

## DS15BR400/DS15BR401 4-Channel LVDS Buffer/Repeater with Pre-Emphasis

Check for Samples: [DS15BR400](#), [DS15BR401](#)

### FEATURES

- DC to 2 Gbps Low Jitter, High Noise Immunity, Low Power Operation
- 6 dB of Pre-emphasis Drives Lossy Backplanes and Cables
- LVDS/CML/LVPECL Compatible Input, LVDS Output
- On-chip 100  $\Omega$  output termination, optional 100  $\Omega$  Input Termination
- 15 kV ESD Protection on LVDS Inputs and Outputs
- Single 3.3V Supply
- Industrial -40 to +85°C Temperature Range
- Space Saving WQFN-32 or TQFP-48 Packages

### APPLICATIONS

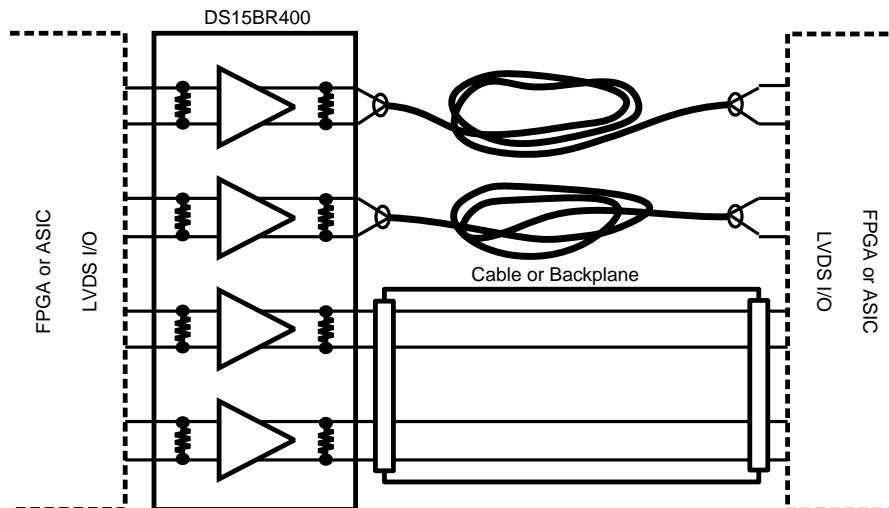
- Cable Extension Applications
- Signal Repeating and Buffering
- Digital Routers

### DESCRIPTION

The DS15BR400/DS15BR401 are four channel LVDS buffer/repeaters capable of data rates of up to 2 Gbps. High speed data paths and flow-through pinout minimize internal device jitter and simplify board layout, while pre-emphasis overcomes ISI jitter effects from lossy backplanes and cables. The differential inputs interface to LVDS, and Bus LVDS signals such as those on TI's 10-, 16-, and 18- bit Bus LVDS SerDes, as well as CML and LVPECL. The differential inputs and outputs of the DS15BR400 are internally terminated with 100 $\Omega$  resistors to improve performance and minimize board space. The DS15BR401 does not have input termination resistors. The repeater function is especially useful for boosting signals for longer distance transmission over lossy cables and backplanes.

The DS15BR400/DS15BR401 are powered from a single 3.3V supply and consume 578 mW (typ). They operate over the full -40°C to +85°C industrial temperature range and are available in space saving WQFN-32 and TQFP-48 packages.

### Typical Application



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## Block and Connection Diagrams

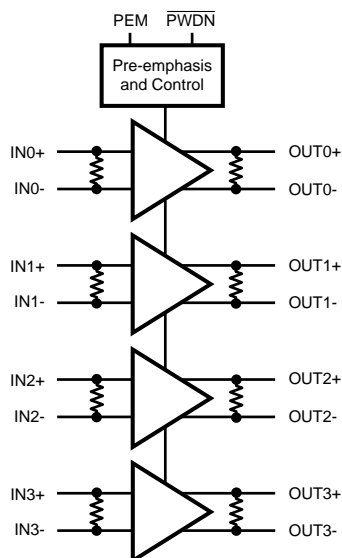


Figure 1. DS15BR400 Block Diagram

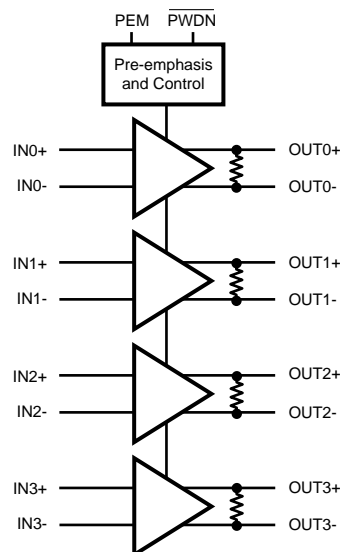
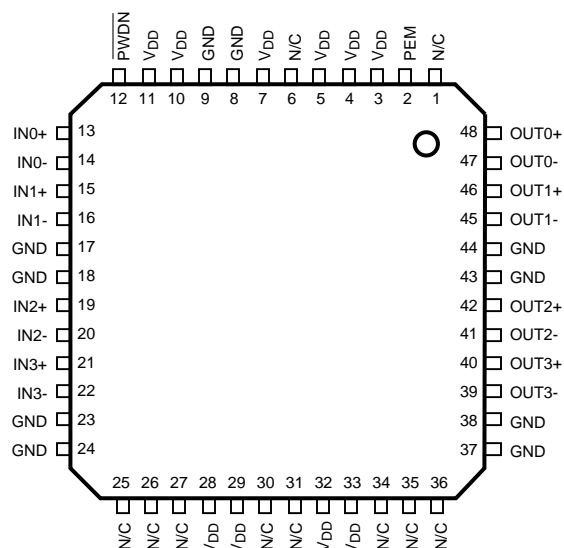
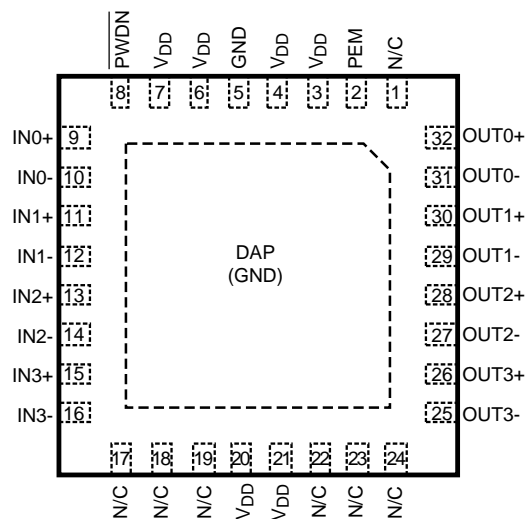


