

## LP2996-N DDR Termination Regulator

Check for Samples: [LP2996-N](#)

### FEATURES

- Source and Sink Current
- Low Output Voltage Offset
- No External Resistors Required
- Linear Topology
- Suspend to Ram (STR) Functionality
- Low External Component Count
- Thermal Shutdown
- Available in SOIC-8, SO PowerPAD-8 or WQFN-16 packages

### APPLICATIONS

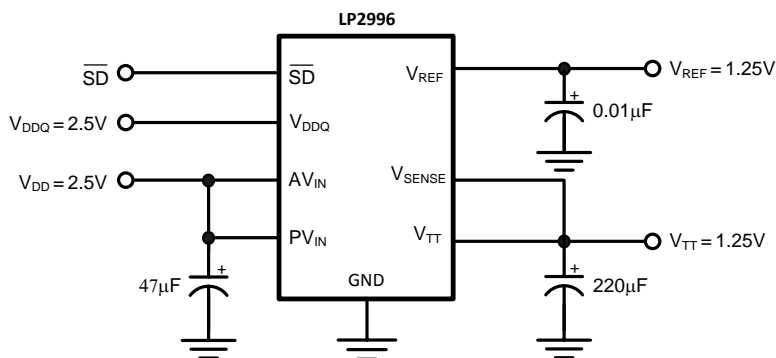
- DDR-I and DDR-II Termination Voltage
- SSTL-2 and SSTL-3 Termination
- HSTL Termination

### DESCRIPTION

The LP2996-N linear regulator is designed to meet the JEDEC SSTL-2 specifications for termination of DDR-SDRAM. The device contains a high-speed operational amplifier to provide excellent response to load transients. The output stage prevents shoot through while delivering 1.5A continuous current and transient peaks up to 3A in the application as required for DDR-SDRAM termination. The LP2996-N also incorporates a  $V_{SENSE}$  pin to provide superior load regulation and a  $V_{REF}$  output as a reference for the chipset and DIMMs.

An additional feature found on the LP2996-N is an active low shutdown ( $\overline{SD}$ ) pin that provides Suspend To RAM (STR) functionality. When  $\overline{SD}$  is pulled low the  $V_{TT}$  output will tri-state providing a high impedance output, but,  $V_{REF}$  will remain active. A power savings advantage can be obtained in this mode through lower quiescent current.

### Typical Application Circuit



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Connection Diagram

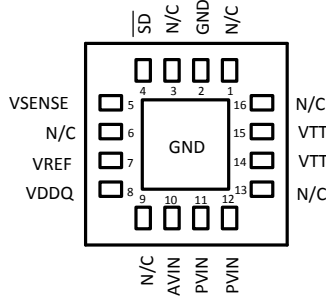


Figure 1. WQFN-16 Layout (Top View)

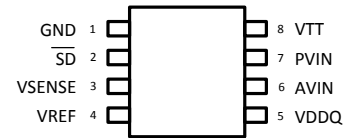


Figure 2. SOIC-8 Layout

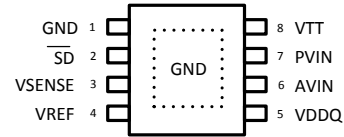


Figure 3. SO PowerPAD-8 Layout

PIN DESCRIPTIONS

| SOIC-8 Pin or SO PowerPAD-8 Pin | WQFN Pin           | Name            | Function                                               |
|---------------------------------|--------------------|-----------------|--------------------------------------------------------|
| 1                               | 2                  | GND             | Ground                                                 |
| 2                               | 4                  | $\overline{SD}$ | Shutdown                                               |
| 3                               | 5                  | VSENSE          | Feedback pin for regulating $V_{TT}$ .                 |
| 4                               | 7                  | VREF            | Buffered internal reference voltage of $V_{DDQ}/2$     |
| 5                               | 8                  | VDDQ            | Input for internal reference equal to $V_{DDQ}/2$      |
| 6                               | 10                 | AVIN            | Analog input pin                                       |
| 7                               | 11, 12             | PVIN            | Power input pin                                        |
| 8                               | 14, 15             | VTT             | Output voltage for connection to termination resistors |
| -                               | 1, 3, 6, 9, 13, 16 | NC              | No internal connection                                 |
|                                 | EP                 | EP              | Exposed pad thermal connection. Connect to Ground.     |



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)(2)</sup>

|                                                    |                 |
|----------------------------------------------------|-----------------|
| AVIN to GND                                        | -0.3V to +6V    |
| PVIN to GND                                        | -0.3V to AVIN   |
| VDDQ <sup>(3)</sup>                                | -0.3V to +6V    |
| Storage Temp. Range                                | -65°C to +150°C |
| Junction Temperature                               | 150°C           |
| SOIC-8 Thermal Resistance ( $\theta_{JA}$ )        | 151°C/W         |
| SO PowerPAD-8 Thermal Resistance ( $\theta_{JA}$ ) | 43°C/W          |
| WQFN-16 Thermal Resistance ( $\theta_{JA}$ )       | 51°C/W          |
| Lead Temperature (Soldering, 10 sec)               | 260°C           |
| ESD Rating <sup>(4)</sup>                          | 1kV             |

- (1) Absolute maximum ratings indicate limits beyond which damage to the device may occur. Operating range indicates conditions for which the device is intended to be functional, but does not ensure specific performance limits. For ensured specifications and test conditions see Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
- (3) VDDQ voltage must be less than  $2 \times (AVIN - 1)$  or 6V, whichever is smaller.
- (4) The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

## Operating Range

|                                     |               |
|-------------------------------------|---------------|
| Junction Temp. Range <sup>(1)</sup> | 0°C to +125°C |
| AVIN to GND                         | 2.2V to 5.5V  |
| PVIN Supply Voltage                 | 0 to AVIN     |
| SD Input Voltage                    | 0 to AVIN     |

(1) At elevated temperatures, devices must be derated based on thermal resistance. The device in the SOIC-8 package must be derated at  $\theta_{JA} = 151.2^\circ \text{C/W}$  junction to ambient with no heat sink.

## Electrical Characteristics

Specifications with standard typeface are for  $T_J = 25^\circ\text{C}$  and limits in **boldface type** apply over the full **Operating Temperature Range** ( $T_J = 0^\circ\text{C}$  to  $+125^\circ\text{C}$ )<sup>(1)</sup>. Unless otherwise specified, AVIN = PVIN = 2.5V, VDDQ = 2.5V<sup>(2)</sup>.

