

## 16-A, 4.5-V to 14-V INPUT, NON-ISOLATED, WIDE-OUTPUT, ADJUSTABLE POWER MODULE WITH *TurboTrans*<sup>™</sup>

### FEATURES

- Up to 16-A Output Current
- 4.5-V to 14-V Input Voltage
- Wide-Output Voltage Adjust (0.7 V to 5.5 V)
- ±1.5% Total Output Voltage Variation
- Efficiencies up to 96%
- Output Overcurrent Protection (Nonlatching, Auto-Reset)
- Operating Temperature: –40°C to 85°C
- Safety Agency Approvals:
  - UL 1950, CSA 22.2 950, EN60950 VDE (Pending)
- On/Off Inhibit
- Differential Output Voltage Remote Sense
- Adjustable Undervoltage Lockout
- TurboTrans<sup>™</sup> Technology
- Designed to meet Ultra-Fast Transient Requirements up to 300 A/μs
- SmartSync Technology
- Auto-Track<sup>™</sup> Sequencing

### APPLICATIONS

- Complex Multi-Voltage Systems
- Microprocessors
- Bus Drivers



### DESCRIPTION

The PTH08T220W is a high-performance 16-A rated, non-isolated power module. This regulator represents the 2<sup>nd</sup> generation of the popular PTH series power modules.

Operating from an input voltage range of 4.5 V to 14 V, the PTH08T220W requires a single resistor to set the output voltage to any value over the range, 0.7 V to 5.5 V. The wide input voltage range makes the PTH08T220W particularly suitable for advanced computing and server applications that utilize a loosely regulated 8-V to 12-V intermediate distribution bus. Additionally, the wide input voltage range increases design flexibility by supporting operation with tightly regulated 5-V, 8-V, or 12-V intermediate bus architectures.

The module incorporates a comprehensive list of features. Output over-current and over-temperature shutdown protects against most load faults. A differential remote sense ensures tight load regulation. An adjustable under-voltage lockout allows the turn-on voltage threshold to be customized. Auto-Track<sup>™</sup> sequencing is a popular feature that greatly simplifies the simultaneous power-up and power-down of multiple modules in a power system.

The PTH08T220W includes new patent pending technologies, *TurboTrans*<sup>™</sup> and *SmartSync*. The *TurboTrans* feature optimizes the transient response of the regulator while simultaneously reducing the quantity of external output capacitors required to meet a target voltage deviation specification. Additionally, for a target output capacitor bank, *TurboTrans* can be used to significantly improve the regulators transient response by reducing the peak voltage deviation. *SmartSync* allows for switching frequency synchronization of multiple modules, thus simplifying EMI noise suppression tasks and/or reducing input capacitor RMS current requirements.

The module uses double-sided surface mount construction to provide a low profile and compact footprint. Package options include both through-hole and surface mount configurations that are lead (Pb) - free and RoHS compatible.

PRODUCT PREVIEW

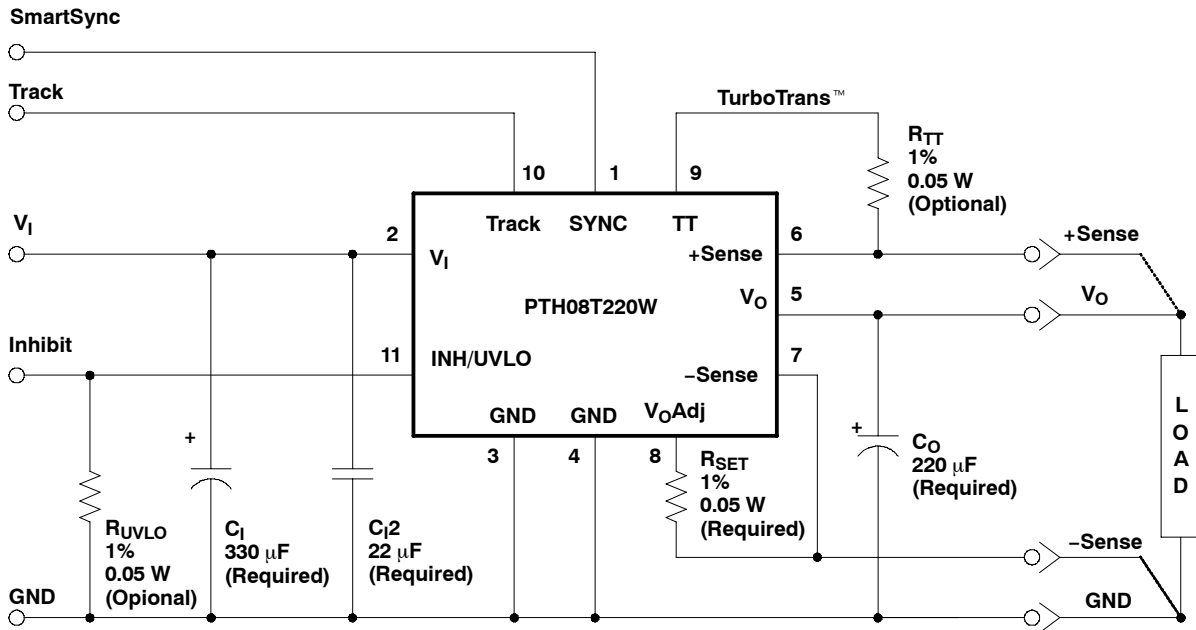


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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.



A.  $R_{SET}$  required to set the output voltage to a value higher than 0.7 V. See *Electrical Characteristics* table.

**ORDERING INFORMATION**

For the most current package and ordering information, see the Package Option Addendum at the end of this datasheet, or see the TI website at [www.ti.com](http://www.ti.com).

**ENVIRONMENTAL AND ABSOLUTE MAXIMUM RATINGS**

(Voltages are with respect to GND)

				UNIT
$V_I$	Input voltage	Track	-0.3 to $V_I + 0.3$	V
$T_A$	Operating temperature range	Over $V_I$ range	-40 to 85	°C
$T_{wave}$	Wave soldering temperature	Surface temperature of module body or pins for 5 seconds maximum.	PTH08T220WAD 260	
$T_{reflow}$	Solder reflow temperature	Surface temperature of module body or pins	PTH08T220WAS 235 <sup>(1)</sup> PTH08T220WAZ 260 <sup>(1)</sup>	
$T_{stg}$	Storage temperature		-40 to 125	
	Mechanical shock	Per Mil-STD-883D, Method 2002.3 1 mssec, 1/2 sine, mounted	AD, AS, and AZ suffix 20	G
	Mechanical vibration	Mil-STD-883D, Method 2007.2 20-2000 Hz	AD suffix 500 AS and AZ suffix 125	
	Weight		5	grams
	Flammability	Meets UL94V-O		

(1) During reflow of surface mount package version do not elevate peak temperature of the module, pins or internal components above the stated maximum.

PRODUCT PREVIEW

**ELECTRICAL CHARACTERISTICS**

$T_A = 25^\circ\text{C}$ ,  $V_i = 5\text{ V}$ ,  $V_O = 3.3\text{ V}$ ,  $C_1 = 330\ \mu\text{F}$ ,  $C_2 = 22\ \mu\text{F}$ ,  $C_O = 220\ \mu\text{F}$ , and  $I_O = I_O\ \text{max}$  (unless otherwise stated)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$I_O$	Output current	Over $V_O$ range	$25^\circ\text{C}$ , natural convection	0		16	A
$V_i$	Input voltage range	Over $I_O$ range	$0.7 \leq V_O \leq 1.2$	4.5		$V_O \times 11$ <sup>(1)</sup>	V
			$1.3 \leq V_O \leq 3.6$	4.5		14	
			$3.7 \leq V_O \leq 5.5$	$V_O + 2$		14	
$V_{O\text{ADJ}}$	Output voltage adjust range	Over $I_O$ range		0.7		5.5	V
$V_O$	Set-point voltage tolerance				$\pm 0.5$	$\pm 1$ <sup>(2)</sup>	$\%V_O$
	Temperature variation	$-40^\circ\text{C} < T_A < 85^\circ\text{C}$			$\pm 0.3$		$\%V_O$
	Line regulation	Over $V_i$ range			$\pm 3$		mV
	Load regulation	Over $I_O$ range				$\pm 2$	mV
	Total output variation	Includes set-point, line, load, $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$					$\pm 1.5$ <sup>(2)</sup>
$\eta$	Efficiency	$I_O = 16\text{ A}$	$R_{\text{SET}} = 1.21\ \text{k}\Omega$ , $V_O = 3.3\text{ V}$			94%	
			$R_{\text{SET}} = 2.38\ \text{k}\Omega$ , $V_O = 2.5\text{ V}$			91%	
			$R_{\text{SET}} = 4.78\ \text{k}\Omega$ , $V_O = 1.8\text{ V}$			88%	
			$R_{\text{SET}} = 7.09\ \text{k}\Omega$ , $V_O = 1.5\text{ V}$			87%	
			$R_{\text{SET}} = 12.1\ \text{k}\Omega$ , $V_O = 1.2\text{ V}$			84%	
			$R_{\text{SET}} = 20.8\ \text{k}\Omega$ , $V_O = 1.0\text{ V}$			82%	
	$V_O$ Ripple (peak-to-peak)	20-MHz bandwidth			15 <sup>(3)</sup>		mV <sub>PP</sub>
$I_{\text{LIM}}$	Overcurrent threshold	Reset, followed by auto-recovery			32		A
$t_{\text{tr}}$	Transient response	5 A/ $\mu\text{s}$ load step 50 to 100% $I_{O\text{max}}$	w/o Turbotrans	Recovery time		TBD	$\mu\text{s}$
				$V_O$ over/undershoot		TBD	mV
			w/ TurboTrans	Recovery time		TBD	$\mu\text{s}$
				$V_O$ over/undershoot		TBD	mV
	$C_O = 1330\ \mu\text{F}$						
$I_{\text{IL}}$	Track input current (pin 10)	Pin to GND				$-130$ <sup>(4)</sup>	$\mu\text{A}$
$dV_{\text{track}}/dt$	Track slew rate capability	$C_O \leq C_O$ (max)				1	V/ms
$UVLO_{\text{ADJ}}$	Adjustable Under-voltage lockout (pin 11)	$V_i$ increasing, $R_{UVLO} = \text{OPEN}$			4.3	4.45	V
		$V_i$ decreasing, $R_{UVLO} = \text{OPEN}$			4.0	4.2	
		Hysteresis, $R_{UVLO} \leq 52.3\ \text{k}\Omega$			0.5		
	Inhibit control (pin 11)	Input high voltage ( $V_{\text{IH}}$ )		$V_i - 0.5$		Open <sup>(5)</sup>	V
		Input low voltage ( $V_{\text{IL}}$ )		$-0.2$		0.8	
		Input low current ( $I_{\text{IL}}$ ), Pin 11 to GND			$-235$		$\mu\text{A}$
$I_{\text{in}}$	Input standby current	Inhibit (pin 11) to GND, Track (pin 10) open			5		mA
$f_s$	Switching frequency	Over $V_i$ and $I_O$ ranges			300		kHz
$f_{\text{SYNC}}$	Synchronization (SYNC) frequency			240		400	kHz
$V_{\text{SYNCH}}$	SYNC High-Level Input Voltage			2		5.5	V
$V_{\text{SYNCL}}$	SYNC Low-Level Input Voltage					0.8	V
$t_{\text{SYNC}}$	SYNC Minimum Pulse Width			200			nSec
$C_1$	External input capacitance	Nonceramic		330 <sup>(6)</sup>			$\mu\text{F}$
		Ceramic		22 <sup>(6)</sup>			

- The maximum input voltage is duty cycle limited to ( $V_O \times 11$ ) or 14 volts, whichever is less. The maximum allowable input voltage is a function of switching frequency, and may increase or decrease when the SmartSync feature is utilized. Please review the SmartSync section of the Application Information for further guidance.
- The set-point voltage tolerance is affected by the tolerance and stability of  $R_{\text{SET}}$ . The stated limit is unconditionally met if  $R_{\text{SET}}$  has a tolerance of 1% with 100 ppm/ $^\circ\text{C}$  or better temperature stability.
- For output voltages less than 1.7 V, the ripple may increase (up to 2x) when operating at input voltages greater than ( $V_O \times 8$ ).
- A low-leakage (<100 nA), open-drain device, such as MOSFET or voltage supervisor IC, is recommended to control pin 10. The open-circuit voltage is less than  $8 V_{\text{dc}}$ .
- This control pin has an internal pullup to the input voltage  $V_i$ . If it is left open-circuit, the module operates when input power is applied. A small, low-leakage (<100 nA) MOSFET is recommended for control. For additional information, see the related application note.
- A 330  $\mu\text{F}$  electrolytic and a 22  $\mu\text{F}$  ceramic input capacitor is required for proper operation. The electrolytic capacitor must be rated for a minimum of 700 mA rms of ripple current.

