June 29, 2012

LP2998

DDR-I and DDR-II Termination Regulator

General Description

The LP2998 linear regulator is designed to meet JEDEC SSTL-2 and JEDEC SSTL-18 specifications for termination of DDR1-SDRAM and DDR-II memory. 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 as required for DDR1-SDRAM termination, and 0.5A continuous current as required for DDR-II termination. The LP2998 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 LP2998 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, while V_{REF} remains active. A power savings advantage can be obtained in this mode through lower quiescent current.

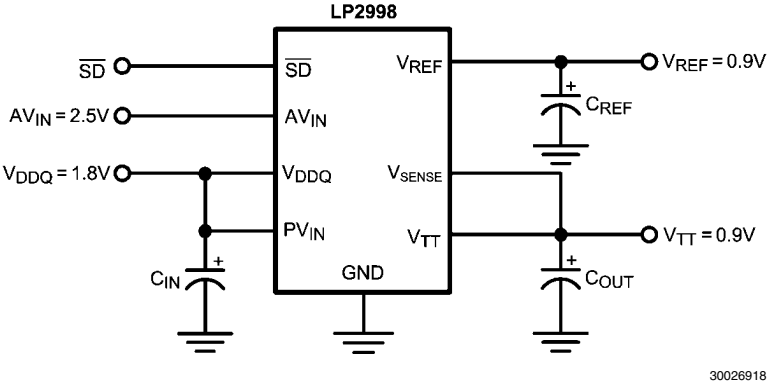
Features

- 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 SO-8, PSOP-8 packages

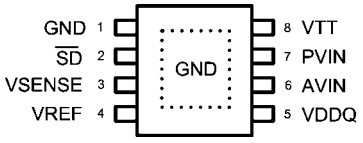
Applications

- DDR-I, DDR-II and DDR-III Termination Voltage
- SSTL-18 Termination
- SSTL-2 and SSTL-3 Termination
- HSTL Termination

Typical Application Circuit



Connection Diagrams



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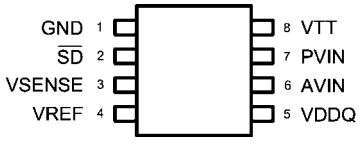
Top View
PSOP-8 Layout



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Top View
SO-8 Layout

Pin Descriptions

SO-8 Pin or PSOP-8 Pin	Name	Function
1	GND	Ground.
2	$\overline{SD}$	Shutdown.
3	VSENSE	Feedback pin for regulating V_{TT}.
4	VREF	Buffered internal reference voltage of V_{DDQ} /2.
5	VDDQ	Input for internal reference equal to V_{DDQ}/2.
6	AVIN	Analog input pin.
7	PVIN	Power input pin.
8	VTT	Output voltage for connection to termination resistors.
	EP	Exposed pad thermal connection. Connect to Ground (PSOP-8 only).

Ordering Information

Order Number	Package Type	NSC Package Drawing	Supplied As
LP2998MA	SO-8	M08A	95 Units per Rail
LP2998MAX	SO-8	M08A	2500 Units Tape and Reel
LP2998MAE	SO-8	M08A	250 Units Tape and Reel
LP2998MR	PSOP-8	MRA08A	95 Units per Rail
LP2998MRX	PSOP-8	MRA08A	2500 Units Tape and Reel
LP2998MRE	PSOP-8	MRA08A	250 Units Tape and Reel

Absolute Maximum Ratings (*Note 1*)

If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

AVIN to GND	−0.3V to +6V
PVIN to GND	-0.3V to AVIN
VDDQ (*Note 2*)	−0.3V to +6V
Storage Temp. Range	−65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 sec)	260°C
SO-8 Thermal Resistance (θ_{JA})	151°C/W
PSOP-8 Thermal Resistance (θ_{JA})	43°C/W
Minimum ESD Rating (*Note 3*)	1kV

Operating Range

Junction Temp. Range (*Note 4*)	-40°C to +125°C
AVIN to GND	2.2V to 5.5V

Electrical Characteristics

Specifications with standard typeface are for T_J = 25°C and limits in **boldface type** apply over the full **Operating Temperature Range** (T_J = -40°C to +125°C) (*Note 5*). Unless otherwise specified, VIN = AVIN = PVIN = 2.5V.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{REF}	V_{REF} Voltage (DDR I)	VIN = VDDQ = 2.3V	**1.135**	1.158	**1.185**	V
		VIN = VDDQ = 2.5V	**1.235**	1.258	**1.285**	V
		VIN = VDDQ = 2.7V	**1.335**	1.358	**1.385**	V
	V_{REF} Voltage (DDR II)	PVIN = VDDQ = 1.7V	**0.837**	0.860	**0.887**	V
		PVIN = VDDQ = 1.8V	**0.887**	0.910	**0.937**	V
		PVIN = VDDQ = 1.9V	**0.936**	0.959	**0.986**	V
	V_{REF} Voltage (DDR III)	PVIN = VDDQ = 1.35V	**0.669**	0.684	**0.699**	V
		PVIN = VDDQ = 1.5V	**0.743**	0.758	**0.773**	V
		PVIN = VDDQ = 1.6V	**0.793**	0.808	**0.823**	V
Z_{VREF}	V_{REF} Output Impedance	I_{REF} = -30 to +30 µA		2.5		kΩ