| Symbol               | Parameter                                             | Conditions                                                                                                  | Min                                          | Typ                     | Max                                          | Units         |
|----------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------------|----------------------------------------------|---------------|
| $V_{REF}$            | $V_{REF}$ Voltage                                     | VIN = VDDQ = 2.3V<br>VIN = VDDQ = 2.5V<br>VIN = VDDQ = 2.7V                                                 | <b>1.135</b><br><b>1.235</b><br><b>1.335</b> | 1.158<br>1.258<br>1.358 | <b>1.185</b><br><b>1.285</b><br><b>1.385</b> | V             |
| $Z_{VREF}$           | $V_{REF}$ Output Impedance                            | $I_{REF} = -30$ to $+30 \mu\text{A}$                                                                        |                                              | 2.5                     |                                              | k $\Omega$    |
| $V_{TT}$             | $V_{TT}$ Output Voltage                               | $I_{OUT} = 0\text{A}$<br>VIN = VDDQ = 2.3V<br>VIN = VDDQ = 2.5V<br>VIN = VDDQ = 2.7V                        | <b>1.125</b><br><b>1.225</b><br><b>1.325</b> | 1.159<br>1.259<br>1.359 | <b>1.190</b><br><b>1.290</b><br><b>1.390</b> | V             |
|                      |                                                       | $I_{OUT} = \pm 1.5\text{A}$ <sup>(3)</sup><br>VIN = VDDQ = 2.3V<br>VIN = VDDQ = 2.5V<br>VIN = VDDQ = 2.7V   | <b>1.125</b><br><b>1.225</b><br><b>1.325</b> | 1.159<br>1.259<br>1.359 | <b>1.190</b><br><b>1.290</b><br><b>1.390</b> | V             |
| $V_{OS_{TT}/V_{TT}}$ | $V_{TT}$ Output Voltage Offset ( $V_{REF} - V_{TT}$ ) | $I_{OUT} = 0\text{A}$<br>$I_{OUT} = -1.5\text{A}$ <sup>(3)</sup><br>$I_{OUT} = +1.5\text{A}$ <sup>(3)</sup> | <b>-20</b><br><b>-25</b><br><b>-25</b>       | 0<br>0<br>0             | <b>20</b><br><b>25</b><br><b>25</b>          | mV            |
| $I_Q$                | Quiescent Current <sup>(4)</sup>                      | $I_{OUT} = 0\text{A}$ <sup>(1)</sup>                                                                        |                                              | 320                     | <b>500</b>                                   | $\mu\text{A}$ |
| $Z_{VDDQ}$           | VDDQ Input Impedance                                  |                                                                                                             |                                              | 100                     |                                              | k $\Omega$    |
| $I_{SD}$             | Quiescent Current in Shutdown <sup>(4)</sup>          | SD = 0V                                                                                                     |                                              | 115                     | <b>150</b>                                   | $\mu\text{A}$ |
| $I_{Q\_SD}$          | Shutdown Leakage Current                              | SD = 0V                                                                                                     |                                              | 2                       | <b>5</b>                                     | $\mu\text{A}$ |
| $V_{IH}$             | Minimum Shutdown High Level                           |                                                                                                             | <b>1.9</b>                                   |                         |                                              | V             |
| $V_{IL}$             | Maximum Shutdown Low Level                            |                                                                                                             |                                              |                         | <b>0.8</b>                                   | V             |
| $I_V$                | $V_{TT}$ Leakage Current in Shutdown                  | SD = 0V<br>$V_{TT} = 1.25\text{V}$                                                                          |                                              | 1                       | <b>10</b>                                    | $\mu\text{A}$ |
| $I_{SENSE}$          | $V_{SENSE}$ Input Current                             |                                                                                                             |                                              | 13                      |                                              | nA            |
| $T_{SD}$             | Thermal Shutdown                                      | See <sup>(5)</sup>                                                                                          |                                              | 165                     |                                              | Celcius       |
| $T_{SD\_HYS}$        | Thermal Shutdown Hysteresis                           |                                                                                                             |                                              | 10                      |                                              | Celcius       |

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are specified through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate Texas Instruments' Average Outgoing Quality Level (AOQL).

(2) VIN is defined as VIN = AVIN = PVIN.

(3)  $V_{TT}$  load regulation is tested by using a 10 ms current pulse and measuring  $V_{TT}$ .

(4) Quiescent current defined as the current flow into AVIN.

(5) The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_{J(MAX)}$ , the junction to ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . Exceeding the maximum allowable power dissipation will cause excessive die temperature and the regulator will go into thermal shutdown.

### Typical Performance Characteristics

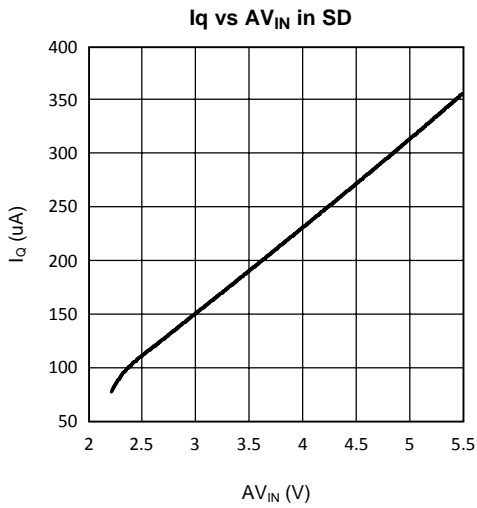


Figure 4.

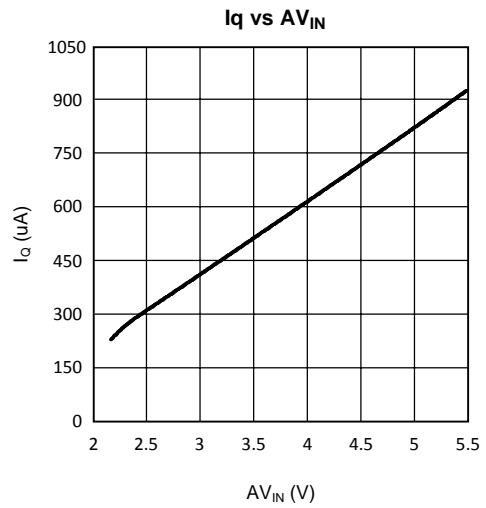


Figure 5.

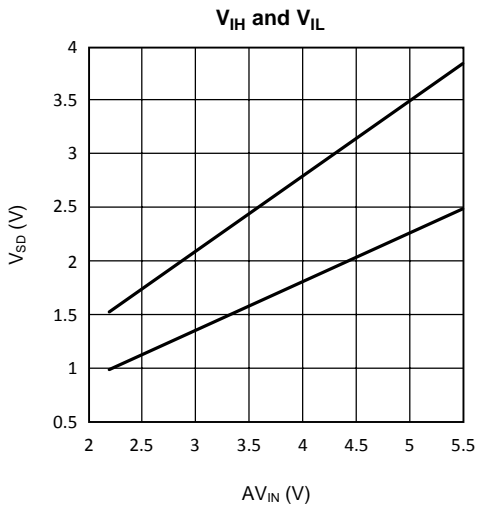


Figure 6.

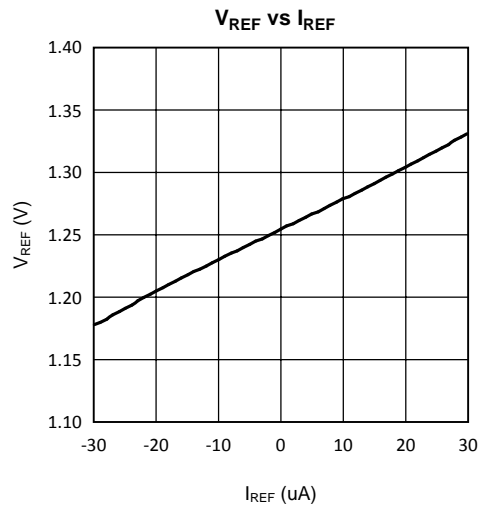


Figure 7.

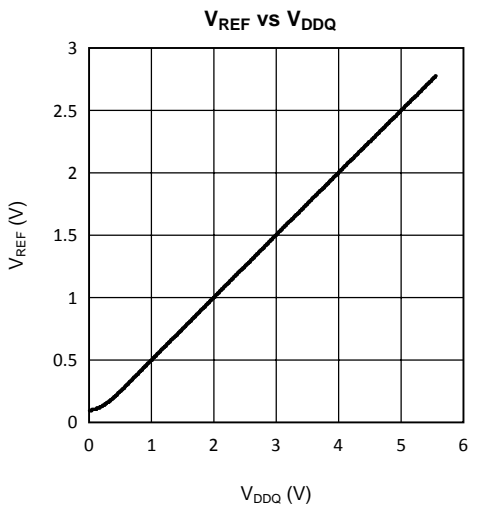


Figure 8.

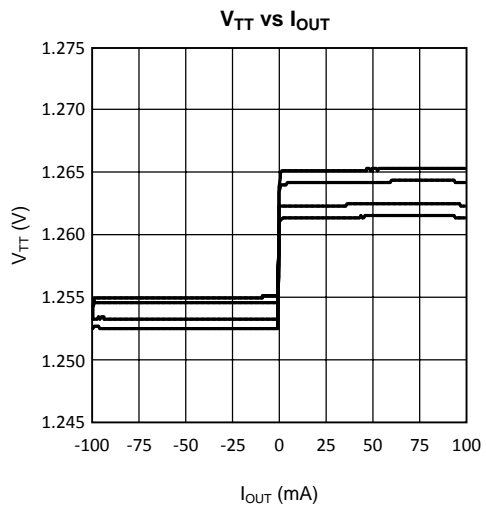


Figure 9.