Figure 2. DS15BR401 Block Diagram

Figure 3. TQFP Pinout - Top View  
Package Number PFB0048AFigure 4. WQFN Pinout - Top View  
Package Number RTV0032A

### PIN DESCRIPTIONS

| Pin Name                   | TQFP Pin Number | WQFN Pin Number | I/O, Type | Description  |
|----------------------------|-----------------|-----------------|-----------|--|
| <b>DIFFERENTIAL INPUTS</b> |                 |                 |           |  |
| IN0+<br>IN0-               | 13<br>14        | 9<br>10         | I, LVDS   | Channel 0 inverting and non-inverting differential inputs. |
| IN1+<br>IN1-               | 15<br>16        | 11<br>12        | I, LVDS   | Channel 1 inverting and non-inverting differential inputs. |
| IN2+<br>IN2-               | 19<br>20        | 13<br>14        | I, LVDS   | Channel 2 inverting and non-inverting differential inputs. |
| IN3+<br>IN3-               | 21<br>22        | 15<br>16        | I, LVDS   | Channel 3 inverting and non-inverting differential inputs. |

**PIN DESCRIPTIONS (continued)**

| Pin Name                         | TQFP Pin Number                            | WQFN Pin Number               | I/O, Type | Description   |
|----------------------------------|--|-------------------------------|-----------|---|
| <b>DIFFERENTIAL OUTPUTS</b>      |  |                               |           |   |
| OUT0+<br>OUT0-                   | 48<br>47                                   | 32<br>31                      | O, LVDS   | Channel 0 inverting and non-inverting differential outputs. <sup>(1)</sup>  |
| OUT1+<br>OUT1-                   | 46<br>45                                   | 30<br>29                      | O, LVDS   | Channel 1 inverting and non-inverting differential outputs. <sup>(1)</sup>  |
| OUT2+<br>OUT2-                   | 42<br>41                                   | 28<br>27                      | O, LVDS   | Channel 2 inverting and non-inverting differential outputs. <sup>(1)</sup>  |
| OUT3+<br>OUT3-                   | 40<br>39                                   | 26<br>25                      | O, LVDS   | Channel 3 inverting and non-inverting differential outputs. <sup>(1)</sup>  |
| <b>DIGITAL CONTROL INTERFACE</b> |  |                               |           |   |
| PWDN                             | 12   | 8                             | I, LVTTTL | A logic low at $\overline{\text{PWDN}}$ activates the hardware power down mode (all channels).  |
| PEM                              | 2  | 2                             | I, LVTTTL | Pre-emphasis Control Input (affects all Channels)   |
| <b>POWER</b>                     |  |                               |           |   |
| V <sub>DD</sub>                  | 3, 4, 5, 7, 10,<br>11, 28, 29, 32,<br>33   | 3, 4, 6, 7, 20,<br>21         | I, Power  | V <sub>DD</sub> = 3.3V, ±10%  |
| GND                              | 8, 9, 17, 18, 23,<br>24, 37, 38, 43,<br>44 | 5 <sup>(2)</sup>              | I, Ground | Ground reference for LVDS and CMOS circuitry. For the WQFN package, the DAP is used as the primary GND connection to the device in addition to the pin numbers listed. The DAP is the exposed metal contact at the bottom of the WQFN-32 package. It should be connected to the ground plane with at least 4 vias for optimal AC and thermal performance. |
| N/C                              | 1,6, 25, 26, 27,<br>30, 31, 34, 35,<br>36  | 1, 17,<br>18,19,22, 23,<br>24 |           | No Connect  |

- (1) The LVDS outputs do not support a multidrop (BLVDS) environment. The LVDS output characteristics of the DS15BR400 and DS15BR401 are optimized for point-to-point backplane and cable applications.
- (2) Note that for the WQFN package the GND is connected thru the DAP on the back side of the WQFN package in addition to the actual pin numbers listed.



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.

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

|                                      |                            |
|--------------------------------------|----------------------------|
| Supply Voltage ( $V_{DD}$ )          | -0.3V to +4.0V             |
| CMOS Input Voltage                   | -0.3V to ( $V_{DD}+0.3V$ ) |
| LVDS Receiver Input Voltage          | -0.3V to ( $V_{DD}+0.3V$ ) |
| LVDS Driver Output Voltage           | -0.3V to ( $V_{DD}+0.3V$ ) |
| LVDS Output Short Circuit Current    | +40 mA                     |
| Junction Temperature                 | +150°C                     |
| Storage Temperature                  | -65°C to +150°C            |
| Lead Temperature (Solder, 4sec)      | 260°C                      |
| Max Pkg Power Capacity @ 25°C        |                            |
| TQFP                                 | 1.64W                      |
| WQFN                                 | 4.16W                      |
| Thermal Resistance ( $\theta_{JA}$ ) |                            |
| TQFP                                 | 76°C/W                     |
| WQFN                                 | 30°C/W                     |
| Package Derating above +25°C         |                            |
| TQFP                                 | 13.2mW/°C                  |
| WQFN                                 | 33.3mW/°C                  |
| ESD Last Passing Voltage             |                            |
| HBM, 1.5k $\Omega$ , 100pF           | 8 kV                       |
| LVDS pins to GND only                | 15 kV                      |
| EIAJ, 0 $\Omega$ , 200pF             | 250V                       |
| Charged Device Model                 | 1000V                      |

- (1) Absolute maximum ratings are those values beyond which damage to the device may occur. The databook specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. TI does not recommend operation of products outside of recommended operation conditions.

