

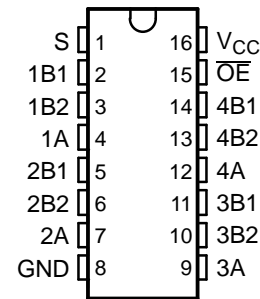
## FEATURES

- **Low and Flat ON-State Resistance ( $r_{on}$ ) Characteristics Over Operating Range ( $r_{on} = 3 \Omega$  Typ)**
- **0- to 10-V Switching on Data I/O Ports**
- **Bidirectional Data Flow With Near-Zero Propagation Delay**
- **Low Input/Output Capacitance Minimizes Loading and Signal Distortion ( $C_{io(OFF)} = 20$  pF Max, B Port)**
- **$V_{CC}$  Operating Range From 4.75 V to 5.25 V**
- **Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II**
- **ESD Performance Tested Per JESD 22**
  - 2000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)
- **Supports Both Digital and Analog Applications**

## APPLICATIONS

- **PCI Interface**
- **Differential Signal Interface**
- **Memory Interleaving**
- **Bus Isolation**
- **Low-Distortion Signal Gating**

DBQ OR PW PACKAGE  
(TOP VIEW)



## DESCRIPTION/ORDERING INFORMATION

The TS5N412 is a high-bandwidth FET bus switch utilizing a charge pump to elevate the gate voltage of the pass transistor, providing a low and flat ON-state resistance ( $r_{on}$ ). The low and flat ON-state resistance allows for minimal propagation delay and supports rail-to-rail switching on the data input/output (I/O) ports. The device also features low data I/O capacitance to minimize capacitive loading and signal distortion on the data bus. Specifically designed to support high-bandwidth applications, the TS5N412 provides an optimized interface solution ideally suited for broadband communications, networking, and data-intensive computing systems.

The TS5N412 is a 4-bit 1-of-2 multiplexer/demultiplexer with a single output-enable ( $\overline{OE}$ ) input. The select (S) inputs control the data path of the multiplexer/demultiplexer. When  $\overline{OE}$  is low, the multiplexer/demultiplexer is enabled and the A port is connected to the B port, allowing bidirectional data flow between ports. When  $\overline{OE}$  is high, the multiplexer/demultiplexer is disabled and a high-impedance state exists between the A and B ports.

This device is fully specified for partial-power-down applications using  $I_{off}$ . The  $I_{off}$  circuitry prevents damaging current backflow through the device when it is powered down. The device has isolation during power off.

To ensure the high-impedance state during power up or power down,  $\overline{OE}$  should be tied to  $V_{CC}$  through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

## ORDERING INFORMATION

| $T_A$         | PACKAGE <sup>(1)</sup> |               | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---------------|------------------------|---------------|-----------------------|------------------|
| –40°C to 85°C | SSOP (QSOP) – DBQ      | Tape and reel | TS5N412DBQR           | YB412            |
|               | TSSOP – PW             | Tape and reel | TS5N412PWR            |                  |

(1) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



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

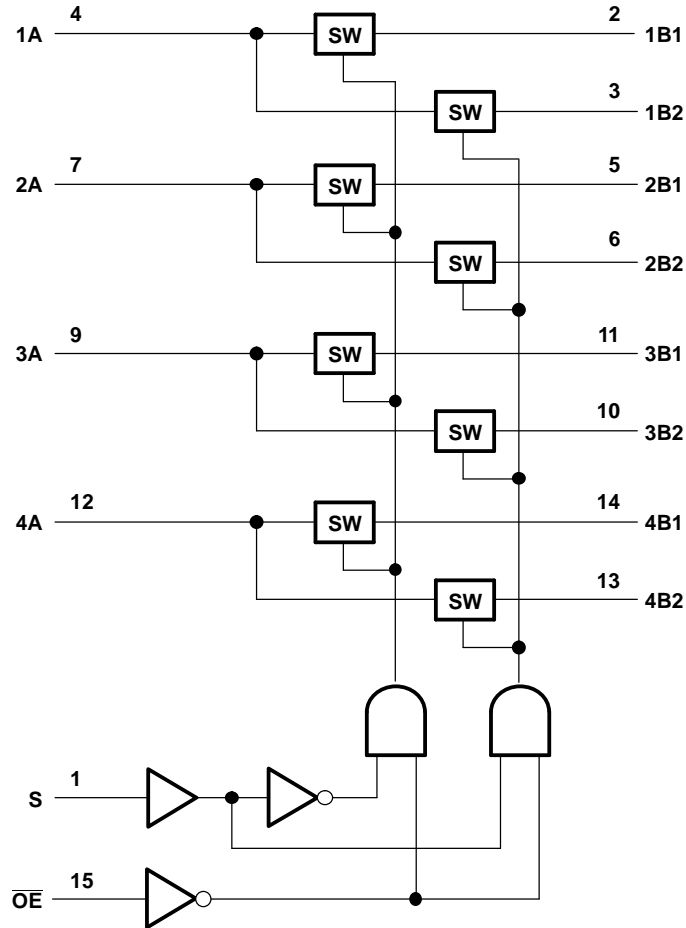
**TS5N412**  
**4-BIT 1-OF-2 FET MULTIPLEXER/DEMULTIPLEXER**  
**HIGH-BANDWIDTH BUS SWITCH**

SCDS207–AUGUST 2005

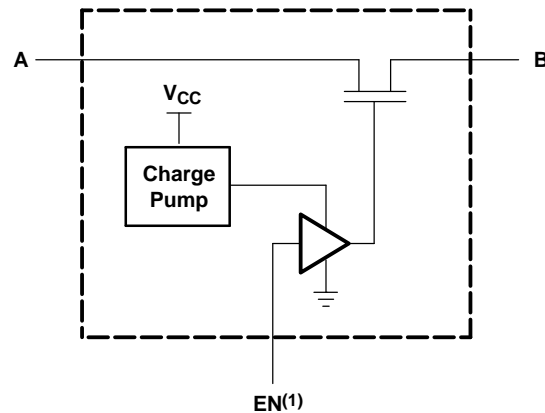
**FUNCTION TABLE**

| INPUTS          |   | INPUT/OUTPUT<br>A | FUNCTION         |
|-----------------|---|-------------------|------------------|
| $\overline{OE}$ | S |                   |                  |
| L               | L | B1                | A port = B1 port |
| L               | H | B2                | A port = B2 port |
| H               | X | Z                 | Disconnect       |

**LOGIC DIAGRAM (POSITIVE LOGIC)**



SIMPLIFIED SCHEMATIC, EACH FET SWITCH (SW)



(1) EN is the internal enable signal applied to the switch.

**Absolute Maximum Ratings<sup>(1)</sup>**

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

|               |   | MIN  | MAX  | UNIT |
|---------------|---|------|------|------|
| $V_{CC}$      | Supply voltage range                          | -0.5 | 7    | V    |
| $V_{IN}$      | Control input voltage range <sup>(2)(3)</sup> | -0.5 | 7    | V    |
| $V_{I/O}$     | Switch I/O voltage range <sup>(2)(3)(4)</sup> | -0.5 | 11   | V    |
| $I_{I/O}$     | ON-state switch current <sup>(5)</sup>        |      | ±100 | mA   |
|               | Continuous current through $V_{CC}$ or GND    |      | ±100 | mA   |
| $\theta_{JA}$ | Package thermal impedance <sup>(6)</sup>      |      | 90   | °C/W |
|               |   |      | 108  |      |
| $T_{stg}$     | Storage temperature range                     | -65  | 150  | °C   |

- (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 voltages are with respect to ground, unless otherwise specified.
- (3) The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
- (4)  $V_I$  and  $V_O$  are used to denote specific conditions for  $V_{I/O}$ .
- (5)  $I_I$  and  $I_O$  are used to denote specific conditions for  $I_{I/O}$ .
- (6) The package thermal impedance is calculated in accordance with JESD 51-7.

