# 2.5 Gbps 2-TO-1 DVI/HDMI SWITCH

## FEATURES

- **Compatible with HDMI 1.3a**
- **Supports 2.5 Gbps Signaling Rate for 480i/p, 720i/p, and 1080i/p Resolutions up to 12-Bit Color Depth**
- **Integrated Switchable Receiver Termination**
- **Selectable Receiver Equalization to Accommodate to Different Input Cable Lengths**
- **Intra-Pair Skew < 40 ps**
- **Inter-Pair Skew < 65 ps**
- **HBM ESD Protection Exceeds 8 kV to TMDS Inputs**
- **3.3-V Fixed Supply to TMDS I/Os**
- **5-V Fixed Supply to HPD, DDC, and Source Selection Circuits**
- **64-Pin TQFP Package**
- **Footprint Compatible with 3-to-1 Switch TMDS351 with Port 1 Disabled**
- **ROHS Compatible and 260°C Reflow Rated**
- **TMDS251 is Available with Port 3 Disabled and Ports 1 and 2 Enabled**
- **Supports 5-V to 3.3-V Level Shifting on DDC Links**

## APPLICATIONS

- **Digital TV**
- **Digital Projector**

## DESCRIPTION

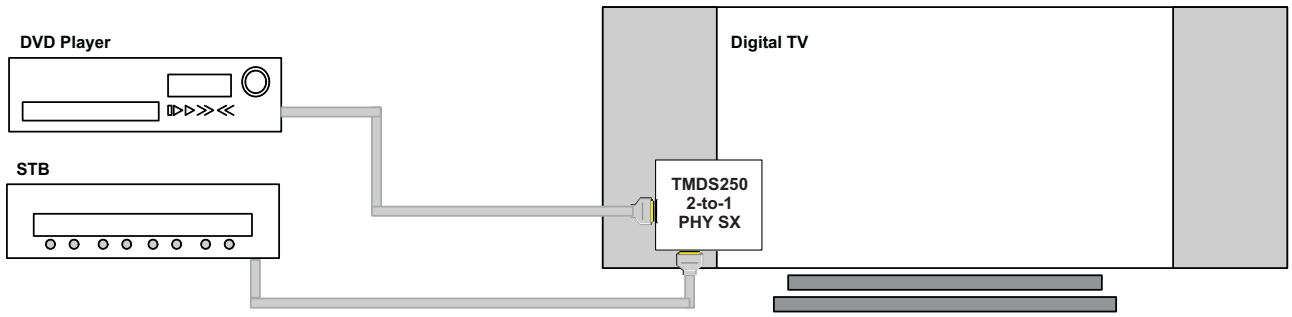
The TMDS250 is a 2-port digital video interface (DVI) or high-definition multimedia interface (HDMI) switch that allows up to 2 DVI or HDMI ports to be switched to a single display terminal. Four TMDS channels, one hot plug detector, and a digital display control (DDC) interface are supported on each port. Each TMDS channel supports signaling rates up to 2.5 Gbps to allow 1080p resolution in 12-bit color depth.

The input port is enabled by configuring source selectors, S1 and S2. When an input port is selected, the TMDS inputs are connected to the TMDS outputs through a 2-to-1 multiplexer, the MOSFET between the input DDC channel and the output DDC channel is turned on, and the HPD output follows the state of the HPD_SINK. The other input port is inactive with disconnected input terminations, disconnected TMDS inputs to the outputs, disconnected DDC inputs to the outputs, and the HPD outputs are low state. Check the source selection look up table for the details of port selections.

When S1 is high and S2 is low, all input terminations are disconnected, TMDS inputs are high impedance with standard TMDS terminations, all internal MOSFETs are turned off to disable the DDC links, and all HPD outputs are connected to the HPD_SINK. This allows the initiation of the HDMI physical address discovery process.

Termination resistors (50-Ω), pulled up to $V_{CC}$, are integrated at each TMDS receiver input. External terminations are not required. A precision resistor is connected externally from the VSADJ pin to ground for setting the differential output voltage to be compliant with the TMDS standard.

**Typical Application**




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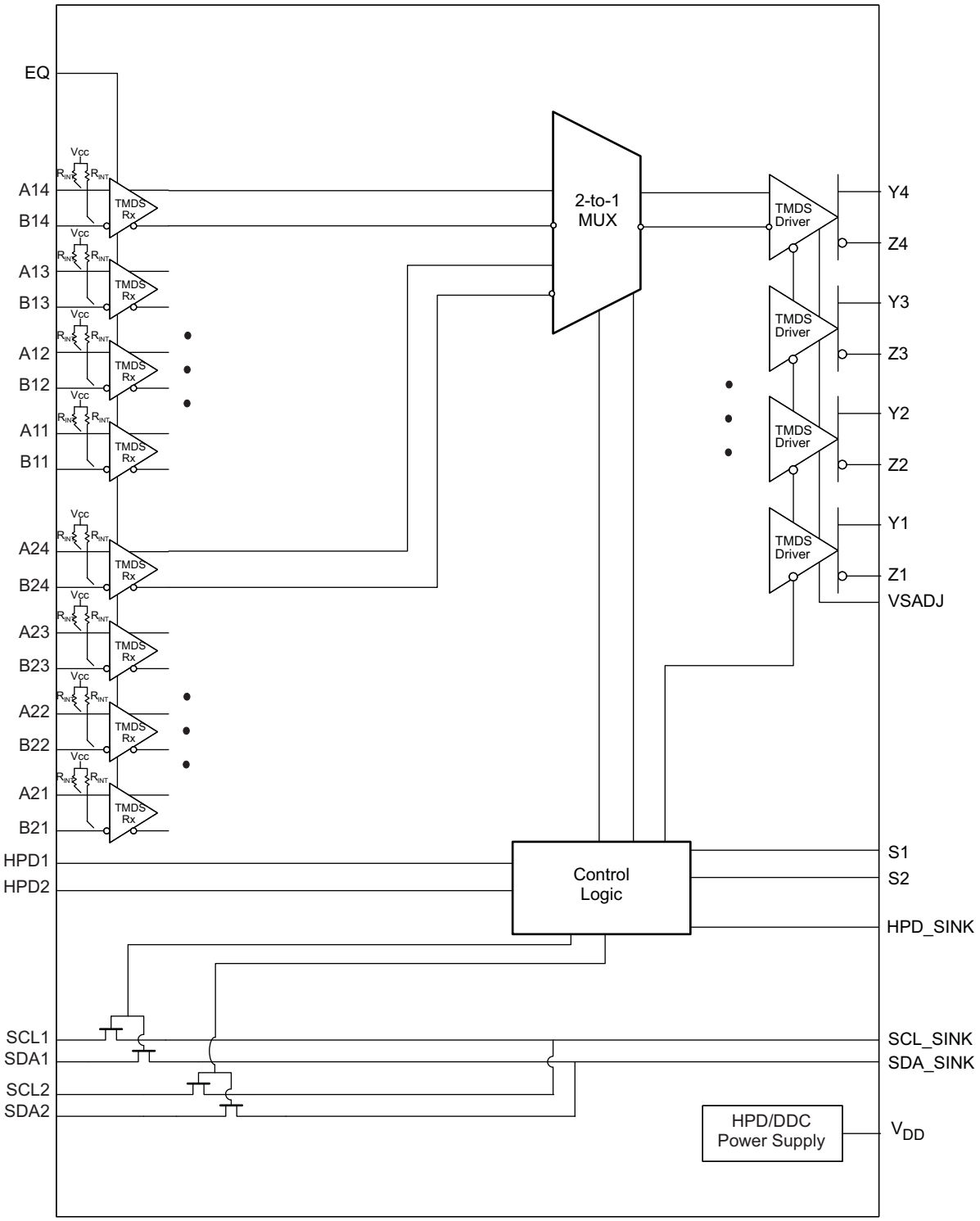
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The TMDS250 provides two levels of receiver input equalization for different ranges of cable lengths. Each TMDS receiver owns frequency responsive equalization circuits. When EQ sets low, the receiver supports the input connection in short range HDMI cables. When EQ sets high, the receiver supports the input connection in long range HDMI cables. The TMDS250 supports power saving operation. When a system is under standby mode and there is no digital audio/visual content from a connected source, the 3.3-V supply voltage, $V_{CC}$, can be powered off to minimize power consumption from the TMDS inputs, outputs, and internal switching circuits. The HPD, DDC, and source selection circuits are powered up by the 5-V supply voltage, $V_{DD}$, to maintain the system hot plug detect response, the DDC link from the selected source to the sink under system standby operation. The device is characterized for operation from 0°C to 70°C.

