# TPD5S116 HDMI Companion Chip with ESD Protection, Level Shifting Buffers, 5V Load Switch with Current Limit

## 1 Features

- IEC 61000-4-2 Level 4 ESD Protection
  - ±15-kV Contact Discharge on External Lines
  - ±15-kV Air-gap Discharge on External Lines
- Conforms to HDMI Control and 5VOUT Compliance Tests without External Components
- Supports HDMI1.3, HDMI1.4, and HDMI2.0 Standards
- Auto-direction Sensing I2C Level Shifter with One-Shot Circuit to Drive Long HDMI Cable (750-pF Load)
- Back Drive Protection
- 55-mA Load Switch with Current Limit for Short Circuit Protection
- Hot Plug Detect Module with Pull Down Resistor
- Integrated Pull-up and Pull-down Resistors per HDMI Specification
- Utility Pin ESD Protection for Ethernet and Audio Return

## 2 Applications

- End Equipment
  - Cell Phones
  - eBook
  - Portable Media Players
  - Tablet
  - Set Top Box
- Interfaces
  - HDMI

## 3 Description

TPD5S116 is a single-chip HDMI interface Electrostatic Discharge (ESD) protection device with auto-direction sensing I2C voltage level shifting buffers and a 5-V HDMI compliant current limited load switch. Other key features are hot-plug-detect and Transient Voltage Suppression (TVS) with ESD protection diodes. Each connector-side pin has a TVS diode for circuit protection from ESD. An internal 3.3-V node powers the CEC pin, eliminating the need for a 3.3-V supply on board.

TPD5S116 integrates all external termination resistors needed for the HPD, CEC, SCL, and SDA lines. There are three non-inverting bi-directional translation circuits for the SDA, SCL, and CEC lines. Each has a common power rail (VCCA) on system side from 1.1 V to 3.6 V. A 55-mA current limiting switch regulates current sent from 5V_SYS to 5V_CON. The SCL and SDA pins meet the I2C specification and can drive capacitive loads greater than 750 pF, which exceeds HDMI2.0 specifications. The HPD_CON port has a glitch filter to avoid false detection due to plug bouncing during the HDMI connector insertion.

The TPD5S116 offers reverse current blocking at the 5V_CON pin. In fault conditions, such as when two HDMI transmitters are connected to the same HDMI cable, TPD5S116 ensures that the system is safe from powering up through an external HDMI transmitter. The SCL_CON, SDA_CON, CEC_CON, and HPD_CON pins also feature reverse-current blocking, which ensures that the system sees no leakage if an HDMI receiver is connected while the system is powered off.

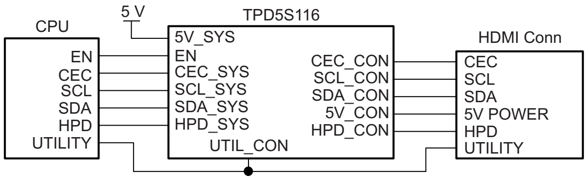
The EN pin enables the hot-plug detect and load switch. The level shifters are enabled after a valid HPD signal is detected.

### Device Information(1)

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| TPD5S116 | DSBGA (15) | 2.13 mm x 1.33 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

## 4 Simplified Schematic



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## 5 Revision History

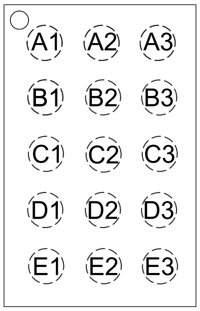
| Changes from Revision B (April 2015) to Revision C | Page |
|---|---|
| • Updated non-technical formatting. | 1 |

| Changes from Revision A (March 2012) to Revision B | Page |
|---|---|
| • Added ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. | 1 |
| • Updated datasheet to reflect HDMI2.0 compliance. | 1 |

| Changes from Original (December 2012) to Revision A | Page |
|---|---|
| • Changed the YFF package dimensions | 1 |

# 6 Pin Configuration and Functions

**YFF Package**
**15-Pin DSBGA**
**Top View**



## Pin Assignments

| | 1 | 2 | 3 |
|---|---|---|---|
| **A** | CEC_SYS | $V_{CCA}$ | CEC_CON |
| **B** | SCL_SYS | GND | SCL_CON |
| **C** | SDA_SYS | EN | SDA_CON |
| **D** | 5V_SYS | GND | 5V_CON |
| **E** | HPD_SYS | UTI_CON | HPD_CON |

## Pin Functions

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | DSBGA | | |
| 5V_CON | D3 | Output Power | HDMI connector-side external 5V Supply; output of load switch |
| 5V_SYS | D1 | Input Power | System-side PCB 5V supply; input of load switch |
| CEC_SYS | A1 | IO Port | HDMI system-side CEC signal pin referenced to $V_{CCA}$. Connect to HDMI controller. |
| CEC_CON | A3 | IO Port | HDMI connector-side CEC signal pin referenced to internal 3.3V supply. Connect to HDMI connector CEC pin. |
| EN | C2 | Control Input | Disables the load switch and HPD when EN =L. The EN pin is referenced to $V_{CCA}$ |
| GND | B2, D2 | Ground | Connect to System Ground Plane |
| HPD_SYS | E1 | Output | HDMI system-side: Hot plug detect Output referenced to $V_{CCA}$. Connect to HDMI controller Hot plug detect input pin |
| HPD_CON | E3 | Input | HDMI connector-side: Hot plug detect Input. Connect directly to HDMI Connector Hot Plug Detect pin |
| SCL_CON | B3 | IO Port | HDMI connector-side SCL signal pin referenced to 5V_CON supply. Connect to HDMI connector SCL pin. |
| SDA_CON | C3 | IO Port | HDMI connector-side SDA signal pin referenced to 5V_CON supply. Connect to HDMI connector SDA pin. |
| SCL_SYS | B1 | IO Port | HDMI system-side SCL signal pin referenced to $V_{CCA}$. Connect to HDMI controller. |
| SDA_SYS | C1 | IO Port | HDMI system-side SDA signal pin referenced to $V_{CCA}$. Connect to HDMI controller. |
| UTI_CON | E2 | IO Port | Protects the HDMI connector's utility pin |
| $V_{CCA}$ | A2 | Input Supply | Internal PCB Low Voltage Supply (Same as the HDMI Controller Chip Supply) |

# 7 Specifications

## 7.1 Absolute Maximum Ratings(1)

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

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CCA}$ | Supply voltage range | | –0.3 | 6 | V |
| 5V_SYS | Supply voltage range | | –0.3 | 6 | V |
| $V_I$ | Input voltage range(2) | SCL_SYS, SDA_SYS, CEC_SYS, EN | –0.3 | 6 | V |
| | | SCL_CON, SDA_CON, CEC_CON, HPD_CON | –0.3 | 6 | |
| $V_O$ | Voltage range applied to any output in the high-impedance or power-off state(2)(3) | SCL_SYS, SDA_SYS, CEC_SYS, HPD_SYS | –0.3 | 6 | V |
| | | SCL_CON, SDA_CON, CEC_CON, HPD_CON | –0.3 | 6 | |
| $V_O$ | Voltage range applied to any output in the high or low state(2)(3) | SCL_SYS, SDA_SYS, CEC_SYS,HPD_SYS | –0.3 | $V_{CCA}$ + 0.5 | V |
| | | SCL_CON, SDA_CON, CEC_CON | –0.3 | 5V_SYS + 0.5 | |
| $I_{IK}$ | Input clamp current | VI < 0 | | –50 | mA |
| $I_{OK}$ | Output clamp current | VO < 0 | | –50 | mA |
| | Continuous current through 5V_SYS, or GND | | | ±100 | mA |
| $T_{stg}$ | Storage temperature range | | –65 | 150 | °C |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
(3) The package thermal impedance is calculated in accordance with JESD 51-7.

## 7.2 ESD Ratings

| | | | | VALUE | UNIT |
|---|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | All pins | ±2000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | | | |
| | | IEC 61000-4-2 Contact Discharge | Pins SCL_CON, SDA_CON, CEC_CON, HPD_CON, 5V_CON, UTI_CON | ±15000 | |
| | | IEC 61000-4-2 Air-gap ESD | | | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions. Pins listed as 2000 V may actually have higher performance.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions. Pins listed as 2000 V may actually have higher performance.

## 7.3 Recommended Operating Conditions

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

| PARAMETER | | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{CCA}$ | Supply Voltage | | | 1.1 | | 5.5 | V |
| 5V_SYS | Supply Voltage | | | 4.5 | | 5.5 | V |
| $V_{IH}$ | High-level input voltage | SCL_SYS, SDA_SYS, | $V_{CCA}$ = 1.1 V to 5.5 V | $0.7 \times V_{CCA}$ | | $V_{CCA}$ | V |
| | | CEC_SYS, | $V_{CCA}$ = 1.1 V to 5.5 V | $0.7 \times V_{CCA}$ | | $V_{CCA}$ | V |
| | | EN | $V_{CCA}$ = 1.1 V to 5.5 V | 1 | | $V_{CCA}$ | V |
| | | SCL_CON, SDA_CON, | 5V_ SYS = 5.5 V | 0.7 × 5V_SYS | | 5V_SYS | V |
| | | CEC_CON | 5V_ SYS = 5.5 V | $0.7 \times V_{3P3}$ | | $V_{3P3}$ | |
| | | HPD_CON | 5V_ SYS = 5.5 V | 2 | | 5V_SYS | |
| $V_{IL}$ | Low-level input voltage | SCL_SYS, SDA_SYS, | $V_{CCA}$ = 1.1 V to 5.5 V | –0.5 | | $0.082 \times V_{CCA}$ | V |
| | | CEC_SYS, | $V_{CCA}$ = 1.1 V to 5.5 V | –0.5 | | $0.082 \times V_{CCA}$ | V |
| | | EN | $V_{CCA}$ = 1.1 V to 5.5 V | –0.5 | | 0.4 | V |
| | | SCL_CON, SDA_CON, | 5V_ SYS = 5.5 V | –0.5 | | 0.3 × 5V_SYS | V |
| | | CEC_CON | 5V_ SYS = 5.5 V | –0.5 | | $0.3 \times V_{3P3}$ | V |
| | | HPD_CON | 5V_ SYS = 5.5 V | 0 | | 0.8 | V |
| $V_{ILC}$ | (contention) Low-level input voltage | SCL_SYS, SDA_SYS, CEC_SYS | $V_{CCA}$ = 1.1 V to 5.5 V | –0.5 | | $0.0524 \times V_{CCA}$ | V |
| $V_{OL} - V_{ILC}$ | Delta between VOL and VILC | SCL_SYS, SDA_SYS, CEC_SYS | $V_{CCA}$ = 1.8 V | | $0.1 \times V_{CCA}$ | | mV |
| $T_A$ | Operating free-air temperature | | | –40 | | 85 | °C |