**Recommended Operating Conditions<sup>(1)</sup>**

|           |                                  | MIN  | MAX  | UNIT |
|-----------|----------------------------------|------|------|------|
| $V_{CC}$  | Supply voltage                   | 4.75 | 5.25 | V    |
| $V_{IH}$  | High-level control input voltage | 2    | 5.25 | V    |
| $V_{IL}$  | Low-level control input voltage  | 0    | 0.8  | V    |
| $V_{I/O}$ | Data input/output voltage        | 0    | 10   | V    |
| $T_A$     | Operating free-air temperature   | -40  | 85   | °C   |

- (1) All unused inputs of the device must be held at  $V_{CC}$  or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

# TS5N412

## 4-BIT 1-OF-2 FET MULTIPLEXER/DEMULTIPLEXER

### HIGH-BANDWIDTH BUS SWITCH

SCDS207–AUGUST 2005

### Electrical Characteristics<sup>(1)</sup>

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

| PARAMETER               |                | TEST CONDITIONS  |                                   |                                   | MIN                             | TYP <sup>(2)</sup> | MAX  | UNIT          |
|-------------------------|----------------|--|-----------------------------------|-----------------------------------|---------------------------------|--------------------|------|---------------|
| $I_{IN}$                | Control inputs | $V_{CC} = 5.25\text{ V}$ ,                                 | $V_{IN} = 0\text{ to }V_{CC}$     |                                   |                                 |                    | 10   | $\mu\text{A}$ |
| $I_{OZ}$ <sup>(3)</sup> |                | $V_{CC} = 5.25\text{ V}$ ,                                 | $V_O = 0\text{ to }10\text{ V}$ , | Switch OFF,                       |                                 |                    | 10   | $\mu\text{A}$ |
|                         |                | $V_{CC} = 0\text{ V}$ ,                                    | $V_O = \text{Open}$ ,             | $V_{IN} = V_{CC}\text{ or GND}$   | $V_I = 0\text{ to }10\text{ V}$ |                    |      |               |
| $I_{CC}$                |                | $V_{CC} = 5.25\text{ V}$ ,                                 | $I_{I/O} = 0$ ,                   | Switch ON or OFF,                 |                                 |                    | 10   | $\text{mA}$   |
| $C_{in}$                | Control inputs | $V_{CC} = 5\text{ V}$ ,                                    | $V_{IN} = 10\text{ V or }0$       |                                   |                                 |                    | 10   | $\text{pF}$   |
| $C_{io(OFF)}$           | A port         | $V_{CC} = 5\text{ V}$ ,                                    | Switch OFF,                       | $V_{IN} = V_{CC}\text{ or GND}$ , | $V_{I/O} = 10\text{ V or }0$    |                    | 35   | $\text{pF}$   |
|                         | B port         | $V_{CC} = 5\text{ V}$ ,                                    | Switch OFF,                       | $V_{IN} = V_{CC}\text{ or GND}$ , | $V_{I/O} = 10\text{ V or }0$    |                    | 20   |               |
| $C_{io(ON)}$            |                | $V_{CC} = 5\text{ V}$ ,                                    | Switch ON,                        | $V_{IN} = V_{CC}\text{ or GND}$ , | $V_{I/O} = 10\text{ V or }0$    |                    | 80   | $\text{pF}$   |
| $r_{on}$ <sup>(4)</sup> |                | $V_{CC} = 4.75\text{ V}$ ,<br>TYP at $V_{CC} = 5\text{ V}$ | $V_I = 0$ ,                       | $I_O = 50\text{ mA}$              |                                 | 3                  | 7.5  | $\Omega$      |
|                         |                |  | $V_I = 8\text{ V}$ ,              | $I_O = -50\text{ mA}$             |                                 |                    | 7.5  |               |
|                         |                |  | $V_I = 10\text{ V}$ ,             | $I_O = -50\text{ mA}$             |                                 |                    | 12.5 |               |

- (1)  $V_{IN}$  and  $I_{IN}$  refer to control inputs.  $V_I$ ,  $V_O$ ,  $I_I$ , and  $I_O$  refer to data pins  
(2) All typical values are at  $V_{CC} = 5\text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .  
(3) For I/O ports, the parameter  $I_{OZ}$  includes the I/O leakage current.  
(4) Measured by the voltage drop between the A and B terminals at the indicated current through the switch. ON-state resistance is determined by the lower of the voltages of the two (A or B) terminals.

### Switching Characteristics

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 3](#))

| PARAMETER      | FROM (INPUT)    | TO (OUTPUT) | $V_{CC} = 5\text{ V} \pm 0.25\text{ V}$ |     | UNIT |
|----------------|-----------------|-------------|---|-----|------|
|                |                 |             | MIN                                     | MAX |      |
| $t_{pd}^{(1)}$ | A or B          | B or A      |   | 3   | ns   |
| $t_{pd(s)}$    | S               | A           |   | 200 | ns   |
| $t_{en}$       | S               | B           |   | 200 | ns   |
|                | $\overline{OE}$ | A or B      |   | 200 |      |
| $t_{dis}$      | S               | B           |   | 200 | ns   |
|                | $OE$            | A or B      |   | 200 |      |

- (1) The propagation delay is the calculated RC time constant of the typical ON-state resistance of the switch and the specified load capacitance, when driven by an ideal voltage source (zero output impedance).

### Dynamic Characteristics

over recommended operating free-air temperature range,  $V_{CC} = 5\text{ V} \pm 5\%$  (unless otherwise noted)

| PARAMETER                     | TEST CONDITIONS   | MIN | TYP <sup>(1)</sup> | MAX | UNIT |
|-------------------------------|---|-----|--------------------|-----|------|
| Bandwidth (BW) <sup>(2)</sup> | $R_L = 50\ \Omega$ , $V_I = 0.632\text{ V (P-P)}$ , See <a href="#">Figure 4</a>  |     | 25                 |     | MHz  |
| OFF isolation ( $O_{ISO}$ )   | $R_L = 50\ \Omega$ , $V_I = 0.632\text{ V (P-P)}$ , $f = 25\text{ MHz}$ , See <a href="#">Figure 5</a>                              |     | -50                |     | dB   |
| Crosstalk ( $X_{TALK}$ )      | $R_L = 50\ \Omega$ , $V_I = 0.632\text{ V (P-P)}$ , $f = 25\text{ MHz}$ , See <a href="#">Figure 6</a> and <a href="#">Figure 7</a> |     | -50                |     | dB   |

- (1) All typical values are at  $V_{CC} = 5\text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .  
(2) Bandwidth is the frequency at which the gain is -3 dB below the DC gain.