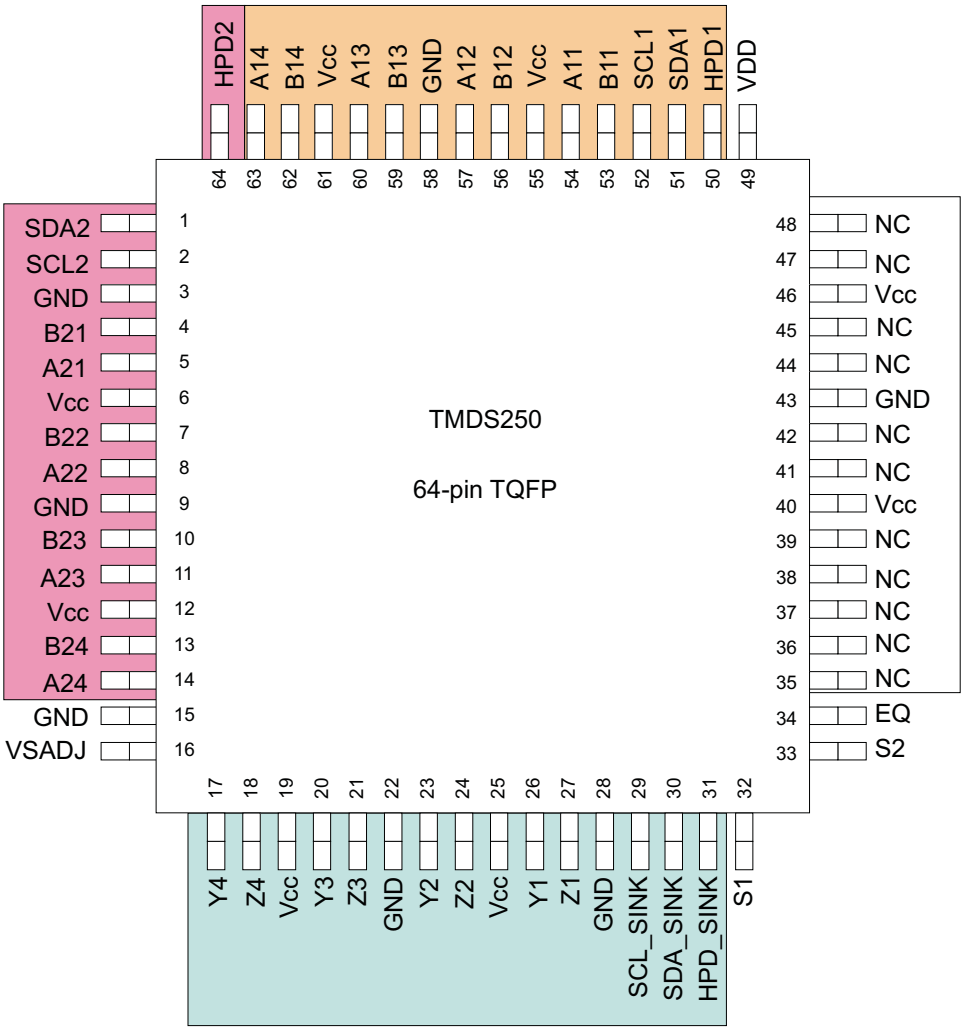

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## FUNCTIONAL BLOCK DIAGRAM



**PAG PACKAGE**
**(TOP VIEW)**





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## TERMINAL FUNCTIONS

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| A11, A12, A13, A14 | 54, 57, 60, 63 | I | Source port 1 TMDS positive inputs |
| A21, A22, A23, A24 | 5, 8, 11, 14 | I | Source port 2 TMDS positive inputs |
| B11, B12, B13, B14 | 53, 56, 59, 62 | I | Source port 1 TMDS negative inputs |
| B21, B22, B23, B24 | 4, 7, 10, 13 | I | Source port 2 TMDS negative inputs |
| Y1, Y2, Y3, Y4 | 26, 23, 20, 17 | O | Sink port TMDS positive outputs |
| Z1, Z2, Z3, Z4 | 27, 24, 21, 18 | O | Sink port TMDS negative outputs |
| SCL1 | 52 | I/O | Source port 1 DDC $I^2C$ clock line |
| SDA1 | 51 | I/O | Source port 1 DDC $I^2C$ data line |
| SCL2 | 2 | I/O | Source port 2 DDC $I^2C$ clock line |
| SDA2 | 1 | I/O | Source port 2 DDC $I^2C$ data line |
| SCL_SINK | 29 | I/O | Sink port DDC $I^2C$ clock line |
| SDA_SINK | 30 | I/O | Sink port DDC $I^2C$ data line |
| HPD1 | 50 | O | Source port 1 hot plug detector output (status pin) |
| HPD2 | 64 | O | Source port 2 hot plug detector output (status pin) |
| HPD_SINK | 31 | I | Sink port hot plug detector input (status pin) |
| S1, S2 | 32, 33 | I | Source selector |
| EQ | 34 | I | TMDS Input equalization selector (control pin)<br>EQ = Low – HDMI 1.3 compliant cable<br>EQ = High – 10m 28 AWG HDMI cable |
| VSADJ | 16 | I | TMDS compliant voltage swing control (control pin) |
| $V_{DD}$ | 49 | | HPD/DDC Power supply |
| $V_{CC}$ | 6, 12, 19, 25, 40, 46, 55, 61 | | Power supply |
| GND | 3, 9, 15, 22, 28, 43, 58 | | Ground |
| NC | 35-39, 41, 42, 44, 45, 47, 48 | | No connect: these pins should be left floating |

### Table 1. Source Selection Lookup(1)

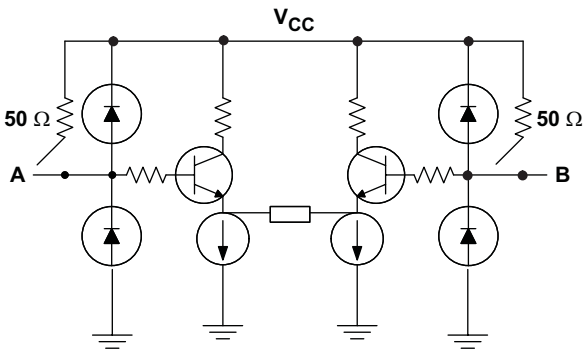
| CONTROL BITS | | I/O SELECTED | | HOT PLUG DETECT STATUS | |
|---|---|---|---|---|---|
| S1 | S2 | Y/Z | SCL_SINK<br>SDA_SINK | HPD1 | HPD2 |
| L | H | A1/B1<br>Terminations of A2/B2 are disconnected | SCL1<br>SDA1 | HPD_SINK | L |
| L | L | A2/B2<br>Terminations of A1/B1 are disconnected | SCL2<br>SDA2 | L | HPD_SINK |
| H | H | Disallowed (indeterminate) State<br>All terminations are disconnected | None (Z)<br>Are pulled HIGH by external pull-up termination | L | L |
| H | L | None (Z)<br>All terminations are disconnected | | HPD_SINK | HPD_SINK |

(1) H: Logic high; L: Logic low; X: Don't care; Z: High impedance

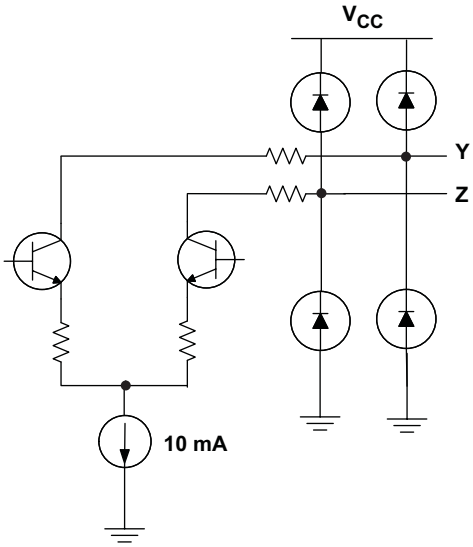
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## EQUIVALENT INPUT AND OUTPUT SCHEMATIC DIAGRAMS

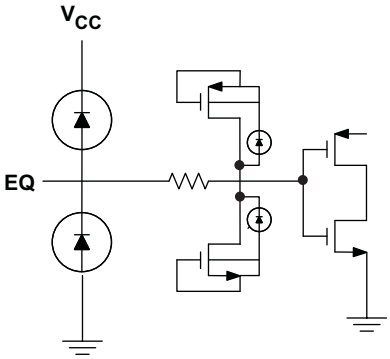
**TMDS Input Stage**



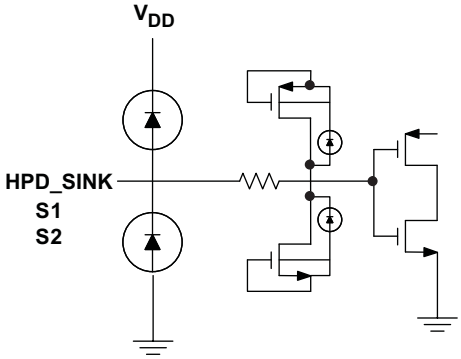

**TMDS Output Stage**



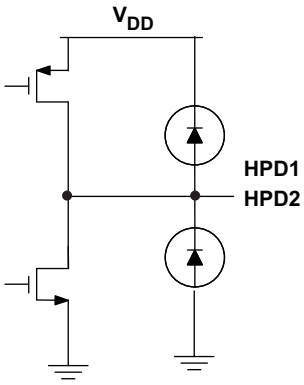

**Control Input Stage**



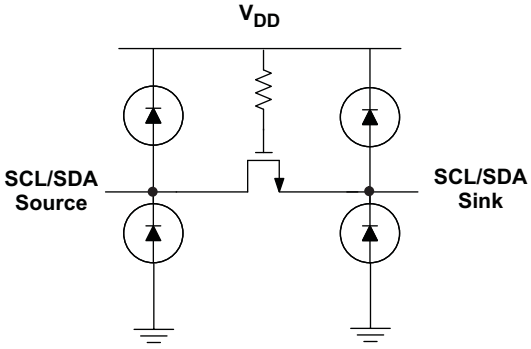

**Status and Source Selector**




**HPD Output Stage**




**DDC Pass Gate**





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## ORDERING INFORMATION(1)

| PART NUMBER | PART MARKING | PACKAGE |
|---|---|---|
| TMDS250PAGR | TMDS250 | 64-PIN TQFP Tape/Reel |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)(1)

| | | | UNIT |
|---|---|---|---|
| Supply voltage range(2) | $V_{CC}$ | | –0.5 V to 4 V |
| | $V_{DD}$ | | –0.5 V to 6 V |
| Voltage range | Anm(3), Bnm | | 2.5 V to 4 V |
| | Ym, Zm, VSADJ, EQ | | –0.5V to 4 V |
| | SCLn, SCL_SINK, SDAn, SDA_SINK, HPDn, HPD_SINK, S1, S2 | | –0.5 V to 6 V |
| Electrostatic discharge | Human body model(4) | Anm, Bnm, Ym, Zm | ±8000 V |
| | | All pins | ±4000 V |
| | Charged-device model(5) (all pins) | | ±1500 V |
| | Machine model (6) (all pins) | | ±200 V |
| Continuous power dissipation | | | See Dissipation Rating Table |

(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 other 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 I/O bus voltages, are with respect to network ground terminal.
(3) n = 1, 2; m = 1, 2, 3, 4
(4) Tested in accordance with JEDEC Standard 22, Test Method A114-B
(5) Tested in accordance with JEDEC Standard 22, Test Method C101-A
(6) Tested in accordance with JEDEC Standard 22, Test Method A115-A

## DISSIPATION RATINGS

| PACKAGE | PCB JEDEC STANDARD | $T_A \le 25°C$ | DERATING FACTOR (1) ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING |
|---|---|---|---|---|
| 64-TQFP PAG | Low-K | 1111 mW | 11.19 mW/°C | 611 mW |
| | High-K | 1492 mW | 14.92 | 820 mW |

(1) This is the inverse of the junction-to-ambient thermal resistance when board-mounted and with no air flow.

## THERMAL CHARACTERISTICS

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

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX(1) | UNIT |
|---|---|---|---|---|---|---|
| $R_{\theta JB}$ | Junction-to-board thermal resistance | | | 33.4 | | °C/W |
| $R_{\theta JC}$ | Junction- to-case thermal resistance | | | 15.6 | | °C/W |
| $P_D$ | Device power dissipation | $V_{IH} = V_{CC}$, $V_{IL} = V_{CC}$ - 0.6 V, $R_T$ = 50 Ω, $AV_{CC}$ = 3.3V, Am/Bm(2:4) = 2.5-Gbps HDMI data pattern, Am/Bm(1) = 250-MHz clock | | 590 | 750 | mW |

(1) The maximum rating is simulation under 3.6-V $V_{CC}$, 5.5-V $V_{DD}$, and 600 mV $V_{ID}$.