**PRODUCT PREVIEW**

**ELECTRICAL CHARACTERISTICS (continued)**

$T_A = 25^\circ\text{C}$ ,  $V_i = 5\text{ V}$ ,  $V_o = 3.3\text{ V}$ ,  $C_i = 330\ \mu\text{F}$ ,  $C_{i2} = 22\ \mu\text{F}$ ,  $C_o = 220\ \mu\text{F}$ , and  $I_o = I_o\ \text{max}$  (unless otherwise stated)

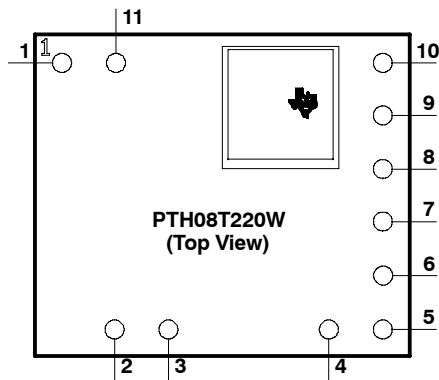
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
C <sub>O</sub>	External output capacitance	w/o TurboTrans	Capacitance Value	Nonceramic	220 <sup>(7)</sup>	TBD <sup>(8)</sup>	$\mu\text{F}$
				Ceramic		TBD	
			Equivalent series resistance (non-ceramic)		TBD		$\text{m}\Omega$
	w/ TurboTrans	Capacitance Value		see table <sup>(7)(9)</sup>		$\mu\text{F}$	
		Capacitance $\times$ ESR product (C <sub>O</sub> $\times$ ESR)			10000 <sup>(9)</sup>	$\mu\text{F}\times\text{m}\Omega$	
MTBF	Reliability	Per Bellcore TR-332, 50% stress, $T_A = 40^\circ\text{C}$ , ground benign			TBD		$10^6\ \text{Hr}$

- (7) A 220  $\mu\text{F}$  external output capacitor is required for basic operation. The minimum output capacitance requirement increases when *TurboTrans*<sup>™</sup> (TT) technology is utilized. See related Application Information for more guidance.
- (8) This is the calculated maximum disregarding *TurboTrans*<sup>™</sup> technology. When the *TurboTrans*<sup>™</sup> feature is utilized, the minimum output capacitance must be increased.
- (9) When using *TurboTrans*<sup>™</sup> technology, a minimum value of output capacitance is required for proper operation. Additionally, low ESR capacitors are required for proper operation. See the application notes for further guidance.

**TERMINAL FUNCTIONS**

TERMINAL		DESCRIPTION
NAME	NO.	
V <sub>I</sub>	2	The positive input voltage power node to the module, which is referenced to common GND.
V <sub>O</sub>	5	The regulated positive power output with respect to the GND.
GND	3, 4	This is the common ground connection for the V <sub>I</sub> and V <sub>O</sub> power connections. It is also the 0 V <sub>dc</sub> reference for the control inputs.
Inhibit <sup>(1)</sup> and UVLO	11	<p>The Inhibit pin is an open-collector/drain, negative logic input that is referenced to GND. Applying a low level ground signal to this input disables the module's output and turns off the output voltage. When the Inhibit control is active, the input current drawn by the regulator is significantly reduced. If the Inhibit pin is left open-circuit, the module produces an output whenever a valid input source is applied.</p> <p>This pin is also used for input undervoltage lockout (UVLO) programming. Connecting a resistor from this pin to GND (pin 3) allows the ON threshold of the UVLO to be adjusted higher than the default value. For more information, see the Application Information section.</p>
V <sub>O</sub> Adjust	8	<p>A 0.1 W 1% resistor must be directly connected between this pin and pin 7 (–Sense) to set the output voltage to a value higher than 0.7 V. The temperature stability of the resistor should be 100 ppm/°C (or better). The setpoint range for the output voltage is from 0.7 V to 5.5 V. If left open circuit, the output voltage will default to its lowest value. For further information, on output voltage adjustment see the related application note.</p> <p>The specification table gives the preferred resistor values for a number of standard output voltages.</p>
+ Sense	6	The sense input allows the regulation circuit to compensate for voltage drop between the module and the load. For optimal voltage accuracy, +Sense must be connected to V <sub>O</sub> , very close to the load.
– Sense	7	The sense input allows the regulation circuit to compensate for voltage drop between the module and the load. For optimal voltage accuracy, –Sense must be connected to GND (pin 4), very close to the load.
Track	10	<p>This is an analog control input that enables the output voltage to follow an external voltage. This pin becomes active typically 20 ms after the input voltage has been applied, and allows direct control of the output voltage from 0 V up to the nominal set-point voltage. Within this range the module's output voltage follows the voltage at the Track pin on a volt-for-volt basis. When the control voltage is raised above this range, the module regulates at its set-point voltage. The feature allows the output voltage to rise simultaneously with other modules powered from the same input bus. If unused, this input should be connected to V<sub>I</sub>.</p> <p>NOTE: Due to the undervoltage lockout feature, the output of the module cannot follow its own input voltage during power up. For more information, see the related application note.</p>
TurboTrans™	9	This input pin adjusts the transient response of the regulator. To activate the TurboTrans™ feature, a 1%, 50 mW resistor must be connected between this pin and pin 6 (+Sense) very close to the module. For a given value of output capacitance, a reduction in peak output voltage deviation is achieved by utilizing this feature. If unused, this pin must be left open-circuit. The resistance requirement can be selected from the TurboTrans™ resistor table in the Application Information section. External capacitance must never be connected to this pin.
SmartSync	1	This input pin synchronizes the switching frequency of the module to an external clock frequency. The SmartSync feature can be used to synchronize the switching frequency of multiple PTH08T220W modules, aiding EMI noise suppression efforts. If unused, this pin should be connected to GND (pin 3). For more information, please review the Application Information section.

(1) Denotes negative logic: Open = Normal operation, Ground = Function active



TYPICAL CHARACTERISTICS <sup>(1)(2)</sup>

CHARACTERISTIC DATA ( $V_I = 12\text{ V}$ )

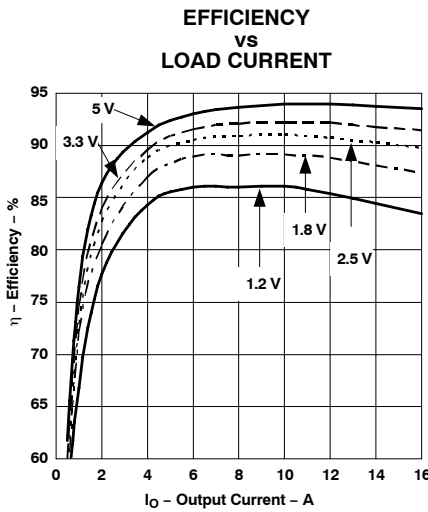


Figure 1.

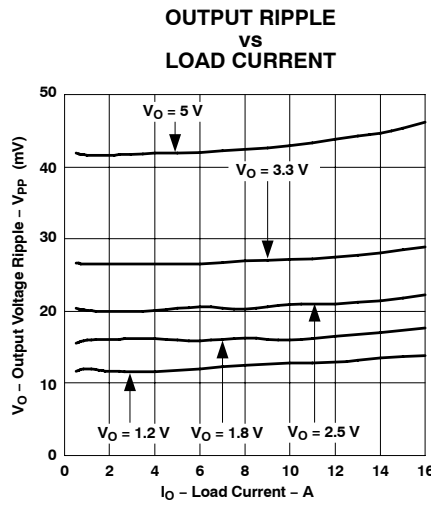


Figure 2.

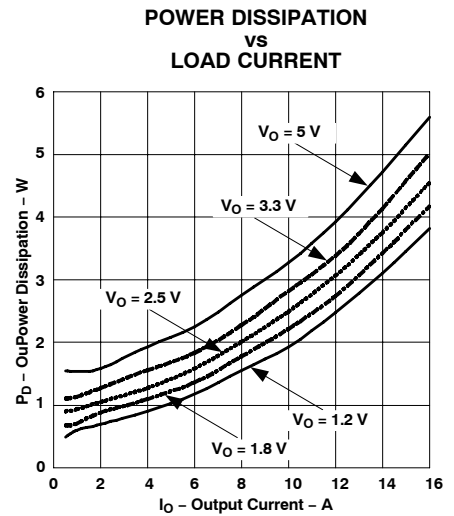


Figure 3.

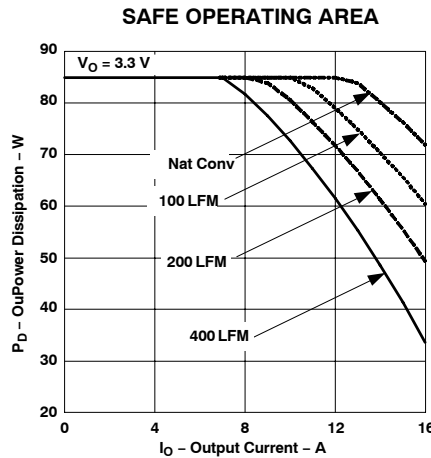


Figure 4.

- (1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to [Figure 1](#), [Figure 2](#), and [Figure 3](#).
- (2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to modules soldered directly to a 100 mm x 100 mm double-sided PCB with 2 oz. copper. For surface mount packages (AS and AZ suffix), multiple vias must be utilized. Please refer to the mechanical specification for more information. Applies to [Figure 4](#).

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS<sup>(1)(2)</sup>

CHARACTERISTIC DATA ( $V_I = 5\text{ V}$ )

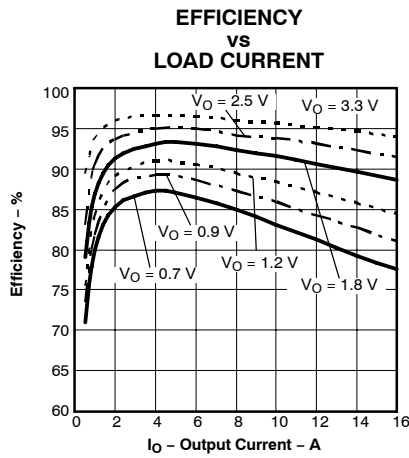


Figure 5.

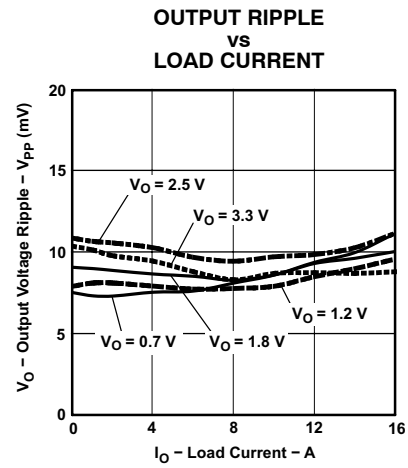


Figure 6.

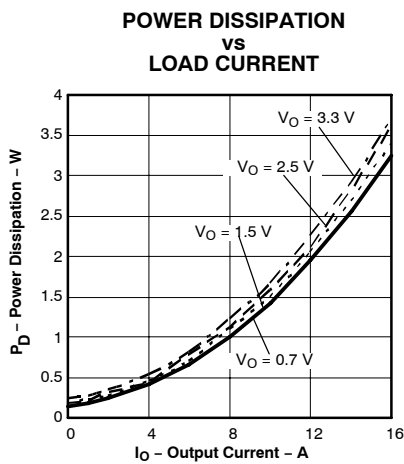


Figure 7.

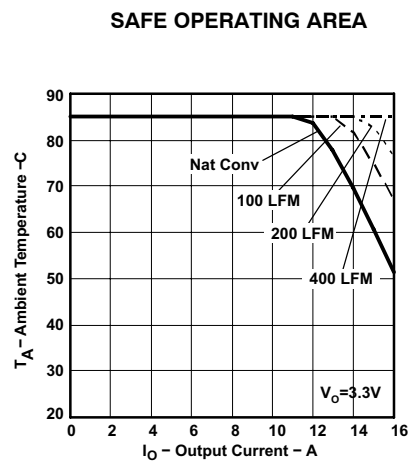


Figure 8.

- (1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to [Figure 5](#), [Figure 6](#), and [Figure 7](#).
- (2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to modules soldered directly to a 100 mm x 100 mm double-sided PCB with 2 oz. copper. For surface mount packages (AS and AZ suffix), multiple vias must be utilized. Please refer to the mechanical specification for more information. Applies to [Figure 8](#).

PRODUCT PREVIEW

## APPLICATION INFORMATION

### CAPACITOR RECOMMENDATIONS FOR THE PTH08T220W POWER MODULE

#### Input Capacitor (Required)

The required input capacitors are a combination of a 22  $\mu\text{F}$  X5R/X7R ceramic and 330- $\mu\text{F}$  electrolytic type. When  $V_O > 2.1\text{ V}$  and  $I_O$  is  $\geq 11\text{ A}$ , the 330- $\mu\text{F}$  capacitor must be rated to 1500 mArms ripple current capability. For other conditions,  $V_O \leq 3.5\text{ V}$  to  $2.1\text{ V}$  with  $I_O$  at  $< 11\text{ A}$  load, and  $V_O \leq 2.1\text{ V}$  at all loads, the ripple current rating must be at least 950 mArms. The size and value of the input capacitor is determined by the converter's transient performance capability. This minimum value assumes that the converter is supplied with a responsive, low inductance input source. This source should have ample capacitive decoupling, and be distributed to the converter via PCB power and ground planes.

The above ripple current requirements are *conditional* that the 22- $\mu\text{F}$  ceramic capacitor is present. The 22- $\mu\text{F}$  X5R/X7R ceramic capacitor is necessary to reduce both the magnitude of ripple current through the electrolytic capacitor and the amount of ripple current reflected back to the input source. Ceramic capacitors should be located within 0.5 inch. (1.3 cm) of the module's input pins. Additional ceramic capacitors can be added to reduce the RMS ripple current requirement for the electrolytic capacitor.

For high-performance applications, or wherever the input source performance is degraded, 680- $\mu\text{F}$  of input capacitance is recommended. The additional input capacitance above the minimum level insures an optimized performance.

Ripple current (rms) rating, less than 100  $\text{m}\Omega$  of equivalent series resistance (ESR), and temperature are the main considerations when selecting input capacitors.

Regular tantalum capacitors are not recommended for the input bus. These capacitors require a recommended minimum voltage rating of  $2 \times$  (maximum dc voltage + ac ripple). This is standard practice to ensure reliability. No tantalum capacitors were found with a sufficient voltage rating to meet this requirement. When the operating temperature is below  $0^\circ\text{C}$ , the ESR of aluminum electrolytic capacitors increases. For these applications, Os-Con, poly-aluminum, and polymer-tantalum types should be considered. Adding one or two ceramic capacitors to the input attenuates high-frequency reflected ripple current.