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{TT}	V_{TT} Output Voltage (DDR I) (*Note 8*)	I_{OUT} = 0A				
		VIN = VDDQ = 2.3V	**1.120**	1.159	**1.190**	V
		VIN = VDDQ = 2.5V	**1.210**	1.259	**1.290**	V
		VIN = VDDQ = 2.7V	**1.320**	1.359	**1.390**	V
		I_{OUT} = +/- 1.5A				
		VIN = VDDQ = 2.3V	**1.125**	1.159	**1.190**	V
		VIN = VDDQ = 2.5V	**1.225**	1.259	**1.290**	V
		VIN = VDDQ = 2.7V	**1.325**	1.359	**1.390**	V
	V_{TT} Output Voltage (DDR II) (*Note 8*)	I_{OUT} = 0A, AVIN = 2.5V				
		PVIN = VDDQ = 1.7V	**0.822**	0.856	**0.887**	V
		PVIN = VDDQ = 1.8V	**0.874**	0.908	**0.939**	V
		PVIN = VDDQ = 1.9V	**0.923**	0.957	**0.988**	V
		I_{OUT} = +/- 0.5A, AVIN = 2.5V				
		PVIN = VDDQ = 1.7V	**0.820**	0.856	**0.890**	V
		PVIN = VDDQ = 1.8V	**0.870**	0.908	**0.940**	V
		PVIN = VDDQ = 1.9V	**0.920**	0.957	**0.990**	V
	V_{TT} Output Voltage (DDR III) (*Note 8*)	I_{OUT} = 0A, AVIN = 2.5V				
		PVIN = VDDQ = 1.35V	**0.656**	0.677	**0.698**	V
		PVIN = VDDQ = 1.5V	**0.731**	0.752	**0.773**	V
		PVIN = VDDQ = 1.6V	**0.781**	0.802	**0.823**	V
		I_{OUT} = +0.2A, AVIN = 2.5V PVIN = VDDQ = 1.35V	**0.667**	0.688	**0.710**	V
		I_{OUT} = -0.2A, AVIN = 2.5V PVIN = VDDQ = 1.35V	**0.641**	0.673	**0.694**	V
		I_{OUT} = +0.4A, AVIN = 2.5V PVIN = VDDQ = 1.5V	**0.740**	0.763	**0.786**	V
		I_{OUT} = -0.4A, AVIN = 2.5V PVIN = VDDQ = 1.5V	**0.731**	0.752	**0.773**	V
		I_{OUT} = +0.5A, AVIN = 2.5V PVIN = VDDQ = 1.6V	**0.790**	0.813	**0.836**	V
		I_{OUT} = -0.5A, AVIN = 2.5V PVIN = VDDQ = 1.6V	**0.781**	0.802	**0.823**	V
VOS_{Vtt}	V_{TT} Output Voltage Offset (V_{REF} – V_{TT}) for DDR I (*Note 8*)	I_{OUT} = 0A	**-30**	0	**30**	mV
		I_{OUT} = -1.5A	**-30**	0	**30**	mV
		I_{OUT} = +1.5A	**-30**	0	**30**	mV
	V_{TT} Output Voltage Offset (V_{REF} – V_{TT}) for DDR II (*Note 8*)					
		I_{OUT} = 0A	**-30**	0	**30**	mV
		I_{OUT} = -0.5A	**-30**	0	**30**	mV
		I_{OUT} = +0.5A	**-30**	0	**30**	mV
	V_{TT} Output Voltage Offset (V_{REF} – V_{TT}) for DDR III (*Note 8*)	I_{OUT} = 0A	**-30**	0	**30**	mV
		I_{OUT} = ±0.2A	**-30**	0	**30**	mV
		I_{OUT} = ±0.4A	**-30**	0	**30**	mV
		I_{OUT} = ±0.5A	**-30**	0	**30**	mV
I_Q	Quiescent Current (*Note 6*)	I_{OUT} = 0A		320	**500**	µA
Z_{VDDQ}	VDDQ Input Impedance			100		kΩ
I_{SD}	Quiescent current in shutdown (*Note 6*)	SD = 0V		115	**150**	µA
I_{Q_SD}	Shutdown leakage current	SD = 0V		2	**5**	µA
V_{IH}	Minimum Shutdown High Level		**1.9**			V
V_{IL}	Maximum Shutdown Low Level				**0.8**	V
Iv	V_{TT} leakage current in shutdown	SD = 0V V_{TT} = 1.25V		1	**10**	µA

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{SENSE}	V_{SENSE} Input current			13		nA
T_{SD}	Thermal Shutdown (*Note 7*)			165		°C
T_{SD_HYS}	Thermal Shutdown Hysteresis			10		°C

Note 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 guarantee specific performance limits. For guaranteed specifications and test conditions see Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 2: VDDQ voltage must be less than 2 x (AVIN - 1) or 6V, whichever is smaller.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Note 4: At elevated temperatures, devices must be derated based on thermal resistance. The device in the SO-8 package must be derated at θ_{JA} = 151.2° C/W junction to ambient with no heat sink.

Note 5: Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate National's Average Outgoing Quality Level (AOQL).

Note 6: Quiescent current is defined as the current flow into AVIN.

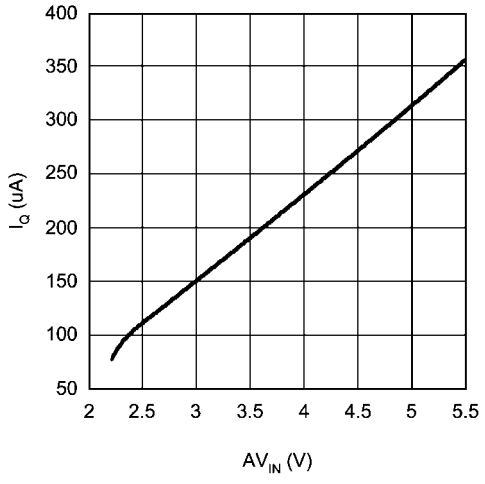
Note 7: The maximum allowable power dissipation is a function of the maximum junction temperature, $T_{J(MAX)}$, the junction to ambient thermal resistance, θ_{JA}, and the ambient temperature, T_A. Exceeding the maximum allowable power dissipation will cause excessive die temperature and the regulator will go into thermal shutdown.

Note 8: V_{TT} load regulation is tested by using a 10 ms current pulse and measuring V_{TT}.

Typical Performance Characteristics

Unless otherwise specified VIN = AVIN = PVIN = 2.5V

Iq vs AV_{IN} in SD



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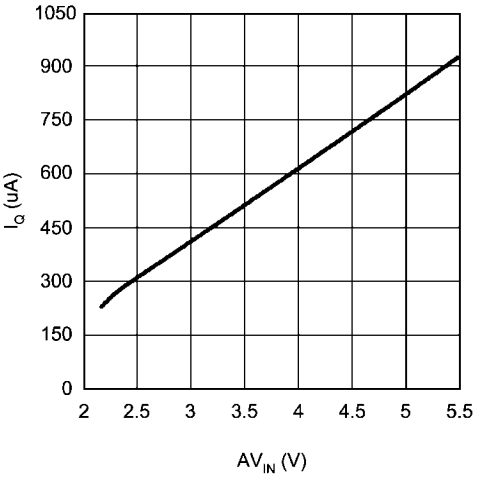
Iq vs AV_{IN}