## RECOMMENDED OPERATING CONDITIONS

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage | 3 | 3.3 | 3.6 | V |
| $V_{DD}$ | Standby supply voltage | 4.5 | 5 | 5.5 | V |

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## RECOMMENDED OPERATING CONDITIONS (continued)

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $T_A$ | Operating free-air temperature | 0 | | 70 | °C |
| **TMDS DIFFERENTIAL PINS** | | | | | |
| $V_{IC}$ | Input common mode voltage | $V_{CC}$–0.4 | | $V_{CC}$+0.01 | V |
| $V_{ID}$ | Receiver peak-to-peak differential input voltage | 150 | | 1560 | mVp-p |
| $R_{VSADJ}$ | Resistor for TMDS compliant voltage swing range | 3.66 | 4.02 | 4.47 | kΩ |
| $AV_{CC}$ | TMDS output termination voltage, see Figure 1 | 3 | 3.3 | 3.6 | V |
| $R_T$ | Termination resistance, see Figure 1 | 45 | 50 | 55 | Ω |
| | Signaling rate | 0 | | 2.5 | Gbps |
| **CONTROL PINS** | | | | | |
| $V_{IH}$ | LVTTL High-level input voltage | 2 | | $V_{CC}$ | V |
| $V_{IL}$ | LVTTL Low-level input voltage | GND | | 0.8 | V |
| **DDC I/O PINS** | | | | | |
| $V_{I(DDC)}$ | DDC Input voltage | GND | | $V_{DD}$ | V |
| **STATUS and SOURCE SELECTOR PINS** | | | | | |
| $V_{IH}$ | LVTTL High-level input voltage | 2 | | $V_{DD}$ | V |
| $V_{IL}$ | LVTTL Low-level input voltage | GND | | 0.8 | V |

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP(1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_{CC}$ | Supply current | $V_{IH}$ = $V_{CC}$, $V_{IL}$ = $V_{CC}$ – 0.6 V, $R_T$ = 50 Ω, $AV_{CC}$ = 3.3 V Am/Bm(2:4) = 2.5 Gbps HDMI data pattern Am/Bm(1) = 250 MHz clock | S1/S2 = Low/Low, Low/High, High/High | | 176 | 200 | mA |
| | | | S1/S2 = High/Low | | 8 | 20 | |
| $I_{DD}$ | Power supply current, 5-V | $V_{IH}$ = $V_{CC}$, $V_{IL}$ = $V_{CC}$ – 0.6 V, $R_T$ = 50 Ω, $AV_{CC}$ = 3.3 V Am/Bm(2:4) = 2.5 Gbps HDMI data pattern Am/Bm(1) = 250 MHz clock | | | 2 | 5 | mA |
| **TMDS DIFFERENTIAL PINS** | | | | | | | |
| $V_{OH}$ | Single-ended high-level output voltage | See Figure 2, $AV_{CC}$ = 3.3 V, $R_T$ = 50 Ω | | $AV_{CC}$–10 | | $AV_{CC}$+10 | mV |
| $V_{OL}$ | Single-ended low-level output voltage | | | $AV_{CC}$–600 | | $AV_{CC}$–400 | mV |
| $V_{swing}$ | Single-ended output swing voltage | | | 400 | | 600 | mV |
| $V_{OD(O)}$ | Overshoot of output differential voltage | | | | | 15% | 2× $V_{swing}$ |
| $V_{OD(U)}$ | Undershoot of output differential voltage | | | | | 25% | 2× $V_{swing}$ |
| $\Delta V_{OC(SS)}$ | Change in steady-state common-mode output voltage between logic states | | | | | 5 | mV |
| $I_{(OS)}$ | Short circuit output current | See Figure 3 | | -12 | | 12 | mA |
| $V_{I(open)}$ | Single-ended input voltage under high impedance input or open input | $I_I$ = 10 µA | | $V_{CC}$–10 | | $V_{CC}$+10 | mV |
| $R_{INT}$ | Input termination resistance | $V_{IN}$ = 2.9 V | | 45 | 50 | 55 | Ω |
| **CONTROL PINS** | | | | | | | |
| $I_{IH}$ | High-level digital input current(2) | $V_{IH}$ = 2 V or $V_{CC}$ | | -10 | | 10 | µA |
| $I_{IL}$ | Low-level digital input current(2) | $V_{IL}$ = GND or 0.8 V | | -10 | | 10 | µA |
| **DDC I/O PINS** | | | | | | | |
| $I_{lkg}$ | Input leakage current | $V_I$ = 0.1 $V_{DD}$ to 0.9 $V_{DD}$ to isolated DDC inputs | | -10 | | 10 | µA |
| $C_{IO}$ | Input/output capacitance | $V_{I(pp)}$ = 1 V, 100 kHz | | | | 10 | pF |
| $R_{ON}$ | Switch resistance | $I_O$ = 3 mA, $V_O$ = 0.4 V | | | 27 | 40 | Ω |
| $V_{PASS}$ | Switch output voltage | $V_I$ = 5 V, $I_O$ = 100 µA | | 2.4 | | 2.7 | V |
| **STATUS AND SOURCE SELECTOR PINS** | | | | | | | |

(1) All typical values are at 25°C and with a 3.3-V supply.
(2) $I_{IH}$ and $I_{IL}$ specifications are not applicable to the VSADJ pin.


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## ELECTRICAL CHARACTERISTICS (continued)

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP(1) | MAX | UNIT |
|---|---|---|---|---|---|---|
| $I_{IH}$ | High-level digital input current | $V_{IH}$ = 2 V or $V_{DD}$ | -10 | | 10 | µA |
| $I_{IL}$ | Low-level digital input current | $V_{IL}$ = GND or 0.8 V | -10 | | 10 | µA |
| $V_{OH}$ | TTL High-level output voltage | $I_{OH}$ = –100 µA | 2.4 | | $V_{DD}$ | V |
| $V_{OL}$ | TTL Low-level output voltage | $I_{OL}$ = 100 µA | GND | | 0.4 | V |

## SWITCHING CHARACTERISTICS(1)

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP(2) | MAX | UNIT |
|---|---|---|---|---|---|---|
| **TMDS DIFFERENTIAL PINS (Y/Z)** | | | | | | |
| $t_{PLH}$ | Propagation delay time, low-to-high-level output | See Figure 2, $AV_{CC}$ = 3.3 V, $R_T$ = 50 Ω | 400 | 650 | 900 | ps |
| $t_{PHL}$ | Propagation delay time, high-to-low-level output | | 400 | 650 | 900 | ps |
| $t_r$ | Differential output signal rise time (20% - 80%) | | 60 | 80 | 140 | ps |
| $t_f$ | Differential output signal fall time (20% - 80%) | | 60 | 80 | 140 | ps |
| $t_{sk(p)}$ | Pulse skew ($\lvert t_{PHL} - t_{PLH} \rvert$)(3) | | | 6 | 20 | ps |
| $t_{sk(D)}$ | Intra-pair differential skew, see Figure 4 | | | 20 | 40 | ps |
| $t_{sk(o)}$ | Inter-pair channel-to-channel output skew(4) | | | 30 | 65 | ps |
| $t_{sk(pp)}$ | Part-to-part skew (5) | | | | 510 | ps |
| $t_{jit(pp)}$ | Peak-to-peak output jitter from Yj/Zj(1) residual jitter | See Figure 5, Am/Bm(1) = 250 MHz clock, Am/Bm(2:4) = 2.5 Gbps HDMI pattern | | 8 | 20 | ps |
| $t_{jit(pp)}$ | Peak-to-peak output jitter from Yj/Zj(2:4) residual jitter | | | 60 | 80 | ps |
| $t_{SX}$ | Select to switch output | See Figure 6, 10-mA Current source to the input | | 50 | 70 | ns |
| $t_{en}$ | Enable time | | | 170 | 200 | ns |
| $t_{dis}$ | Disable time | | | 9 | 15 | ns |
| $t_{pd(DDC)}$ | Propagation delay from SCLn to SCL_SINK or SDAn to SDA_SINK or SDA_SINK to SDAn | See Figure 7, $C_L$ = 10 pF | | 8 | 15 | ns |
| $t_{sx(DDC)}$ | Switch time from SCLn to SCL_SINK | | | 8 | 15 | ns |
| $t_{pd(HPD)}$ | Propagation delay (from HPD_SINK to the active port of HPD) | | | 14 | 20 | ns |
| $t_{sx(HPD)}$ | Switch time from port select to the latest valid status of HPD | | | 33 | 50 | ns |

(1) Measurements are made with the Agilent 81250 ParBert System with a N4872A generator (600 fs $t_{JIT(CLK)}$, 13 ps $t_{JIT(pp)}$) and a N4873A analyzer.
(2) All typical values are at 25°C and with a 3.3-V supply.
(3) $t_{sk(p)}$ is the magnitude of the time difference between $t_{PLH}$ and $t_{PHL}$ of a specified terminal.
(4) $t_{sk(o)}$ is the magnitude of the difference in propagation delay times between any specified terminals of a sink-port bank when inputs of the active source port are tied together.
(5) $t_{sk(pp)}$ is the magnitude of the difference in propagation delay times between any specified terminals of two devices when both devices operate with the same source, the same supply voltages, at the same temperature, and have identical packages and test circuits.

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## PARAMETER MEASUREMENT INFORMATION

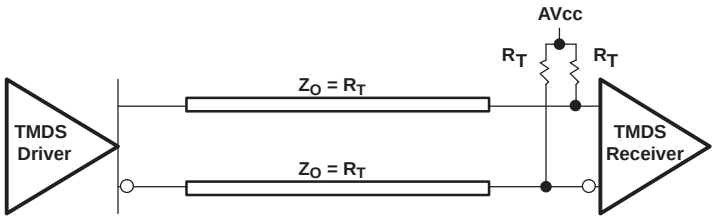
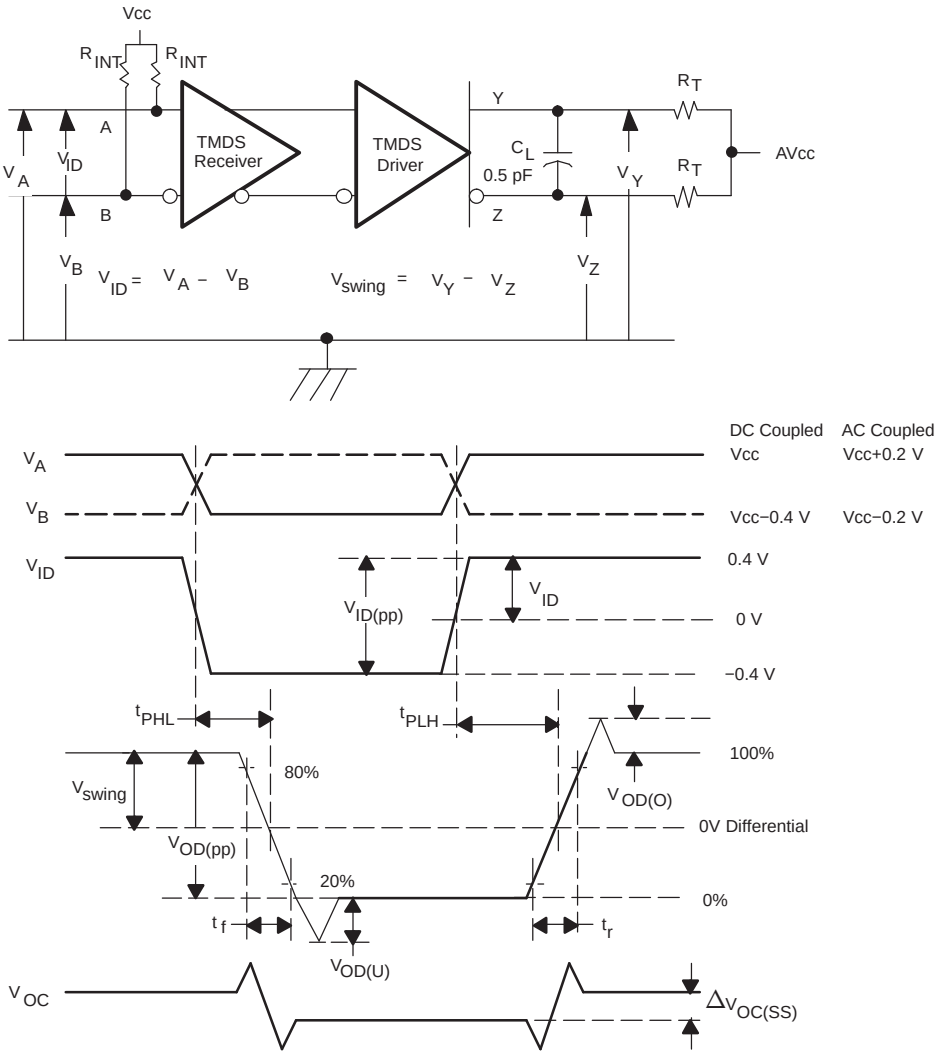