**TYPICAL PERFORMANCE**

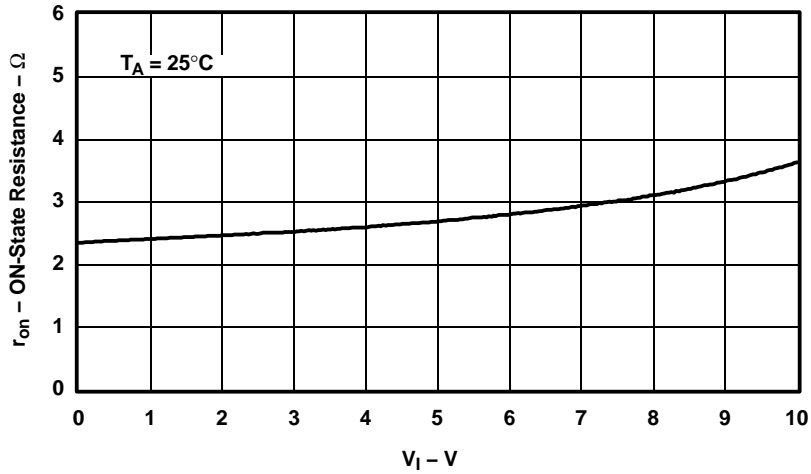


Figure 1. Typical  $r_{on}$  vs  $V_I$ ,  $V_{CC} = 5\text{ V}$  and  $I_O = -50\text{ mA}$

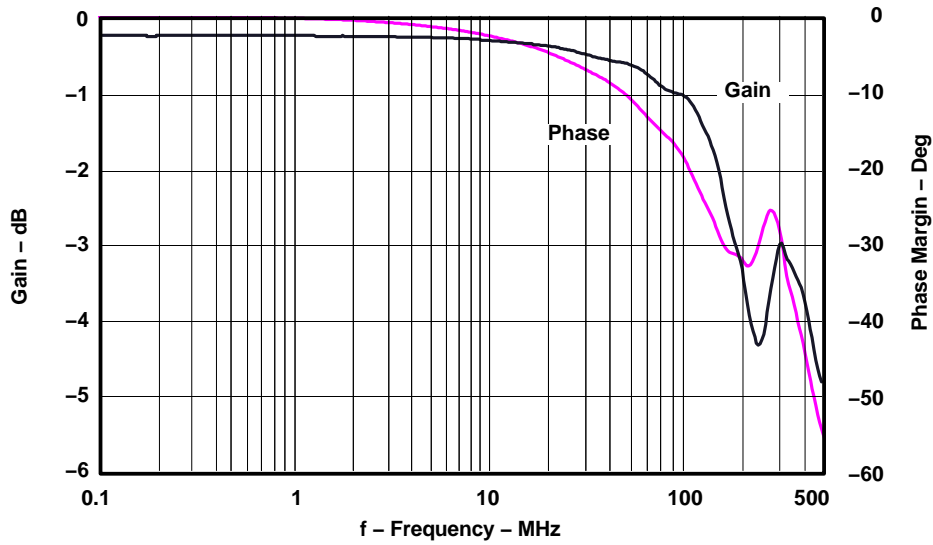


Figure 2. Frequency Response vs Bandwidth

TYPICAL PERFORMANCE

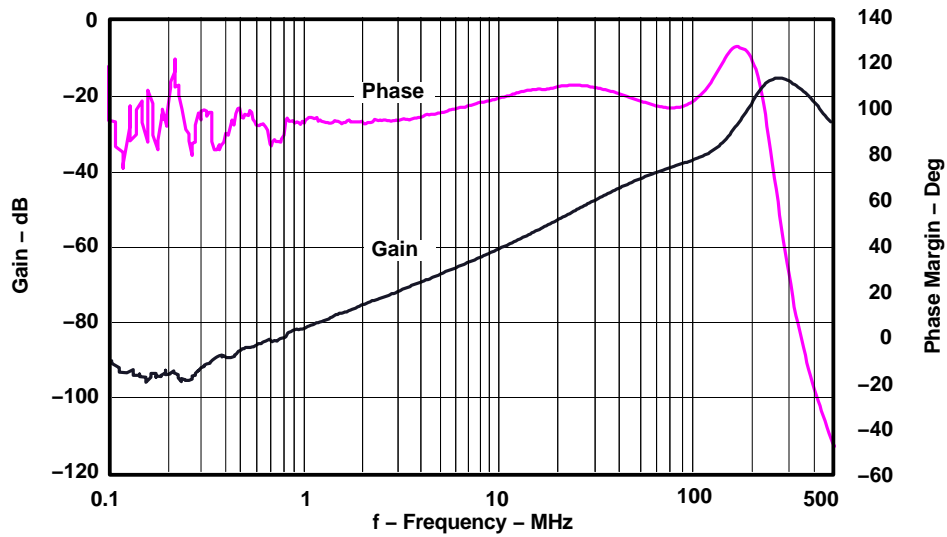


Figure 3. Frequency Response vs OFF Isolation

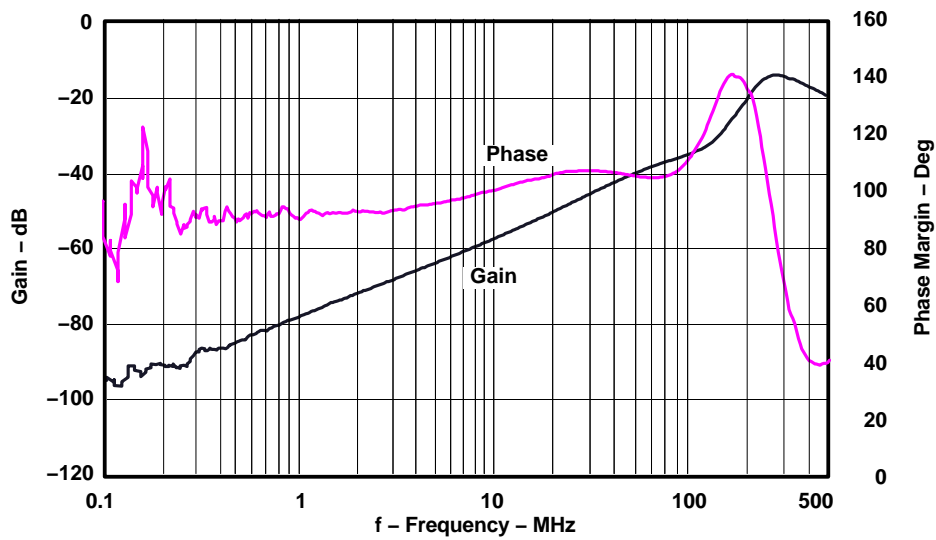
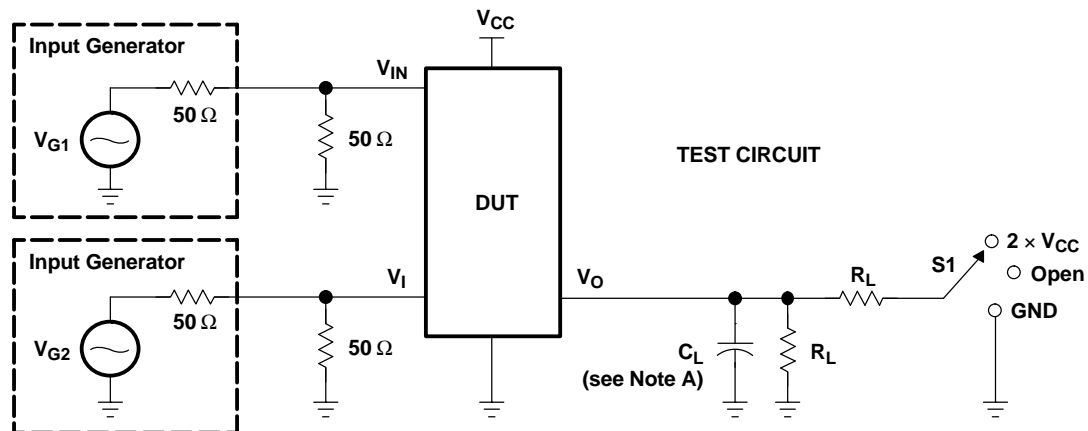