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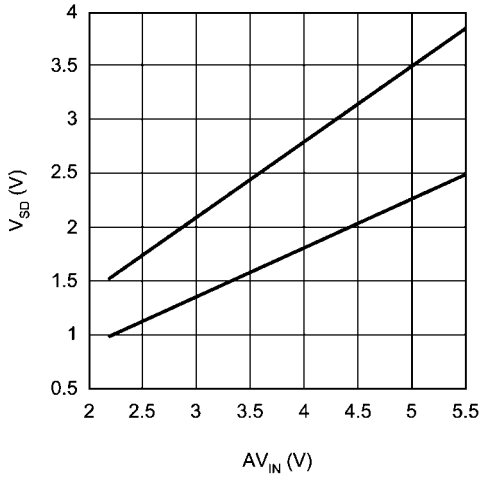
V_{IH} and V_{IL}



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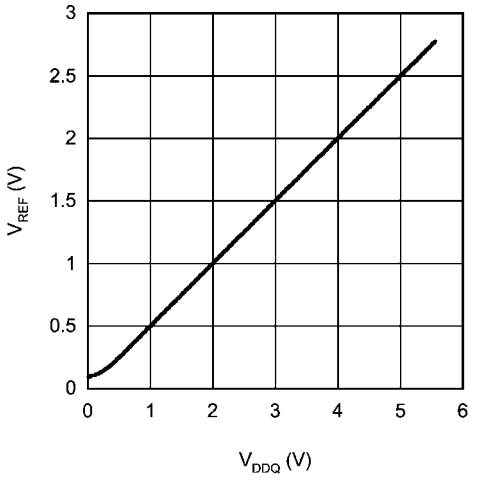
V_{REF} vs V_{DDQ}



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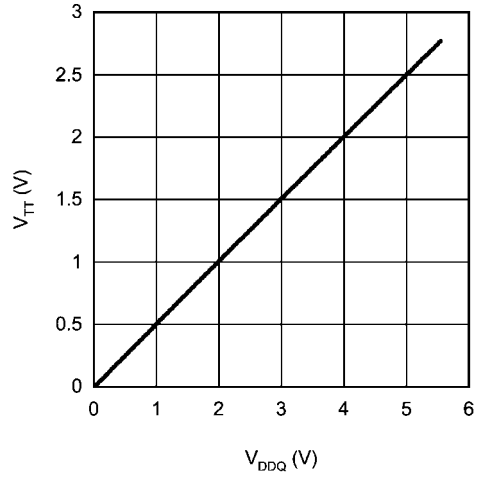
V_{TT} vs V_{DDQ}



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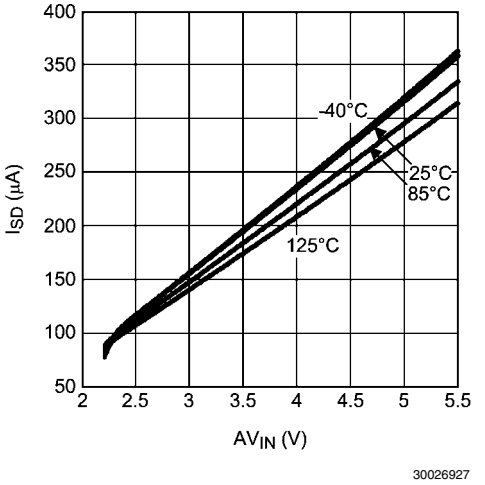
I_{SD} vs AV_{IN} over Temperature



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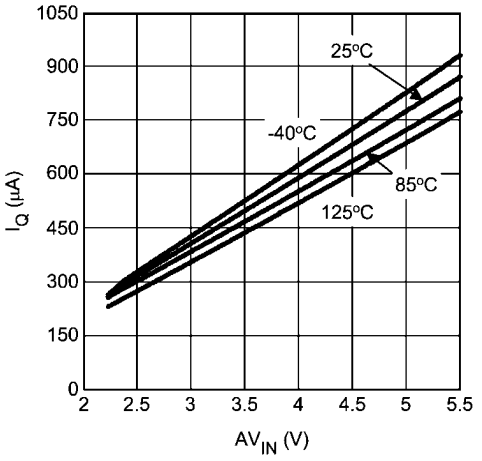
Iq vs AV_{IN} over Temperature



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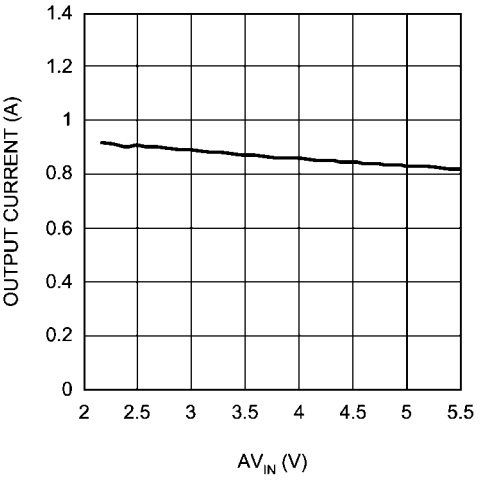
Maximum Sourcing Current vs AV_{IN} (V_{DDQ} = 1.8V, PV_{IN} = 1.8V)



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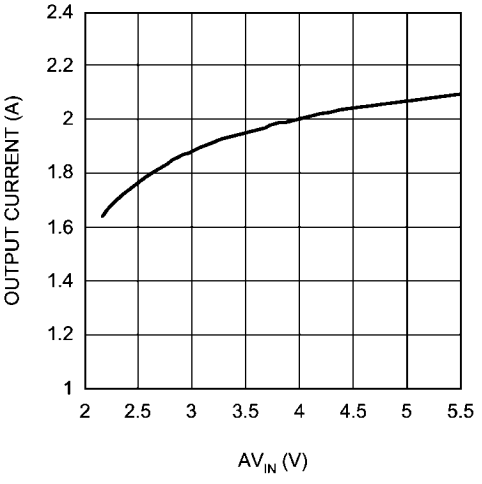
Maximum Sinking Current vs AV_{IN} (V_{DDQ} = 1.8V)



