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PT6722—12V

14-A Low-Voltage Programmable Integrated Switching Regulator

EXCALIBUR

SLTS161

(Revised 10/2/2001)



Features

- 12V Input
- 14-A Output Current
- 5-Bit Programmable Output: 1.1V to 1.85V (25mV Steps)
- VRM 9.0 Compatible
- 82% Efficiency
- Standby On/Off Control
- Differential Remote Sense
- Over-Voltage Protection Drive
- Power Good Signal
- Short Circuit Protection
- Space Saving Solderable Case
- $4.7 \cdot 10^6$ Hrs. MTBF

Description

The PT6722 is a fully integrated 14-A switching regulator housed in a space-saving solderable package. The PT6722 operates from 12V to provide a high-performance low-voltage output that is programmable over the range 1.1V to 1.85V. This output voltage range is specifically suited to high performance µP and DSP applications that require core supply voltages below 1.3V. The voltage control inputs are also TTL compatible. Additional features include output short circuit protection, a "Power Good" output, and an over-voltage protection (OVP) drive.

Ordering Information

PT6722❑ = 1.1 to 1.85 Volts

PT Series Suffix (PT1234x)

Case/Pin Configuration	Order Suffix	Package Code
Vertical	**N**	(ELD)
Horizontal	**A**	(ELA)
SMD	**C**	(ELC)

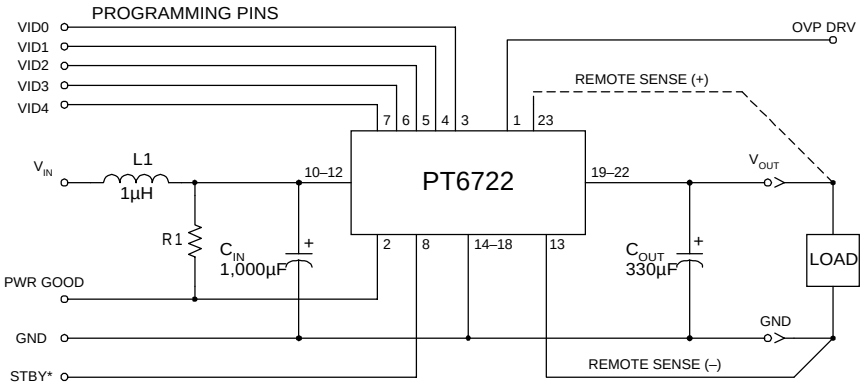
(Reference the applicable package code drawing for the dimensions and PC layout)

Pin-Out Information

Pin	Function	Pin	Function
1	OVP Drive	13	Rem Sense Gnd (2)
2	Pwr Good	14	GND
3	VID0	15	GND
4	VID1	16	GND
5	VID2	17	GND
6	VID3	18	GND
7	VID4	19	V_{out}
8	STBY*	20	V_{out}
9	Do not connect	21	V_{out}
10	V_{in}	22	V_{out}
11	V_{in}	23	Rem Sense V_{out}
12	V_{in}		

For STBY* pin: open = output enabled
ground = output disabled.

Standard Application



C_{in}/C_{out}: Required electrolytic capacitors –see footnotes.
L_1: Optional 1µH input choke –see footnotes
R_1: 10-kΩ pull-up for Pwr Good signal.
Pwr Good is high when the output is within specification.

Programming Information

VID3	VID2	VID1	VID0	VID4=1 Vout	VID4=0 Vout
1	1	1	1	0.000V	1.475V
1	1	1	0	1.100V	1.500V
1	1	0	1	1.125V	1.525V
1	1	0	0	1.150V	1.550V
1	0	1	1	1.175V	1.575V
1	0	1	0	1.200V	1.600V
1	0	0	1	1.225V	1.625V
1	0	0	0	1.250V	1.650V
0	1	1	1	1.275V	1.675V
0	1	1	0	1.300V	1.700V
0	1	0	1	1.325V	1.725V
0	1	0	0	1.350V	1.750V
0	0	1	1	1.375V	1.775V
0	0	1	0	1.400V	1.800V
0	0	0	1	1.425V	1.825V
0	0	0	0	1.450V	1.850V

Logic 0 = Pin 13 potential (remote sense gnd)
Logic 1 = Open circuit (no pull-up resistors)
VID4 may not be changed while the unit is operating.