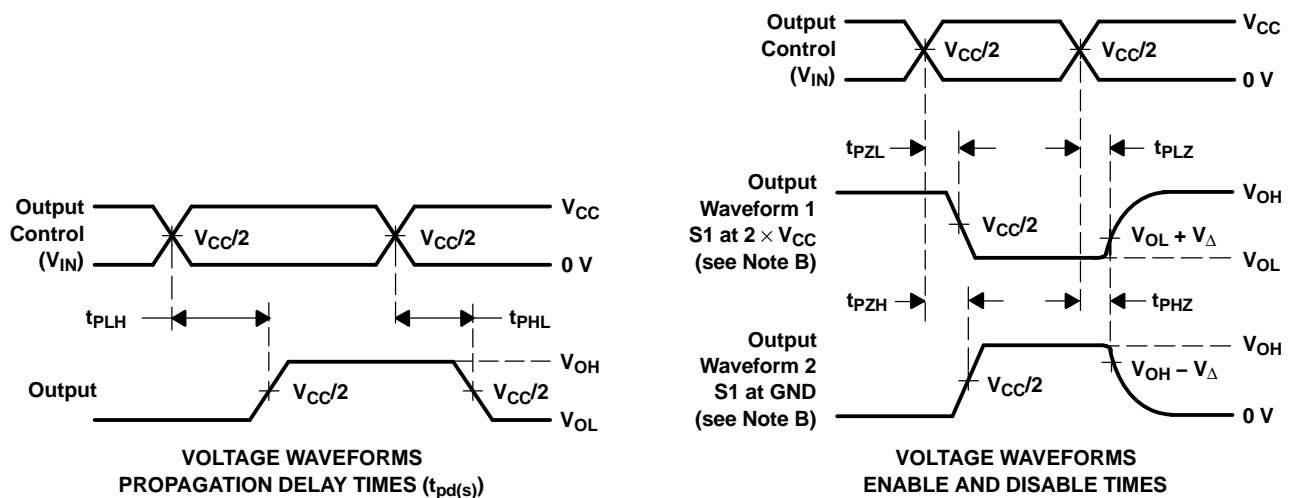
Figure 4. Frequency Response vs Crosstalk

PARAMETER MEASUREMENT INFORMATION



| TEST                               | V <sub>CC</sub> | S1                  | R <sub>L</sub> | V <sub>I</sub>  | C <sub>L</sub> | V <sub>Δ</sub> |
|------------------------------------|-----------------|---------------------|----------------|-----------------|----------------|----------------|
| t <sub>pd(s)</sub> <sup>†</sup>    | 5 V ± 0.25 V    | Open                | 100 Ω          | V <sub>CC</sub> | 35 pF          |                |
| t <sub>PLZ</sub> /t <sub>PZL</sub> | 5 V ± 0.25 V    | 2 × V <sub>CC</sub> | 100 Ω          | GND             | 35 pF          | 0.3 V          |
| t <sub>PHZ</sub> /t <sub>PZH</sub> | 5 V ± 0.25 V    | GND                 | 100 Ω          | V <sub>CC</sub> | 35 pF          | 0.3 V          |

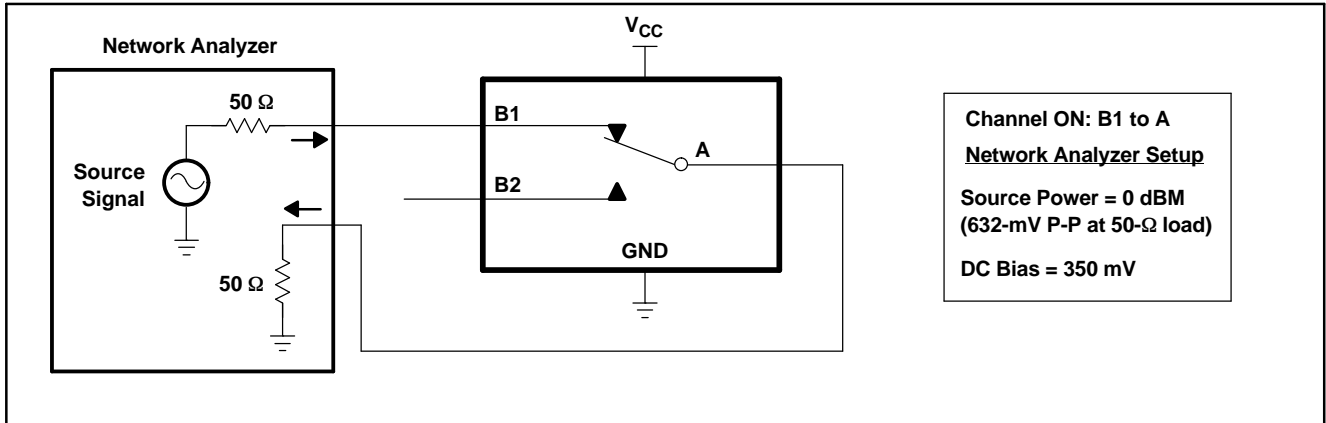
<sup>†</sup> t<sub>pd(s)</sub> is measured with Demux inputs at opposite voltage levels, i.e. V<sub>B1</sub> = 5 V, V<sub>B2</sub> = GND.