## 7.4 Thermal Information

| THERMAL METRIC (1) | | TPDSS116 | UNIT |
|---|---|---|---|
| | | YFF (DSBGA) | |
| | | 12 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 79.6 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 0.6 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 13 | °C/W |
| $\Psi_{JT}$ | Junction-to-top characterization parameter | 2.4 | °C/W |
| $\Psi_{JB}$ | Junction-to-board characterization parameter | 13 | °C/W |

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

## 7.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted) and $V_{CCA}$ = 1.1 V to 5.5 V and 5V_SYS = 5.5 V. Typical values measured at $V_{CCA}$ = 1.8 V and 5V_SYS = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **Supply Current** | | | | | | |
| $I_{CC5V}$ | Disabled | 5V_SYS =5V, 5V_CON =Open EN = GND, HPD_CON = GND | | 2 | 10 | µA |
| | Load Switch active | 5V_SYS =5V, 5V_CON =Open EN = $V_{CCA}$, HPD_CON = GND | | 30 | 50 | µA |
| | Active | 5V_SYS =5V, 5V_CON =Open EN = $V_{CCA}$, HPD_CON = 5V | | 125 | 200 | µA |
| **Load Switch** | | | | | | |
| $V_{REV}$ | Reverse voltage comparator trip point | 5V_SYS=4V, 5V_CON > 5V_SYS | | 100 | | mV |
| $I_{OFF}$ | Leakage Current | 5V_CON = 0V, 5V_SYS = 5 V , EN = GND, HPD_CON = GND Measured at 5V_SYS pin. | | 1 | 5 | µA |
| | | 5V_CON = 0V, 5V_SYS= 5 V , EN = GND, HPD_CON = 5 V Measured at 5V_SYS pin | | 1 | 5 | µA |
| | | 5V_CON = 5V, 5V_SYS = 0 V , EN = GND, HPD_CON = GND Measured at 5V_CON pin. | | 1 | 5 | µA |
| | | 5V_CON = 5V, 5V_SYS = 0 V EN = GND, HPD_CON = 5 V Measured at 5V_CON pin. | | 1 | 5 | µA |
| | | 5V_CON = 5V, 5V_SYS = 0 V, EN=$V_{CCA}$, HPD_CON = GND Measured at 5V_CON pin. | | 1 | 5 | µA |
| | | 5V_CON = 5 V, 5V_SYS = 0 V, EN = $V_{CCA}$, HPD_CON = 5 V Measured at 5V_CON pin. | | 1 | 5 | µA |
| $I_{SC}$ | Short circuit current at 5V_CON | 5V_SYS = 5 V, 5V_CON = GND | 110 | 140 | 170 | mA |
| $T_{DEGLITCH}$ | Deglitch time against false short | 5V_SYS = 5 V , EN = $V_{CCA}$, Short 5V_CON | | 3 | | µs |
| UVLO | Under voltage lockout rising | 5V_SYS = 0 V to 5 V, RL = 100 Ω, CL = 1 µF | | 2.85 | | V |
| UVLO_HYS | Under voltage lockout falling hysteresis | 5V_SYS = 5 V to 0 V, RL = 100 Ω, CL = 1 µF | | 200 | | mV |
| $V_{DROP}$ | 5V_OUT output voltage drop | 5V_SYS = 5 V, I5V_OUT = 55 mA | | 38.5 | 55 | mV |
| $I_{RUSH}$ | Inrush Current | 5V_SYS = 5 V, RL = 100 Ω, Cin=10uF, C = 1 µF | | 140 | | mA |
| $T_{ON}$ | Turn on Time, EN to 5V_CON | 5V_SYS = 5 V, RL = 100 Ω, Cin=10uF, C = 1 µF | | 92.3 | | µs |
| $T_{OFF}$ | Turn off Time, EN to 5V_CON | 5V_SYS = 5 V, RL = 100 Ω, Cin=10uF, C = 1 µF | | 5 | | µs |
| $T_{SHUT}$ | Thermal Shutdown | Shutdown threshold, TRIP (1) | | 166 | | °C |
| | | HYST (2) | | 23 | | |

(1) The TPD5S116 turns off after the device temperature reaches the TRIP temperature.
(2) Once the thermal shut-down circuit turns off the load switch, the switch turns on again after the device junction temperature cools down to a temperature equals to or less than TRIP-HYST.

## 7.6 Voltage Level Shifter, SCL, SDA Lines

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

| PARAMETER | | TEST CONDITIONS | | $V_{CCA}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{OH\_SYS}$ | | $I_{OH} = –10$ μA | $V_I = V_{IH}$ | | 0.8 × $V_{CCA}$ | | $V_{CCA}$ + 0.02 | V |
| $V_{OL\_SYS}$ | | $I_{OL} = 10$ μA | $V_I = V_{IL}$ | | | | 0.17 × $V_{CCA}$ | V |
| $V_{OH\_CON}$ | | $I_{OH} = –10$ μA | $V_I = V_{IH}$ | | 0.8 x 5V_SYS | | 5V_SYS+ 0.02 | V |
| $V_{OL\_CON}$ | | $I_{OH} = 3$ mA | $V_I = V_{IL}$ | | | 0.3 | 0.4 | V |
| ΔVT Hysteresis at the SDx_IN (VT+ - VT-) | | | | | | 40 | | mV |
| ΔVT Hysteresis at the SDx_OUT (VT+ - VT-) | | | | | | 400 | | mV |
| $R_{PU}$ (Internal pull-up) | | SCL_SYS, SDA_SYS | Pull-up connected to $V_{CCA}$ rail | | | 5 | | kΩ |
| | | SCL_CON, SDA_CON | Pull-up connected to 5V rail | | | 1.75 | | |
| $I_{PULLUPAC}$ Transient Boosted Pull-up Current (rise-time accelerator) | | SCL_CON, SDA_CON | Pull-up connected to 5V rail | | | 13 | | mA |
| $I_{off}$ | SYS Port | $V_{CCA}$ = 0V, $V_I$ or $V_O$ = 0 to 3.6 V | | 0 V | | | ±5 | μA |
| | CON Port | 5V_CON=0V, $V_I$ or $V_O$ = 0 to 5.5 V | | 0 V | | | ±5 | |
| $I_{OZ}$ | SYS Port | $V_I = V_{CCI}$ or GND | | | | | ±5 | |

## 7.7 Voltage Level Shifter, CEC Line

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

| PARAMETER | | TEST CONDITIONS | | $V_{CCA}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{OH\_SYS}$ | | $I_{OH} = –10$ μA | $V_I = V_{IH}$ | | 0.8 × $V_{CCA}$ | | $V_{CCA}$ + 0.02 | V |
| $V_{OL\_SYS}$ | | $I_{OL} = 10$ μA | $V_I = V_{IL}$ | | | | 0.17 × $V_{CCA}$ | V |
| $V_{OH\_CON}$ | | $I_{OH} = –10$ μA | $V_I = V_{IH}$ | | 0.8 x $V_{3P3}$ | | | V |
| $V_{OL\_CON}$ | | $I_{OH} = 3$ mA | $V_I = V_{IL}$ | | | 0.3 | 0.4 | V |
| ΔVT Hysteresis at the CEC_SYS (VT+ - VT-) | | | | | | 30 | | mV |
| ΔVT Hysteresis at the CEC_CON (VT+ - VT-) | | | | | | 283 | | mV |
| $R_{PU}$ (Internal pull-up) | | CEC_SYS | Pull-up connected to $V_{CCA}$ rail | | | 5 | | kΩ |
| | | CEC_CON | Pull-up connected to 3.3V rail | | 22 | 26 | 30 | kΩ |
| $R_{PD}$ (Internal pull-down) | | CEC_CON | Pull-down connected connector-side | | | 10 | | MΩ |
| $I_{off}$ | SYS Port | $V_{CCA}$ = 0V, $V_I$ or $V_O$ = 0 to 3.6 V | | 0 V | | | ±5 | μA |
| | CON Port | 5V_CON=0V, $V_I$ or $V_O$ = 0 to 5.5 V | | 0 V | | | ±1.8 | |
| $I_{OZ}$ | SYS Port | $V_I = V_{CCI}$ or GND | | | | | ±5 | |

## 7.8 Voltage Level Shifter, HPD Line

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

| PARAMETER | | TEST CONDITIONS | | $V_{CCA}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{OH\_SYS}$ | | $I_{OH}$ = 1 mA | $V_I = V_{IH}$ | 1.2 V to 5.0 V | $V_{CCA}$ × 0.7 | | | V |
| $V_{OH\_SYS\_1P1}$ | | $I_{OH}$ = 100 µA | $V_I = V_{IH}$ | 1.1 V | $V_{CCA}$ × 0.7 | | | V |
| $V_{OL\_SYS}$ | | $I_{OL}$ = 3 µA | $V_I = V_{IL}$ | 1.2 V to 5.0 V | | | 0.4 | V |
| $V_{OL\_SYS\_1P1}$ | | $I_{OL}$ = 3 mA | $V_I = V_{IL}$ | 1.1 V | | | 0.68 | V |
| ΔVT Hysteresis at the CEC_CON (VT+ - VT-) | | | | 1.2 V to 5.0 V | | 500 | | mV |
| $R_{PD\_IN}$ (Input internal pull-down resistor) | | | Pull-down connected to GND | | 60 | 100 | 140 | kΩ |
| $R_{PD\_OUT}$ (Output internal pull-down resistor) | | | Pull-down connected to GND | | 60 | 100 | 140 | kΩ |
| TFILT | Glitch Filter Duration | HPD_CON = 5 V, EN = $V_{CCA}$, Short HPD_SYS | | | | 10 | | µs |

## 7.9 EN

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

| PARAMETER | TEST CONDITIONS | $V_{CCA}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $R_{PD\ EN}$ (Internal pull-down resistor) | Pull-down connected to GND | 1.8 V | | 470 | | kΩ |

## 7.10 Utility Pin

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

| PARAMETER | DESCRIPTION | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{RWM}$ | Reverse stand-off voltage | | | | 6 | V |
| $V_{CLAMP}$ | Clamp voltage with ESD strike | IPP = 1 A, tp = 8/20 µSec, from I/O to GND(1) | | 8 | | V |
| | | IPP = 5 A, tp = 8/20 µSec, , from I/O to GND(1) | | 10 | | |
| $R_{DYN}$ | Dynamic resistance | UTI pin to GND Pin(2) | | 0.33 | | Ω |
| $C_{UTI}$ | Line capacitance | $V_{IO}$=0V, f=1GHz, I/O to GND | | 5.5 | | pF |
| $V_{BR}$ | Break-down voltage | $I_{IO}$ = 1mA | 7 | | | V |
| $I_{LEAK}$ | Leakage current | $V_{IO}$ = 3V | | 1 | 10 | nA |

(1) Non-repetitive current pulse 8/20us exponentially decaying waveform according to IEC 61000-4-5
(2) Extraction of RDYN using least squares fit of TLP characteristics between I=10A and I=20A