PT6700 Product Family Comparison

		Input Voltage	Adjust Method	Program Range	OVP/ Pwr Good	+12V Bias Required
	PT6701	5V	5-Bit	1.3V– 3.5V	✓	
	PT6702	3.3V	4-Bit	1.3V– 2.05V	✓	
	PT6703	3.3V/5V	5-Bit	1.1V– 1.85V	✓	
#	**PT6705**	5V	Resistor	1.5V–3.3V		✓
#	**PT6715**	5V	Resistor	1.5V–3.3V		
	PT6721	12V	5-Bit	1.3V– 3.5V	✓	
	PT6722	12V	5-Bit	1.1V– 1.85V	✓	
#	**PT6725**	12V	Resistor	1.5V–5.0V		

–Indicates a series of products that have a nominal output voltage set-point and may be adjusted with an external resistor.

Specifications (Unless otherwise stated, T_a =25°C, V_{in} =12V, C_{out} =330µF, and I_o =$I_o$max)

Characteristic	Symbol	Conditions		PT6722 Min	PT6722 Typ	PT6722 Max	Units
Output Current	I_o	T_a =+60°C, 200LFM T_a =+25°C, natural convection		0.1 (1) 0.1 (1)	— —	14 14	A
Input Voltage Range	V_{in}	Over I_o Range		10.8	—	13.2	VDC
Set Point Voltage Tolerance	V_o tol			—	±10	±20 (2)	mV
Temperature Variation	Reg_{temp}	–40° >T_a > +85°C		—	±0.5	—	%V_o
Line Regulation	Reg_{line}	Over V_{in} range		—	±2.5	±5	mV
Load Regulation	Reg_{load}	Over I_o range		—	±2.5	±10	mV
Total Output Voltage Variation	ΔV_otot	Includes set-point, line, load, –40° >T_a > +85°C		—	±25	±36	mV
Efficiency	η	I_o =8A	V_o =1.8V V_o =1.2V	— —	83 78	— —	%
V_o Ripple (pk-pk)	V_r	20MHz bandwidth		—	20	—	mV_{pp}
Transient Response	t_{tr}	0.1A/µs load step, 6A to 12A		—	50	—	µs
	ΔV_{tr}	V_o over/undershoot		—	±70	—	mV
Short Circuit Current	I_{sc}			—	20	30	A
Switching Frequency	f_o	Over V_{in} range		300	350	400	kHz
Standby Control (pin 8) Input High Voltage Input Low Voltage Input Low Current	 V_{IH} V_{IL} I_{IL}	 Referenced to GND (pin 14) Pin 8 to GND		 4.0 –0.2 —	 — 0.4 10	 Open (3) 1.0 –	 V µA
Standby Input Current	I_{in} standby	pins 8 & 14 connected		—	5	10	mA
External Output Capacitance	C_{out}			330 (4)	—	15,000	µF
Operating Temperature Range	T_a	Over V_{in} range		-40	—	+85 (5)	°C
Storage Temperature	T_s	—		-40	—	+125	°C
Reliability	MTBF	Per Bellcore TR-332 50% stress, T_a =40°C, ground benign		11.7	—	—	10^6 Hrs
Mechanical Shock	—	Per Mil-Std-883D, method 2002.3, 1mS, half-sine, mounted to a fixture		—	500	—	G's
Mechanical Vibration	—	Per Mil-Std-883D, method 2007.2, 20-2000Hz, soldered in a PC board		—	15 (6)	—	G's
Weight	—	—		—	26	—	grams
Flammability	—	Materials meet UL 94V-0					

Notes: *(1) ISR-will operate down to no load with reduced specifications.*
(2) If the remote sense ground is not used, pin 13 must be connected to pin 14 for optimal output voltage accuracy.
(3) The Standby control (pin 8) has an internal pull-up, and if left open-circuit the module will operate when input power is applied. A small low-leakage (<100nA) MOSFET must be used to control this input. The open-circuit voltage is less than 10V. See application notes for further information.
(4) For operation below 0°C, Cin and Cout must have stable characteristics. Use either low ESR tantalum or Oscon® capacitors.
(5) See Safe Operating Area curves.
(6) The case pins on the through-hole package types (suffixes N & A) must be soldered. For more information see the applicable package outline drawing.