**Figure 1. Termination for TMDS Output Driver**




NOTE: All input pulses are supplied by a generator having the following characteristics: $t_r$ or $t_f$ < 100 ps, 100 MHz from Agilent 81250. $C_L$ includes instrumentation and fixture capacitance within 0.06 m of the D.U.T. Measurement equipment provides a bandwidth of 20 GHz minimum.

**Figure 2. TMDS Input, Output, and Timing Definitions**


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## PARAMETER MEASUREMENT INFORMATION (continued)

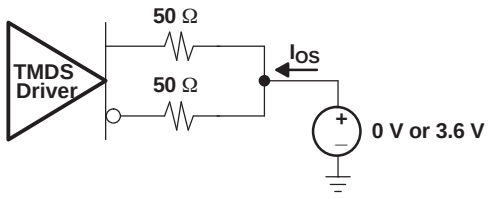



**Figure 3. Short Circuit Output Current Test Circuit**

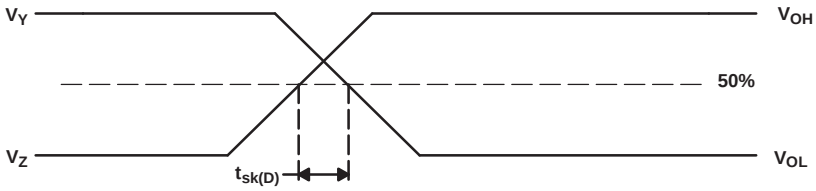
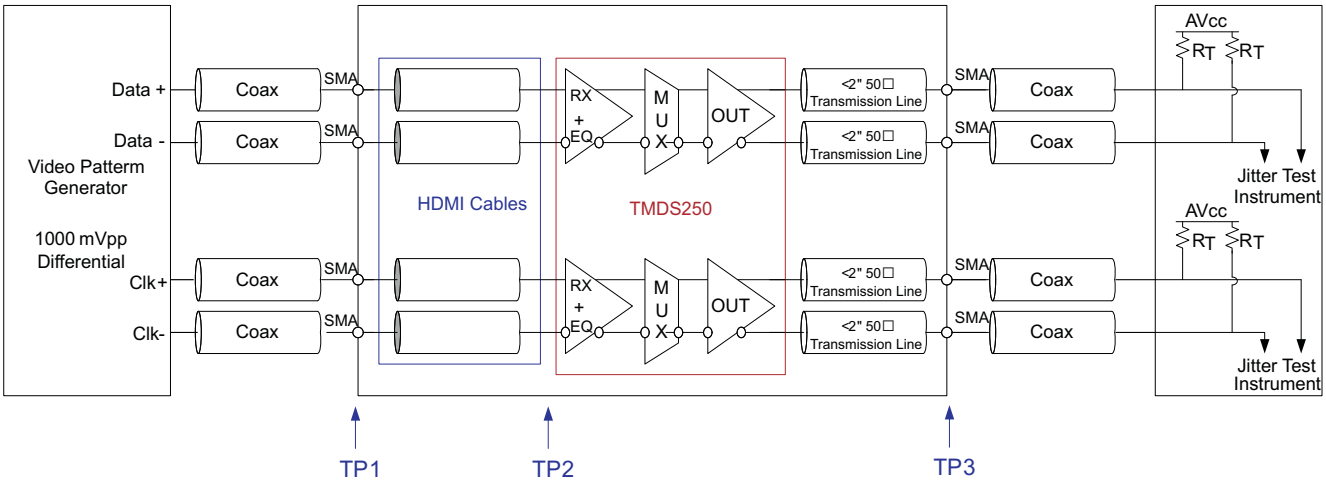



**Figure 4. Definition of Intra-Pair Differential Skew**




A. HDMI 1.3 compliant cable when EQ = Low, and 10m 28AWG input cable when EQ = High.

B. All jitters are measured in BER of $10^{-9}$

C. The residual jitter reflects the total jitter measured at the output of the DUT, TP3, subtract the total jitter from the signal generator, TP1

**Figure 5. Jitter Test Circuit**

## PARAMETER MEASUREMENT INFORMATION (continued)

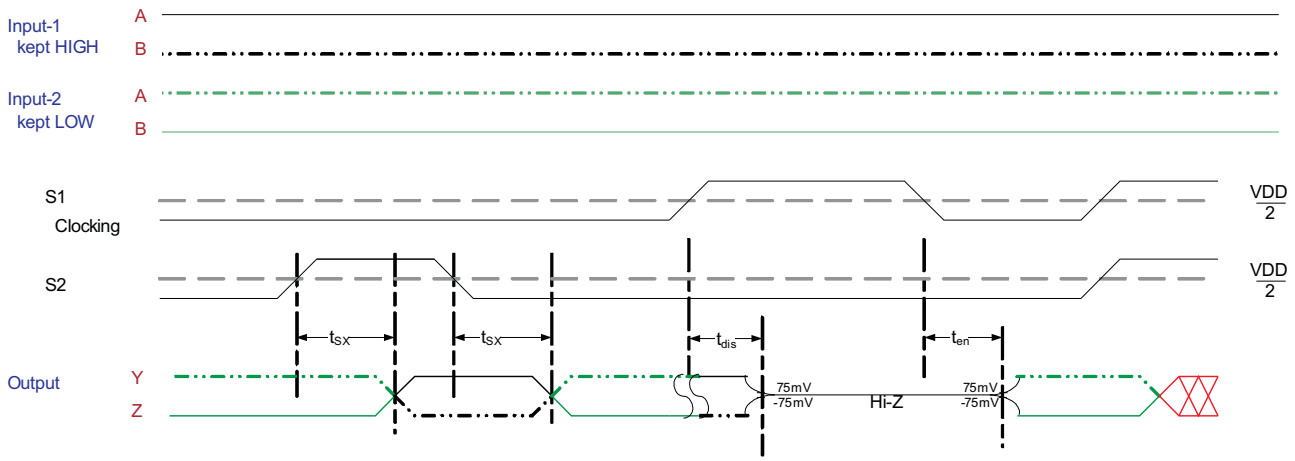



**Figure 6. TMDS Outputs Control Timing Definitions**

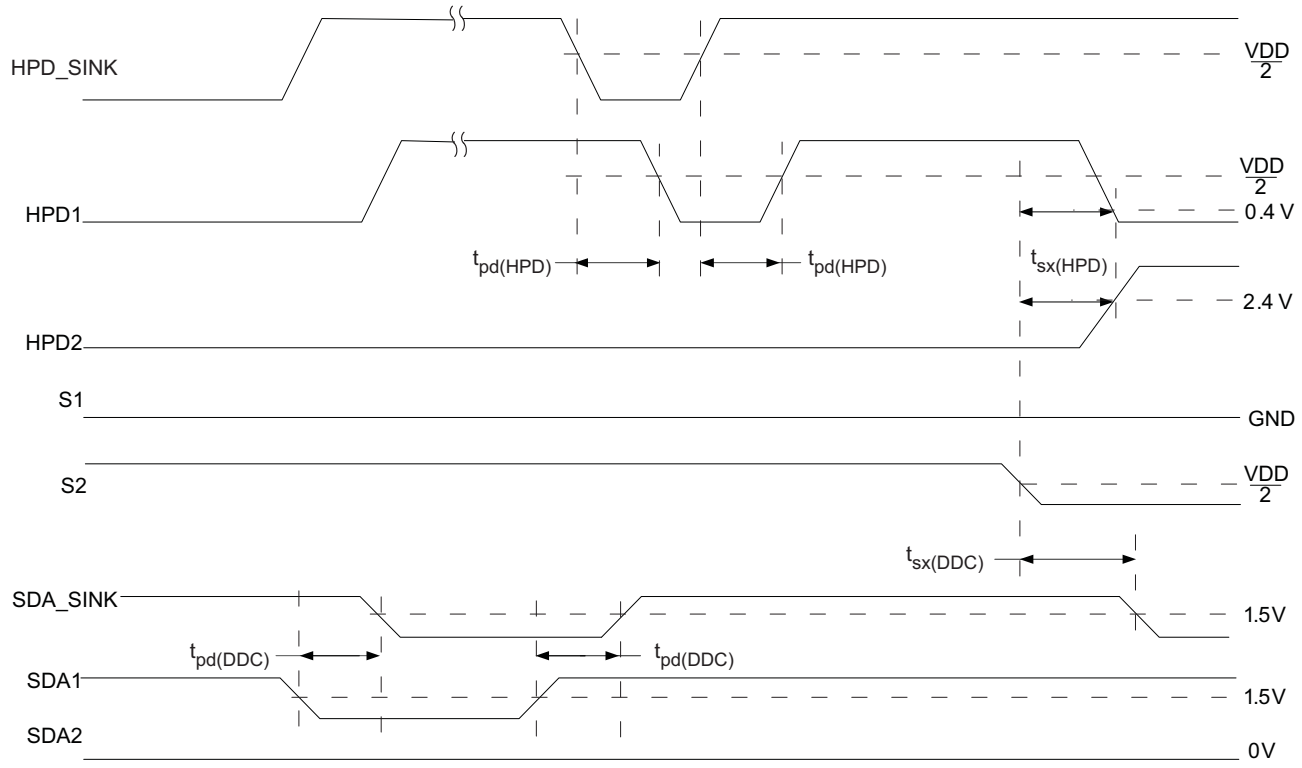



**Figure 7. Port Switch Timing Definitions**


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## TYPICAL CHARACTERISTICS

SUPPLY CURRENT
vs
SIGNAL RATE

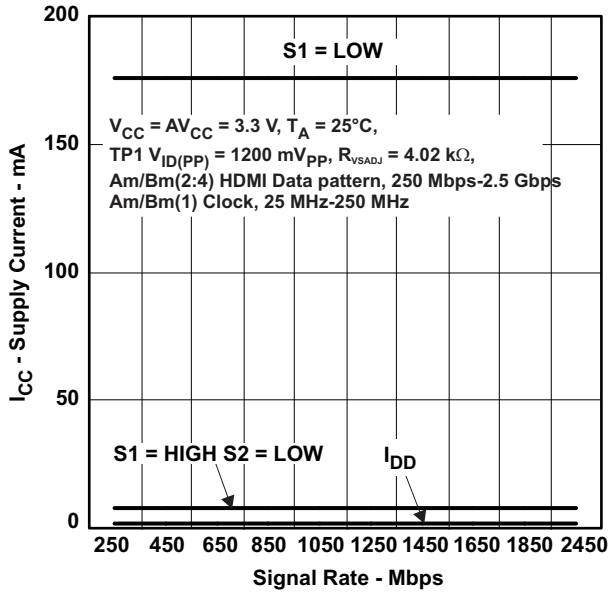



Figure 8.