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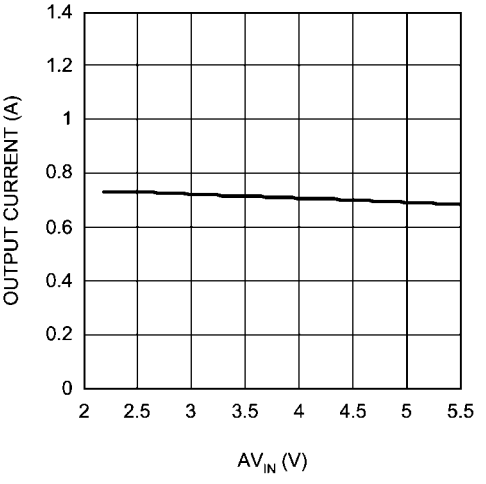
Maximum Sourcing Current vs AV_{IN} (V_{DDQ} = 2.5V, PV_{IN} = 1.8V)



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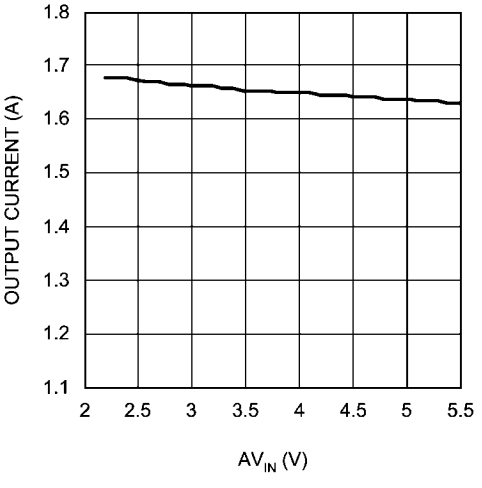
Maximum Sourcing Current vs AV_{IN} (V_{DDQ} = 2.5V, PV_{IN} = 2.5V)



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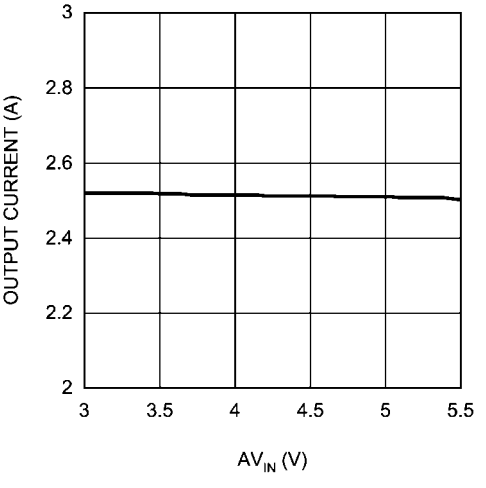
Maximum Sourcing Current vs AV_{IN} (V_{DDQ} = 2.5V, PV_{IN} = 3.3V)



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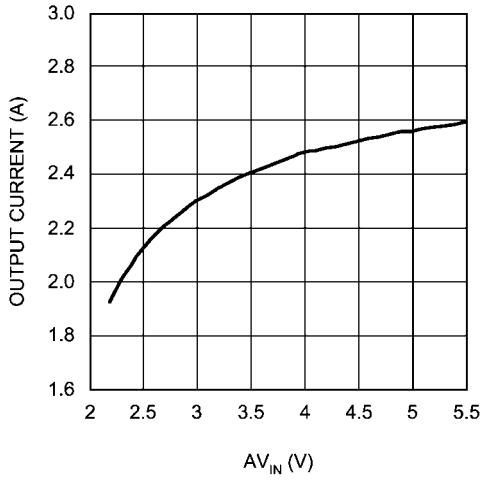
Maximum Sinking Current vs AV_{IN} (V_{DDQ} = 2.5V)



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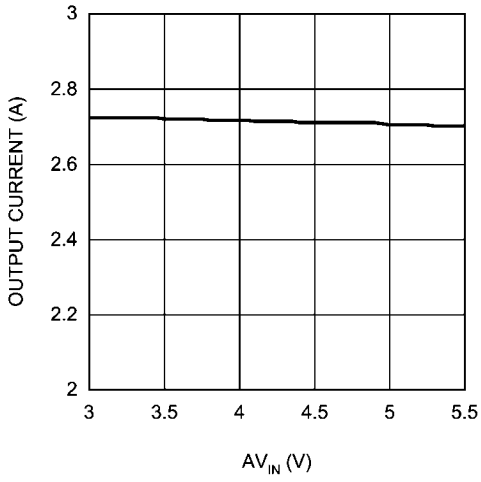
Maximum Sourcing Current vs AV_{IN} (V_{DDQ} = 1.8V, PV_{IN} = 3.3V)



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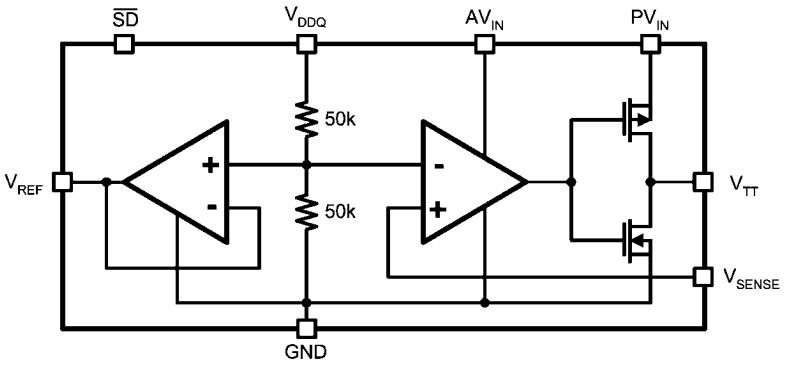
Block Diagram



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Description

The LP2998 is a linear bus termination regulator designed to meet the JEDEC requirements of SSTL-2 and SSTL-18. The output, V_{TT} is capable of sinking and sourcing current while regulating the output voltage equal to VDDQ / 2. The output stage has been designed to maintain excellent load regulation while preventing shoot through. The LP2998 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 LP2998 to provide a termination solution for the next generation of DDR-SDRAM memory (DDRII). The LP2998 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 LP2998. This implementation can be seen below in .