Typical Performance Characteristics (continued)

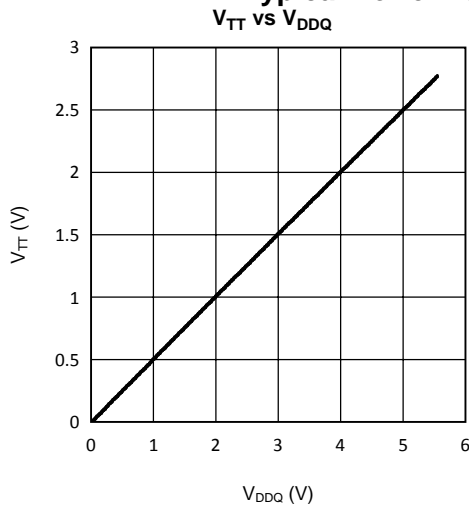


Figure 10.

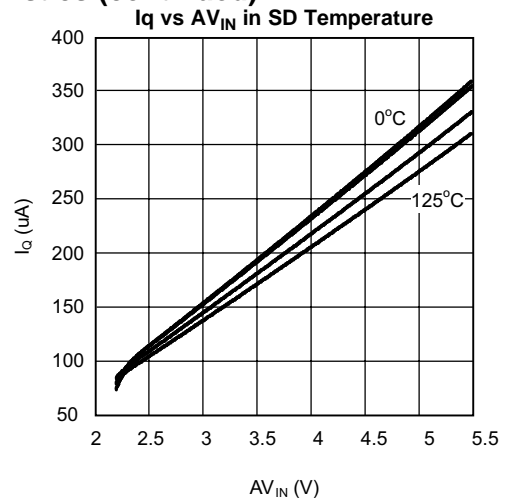


Figure 11.

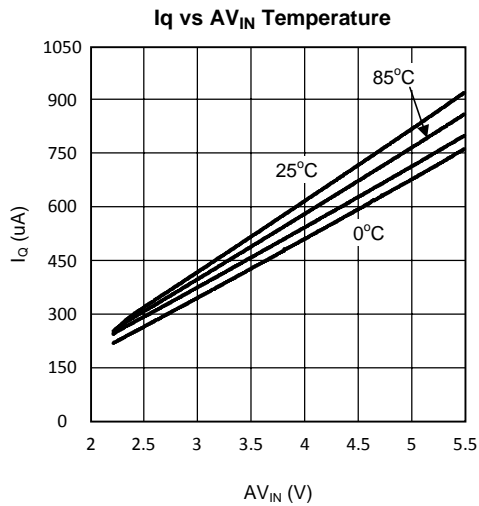


Figure 12.

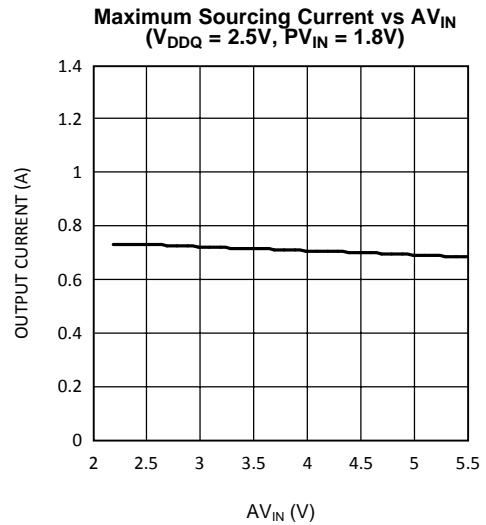


Figure 13.

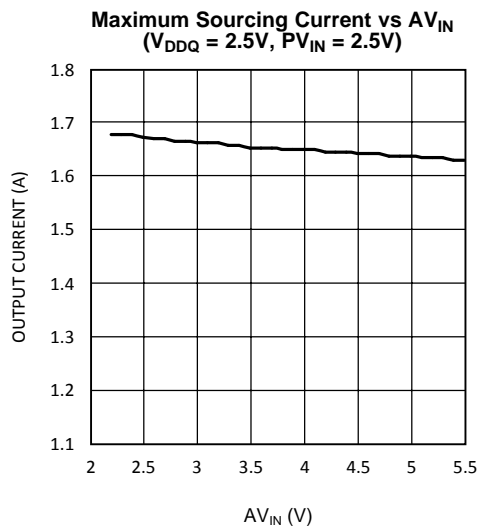


Figure 14.

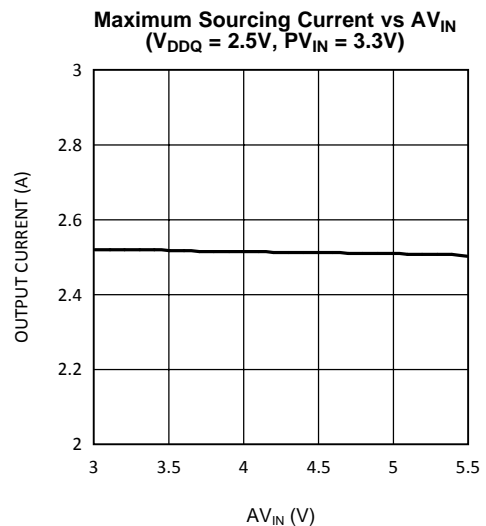


Figure 15.

Typical Performance Characteristics (continued)

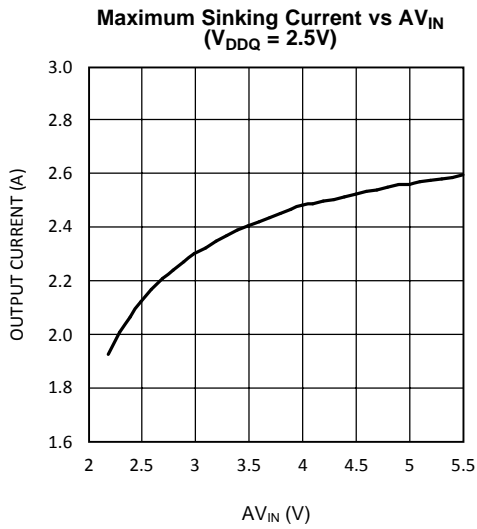


Figure 16.

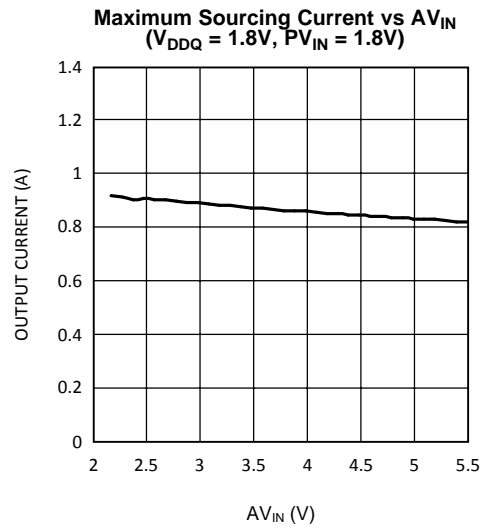


Figure 17.

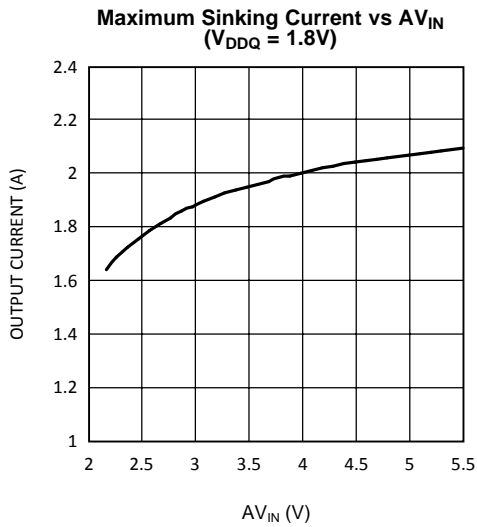


Figure 18.