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

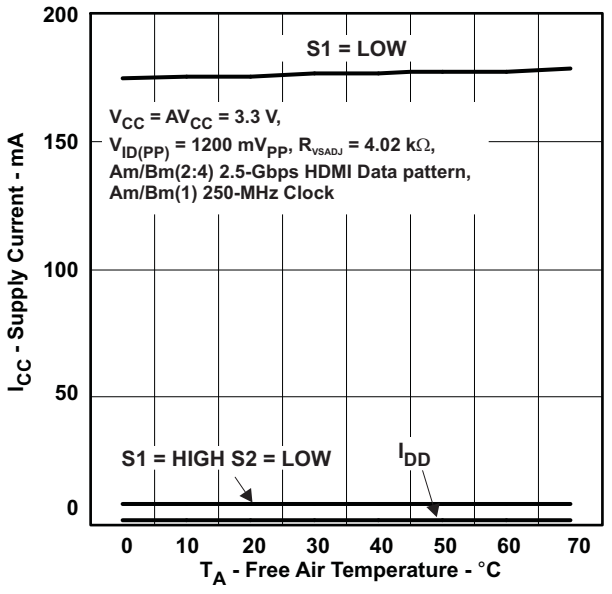
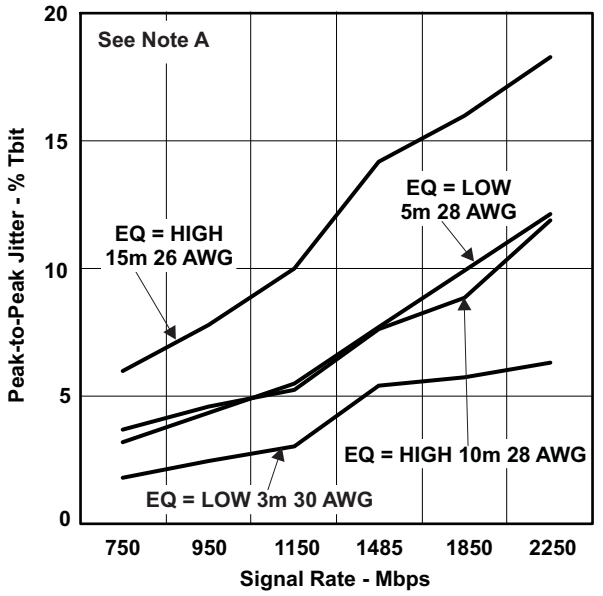



Figure 9.

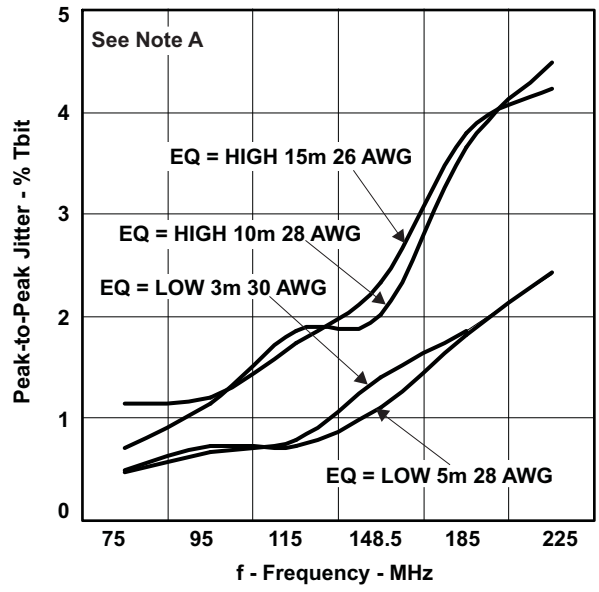
RESIDUAL PEAK-TO-PEAK JITTER
(Data Channels)
vs
SIGNAL RATE




A. Channels 2, 3, 4, $V_{CC}$ = $AV_{CC}$ = 3.3 V, $T_A$ = 25°C, $R_{VSADJ}$ = 4.02 kΩ, See Figure 5

**Figure 10.**

RESIDUAL PEAK-TO-PEAK JITTER
(Clock Channel)
vs
FREQUENCY

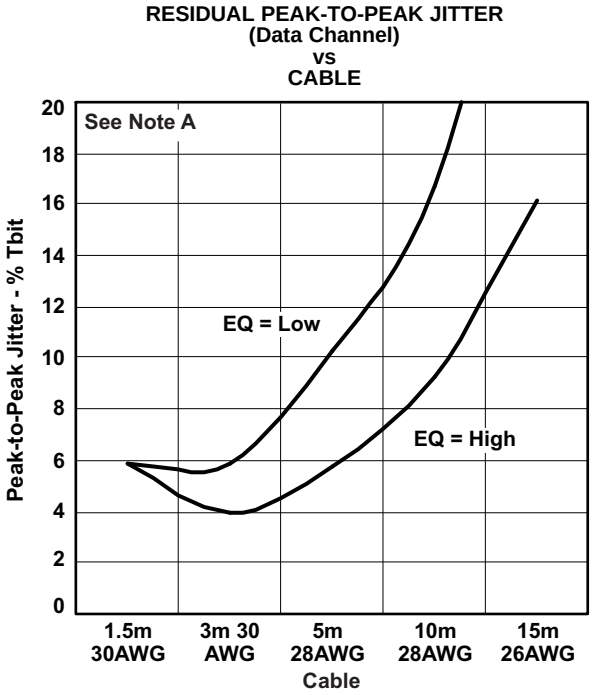



A. Channel 1, $V_{CC}$ = $AV_{CC}$ = 3.3 V, $T_A$ = 25°C, $R_{VSADJ}$ = 4.02 kΩ, See Figure 5

**Figure 11.**

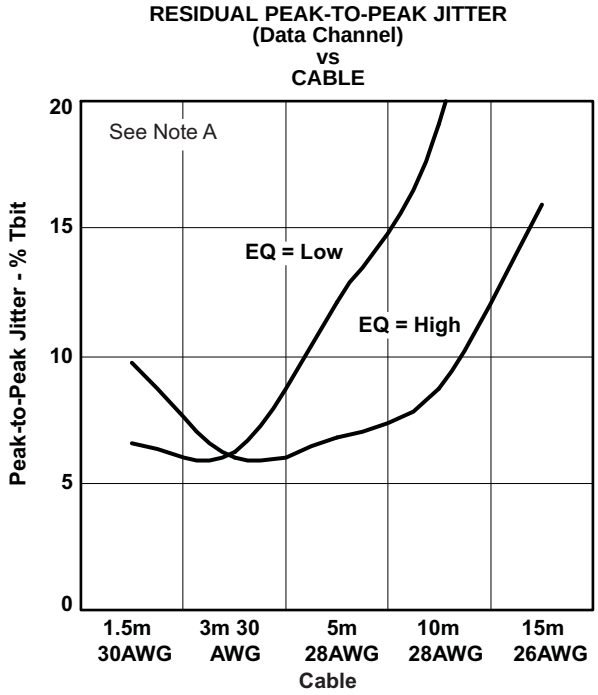
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## TYPICAL CHARACTERISTICS (continued)




A. 1080p 10-Bit, $V_{CC}$ = $AV_{CC}$ = 3.3 V, $T_A$ = 25°C, $R_{VSADJ}$ = 4.02 kΩ, See Figure 5, Clock Channel = 185.6 MHz, Data Channel = 1.856 Gbps

**Figure 12.**




A. 1080p 12-Bit, $V_{CC}$ = $AV_{CC}$ = 3.3 V, $T_A$ = 25°C, $R_{VSADJ}$ = 4.02 kΩ, See Figure 5, Clock Channel = 222.8 MHz, Data Channel = 2.228 Gbps

**Figure 13.**


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## APPLICATION INFORMATION

### Supply Voltage

The TMDS250 is powered up with two different power sources. One is 3.3-V $V_{CC}$ for the TMDS circuitry, and the other is 5-V $V_{DD}$ for HPD, DDC, and most of the control logic. It is recommended to provide the same 3.3-V power source to the TMDS circuitry of the TMDS250 and its output termination voltage. This minimizes the leakage current from the ESD protection circuitry. When the digital television (DTV) is in standby mode operation, the same common 3.3-V power source can be turned on or off. Either way will minimize the leakage current in the device, and in the receiver connected at the output where the termination is integrated.

### TMDS Inputs

Selectable frequency response equalization circuitries are provided to all twelve differential input to support short range and long range cable connections. The frequency response compensation curves and target cable losses are shown in Figure 14 and Figure 15.