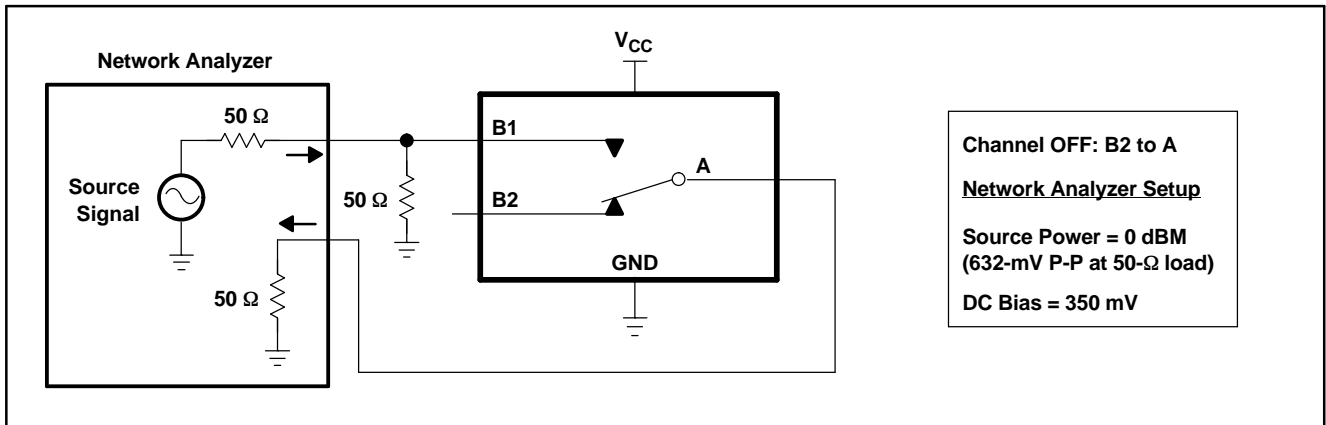
- NOTES:
- A. C<sub>L</sub> includes probe and jig capacitance.
  - B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.
  - C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> < 25 ns, t<sub>f</sub> < 25 ns.
  - D. The outputs are measured one at a time, with one transition per measurement.
  - E. t<sub>PLZ</sub> and t<sub>PHZ</sub> are the same as t<sub>dis</sub>.
  - F. t<sub>PZL</sub> and t<sub>PZH</sub> are the same as t<sub>en</sub>.
  - G. t<sub>PLH</sub> and t<sub>PHL</sub> are the same as t<sub>pd(s)</sub>. The t<sub>pd</sub> propagation delay is the calculated RC time constant of the typical ON-state resistance of the switch and the specified load capacitance, when driven by an ideal voltage source (zero output impedance).
  - H. All parameters and waveforms are not applicable to all devices.

Figure 5. Test Circuit and Voltage Waveforms

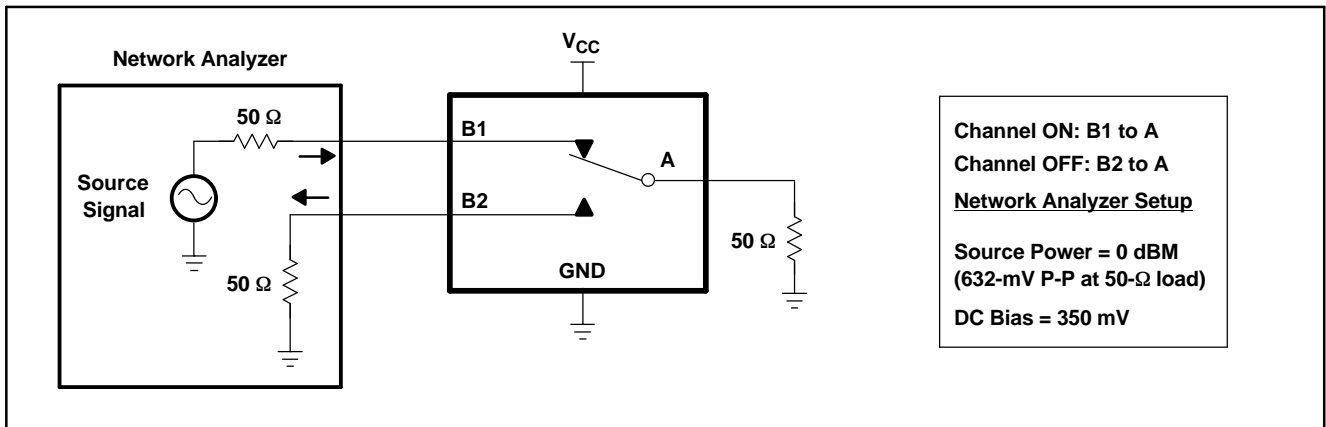
**PARAMETER MEASUREMENT INFORMATION**



**Figure 6. Bandwidth (BW)**



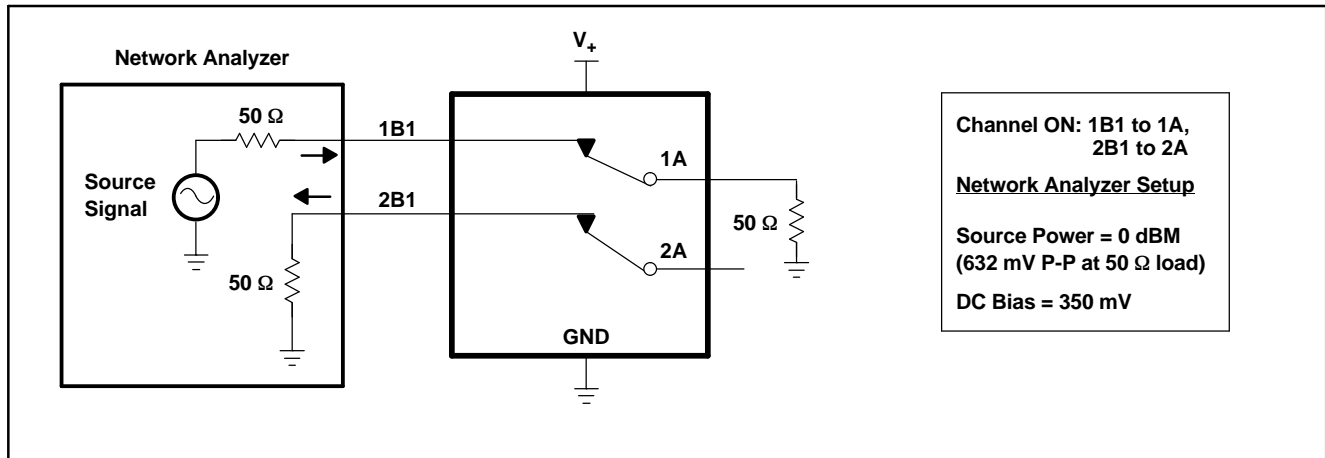
**Figure 7. OFF Isolation ( $O_{ISO}$ )**