#### TurboTrans Output Capacitor

The PTH08T220W requires a minimum output capacitance of 330- $\mu\text{F}$ . The required capacitance above 330  $\mu\text{F}$  will be determined by actual transient deviation requirements.

TurboTrans allows the designer to optimize the capacitance load according to the system transient design requirement. High quality, ultra-low ESR capacitors are required to maximize TurboTrans effectiveness. Capacitors with a capacitance ( $\mu\text{F}$ )  $\times$  ESR ( $\text{m}\Omega$ ) product of  $\leq 10,000\text{ m}\Omega \times \mu\text{F}$  are required.

Working Example:

A bank of 6 identical capacitors, each with a capacitance of 330  $\mu\text{F}$  and 5  $\text{m}\Omega$  ESR, has a  $C \times \text{ESR}$  product of 1650  $\mu\text{F} \times \text{m}\Omega$  ( $330\text{ }\mu\text{F} \times 5\text{ m}\Omega$ ).

Using TurboTrans in conjunction with the high quality capacitors (capacitance ( $\mu\text{F}$ )  $\times$  ESR ( $\text{m}\Omega$ )) reduces the overall capacitance requirement while meeting the minimum transient amplitude level.

[Table 1](#) includes a preferred list of capacitors by type and vendor. See the Output Bus / TurboTrans column.

Note: See the TurboTrans Technology Application Notes within this document for selection of specific capacitance.

#### Non-TurboTrans Output Capacitor

The PTH08T220W requires a minimum output capacitance of 330  $\mu\text{F}$ . Non-TurboTrans applications must observe minimum output capacitance ESR limits.

A combination of 200  $\mu\text{F}$  of ceramic capacitors plus low ESR (15  $\text{m}\Omega$  to 30  $\text{m}\Omega$ ) Os-Con electrolytic/tantalum type capacitors can be used. When using Polymer tantalum types, tantalum type, or Oscon types only, the capacitor ESR bank limit is 3  $\text{m}\Omega$  to 5  $\text{m}\Omega$ . (Note: no ceramic capacitors are required). This is necessary for the



## APPLICATION INFORMATION (continued)

stable operation of the regulator. Additional capacitance can be added to improve the module's performance to load transients. High quality computer-grade electrolytic capacitors are recommended. Aluminum electrolytic capacitors provide adequate decoupling over the frequency range, 2 kHz to 150 kHz, and are suitable when ambient temperatures are above -20°C. For operation below -20°C, tantalum, ceramic, or Os-Con type capacitors are necessary.

When using a combination of one or more non-ceramic capacitors, the calculated equivalent ESR should be no lower than 2 mΩ (4 mΩ when calculating using the manufacturer's maximum ESR values). A list of preferred low-ESR type capacitors, are identified in [Table 1](#).

### Ceramic Capacitors

Above 150 kHz the performance of aluminum electrolytic capacitors is less effective. Multilayer ceramic capacitors have very low ESR and a resonant frequency higher than the bandwidth of the regulator. They can be used to reduce the reflected ripple current at the input as well as improve the transient response of the output.

When used on the output their combined ESR is not critical as long as the total value of ceramic capacitors, with values between 10 μF and 100 μF, does not exceed 3000 μF (non-TurboTrans). In TurboTrans applications, when ceramic capacitors are used on the output bus, total capacitance including bulk and ceramic types is not to exceed 14,000 μF.

### Tantalum, Polymer-Tantalum Capacitors

Tantalum type capacitors are only used on the output bus, and are recommended for applications where the ambient operating temperature is less than 0°C. The AVX TPS series and Kemet capacitor series are suggested over many other tantalum types due to their higher rated surge, power dissipation, and ripple current capability. As a caution, many general-purpose tantalum capacitors have higher ESR, reduced power dissipation, and lower ripple current capability. These capacitors are also less reliable due to their reduced power dissipation and surge current ratings. Tantalum capacitors that have no stated ESR or surge current rating are not recommended for power applications.

### Capacitor Table

[Table 1](#) identifies the characteristics of capacitors from a number of vendors with acceptable ESR and ripple current (rms) ratings. The recommended number of capacitors required at both the input and output buses is identified for each capacitor type.

*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 (at 100 kHz) are critical parameters necessary to ensure both optimum regulator performance and long capacitor life.*

### Designing for Fast Load Transients

The transient response of the dc/dc converter has been characterized using a load transient with a di/dt of 2.5 A/μs. The typical voltage deviation for this load transient is given in the Electrical Characteristics table using the minimum required value of output capacitance. As the di/dt of a transient is increased, the response of a converter's regulation circuit ultimately depends on its output capacitor decoupling network. This is an inherent limitation with any dc/dc converter once the speed of the transient exceeds its bandwidth capability.

If the target application specifies a higher di/dt or lower voltage deviation, the requirement can only be met with additional low ESR ceramic capacitor decoupling. Generally, with 50% load steps at > 100 A/μs, adding multiple 10 μF ceramic capacitors plus 10 × 1 μF, including numerous high frequency ceramics (≤ 0.1 μF) are all that is required to soften the transient higher frequency edges. Special attention is essential with regards to location, types, and position of higher frequency ceramic and lower ESR bulk capacitors. DSP, FPGA and ASIC vendors identify types, location and capacitance required for optimum performance of the high frequency devices. The details regarding the PCB layout and capacitor/component placement are important at these high frequencies. Low impedance buses and unbroken PCB copper planes with components located as close to the high frequency processor are essential for optimizing transient performance. In many instances additional capacitors may be required to insure and minimize transient aberrations.

**APPLICATION INFORMATION (continued)****Table 1. Input/Output Capacitors<sup>(1)</sup>**

Capacitor Vendor, Type Series (Style)	Capacitor Characteristics					Quantity			Vendor Part No.
	Working Voltage	Value (μF)	Max. ESR at 100 kHz	Max Ripple Current at 85°C (Irms)	Physical Size (mm)	Input Bus	Output Bus		
							No TurboTrans	TurboTrans (Cap Type) <sup>(2)</sup>	
Panasonic	25 V	1000	0.043Ω	>1690 mA	16 × 15	1	≥ 2 <sup>(3)</sup>	N/R <sup>(4)</sup>	EEUFC1E102S
FC (Radial)	25 V	820	0.038Ω	1655 mA	12 × 20	1	≥ 1 <sup>(3)</sup>	N/R <sup>(4)</sup>	EEUFC1E821S
FC(SMD)	35 V	470	0.043Ω	>1690mA	16 × 16,5	1	≥ 1 <sup>(3)</sup>	N/R <sup>(4)</sup>	EEVFC1V471N
FK(SMD)	35 V	1000	0.035Ω	1800 mA	16 × 16,5	1	≥ 2 <sup>(5)</sup>	N/R <sup>(4)</sup>	EEVFK1V102M
United Chemi-Con									
PTB(SMD) Polymer Tantalum	6.3 V	330	0.025Ω	2600 mA	7,3x 4,3x 2.8	N/R <sup>(6)</sup>	≥ 1 ~ ≤ 4 <sup>(3)</sup>	C ≥ 2 <sup>(2)</sup>	4PTB337MD6TER (V <sub>i</sub> :V <sub>o</sub> ≥5.1V) <sup>(7)</sup>
LXZ, Aluminum (Radial)	35 V	680	0.038Ω	1660 mA	12,5 × 20	1	≥ 1 ~ ≤ 3 <sup>(3)</sup>	N/R <sup>(4)</sup>	LXZ35VB681M12X20LL
PS, Poly-Aluminum(Radial)	16 V	330	0.014Ω	5060 mA	10 × 12,5	1	≥ 1 ~ ≤ 3	B ≥ 2 <sup>(2)</sup>	16PS330MJ12
PXA, Poly-Aluminum (SMD)	16 V	330	0.014Ω	5050 mA	10 × 12,2	1	≥ 1 ~ ≤ 3	B ≥ 2 <sup>(2)</sup>	PXA16VC331MJ12TP
PS, Poly-Aluminum(Radial)	6.3 V	390	0.012Ω	5500 mA	80 × 112,5	N/R <sup>(6)</sup>	≥ 1 ~ ≤ 2	B ≥ 1 <sup>(2)</sup>	6PS390MH11 (V <sub>i</sub> :V <sub>o</sub> ≥5.1V) <sup>(7)</sup>
PXA, Poly-Aluminum(Radial)	10 V	330	0.014Ω	4420 mA	8 × 12,2	N/R <sup>(6)</sup>	≥ 1 ~ ≤ 2	B ≥ 1 <sup>(2)</sup>	PXA10VC331MH12 (V <sub>i</sub> :V <sub>o</sub> ≥5.5V) <sup>(7)</sup>
Nichicon, Aluminum	25 V	1000	0.043Ω	1520 mA	18 × 15	1	≥ 2 <sup>(3)</sup>	N/R <sup>(4)</sup>	UPM1E102MHH6
HD (Radial)	35 V	470	0.023Ω	1820 mA	10 × 20	1	≥ 2 <sup>(3)</sup>	N/R <sup>(4)</sup>	UHD1V471HR
Panasonic, Poly-Aluminum:	2.0 V	390	0.005Ω	4000 mA	7,3 L×4,3 W ×4,2H	N/R <sup>(6)</sup>	N/R <sup>(6)</sup>	B ≥ 2 <sup>(2)</sup>	EEFSE0J391R(V <sub>o</sub> ≤1.6V) <sup>(8)</sup>

**(1) Capacitor Supplier Verification**

Please verify availability of capacitors identified in this table. Capacitor suppliers may recommend alternative part numbers because of limited availability or obsolete products. In some instances, the capacitor product life cycle may be in decline and have short-term consideration for obsolescence.

**RoHS, Lead-free and Material Details**

See the capacitor suppliers regarding material composition, RoHS status, lead-free status, and manufacturing process requirements. Component designators or part number deviations can occur when material composition or soldering requirements are updated.

**(2) Required capacitors with TurboTrans. See the TransTrans Application information for Capacitor Selection Capacitor Type Groups by ESR (Equivalent Series Resistance) :**

- Type A = (100 < capacitance × ESR ≤ 1000)
- Type B = (1,000 < capacitance × ESR ≤ 5,000)
- Type C = (5,001 < capacitance × ESR ≤ 10,000)

**(3) Total bulk nonceramic capacitors on the output bus with ESR of ≥ 15mΩ to ≤ 30mΩ requires an additional ≥ 200 μF of ceramic capacitor.****(4) Aluminum Electrolytic capacitor not recommended for the TurboTrans due to higher ESR × capacitance products. Aluminum and higher ESR capacitors can be used in conjunction with lower ESR capacitance.****(5) Output bulk capacitor's maximum ESR is ≥ 30 mΩ. Additional ceramic capacitance of ≥ 200 μF is required.****(6) N/R – Not recommended. The voltage rating does not meet the minimum operating limits.****(7) The voltage rating and derating of this capacitor only allows it to be used for voltages that are equal to or less than 5.1 V.****(8) The voltage rating of this capacitor only allows it to be used for output voltage that is equal to or less than 80% of the working voltage.**