## 7.11 I/O Capacitances

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

| PARAMETER | | TEST CONDITONS | SUPPLY & EN SIGNAL | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $C_I$ | EN | $V_{BIAS} = V_{CCA}/2$, f = 1 MHz, 30 mV p-p AC signal | | | 8 | 9 | pF |
| $C_I$ | HPD_CON | $V_{BIAS}$ = 0 V – 5 V , f = 1 MHz, 30 mV p-p AC signal | | | 7 | 7.5 | pF |

## I/O Capacitances (continued)

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

| PARAMETER | | TEST CONDITONS | SUPPLY & EN SIGNAL | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $C_{IO}$ | SYS port | $V_{BIAS}$ = 1.8 V, f = 1 MHz, 30 mV p-p AC signal | | | 6.5 | 9.5 | pF |
| | CON port | $V_{BIAS}$ = 2.5 V, f = 1 MHz, 30 mV p-p AC signal | | | 15 | 20 | pF |
| | SCL_CON, SDA_CON | $V_{BIAS}$ = 2.5V, f = 100 kHz, 3.5 V p-p AC signal | $V_{CCA}$= 3.6 V, 5V_SYS = 5 V, EN = HPD_CON = 0 V | | 17 | | pF |
| | CEC_CON | $V_{BIAS}$ = 1.65 V, f = 100 kHz, 2.5 V p-p AC signal | $V_{CCA}$= 3.6 V, 5V_SYS = 5 V, EN=HPD_CON = 0 V | | 13 | | pF |
| | CEC_CON | $V_{BIAS}$ = 1.65 V, f = 100 kHz, 2.5 V p-p AC signal | $V_{CCA}$= 0 V 5V_SYS = 0 V EN = HPD_CON = 0 V | | 12 | | pF |

## 7.12 Dynamic Load Characteristics

Propagation delays measured from 50% threshold to 50% threshold, Rise time measured from 30% to 70% threshold, Fall time measured from 70% to 30% threshold

| PARAMETER | | TEST CONDITION | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $C_L$ | Bus Load Capacitance (connector-side) | | | | 750 | pF |
| | Bus Load Capacitance (System Side) | | | | 30 | |

## 7.13 SCL, SDA Lines, $V_{CCA}$ = 1.2 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.2 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 316 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 286 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 489 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 199 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 110 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 229 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.14 CEC Line, $V_{CCA}$ = 1.2 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.2 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 436 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 97 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.8 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 319 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 37 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 114 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 234 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.15 HPD Line, $V_{CCA}$ = 1.2 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.2 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 14 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 18 | | ns |

## 7.16 SCL, SDA Lines, $V_{CCA}$ = 1.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 297 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 224 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 473 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 193 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 87 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 226 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.17 CEC Line, $V_{CCA}$ = 1.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 419 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 102 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.7 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 314 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 39 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 115 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 230 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.18 HPD Line, $V_{CCA}$ = 1.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 8 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 9.5 | | ns |

## 7.19 SCL, SDA Lines, $V_{CCA}$ = 1.8 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.8 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 292 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 192 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 466 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 190 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 75 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 224 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.20 CEC Line, $V_{CCA}$ = 1.8 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 1.8 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 417 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 108 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.7 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 312 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 41 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 114 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 228 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.21 HPD Line, $V_{CCA}$ = 1.8 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5V; $V_{CCA}$ = 1.8 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 5.5 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 7 | | ns |

## 7.22 SCL, SDA Lines, $V_{CCA}$ = 2.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 2.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 291 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 154 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 455 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 186 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 64 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 221 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.23 CEC Line, $V_{CCA}$ = 2.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 2.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 421 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 122 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.7 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 311 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 49 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 114 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 225 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.24 HPD Line, $V_{CCA}$ = 2.5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 2.5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 4 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 5 | | ns |

## 7.25 SCL, SDA Lines, $V_{CCA}$ = 3.3 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 3.3 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 292 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 133 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 449 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 184 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 57 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 218 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.26 CEC Line, $V_{CCA}$ = 3.3 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 3.3 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 428 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 138 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.7 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 309 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 59 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 114 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 223 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.27 HPD Line, $V_{CCA}$ = 3.3 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 3.3 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 3 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 3.5 | | ns |

## 7.28 SCL, SDA Lines, $V_{CCA}$ = 5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 298 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 113 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | DDC Channels Enabled | | 442 | | ns |
| | | CON to SYS | DDC Channels Enabled | | 182 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | DDC Channels Enabled | | 52 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | DDC Channels Enabled | | 82 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | DDC Channels Enabled | | 217 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | DDC Channels Enabled | | 86 | | ns |
| $F_{MAX}$ | Maximum Switching Frequency | | DDC Channels Enabled | 400 | | | kHz |

## 7.29 CEC Line, $V_{CCA}$ = 5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 446 | | ns |
| | | CON to SYS | CEC Channels Enabled | | 169 | | ns |
| $T_{PLH}$ | Propagation Delay | SYS to CON | CEC Channels Enabled | | 13.7 | | µs |
| | | CON to SYS | CEC Channels Enabled | | 306 | | ns |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 82 | | ns |
| $T_{FALL}$ | CON Port Fall Time | CON Port | CEC Channels Enabled | | 114 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 221 | | ns |
| $T_{RISE}$ | CON Port Rise Time | CON Port | CEC Channels Enabled | | 16.6 | | µs |

## 7.30 HPD Line, $V_{CCA}$ = 5 V

over operating free-air temperature range (unless otherwise noted) and 5V_CON = 5 V; $V_{CCA}$ = 5 V

| PARAMETER | | PINS | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $T_{PHL}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 10.1 | | µs |
| $T_{PLH}$ | Propagation Delay | CON to SYS | CEC Channels Enabled | | 9.7 | | µs |
| $T_{FALL}$ | SYS Port Fall Time | SYS Port | CEC Channels Enabled | | 2.5 | | ns |
| $T_{RISE}$ | SYS Port Rise Time | SYS Port | CEC Channels Enabled | | 2.5 | | ns |

## 7.31 Typical Characteristics

At $T_A$ = 25°C, unless otherwise noted.

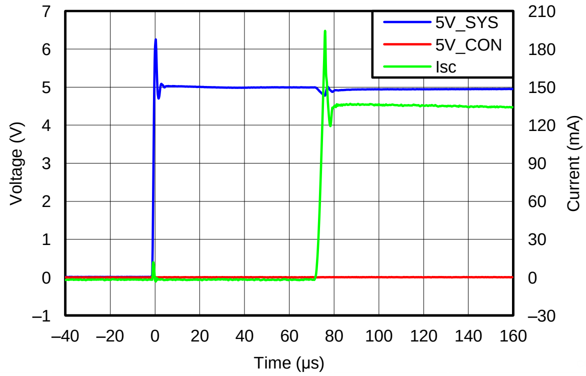


**Figure 1. Power up to Short Circuit**

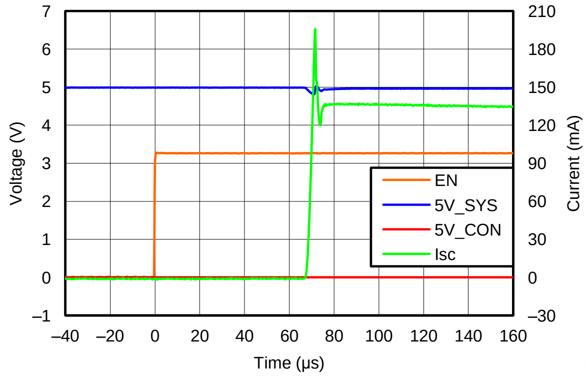


**Figure 2. Enable to Short Circuit**

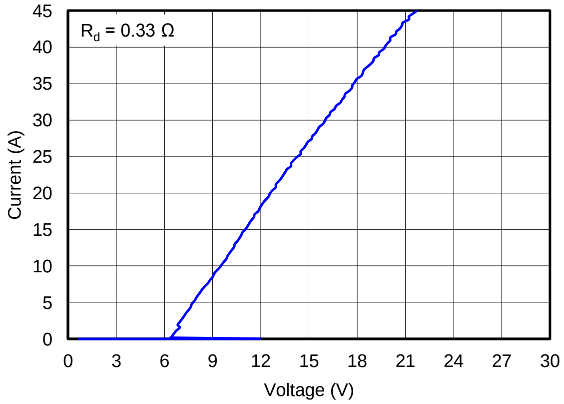


**Figure 3. Utility Pin TLP Curve**

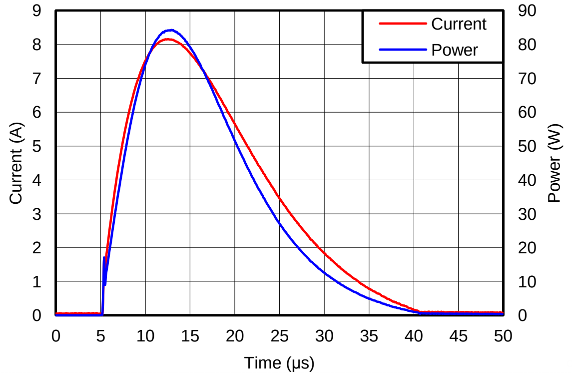


**Figure 4. Utility Pin Surge Curves**

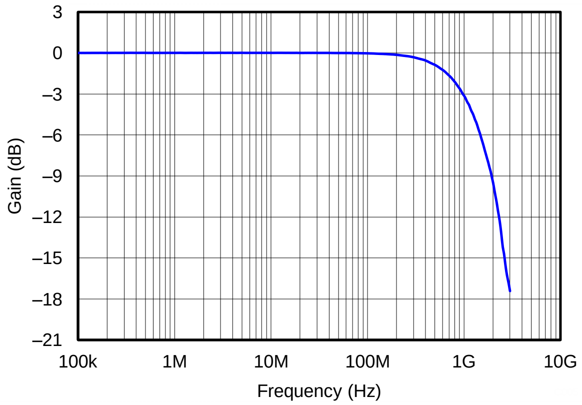


**Figure 5. Utility Pin Insertion Loss**

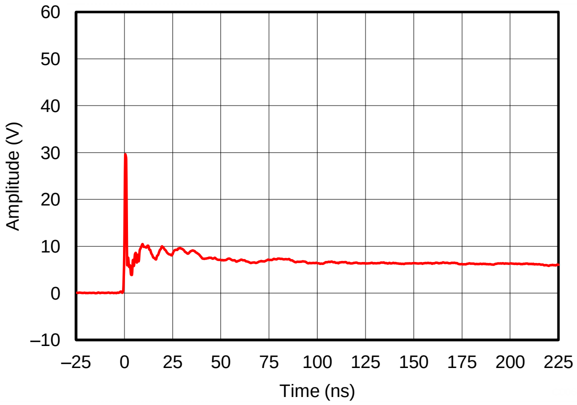


**Figure 6. Utility Pin, +8kv IEC Voltage Clamp Waveform**

## Typical Characteristics (continued)

At $T_A$ = 25°C, unless otherwise noted.