**Figure 8. Crosstalk ( $X_{TALK}$ )**



**PARAMETER MEASUREMENT INFORMATION (continued)**



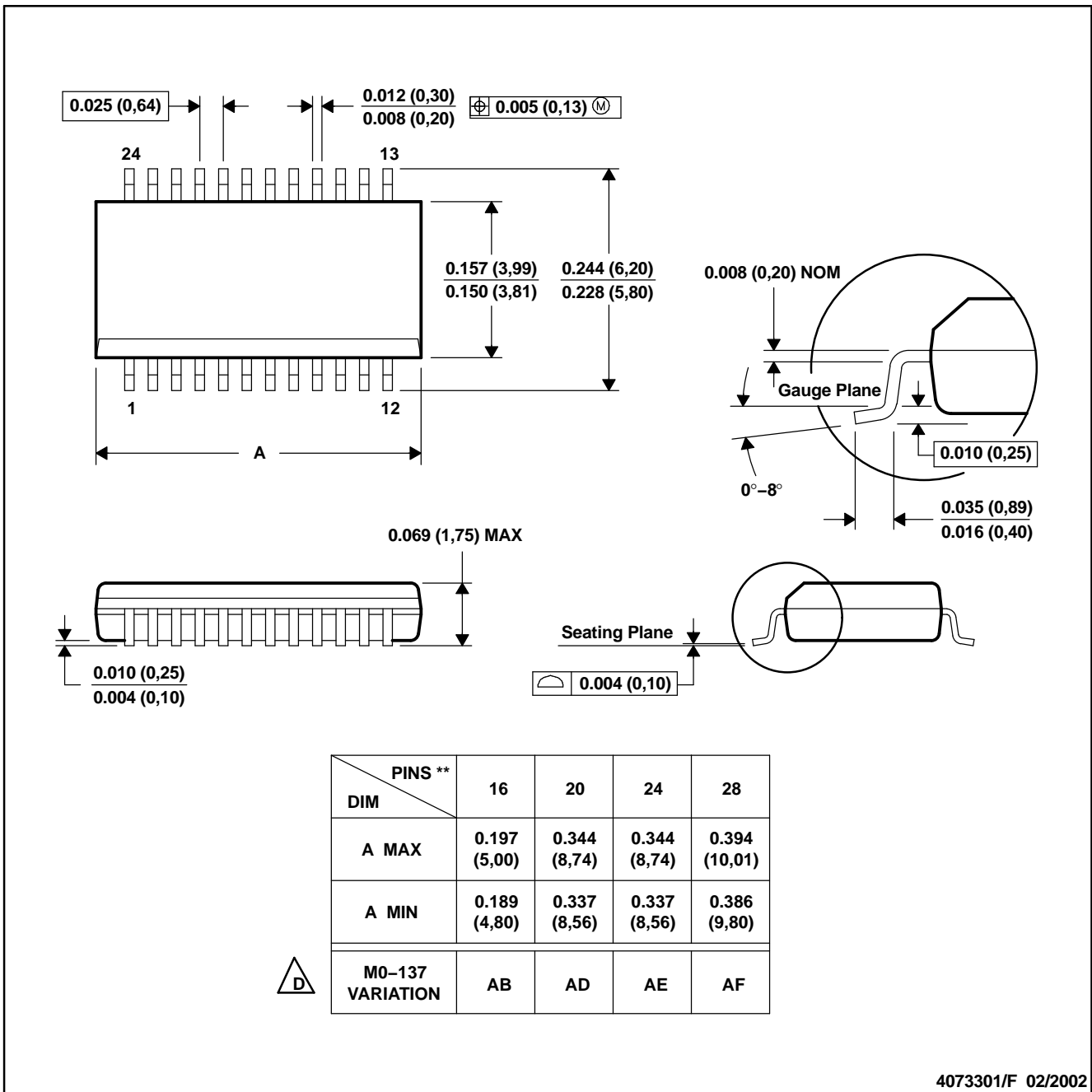
**Figure 9. Adjacent Channel Crosstalk ( $X_{TALK}$ )**

**TS5N412**  
**4-BIT 1-OF-2 FET MULTIPLEXER/DEMULTIPLEXER**  
**HIGH-BANDWIDTH BUS SWITCH**

SCDS207–AUGUST 2005

**MECHANICAL DATA**

**DBQ (R-PDSO-G\*\*)**

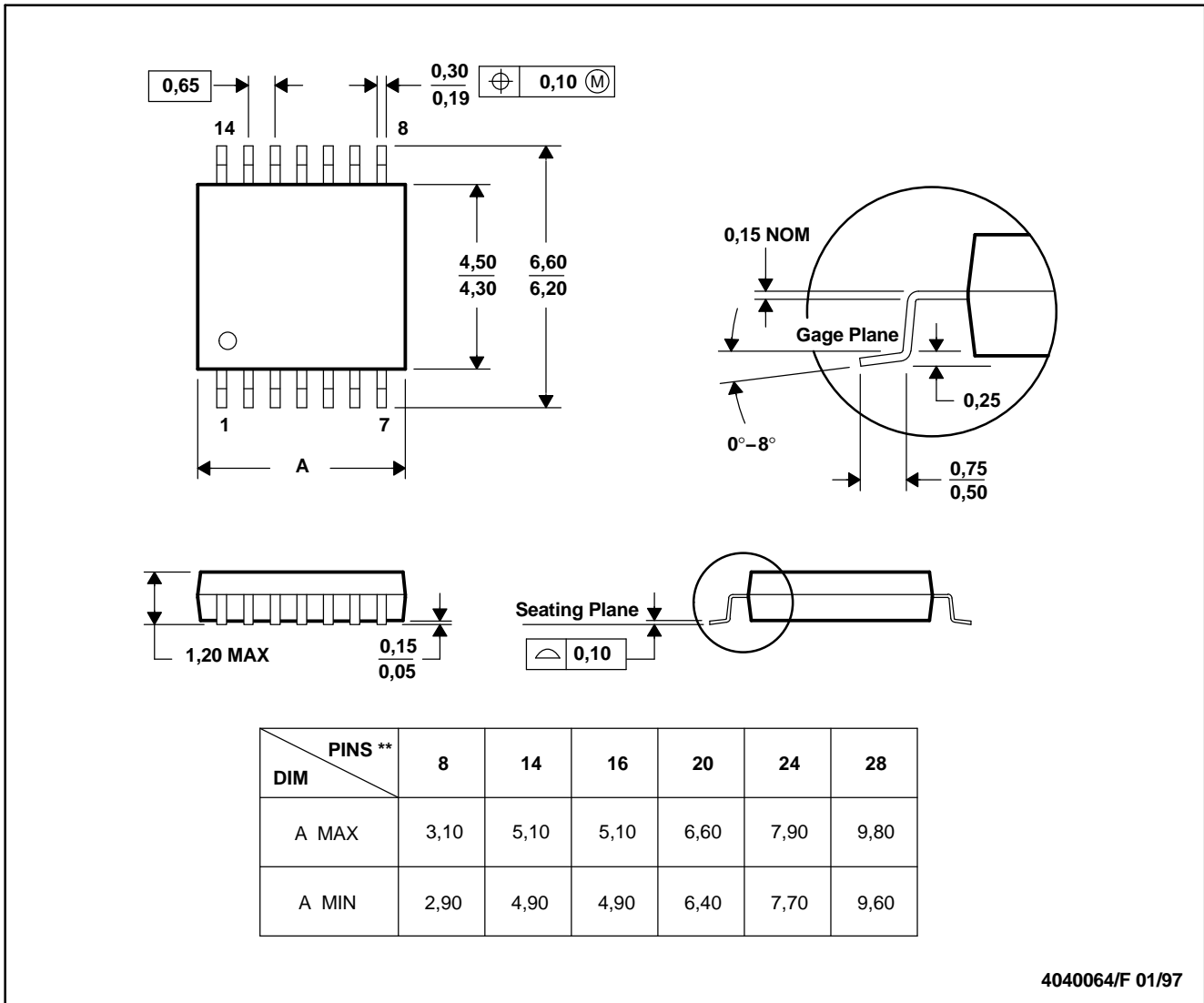


- NOTES: A. All linear dimensions are in inches (millimeters).  
B. This drawing is subject to change without notice.  
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).  
D. Falls within JEDEC MO–137.

### MECHANICAL DATA

#### PW (R-PDSO-G\*\*)

14 PINS SHOWN



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
  - D. Falls within JEDEC MO-153

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|----------------------|------------------------------|-----------------------------|
| TS5N412DBQR      | ACTIVE                | SSOP         | DBQ             | 16   | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TS5N412DBQRE4    | ACTIVE                | SSOP         | DBQ             | 16   | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TS5N412DBQRG4    | ACTIVE                | SSOP         | DBQ             | 16   | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TS5N412PW        | ACTIVE                | TSSOP        | PW              | 16   | 90          | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TS5N412PWE4      | ACTIVE                | TSSOP        | PW              | 16   | 90          | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TS5N412PWG4      | ACTIVE                | TSSOP        | PW              | 16   | 90          | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TS5N412PWR       | ACTIVE                | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TS5N412PWRE4     | ACTIVE                | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TS5N412PWRG4     | ACTIVE                | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |

<sup>(1)</sup> 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.