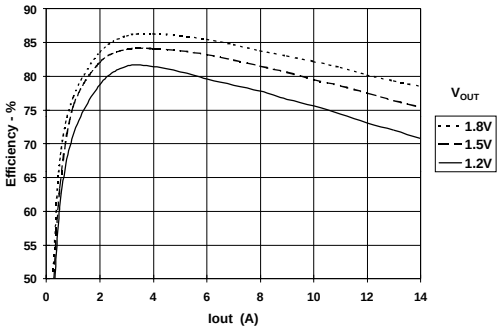
External Capacitors: *The PT6722 requires a minimum ouput capacitance of 330µF, and a minimum input capacitance of 1,000µF for proper operation. The input capacitance must be rated for a minimum of 1.6Arms of ripple current. For transient or dynamic load applications, additional input and output capacitance may be required.The maximum allowable output capacitance is 15,000µF. For more information refer to the application note regarding capacitor selection for this product.*

Input Inductor: *An input filter inductor is optional for most applications. The inductor must be sized to handle 3ADC with a typical value of 1µH.*

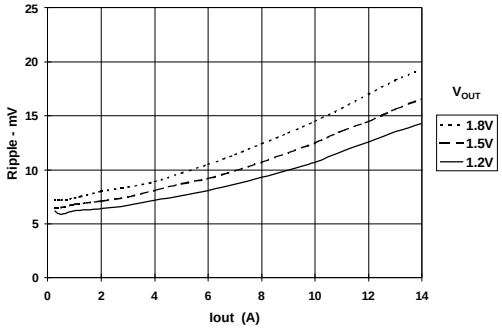
Typical Characteristics

PT6722 Performance; V_{in} =12V (See Note A)

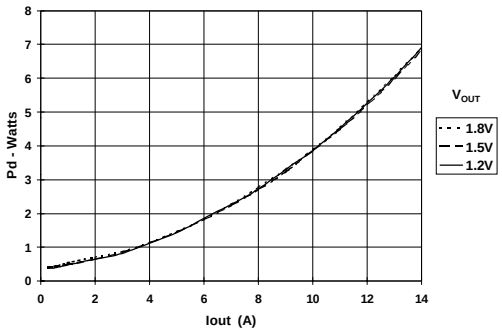
Efficiency vs Output Current



Ripple vs Output Current

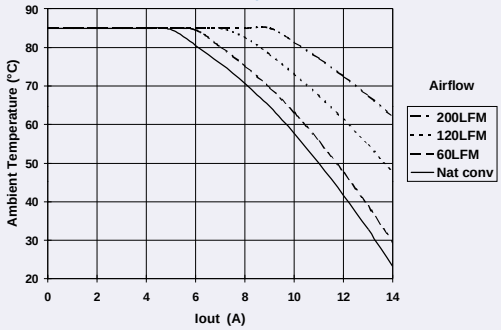


Power Dissipation vs Output Current



PT6722 Thermal Derating; V_{in} =12V (See Note A)

Safe Operating Area; V_o =1.8V



Note A: *Characteristic data has been developed from actual products tested at 25°C. This data is considered typical data for the Converter.*
Note B: *SOA curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures*

Operating Features of the Programmable PT6700 "Excalibur™" Series ISRs

Power Good

Programmable versions of the PT6700 Series regulators incorporate a *PWR Good* output (pin 2). This output is open-drain and generates an acitve-high signal when the sensed output from the ISR is within a nominal ±10% of the programmed set point. When the regulated output is outside this range, pin 2 asserts a logic low (typically <0.1V). A 10-kΩ pull-up resistor to a valid bus voltage is required. If the power good feature is not used, the pull-up resistor can be omitted. The maximum voltage that may be applied to the pull-up resistor is 15V.

