

PTH08T250W 50-A, 4.5-V to 14-V Input, Non-isolated, Wide Output Adjust, Power Module with TurboTrans™ Technology

1 Features

- Up to 50-A Output Current
- 4.5-V to 14-V Input Voltage
- Wide-Output Voltage Adjust (0.7 V to 3.6 V)
- $\pm 1.5\%$ 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/IEC/CSA-C22.2 60950-1
- Prebias Startup
- On/Off Inhibit
- Differential Output Voltage Remote Sense
- Adjustable Undervoltage Lockout
- Auto-Track™ Sequencing
- Multi-Phase, Switch-Mode Topology
- TurboTrans™ Technology
- Designed to meet Ultra-Fast Transient Requirements up to 300 A/ μs
- SmartSync Technology
- Parallel Operation
- POLA™ Compatible

2 Applications

- Complex Multi-Voltage Systems
- Servers
- Workstations

3 Description

The PTH08T250W device is a high-performance 50-A rated, non-isolated power module. This module represents the 2nd generation of the popular PTH series power modules with a reduced footprint and improved features.

Operating from an input voltage range of 4.5 V to 14 V, the device requires a single resistor to set the output voltage to any value over the range, 0.7 V to 3.6 V. The wide input voltage range makes the this device 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 overcurrent 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™ sequencing is a popular feature that greatly simplifies the simultaneous power-up and power-down of multiple modules in a power system. Additionally, the capability to current share between multiple PTH08T250W modules allows for load currents greater than 50 A on a single rail.

The device includes **TurboTrans™** and the new patent-pending **SmartSync** technologies. 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 technology can be used to significantly improve the regulators transient response by reducing the peak voltage deviation. SmartSync technology allows for switching frequency synchronization of multiple modules, thus simplifying EMI noise suppression tasks and reducing input capacitor RMS current requirements.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
PTH08T250W	ECT	38.61 mm × 25.91 mm
	ECU	38.61 mm × 25.91 mm
	BCU	38.61 mm × 25.91 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

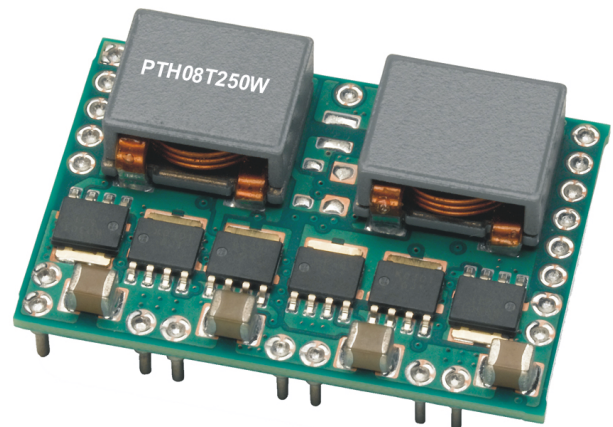


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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