**Recommended Operating Conditions**

|  |                |
|--|----------------|
| Supply Voltage ( $V_{DD}$ )            | 3.0V to 3.6V   |
| Input Voltage ( $V_I$ ) <sup>(1)</sup> | 0V to $V_{DD}$ |
| Output Voltage ( $V_O$ )               | 0V to $V_{DD}$ |
| Operating Temperature ( $T_A$ )        |                |
| Industrial                             | -40°C to +85°C |

- (1)  $V_{ID\ max} < 2.4V$

**Electrical Characteristics**

Over recommended operating supply and temperature ranges unless other specified.

| Symbol   | Parameter                | Conditions  | Min  | Typ<br>(1) | Max      | Units   |
|--|--------------------------|---|------|------------|----------|---------|
| <b>LVCMOS DC SPECIFICATIONS</b> ( $\overline{PWDN}$ , PEM) |                          |   |      |            |          |         |
| $V_{IH}$   | High Level Input Voltage |   | 2.0  |            | $V_{DD}$ | V       |
| $V_{IL}$   | Low Level Input Voltage  |   | GND  |            | 0.8      | V       |
| $I_{IH}$   | High Level Input Current | $V_{IN} = V_{DD} = 3.6V$ ( $\overline{PWDN}$ pin) | -10  |            | +10      | $\mu A$ |
| $I_{IHR}$  | High Level Input Current | $V_{IN} = V_{DD} = 3.6V$ (PEM pin)                | 40   |            | 200      | $\mu A$ |
| $I_{IL}$   | Low Level Input Current  | $V_{IN} = V_{SS}$ , $V_{DD} = 3.6V$               | -10  |            | +10      | $\mu A$ |
| $C_{IN1}$  | LVCMOS Input Capacitance | Any Digital Input Pin to $V_{SS}$                 |      | 5.5        |          | pF      |
| $V_{CL}$   | Input Clamp Voltage      | $I_{CL} = -18\ mA$ , $V_{DD} = 0V$                | -1.5 | -0.8       |          | V       |

- (1) Typical parameters are measured at  $V_{DD} = 3.3V$ ,  $T_A = 25^\circ C$ . They are for reference purposes, and are not production-tested.

## Electrical Characteristics (continued)

Over recommended operating supply and temperature ranges unless other specified.

| Symbol                                 | Parameter   | Conditions   | Min  | Typ<br>(1) | Max   | Units |
|--|---|--|------|------------|-------|-------|
| LVDS INPUT DC SPECIFICATIONS (INn±)    |   |  |      |            |       |       |
| V <sub>TH</sub>                        | Differential Input High Threshold <sup>(2)</sup>            | V <sub>CM</sub> = 0.8V to 3.55V, V <sub>DD</sub> = 3.6V  |      | 0          | 100   | mV    |
| V <sub>TL</sub>                        | Differential Input Low Threshold <sup>(2)</sup>             | V <sub>CM</sub> = 0.8V to 3.55V, V <sub>DD</sub> = 3.6V  | –100 | 0          |       | mV    |
| V <sub>ID</sub>                        | Differential Input Voltage                                  | V <sub>CM</sub> = 0.8V to 3.55V, V <sub>DD</sub> = 3.6V  | 100  |            | 2400  | mV    |
| V <sub>CMR</sub>                       | Common Mode Voltage Range                                   | V <sub>ID</sub> = 150 mV, V <sub>DD</sub> = 3.6V   | 0.05 |            | 3.55  | V     |
| C <sub>IN2</sub>                       | LVDS Input Capacitance                                      | IN+ or IN– to V <sub>SS</sub>  |      | 3.0        |       | pF    |
| I <sub>IN</sub>                        | Input Current   | V <sub>IN</sub> = 3.6V, V <sub>DD</sub> = 3.6V   | –10  |            | +10   | μA    |
|  |   | V <sub>IN</sub> = 0V, V <sub>DD</sub> = 3.6V   | –10  |            | +10   | μA    |
| LVDS OUTPUT DC SPECIFICATIONS (OUTn±)  |   |  |      |            |       |       |
| V <sub>OD</sub>                        | Differential Output Voltage, 0% Pre-emphasis <sup>(2)</sup> | R <sub>L</sub> = 100Ω external resistor between OUT+ and OUT–<br><a href="#">Figure 5</a>  | 250  | 360        | 500   | mV    |
| ΔV <sub>OD</sub>                       | Change in V <sub>OD</sub> between Complementary States      |  | –35  |            | 35    | mV    |
| V <sub>OS</sub>                        | Offset Voltage <sup>(3)</sup>                               |  | 1.05 | 1.18       | 1.475 | V     |
| ΔV <sub>OS</sub>                       | Change in V <sub>OS</sub> between Complementary States      |  | –35  |            | 35    | mV    |
| C <sub>OUT</sub>                       | LVDS Output Capacitance                                     | OUT+ or OUT– to V <sub>SS</sub>  |      | 2.5        |       | pF    |
| I <sub>OS</sub>                        | Output Short Circuit Current                                | OUT+ or OUT– Short to GND  |      | –21        | –40   | mA    |
|  |   | OUT+ or OUT– Short to V <sub>DD</sub>  |      | 6          | 40    | mA    |
| SUPPLY CURRENT (Static)                |   |  |      |            |       |       |
| I <sub>CC</sub>                        | Supply Current  | All inputs and outputs enabled and active, terminated with differential load of 100Ω between OUT+ and OUT–. PEM = L  |      | 175        | 215   | mA    |
| I <sub>CCZ</sub>                       | Supply Current - Power Down Mode                            | PWDN = L, PEM = L  |      | 20         | 200   | μA    |
| SWITCHING CHARACTERISTICS—LVDS OUTPUTS |   |  |      |            |       |       |
| t <sub>LHT</sub>                       | Differential Low to High Transition Time <sup>(4)</sup>     | Use an alternating 1 and 0 pattern at 200 Mbps, measure between 20% and 80% of V <sub>OD</sub> .<br><a href="#">Figure 6</a> , <a href="#">Figure 8</a>        |      | 170        | 250   | ps    |
| t <sub>HLT</sub>                       | Differential High to Low Transition Time <sup>(4)</sup>     |  |      | 170        | 250   | ps    |
| t <sub>PLHD</sub>                      | Differential Low to High Propagation Delay                  | Use an alternating 1 and 0 pattern at 200 Mbps, measure at 50% V <sub>OD</sub> between input to output.<br><a href="#">Figure 6</a> , <a href="#">Figure 7</a> |      | 1.0        | 2.0   | ns    |
| t <sub>PHLD</sub>                      | Differential High to Low Propagation Delay                  |  |      | 1.0        | 2.0   | ns    |
| t <sub>SKD1</sub>                      | Pulse Skew <sup>(4)</sup>                                   | t <sub>PLHD</sub> –t <sub>PHLD</sub>   |      | 10         | 60    | ps    |
| t <sub>SKCC</sub>                      | Output Channel to Channel Skew <sup>(4)</sup>               | Difference in propagation delay (t <sub>PLHD</sub> or t <sub>PHLD</sub> ) among all output channels.   |      | 25         | 75    | ps    |
| t <sub>SKP</sub>                       | Part to Part Skew <sup>(4)</sup>                            | Common edge, parts at same temp and V <sub>CC</sub>  |      |            | 550   | ps    |

