



Features

- +5-V Input
- 13-A Output Current
- 5-Bit Programmable Output: 1.3V to 3.5V
- VRM 8.3 Compatible
- 90% Efficiency
- Standby On/Off Control
- Differential Remote Sense
- Over-Voltage Protection Drive
- Power Good Signal
- Short Circuit Protection
- Space Saving Solderable Case
- 4.7·10⁶ Hrs. MTBF

Description

The PT6701 Excalibur™ power module is a fully integrated 13-A switching regulator housed in a space-saving solderable package. The PT6701 operates from a +5V input to provide a high-performance low-voltage power source for the industry's latest μ Ps, DSPs, and bus drivers. The PT6701 is programmable from 1.3V to 3.5V with a 5-bit input, which is compatible with Intel's Pentium® II Processor.

The PT6701 has output short circuit protection, a "Power Good" output, and an over-voltage protection (OVP) drive.

Ordering Information

PT6701□ = 1.3 to 3.5 Volts
(For dimensions and PC board layout, see Package Styles 1300 & 1310.)

PT Series Suffix (PT1234X)

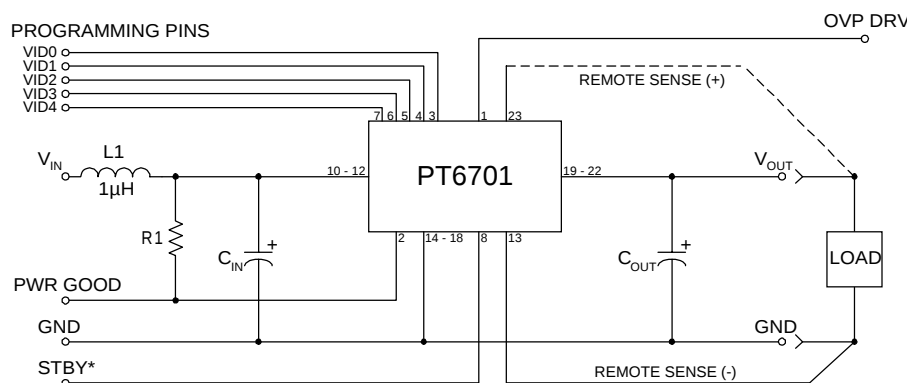
Case/Pin Configuration	
Vertical Through-Hole	N
Horizontal Through-Hole	A
Horizontal Surface Mount	C

Pin-Out Information

Pin	Function	Pin	Function
1	OVP Drive	13	Remote 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	Remote Sense V _{out}
12	V _{in}		

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

Standard Application



C_{in}: Required 1000 μ F electrolytic capacitor –see table footnotes.
C_{out}: Required 330 μ F electrolytic capacitor –see table footnote
L₁: Optional 1 μ H input choke –see table footnotes
R₁: 10-k Ω 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	2.00V	1.30V
1	1	1	0	2.10V	1.35V
1	1	0	1	2.20V	1.40V
1	1	0	0	2.30V	1.45V
1	0	1	1	2.40V	1.50V
1	0	1	0	2.50V	1.55V
1	0	0	1	2.60V	1.60V
1	0	0	0	2.70V	1.65V
0	1	1	1	2.80V	1.70V
0	1	1	0	2.90V	1.75V
0	1	0	1	3.00V	1.80V
0	1	0	0	3.10V	1.85V
0	0	1	1	3.20V	1.90V
0	0	1	0	3.30V	1.95V
0	0	0	1	3.40V	2.00V
0	0	0	0	3.50V	2.05V

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, $T_a = 25^\circ\text{C}$, $V_{in} = 5\text{V}$, $C_{out} = 330\mu\text{F}$, and $I_o = I_{o,max}$)