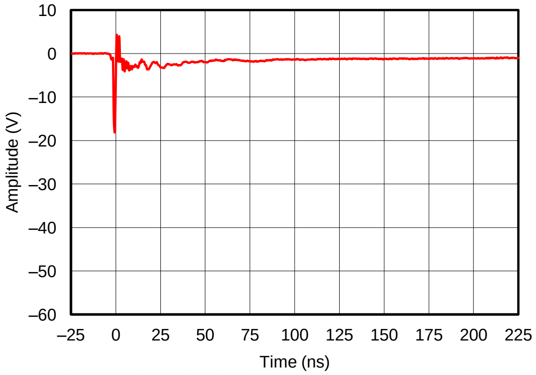


**Figure 7. Utility Pin, -8kv IEC Voltage Clamp Waveform**

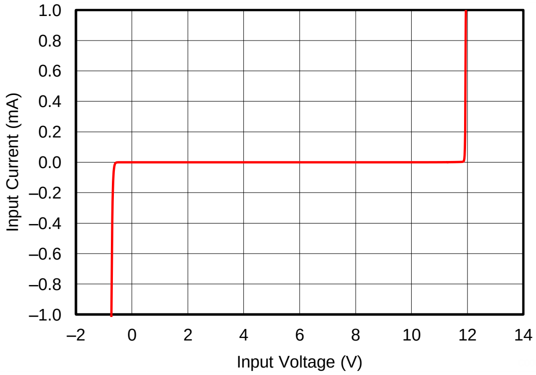


**Figure 8. Utility Pin IV Curve**

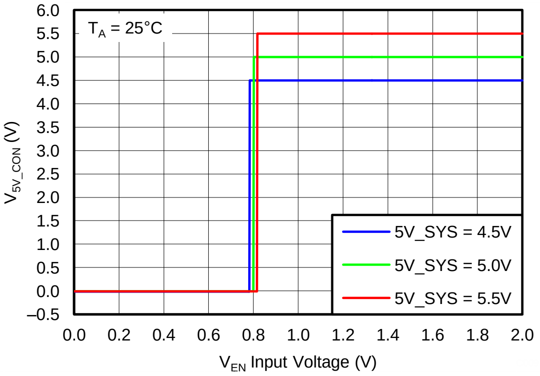


**Figure 9. EN $V_{TH}$**

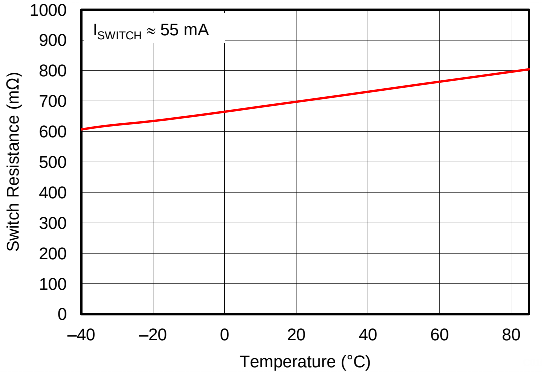


**Figure 10. $R_{DS}$ for $I_{SWITCH}$**

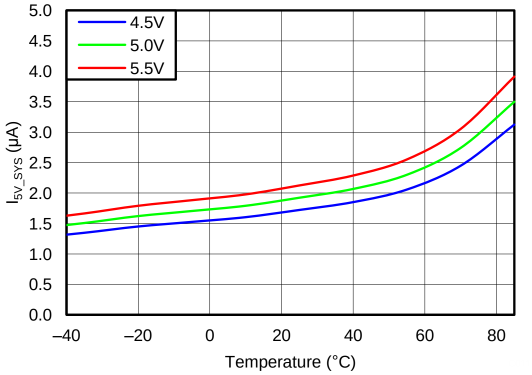


**Figure 11. $I_{5V\_SYS}$ vs. Temperature**

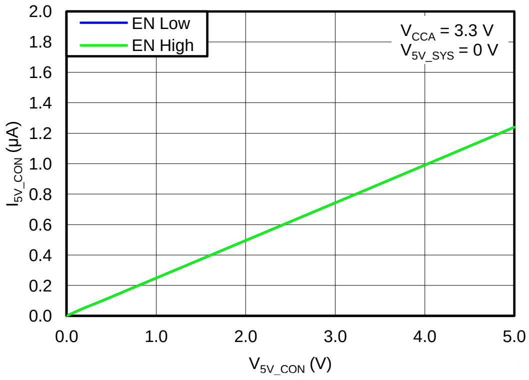


**Figure 12. Reverse Switch Current**

## Typical Characteristics (continued)

At $T_A$ = 25°C, unless otherwise noted.

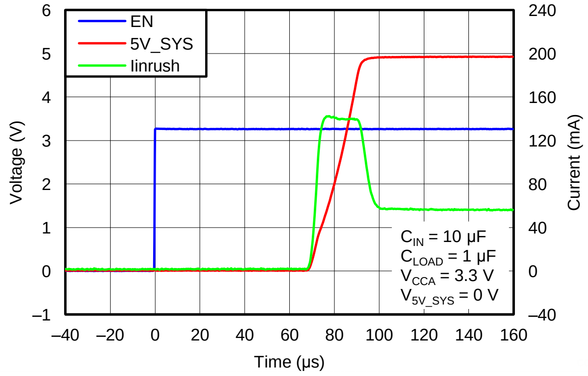


**Figure 13. $I_{INRUSH}$ Waveform**

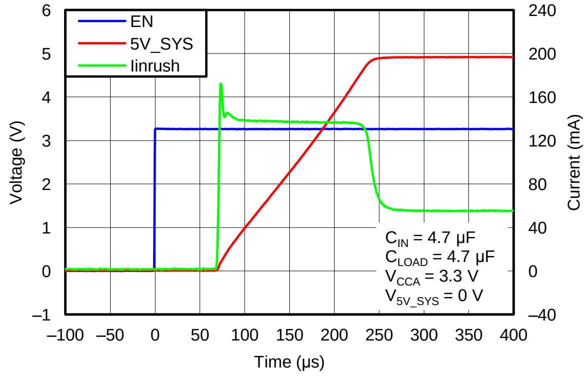


**Figure 14. $I_{INRUSH}$ Waveform**

# 8 Detailed Description

## 8.1 Overview

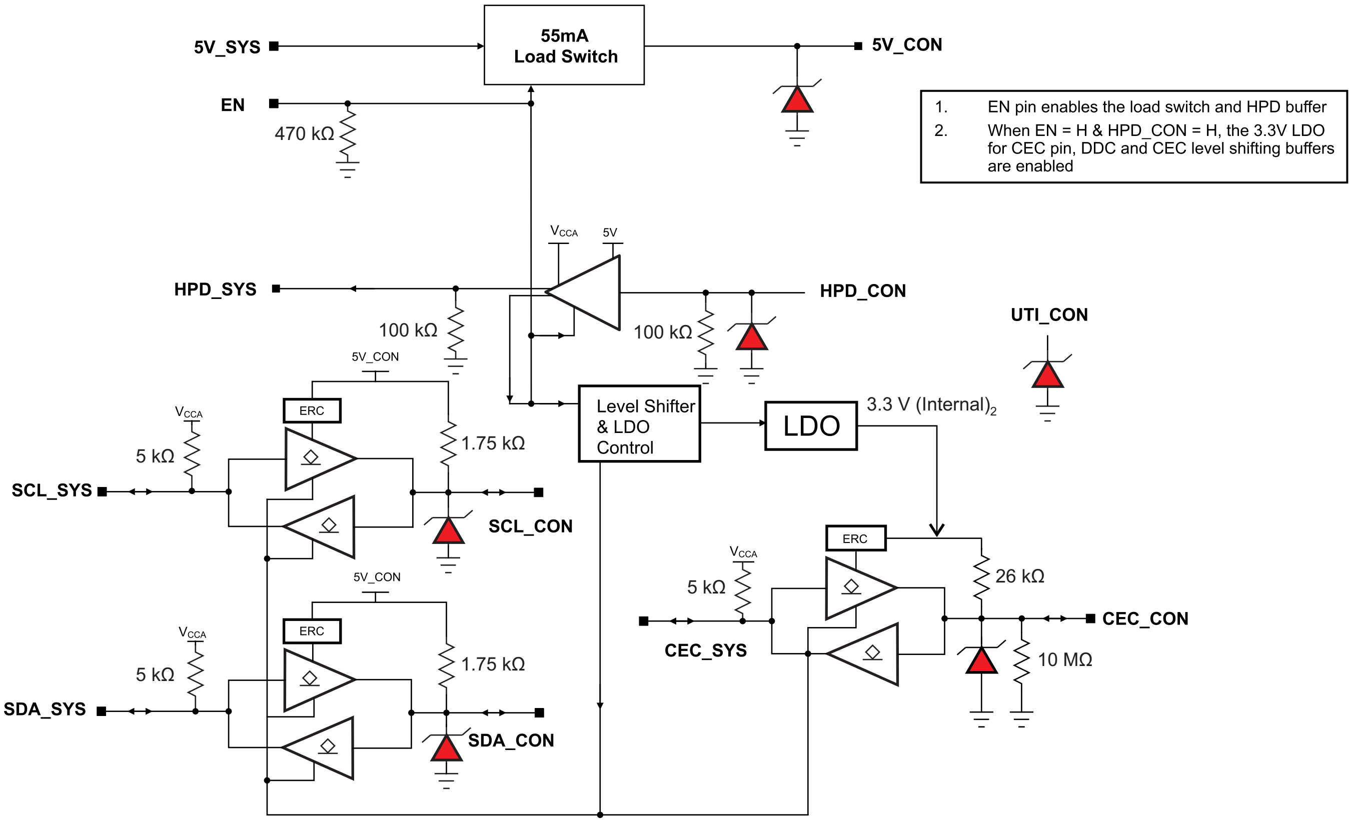
TPD5S116 is a single-chip HDMI interface electrostatic discharge (ESD) protection product with auto-direction sensing I2C voltage level shift buffers, a 5-V HDMI compliant current limited load switch, hot-plug-detect, and transient voltage suppression (TVS) with ESD protection diodes. Each connector-side pin has a TVS diode for circuit protection from ESD. The device pin mapping can be routed to either an HDMI Type D or Type C connector. An internal 3.3-V node powers the CEC pin, eliminating the need for a 3.3-V supply on board.

TPD5S116 integrates all of the external termination resistors at the HPD, CEC, SCL, and SDA lines. There are three non-inverting bidirectional translation circuits for the SDA, SCL, and CEC lines. Each has a common power rail ($V_{CCA}$) on system-side from 1.1 V to 3.6V. A 55-mA current limiting switch regulates current sent from 5V_SYS to 5V_CON. The SCL and SDA pins meet the I2C specification and can drive capacitive loads greater than 750 pF, which exceeds HDMI2.0 specifications. The HPD_CON port has a glitch filter to avoid false detection due to plug bouncing during the HDMI connector insertion.

The TPD5S116 offers reverse current blocking at the 5V_CON pin. In fault conditions, such as when two HDMI transmitters are connected to the same HDMI cable, TPD5S116 ensures that the system is safe from powering up through external HDMI transmitter. The SCL_CON, SDA_CON, CEC_CON, and HPD_CON pins also feature reverse-current blocking, which ensures that the system sees no leakage if an HDMI receiver is connected while the system is powered off.