(2) Differential output voltage V<sub>OD</sub> is defined as ABS(OUT+–OUT–). Differential input voltage V<sub>ID</sub> is defined as ABS(IN+–IN–).

(3) Output offset voltage V<sub>OS</sub> is defined as the average of the LVDS single-ended output voltages at logic high and logic low states.

(4) Not production tested. Ensured by a statistical analysis on a sample basis at the time of characterization.

## Electrical Characteristics (continued)

Over recommended operating supply and temperature ranges unless other specified.

| Symbol    | Parameter                       | Conditions   | Min | Typ<br>(1) | Max | Units   |
|-----------|---------------------------------|--|-----|------------|-----|---------|
| $t_{JIT}$ | Jitter (0% Pre-emphasis)<br>(5) | RJ - Alternating 1 and 0 at 750 MHz (6)  |     | 0.5        | 1.5 | ps      |
|           |                                 | DJ - K28.5 Pattern, 1.5 Gbps (7)   |     | 14         | 30  | ps      |
|           |                                 | TJ - PRBS $2^{23}-1$ Pattern, 1.5 Gbps (8)   |     | 14         | 31  | ps      |
| $t_{ON}$  | LVDS Output Enable Time         | Time from $\overline{PWDN}$ to $OUT_{\pm}$ change from TRI-STATE to active.<br>Figure 9, Figure 10 |     |            | 20  | $\mu$ s |
| $t_{OFF}$ | LVDS Output Disable Time        | Time from $\overline{PWDN}$ to $OUT_{\pm}$ change from active to TRI-STATE.<br>Figure 9, Figure 10 |     |            | 12  | ns      |

(5) Jitter is not production tested, but ensured through characterization on a sample basis.

(6) Random Jitter, or RJ, is measured RMS with a histogram including 1500 histogram window hits. Stimulus and fixture Jitter has been subtracted. The input voltage =  $V_{ID}$  = 500 mV, input common mode voltage =  $V_{ICM}$  = 1.2V, 50% duty cycle at 750 MHz,  $t_r = t_f = 50$  ps (20% to 80%).

(7) Deterministic Jitter, or DJ, is a peak to peak value. Stimulus and fixture jitter has been subtracted. The input voltage =  $V_{ID}$  = 500 mV, input common mode voltage =  $V_{ICM}$  = 1.2V, K28.5 pattern at 1.5 Gbps,  $t_r = t_f = 50$  ps (20% to 80%). The K28.5 pattern is repeating bit streams of (0011111010 1100000101).

(8) Total Jitter, or TJ, is measured peak to peak with a histogram including 3500 window hits. Stimulus and fixture Jitter has been subtracted. The input voltage =  $V_{ID}$  = 500 mV, input common mode voltage =  $V_{ICM}$  = 1.2V,  $2^{23}-1$  PRBS pattern at 1.5 Gbps,  $t_r = t_f = 50$  ps (20% to 80%).