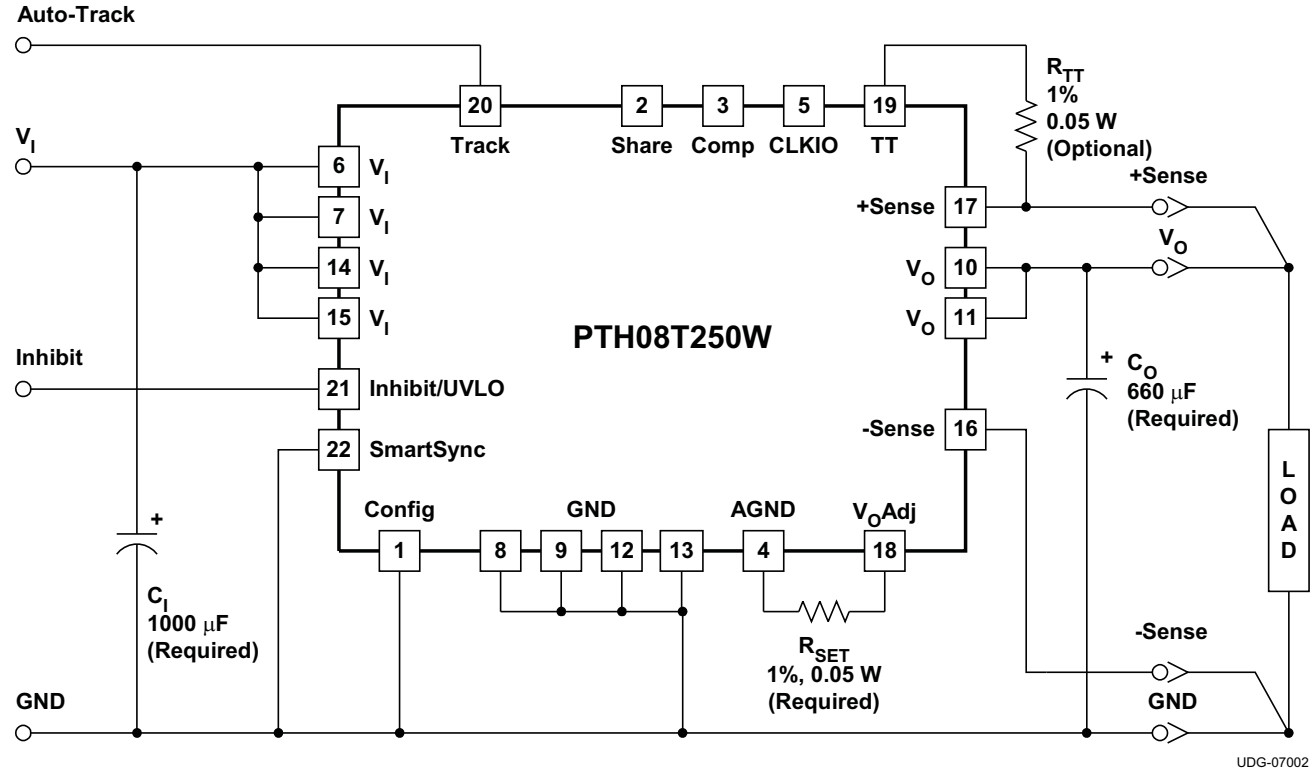
Changes from Revision H (July 2017) to Revision I	Page
• Corrected body size error in <i>Device Information</i> table	1

Changes from Revision G (November 2010) to Revision H	Page
• Changed typical overcurrent protection threshold (ILIM) from "100 A" to "85 A" in Electrical Characteristics table	6

5 Description (continued)

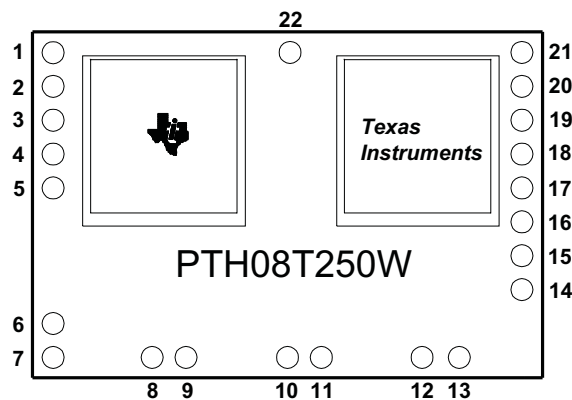
R_{SET} is required to set the output voltage higher than 0.7 V. See the *Electrical Characteristics* table for more information.

Double-sided surface mount construction provides a low profile and compact footprint. Package options include both through-hole and surface mount configurations that are lead (Pb)-free and RoHS compatible.



6 Pin Configuration and Functions

ECT, ECU or EBU Package
22 Pin
(Top View)