The EN pin enables the hot-plug detect and load switch. The level shifters are enabled after a valid HPD signal is detected.

## 8.2 Functional Block Diagram



## 8.3 Feature Description

### 8.3.1 IEC 61000-4-2 Level 4 ESD Protection

In many cases, the core ICs, such as the scalar chipset, may not have robust ESD cells to sustain system-level ESD strikes. In these cases, the TPD5S116 provides the desired system-level ESD protection, such as the IEC 61000-4-2 Level 4 ESD protection of ±15-kV Contact and Air-gap ratings by absorbing the energy associated with the ESD strike.

### 8.3.2 Conforms to HDMI Control and 5VOUT Compliance Tests Without External Components

The TPD5S116 is designed to be fully compliant to the HDMI 7-13 Compliance Test. See *HDMI Compliance* for a detailed procedure.

### 8.3.3 Auto-direction Sensing I2C Level Shifter with One-Shot Circuit to Drive Long HDMI Cable (750-pF Load)

The TPD5S116 contains three bidirectional open-drain buffers specifically designed to support up-translation/down-translation between the low voltage, $V_{CCA}$ side DDC-bus and the 5-V DDC-bus or 3.3-V CEC line. The HDMI cable side of the DDC lines incorporates rise-time accelerators to support a high capacitive load on the HDMI cable side. The rise time accelerators boost the cable side DDC signal independent of which side of the bus is releasing the signal.

### 8.3.4 Back Drive Protection

The TPD5S116 offers reverse current blocking at the 5V_CON pin. In fault conditions, such as when two HDMI transmitters are connected to the same HDMI cable, TPD5S116 ensures that the system is safe from powering up through an external HDMI transmitter. The SCL_CON, SDA_CON, CEC_CON, and HPD_CON pins also feature reverse-current blocking, which ensures that the system sees no leakage if an HDMI receiver is connected while the system is powered off.

### 8.3.5 55-mA Load Switch with Short Circuit Protection

A 55-mA current limiting switch regulates current sent from 5V_SYS to 5V_CON. This provides protection from a short-circuit or excessive load when there is a fault condition, such as a defective HDMI cable.

### 8.3.6 Hot Plug Detect Module with Pull Down Resistor

Once TPD5S116 is enabled and the system's 5-V source is on, TPD5S116 is ready for continual HDMI receiver detection. When an HDMI cable connects a receiving and transmitting device together, the 5 V on the load switch (5V_CON) flows through the receiving device's internal resistor and into HPD's input (HPD_CON). The HPD buffer's output (HPD_SYS) then goes high, indicating to the transmitter that a receiving device is connected. To save power, periodic detection can be done by turning on and off the TPD5S116 before a receiving device is connected. HPD_CON port has a glitch filter to avoid false detection due to plug bouncing during the HDMI connector insertion. An integrated pull-down resistor for HPD_CON eliminates the need for an additional external component.

### 8.3.7 Integrated Pull-up and Pull-down Resistors per HDMI Specification

The system is designed to work properly according to the HDMI 2.0 specification with no external pull-up resistors on the DDC, CEC, and HPD lines.

### 8.3.8 Utility Pin ESD Protection for Ethernet and Audio Return

A TVS is provided for the Utility Pin in the HDMI connector. This pin should be routed to the TPD5S116 for proper ESD protection regardless of whether Utility is used in the application.

### 8.3.9 DDC/CEC LEVEL SHIFT Circuit Operation

The TPD5S116 enables DDC translation from $V_{CCA}$ (system-side - Port A in Figure 15) voltage levels to 5-V (HDMI connector-side - Port B in Figure 15) voltage levels without degradation of system performance. The TPD5S116 contains two bidirectional open-drain buffers specifically designed to support up-translation/down-translation between the low voltage, $V_{CCA}$ side DDC-bus and the 5-V DDC-bus. The connector port I/Os are over-voltage tolerant to 5.5 V, even when the device is un-powered. After power-up and with enable pin and

## Feature Description (continued)

HPD_CON pin HIGH, a LOW level on the system port (below approximately $V_{ILC}$ = 0.08 × $V_{CCA}$ V) turns the connector port driver (either SDA or SCL) on and drives port B down to $V_{OL\_CON}$ V. When the system port rises above approximately 0.10 × $V_{CCA}$ V, the connector port pull-down driver is turned off and the internal pull-up resistor pulls the pin HIGH. When the connector port falls first and goes below 0.3 × 5 V_CON V, a CMOS hysteresis input buffer detects the falling edge, turns on the system port driver, and pulls port A down to approximately $V_{OLA}$. The connector port pull-down is not enabled unless the system port voltage goes below $V_{ILC}$, in which case the connector port pull-down driver is enabled until system port rises above ($V_{ILC}$ + $\Delta V_{T\text{-}HYSTA}$). If the connector port is not externally driven LOW, its voltage will continue to rise due to the internal pull-up resistor.

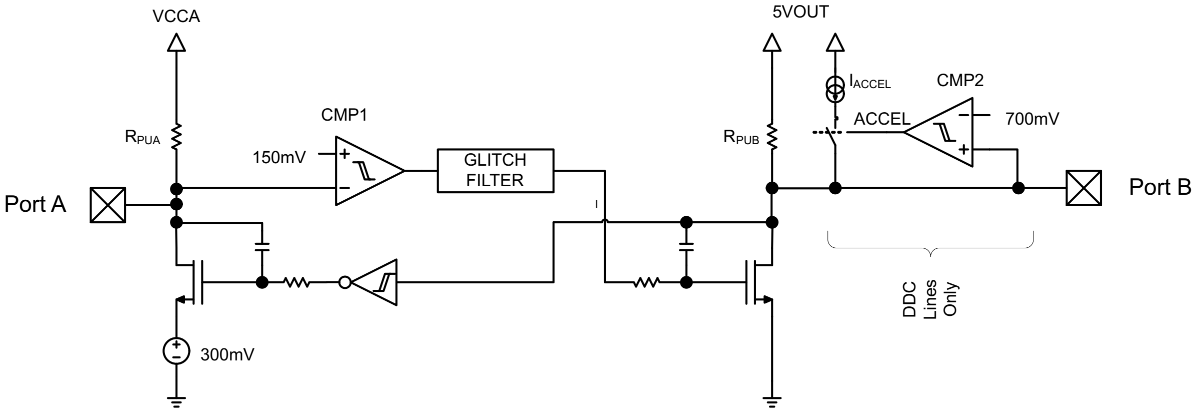


**Figure 15. DDC/CEC Level Shifter Block Diagram**

### 8.3.10 DDC/CEC Level Shifter Operational Notes For $V_{CCA}$ = 1.8V

- The threshold of CMP1 is ~150 mV +/- the 40mV of total hysteresis.
- The comparator will trip for a falling waveform at ~130mV
- The comparator will trip for a rising waveform at ~170mV
- To be recognized as a zero, the level at system port must first go below 130mV ($V_{ILC}$ in spec) and then stay below 170mV ($V_{IL\_SYS}$ in spec)
- To be recognized as a one, the level at system port must first go above 170mV and then stay above 130mV
- $V_{ILC}$ is set to 110mV in Electrical Characteristics Table to give some margin to the 130mV
- $V_{IL\_SYS}$ is set to 140mV in the Electrical Characteristics Table to give some margin to the 170mV
- $V_{IH\_SYS}$ is set to 70% of $V_{CCA}$ to be consistent with standard CMOS levels

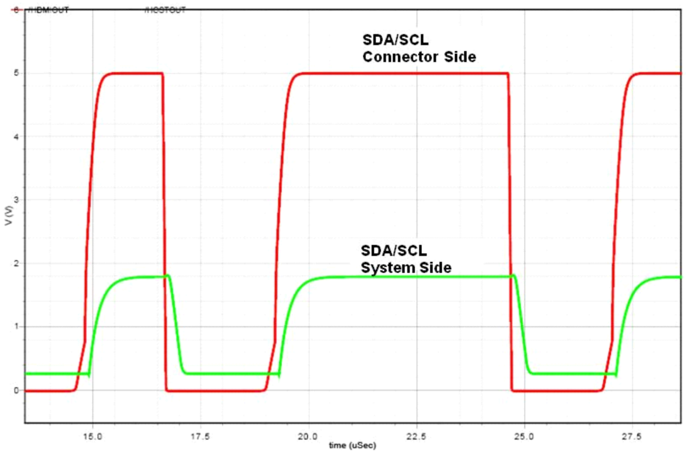


**Figure 16. DDC Level Shifter Operation (Connector To System Direction)**

## Feature Description (continued)

### 8.3.11 Rise-Time Accelerators

The HDMI cable side of the DDC lines incorporates rise-time accelerators to support the high capacitive load on the HDMI cable side. The rise time accelerator boosts the cable side DDC signal independent of which side of the bus is releasing the signal.

### 8.3.12 Noise Considerations

Ground offset between the TPD5S116 ground and the ground of devices on the system port of the TPD5S116 must be avoided. The reason for this cautionary remark is that a CMOS/NMOS open-drain capable of sinking 3 mA of current at 0.4 V will have an output resistance of 133Ω or less (R = E / I). Such a driver will share enough current with the system port output pull-down of the TPD5S116 to be seen as a LOW as long as the ground offset is zero. If the ground offset is greater than 0 V, then the driver resistance must be less. Since $V_{ILC}$ can be as low as 90 mV at cold temperatures and the low end of the current distribution, the maximum ground offset should not exceed 50 mV. Bus repeaters that use an output offset are not interoperable with the system port of the TPD5S116 as their output LOW levels will not be recognized by the TPD5S116 as a LOW. If the TPD5S116 is placed in an application where the $V_{IL\_SYS}$ does not go below $V_{ILC}$, it will pull connector port LOW initially when system port input transitions LOW but the connector port will return HIGH, so it will not reproduce the system port input on connector port. Such applications should be avoided. The connector port is interoperable with all I2C-bus slaves, masters and repeaters.

### 8.3.13 HDMI Compliance

The TPD5S116 is designed to be fully compliant to the HDMI 7-13 capacitance specification. Both power on and power off capacitance measurements are done on the CEC, SDA, and SCL connector-side pins using a Hioki 3522-50 meter. In the power on setup, connect TPD5S116’s EN and HPD_CON pins low and 5V_SYS and $V_{CCA}$ pins high. Use the Hioki meter to measure the test fixture with and without the TPD5S116 and subtract to obtain the capacitance. In the power off setup, connect TPD5S116’s EN, HPD_CON, 5V_SYS, and $V_{CCA}$ pins low and conduct the same test with the Hioki meter. Read the $C_p$ result from the Hioki meter.