**OBSELETE:** TI has discontinued the production of the device.

<sup>(2)</sup> 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)

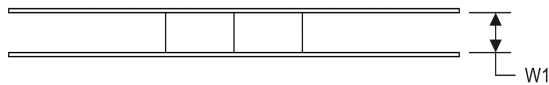
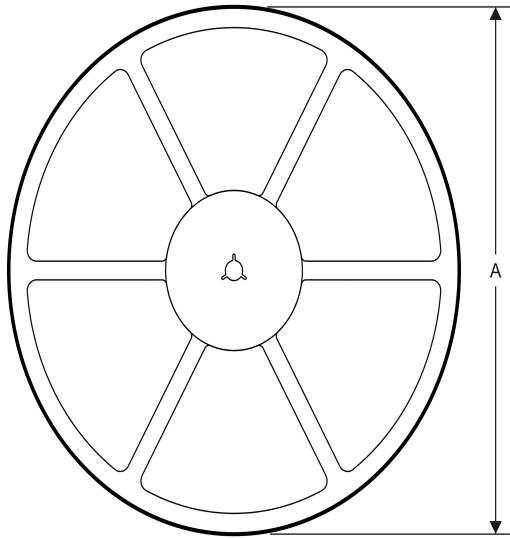
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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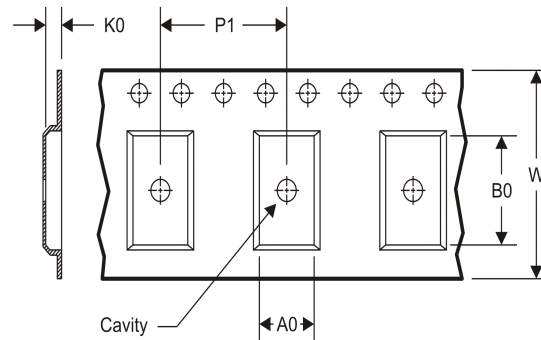
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**TAPE AND REEL INFORMATION**

**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                   |

**TAPE AND REEL INFORMATION**

\*All dimensions are nominal

| Device     | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TS5N412PWR | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device     | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TS5N412PWR | TSSOP        | PW              | 16   | 2000 | 367.0       | 367.0      | 35.0        |

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



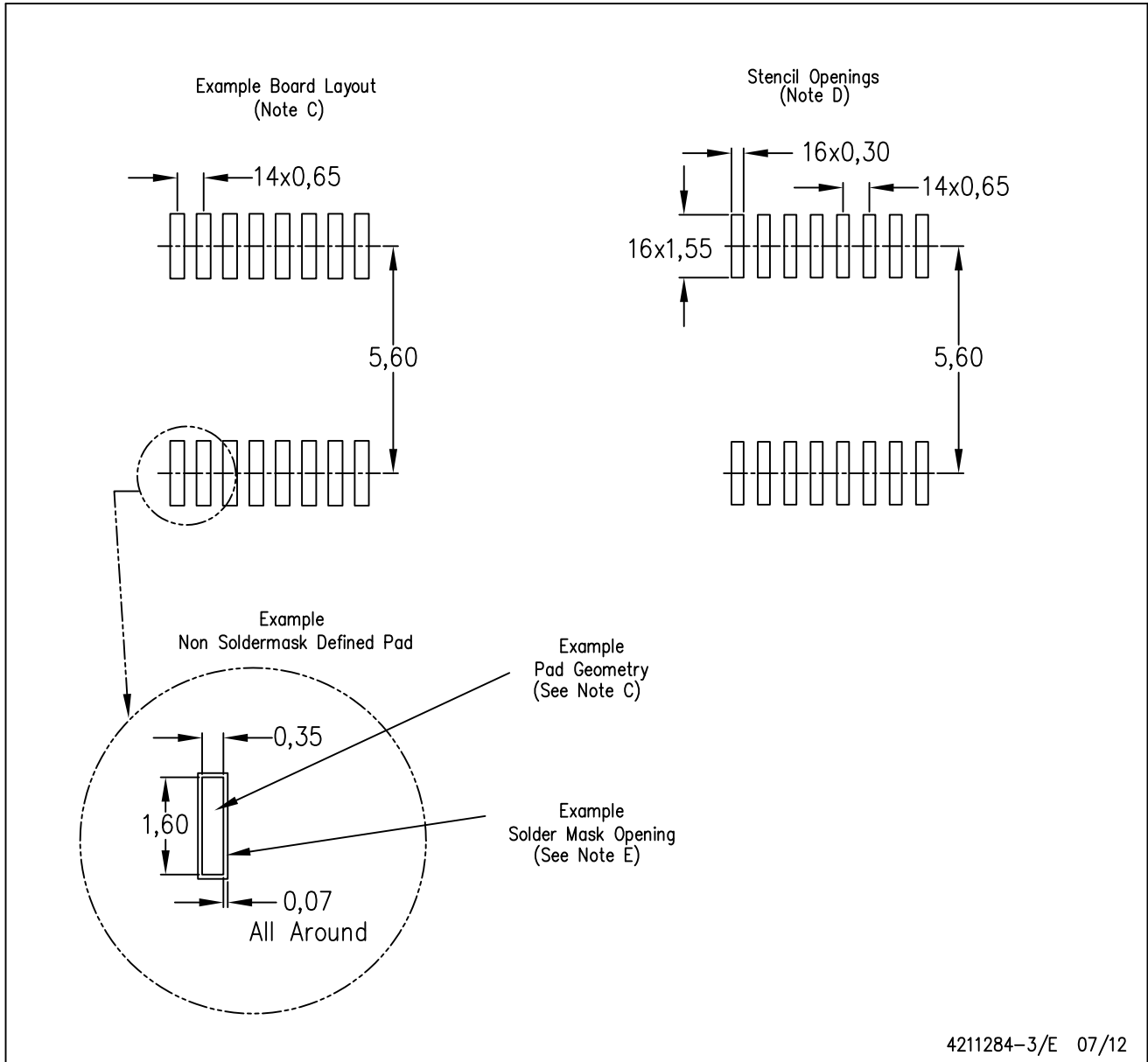
4040064-4/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153



PW (R-PDSO-G16)