**APPLICATION INFORMATION (continued)**

**Table 1. Input/Output Capacitors (continued)**

Capacitor Vendor, Type Series (Style)	Capacitor Characteristics					Quantity			Vendor Part No.
	Working Voltage	Value (µF)	Max. ESR at 100 kHz	Max Ripple Current at 85°C (Irms)	Physical Size (mm)	Input Bus	Output Bus		
							No TurboTrans	TurboTrans (Cap Type) <sup>(2)</sup>	
Sanyo									
TPE, Poscap (SMD)	10V	330	0.025Ω	3300 mA	7,3 × 4,3	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 3	C ≥ 1 <sup>(10)</sup>	10TPE330MF (V <sub>O</sub> ≤ 5 V) <sup>(11)</sup>
TPE Poscap(SMD)	2.5 V	470	0.007Ω	4400 mA	7,3 × 4,3	N/R <sup>(9)</sup>	≥ 1 ≤ 2	B ≥ 2 <sup>(10)</sup>	2R5TPE470M7(V <sub>O</sub> ≤ 1.8 V) <sup>(11)</sup>
TPD Poscap (SMD)	2.5 V	1000	0.005Ω	6100 mA	7,3 × 4,3	N/R <sup>(9)</sup>	≤ 1	B ≥ 1 <sup>(10)</sup>	2R5TPD1000M5(V <sub>O</sub> ≤ 1.8 V) <sup>(11)</sup>
SEP, Os-Con (Radial)	16 V	330	0.016Ω	>4700 mA	10 × 13	1	≥ 1 ~ ≤ 2	B ≥ 1 <sup>(10)</sup>	16SEP330M
SEPC, Os-Con (Radial)	16 V	470	0.010Ω	6100 mA	10 × 13	1	≥ 1 ~ ≤ 2	B ≥ 2 <sup>(10)</sup>	16SEPC470M
SVP, Os-Con (SMD)	16 V	330	0.016Ω	4700mA	10 × 12,6	1	≥ 1 ~ ≤ 2 <sup>(12)</sup>	B ≥ 1 <sup>(10)(12)</sup>	16SVP330M
AVX, Tantalum, Series III	10 V	330	0.040Ω	>18280	7,3 L	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 6 <sup>(12)</sup>	N/R <sup>(13)</sup>	TPSE337M010R0040 (V <sub>O</sub> ≤ 5 V) <sup>(11)</sup>
TPM Multianode	10 V	330	0.023Ω	mA	× 4,3 W	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 3 <sup>(12)</sup>	C ≥ 2 <sup>(10)(12)</sup>	TPME337M010#0035
				>3000 mA	× 4,1 H				
TPS Series III (SMD)	4 V	1000	0.035Ω	2405	7,3 L × 5,7 W	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 5 <sup>(12)</sup>	N/R <sup>(13)</sup>	TPSV108K004R0035 (V <sub>O</sub> ≤ 2.1 V) <sup>(11)</sup>
Kemet, Poly-Tantalum	10 V	330	0.025Ω	2600 mA	4,3 W	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 3 <sup>(12)</sup>	C ≥ 2 <sup>(10)</sup>	T520X337M010ASE025 (V <sub>i</sub> :V <sub>O</sub> ≥5.1V) <sup>(14)</sup>
T520 (SMD)	6.3 V	330	0.015Ω	>3800 mA	× 7,3 L	N/R <sup>(9)</sup>	≥ 2 ~ ≤ 3	B ≥ 2 <sup>(10)</sup>	T530X337M010ASE015 (V <sub>i</sub> :V <sub>O</sub> ≥5.1V) <sup>(14)</sup>
T530 (SMD)	4 V	680	0.005Ω	7300 mA	× 4 H	N/R <sup>(9)</sup>	≤ 1	B ≥ 1 <sup>(10)</sup>	T530X687M004ASE005 (V <sub>O</sub> ≤ 3.5 V) <sup>(11)</sup>
T530 (SMD)	2.5 V	1000	0.005Ω	7300 mA	4,3 w × 7,3 L	N/R <sup>(9)</sup>	≤ 1	B ≥ 1 <sup>(10)</sup>	T530X108M2R5ASE005 (V <sub>O</sub> ≤ 2.0 V) <sup>(11)</sup>
Vishay-Sprague									
597D, Tantalum (SMD)	10V	330	0.035Ω	2500 mA	7,3L × 5,7 W × 4,1H	N/R <sup>(9)</sup>	≥ 1 ~ ≤ 5	N/R <sup>(13)</sup>	597D337X010E2T
94SA, Os-con (Radial)	16 V	470	0.020Ω	6080 mA	12 × 22	1	≥ 1 ~ ≤ 3	C ≥ 2 <sup>(10)</sup>	94SA477X0016GBP
94SVP Os-Con(SMD)	16 V	330	0.017Ω	>4500 mA	10 × 12,7	2	≥ 2 ~ ≤ 3	C ≥ 1 <sup>(10)</sup>	94SVP337X06F12
Kemet, Ceramic X5R (SMD)	16 V	10	0.002Ω	–	3225	1	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C1210C106M4PAC
	6.3 V	47	0.002Ω	–		N/R <sup>(9)</sup>	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C1210C476K9PAC
Murata, Ceramic X5R (SMD)	6.3 V	100	0.002Ω	–	3225	N/R <sup>(9)</sup>	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	GRM32ER60J107M
	6.3 V	47				N/R <sup>(9)</sup>	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	GRM32ER60J476M
	25 V	22				1	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	GRM32ER61E226K
	16 V	10				1	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	GRM32DR61C106K
TDK, Ceramic X5R (SMD)	6.3 V	100	0.002Ω	–	3225	N/R <sup>(9)</sup>	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C3225X5R0J107MT
	6.3 V	47				N/R <sup>(9)</sup>	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C3225X5R0J476MT
	16 V	10				1	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C3225X5R1C106MT0
	16 V	22				1	≥ 1 <sup>(15)</sup>	A <sup>(10)</sup>	C3225X5R1C226MT

(9) N/R – Not recommended. The voltage rating does not meet the minimum operating limits.

(10) Required capacitors with TurboTrans. See the TransTrans Application information for Capacitor Selection Capacitor Type Groups by ESR (Equivalent Series Resistance) :

- Type A = (100 < capacitance × ESR ≤ 1000)
- Type B = (1,000 < capacitance × ESR ≤ 5,000)
- Type C = (5,001 < capacitance × ESR ≤ 10,000)

(11) The voltage rating of this capacitor only allows it to be used for output voltage that is equal to or less than 80% of the working voltage.

(12) Total bulk nonceramic capacitors on the output bus with ESR of ≥ 15mΩ to ≤ 30mΩ requires an additional ≥ 200 µF of ceramic capacitor.

(13) Aluminum Electrolytic capacitor not recommended for the TurboTrans due to higher ESR × capacitance products. Aluminum and higher ESR capacitors can be used in conjunction with lower ESR capacitance.

(14) The voltage rating and derating of this capacitor only allows it to be used for voltages that are equal to or less than 5.1 V.

(15) Maximum ceramic capacitance on the output bus is ≤ 3000 µF. Any combination of the ceramic capacitor values is limited to 3000 µF for non-TurboTrans applications. The total capacitance is limited to 14,000 µF which includes all ceramic and non-ceramic types.

## TurboTrans™ Technology

TurboTrans technology is a feature introduced in the T2 generation of the PTH/PTV family of power modules. TurboTrans optimizes the transient response of the regulator with added external capacitance using a single external resistor. Benefits of this technology include reduced output capacitance, minimized output voltage deviation following a load transient, and enhanced stability when using ultra-low ESR output capacitors. The amount of output capacitance required to meet a target output voltage deviation will be reduced with TurboTrans activated. Likewise, for a given amount of output capacitance, with TurboTrans engaged, the amplitude of the voltage deviation following a load transient will be reduced. Applications requiring tight transient voltage tolerances and minimized capacitor footprint area will benefit greatly from this technology.

## TurboTrans™ Selection

Utilizing TurboTrans requires connecting a resistor,  $R_{TT}$ , between the +Sense pin (pin 6) and the TurboTrans pin (pin 9). The value of the resistor directly corresponds to the amount of output capacitance required. All T2 products require a minimum value of output capacitance whether or not TurboTrans is utilized. For the PTH08T220W, the minimum required capacitance is 220  $\mu\text{F}$ . When using TurboTrans, capacitors with a capacitance  $\times$  ESR product below 10,000  $\mu\text{F}\times\text{m}\Omega$  are required. (Multiply the capacitance (in  $\mu\text{F}$ ) by the ESR (in  $\text{m}\Omega$ ) to determine the capacitance  $\times$  ESR product.) See the Capacitor Selection section of the datasheet for a variety of capacitors that meet this criteria.

Figure 9 thru Figure 13 show the amount of output capacitance required to meet a desired transient voltage deviation with and without TurboTrans for several capacitor types; Type A (e.g. ceramic), Type B (e.g. polymer-tantalum), and Type C (e.g. OS-CON). To calculate the proper value of  $R_{TT}$ , first determine your required transient voltage deviation limits and magnitude of your transient load step. Next, determine what type of output capacitors will be used. (If more than one type of output capacitor is used, select the capacitor type that makes up the majority of your total output capacitance.) Knowing this information, use the chart in Figure 9 thru Figure 13 that corresponds to the capacitor type selected. To use the chart, begin by dividing the maximum voltage deviation limit (in mV) by the magnitude of your load step (in Amps). This gives a mV/A value. Find this value on the Y-axis of the appropriate chart. Read across the graph to the 'With TurboTrans' plot. From this point, read down to the X-axis which lists the minimum required capacitance,  $C_O$ , to meet that transient voltage deviation. The required  $R_{TT}$  resistor value can then be calculated using the equation or selected from the TurboTrans table. The TurboTrans tables include both the required output capacitance and the corresponding  $R_{TT}$  values to meet several values of transient voltage deviation for 25% (4 A), 50% (8 A), and 75% (12 A) output load steps.

The chart can also be used to determine the achievable transient voltage deviation for a given amount of output capacitance. Selecting the amount of output capacitance along the X-axis, reading up to the 'With TurboTrans' curve, and then over to the Y-axis, gives the transient voltage deviation limit for that value of output capacitance. The required  $R_{TT}$  resistor value can be calculated using the equation or selected from the TurboTrans table.

As an example, let's look at a 12-V application requiring a 40 mV deviation during an 8 A, 50% load transient. A majority of 330  $\mu\text{F}$ , 10  $\text{m}\Omega$  output capacitors will be used. Use the 12 V, Type B capacitor chart, Figure 10. Dividing 40 mV by 8 A gives 5 mV/A transient voltage deviation per amp of transient load step. Select 5 mV/A on the Y-axis and read across to the 'With TurboTrans' plot. Following this point down to the X-axis gives us a minimum required output capacitance of approximately 8000  $\mu\text{F}$ . The required  $R_{TT}$  resistor value for 8000  $\mu\text{F}$  can then be calculated or selected from Table 3. The required  $R_{TT}$  resistor is approximately 4.12 k $\Omega$ .

To see the benefit of TurboTrans, follow the 5 mV/A marking across to the 'Without TurboTrans' plot. Following that point down shows that you would need a minimum of 4500  $\mu\text{F}$  of output capacitance to meet the same transient deviation limit. This is the benefit of TurboTrans. A typical TurboTrans schematic and waveforms are shown in Figure 14 and Figure 15.

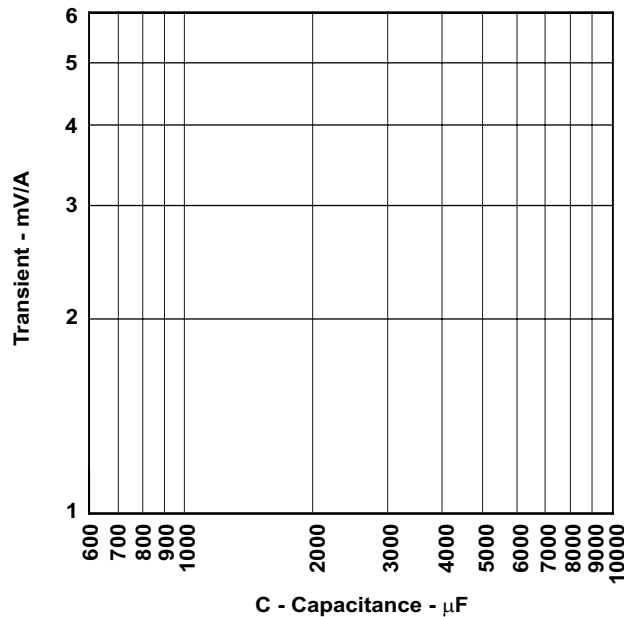


Figure 9.

Table 2. Type A TurboTrans  $C_O$  Values and Required  $R_{TT}$  Selection Table

Transient Voltage Deviation (mV)			$C_O$ Minimum Required Output Capacitance ( $\mu\text{F}$ )	$R_{TT}$ Required TurboTrans Resistor ( $\Omega$ )
25% load step (4 A)	50% load step (8 A)	75% load step (12 A)		
tbd	tbd	tbd	tbd	open
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd
tbd	tbd	tbd	tbd	tbd

**$R_{TT}$  Resistor Selection**

The TurboTrans resistor value,  $R_{TT}$  can be determined from the TurboTrans programming, see [Equation 1](#)

$$R_{TT} = 40 \times \frac{[1 - (C_O/1100)]}{[(5 \times C_O/1100) - 1]} \tag{1}$$

Where  $R_{TT}$  is the resistance value in  $k\Omega$  and  $C_O$  is the total output capacitance in  $\mu\text{F}$ .  $C_O$  values greater than or equal to 1100  $\mu\text{F}$  require  $R_{TT}$  to be a short,  $0\Omega$ .

To ensure stability, a minimum amount of output capacitance is required for a given  $R_{TT}$  resistor value. The value of  $R_{TT}$  must be calculated using the minimum required output capacitance determined from the capacitor transient response charts above.

PRODUCT PREVIEW

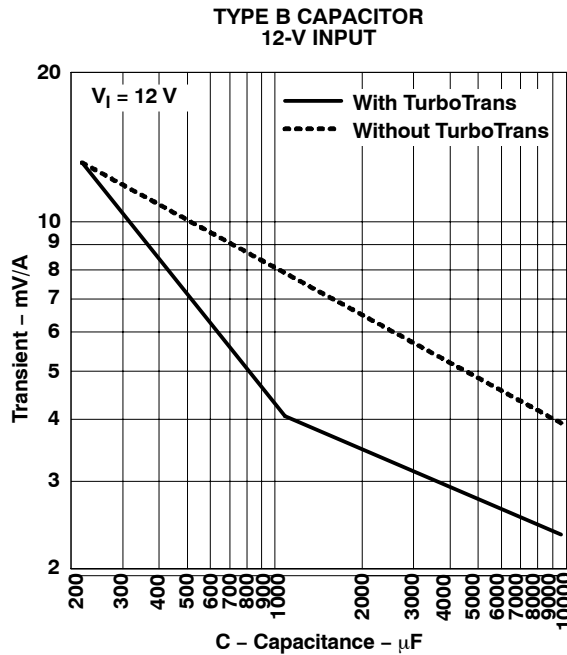


Figure 10. Cap Type B,  $1000 \leq C(\mu\text{F}) \times \text{ESR}(\text{m}\Omega) \leq 5000$  (e.g. Polymer-Tantalum)

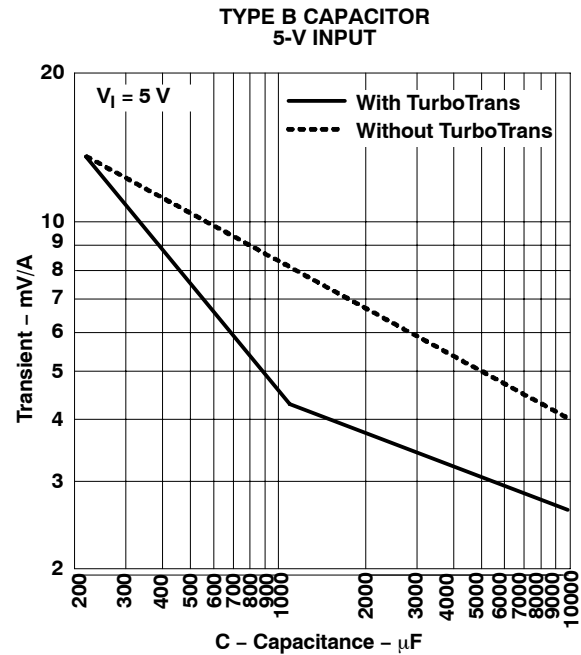


Figure 11. Cap Type B,  $1000 \leq C(\mu\text{F}) \times \text{ESR}(\text{m}\Omega) \leq 5000$  (e.g. Polymer-Tantalum)

Table 3. Type B TurboTrans  $C_O$  Values and Required  $R_{TT}$  Selection Table

Transient Voltage Deviation (mV)			12 Volt Input		5 Volt Input	
25% load step (4 A)	50% load step (8 A)	75% load step (12 A)	$C_O$ Minimum Required Output Capacitance ( $\mu\text{F}$ )	$R_{TT}$ Required TurboTrans Resistor ( $\text{k}\Omega$ )	$C_O$ Minimum Required Output Capacitance ( $\mu\text{F}$ )	$R_{TT}$ Required TurboTrans Resistor ( $\text{k}\Omega$ )
65	125	190	220	open	220	open
50	100	150	270	132	270	132
40	80	120	330	56	330	56
30	60	90	470	20.5	500	17.4
25	50	75	600	10.5	650	8.25
20	40	60	800	4.12	900	2.32
15	30	45	1500 <sup>(1)</sup>	short	1700 <sup>(1)</sup>	short
10	20	30	7000 <sup>(1)</sup>	short	10000 <sup>(1)</sup>	short

(1) The total capacitance must include at least 300  $\mu\text{F}$  of large value ( $> 47 \mu\text{F}$  each) ceramic capacitance (Type A).