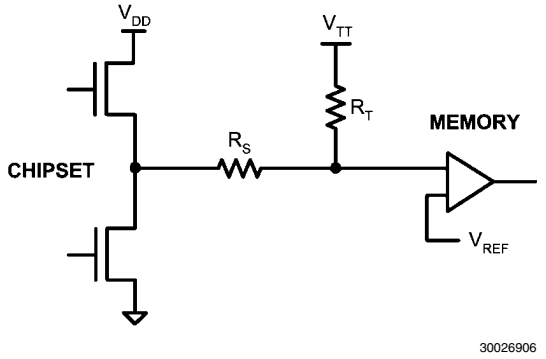

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FIGURE 1. SSTL-Termination Scheme

Pin Descriptions

AVIN AND PVIN

AVIN and PVIN are the input supply pins for the LP2998. 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, under the condition that AVIN is always greater than or equal to PVIN. For SSTL-18 applications, it is recommended to connect PVIN to the 1.8V rail used for the memory core and AVIN to a rail within its operating range of 2.2V to 5.5V (typically a 2.5V supply). PVIN should always be used with either a 1.8V or 2.5V rail. This prevents the thermal limit from tripping because of excessive internal power dissipation. If the junction temperature exceeds the thermal shutdown threshold, the part will enter a shutdown state identical to the manual shutdown where V_{TT} is tri-stated and V_{REF} remains active. A lower rail, such as 1.5V can be used but it will reduce the maximum output current. Therefore it is not recommended for most termination schemes.

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 50kΩ resistors. This guarantees that V_{TT} will precisely track VDDQ / 2. The optimal implementation of VDDQ is as a remote sense. This can be achieved by connecting VDDQ directly to the 1.8V rail at the DIMM instead of PVIN. This ensures that the reference voltage precisely tracks the DDR memory rails without a large voltage drop from the power lines. For SSTL-18 applications, VDDQ will be a 1.8V signal, which will create a 0.9V termination voltage at V_{TT} (See Electrical Characteristics Table for exact values of V_{TT} over temperature).

V_{SENSE}

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 LP2998, 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 con-

nected to V_{TT}. Care should be taken when a long V_{SENSE} trace is implemented in close proximity to the memory. Noise pick-up in the V_{SENSE} trace can cause problems with precise regulation of V_{TT}. A small 0.1uF ceramic capacitor placed next to the V_{SENSE} pin can help filter any high frequency signals and prevent errors.

SHUTDOWN

The LP2998 contains an active low shutdown pin that can be used for suspend to RAM functionality. In this condition, the V_{TT} output will tri-state while the V_{REF} output remains active providing a constant reference signal for the memory and chipset. During shutdown, V_{TT} should not be exposed to voltages that exceed PVIN. With the shutdown pin asserted low the quiescent current of the LP2998 will drop. However, VDDQ will always maintain its constant impedance of 100kΩ 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_{REF}

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

V_{TT}

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 VDDQ / 2. The LP2998 is designed to handle continuous currents of up to +/- 1.5A with excellent load regulation. If a transient is expected to last above the maximum continuous current rating for a significant amount of time, then the bulk output capacitor should be sized large enough to prevent an excessive voltage drop. If the LP2998 is to operate in elevated temperatures for long durations, care should be taken to ensure that the maximum operating junction temperature is not exceeded. Proper thermal de-rating should always be used (Please refer to the Thermal Dissipation section). If the junction temperature exceeds the thermal shutdown threshold, V_{TT} will tri-state until the part returns below the temperature hysteresis trip-point.

Component Selections

INPUT CAPACITOR

The LP2998 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 and is dependent on the application required. A typical value recommended for AL electrolytic capacitors is 22 µF. Ceramic capacitors can also be used. A value in the range of 10 µF with X5R or better would be an ideal choice. The input capacitance can be reduced if the LP2998 is placed close to the bulk capacitance from the output of the 1.8V DC-DC converter. For the AVIN pin, a small 0.1uF ceramic capacitor is sufficient to prevent excessive noise from coupling into the device.

OUTPUT CAPACITOR

The LP2998 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_{TT}. As a general recommendation the output capacitor should be sized above 100 µF 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 (100 kHz) should be used for the LP2998. 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 tend to have rapidly increasing ESR at cold temperatures.

Ceramic - Ceramic capacitors typically have a low capacitance, in the range of 10 to 100 µF. They also have excellent AC performance for bypassing noise because of very low ESR (typically less than 10 mΩ). 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 type.

Thermal Dissipation

Since the LP2998 is a linear regulator, any current flow from V_{TT} will result in internal power dissipation and heat generation. To prevent damaging the part by exceeding the maximum allowable operating junction temperature, care should be taken to derate the part based on the maximum expected ambient temperature and power dissipation. The maximum allowable internal temperature rise (T_{Rmax}) can be calculated given the maximum ambient temperature (T_{Amax}) of the application and the maximum allowable junction temperature (T_{Jmax}).

$$T_{Rmax} = T_{Jmax} - T_{Amax}$$

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

$$P_{Dmax} = T_{Rmax} / \theta_{JA}$$

The θ_{JA} of the LP2998 will depend on several variables: the package used; the thickness of copper; the number of vias and the airflow. For instance, the θ_{JA} of the SO-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 2* shows how the θ_{JA} varies with airflow for the two boards mentioned.

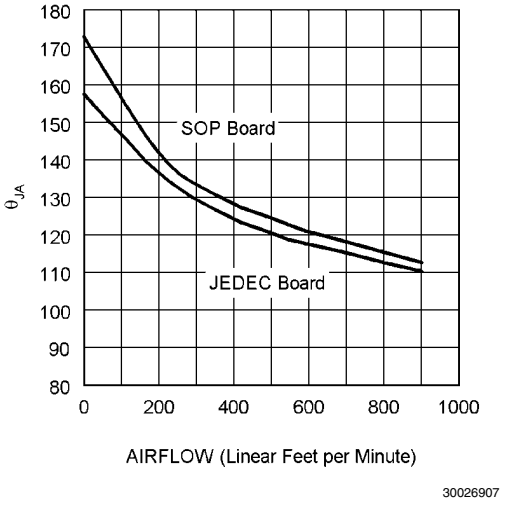


FIGURE 2. θ_{JA} vs Airflow (SO-8)

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 θ_{JA} further than the nominal values shown in *Figure 2*

Optimizing the θ_{JA} and placing the LP2998 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 currents 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,

$$P_{AVIN} = I_{AVIN} * V_{AVIN}$$

$$P_{VDDQ} = V_{VDDQ} * I_{VDDQ} = V_{VDDQ^2} \times R_{VDDQ}$$

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

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

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

The power dissipation of the LP2998 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.