- SCL_CON, SDA_CON Test:
  - Measure the large signal capacitance at SCL_CON & SDA_CON pins at either power-up or power down conditions:
    - VBIAS = 2.5 V
    - f = 100 kHz
    - 3.5 V p-p ac signal
- CEC Test:
  - Measure the large signal capacitance of the CEC_CON pin at both power-up and power down conditions:
    - VBIAS = 1.65 V,
    - f = 100 kHz
    - 2.5V p-p ac signal

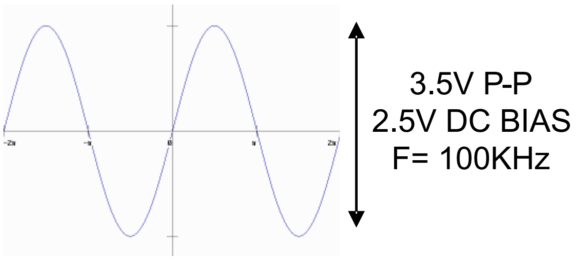


Figure 17. Hioki Meter Signal Set-Up For Scl, Sda Cap Measurement

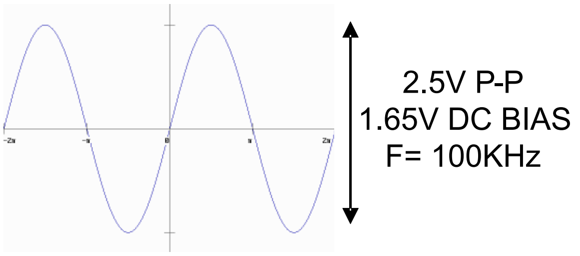


Figure 18. Hioki Meter Signal Set-Up For Cec Cap Measurement

## 8.4 Device Functional Modes

HDMI Driver Chip is controlling the TPD5S116 via only one control line (EN). The DDC and CEC level shifting buffers become active after HPD_CON receives a valid high signal and EN is high. EN and HPD_CON control the TPD5S116 power saving options according to the following table:

**Table 1. Function Table – Power Saving Options**

| HPD_CON | EN | $V_{CCA}$ | 5V_SYS | 5V_CON | Dxx_SYS CEC_SYS Pull-ups | DCC_CON Pull-ups | CEC_CON Pull-ups | CEC LDO | LOAD SW & HPD | DCC/CEC VLTs | ICCA Typ | ICC5V Typ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **L** | **L** | 1.2V – 5.0V | 5.0V | High-Z | Off | Off | Off | Off | Off | Off | 1µA | 2µA | Fully Disabled |
| **L** | **H** | 1.2V – 5.0V | 5.0V | 5.0V | On | On | Off | Off | On | Off | 1µA | 30µA | Load Switch on |
| **H** | **L** | 1.2V – 5.0V | 5.0V | High-Z | Off | Off | Off | Off | Off | Off | 1µA | 2µA | Not Valid State |
| **H** | **H** | 1.2V – 5.0V | 5.0V | 5.0V | On | On | On | On | On | On | 24µA | 125µA | Fully On |
| **X** | **X** | 0V | 0V | High-Z | High-Z | High-Z | High-Z | Off | Off | Off | 0 | 0 | Power Down |
| **X** | **X** | 1.2V – 5.0V | 0V | High-Z | High-Z | High-Z | High-Z | Off | Off | Off | 1 | 0 | Power Down |
| **X** | **X** | 0V | 5.0V | High-Z | High-Z | High-Z | High-Z | Off | Off | Off | 0 | 1 | Power Down |

# 9 Applications and Implementations

**NOTE**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

## 9.1 Application Information

TPD5S116 provides IEC 61000-4-2 Level 4 Contact ESD rating to the HDMI 2.0 transmitter port, with backwards compatibility. Buffered voltage level translators (VLT) translate DDC and CEC channels bidirectionally. The system is designed to work properly with no external pull-up resistors on the DDC, CEC, and HPD lines. The CEC line has an integrated 3.3-V rail, eliminating the need for a 3.3-V supply on board.

## 9.2 Typical Application

The TPD5S116 is placed as close as possible to the HDMI connector to provide voltage level translation, 5V_OUT current limiting and overall ESD protection for the HDMI Controller.

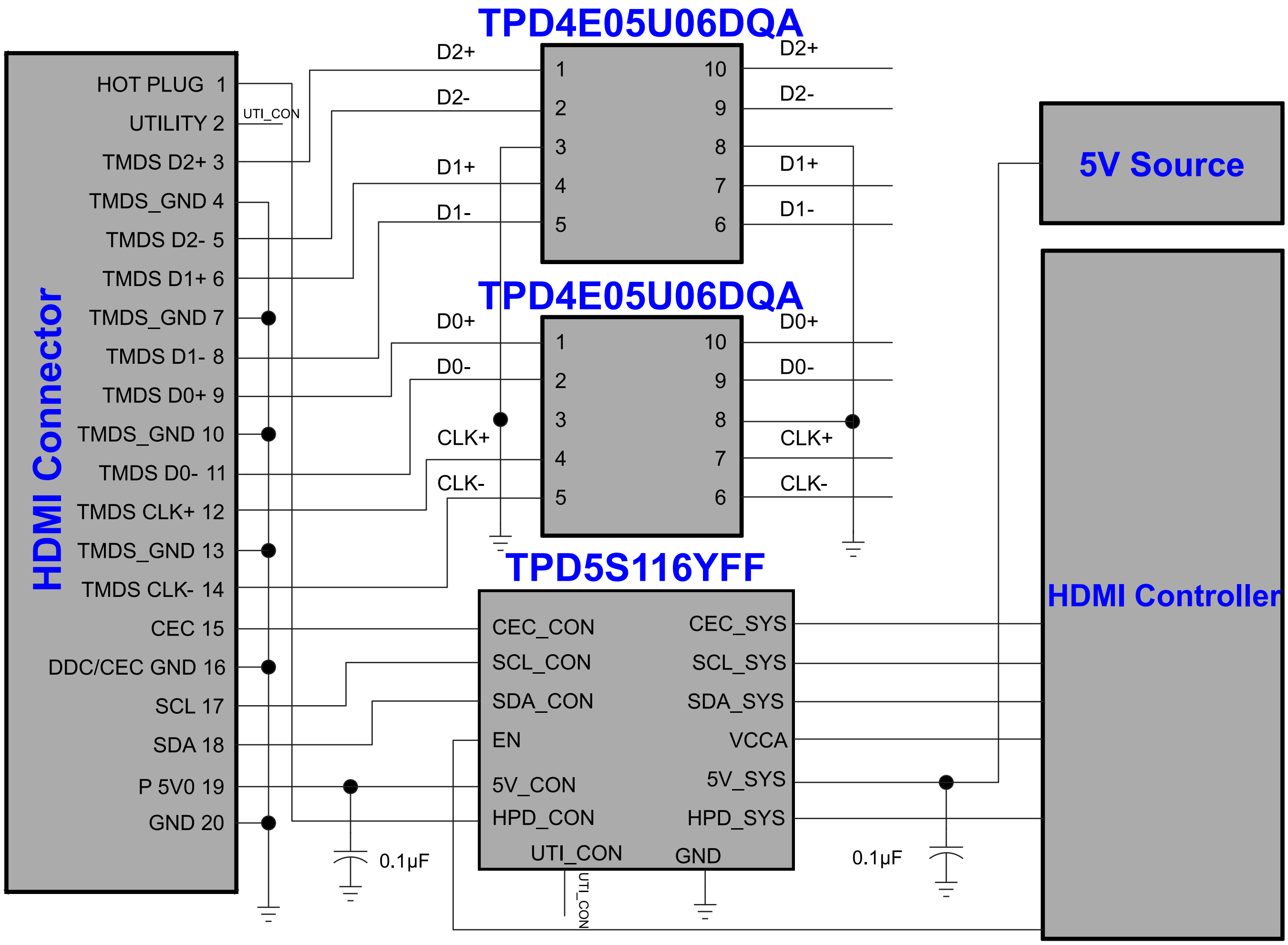


Figure 19. Application Schematics For HDMI Controllers With One GPIO For HDMI Interface Control

## Typical Application (continued)

### 9.2.1 Design Requirements

For this example, use Table 2 as the input parameters:

**Table 2. HDMI Controller Using One Control Line Design Parameters**

| DESIGN PARAMETERS | | | EXAMPLE VALUE |
|---|---|---|---|
| Voltage on $V_{CCA}$ | | | 1.8 V |
| Voltage on 5V_SYS | | | 5.0 V |
| Drive EN low (disabled) | | | -0.5 – 0.4 V |
| Drive EN low (enabled) | | | 1.0 V to 1.8 V |
| Drive HPD_CON low (disabled) | | | 0 V – 0.8 V |
| Drive HPD_CON high (enabled) | | | 2.0 V – 5.0 V |
| Drive a logical "1" | SYS to CON | SCL and SDA | 1.26 V – 1.8 V |
| | | CEC | |
| | CON to SYS | SCL and SDA | 3.5 V – 5.0 V |
| | | CEC | 2.31 V – 3.3 V |
| Drive a logical "0" | SYS to CON | SCL and SDA | -0.5 V – 0.11 V |
| | | CEC | |
| | CON to SYS | SCL and SDA | -0.5 V – 1.5 V |
| | | CEC | -0.5 V – 0.99 V |

### 9.2.2 Detailed Design Procedure

To begin the design process the designer needs to know the 5V_SYS voltage range and the logic level, $V_{CCA}$, voltage range.

#### *9.2.2.1 Resistor Pull-Up Value Selection*

The system is designed to work properly with no external pull-up resistors on the DDC, CEC, and HPD lines.

#### *9.2.2.2 Input Capacitor (Optional)*

To limit the voltage drop on the input supply caused by transient in-rush currents when the switch turns on into a discharged load capacitor or short-circuit, a capacitor needs to be placed between 5V_SYS and GND. A 10-µF ceramic capacitor, $C_{IN}$, placed close to the pins, is usually sufficient. Higher values of $C_{IN}$ can be used to further reduce the voltage drop during high-current application. When switching heavy loads, it is recommended to have an input capacitor about 10 times higher than the output capacitor to avoid excessive voltage drop.

#### *9.2.2.3 Output Capacitor (Optional)*

Due to the integrated body diode in the NMOS switch, a $C_{IN}$ greater than $C_{LOAD}$ is highly recommended. A $C_{LOAD}$ greater than $C_{IN}$ can cause 5V_CON to exceed 5V_SYS when the system supply is removed. A $C_{IN}$ to $C_{LOAD}$ ratio of 10 to 1 is recommended for minimizing 5V_SYS dip caused by inrush currents during startup.