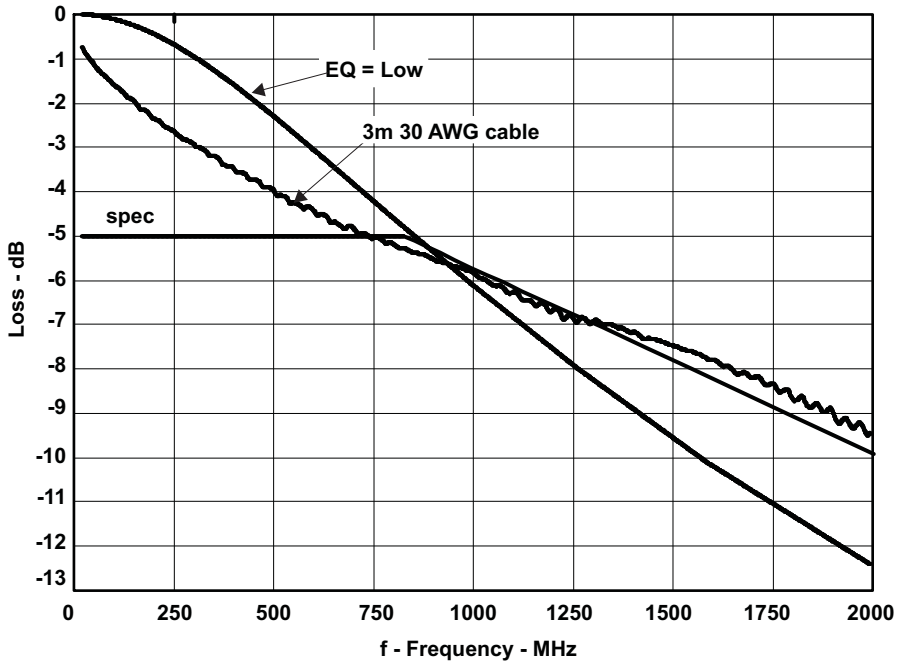



**Figure 14. Frequency Response Compensation Curve at EQ = L**

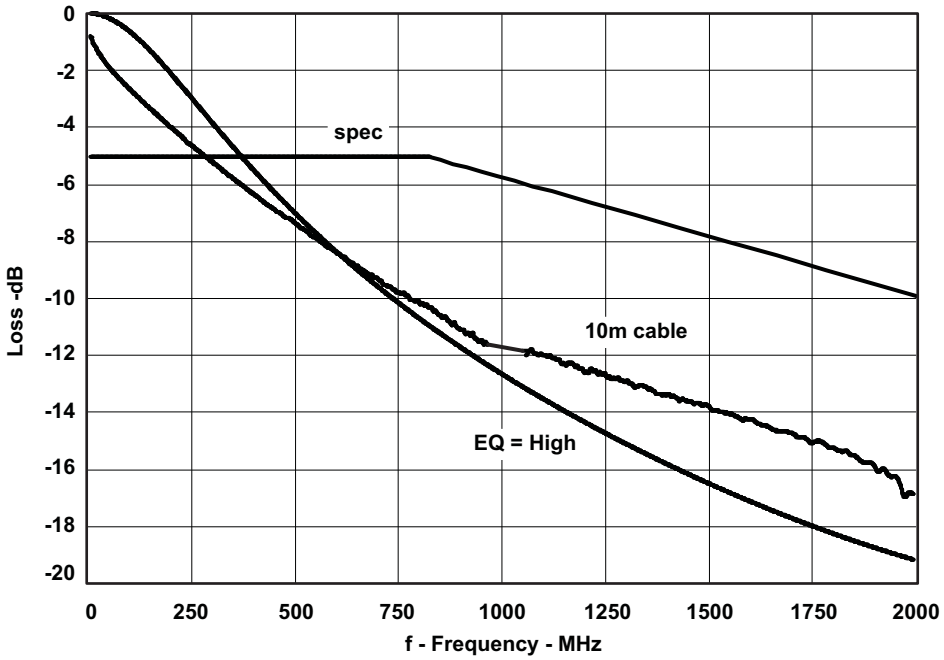



**Figure 15. Frequency Response Compensation Curve at EQ = H**

Internal termination circuitry which can be switched on or off, provides 50-Ω resistance to each differential input pin when a port is selected. External terminations are not required. When the termination is switched on, current will flow to the TMDS driver. When a port is not selected, the termination is open. This stops supply current flowing from the input pins of the unselected ports. This switchable termination provides the connected HDMI source another method of determining the sink port status, and whether it is selected or not selected, without referring to the HPD pin status.

## TMDS Input Fail-Safe

The TMDS input does not incorporate a fail-safe circuit. To implement fail-safe, the input can be externally biased to prevent output oscillation. One pin can be pulled high to $V_{CC}$ with the other grounded through a 1-kΩ resistor as shown in Figure 16.

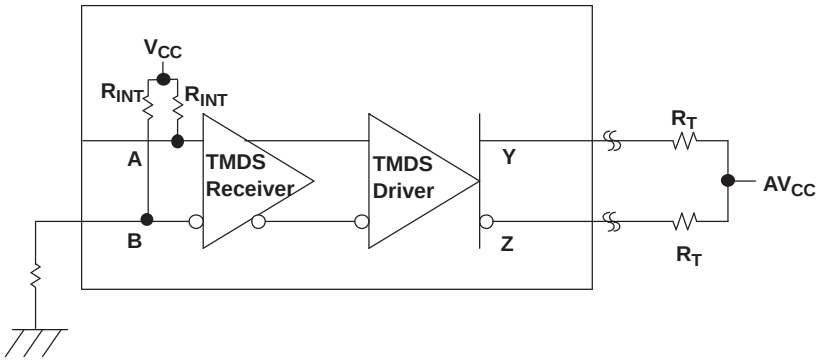



**Figure 16. TMDS Input Fail-Safe Recommendation**

## TMDS Outputs

A 10% precision resistor, 4.02-kΩ, is recommended to control the output swing to the HDMI compliant 400 mV to 600 mV range (500 mV typical). The TMDS outputs are high impedance under standby mode operation, S1 = H and S2 = L.


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## HPD Pins

The HPD circuits are powered by the 5-V supply. They provide 5-V TTL output signals to the SOURCE with a typical 1-kΩ output resistance. An external 1-kΩ resistor is not needed here. The HPD output of the selected source port follows the logic level of the HPD_SINK input. Unselected HPD outputs are kept low. When the device is in standby mode, all HPD outputs follow HPD_SINK. A 1-kΩ resistor to ground keeps all HPD outputs low in standby mode if a fixed low state is preferred.

## DDC Channels

The DDC circuits (SDA, SCL) are powered by a 5-V supply. The I/O pins can connect to the 5-V termination voltages directly. A 47-kΩ pull-up resistor to the 5 V is recommended on the SCL1 and SCL2 pins. There is no pull-up resistor on the SDA pins. The pull-up resistor can be replaced with a different value.

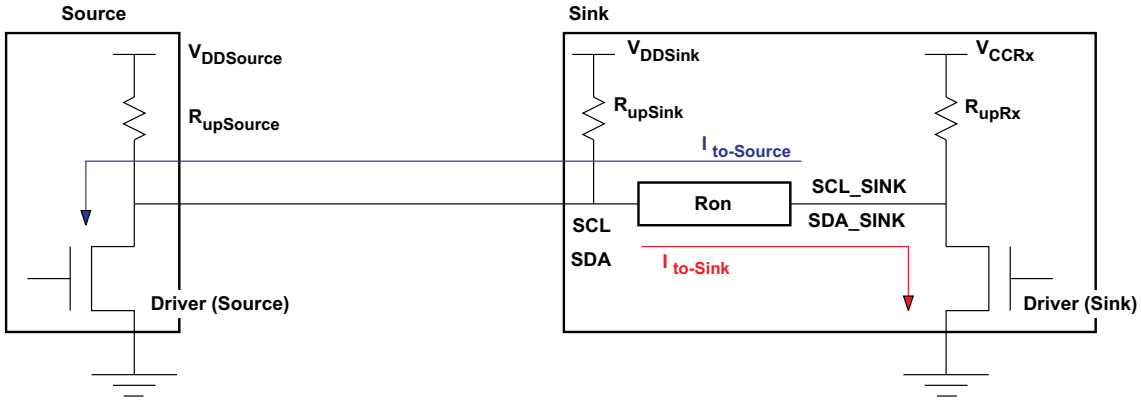



**Figure 17. Simplified Electrical Circuit Model for DDC Channel**

In Figure 17, when the Driver (Sink) pulls the bus low, the highest voltage level is $V_{ol(Sink)max}$. The current flow through the pass-gate resistor can be presented as:

$$Ito - Sink = \frac{V_{dd} - V_{ol(Sink)max}}{R_{upSource} \parallel R_{upSink}} \quad (1)$$

where the $V_{ddsource} = V_{ddsink} = V_{dd}$

To simplify the equation, $V_{ol(Sink)max}$ is set equal to 0 V to reach equation (2):

$$Ito - Sink = \frac{V_{dd}}{R_{upSource} \parallel R_{upSink}} \quad (2)$$

The voltage at the input of the SINK is Ito - Sink × Ron + $V_{ol(Sink)max}$, which should be lower than the minimum input low threshold voltage of the Driver (Source), $V_{ith(Source)min}$ to keep the bus in correct interoperations.

$$V_{ith(Source)min} > Ito - Sink \times Ron + V_{ol(Sink)max} \quad (3)$$

By combining equations (2) and (3), the minimum pull-up resistor at the Sink input is:

$$R_{upSink} \geq \frac{V_{dd} \times Ron \times R_{upSource}}{(V_{ith(Source)min} - V_{ol(Sink)max}) \times R_{upSource} - V_{dd} \times Ron} \quad (4)$$

Applying the same methodology to calculate the pull-up resistor at the input of the Driver (Sink), the minimum pull-up resistor is:

$$R_{upRx} \geq \frac{V_{ccRx} \times Ron}{(V_{ith(Sink)min} - V_{ol(Source)max})} \quad (5)$$

The data sheet $V_{PASS}$ specification ensures the maximum output voltage is clamped at 3.6 V to support a 3.3-V connection. Resistors pulling up to 3.3 V on SCL_SINK and SDA_SINK ensure the high level does not exceed the 3.3-V termination voltage.

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## Layout Considerations

The high-speed differential TMDS inputs are the most critical paths for the TMDS250. There are several considerations to minimize discontinuities on these transmission lines between the connectors and the device:

- Maintain 100-Ω differential transmission line impedance into and out of the TMDS250
- Keep an uninterrupted ground plane beneath the high-speed I/Os
- Keep the ground-path vias to the device as close as possible to allow the shortest return current path
- Keep the trace lengths of the TMDS signals between connector and device as short as possible

## Using the TMDS250 in Systems with Different CEC Link Requirements

The TMDS250 supports a DTV with up to three HDMI inputs when used in conjunction with a signal-port HDMI receiver or three HDMI inputs when used in conjunction with a dual-port HDMI receiver. Figure 18 and Figure 19 show simplified application block diagrams for the TMDS250 in different DTVs with different consumer electronic control (CEC) requirements. The CEC is an optional feature of the HDMI interface for centralizing and simplifying user control instructions from multiple audio/video products in an inter-connected system, even when all the audio/video products are from different manufacturers. This feature minimizes the number of remote controls in a system, as well as reducing the number of times buttons need to be pressed.

## A DTV Supporting a Passive CEC Link

In Figure 18, the DTV does not have the capability of handling CEC signals, but allows CEC signals to pass over the CEC bus. The source selection is done by the control command of the DTV. The user cannot force the command from any audio/video product on the CEC bus. The selected source reads the E-EDID data after receiving an asserted HPD signal. The micro-controller loads different CEC physical addresses while changing the source by means of the S1 and S2 pins.