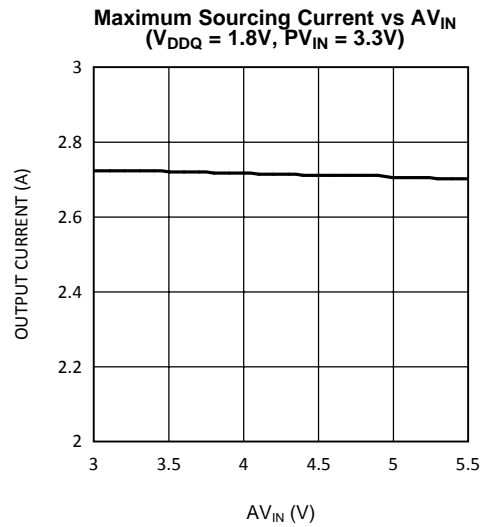
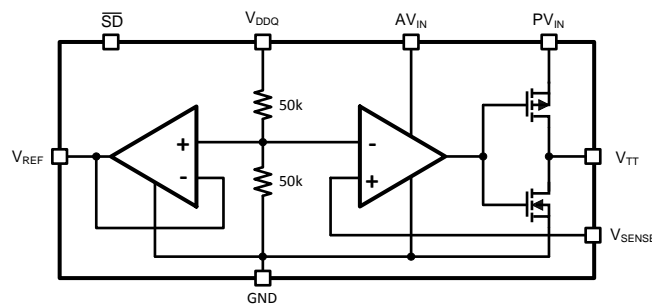


Figure 19.

BLOCK DIAGRAM



## Description

The LP2996-N is a linear bus termination regulator designed to meet the JEDEC requirements of SSTL-2. The output,  $V_{TT}$  is capable of sinking and sourcing current while regulating the output voltage equal to  $V_{DDQ} / 2$ . The output stage has been designed to maintain excellent load regulation while preventing shoot through. The LP2996-N also incorporates two distinct power rails that separates the analog circuitry from the power output stage. This allows a split rail approach to be utilized to decrease internal power dissipation. It also permits the LP2996-N to provide a termination solution for the next generation of DDR-SDRAM memory (DDRII). For new designs, the LP2997 or LP2998 is recommended for DDR-II applications. The LP2996-N can also be used to provide a termination voltage for other logic schemes such as SSTL-3 or HSTL.

Series Stub Termination Logic (SSTL) was created to improve signal integrity of the data transmission across the memory bus. This termination scheme is essential to prevent data error from signal reflections while transmitting at high frequencies encountered with DDR-SDRAM. The most common form of termination is Class II single parallel termination. This involves one  $R_S$  series resistor from the chipset to the memory and one  $R_T$  termination resistor. Typical values for  $R_S$  and  $R_T$  are 25 Ohms, although these can be changed to scale the current requirements from the LP2996-N. This implementation can be seen below in [Figure 20](#).

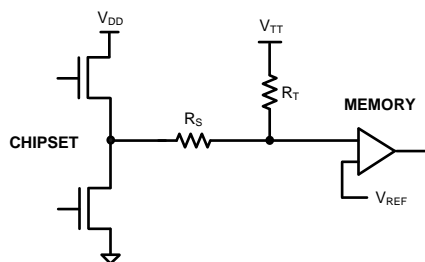


Figure 20. SSTL-Termination Scheme

## PIN DESCRIPTIONS

### AVIN AND PVIN

AVIN and PVIN are the input supply pins for the LP2996-N. AVIN is used to supply all the internal control circuitry. PVIN, however, is used exclusively to provide the rail voltage for the output stage used to create  $V_{TT}$ . These pins have the capability to work off separate supplies depending on the application. Higher voltages on PVIN will increase the maximum continuous output current because of output RDSON limitations at voltages close to  $V_{TT}$ . The disadvantage of high values of PVIN is that the internal power loss will also increase, thermally limiting the design. For SSTL-2 applications, a good compromise would be to connect the AVIN and PVIN directly together at 2.5V. This eliminates the need for bypassing the two supply pins separately. The only limitation on input voltage selection is that PVIN must be equal to or lower than AVIN. It is recommended to connect PVIN to voltage rails equal to or less than 3.3V to prevent the thermal limit from tripping because of excessive internal power dissipation. If the junction temperature exceeds the thermal shutdown than the part will enter a shutdown state identical to the manual shutdown where  $V_{TT}$  is tri-stated and  $V_{REF}$  remains active.

### VDDQ

VDDQ is the input used to create the internal reference voltage for regulating  $V_{TT}$ . The reference voltage is generated from a resistor divider of two internal 50k $\Omega$  resistors. This ensures that  $V_{TT}$  will track  $V_{DDQ} / 2$  precisely. The optimal implementation of VDDQ is as a remote sense. This can be achieved by connecting VDDQ directly to the 2.5V rail at the DIMM instead of AVIN and PVIN. This ensures that the reference voltage tracks the DDR memory rails precisely without a large voltage drop from the power lines. For SSTL-2 applications VDDQ will be a 2.5V signal, which will create a 1.25V termination voltage at  $V_{TT}$  (See Electrical Characteristics Table for exact values of  $V_{TT}$  over temperature).

**V<sub>SENSE</sub>**

The purpose of the sense pin is to provide improved remote load regulation. In most motherboard applications the termination resistors will connect to  $V_{TT}$  in a long plane. If the output voltage was regulated only at the output of the LP2996-N then the long trace will cause a significant IR drop resulting in a termination voltage lower at one end of the bus than the other. The  $V_{SENSE}$  pin can be used to improve this performance, by connecting it to the middle of the bus. This will provide a better distribution across the entire termination bus. If remote load regulation is not used then the  $V_{SENSE}$  pin must still be connected to  $V_{TT}$ . Care should be taken when a long  $V_{SENSE}$  trace is implemented in close proximity to the memory. Noise pickup in the  $V_{SENSE}$  trace can cause problems with precise regulation of  $V_{TT}$ . A small 0.1 $\mu$ F ceramic capacitor placed next to the  $V_{SENSE}$  pin can help filter any high frequency signals and preventing errors.

**SHUTDOWN**

The LP2996-N contains an active low shutdown pin that can be used to tri-state  $V_{TT}$ . During shutdown  $V_{TT}$  should not be exposed to voltages that exceed  $AVIN$ . With the shutdown pin asserted low the quiescent current of the LP2996-N will drop, however,  $V_{DDQ}$  will always maintain its constant impedance of 100k $\Omega$  for generating the internal reference. Therefore to calculate the total power loss in shutdown both currents need to be considered. For more information refer to the [Thermal Dissipation](#) section. The shutdown pin also has an internal pull-up current, therefore to turn the part on the shutdown pin can either be connected to  $AVIN$  or left open.

**V<sub>REF</sub>**

$V_{REF}$  provides the buffered output of the internal reference voltage  $V_{DDQ} / 2$ . This output should be used to provide the reference voltage for the Northbridge chipset and memory. Since these inputs are typically an extremely high impedance, there should be little current drawn from  $V_{REF}$ . For improved performance, an output bypass capacitor can be used, located close to the pin, to help with noise. A ceramic capacitor in the range of 0.1  $\mu$ F to 0.01  $\mu$ F is recommended. This output remains active during the shutdown state and thermal shutdown events for the suspend to RAM functionality.

**V<sub>TT</sub>**

$V_{TT}$  is the regulated output that is used to terminate the bus resistors. It is capable of sinking and sourcing current while regulating the output precisely to  $V_{DDQ} / 2$ . The LP2996-N is designed to handle peak transient currents of up to  $\pm 3A$  with a fast transient response. The maximum continuous current is a function of  $V_{IN}$  and can be viewed in the [Typical Performance Characteristics](#) section. If a transient is expected to last above the maximum continuous current rating for a significant amount of time then the output capacitor should be sized large enough to prevent an excessive voltage drop. Despite the fact that the LP2996-N is designed to handle large transient output currents it is not capable of handling these for long durations, under all conditions. The reason for this is the standard packages are not able to thermally dissipate the heat as a result of the internal power loss. If large currents are required for longer durations, then care should be taken to ensure that the maximum junction temperature is not exceeded. Proper thermal derating should always be used (please refer to the [Thermal Dissipation](#) section). If the junction temperature exceeds the thermal shutdown point than  $V_{TT}$  will tri-state until the part returns below the hysteretic trip-point.