Characteristic	Symbol	Conditions	PT6701			Units
			Min	Typ	Max	
Output Current	I_o	$T_a = +60^\circ\text{C}$, 200LFM $T_a = +25^\circ\text{C}$, natural convection	0.1 ⁽¹⁾ 0.1 ⁽¹⁾	— —	13.0 13.0	A
Input Voltage Range	V_{in}	Over I_o Range	4.5	—	5.5	VDC
Set Point Voltage Tolerance	V_o tol		—	± 0.5	± 1.25 ⁽²⁾	% V_o
Temperature Variation	Reg_{temp}	$-40^\circ > T_a > +85^\circ\text{C}$	—	± 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	$\Delta V_{o,tot}$	Includes set-point, line, load, $-40^\circ > T_a > +85^\circ\text{C}$	—	± 25	—	mV
Efficiency	η	$I_o = 9\text{A}$	$V_o = 3.3\text{V}$ — $V_o = 2.5\text{V}$ — $V_o = 1.8\text{V}$ — $V_o = 1.5\text{V}$ —	91 88 84 83	— — — —	%
V_o Ripple (pk-pk)	V_r	20MHz bandwidth	—	35	—	mV _{pp}
Transient Response	t_{tr}	1A/ μs load step, 6A to 12A	—	50	—	μs
	ΔV_{tr}	V_o over/undershoot	—	± 100	—	mV
Short Circuit Current	I_{sc}		—	20	—	A
Switching Frequency	f_o	Over V_{in} range	300	350	400	kHz
Standby Control (pin 8)	V_{IH}	Referenced to GND (pin 14)	—	—	Open ⁽³⁾	V
Input High Voltage	V_{IL}		–0.2	0.4	1.0	
Input Low Voltage	I_{IL}	Pin 8 to GND	—	10	—	μA
Input Low Current	I_{in} standby	pins 8 & 14 connected	—	20	30	mA
External Output Capacitance	C_{out}		330 ⁽⁴⁾	—	15,000	μF
Maximum Operating Temperature Range	T_a	Over V_{in} range	–40	—	+85 ⁽⁵⁾	$^\circ\text{C}$
Storage Temperature	T_s		–40	—	+125	$^\circ\text{C}$
Reliability	MTBF	Per Bellcore TR-332 50% stress, $T_a = 40^\circ\text{C}$, ground benign	4.7	—	—	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	—	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.

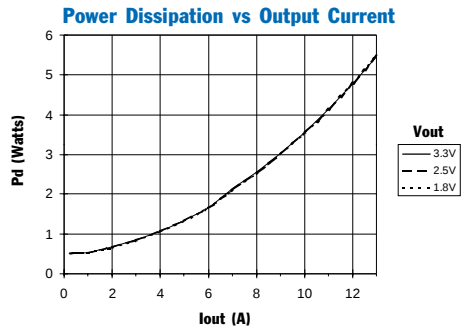
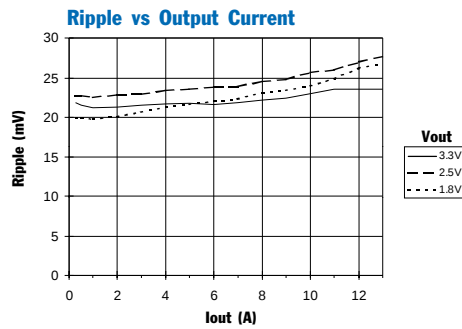
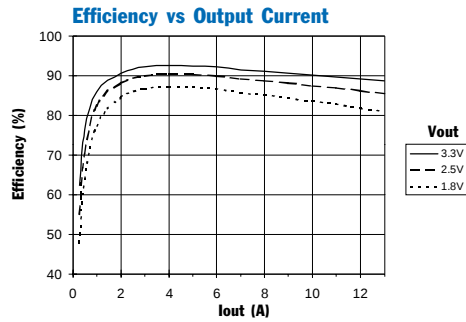
(3) The Standby control (pin 8) has an internal pull-up, and if left open-circuit the module will operate when input power is applied. A small low-leakage (<100nA) MOSFET must be used to control this input. The open-circuit voltage is less than 10V. See application notes for further information.

(4) For operation below 0°C , C_{in} and C_{out} must have stable characteristics. Use either low ESR tantalum or Oscon® capacitors.

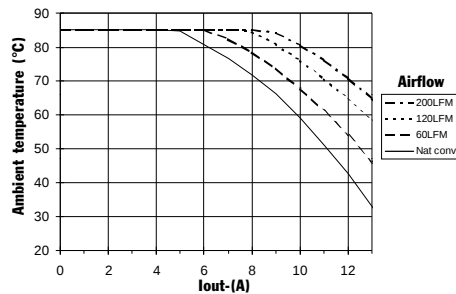
(5) See Safe Operating Area curves.

External Capacitors: The PT6701 requires a minimum output capacitance of 330 μF , and a minimum input capacitance of 1,000 μF for proper operation. The input capacitance must be rated for a minimum of 2.0Arms of ripple current. For transient or dynamic load applications, additional input and output capacitance may be required. The maximum allowable output capacitance is 15,000 μF . 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 10.0ADC with a typical value of 1 μH .