### 9.2.3 Application Curve

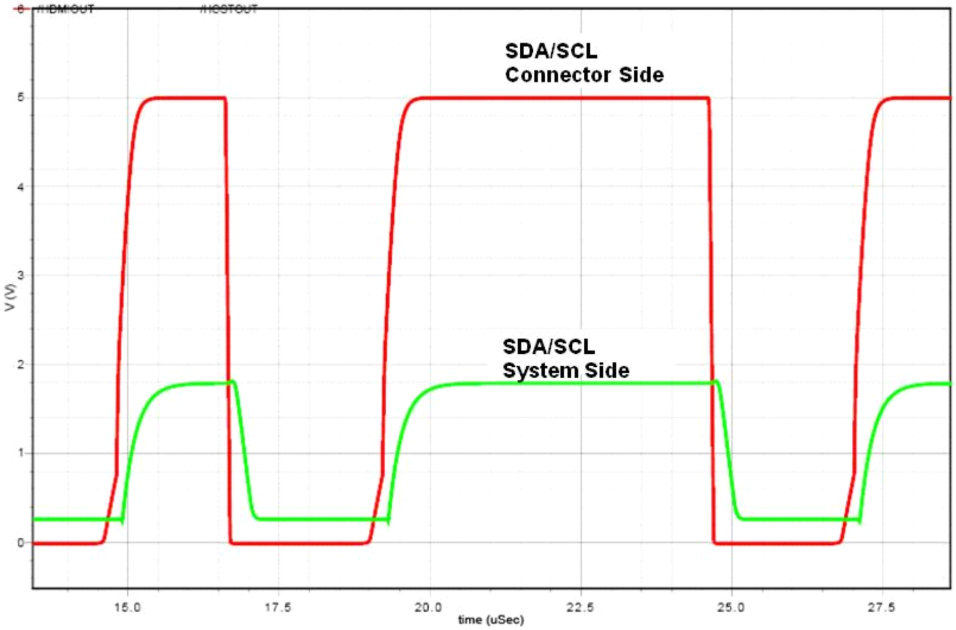


**Figure 20. DDC Level Shifter Operation (Connector To System Direction)**

## 10 Power Supply Requirements

TPD5S116 has two power input pins: 5V_SYS and $V_{CCA}$. It can operate normally with 5V_SYS between 4.5 V and 5.5 V; and $V_{CCA}$ between 1.1 V and 5.5 V. Thus, the power supply (with a ripple of $V_{RIPPLE}$) requirement for TPD5S116 for 5V_SYS is between 4.5 V + ½$V_{RIPPLE}$ and 5.5 V – ½$V_{RIPPLE}$; and for $V_{CCA}$ it is between 1.1 V + ½$V_{RIPPLE}$ and 5.5 V – ½$V_{RIPPLE}$.

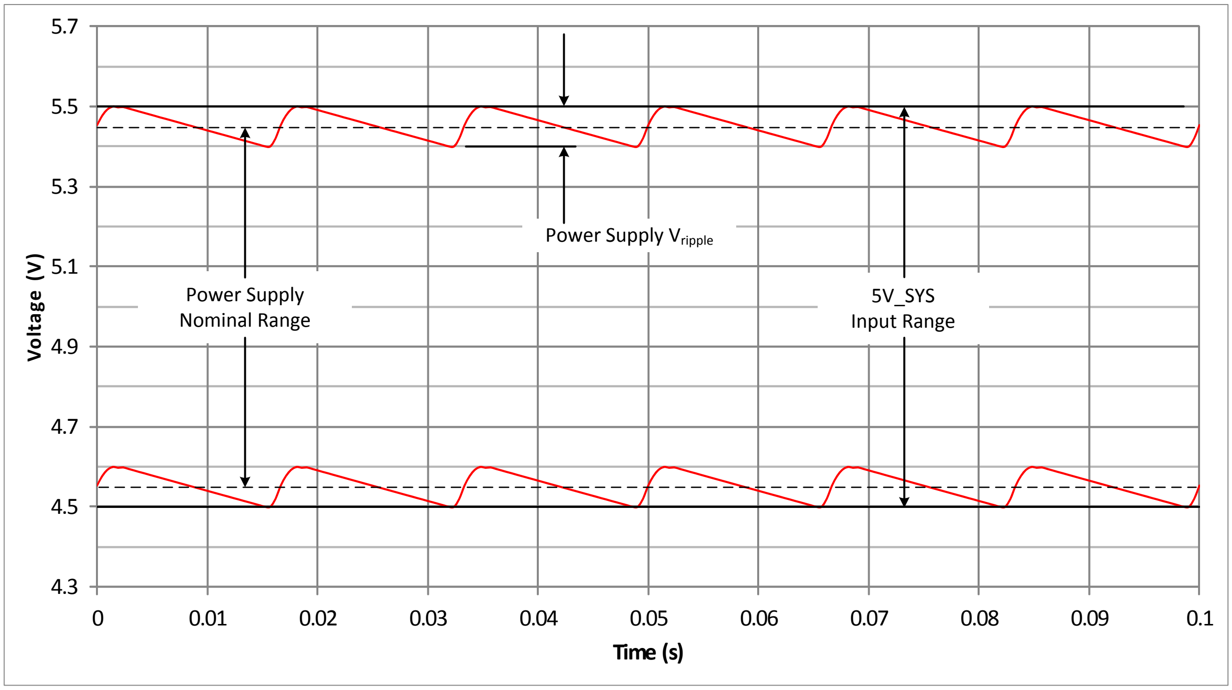


**Figure 21. Power Supply Ripple and TPD5S116 5V_SYS Voltage Requirements**

# 11 Layout

## 11.1 Layout Guidelines

- The optimum placement is as close to the connector as possible.
  - EMI during an ESD event can couple from the trace being struck to other nearby unprotected traces, resulting in early system failures. Therefore, the PCB designer needs to minimize the possibility of EMI coupling by keeping any unprotected traces away from the protected traces which are between the TVS and the connector.
- Route the protected traces as straight as possible.
- Avoid using VIAs between the connecter and an I/O protection pin on TPD5S116.
- Avoid 90º turns in traces.
  - Electric fields tend to build up on corners, increasing EMI coupling.
- Minimize impedance on the path to GND for maximum ESD dissipation.
- The capacitors on 5V_CON and 5V_SYS should be placed close to their respective pins on TPD5S116.

## 11.2 Layout Example

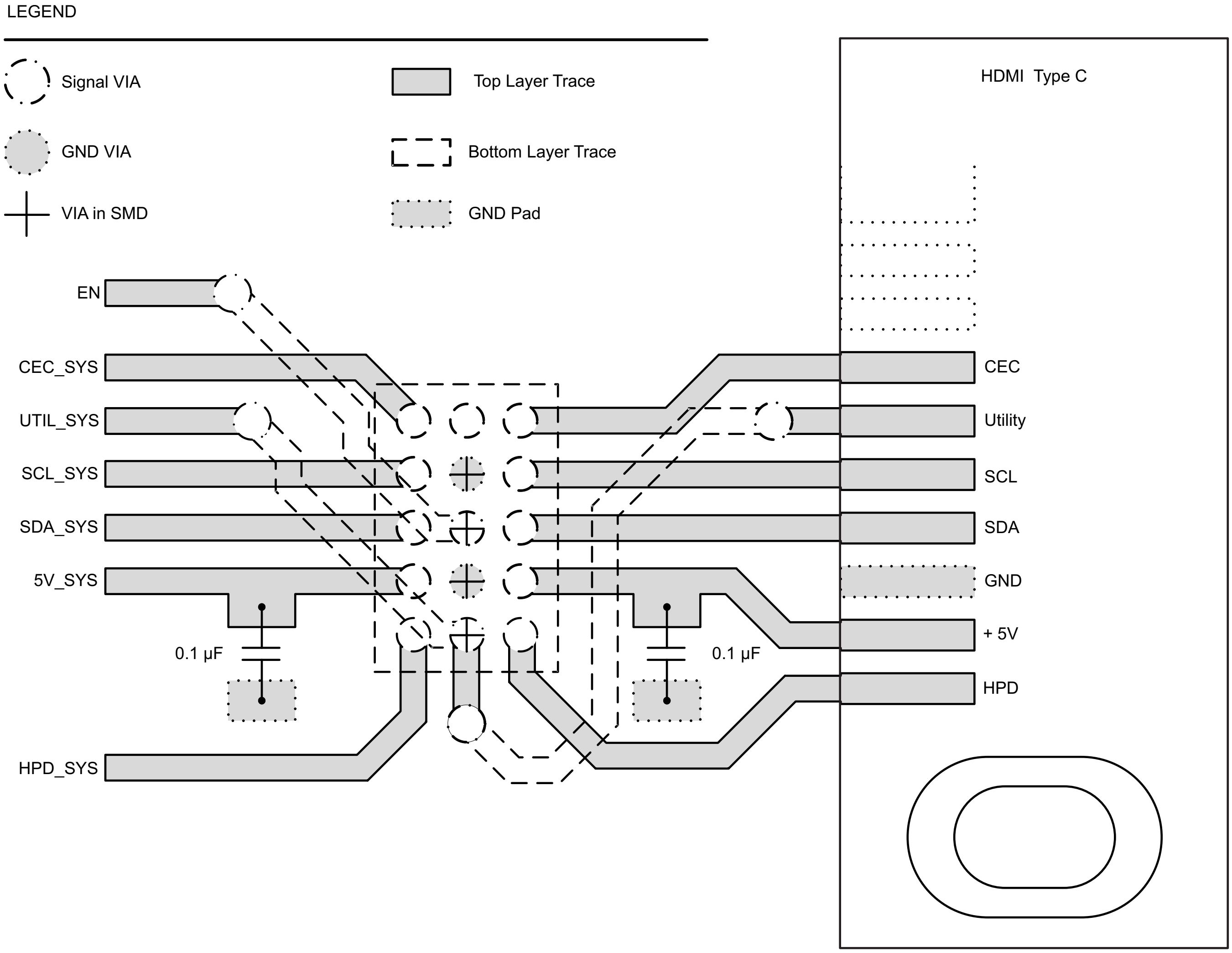


**Figure 22. TPD5S116 HDMI Layout Example**

# 12 Device and Documentation Support

## 12.1 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

**TI E2E™ Online Community** ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

## 12.2 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

## 12.3 Electrostatic Discharge Caution

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.