## COMPONENT SELECTIONS

### INPUT CAPACITOR

The LP2996-N does not require a capacitor for input stability, but it is recommended for improved performance during large load transients to prevent the input rail from dropping. The input capacitor should be located as close as possible to the PVIN pin. Several recommendations exist dependent on the application required. A typical value recommended for AL electrolytic capacitors is 50  $\mu\text{F}$ . Ceramic capacitors can also be used, a value in the range of 10  $\mu\text{F}$  with X5R or better would be an ideal choice. The input capacitance can be reduced if the LP2996-N is placed close to the bulk capacitance from the output of the 2.5V DC-DC converter. If the two supply rails (AVIN and PVIN) are separated then the 47 $\mu\text{F}$  capacitor should be placed as close to possible to the PVIN rail. An additional 0.1 $\mu\text{F}$  ceramic capacitor can be placed on the AVIN rail to prevent excessive noise from coupling into the device.

### OUTPUT CAPACITOR

The LP2996-N has been designed to be insensitive of output capacitor size or ESR (Equivalent Series Resistance). This allows the flexibility to use any capacitor desired. The choice for output capacitor will be determined solely on the application and the requirements for load transient response of  $V_{\text{TT}}$ . As a general recommendation the output capacitor should be sized above 100  $\mu\text{F}$  with a low ESR for SSTL applications with DDR-SDRAM. The value of ESR should be determined by the maximum current spikes expected and the extent at which the output voltage is allowed to droop. Several capacitor options are available on the market and a few of these are highlighted below:

**AL** - It should be noted that many aluminum electrolytics only specify impedance at a frequency of 120 Hz, which indicates they have poor high frequency performance. Only aluminum electrolytics that have an impedance specified at a higher frequency (between 20 kHz and 100 kHz) should be used for the LP2996-N. To improve the ESR several AL electrolytics can be combined in parallel for an overall reduction. An important note to be aware of is the extent at which the ESR will change over temperature. Aluminum electrolytic capacitors can have their ESR rapidly increase at cold temperatures.

**Ceramic** - Ceramic capacitors typically have a low capacitance, in the range of 10 to 100  $\mu\text{F}$  range, but they have excellent AC performance for bypassing noise because of very low ESR (typically less than 10 m $\Omega$ ). However, some dielectric types do not have good capacitance characteristics as a function of voltage and temperature. Because of the typically low value of capacitance it is recommended to use ceramic capacitors in parallel with another capacitor such as an aluminum electrolytic. A dielectric of X5R or better is recommended for all ceramic capacitors.

**Hybrid** - Several hybrid capacitors such as OS-CON and SP are available from several manufacturers. These offer a large capacitance while maintaining a low ESR. These are the best solution when size and performance are critical, although their cost is typically higher than any other capacitor.

### Thermal Dissipation

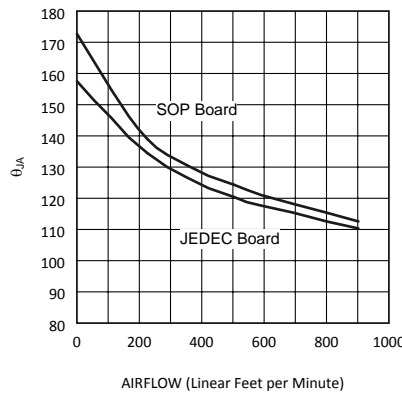
Since the LP2996-N is a linear regulator any current flow from  $V_{\text{TT}}$  will result in internal power dissipation generating heat. To prevent damaging the part from exceeding the maximum allowable junction temperature, care should be taken to derate the part dependent on the maximum expected ambient temperature and power dissipation. The maximum allowable internal temperature rise ( $T_{\text{Rmax}}$ ) can be calculated given the maximum ambient temperature ( $T_{\text{Amax}}$ ) of the application and the maximum allowable junction temperature ( $T_{\text{Jmax}}$ ).

$$T_{\text{Rmax}} = T_{\text{Jmax}} - T_{\text{Amax}} \quad (1)$$

From this equation, the maximum power dissipation ( $P_{\text{Dmax}}$ ) of the part can be calculated:

$$P_{\text{Dmax}} = T_{\text{Rmax}} / \theta_{\text{JA}} \quad (2)$$

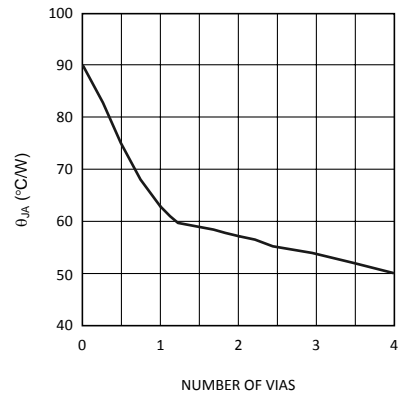
The  $\theta_{\text{JA}}$  of the LP2996-N will be dependent on several variables: the package used; the thickness of copper; the number of vias and the airflow. For instance, the  $\theta_{\text{JA}}$  of the SOIC-8 is 163°C/W with the package mounted to a standard 8x4 2-layer board with 1oz. copper, no airflow, and 0.5W dissipation at room temperature. This value can be reduced to 151.2°C/W by changing to a 3x4 board with 2 oz. copper that is the JEDEC standard. [Figure 21](#) shows how the  $\theta_{\text{JA}}$  varies with airflow for the two boards mentioned.



**Figure 21.  $\theta_{JA}$  vs Airflow (SOIC-8)**

Additional improvements can be made by the judicious use of vias to connect the part and dissipate heat to an internal ground plane. Using larger traces and more copper on the top side of the board can also help. With careful layout it is possible to reduce the  $\theta_{JA}$  further than the nominal values shown in [Figure 21](#)

Layout is also extremely critical to maximize the output current with the WQFN package. By simply placing vias under the DAP the  $\theta_{JA}$  can be lowered significantly. [Figure 22](#) shows the WQFN thermal data when placed on a 4-layer JEDEC board with copper thickness of 0.5/1/1/0.5 oz. The number of vias, with a pitch of 1.27 mm, has been increased to the maximum of 4 where a  $\theta_{JA}$  of 50.41°C/W can be obtained. Via wall thickness for this calculation is 0.036 mm for 1oz. Copper.



**Figure 22. WQFN-16  $\theta_{JA}$  vs # of Vias (4 Layer JEDEC Board)**

Additional improvements in lowering the  $\theta_{JA}$  can also be achieved with a constant airflow across the package. Maintaining the same conditions as above and utilizing the 2x2 via array, [Figure 23](#) shows how the  $\theta_{JA}$  varies with airflow.

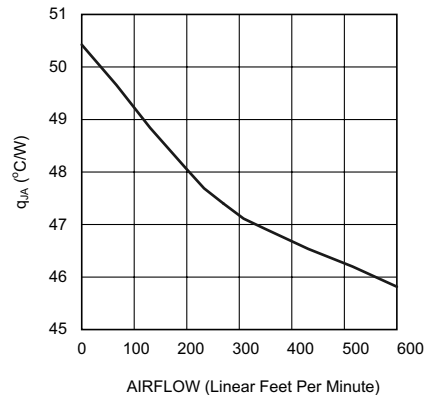


Figure 23.  $\theta_{JA}$  vs Airflow Speed (JEDEC Board with 4 Vias)

Optimizing the  $\theta_{JA}$  and placing the LP2996-N in a section of a board exposed to lower ambient temperature allows the part to operate with higher power dissipation. The internal power dissipation can be calculated by summing the three main sources of loss: output current at  $V_{TT}$ , either sinking or sourcing, and quiescent current at AVIN and VDDQ. During the active state (when shutdown is not held low) the total internal power dissipation can be calculated from the following equations:

$$P_D = P_{AVIN} + P_{VDDQ} + P_{VTT}$$

where

$$P_{AVIN} = I_{AVIN} \times V_{AVIN} \tag{3}$$

$$P_{VDDQ} = V_{VDDQ} \times I_{VDDQ} = V_{VDDQ2} \times R_{VDDQ} \tag{4}$$

$$P_{VTT} = V_{VTT} \times I_{LOAD} \text{ (Sinking) or } \tag{5}$$

$$P_{VTT} = (V_{PVIN} - V_{VTT}) \times I_{LOAD} \text{ (Sourcing)} \tag{6}$$

To calculate the maximum power dissipation at  $V_{TT}$  both conditions at  $V_{TT}$  need to be examined, sinking and sourcing current. Although only one equation will add into the total,  $V_{TT}$  cannot source and sink current simultaneously.