## DC Test Circuits

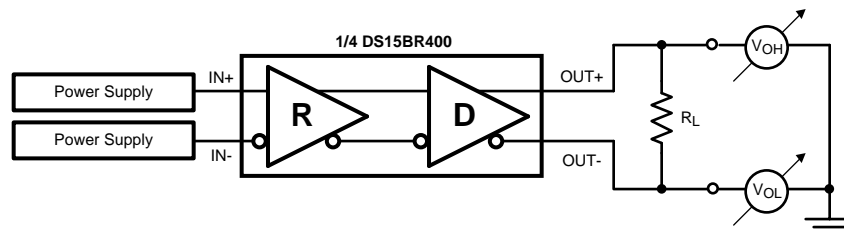


Figure 5. Differential Driver DC Test Circuit

## AC Test Circuits and Timing Diagrams

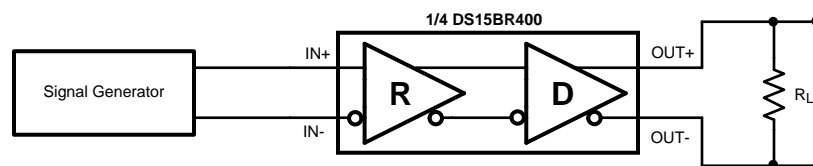


Figure 6. Differential Driver AC Test Circuit

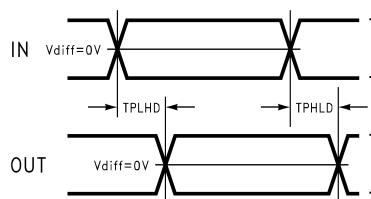
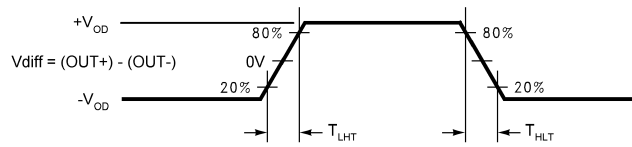
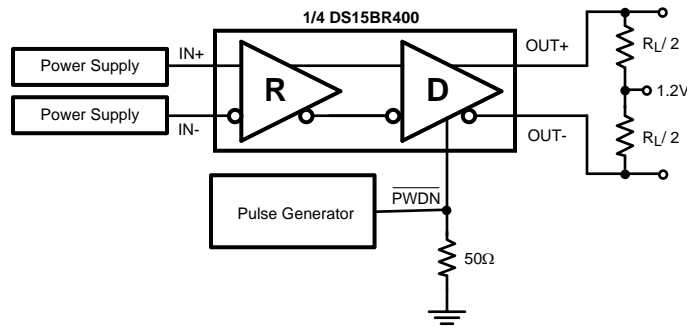


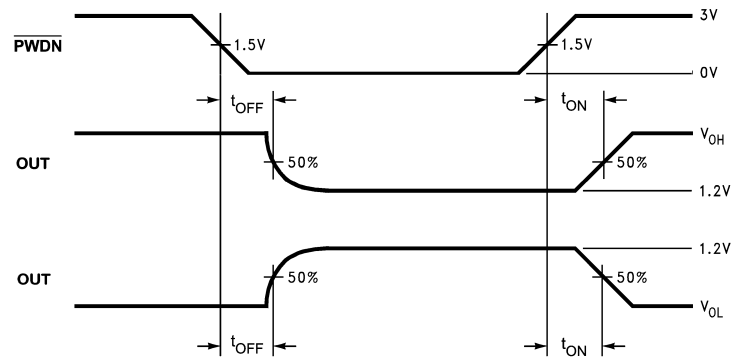
Figure 7. Propagation Delay Timing Diagram



**Figure 8. LVDS Output Transition Times**



**Figure 9. Enable/Disable Time Test Circuit**



**Figure 10. Enable/Disable Time Diagram**

## APPLICATION INFORMATION

### INTERNAL TERMINATIONS

The DS15BR400 has integrated termination resistors on both the input and outputs. The inputs have a 100Ω resistor across the differential pair, placing the receiver termination as close as possible to the input stage of the device. The LVDS outputs also contain an integrated 100Ω ohm termination resistor, this resistor is used to minimize the output return loss and does not take the place of the 100 ohm termination at the inputs to the receiving device. The integrated terminations improve signal integrity and decrease the external component count resulting in space savings. The DS15BR401 has 100Ω output terminations only.

### OUTPUT CHARACTERISTICS

The output characteristics of the DS15BRB400/DS15BR401 have been optimized for point-to-point backplane and cable applications, and are not intended for multipoint or multidrop signaling.

### POWERDOWN MODE

The  $\overline{\text{PWDN}}$  input activates a hardware powerdown mode. When the powerdown mode is active ( $\overline{\text{PWDN}}=\text{L}$ ), all input and output buffers and internal bias circuitry are powered off. When exiting powerdown mode, there is a delay associated with turning on bandgap references and input/output buffer circuits as indicated in the LVDS Output Switching Characteristics.

Upon asserting the power down function ( $\overline{\text{PWDN}} = \text{Low}$ ), and if the Pre-emphasis feature is enable, it is possible for the driver output to source current for a short amount of time lifting the output common mode to  $V_{\text{DD}}$ . To prevent this occurrence, a load discharge pull down path can be used on either output (1 kΩ to ground recommended). Alternately, a commonly deployed external failsafe network will also provide this path (see INPUT FAILSAFE BIASING). The occurrence of this is application dependant, and parameters that will effect if this is of concern include: AC coupling, use of the powerdown feature, presence of the discharge path, presence of the failsafe biasing, the usage of the pre-emphasis feature, and input characteristics of the downstream LVDS Receiver.

### PRE-EMPHASIS

Pre-emphasis dramatically reduces ISI jitter from long or lossy transmission media. One pin is used to select the pre-emphasis level for all outputs, off or on. The pre-emphasis boost is approximately 6 dB at 750 MHz.

**Table 1. Pre-emphasis Control Selection Table**

| PEM | Pre-Emphasis |
|-----|--------------|
| 0   | Off          |
| 1   | On           |

### INPUT FAILSAFE BIASING

Failsafe biasing of the LVDS link should be considered if the downstream Receiver is ON and enabled when the source is in TRI-STATE, powered off, or removed. This will set a valid known input state to the active receiver. This is accomplished by using a pull up resistor to  $V_{\text{DD}}$  on the 'plus' line, and a pull down resistor to GND on the 'minus' line. Resistor values are in the 750 Ohm to several kΩ range. The exact value depends upon the desired common mode bias point, termination resistor(s) and desired input differential voltage setting. Please refer to application note AN-1194 "Failsafe Biasing of LVDS interfaces" ([SNLA051](#)) for more information and a general discussion.