Over-Voltage Protection (OVP)

The PT6700 programmable regulators also incorporate an OVP function. The *OVP DRV* (pin 1) normally has a logic low output (typically <0.1V). When the ISR's sensed output exceeds the programmed output setting by 15%, pin 1 produces a 60mA, +12V drive signal. This drive signal can trigger an SCR, which can be used to disable the input voltage (via a fuse), or alternatively interface to another external monitoring device. When the ISR output voltage returns to within 15% of its programmed setting, pin 1 reverts back to its low state. If the OVP function is not used, pin 1 may be left open circuit.

Stand-By Function

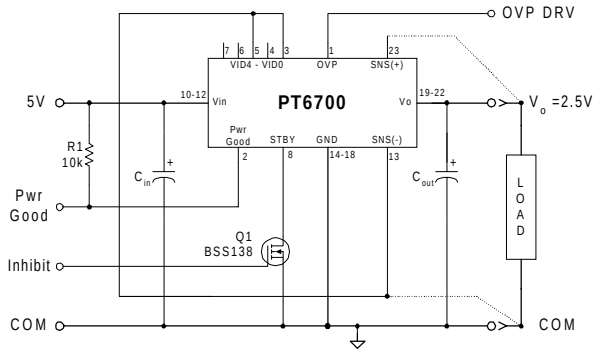
The PT6700 series ISRs incorporate a standby function. This feature may be used for power-up sequencing, or wherever there is a requirement for the output voltage to be controlled by external circuitry.

If the *STBY** input (pin 8) is left open-circuit the regulator operates normally, providing a regulated output when a valid supply voltage is applied to V_{in} (pins 10-12) with respect to GND (pins 14-18). Connecting pin 8 to ground[1] places the regulator in standby mode [2], and reduces the input current to typically 20mA (30mA max). Applying a ground signal to pin 8 prior to power-up, will disable the output during the period that input power is applied. To ensure that the regulator output is properly enabled, pin 8 must be open circuit.

Table 1 Standby Control Requirements [2]

Parameter	Min	Typ	Max
Enable	Open Cct. [1]		
Disable	-0.1V	0.4V	1.0V
I_{stby}		10µA	

Figure 1



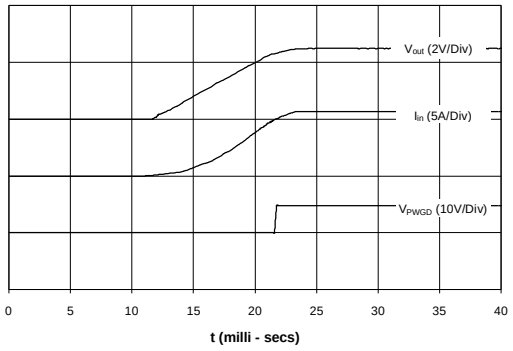
Notes:

1. The standby on a PT6700 series regulator must be controlled with an open-drain low-leakage (<100nA) MOSFET (See fig. 1). Table 1 gives the threshold requirements. *Do Not* use a pull-up resistor. The control input has an open-circuit voltage of between 4Vdc and 5Vdc. To set the regulator output to zero, the control pin must be "pulled" to less than 1.0Vdc by sinking current to ground.
2. When placed in the standby mode, the regulator output may assert a low impedance to ground. If an external voltage is applied to the output, it will sink current and possibly overstress the part.

Turn-On Time

Turning Q_1 in Figure 1 off, removes the low-voltage signal at pin 8. After a 10-15ms delay the regulator output rises and reaches full output voltage within 30ms. Fig. 2 shows the typical waveforms of a PT6701 following the prompt turn-off of Q_1 at time t =0 secs. The output voltage was set to 2.5V, and the waveforms were measured with a 5V input source, and 10A resistive load.

Figure 2



Pin-Coded Output Voltage Programming on Non-Isolated "Excalibur™" Series ISRs

Programmable versions of the PT6700 and PT6720 series of Excalibur ISRs incorporate a pin-coded output voltage control. These regulators include up to five control pins, identified VID0–VID4 (pins 3–7) respectively. By selectively grounding VID0-VID4, the output voltage of these regulators can be programmed in incremental steps over a specified output voltage range. The program code and voltage range is designed to be compatible with the "Voltage ID" specification defined for popular microprocessors. Refer to Figure 1 for the connection schematic, and the applicable data sheet for the program code.