$$P_{VTT} = V_{VTT} \times I_{LOAD} \text{ (Sinking) or } \tag{6}$$

$$P_{VTT} = (V_{PVIN} - V_{VTT}) \times I_{LOAD} \text{ (Sourcing)} \tag{7}$$

The power dissipation of the LP2996-N can also be calculated during the shutdown state. During this condition the output  $V_{TT}$  will tri-state, therefore that term in the power equation will disappear as it cannot sink or source any current (leakage is negligible). The only losses during shutdown will be the reduced quiescent current at AVIN and the constant impedance that is seen at the VDDQ pin.

$$P_D = P_{AVIN} + P_{VDDQ} \tag{8}$$

$$P_{AVIN} = I_{AVIN} \times V_{AVIN} \tag{9}$$

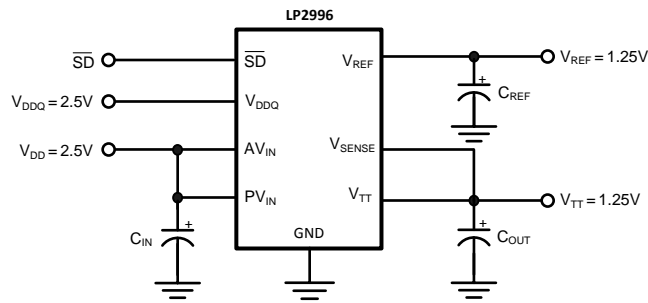
$$P_{VDDQ} = V_{VDDQ} \times I_{VDDQ} = V_{VDDQ2} \times R_{VDDQ} \tag{10}$$

### Typical Application Circuits

Several different application circuits have been shown in [Figure 24](#) through [Figure 33](#) to illustrate some of the options that are possible in configuring the LP2996-N. Graphs of the individual circuit performance can be found in the [Typical Performance Characteristics](#) section in the beginning of the datasheet. These curves illustrate how the maximum output current is affected by changes in AVIN and PVIN.

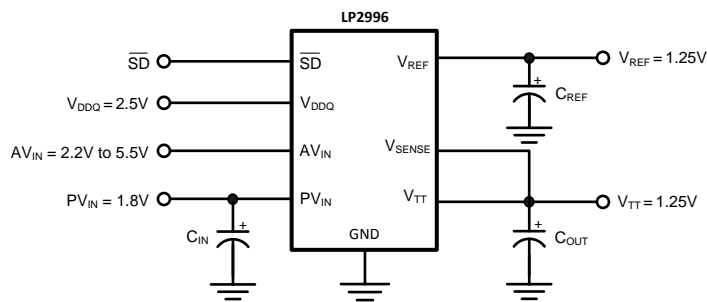
### SSTL-2 APPLICATIONS

For the majority of applications that implement the SSTL-2 termination scheme it is recommended to connect all the input rails to the 2.5V rail. This provides an optimal trade-off between power dissipation and component count and selection. An example of this circuit can be seen in [Figure 24](#).



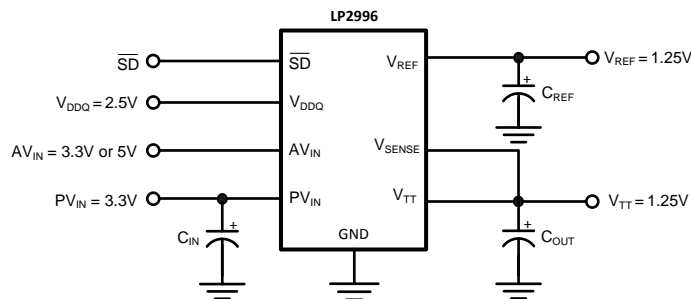
**Figure 24. Recommended SSTL-2 Implementation**

If power dissipation or efficiency is a major concern then the LP2996-N has the ability to operate on split power rails. The output stage (PVIN) can be operated on a lower rail such as 1.8V and the analog circuitry (AVIN) can be connected to a higher rail such as 2.5V, 3.3V or 5V. This allows the internal power dissipation to be lowered when sourcing current from V<sub>TT</sub>. The disadvantage of this circuit is that the maximum continuous current is reduced because of the lower rail voltage, although it is adequate for all motherboard SSTL-2 applications. Increasing the output capacitance can also help if periods of large load transients will be encountered.



**Figure 25. Lower Power Dissipation SSTL-2 Implementation**

The third option for SSTL-2 applications in the situation that a 1.8V rail is not available and it is not desirable to use 2.5V, is to connect the LP2996-N power rail to 3.3V. In this situation AVIN will be limited to operation on the 3.3V or 5V rail as PVIN can never exceed AVIN. This configuration has the ability to provide the maximum continuous output current at the downside of higher thermal dissipation. Care should be taken to prevent the LP2996-N from experiencing large current levels which cause the junction temperature to exceed the maximum. Because of this risk it is not recommended to supply the output stage with a voltage higher than a nominal 3.3V rail.



**Figure 26. SSTL-2 Implementation with higher voltage rails**

## DDR-II APPLICATIONS

With the separate VDDQ pin and an internal resistor divider it is possible to use the LP2996-N in applications utilizing DDR-II memory. Figure 25 and Figure 26 show several implementations of recommended circuits with output curves displayed in the Typical Performance Characteristics. Figure 25 shows the recommended circuit configuration for DDR-II applications. The output stage is connected to the 1.8V rail and the AVIN pin can be connected to either a 3.3V or 5V rail. For new designs, the LP2997 or LP2998 is recommended for DDR-II applications.

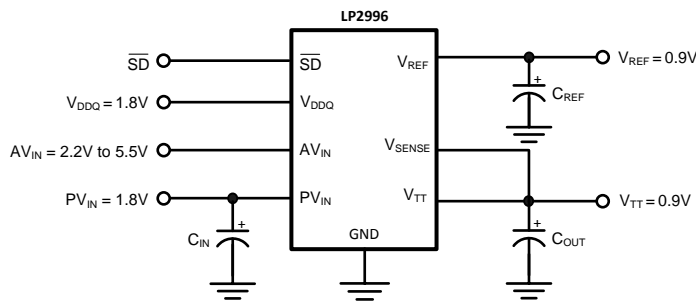


Figure 27. Recommended DDR-II Termination

If it is not desirable to use the 1.8V rail it is possible to connect the output stage to a 3.3V rail. Care should be taken to not exceed the maximum junction temperature as the thermal dissipation increases with lower  $V_{TT}$  output voltages. For this reason it is not recommended to power PVIN off a rail higher than the nominal 3.3V. The advantage of this configuration is that it has the ability to source and sink a higher maximum continuous current.

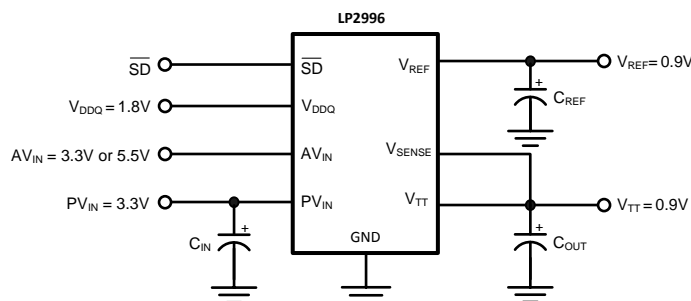


Figure 28. DDR-II Termination with higher voltage rails

## LEVEL SHIFTING

If standards other than SSTL-2 are required, such as SSTL-3, it may be necessary to use a different scaling factor than 0.5 times  $V_{DDQ}$  for regulating the output voltage. Several options are available to scale the output to any voltage required. One method is to level shift the output by using feedback resistors from  $V_{TT}$  to the  $V_{SENSE}$  pin. This has been illustrated in Figure 29 and Figure 30. Figure 29 shows how to use two resistors to level shift  $V_{TT}$  above the internal reference voltage of  $V_{DDQ}/2$ . To calculate the exact voltage at  $V_{TT}$  the following equation can be used.