**$R_{TT}$  Resistor Selection**

The TurboTrans resistor value,  $R_{TT}$  can be determined from the TurboTrans programming, see Equation 2.

$$R_{TT} = 40 \times \frac{[1 - (C_O/1100)]}{[(5 \times C_O/1100) - 1]} \tag{2}$$

Where  $R_{TT}$  is the resistance value in  $\text{k}\Omega$  and  $C_O$  is the total output capacitance in  $\mu\text{F}$ .  $C_O$  values greater than or equal to 1100  $\mu\text{F}$  require  $R_{TT}$  to be a short, 0 $\Omega$ .

To ensure stability, a minimum amount of output capacitance is required for a given  $R_{TT}$  resistor value. The value of  $R_{TT}$  must be calculated using the minimum required output capacitance determined from the capacitor transient response charts above.

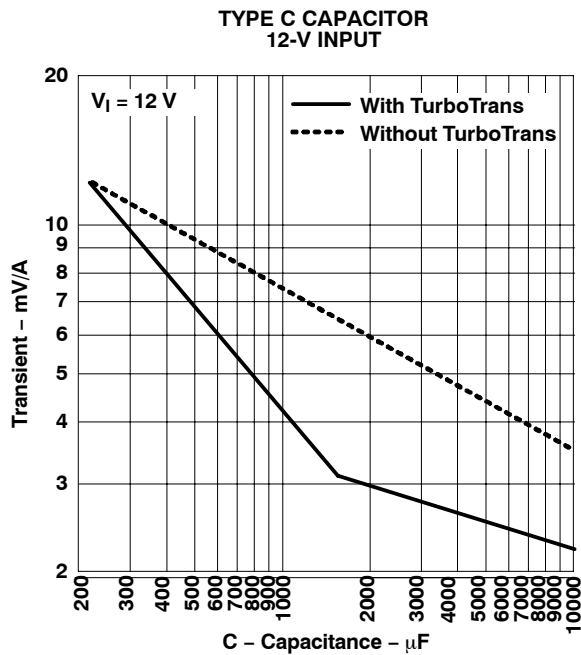


Figure 12. Cap Type C,  $5000 \leq C(\mu\text{F}) \times \text{ESR}(\text{m}\Omega) \leq 10,000$  (e.g. Os-Con)

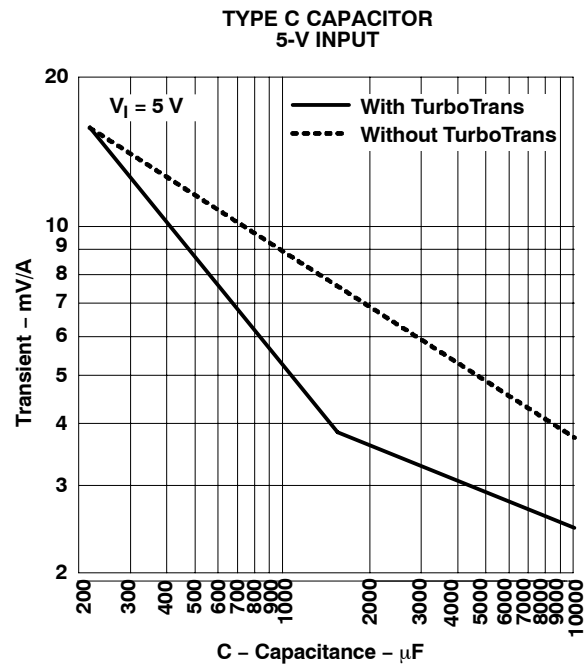


Figure 13. Cap Type C,  $5000 \leq C(\mu\text{F}) \times \text{ESR}(\text{m}\Omega) \leq 10,000$  (e.g. Os-Con)

Table 4. Type C TurboTrans  $C_O$  Values and Required  $R_{TT}$  Selection Table

Transient Voltage Deviation (mV)			12 Volt Input		5 Volt Input	
25% Load Step (8 A)	50% Load Step (8 A)	75% Load Step (12 A)	$C_O$ Minimum Required Output Capacitance ( $\mu\text{F}$ )	$R_{TT}$ Required TurboTrans Resistor ( $\text{k}\Omega$ )	$C_O$ Minimum Required Output Capacitance ( $\mu\text{F}$ )	$R_{TT}$ Required TurboTrans Resistor ( $\text{k}\Omega$ )
65	125	190	220	open	220	open
50	100	150	270	205	330	88.7
40	80	120	330	88.7	550	23.7
30	60	90	470	34.0	630	17.8
25	50	75	600	19.6	800	10.2
20	40	60	800	10.2	1150	3.32
15	30	45	1300 <sup>(1)</sup>	1.78	1700 <sup>(1)</sup>	short
10	20	30	7500 <sup>(1)</sup>	short	10000 <sup>(1)</sup>	short

(1) The total amount must include at least 300  $\mu\text{F}$  of large component value ( $> 47 \mu\text{F}$  each) ceramic capacitance (Type A).

### $R_{TT}$ Resistor Selection

The TurboTrans resistor value,  $R_{TT}$  can be determined from the TurboTrans programming, see Equation 3 .

$$R_{TT} = 40 \times \frac{[1 - (C_O/1540)]}{[(5 \times C_O/1540) - 0.714]} \quad (3)$$

Where  $R_{TT}$  is the resistance value in  $\text{k}\Omega$  and  $C_O$  is the total output capacitance in  $\mu\text{F}$ .  $C_O$  values greater than or equal to 1540  $\mu\text{F}$  require  $R_{TT}$  to be a short,  $0\Omega$ .

To ensure stability, a minimum amount of output capacitance is required for a given  $R_{TT}$  resistor value. The value of  $R_{TT}$  must be calculated using the minimum required output capacitance determined from the capacitor transient response charts above.

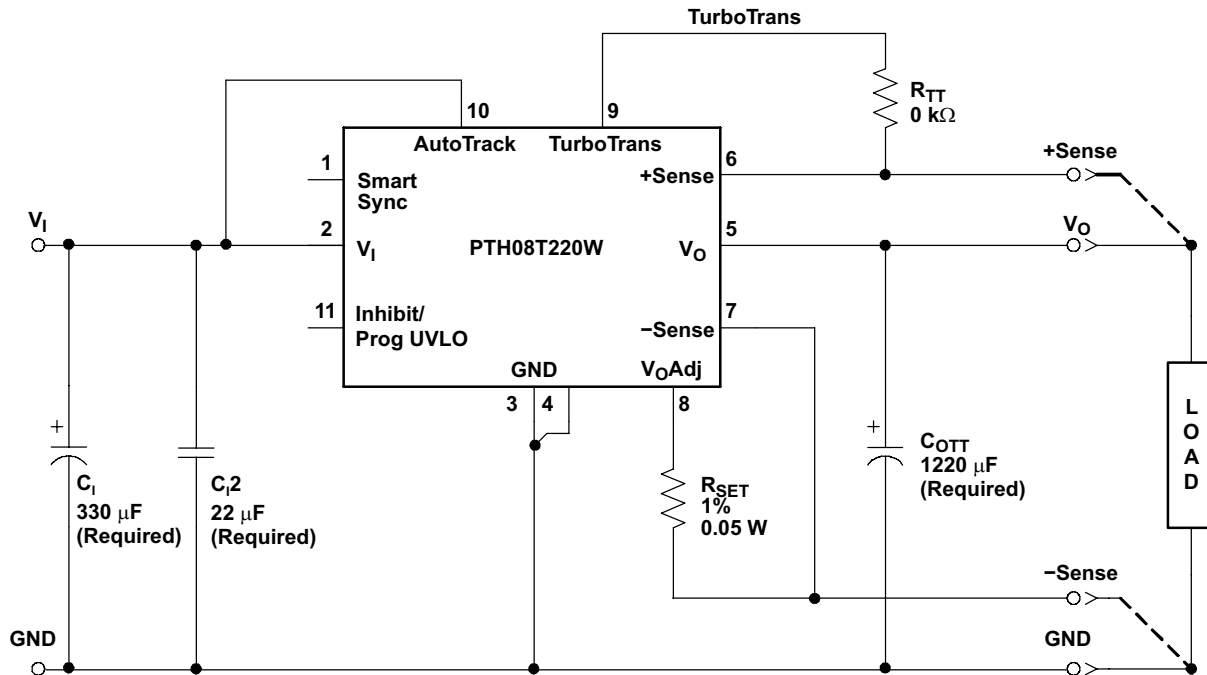


Figure 14. TurboTrans™ with Minimum Capacitance Requirement

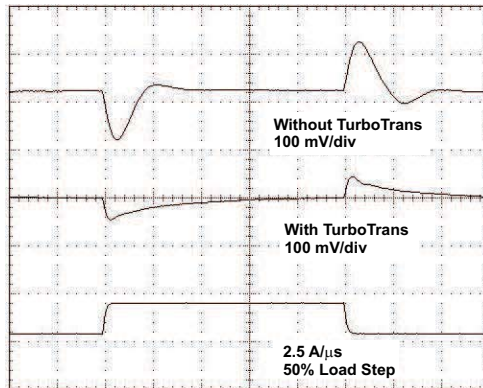


Figure 15. TurboTrans Waveform

### ADJUSTING THE OUTPUT VOLTAGE OF THE PTH08T220W WIDE-OUTPUT ADJUST POWER MODULE

The  $V_o$  Adjust control (pin 8) sets the output voltage of the PTH08T220W. The adjustment range of the PTH08T220W is 0.7 V to 5.5 V. The adjustment method requires the addition of a single external resistor,  $R_{SET}$ , that must be connected directly between the  $V_o$  Adjust and –Sense pins. Table 5 gives the preferred value of the external resistor for a number of standard voltages, along with the actual output voltage that this resistance value provides.

For other output voltages, the value of the required resistor can either be calculated using the following formula, or simply selected from the range of values given in Table 6. Figure 16 shows the placement of the required resistor.

$$R_{SET} = 10 \text{ k}\Omega \times \frac{0.69}{V_o - 0.69} - 1.43 \text{ k}\Omega$$

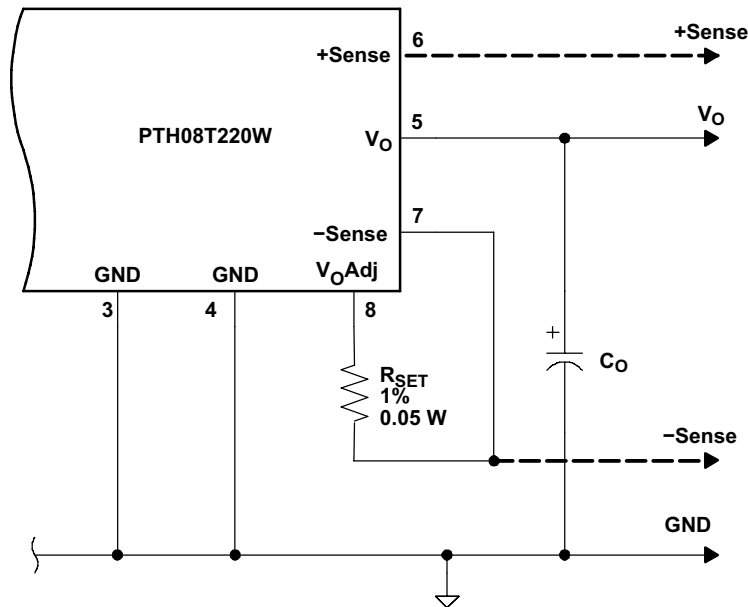
(4)



**Table 5. Preferred Values of  $R_{SET}$  for Standard Output Voltages**

$V_O$ (Standard)	$R_{SET}$ (Preferred Value)	$V_O$ (Actual)
5.0 V <sup>(1)</sup>	171 $\Omega$	5.000 V
3.3 V	1.21 k $\Omega$	3.304 V
2.5 V	2.37 k $\Omega$	2.506 V
1.8 V	4.78 k $\Omega$	1.801 V
1.5 V	7.06 k $\Omega$	1.503 V
1.2 V	12.1 k $\Omega$	1.200 V
1.0 V	20.5 k $\Omega$	1.005 V
0.7 V	681 k $\Omega$	0.700 V

(1) The minimum input voltage is  $(V_O + 2)$  V.