PT6701 Characterization, $V_{in} = 5V$ (See Note A)

Safe Operating Area Curve (See Note B)



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 active-high signal when the sensed output from the ISR is within a nominal $\pm 10\%$ of the programmed set point. When the regulated output is outside this range, pin 2 asserts a logic low (typically $<0.1V$). A 10-k Ω 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

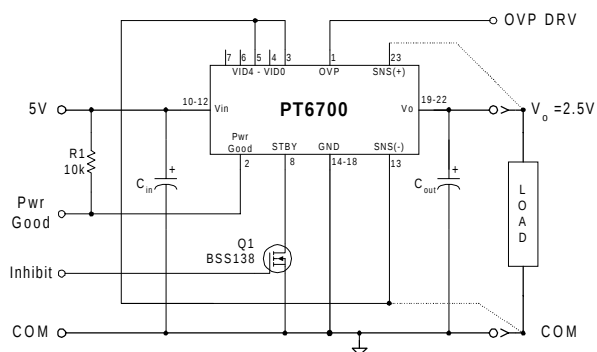
The PT6700 series ISRs incorporate a standby function. This feature may be used for power-up sequencing, or wherever there is a requirement for the output voltage to be controlled by external circuitry.

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! 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 Ckt. ¹		
Disable	-0.1V	0.4V	1.0V
I_{stby}		10 μ A	

Figure 1



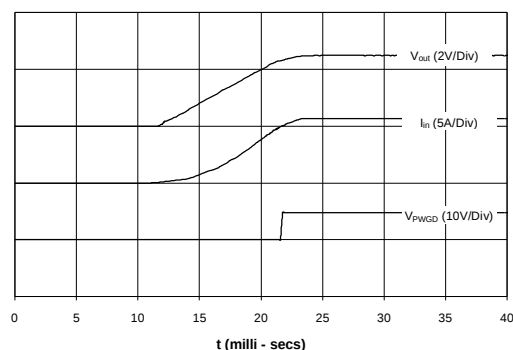
Notes:

- 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.
- 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 over-stress the part.

Turn-On Time

Turning Q1 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 Q1 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 Adjustment on the Non-Isolated “Excalibur™” Series ISRs

The PT6701/6702/6703, and PT6721/6722 Excalibur™ ISRs incorporate a pin-coded control to program the output voltage. Depending on the resolution and adjustment range, there are up to five control pins. They are identified VID0–VID4 (pins 3–7) respectively. When the control pins are left open-circuit the ISR output will regulate at its factory trimmed output voltage. By selectively grounding VID0–VID4, the output voltage can be programmed in incremental steps over the specified output voltage range. The program code and output voltage range of these ISRs may also be compatible with the “Voltage ID” specification defined for popular microprocessors. Refer to Figure 1 below for the connection schematic, and the applicable Data Sheet for the program code.

Notes:

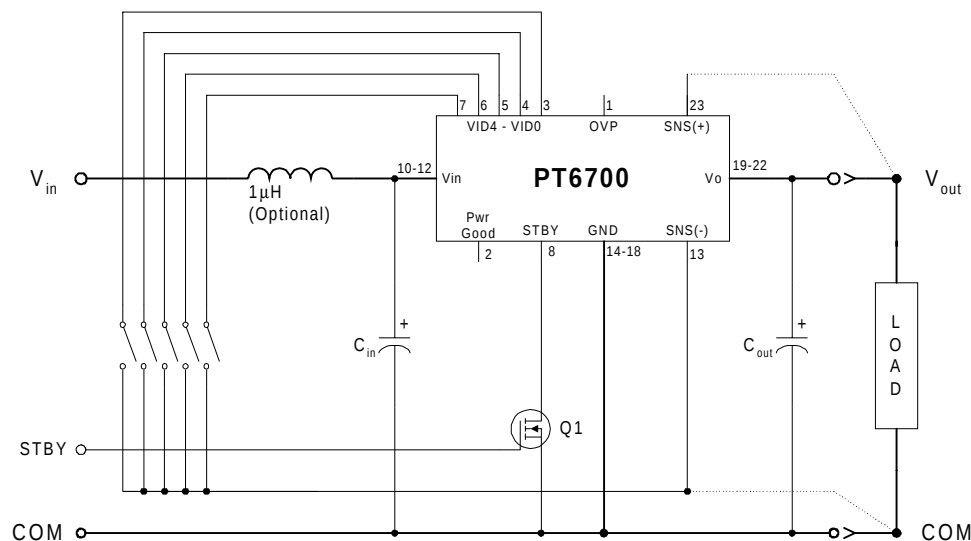
1. The programming convention is as follows:-
Logic 0: Connect to pin13 (Remote Sense Ground).
Logic 1: Open circuit/open drain (See notes 2, & 4)
2. Do not connect pull-up resistors to the voltage programming pins.
3. To minimize output voltage error, always use pin 13 (Remote Sense Ground) as the logic “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, or the 74C906 hex open-drain buffer are examples of appropriate devices.