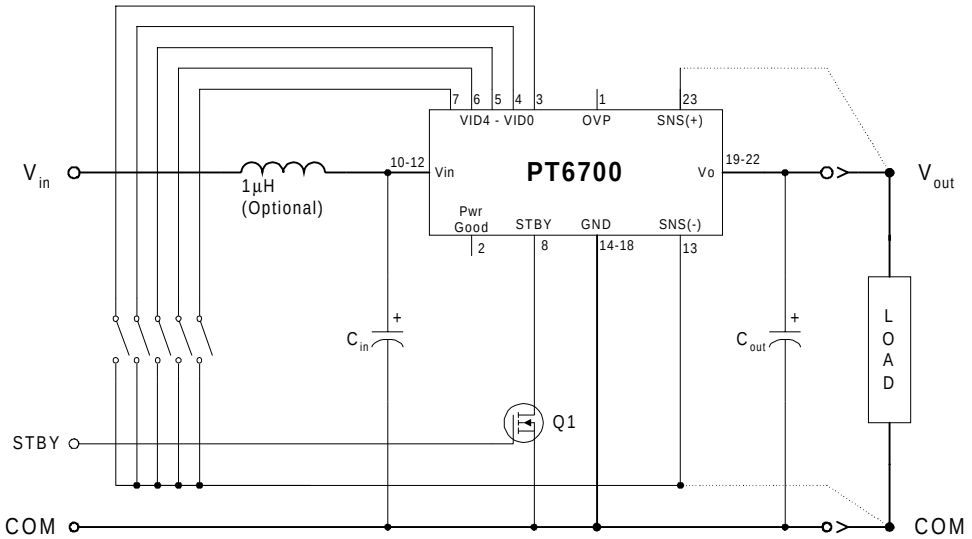
Notes:

1. The programming convention is as follows:-
   Logic 0: Connect to pin13 (Remote Sense Ground).
   Logic 1: Open circuit/open drain (See notes 2, & 4)
2. Do not connect pull-up resistors to the voltage programming pins.
3. To minimize output voltage error, always use pin 13 (Remote Sense Ground) as the logic "0" reference. While the regular ground (pins 14-18) can also be used for programming, doing so will degrade the load regulation of the product.
4. If active devices are used to ground the voltage control pins, low-level open drain MOSFET devices should be used over bipolar transistors. The inherent V_{ce}(sat) in bipolar devices introduces errors in the device's internal voltage control circuit. Discrete transistors such as the BSS138, 2N7002, IRLML2402, are examples of appropriate devices.

Active Voltage Programming:

Special precautions should be taken when making changes to the voltage control progam code while the unit is powered. It is highly recommended that the ISR be either powered down or held in standby. Changes made to the program code while V_{out} is enabled induces high current transients through the device. This is the result of the electrolytic output capacitors being either charged or discharged to the new output voltage set-point. The transient current can be minimized by making only incremental changes to the binary code, i.e. one LSB at a time. A minimum of 100µs settling time between each program state is also recommended. Making non-incremental changes to VID3 and VID4 with the output enabled is discouraged. If they are changed, the transients induced can overstress the device and may also activate the OVP drive output. If the program code cannot be asserted prior to power-up, pull pin 8 (STBY) to GND during the period that the input voltage is applied. The release of pin 8 will then to allow the device to initiate a soft-start power-up to the program voltage.

Figure 1



Capacitor Recommendations for the PT6721, PT6722, and PT6725 Series of Regulators

Input Capacitors

The recommended input capacitance is determined by 1.6 ampere minimum ripple current rating and 1000µF minimum capacitance. Tantalum capacitors listed below cannot be used on the input bus since they are not rated for 12V operation. Ripple current and Equivalent Series Resistance (ESR) values are the major considerations along with temperature when selecting the proper capacitor.

Output Capacitors

The minimum required output capacitance is 330µF with a maximum ESR less than or equal to 50mW. Failure to observe this requirement may lead to regulator instability or oscillation. Electrolytic capacitors have poor ripple performance at frequencies greater than 400kHz, but excellent low frequency transient response. Above the ripple frequency ceramic decoupling capacitors are necessary to improve the transient response and reduce any microprocessor high frequency noise components apparent during higher current excursions. Preferred low ESR type capacitor part numbers are identified in the Table 1 below.