- (1) Use a 0.1 W resistor. The tolerance should be 1%, with temperature stability of 100 ppm/ $^{\circ}$ C (or better). Place the resistor as close to the regulator as possible. Connect the resistor directly between pins 8 and 7 using dedicated PCB traces.
- (2) Never connect capacitors from  $V_O$  Adjust to either + Sense, GND, or  $V_{out}$ . Any capacitance added to the  $V_O$  Adjust pin affects the stability of the regulator.

**Figure 16.  $V_O$  Adjust Resistor Placement**

**Table 6. Output Voltage Set-Point Resistor Values**

$V_a$ Required	$R_{SET}$	$V_a$ Required	$R_{SET}$
0.700	681 k $\Omega$	1.950	4.05 k $\Omega$
0.750	113 k $\Omega$	2.100	3.46 k $\Omega$
0.800	61.3 k $\Omega$	2.250	2.99 k $\Omega$
0.850	41.7 k $\Omega$	2.400	2.61 k $\Omega$
0.900	31.4 k $\Omega$	2.500	2.38 k $\Omega$
0.950	25.1 k $\Omega$	2.700	2.00 k $\Omega$
1.000	20.8 k $\Omega$	2.850	1.76 k $\Omega$
1.050	17.8 k $\Omega$	3.000	1.56 k $\Omega$
1.100	15.4 k $\Omega$	3.150	1.38 k $\Omega$
1.150	13.6 k $\Omega$	3.300	1.21 k $\Omega$
1.200	12.1 k $\Omega$	3.450	1.07 k $\Omega$
1.250	10.9 k $\Omega$	3.600	941 $\Omega$
1.300	9.88 k $\Omega$	3.750	825 $\Omega$
1.350	9.03 k $\Omega$	3.900	720 $\Omega$
1.400	8.29 k $\Omega$	4.100	593 $\Omega$
1.450	7.65 k $\Omega$	4.200	536 $\Omega$
1.500	7.09 k $\Omega$	4.350	455 $\Omega$
1.550	6.59 k $\Omega$	4.500	381 $\Omega$
1.600	6.15 k $\Omega$	4.650	312 $\Omega$
1.650	5.76 k $\Omega$	4.800	249 $\Omega$
1.700	5.40 k $\Omega$	5.000	171 $\Omega$
1.750	5.08 k $\Omega$	5.100	135 $\Omega$
1.800	4.78 k $\Omega$	5.250	83 $\Omega$
1.850	4.52 k $\Omega$	5.400	35 $\Omega$
1.900	4.27 k $\Omega$	5.500	5 $\Omega$

## ADJUSTING THE UNDERVOLTAGE LOCKOUT (UVLO) OF THE PTH08T220W POWER MODULES

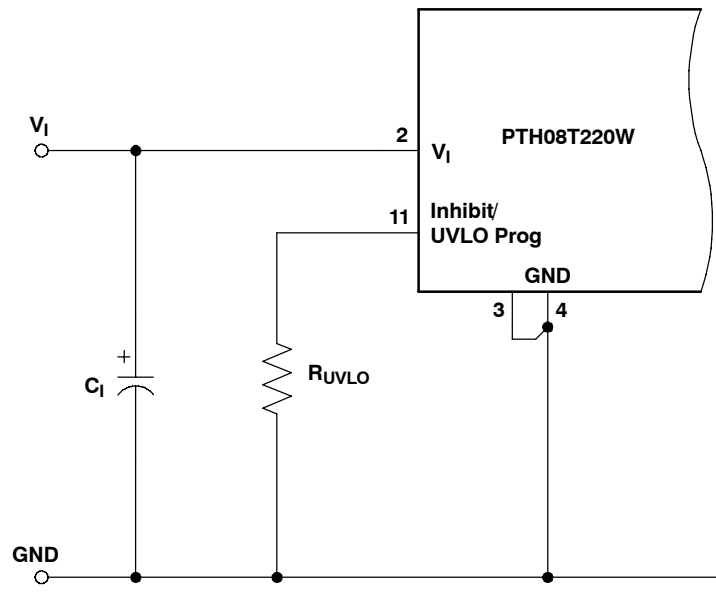
The PTH08T220W power modules incorporate an input undervoltage lockout (UVLO). The UVLO feature prevents the operation of the module until there is sufficient input voltage to produce a valid output voltage. This enables the module to provide a clean, monotonic powerup for the load circuit, and also limits the magnitude of current drawn from the regulator's input source during the power-up sequence.

The UVLO characteristic is defined by the ON threshold ( $V_{THD}$ ) voltage. Below the ON threshold, the Inhibit control is overridden, and the module does not produce an output. The hysteresis voltage, which is the difference between the ON and OFF threshold voltages, is set at 600 mV. The hysteresis prevents start-up oscillations, which can occur if the input voltage droops slightly when the module begins drawing current from the input source.

### UVLO Adjustment

The UVLO feature of the PTH08T220W module allows for limited adjustment of the on threshold voltage. The adjustment is made via the *Inhibit/UVLO Prog* control pin (pin 11). When pin 11 is left open circuit, the ON threshold voltage is internally set to its default value, which is 4.3 volts. When the ON threshold is adjusted higher than 5 volts, the default hysteresis setting is 500 mV. This ensures that the module produces a regulated output when the minimum input voltage is applied (see specifications).

The ON threshold might need to be raised if the module is powered from a tightly regulated 12-V bus. This prevents it from operating if the input bus fails to completely rise to its specified regulation voltage.



**Figure 17. Undervoltage Lockout Adjustment Resistor Placement**

Equation 5 determines the value of  $R_{THD}$  required to adjust  $V_{THD}$  to a new value. The default value is 4.3 V, and it may only be adjusted to a higher value.

$$R_{UVLO} = 1 \text{ k}\Omega \times \frac{27.4 \times (V_I - 1.332) - (1.888 \times 1 \text{ k}\Omega)}{103 - (27.4 \times V_I)} \quad (5)$$

### Calculated Values

Table 7 shows a chart of standard resistor values for  $R_{UVLO}$  for different options of the on-threshold ( $V_{THD}$ ) voltage. For most applications, only the on-threshold voltage should need to be adjusted. In this case select only a value for  $R_{UVLO}$  from right-hand column.

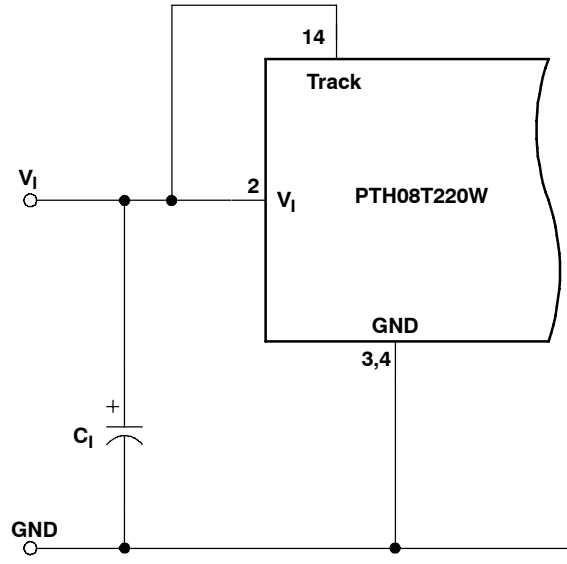
**Table 7. Calculated Values of  $R_{UVLO}$  for Various Values of  $V_{THD}$**

$V_{THD}$	$R_{UVLO}$
7.0 V	23.2 k $\Omega$
7.5 V	19.6 k $\Omega$
8.0 V	16.9 k $\Omega$
8.5 V	14.7 k $\Omega$
9.0 V	13.0 k $\Omega$
9.5 V	11.8 k $\Omega$
10.0 V	10.5 k $\Omega$
10.5 V	9.76 k $\Omega$
11.0 V	8.87 k $\Omega$

**FEATURES OF THE PTH/PTV FAMILY OF NONISOLATED WIDE OUTPUT ADJUST POWER MODULES**

**Soft-Start Power Up**

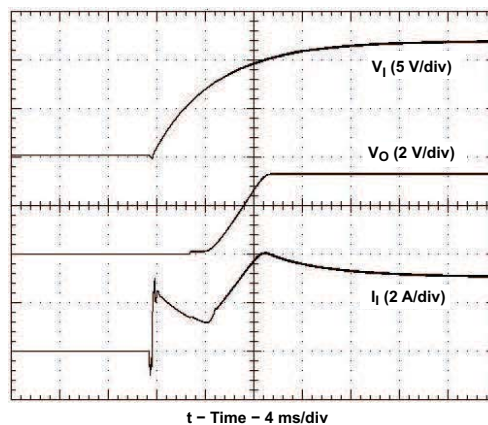
The Auto-Track feature allows the power-up of multiple PTH/PTV modules to be directly controlled from the Track pin. However in a stand-alone configuration, or when the Auto-Track feature is not being used, the Track pin should be directly connected to the input voltage,  $V_I$  (see Figure 18).



**Figure 18. Track Pin Connection**

When the Track pin is connected to the input voltage the Auto-Track function is permanently disengaged. This allows the module to power up entirely under the control of its internal soft-start circuitry. When power up is under soft-start control, the output voltage rises to the set-point at a quicker and more linear rate.

From the moment a valid input voltage is applied, the soft-start control introduces a short time delay (typically 8 ms–15 ms) before allowing the output voltage to rise.



**Figure 19. Power-Up Waveform**

The output then progressively rises to the module’s setpoint voltage. Figure 19 shows the soft-start power-up characteristic of the PTH08T220W operating from a 12-V input bus and configured for a 3.3-V output. The waveforms were measured with a 16-A constant current load and the Auto-Track feature disabled. The initial rise in input current when the input voltage first starts to rise is the charge current drawn by the input capacitors. Power-up is complete within 15 ms.

### Overcurrent Protection

For protection against load faults, all modules incorporate output overcurrent protection. Applying a load that exceeds the regulator's overcurrent threshold causes the regulated output to shut down. Following shutdown, the module periodically attempts to recover by initiating a soft-start power-up. This is described as a *hiccup* mode of operation, whereby the module continues in a cycle of successive shutdown and power up until the load fault is removed. During this period, the average current flowing into the fault is significantly reduced. Once the fault is removed, the module automatically recovers and returns to normal operation.

### Overtemperature Protection (OTP)

A thermal shutdown mechanism protects the module's internal circuitry against excessively high temperatures. A rise in the internal temperature may be the result of a drop in airflow, or a high ambient temperature. If the internal temperature exceeds the OTP threshold, the module's Inhibit control is internally pulled low. This turns the output off. The output voltage drops as the external output capacitors are discharged by the load circuit. The recovery is automatic, and begins with a soft-start power up. It occurs when the sensed temperature decreases by about 10°C below the trip point.

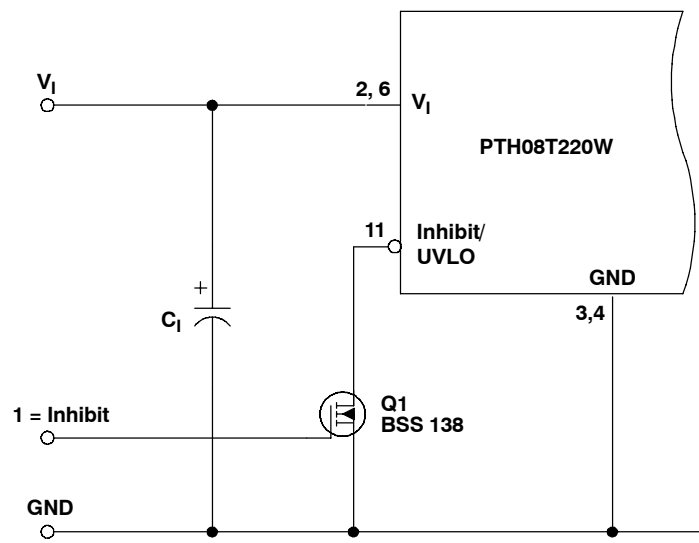
*The overtemperature protection is a last resort mechanism to prevent thermal stress to the regulator. Operation at or close to the thermal shutdown temperature is not recommended and reduces the long-term reliability of the module. Always operate the regulator within the specified safe operating area (SOA) limits for the worst-case conditions of ambient temperature and airflow.*

### On/Off Inhibit

For applications requiring output voltage on/off control, the PTH08T220W incorporates an Inhibit control pin. The inhibit feature can be used wherever there is a requirement for the output voltage from the regulator to be turned off.

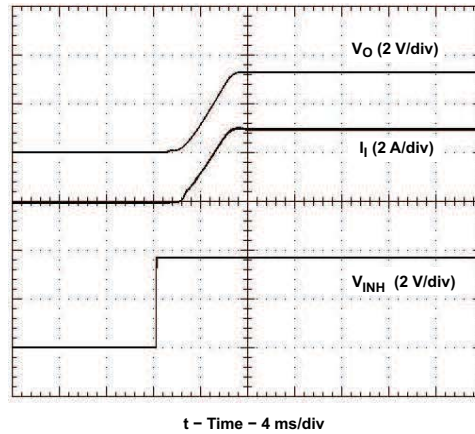
The power modules function normally when the Inhibit pin is left open-circuit, providing a regulated output whenever a valid source voltage is connected to  $V_I$  with respect to GND.

Figure 20 shows the typical application of the inhibit function. Note the discrete transistor (Q1). The Inhibit input has its own internal pull-up. An external pull-up resistor should never be used with the inhibit pin. The input is not compatible with TTL logic devices. An open-collector (or open-drain) discrete transistor is recommended for control.



**Figure 20. On/Off Inhibit Control Circuit**

Turning Q1 on applies a low voltage to the Inhibit control pin and disables the output of the module. If Q1 is then turned off, the module executes a soft-start power-up sequence. A regulated output voltage is produced within 15 ms. Figure 21 shows the typical rise in both the output voltage and input current, following the turn-off of Q1. The turn off of Q1 corresponds to the rise in the waveform, Q1  $V_{DS}$ . The waveforms were measured with a 16-A constant current load.