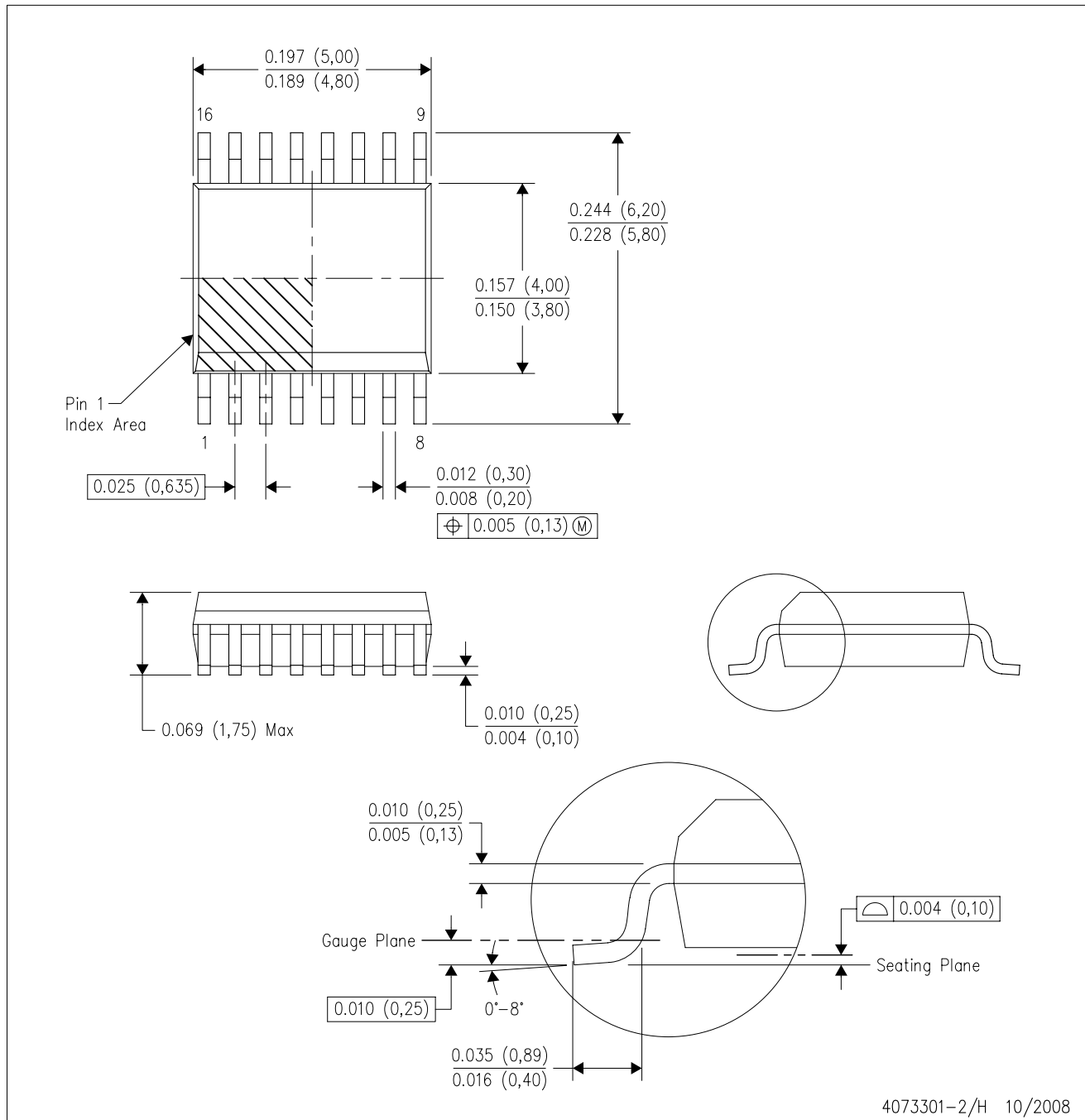
PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

DBQ (R-PDSO-G16)

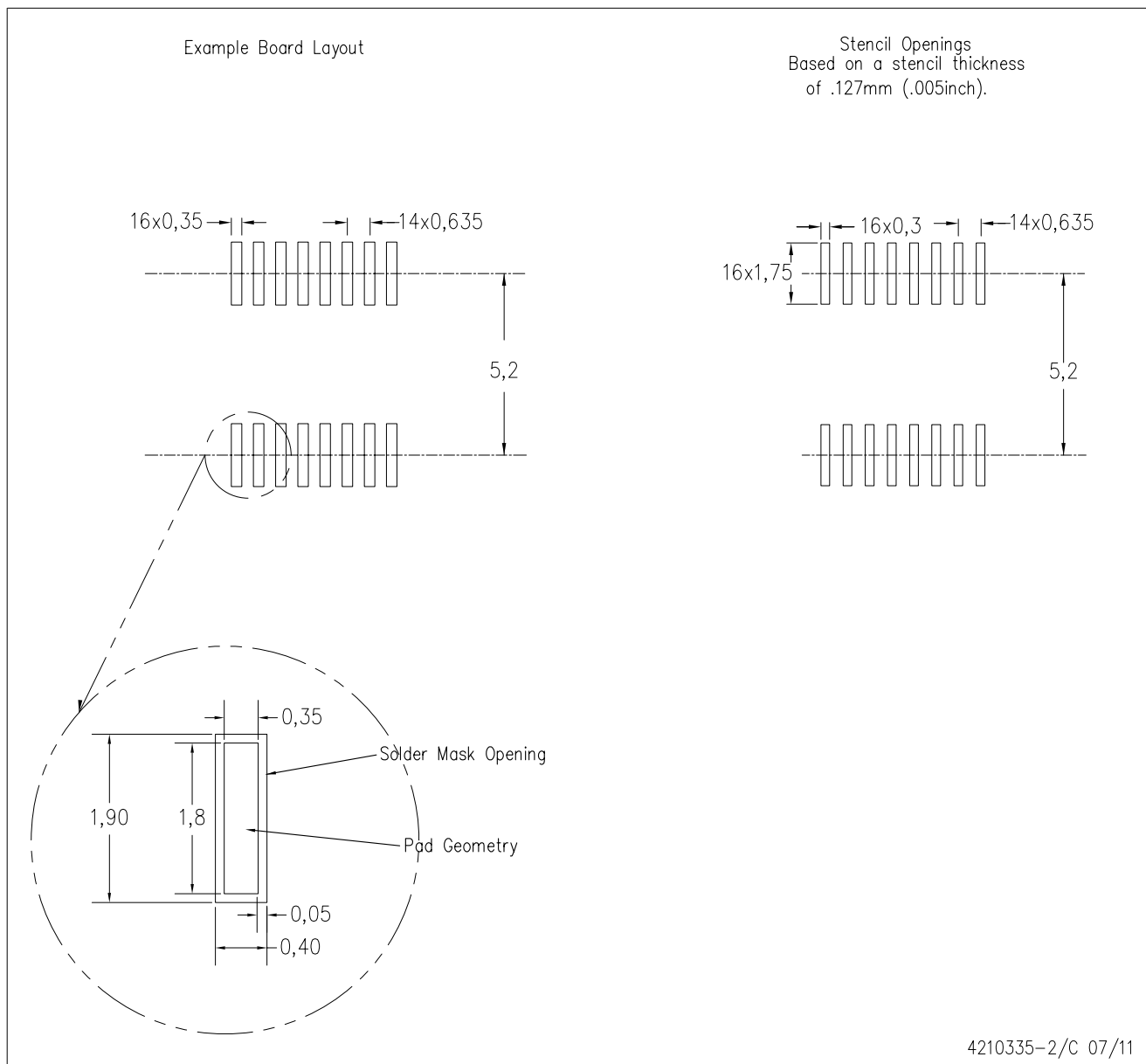
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15) per side.
  - D. Falls within JEDEC MO-137 variation AB.

DBQ (R-PDSO-G16)

PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

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