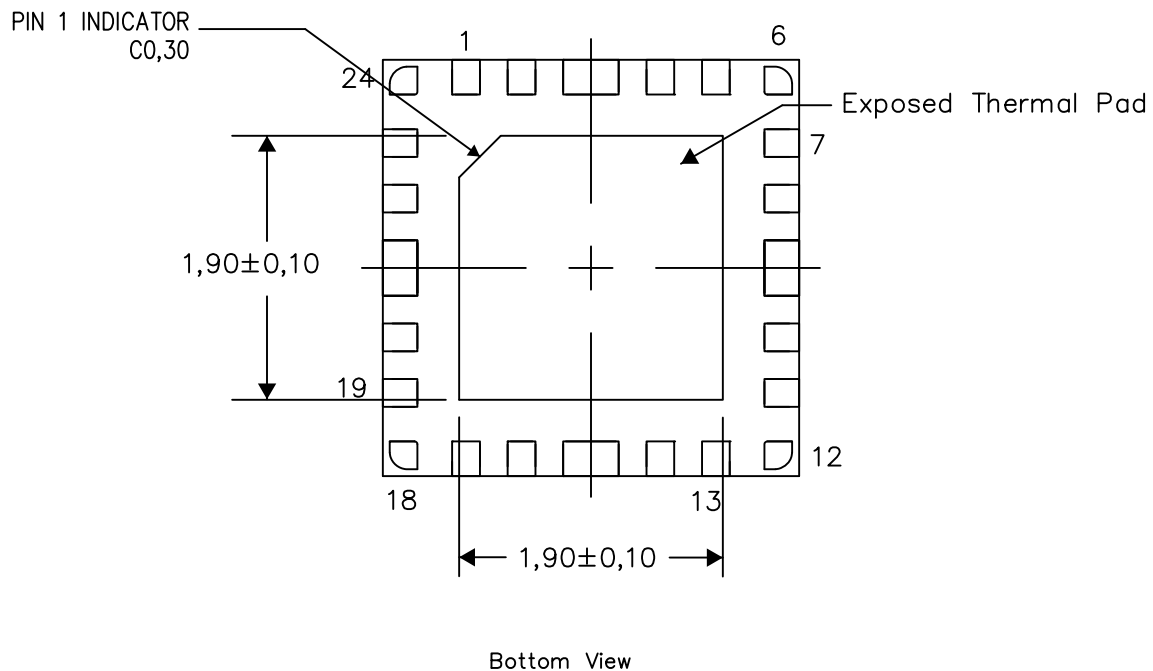
PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

4214706/D 08/13

NOTE: All linear dimensions are in millimeters

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