**Figure 21. Power-Up Response from Inhibit Control**

### Remote Sense

Products with this feature incorporate one or two remote sense pins. Remote sensing improves the load regulation performance of the module by allowing it to compensate for any IR voltage drop between its output and the load. An IR drop is caused by the high output current flowing through the small amount of pin and trace resistance.

To use this feature simply connect the Sense pins to the corresponding output voltage node, close to the load circuit. If a sense pin is left open-circuit, an internal low-value resistor (15- $\Omega$  or less) connected between the pin and the output node, ensures the output remains in regulation.

With the sense pin connected, the difference between the voltage measured directly between the  $V_O$  and GND pins, and that measured at the Sense pins, is the amount of IR drop being compensated by the regulator. This should be limited to a maximum of 0.3 V.

*The remote sense feature is not designed to compensate for the forward drop of nonlinear or frequency dependent components that may be placed in series with the converter output. Examples include OR-ing diodes, filter inductors, ferrite beads, and fuses. When these components are enclosed by the remote sense connection they are effectively placed inside the regulation control loop, which can adversely affect the stability of the regulator.*

### Smart Sync

Smart Sync is a feature that allows multiple power modules to be synchronized to a common frequency. Driving the Smart Sync pins with an external oscillator set to the desired frequency, synchronizes all connected modules to the selected frequency. The synchronization frequency can be higher or lower than the nominal switching frequency of the modules within the range of 240 kHz to 400 kHz. Synchronizing modules powered from the same bus, eliminates beat frequencies reflected back to the input supply, and also reduces EMI filtering requirements. Power modules can also be synchronized out of phase to minimize source current loading and minimize input capacitance requirements. Figure 22 shows a standard circuit with two modules synchronized 180° out of phase with one another using a D flip-flop.

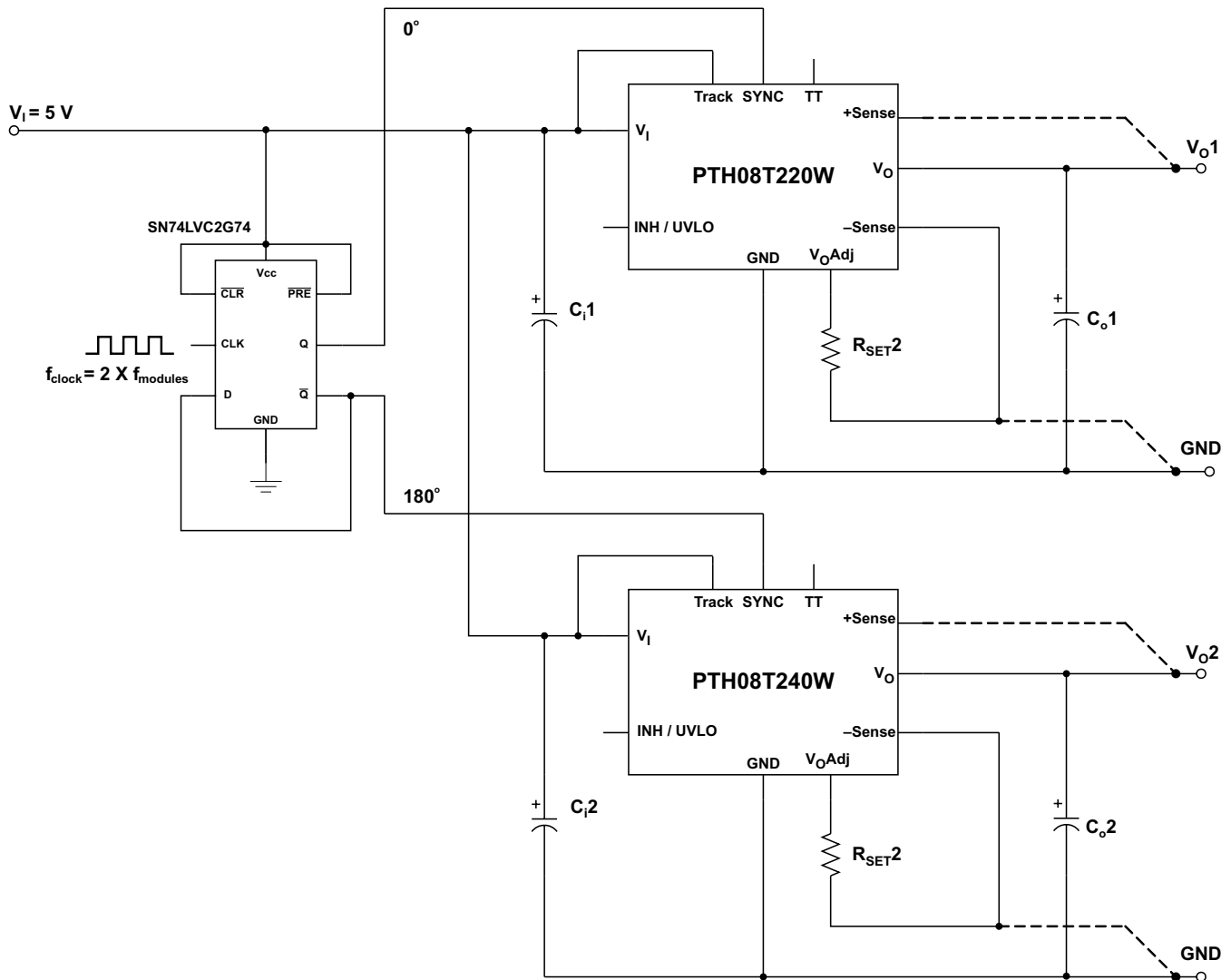


Figure 22. Smart Sync Schematic

### Auto-Track™ Function

The Auto-Track function is unique to the PTH/PTV family, and is available with all POLA products. Auto-Track was designed to simplify the amount of circuitry required to make the output voltage from each module power up and power down in sequence. The sequencing of two or more supply voltages during power up is a common requirement for complex mixed-signal applications that use dual-voltage VLSI ICs such as the TMS320™ DSP family, microprocessors, and ASICs.

### How Auto-Track™ Works

Auto-Track works by forcing the module output voltage to follow a voltage presented at the *Track* control pin <sup>(1)</sup>. This control range is limited to between 0 V and the module set-point voltage. Once the track-pin voltage is raised above the set-point voltage, the module output remains at its set-point <sup>(2)</sup>. As an example, if the *Track* pin of a 2.5-V regulator is at 1 V, the regulated output is 1 V. If the voltage at the *Track* pin rises to 3 V, the regulated output does not go higher than 2.5 V.

When under Auto-Track control, the regulated output from the module follows the voltage at its *Track* pin on a volt-for-volt basis. By connecting the *Track* pin of a number of these modules together, the output voltages follow a common signal during power up and power down. The control signal can be an externally generated master ramp waveform, or the output voltage from another power supply circuit <sup>(3)</sup>. For convenience, the *Track* input incorporates an internal RC-charge circuit. This operates off the module input voltage to produce a suitable rising waveform at power up.

### Typical Application

The basic implementation of Auto-Track allows for simultaneous voltage sequencing of a number of Auto-Track compliant modules. Connecting the *Track* inputs of two or more modules forces their track input to follow the same collective RC-ramp waveform, and allows their power-up sequence to be coordinated from a common Track control signal. This can be an open-collector (or open-drain) device, such as a power-up reset voltage supervisor IC. See U3 in [Figure 23](#).

To coordinate a power-up sequence, the Track control must first be pulled to ground potential. This should be done at or before input power is applied to the modules. The ground signal should be maintained for at least 20 ms after input power has been applied. This brief period gives the modules time to complete their internal soft-start initialization <sup>(4)</sup>, enabling them to produce an output voltage. A low-cost supply voltage supervisor IC, that includes a built-in time delay, is an ideal component for automatically controlling the Track inputs at power up.

[Figure 23](#) shows how the TL7712A supply voltage supervisor IC (U3) can be used to coordinate the sequenced power up of PTH08T220W modules. The output of the TL7712A supervisor becomes active above an input voltage of 3.6 V, enabling it to assert a ground signal to the common track control well before the input voltage has reached the module's undervoltage lockout threshold. The ground signal is maintained until approximately 28 ms after the input voltage has risen above U3's voltage threshold, which is 4.3 V. The 28-ms time period is controlled by the capacitor C3. The value of 2.2  $\mu$ F provides sufficient time delay for the modules to complete their internal soft-start initialization. The output voltage of each module remains at zero until the track control voltage is allowed to rise. When U3 removes the ground signal, the track control voltage automatically rises. This causes the output voltage of each module to rise simultaneously with the other modules, until each reaches its respective set-point voltage.

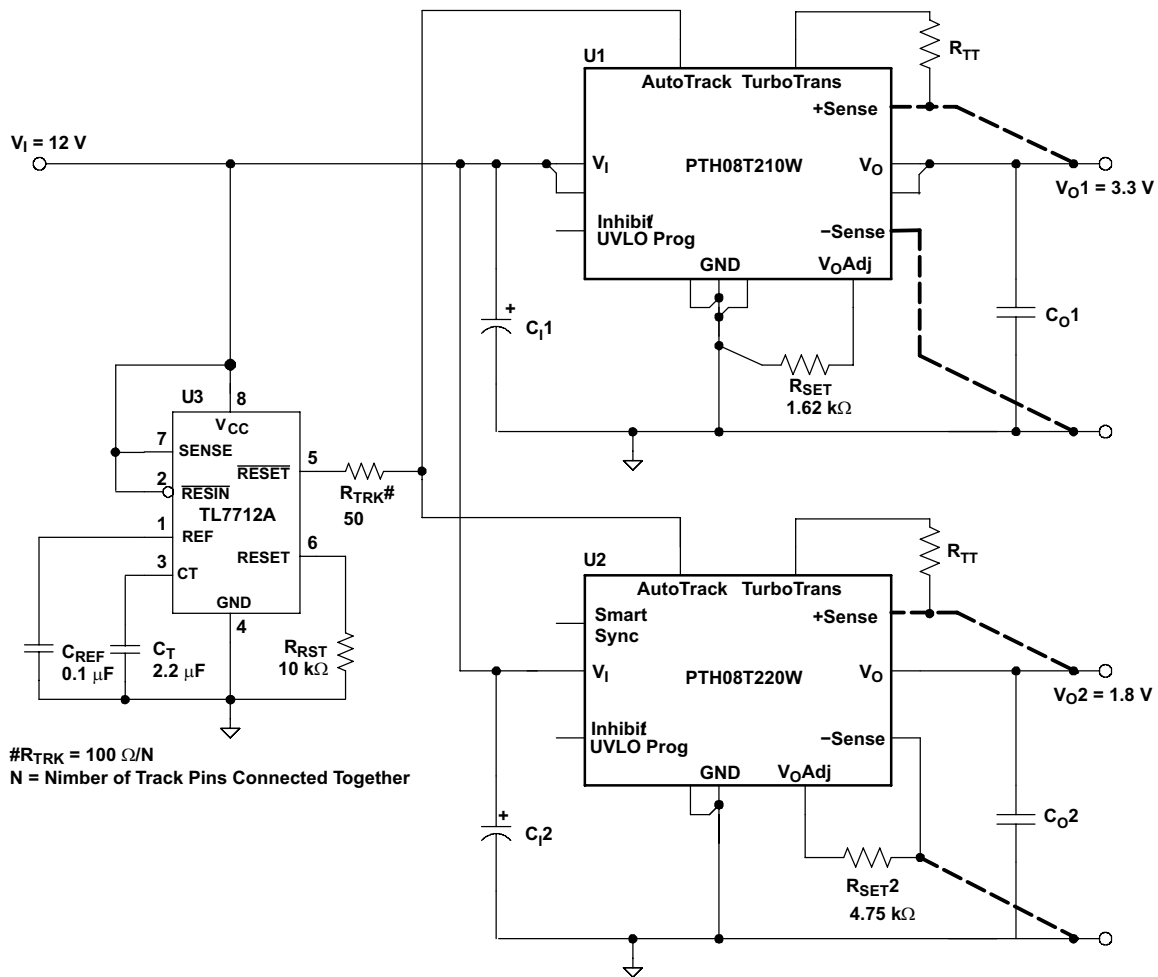
[Figure 24](#) shows the output voltage waveforms after input voltage is applied to the circuit. The waveforms,  $V_{O1}$  and  $V_{O2}$ , represent the output voltages from the two power modules, U1 (3.3 V) and U2 (1.8 V), respectively.  $V_{TRK}$ ,  $V_{O1}$ , and  $V_{O2}$  are shown rising together to produce the desired simultaneous power-up characteristic.

The same circuit also provides a power-down sequence. When the input voltage falls below U3's voltage threshold, the ground signal is re-applied to the common track control. This pulls the track inputs to zero volts, forcing the output of each module to follow, as shown in [Figure 25](#). Power down is normally complete before the input voltage has fallen below the modules' undervoltage lockout. This is an important constraint. Once the modules recognize that an input voltage is no longer present, their outputs can no longer follow the voltage applied at their track input. During a power-down sequence, the fall in the output voltage from the modules is limited by the Auto-Track slew rate capability.



**Notes on Use of Auto-Track™**

1. The *Track* pin voltage must be allowed to rise above the module set-point voltage before the module regulates at its adjusted set-point voltage.
2. The Auto-Track function tracks almost any voltage ramp during power up, and is compatible with ramp speeds of up to 1 V/ms.
3. The absolute maximum voltage that may be applied to the *Track* pin is the input voltage  $V_I$ .
4. The module cannot follow a voltage at its track control input until it has completed its soft-start initialization. This takes about 20 ms from the time that a valid voltage has been applied to its input. During this period, it is recommended that the *Track* pin be held at ground potential.
5. The Auto-Track function is disabled by connecting the *Track* pin to the input voltage ( $V_I$ ). When Auto-Track is disabled, the output voltage rises according to its softstart rate after input power has been applied.
6. The Auto-Track pin should never be used to regulate the module's output voltage for long-term, steady-state operation.