$$V_{TT} = V_{DDQ}/2 ( 1 + R1/R2) \tag{11}$$

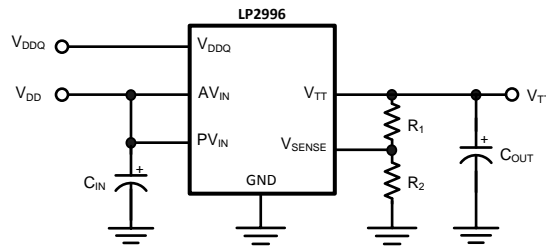


Figure 29. Increasing VTT by Level Shifting

Conversely, the R2 resistor can be placed between V<sub>SENSE</sub> and V<sub>DDQ</sub> to shift the V<sub>TT</sub> output lower than the internal reference voltage of V<sub>DDQ</sub>/2. The equations relating V<sub>TT</sub> and the resistors can be seen below:

$$V_{TT} = V_{DDQ}/2 (1 - R1/R2) \tag{12}$$

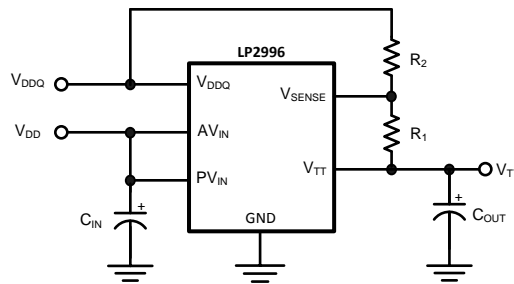


Figure 30. Decreasing VTT by Level Shifting

**HSTL APPLICATIONS**

The LP2996-N can be easily adapted for HSTL applications by connecting V<sub>DDQ</sub> to the 1.5V rail. This will produce a V<sub>TT</sub> and V<sub>REF</sub> voltage of approximately 0.75V for the termination resistors. AVIN and PVIN should be connected to a 2.5V rail for optimal performance.

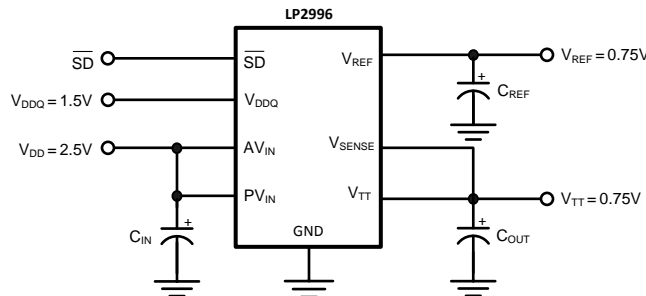


Figure 31. HSTL Application

**QDR APPLICATIONS**

Quad data rate (QDR) applications utilize multiple channels for improved memory performance. However, this increase in bus lines has the effect of increasing the current levels required for termination. The recommended approach in terminating multiple channels is to use a dedicated LP2996-N for each channel. This simplifies layout and reduces the internal power dissipation for each regulator. Separate V<sub>REF</sub> signals can be used for each DIMM bank from the corresponding regulator with the chipset reference provided by a local resistor divider or one of the LP2996-N signals. Because V<sub>REF</sub> and V<sub>TT</sub> are expected to track and the part to part variations are minor, there should be little difference between the reference signals of each LP2996-N.

## OUTPUT CAPACITOR SELECTION

For applications utilizing the LP2996-N to terminate SSTL-2 I/O signals the typical application circuit shown in Figure 30 can be implemented.

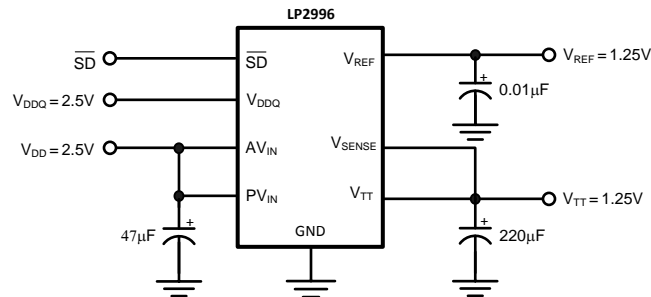


Figure 32. Typical SSTL-2 Application Circuit

This circuit permits termination in a minimum amount of board space and component count. Capacitor selection can be varied depending on the number of lines terminated and the maximum load transient. However, with motherboards and other applications where  $V_{TT}$  is distributed across a long plane it is advisable to use multiple bulk capacitors and addition to high frequency decoupling. Figure 31 shown below depicts an example circuit where 2 bulk output capacitors could be situated at both ends of the  $V_{TT}$  plane for optimal placement. Large aluminum electrolytic capacitors are used for their low ESR and low cost.

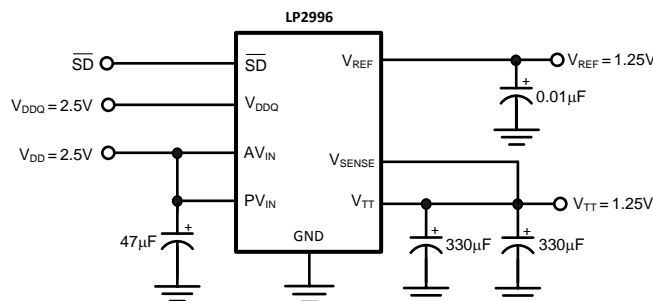


Figure 33. Typical SSTL-2 Application Circuit for Motherboards

In most PC applications an extensive amount of decoupling is required because of the long interconnects encountered with the DDR-SDRAM DIMMs mounted on modules. As a result bulk aluminum electrolytic capacitors in the range of 1000uF are typically used.

## PCB Layout Considerations

1. The input capacitor for the power rail should be placed as close as possible to the PVIN pin.
2.  $V_{SENSE}$  should be connected to the  $V_{TT}$  termination bus at the point where regulation is required. For motherboard applications an ideal location would be at the center of the termination bus.
3.  $V_{DDQ}$  can be connected remotely to the  $V_{DDQ}$  rail input at either the DIMM or the Chipset. This provides the most accurate point for creating the reference voltage.
4. For improved thermal performance excessive top side copper should be used to dissipate heat from the package. Numerous vias from the ground connection to the internal ground plane will help. Additionally these can be located underneath the package if manufacturing standards permit.
5. Care should be taken when routing the  $V_{SENSE}$  trace to avoid noise pickup from switching I/O signals. A 0.1uF ceramic capacitor located close to the  $V_{SENSE}$  can also be used to filter any unwanted high frequency signal. This can be an issue especially if long  $V_{SENSE}$  traces are used.
6.  $V_{REF}$  should be bypassed with a 0.01 µF or 0.1 µF ceramic capacitor for improved performance. This capacitor should be located as close as possible to the  $V_{REF}$  pin.

## REVISION HISTORY

| Changes from Revision I (March 2013) to Revision J         | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">15</a> |



**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LP2996LQ         | ACTIVE        | WQFN         | NHP                | 16   | 1000        | TBD                        | Call TI          | Call TI              | 0 to 125     | L00006B                  | <a href="#">Samples</a> |
| LP2996LQ/NOPB    | ACTIVE        | WQFN         | NHP                | 16   | 1000        | Green (RoHS<br>& no Sb/Br) | SN               | Level-3-260C-168 HR  | 0 to 125     | L00006B                  | <a href="#">Samples</a> |
| LP2996LQX        | ACTIVE        | WQFN         | NHP                | 16   | 4500        | TBD                        | Call TI          | Call TI              | 0 to 125     | L00006B                  | <a href="#">Samples</a> |
| LP2996LQX/NOPB   | ACTIVE        | WQFN         | NHP                | 16   | 4500        | Green (RoHS<br>& no Sb/Br) | SN               | Level-3-260C-168 HR  | 0 to 125     | L00006B                  | <a href="#">Samples</a> |
| LP2996M          | ACTIVE        | SOIC         | D                  | 8    | 95          | TBD                        | Call TI          | Call TI              | 0 to 125     | 2996M                    | <a href="#">Samples</a> |
| LP2996M/NOPB     | ACTIVE        | SOIC         | D                  | 8    | 95          | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | 0 to 125     | 2996M                    | <a href="#">Samples</a> |
| LP2996MR         | ACTIVE        | SO PowerPAD  | DDA                | 8    | 95          | TBD                        | Call TI          | Call TI              | 0 to 125     | LP2996                   | <a href="#">Samples</a> |
| LP2996MR/NOPB    | ACTIVE        | SO PowerPAD  | DDA                | 8    | 95          | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-3-260C-168 HR  | 0 to 125     | LP2996                   | <a href="#">Samples</a> |
| LP2996MRX        | ACTIVE        | SO PowerPAD  | DDA                | 8    | 2500        | TBD                        | Call TI          | Call TI              | 0 to 125     | LP2996                   | <a href="#">Samples</a> |
| LP2996MRX/NOPB   | ACTIVE        | SO PowerPAD  | DDA                | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-3-260C-168 HR  | 0 to 125     | LP2996                   | <a href="#">Samples</a> |
| LP2996MX/NOPB    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | 0 to 125     | 2996M                    | <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.