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

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

$$P_{VDDQ} = V_{VDDQ} * I_{VDDQ} = V_{VDDQ^2} \times R_{VDDQ}$$

Typical Application Circuits

Several different application circuits have been shown in *Figure 3* through *Figure 12* to illustrate some of the options that are possible in configuring the LP2998. Graphs of the individual circuit performance can be found in the *Typical Performance Characteristics* section 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 3*.

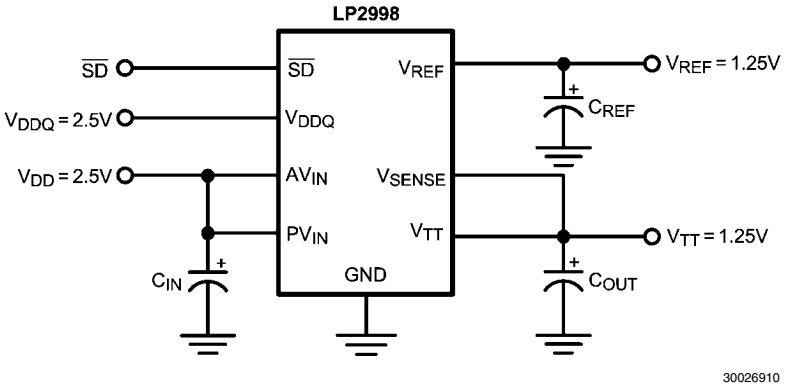


FIGURE 3. Recommended SSTL-2 Implementation

If power dissipation or efficiency is a major concern then the LP2998 has the ability to operate on split power rails (see *Figure 4*). 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_{TT}. 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.

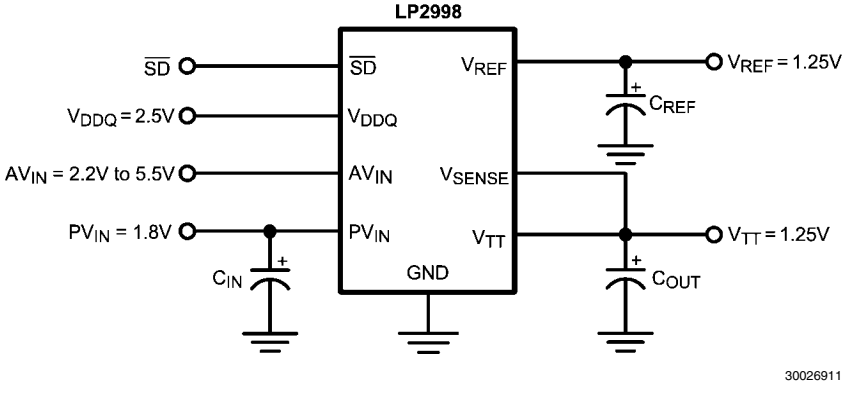


FIGURE 4. Lower Power Dissipation SSTL-2 Implementation

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 LP2998 power rail to 3.3V (see *Figure 5*). 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 LP2998 from experiencing large current levels which cause the device to exceed the maximum operating junction temperature. Because of this risk it is not recommended to supply the output stage with a voltage higher than a nominal 3.3V rail.

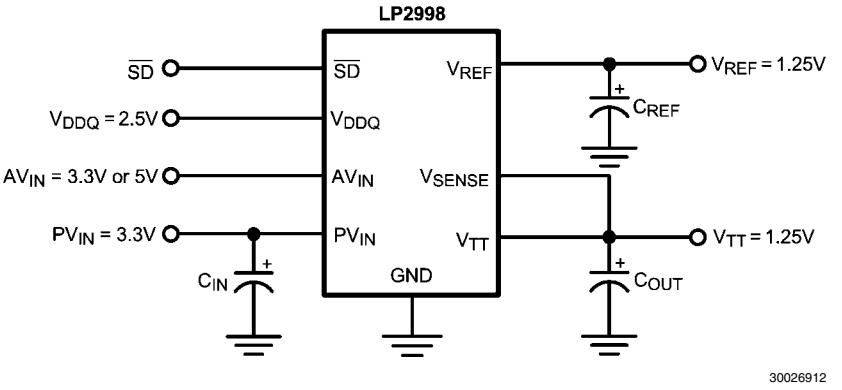


FIGURE 5. SSTL-2 Implementation With Higher Voltage Rails

DDR-II APPLICATIONS

With the separate VDDQ pin and an internal resistor divider it is possible to use the LP2998 in applications utilizing DDR-II memory. *Figure 6* and *Figure 7* show several implementations of recommended circuits with output curves displayed in the *Typical Performance Characteristics*. *Figure 6* 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 2.5, 3.3V or 5.5V rail.

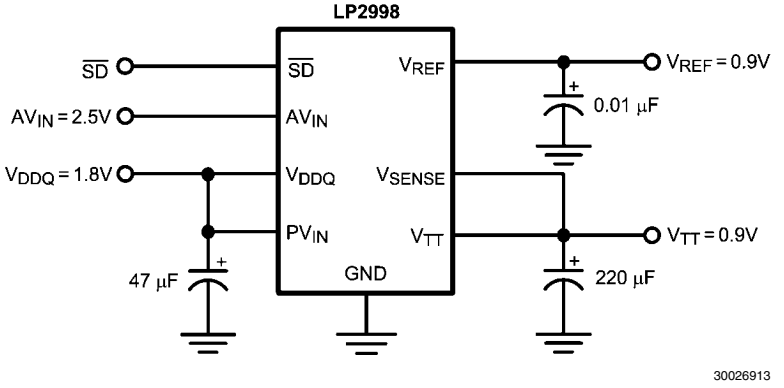


FIGURE 6. Recommended DDR-II Termination

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 operating junction temperature as the thermal dissipation increases with lower V_{TT} output voltages. For this reason it is not recommended to power PVIN with 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.