**Figure 23. Sequenced Power Up and Power Down Using Auto-Track**

PRODUCT PREVIEW

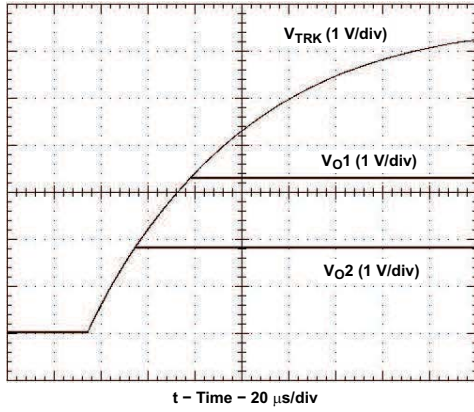


Figure 24. Simultaneous Power Up With Auto-Track Control

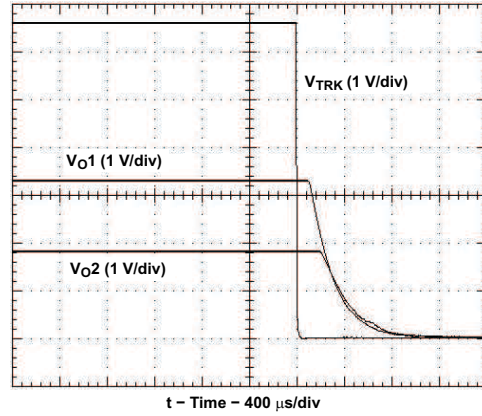


Figure 25. Simultaneous Power Down With Auto-Track Control

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
PTH08T220WAD	ACTIVE	DIP MOD ULE	EAS	11	42	Pb-Free (RoHS)	Call TI	Level-NC-NC-NC
PTH08T220WAH	ACTIVE	DIP MOD ULE	EAS	11	42	TBD	Call TI	Level-NA-NA-NA
PTH08T220WAS	ACTIVE	DIP MOD ULE	EAT	11	42	TBD	Call TI	Level-1-235C-UNLIM
PTH08T220WAST	ACTIVE	DIP MOD ULE	EAT	11	250	TBD	Call TI	Level-1-235C-UNLIM
PTH08T220WAZ	ACTIVE	DIP MOD ULE	EAT	11	42	Pb-Free (RoHS)	Call TI	Level-3-260C-168 HR
PTH08T220WAZT	ACTIVE	DIP MOD ULE	EAT	11	250	Pb-Free (RoHS)	Call TI	Level-3-260C-168 HR

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) 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.

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

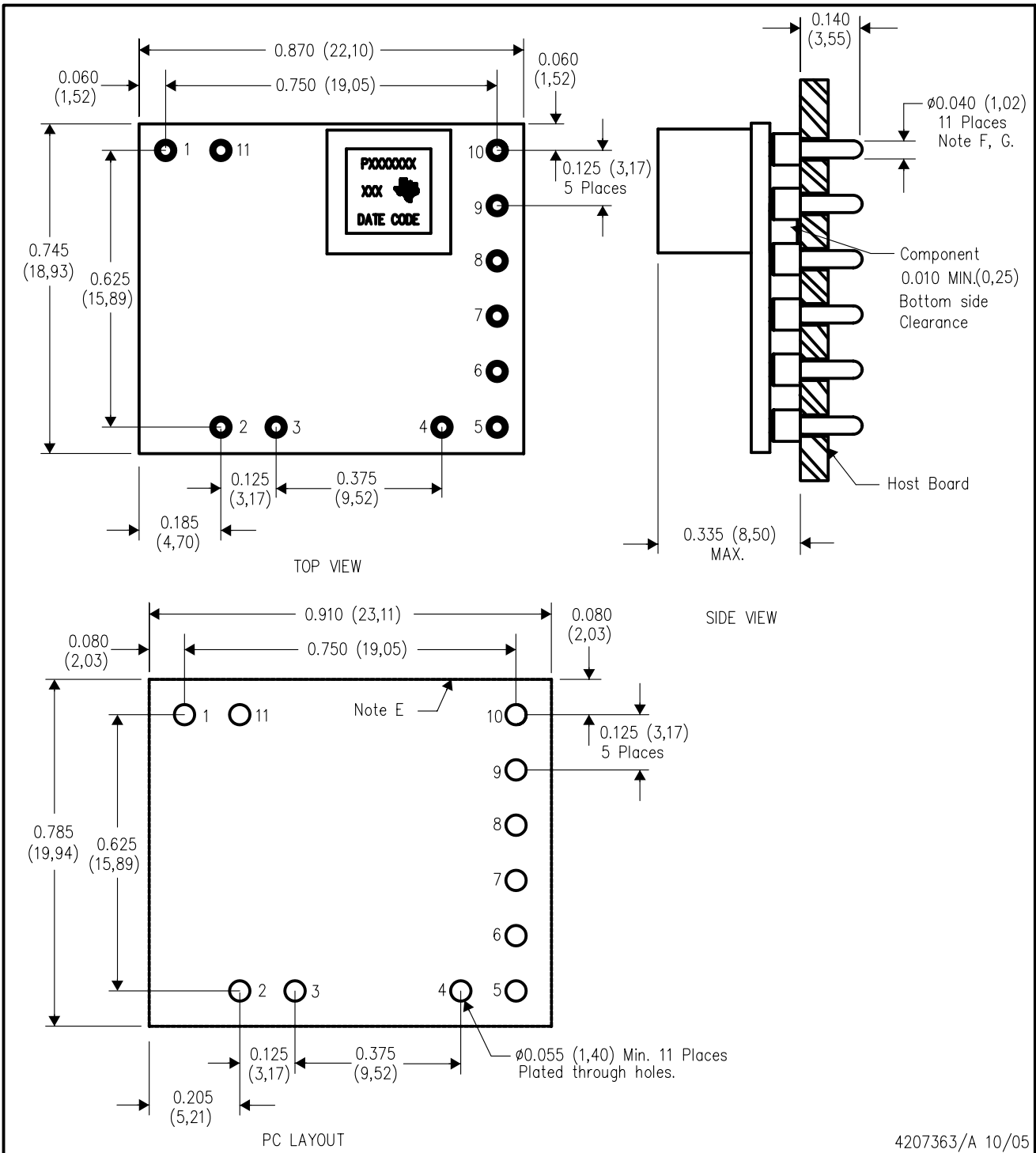
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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EAS (R-PDSS-T11)

DOUBLE SIDED MODULE

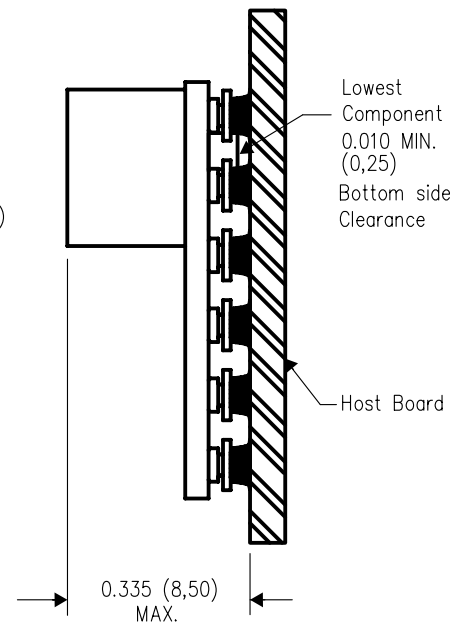
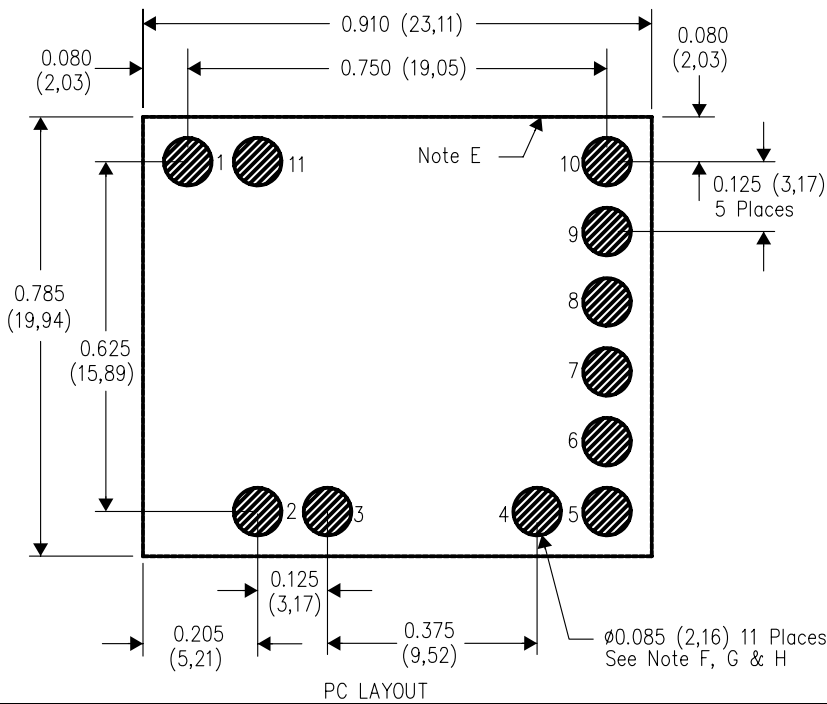
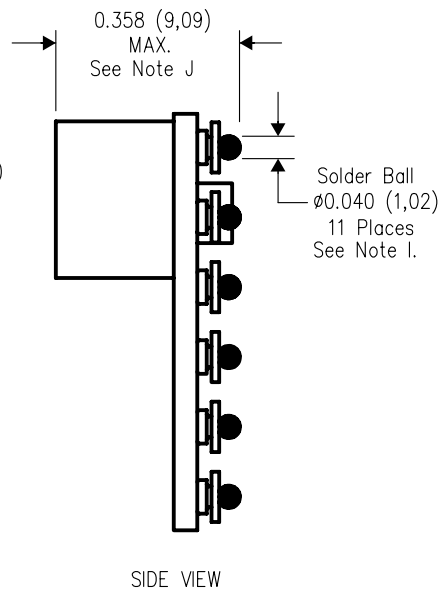
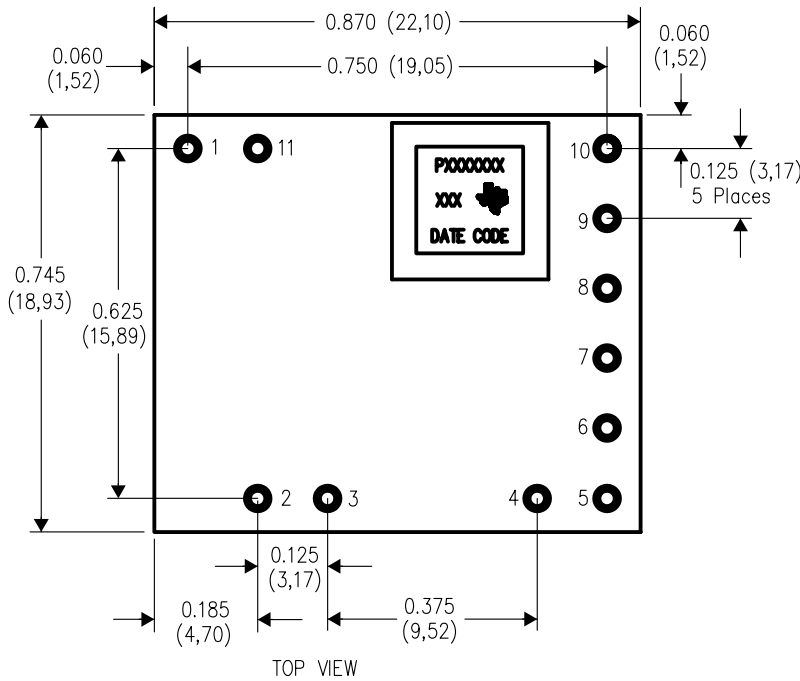


- NOTES:
- A. All linear dimensions are in inches (mm).
  - B. This drawing is subject to change without notice.
  - C. 2 place decimals are  $\pm 0.030$  ( $\pm 0,76\text{mm}$ ).
  - D. 3 place decimals are  $\pm 0.010$  ( $\pm 0,25\text{mm}$ ).
  - E. Recommended keep out area for user components.

- F. Pins are 0.040" (1,02) diameter with 0.070" (1,78) diameter standoff shoulder.
- G. All pins: Material - Copper Alloy  
Finish - Tin (100%) over Nickel plate

EAT (R-PDSS-B11)

DOUBLE SIDED MODULE



4207364/A 10/05

- NOTES:
- A. All linear dimensions are in inches (mm).
  - B. This drawing is subject to change without notice.
  - C. 2 place decimals are  $\pm 0.030$  ( $\pm 0,76$ mm).
  - D. 3 place decimals are  $\pm 0.010$  ( $\pm 0,25$ mm).
  - E. Recommended keep out area for user components.
  - F. Power pin connection should utilize two or more vias to the interior power plane of 0.025 (0,63) I.D. per input, ground and output pin (or the electrical equivalent).

- G. Paste screen opening: 0.080 (2,03) to 0.085 (2,16).  
Paste screen thickness: 0.006 (0,15).
- H. Pad type: Solder mask defined.
- I. All pins: Material – Copper Alloy  
Finish – Tin (100%) over Nickel plate  
Solder Ball – See product data sheet.
- J. Dimension prior to reflow solder.

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DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>	Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
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Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>	Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
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