Tantalum Characteristics

Tantalum capacitors may be used on the output bus but only the AVX TPS series, Sprague 593D/594/595 series, or Kemet T495/T510 series. These capacitors are recommended over many other tantalum types due to their high surge current, excellent power dissipation and ripple current ratings. As a caution, the TAJ Series by AVX is not recommended. This series has considerably higher ESR, reduced power dissipation, and lower ripple current capability. The TAJ series is less reliable compared to the TPS series when determining power dissipation capability.

Capacitor Table

Table 1 identifies the characteristics of capacitors from a number of vendors with acceptable ESR and ripple current (rms) ratings. The suggested minimum quantities per regulator for both the input and output buses are identified.

This is not an extensive capacitor list. Capacitors from other vendors are available with comparable specifications. Those listed are for guidance. The RMS ripple current rating and ESR (Equivalent Series Resistance at 100kHz) are the critical parameters necessary to insure both optimum regulator performance and long capacitor life.

Table 1 Capacitors Characteristic Data

Capacitor Vendor/ Series	Capacitor Characteristics					Quantity		
	Working Voltage	Value(µF)	(ESR) Equivalent Series Resistance	105°C Maximum Ripple Current(Irms)	Physical Size(mm)	Input Bus	Output Bus	Vendor Part Number
Panasonic FC Series/ FA Series	35V 25V 25V	680 1000 1000	0.043Ω 0.038Ω 0.038Ω	1655mA 1655mA 1690mA	12.5x20 12.5x20 16x15	2 1 1	1 2 1	EEUFC1V681 EEUFC1E102 EEUFC1E102S
United Chemi-con LFVSeries	35V 35V 16V	680 1000 470	0.034Ω 0.038Ω 0.084Ω÷2 =0.042Ω	1690mA 1630mA 825mA (x2)	12.5x25 16x20 10x16	2 1 N/R(1)	1 1 2	LXV35VB680M12X25LL LXV35VB102M16X20LL LXV16VB471M10X16LL
Nichicon PL Series/ PM Series	35V 25V 35V	680 1200 1000	0.036Ω 0.039Ω 0.034Ω	1660mA 1600mA 1770mA	12.5x25 18x15 16x20	2 1 1	1 1 1	UPL1V681MHH UPL1E122MHH6 UPM1V102MHH6
Panasonic FC Series Surface Mtg	35V 25V 35V	1000 1000 470	0038Ω 0.038Ω 0.043Ω	2000mA 2000mA 1690mA	18x16.5 18x16.5 16x16.5	1 1 2	1 1 1	EEVFC1V102N EEVFC1E102N EEVFC1V471N
Oscon- SS/SV Series	10V 10V	330 330	0.025Ω 0.020Ω	3500mA 3800mA	10x10.5 10.3x10.3	N/R(1) N/R(1)	1 1	10SS330M (If V_o <5V) 10SV330 (If V_o <5V) Surface Mount (SV)
AVX Tantalum TPS Series	10V 10V	330 330	0.1Ω÷2 =0.05Ω 0.06Ω÷2 =0.03Ω	>2500mA >3000mA	7.3L x 5.7W x 4.1H	N/R(1) N/R(1)	2 2	TPSE337M010R0100 TPSV337M010R0060 Surface Mount
Kemet Tantalum T510/T495 Series	10V 10V	330 220	0.033Ω 0.07Ω÷2 =0.035Ω	1400mA >2000mA	4.3Wx7.3L x4.0H	N/R(1) N/R(1)	1 2	510X337M010AS T495X227M0100AS Surface Mount
Sprague Tantalum 594D Series	10V	330	0.045Ω	2360mA	7.2L x 6W x 4.1H	N/R(1)	1	594D337X0010R2T Surface Mount

Note: *(N/R) 10V tantalums are not recommend for the input bus.*

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
PT6722A	ACTIVE	SIP MODULE	ELA	23	10	Pb-Free (RoHS)	Call TI	N / A for Pkg Type

(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.
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.

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