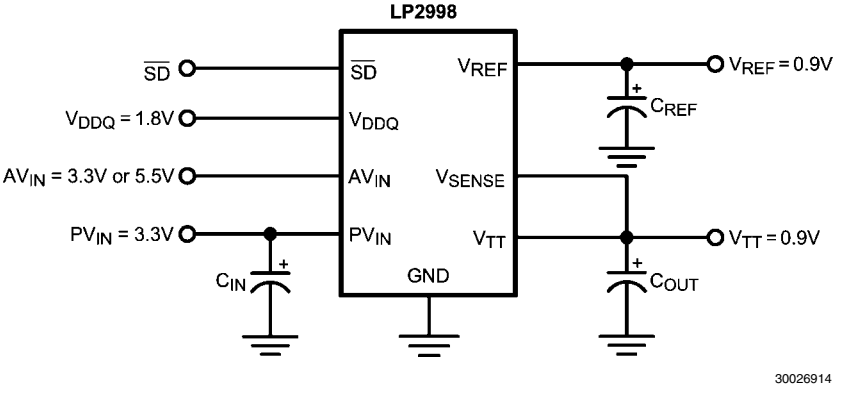


FIGURE 7. DDR-II Termination With Higher Voltage Rails

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 8* and *Figure 9*. *Figure 8* shows how to use two resistors to level shift V_{TT} above the internal reference voltage of VDDQ/2. To calculate the exact voltage at V_{TT} the following equation can be used.

$$V_{TT} = VDDQ/2\ (1 + R1/R2)$$

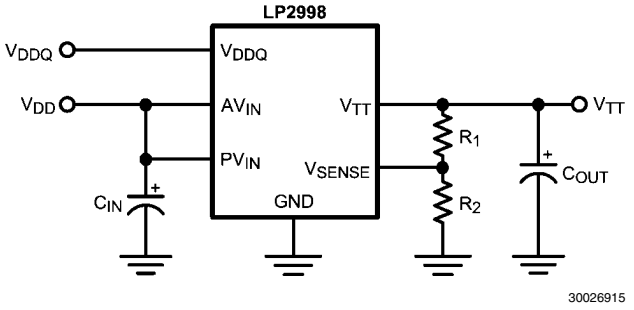


FIGURE 8. Increasing VTT by Level Shifting

Conversely, the R2 resistor can be placed between V_{SENSE} and V_{DDQ} to shift the V_{TT} output lower than the internal reference voltage of VDDQ/2. The equation relating to VTT and the resistors can be used as shown:

$$V_{TT} = VDDQ/2\ (1 - R1/R2)$$

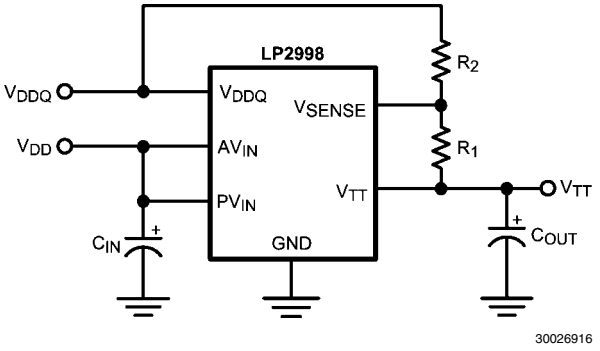


FIGURE 9. Decreasing VTT by Level Shifting

HSTL APPLICATIONS

The LP2998 can be easily adapted for HSTL applications by connecting V_{DDQ} to the 1.5V rail. This will produce a V_{TT} and V_{REF} voltage of approximately 0.75V for the termination resistors. AVIN and PVIN should be connected to a 2.5V rail for optimal performance.

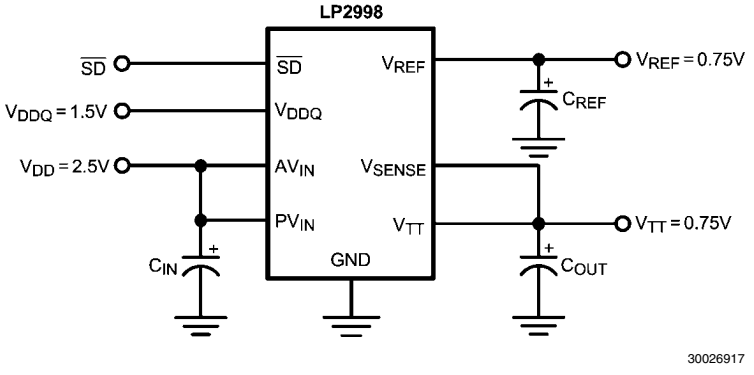


FIGURE 10. HSTL Application

QDR APPLICATIONS

Quad data rate (QDR) applications utilize multiple channels for improved memory performance. However, this increase in bus lines increases the current levels required for termination. The recommended approach in terminating multiple channels is to use a dedicated LP2998 for each channel. This simplifies layout and reduces the internal power dissipation for each regulator. Separate V_{REF} 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 LP2998 signals. Because V_{REF} and V_{TT} are expected to track and the part to part variations are minor, there should be little difference between the reference signals of each LP2998.

OUTPUT CAPACITOR SELECTION

For applications utilizing the LP2998 to terminate SSTL-2 I/O signals the typical application circuit shown in *Figure 11* can be implemented.

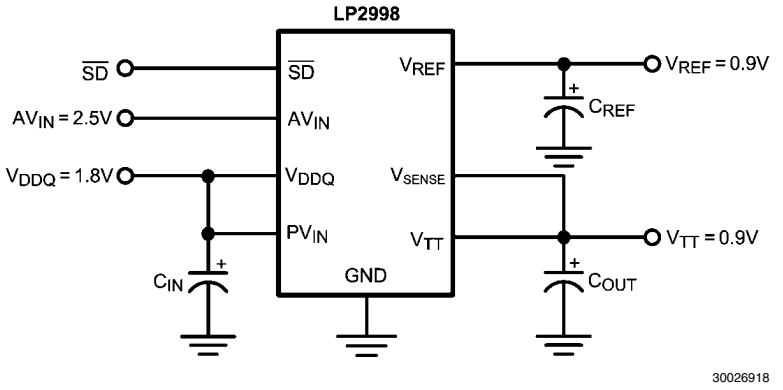


FIGURE 11. Typical SSTL-2 Application Circuit

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 recommended to use multiple bulk capacitors in addition to high frequency decoupling. *Figure 12* 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 typically used for their low ESR and low cost.