### DECOUPLING

Each power or ground lead of the DS15BR400 should be connected to the PCB through a low inductance path. For best results, one or more vias are used to connect a power or ground pin to the nearby plane. Ideally, via placement is immediately adjacent to the pin to avoid adding trace inductance. Placing power plane closer to the top of the board reduces effective via length and its associated inductance.

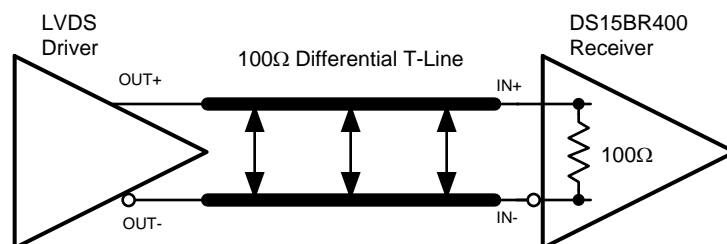


Bypass capacitors should be placed close to VDD pins. Small physical size capacitors, such as 0402, X7R, surface mount capacitors should be used to minimize body inductance of capacitors. Each bypass capacitor is connected to the power and ground plane through vias tangent to the pads of the capacitor. An X7R surface mount capacitor of size 0402 has about 0.5 nH of body inductance. At frequencies above 30 MHz or so, X7R capacitors behave as low impedance inductors. To extend the operating frequency range to a few hundred MHz, an array of different capacitor values like 100 pF, 1 nF, 0.03  $\mu$ F, and 0.1  $\mu$ F are commonly used in parallel. The most effective bypass capacitor can be built using sandwiched layers of power and ground at a separation of 2–3 mils. With a 2 mil FR4 dielectric, there is approximately 500 pF per square inch of PCB.

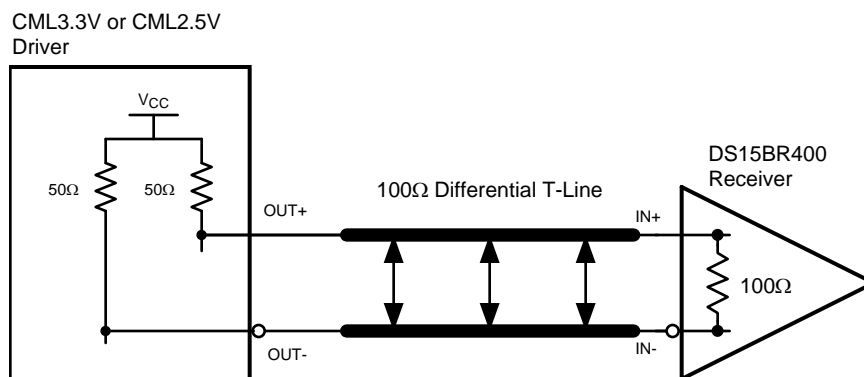
The center tap of the WQFN package housing the DS15BR400 should be connected to a ground plane through an array of vias. The via array reduces the effective inductance to ground and enhances the thermal performance of the WQFN package.

## INPUT INTERFACING

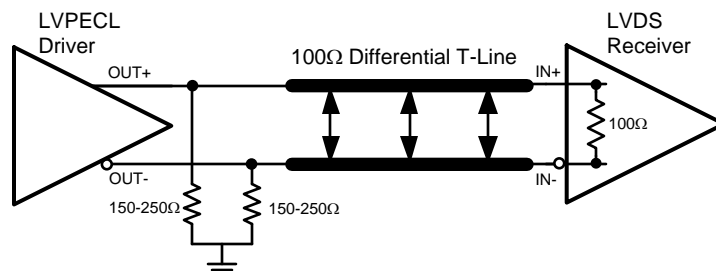
The DS15BR400 and DS15BR401 accept differential signals and allow simple AC or DC coupling. With a wide common mode range, the DS15BR400 and DS15BR401 can be DC-coupled with all common differential drivers (i.e. LVPECL, LVDS, CML). The following three figures illustrate typical DC-coupled interface to common differential drivers. Note that the DS15BR400 inputs are internally terminated with a 100 $\Omega$  resistor while the DS15BR401 inputs are not, therefore the latter requires external input termination.



**Figure 11. Typical LVDS Driver DC-Coupled Interface to DS15BR400 Input**



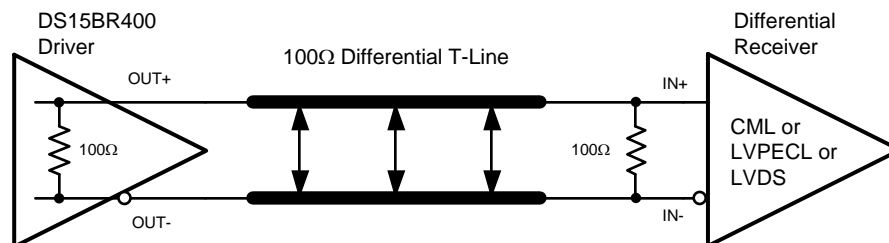
**Figure 12. Typical CML Driver DC-Coupled Interface to DS15BR400 Input**



**Figure 13. Typical LVPECL Driver DC-Coupled Interface to DS15BR400 Input**

## OUTPUT INTERFACING

The DS15BR400 and DS15BR401 output signals that are compliant to the LVDS standard. Their outputs can be DC-coupled to most common differential receivers. Figure 14 illustrates typical DC-coupled interface to common differential receivers and assumes that the receivers have high impedance inputs. While most differential receivers have a common mode input range that can accommodate LVDS compliant signals, it is recommended to check respective receiver's data sheet prior to implementing the suggested interface implementation.