### E-EDID Reading Configurations in Standby Mode

When the DTV system is in standby mode, the sources will not read the E-EDID memory because the 1-kΩ pull-down resistor keeping the HPD_SINK input at logic low forces all HPD pins to output logic low to all sources. The source will not read the E-EDID data with a low on HPD signal. However, if reading the E-EDID data in the system standby mode is preferred, then TMDS250 can still support this need.

The recommended configuration sequences are:

1. Apply the same 3.3-V power to the $V_{CC}$ of TMDS250 and the TMDS line termination at the HDMI receiver
2. Turn off $V_{CC}$, and keep $V_{DD}$ on. The TMDS circuit is off, but the HPD, the DDC and the source selection circuits are active.
3. Set S1 and S2 to select the source port which is allowed to read the E-EDID memory.

Please note if the source has a time-out limitation between the 5 V and the HPD signals, the above configuration is not applicable. Uses individual EEPROMs assigned for each input port, see Figure 19. The solution uses E-EDID data to be readable during system power off or standby mode operations.


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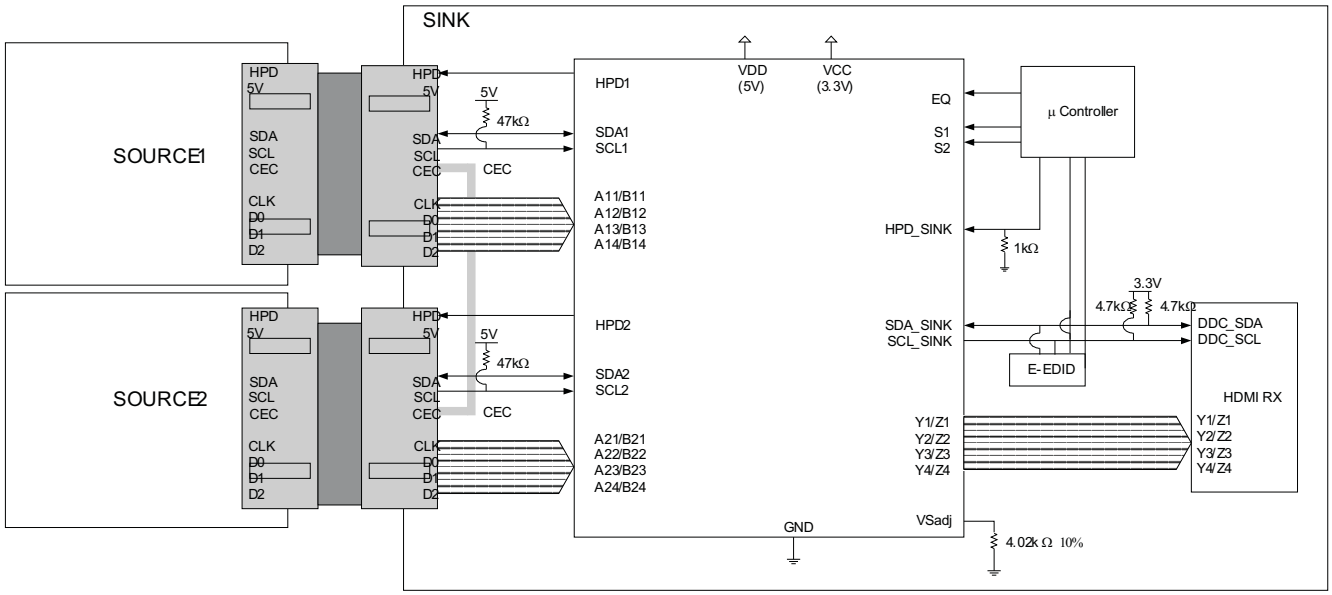



**Figure 18. Two-Port HDMI Enabled DTV with TMDS250 – CEC Commands Passing Through**

## A DTV Supporting an Active CEC Link

In Figure 19, R, and S, the CEC PHY and CEC LOGIC functions are added. The DTV can initiate and/or react to CEC signals from its remote control or other audio/video products on the same CEC bus. All sources must have their own CEC physical address to support the full functionality of the CEC link.

A source reads its CEC physical address stored its E-EDID memory after receiving a logic-high from the HPD feedback. When HPD is high, the sink-assigned CEC physical address should be maintained. Otherwise, when HPD is low the source sets CEC physical address value to (F.F.F.F).

### Case 1 – AC Coupled Source (See Figure 19, Port 1)

When the source TMDS lines are AC coupled or when the source cannot detect the TMDS termination provided in the connected sink, the indication of the source selection can only come from the HPD signal. The TMDS250 HPD1 pin should be applied directly as the HPD signal back to the source.

### Case 2 – DC Coupled Source (See Figure 19, Port 2)

When the source TMDS lines are DC coupled, there are two methods to inform the source that it is the active source to the sink. One is checking the HPD signal from the sink, and the other is checking the termination condition in the sink.

In a full CEC operation mode, the HPD signal is set high whether the port is selected or not. The source loads and maintains the CEC physical address when HPD is high. As soon as HPD goes low, the source loses the CEC physical address. To keep the CEC physical address to the source, the HPD signal is looping back from the source provided 5-V signal through a 1-kΩ pull-up resistor in the sink. This method is acceptable in application where the HDMI transmitter can detect the receiver termination by current sensing, and the receiver has switchable termination on the TMDS inputs. The internal termination resistors are connected to the termination voltage when the port is selected, or they are disconnected when the port is not selected. The TMDS250 features switchable termination on the TMDS inputs.

### Case 3 – External Logic Control for HPD (See Figure 19, Port 3)

When the HDMI transmitter does not have the capability of detecting the receiver termination, using the HPD signal as a reference for sensing port selections is the only possible method. External control logic for switching the connections of the HPD signals between the HPD pins of the TMDS250 and the 5-V signal from the source provides a good solution.

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### *E-EDID Reading Configurations in Standby Mode*

When the TMDS250 is in standby mode operation, S1 = H and S2 = L, all sources can read their E-EDID memories simultaneously with all HPD pins following HPD_SINK in logic-high. HPD_SINK input low will prevent E-EDID reading in standby mode operation.