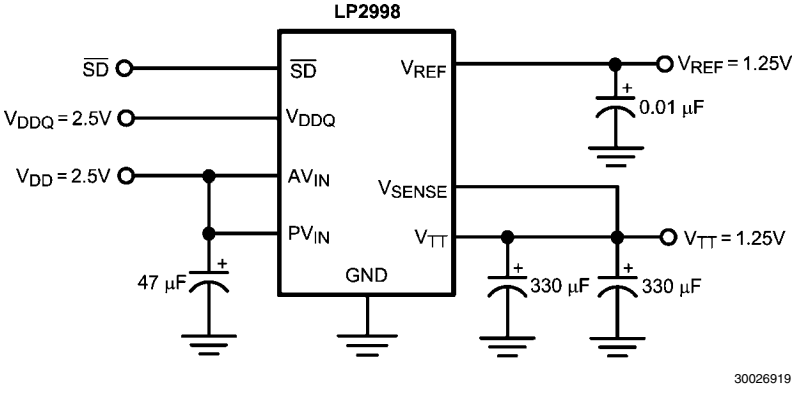


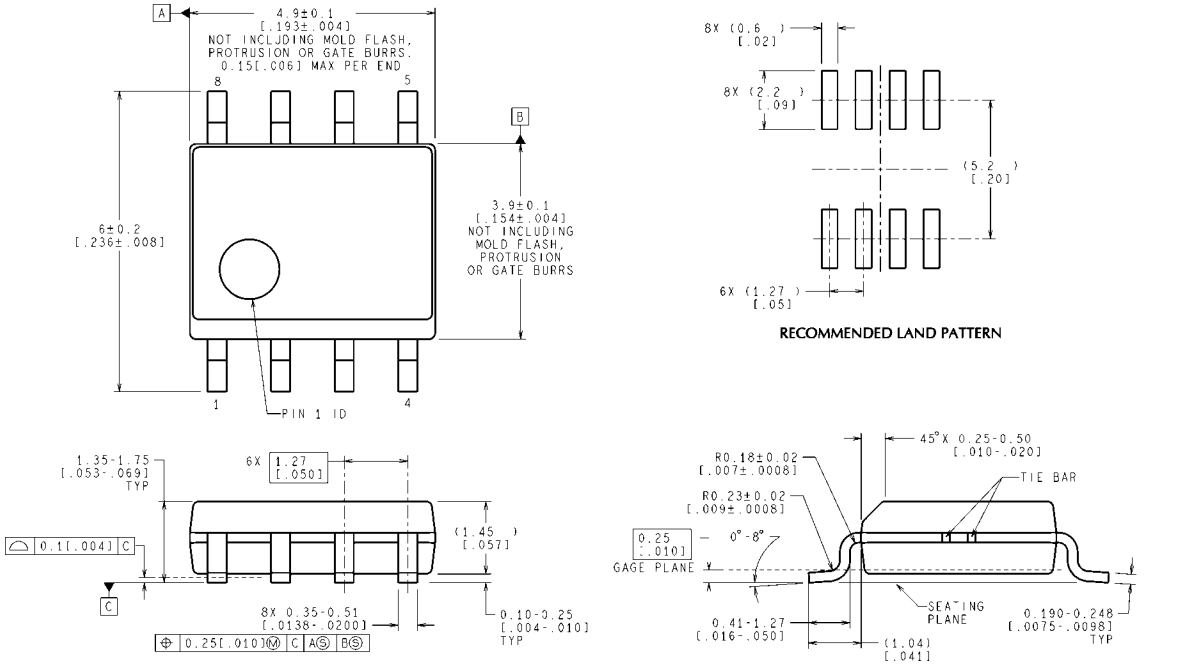
FIGURE 12. Typical SSTL-2 Application Circuit for Motherboards

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 $_{SENSE}$ can also be used to filter any unwanted high frequency signal. This can be an issue especially if long $_{SENSE}$ 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.

Physical Dimensions inches (millimeters) unless otherwise noted



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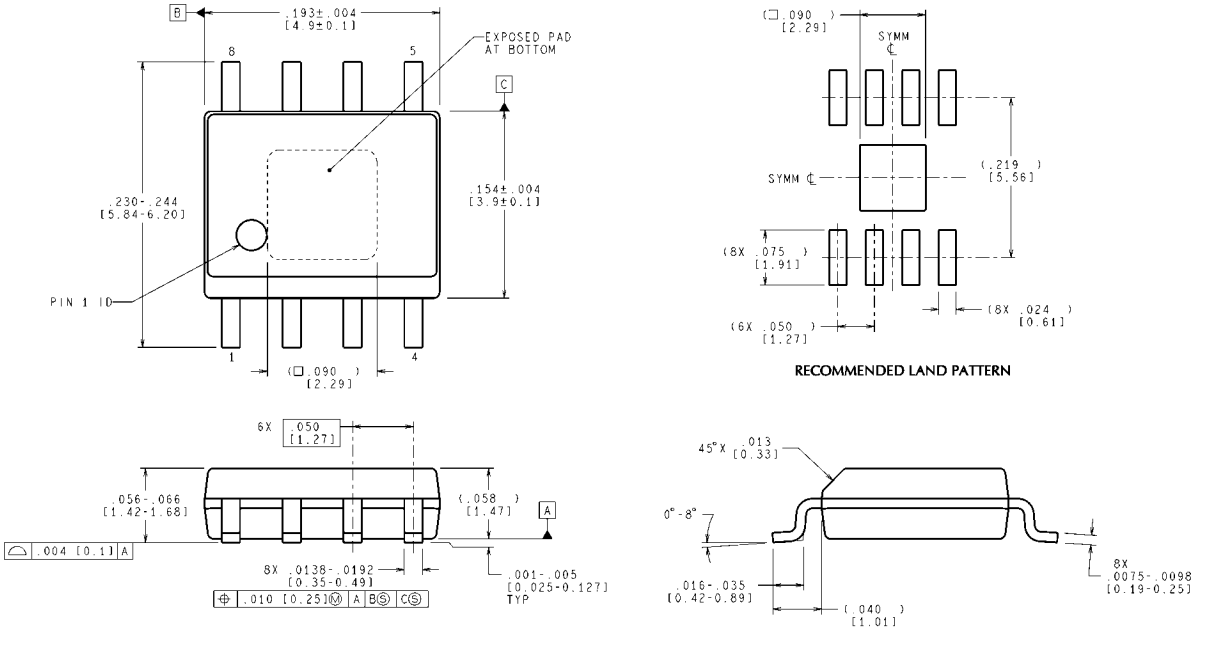
M08A (Rev M)

8-Lead Small Outline Package (M8)
NS Package Number M08A



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