**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.

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

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

(4) Only one of markings shown within the brackets will appear on the physical device.

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**TAPE AND REEL INFORMATION**

**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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LP2996LQ       | WQFN         | NHP             | 16   | 1000 | 178.0              | 12.4               | 4.3     | 4.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LP2996LQ/NOPB  | WQFN         | NHP             | 16   | 1000 | 178.0              | 12.4               | 4.3     | 4.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LP2996LQX      | WQFN         | NHP             | 16   | 4500 | 330.0              | 12.4               | 4.3     | 4.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LP2996LQX/NOPB | WQFN         | NHP             | 16   | 4500 | 330.0              | 12.4               | 4.3     | 4.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LP2996MRX      | SO Power PAD | DDA             | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LP2996MRX/NOPB | SO Power PAD | DDA             | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LP2996MX/NOPB  | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 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) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LP2996LQ       | WQFN         | NHP             | 16   | 1000 | 210.0       | 185.0      | 35.0        |
| LP2996LQ/NOPB  | WQFN         | NHP             | 16   | 1000 | 213.0       | 191.0      | 55.0        |
| LP2996LQX      | WQFN         | NHP             | 16   | 4500 | 367.0       | 367.0      | 35.0        |
| LP2996LQX/NOPB | WQFN         | NHP             | 16   | 4500 | 367.0       | 367.0      | 35.0        |
| LP2996MRX      | SO PowerPAD  | DDA             | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LP2996MRX/NOPB | SO PowerPAD  | DDA             | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LP2996MX/NOPB  | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |

DDA (R-PDSO-G8)

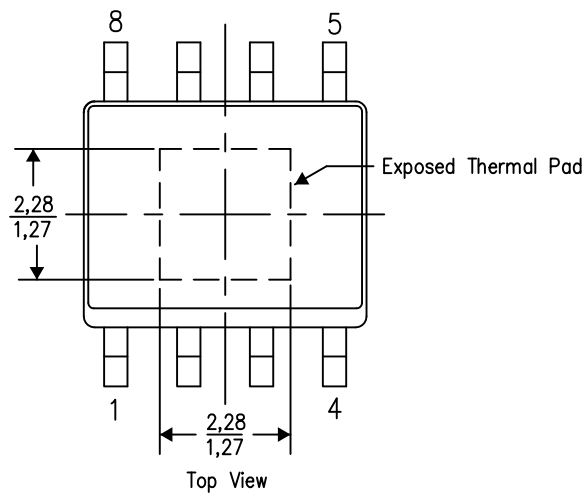
PowerPAD™ PLASTIC SMALL OUTLINE

**THERMAL INFORMATION**

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

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

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



Exposed Thermal Pad Dimensions

4206322-2/L 05/12

NOTE: A. All linear dimensions are in millimeters

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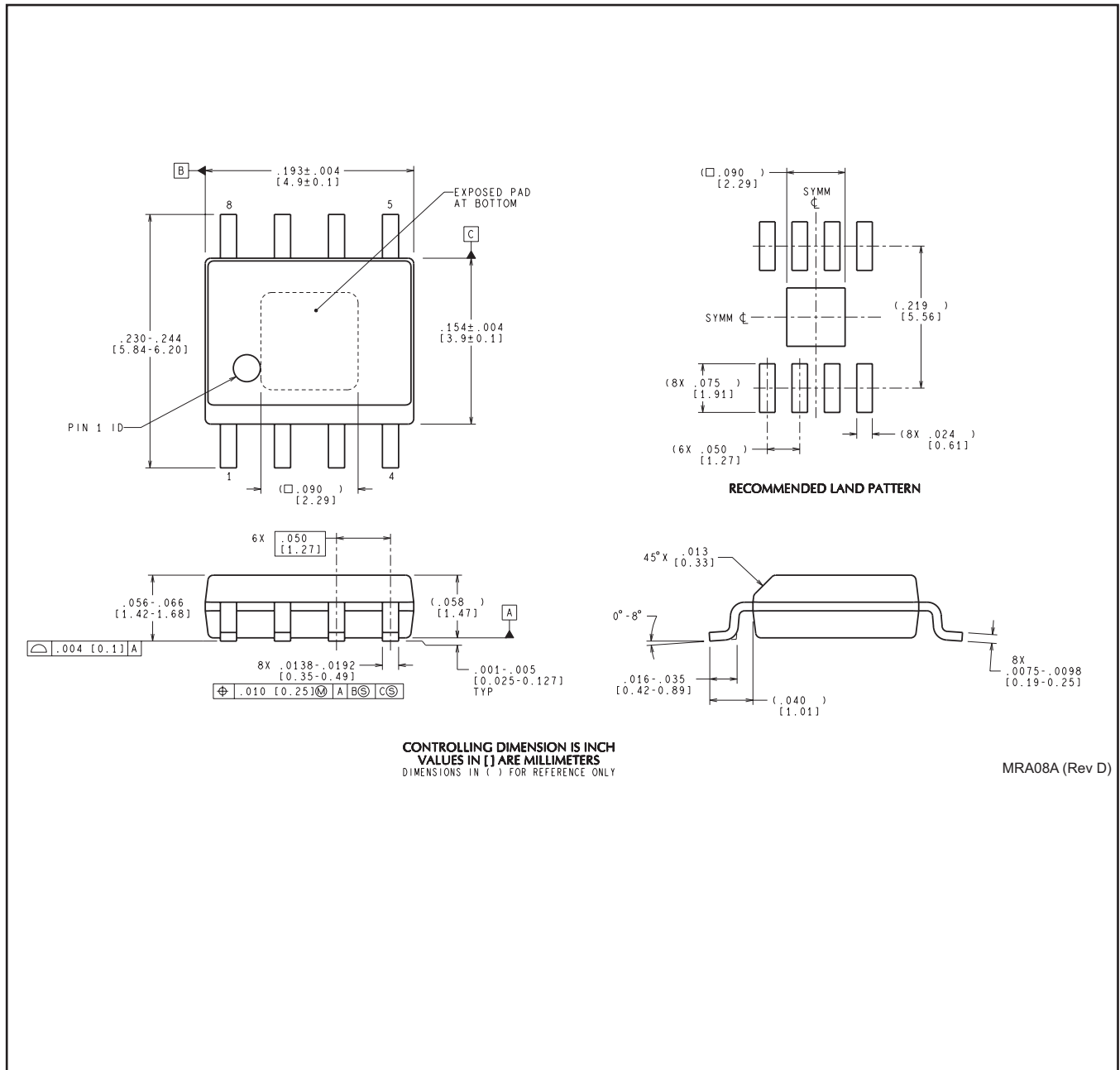


4208951-2/D 04/12

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. 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.
  - F. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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DDA0008A



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MRA08A (Rev D)





D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.  
 D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.  
 E. Reference JEDEC MS-012 variation AA.

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TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

|                              |                                                                                      |
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| Audio                        | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                               |
| Amplifiers                   | <a href="http://amplifier.ti.com">amplifier.ti.com</a>                               |
| Data Converters              | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>                       |
| DLP® Products                | <a href="http://www.dlp.com">www.dlp.com</a>                                         |
| DSP                          | <a href="http://dsp.ti.com">dsp.ti.com</a>                                           |
| Clocks and Timers            | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface                    | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                        | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
| Power Mgmt                   | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers             | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                         | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Applications Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
| Wireless Connectivity        | <a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a> |

### Applications

|                               |                                                                                          |
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| Computers and Peripherals     | <a href="http://www.ti.com/computers">www.ti.com/computers</a>                           |
| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
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| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
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### TI E2E Community

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