**Figure 14. Typical DS15BR400 Output DC-Coupled Interface to an LVDS, CML or LVPECL Receiver**

## Typical Performance Characteristics

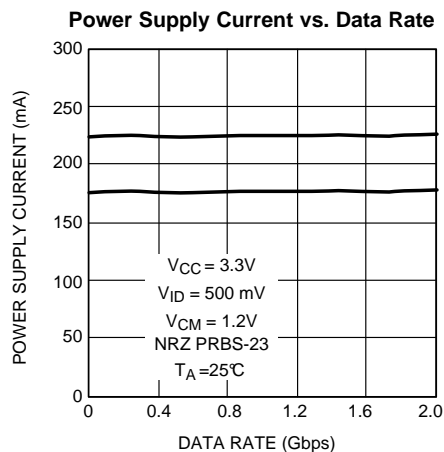


Figure 15.

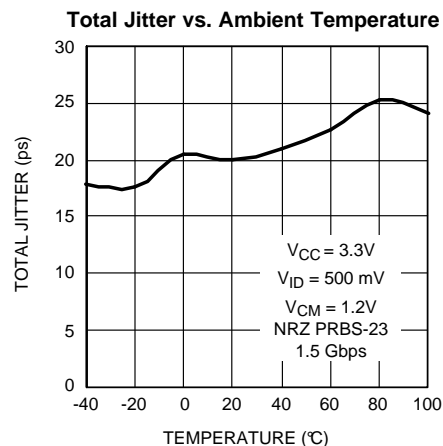


Figure 16.

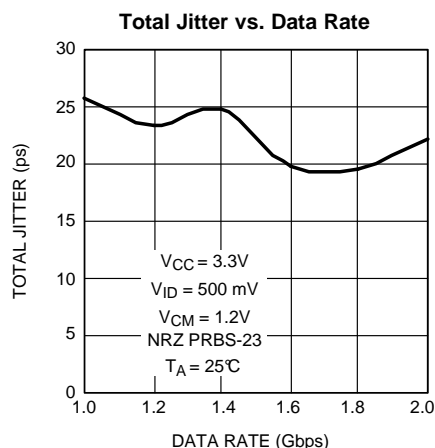


Figure 17.

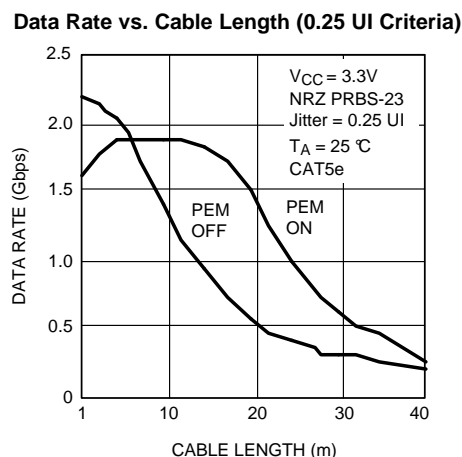


Figure 18. <sup>(1)</sup>

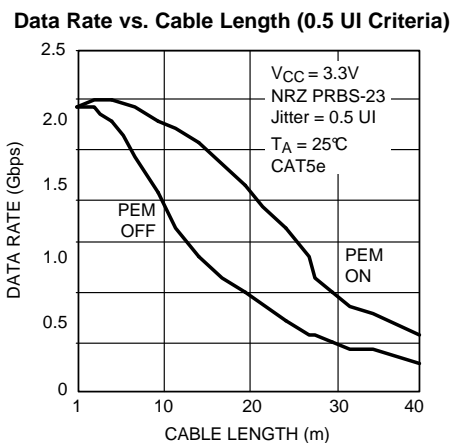


Figure 19. <sup>(1)</sup>

- (1) Data presented in this graph was collected using the DS15BR400EVK, a pair of RJ-45 to SMA adapter boards and various length Belden 1700a cables. The maximum data rate was determined based on total jitter (0.25 UI criteria) measured after the cable. The total jitter was a peak to peak value measured with a histogram including 3000 window hits.

REVISION HISTORY

| Changes from Revision F (April 2013) to Revision G         | Page               |
|--|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">11</a> |

## PACKAGING INFORMATION

| Orderable Device   | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|--------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| DS15BR400TSQ       | NRND          | WQFN         | RTV                | 32   | 1000           | TBD                        | Call TI                 | Call TI              | -40 to 85    | 5R400SQ                 |                         |
| DS15BR400TSQ/NOPB  | ACTIVE        | WQFN         | RTV                | 32   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 5R400SQ                 | <a href="#">Samples</a> |
| DS15BR400TSQX/NOPB | ACTIVE        | WQFN         | RTV                | 32   | 4500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 5R400SQ                 | <a href="#">Samples</a> |
| DS15BR400TVS       | NRND          | TQFP         | PFB                | 48   | 250            | TBD                        | Call TI                 | Call TI              | -40 to 85    | DS15BR<br>400TVS        |                         |
| DS15BR400TVS/NOPB  | ACTIVE        | TQFP         | PFB                | 48   | 250            | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | DS15BR<br>400TVS        | <a href="#">Samples</a> |
| DS15BR400TVSX/NOPB | ACTIVE        | TQFP         | PFB                | 48   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | DS15BR<br>400TVS        | <a href="#">Samples</a> |
| DS15BR401TSQ       | ACTIVE        | WQFN         | RTV                | 32   | 1000           | TBD                        | Call TI                 | Call TI              | -40 to 85    |                         | <a href="#">Samples</a> |
| DS15BR401TSQ/NOPB  | ACTIVE        | WQFN         | RTV                | 32   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 5R401SQ                 | <a href="#">Samples</a> |
| DS15BR401TSQX      | ACTIVE        | WQFN         | RTV                | 32   | 4500           | TBD                        | Call TI                 | Call TI              | -40 to 85    |                         | <a href="#">Samples</a> |
| DS15BR401TSQX/NOPB | ACTIVE        | WQFN         | RTV                | 32   | 4500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 5R401SQ                 | <a href="#">Samples</a> |
| DS15BR401TVS/NOPB  | ACTIVE        | TQFP         | PFB                | 48   | 250            | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | DS15BR<br>401TVS        | <a href="#">Samples</a> |
| DS15BR401TVSX/NOPB | ACTIVE        | TQFP         | PFB                | 48   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | DS15BR<br>401TVS        | <a href="#">Samples</a> |

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

**ACTIVE:** Product device recommended for new designs.

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

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

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

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

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

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

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

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**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.