Active Voltage Programming:

Special precautions should be taken when making changes to the voltage control program 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 100 μ s 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 resulting in a permanent drop in efficiency. If the use of active devices prevents the program code being asserted prior to power-up, pull pin 8 (STBY) to the device GND during the period that the input voltage is applied to V_{in} . Releasing pin 8 will then allow the device output to initiate a soft-start power-up to the new program voltage.

Figure 1



Capacitor Recommendations for the Non-Isolated 13-A Excalibur™ Series of Regulators

Input Capacitors

The recommended input capacitance is determined by the 2.0 ampere minimum ripple current rating and 1000µF minimum capacitance. Capacitors listed below must be rated for a minimum of 2x the input voltage with +5V operation. Ripple current and $\leq 100\text{m}\Omega$ 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 100mΩ. 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 high frequency noise components apparent during higher current excursions. Preferred low ESR type capacitor part numbers are identified in Table 1 below.

Tantalum Characteristics

Tantalum capacitors with a minimum 10V rating are recommended on the output bus, but only the AVX TPS Series, Sprague 594/595 Series, or Kemet T495/T510 Series. The AVX TPS Series, Sprague Series or Kemet Series capacitors are specified over other types due to their higher surge current, excellent power dissipation and ripple current ratings. As a caution, the TAJ Series by AVX is not recommended. This series exhibits considerably higher ESR, reduced power dissipation and lower ripple current capability. The TAJ Series is a 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. The table below is a suggested selection guide for input and output capacitors. Other capacitor vendors are available with comparable RMS ripple current rating and ESR (Equivalent Series Resistance at 100kHz). These critical parameters are necessary to insure both optimum regulator performance and long capacitor life.

Table 1 Capacitors Characteristic Data

Capacitor Vendor Series	Capacitor Characteristics					Quantity		Vendor Number
	Working Voltage	Value(µF)	(ESR) Equivalent Series Resistance	85°C Maximum Ripple Current(Irms)	Physical Size(mm)	Input Bus	Output Bus	
Panasonic FC Surface Mtg FA Radial	25V 35V	1000 330	0.038Ω 0.065Ω	2000mA 1205mA	18x16.5 12.5x16.5	1	1	EEVFC1E102N EEVFC1V331LQ
	25V 25V	330 1200	0.090Ω 0.032Ω	765mA 2000mA	10x12.5 18x15	1	1	EEUFA1E331 EEUFA1E122S
United Chemi -Con LFV Radial FX Surface Mtg	25V 35V	330 1200	0.084Ω 0.028Ω	825mA 2070mA	10x16 16x25	1	1	LXV25VB331M10X16LL LXV35VB122M16X25LL
	16V	2700	0.028Ω	2070mA	16x25	1	1	LXV16VB272M16X25LL
	10V	680	0.015Ω/2=0.007Ω	>7000mA	10X10.5	2	1	10FX680M(Os-con)
	25V 25V 25V	330 2200 330	0.095Ω 0.028Ω 0.095Ω	750mA 2050mA 750mA	10x15 18x20 10x15	1	1	UPL1E331MPH6 UPL1E222MHH6 UPM1E331MPH6
Oscon SS SV	10V 10V	330 330	0.025Ω/3=0.008Ω 0.020Ω/3=0.007Ω	>7000mA >7000mA	10x10.5 10.3x12.6	3 3	1 1	10SS330M 10SV330M(Surface Mtg)
AVX Tantalum TPS- Series	10V 10V	330 330	0.100Ω/3=0.034Ω 0.060Ω/3=0.02Ω	>3500mA >3500mA	7.0Lx 5.97Wx 3.45H	3 3	1 1	TPSV337M010R0100 TPSV337M010R0060
Vishay/Sprague Tantalum 595D/594D	10V 10V	330 680	0.045Ω/3=0.015Ω 0.090Ω/4=0.023Ω	>4600mA >2500mA	7.2L x 6.0W x 3.5H	3 2	1 1	594D337X0010R2T Surface Mount 595D687X0010R2T
Kemet Tantalum T510/T495 Series	10V 10V	330 220	0.035Ω/3=0.012Ω 0.070Ω/5=0.035Ω	>5000mA >3000mA	4.3Wx7.3L x4.0H	3 5	1 2	T510X337M010AS T495X227M010AS Surface Mount
Sanyo Poscap TPB	10V	220	0.040Ω/5=0.008Ω	>3000mA	7.2L x 4.3W x 3.1H	5	2	10TPB220M Surface Mount

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
PT6701A	NRND	SIP MOD ULE	ELA	23	10	TBD	Call TI	Level-1-215C-UNLIM
PT6701C	NRND	SIP MOD ULE	ELC	23	10	TBD	Call TI	Level-3-215C-168HRS
PT6701N	NRND	SIP MOD ULE	ELD	23	10	TBD	Call TI	Level-1-215C-UNLIM

⁽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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