## 12.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

# 13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

# PACKAGE OPTION ADDENDUM

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPD5S116YFFR | ACTIVE | DSBGA | YFF | 15 | 3000 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | RE116 | 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] **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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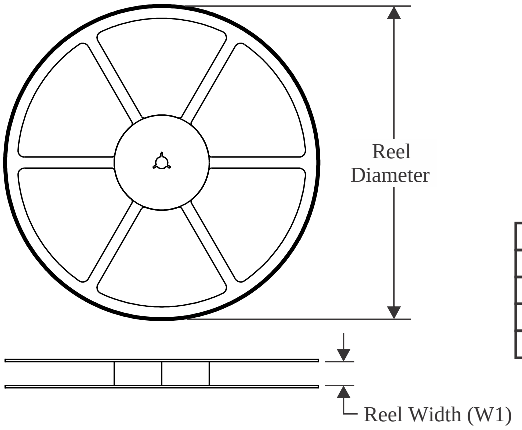
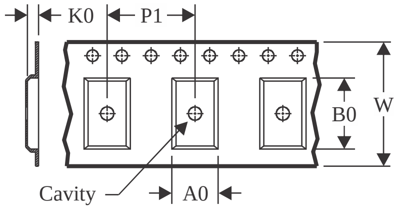
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS

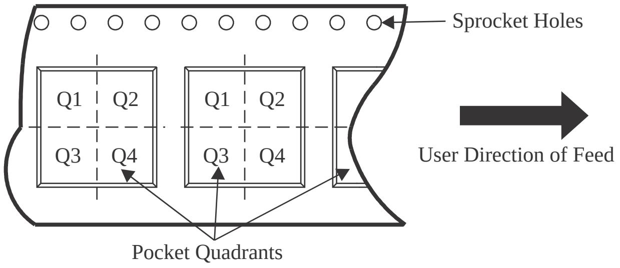


### TAPE DIMENSIONS



| | |
|---|---|
| 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 |

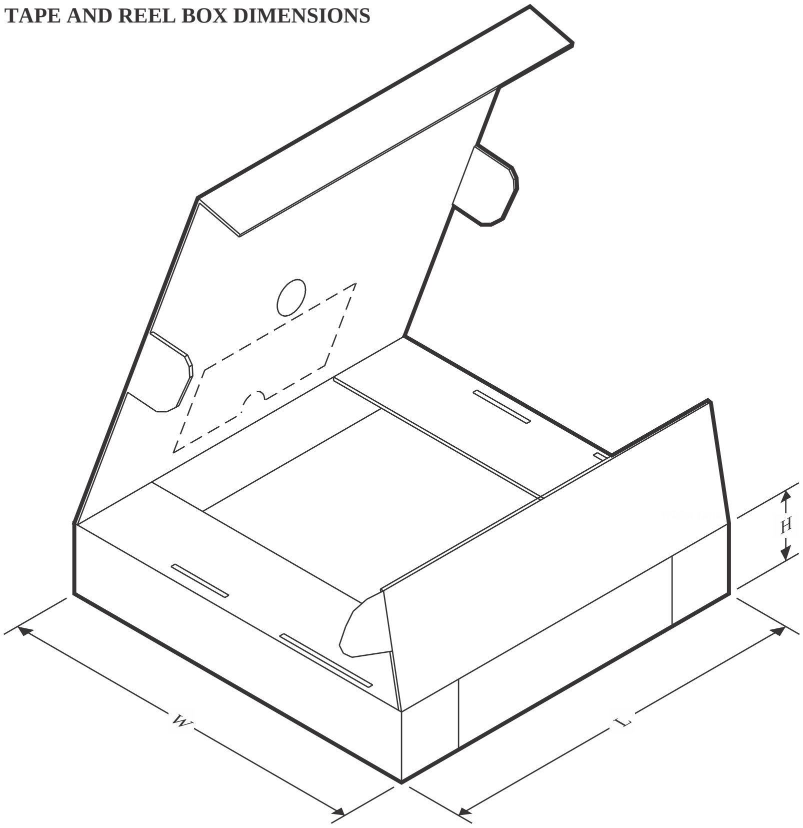
### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

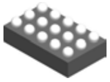
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPD5S116YFFR | DSBGA | YFF | 15 | 3000 | 180.0 | 8.4 | 1.46 | 2.28 | 0.71 | 4.0 | 8.0 | Q1 |

## TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TPD5S116YFFR | DSBGA | YFF | 15 | 3000 | 182.0 | 182.0 | 20.0 |

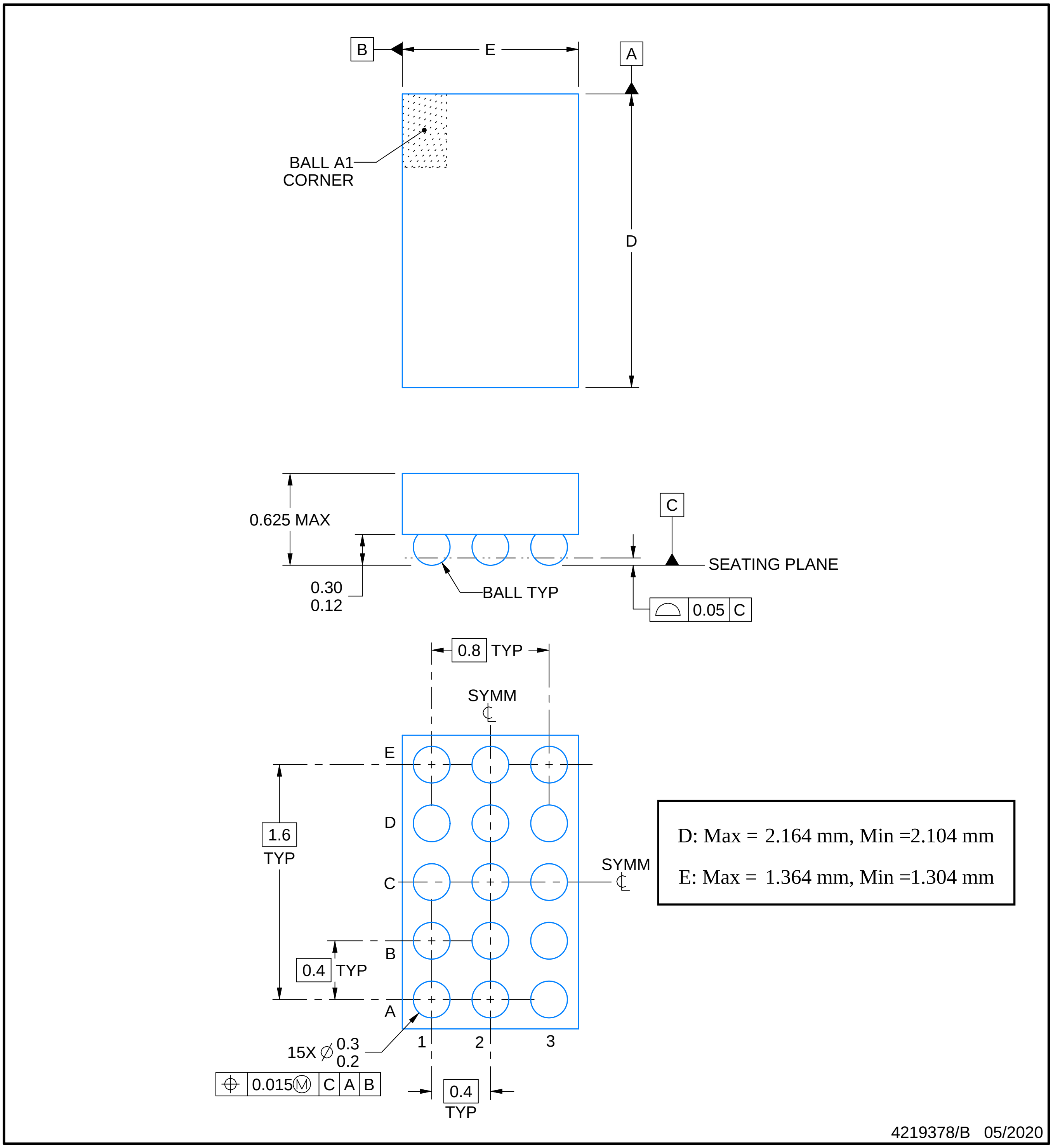


# PACKAGE OUTLINE

**YFF0015**

## DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY

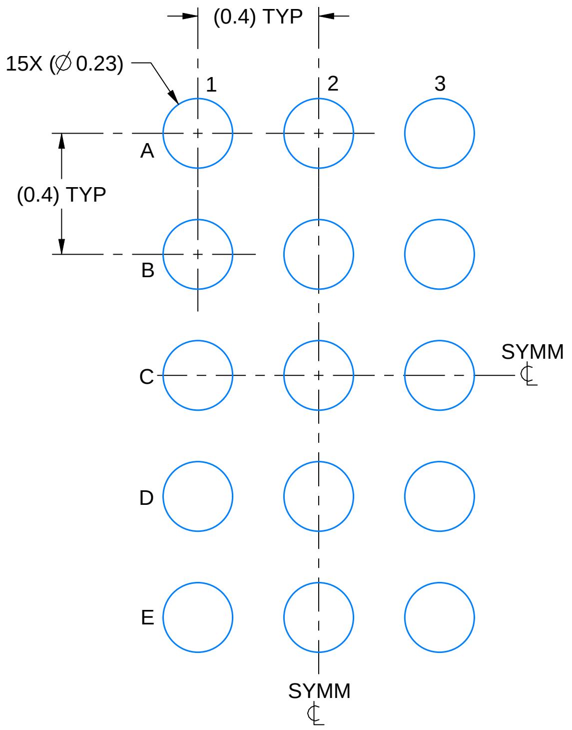


D: Max = 2.164 mm, Min =2.104 mm

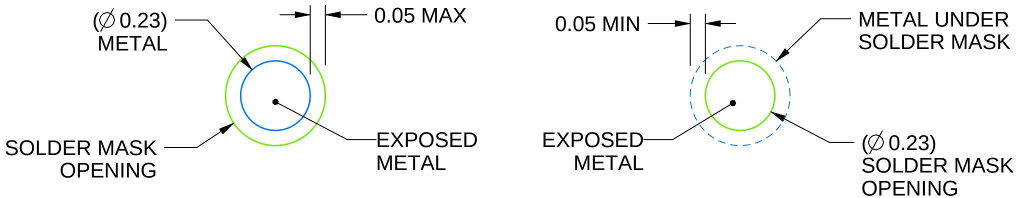
E: Max = 1.364 mm, Min =1.304 mm

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:40X



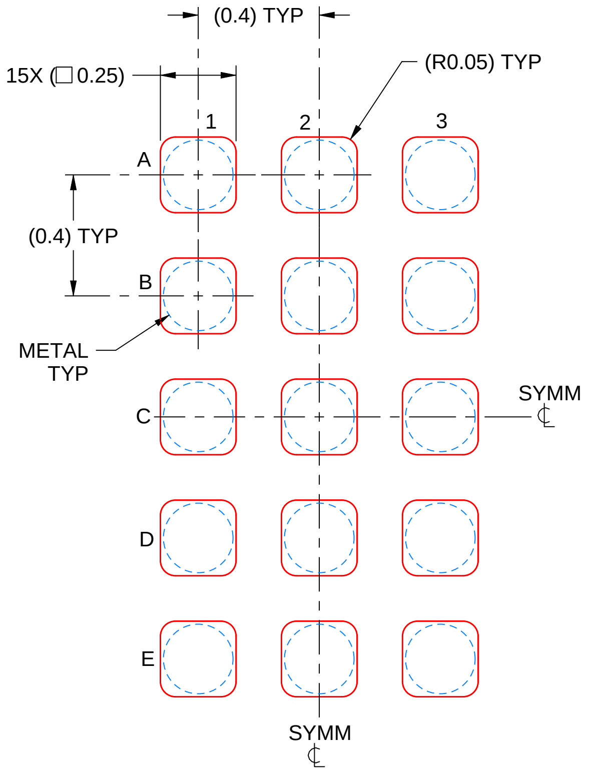
NON-SOLDER MASK
DEFINED

SOLDER MASK
DEFINED

SOLDER MASK DETAILS
NOT TO SCALE

NOTES: (continued)

3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 (www.ti.com/lit/snva009).



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:40X

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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