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

<sup>(5)</sup> 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.

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

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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device             | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| DS15BR400TSQ       | WQFN         | RTV             | 32   | 1000 | 178.0              | 12.4               | 5.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| DS15BR400TSQ/NOPB  | WQFN         | RTV             | 32   | 1000 | 178.0              | 12.4               | 5.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| DS15BR400TSQX/NOPB | WQFN         | RTV             | 32   | 4500 | 330.0              | 12.4               | 5.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| DS15BR400TVSX/NOPB | TQFP         | PFB             | 48   | 1000 | 330.0              | 16.4               | 9.3     | 9.3     | 2.2     | 12.0    | 16.0   | Q2            |
| DS15BR401TSQ/NOPB  | WQFN         | RTV             | 32   | 1000 | 178.0              | 12.4               | 5.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| DS15BR401TSQX/NOPB | WQFN         | RTV             | 32   | 4500 | 330.0              | 12.4               | 5.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| DS15BR401TVSX/NOPB | TQFP         | PFB             | 48   | 1000 | 330.0              | 16.4               | 9.3     | 9.3     | 2.2     | 12.0    | 16.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS

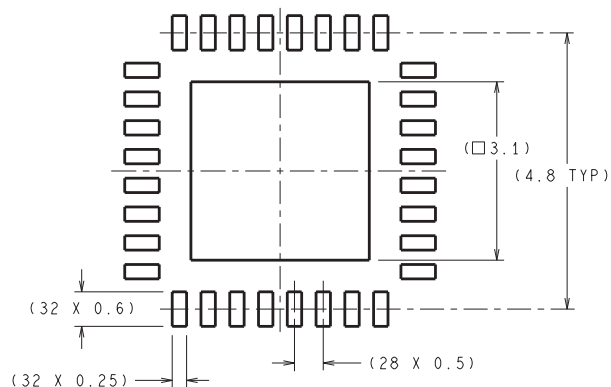


\*All dimensions are nominal

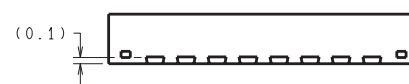
| Device             | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| DS15BR400TSQ       | WQFN         | RTV             | 32   | 1000 | 213.0       | 191.0      | 55.0        |
| DS15BR400TSQ/NOPB  | WQFN         | RTV             | 32   | 1000 | 213.0       | 191.0      | 55.0        |
| DS15BR400TSQX/NOPB | WQFN         | RTV             | 32   | 4500 | 367.0       | 367.0      | 35.0        |
| DS15BR400TVSX/NOPB | TQFP         | PFB             | 48   | 1000 | 367.0       | 367.0      | 38.0        |
| DS15BR401TSQ/NOPB  | WQFN         | RTV             | 32   | 1000 | 213.0       | 191.0      | 55.0        |
| DS15BR401TSQX/NOPB | WQFN         | RTV             | 32   | 4500 | 367.0       | 367.0      | 35.0        |
| DS15BR401TVSX/NOPB | TQFP         | PFB             | 48   | 1000 | 367.0       | 367.0      | 38.0        |



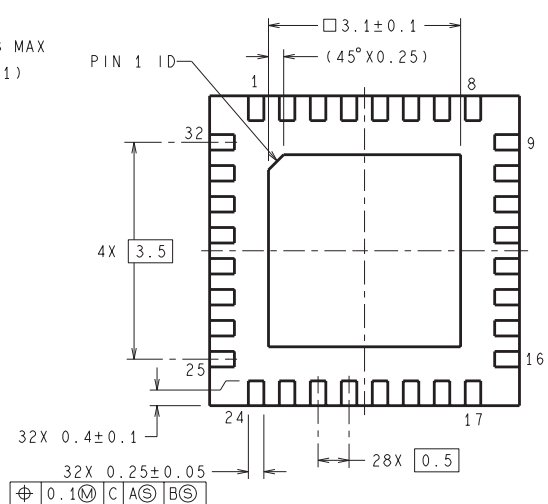
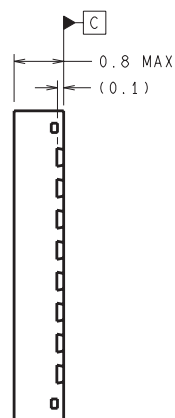
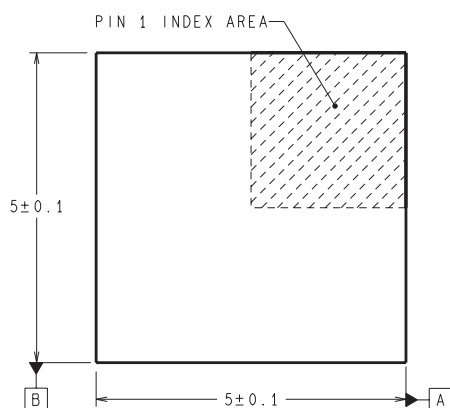
RTV0032A



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SQA32A (Rev B)

## PFB (S-PQFP-G48)

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