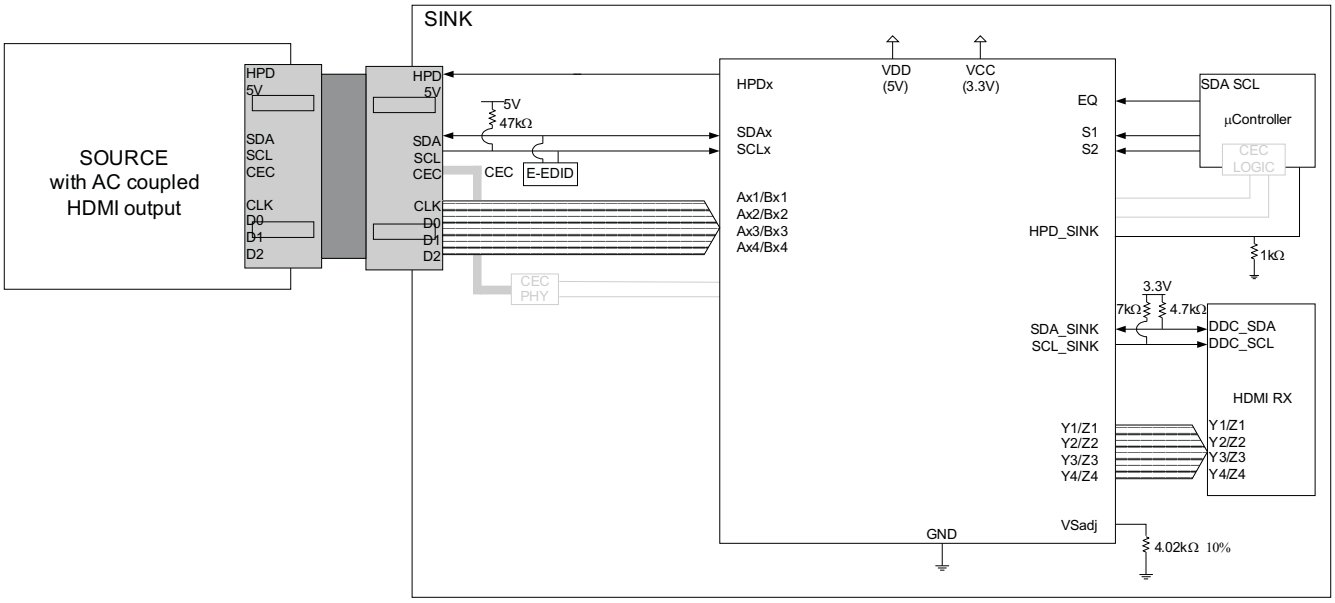



**Figure 19. Two-Port HDMI Enabled DTV with TMDS250 – AC Coupled Source - CEC Commands Active**

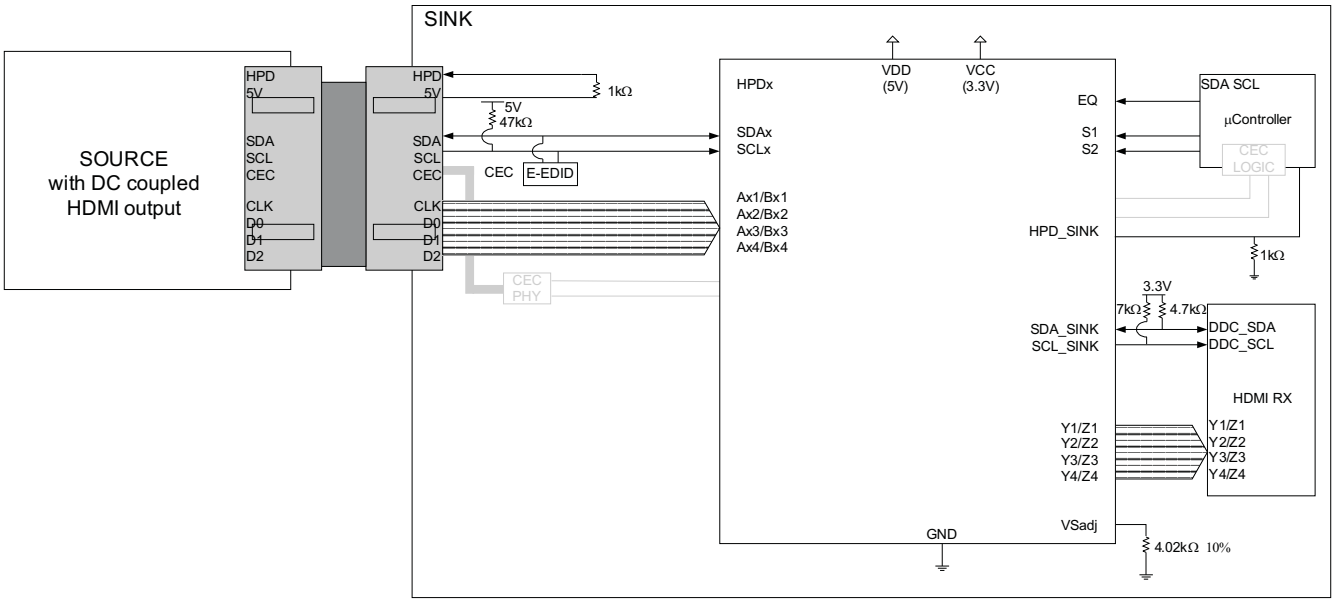



**Figure 20. Two-Port HDMI Enabled DTV with TMDS250 – DC Coupled Source - CEC Commands Active**


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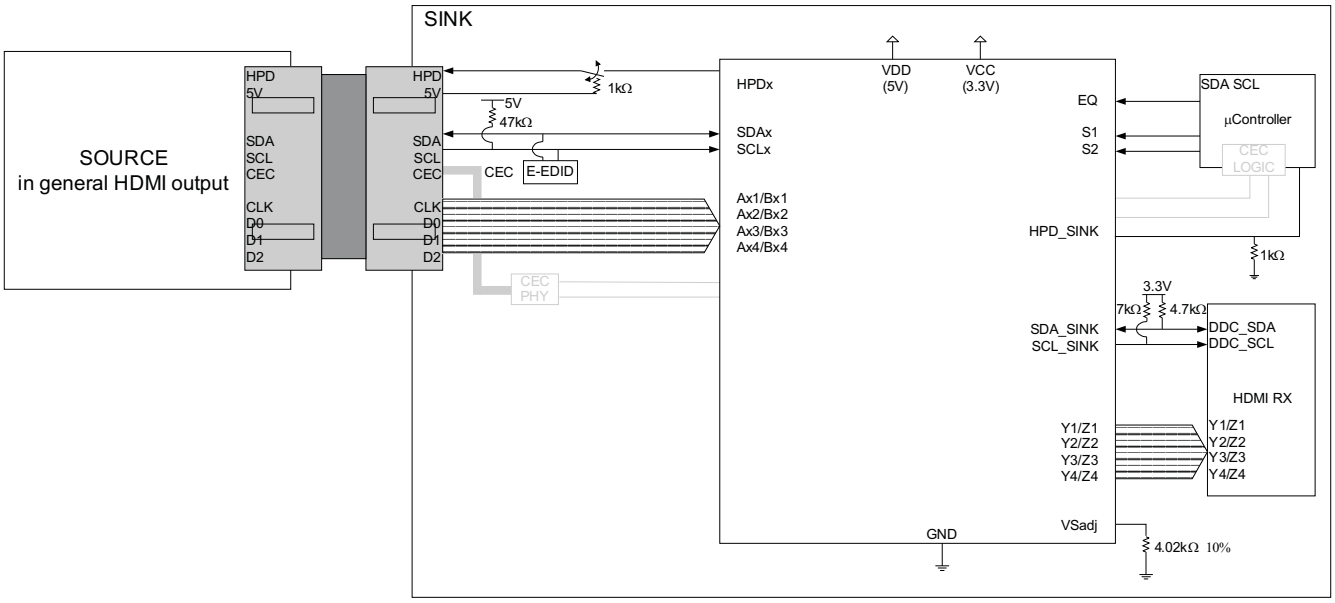



**Figure 21. Two-Port HDMI Enabled DTV with TMDS250 – External Logic - CEC Commands Active**

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| TMDS250PAGR | ACTIVE | TQFP | PAG | 64 | 1500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |
| TMDS250PAGRG4 | ACTIVE | TQFP | PAG | 64 | 1500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR |

(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)

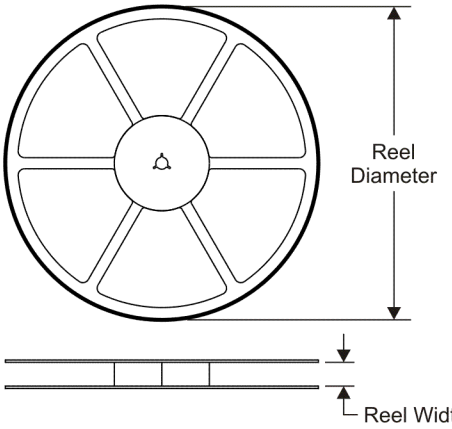
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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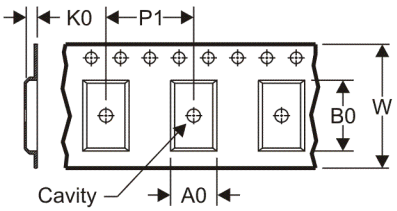
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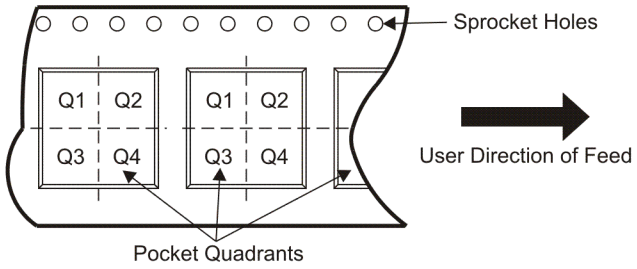



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

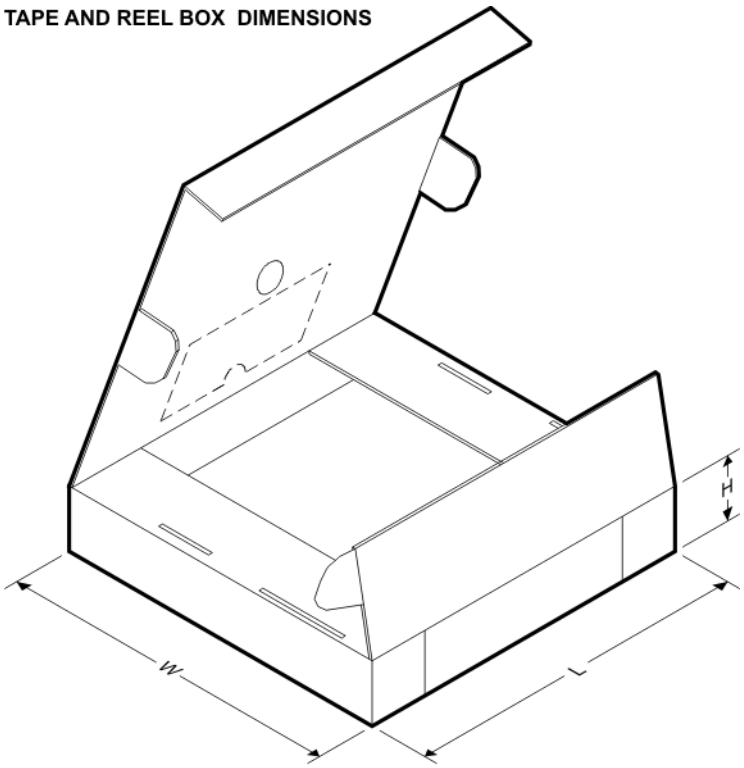
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMDS250PAGR | TQFP | PAG | 64 | 1500 | 330.0 | 24.4 | 13.0 | 13.0 | 1.4 | 16.0 | 24.0 | Q2 |

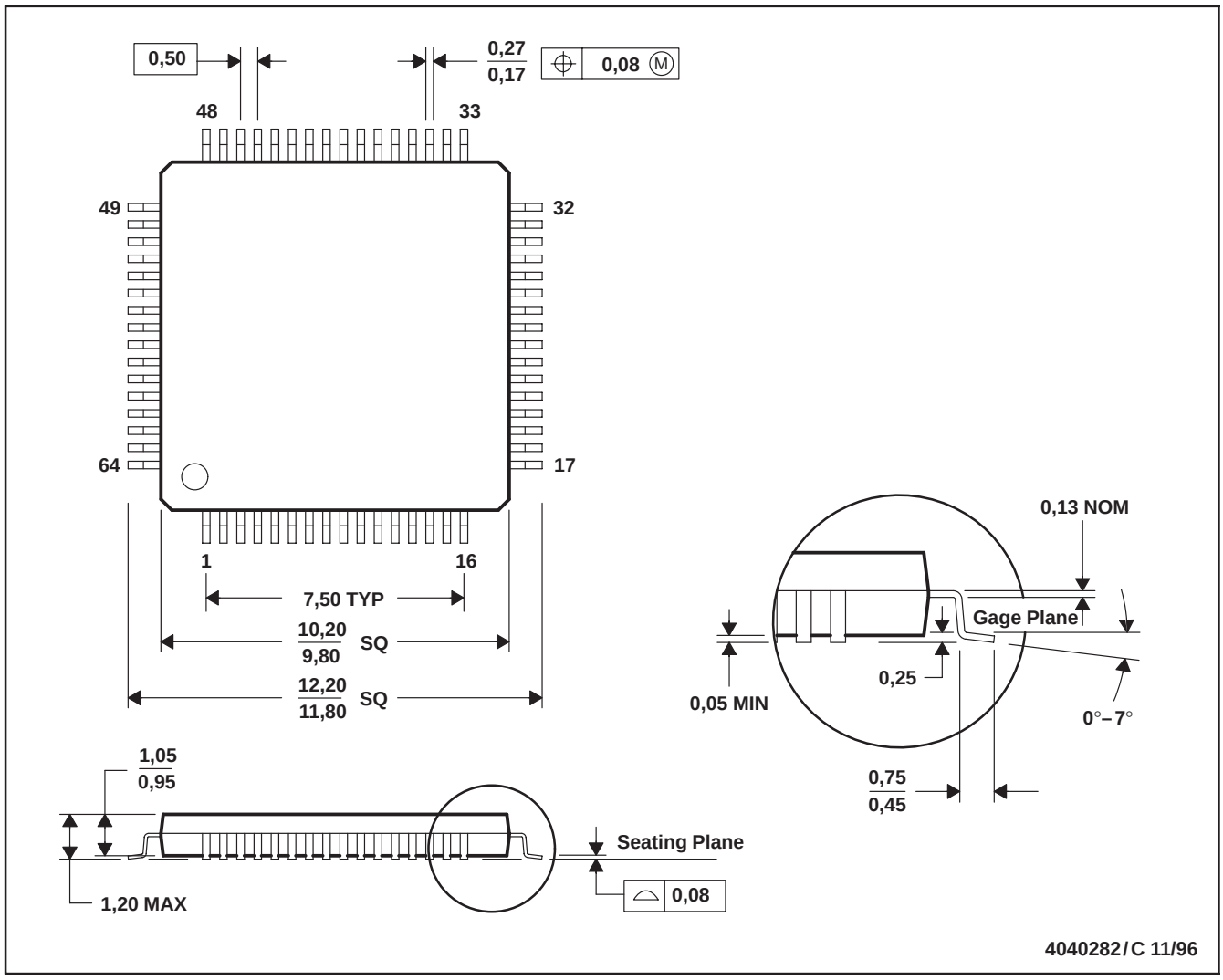
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TMDS250PAGR | TQFP | PAG | 64 | 1500 | 346.0 | 346.0 | 41.0 |

**PAG (S-PQFP-G64)** **PLASTIC QUAD FLATPACK**




NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-026

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