Pin Functions

PIN		DESCRIPTION
NAME	NO.	
V _I	6,7,14,15	The positive input voltage power node to the module, which is referenced to common GND.
V _O	10,11	The regulated positive power output with respect to GND.
GND	8,9,12,13	This is the common ground connection for the V _I and V _O power connections. It is also the 0 V _{dc} reference for the control inputs.
Inhibit ⁽¹⁾ and UVLO	21	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. This pin is also used for input undervoltage lockout (UVLO) programming. Connecting a resistor from this pin to GND (pin 13) allows the ON threshold of the UVLO to be adjusted higher than the default value. For more information, see the Application Information section.
V _O Adjust	18	A 0.05 W 1% resistor must be directly connected between this pin and pin 4 (AGND) 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 3.6 V. If left open circuit, the output voltage defaults to its lowest value. For further information, on output voltage adjustment see the related application note. The specification table gives the preferred resistor values for a number of standard output voltages.
+ Sense	17	The sense input allows the regulation circuit to compensate for voltage drop between the module and the load. The +Sense pin should always be connected to V _O , either at the load for optimal voltage accuracy, or at the module (pin 11).
– Sense	16	The sense input allows the regulation circuit to compensate for voltage drop between the module and the load. The –Sense pin should always be connected to GND, either at the load for optimal voltage accuracy, or at the module (pin 13).
Track	20	This is an analog control input that enables the output voltage to follow an external voltage. This pin becomes active typically 25 ms after a valid 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_I. 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.
TurboTrans™	19	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 17 (+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 unless the TurboTrans resistor value is a short, 0Ω.
SmartSync	22	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 modules, aiding EMI noise suppression efforts. The external synchronization frequency must be present before a valid input voltage is present, or before the release of inhibit control. If unused, this pin MUST be connected to GND. For more information, please review the Application Information section.
CONFIG	1	When two modules are connected together to share load current one must be configured as the MASTER and the other as the SLAVE. This pin is used to configure the module as either MASTER or SLAVE. To configure the module as the MASTER, connect this pin to GND. To configure the module as the SLAVE, connect this pin to V _I (pin 6). When not sharing current, this pin should be connected to GND.
Share	2	This pin is used when connecting two modules together to share load current. When two modules are sharing current the Share pin of both modules must be connected together. When not sharing current, this pin MUST be left open (floating).
Comp	3	This pin is used when connecting two modules together to share load current. When two modules are sharing current the Comp pin of both modules must be connected together. When not sharing current, this pin MUST be left open (floating).
AGND	4	This pin is the internal analog ground of the module. This pin provides the return path for the V _O Adjust resistor (R _{SET}). When two modules are sharing current the AGND pin of both modules must be connected together. Also, when two modules are connected, R _{SET} must be connected only on the MASTER module.
CLKIO	5	This pin is used when connecting two modules together to share load current. When two modules are sharing current the CLKIO pin of both modules must be connected together. When not sharing current, this pin MUST be left open (floating).

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

7 Specifications

7.1 Absolute Maximum Ratings

(Voltages are with respect to GND)

				UNIT
V_{track}	Track pin voltage		–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 (5 seconds maximum)	AD suffix 260	
T_{reflow}	Solder reflow temperature	Surface temperature of module body or pins	AS suffix 235 ⁽¹⁾	
			AZ suffix 260 ⁽¹⁾	
T_{stg}	Storage temperature	Storage temperature of module removed from shipping package	–55 to 125	
T_{pkg}	Packaging temperature	Shipping Tray or Tape and Reel storage or bake temperature	45	G
	Mechanical shock	Per Mil-STD-883D, Method 2002.3 1 msec, 1/2 sine, mounted	AD suffix 500	
			AS and AZ suffix 125	
	Mechanical vibration	Mil-STD-883D, Method 2007.2 20-2000 Hz	20	
	Weight		16.7	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.

7.2 Electrical Characteristics

 $T_A = 25^\circ\text{C}$, $V_I = 12\text{ V}$, $V_O = 3.3\text{ V}$, $C_I = 1000\text{ }\mu\text{F}$, $C_O = 660\text{ }\mu\text{F}$, 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°C, natural convection	0		48	A
			60°C, 200 LFM	0		50	
V_I	Input voltage range	Over I_O range	$0.7 \leq V_O < 1.2$	4.5		14 ⁽¹⁾	V
			$1.2 \leq V_O \leq 3.6$	4.5		14	
$V_{O\text{ADJ}}$	Output voltage adjust range	Over I_O range		0.7		3.6	V
V_O	Set-point voltage tolerance				± 0.5	± 1 ⁽²⁾	% V_O
	Temperature variation	$-40^\circ\text{C} < T_A < 85^\circ\text{C}$			± 0.3		% V_O
	Line regulation	Over V_I range			± 5		mV
	Load regulation	Over I_O range			± 5		mV
	Total output variation	Includes set-point, line, load, $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$				± 1.5 ⁽²⁾	% V_O
η	Efficiency	$I_O = 30\text{ A}$	$R_{\text{SET}} = 1.62\text{ k}\Omega$, $V_O = 3.3\text{ V}$			94%	
			$R_{\text{SET}} = 5.23\text{ k}\Omega$, $V_O = 2.5\text{ V}$			93%	
			$R_{\text{SET}} = 12.7\text{ k}\Omega$, $V_O = 1.8\text{ V}$			91%	
			$R_{\text{SET}} = 19.6\text{ k}\Omega$, $V_O = 1.5\text{ V}$			90%	
			$R_{\text{SET}} = 35.7\text{ k}\Omega$, $V_O = 1.2\text{ V}$			88%	
			$R_{\text{SET}} = 63.4\text{ k}\Omega$, $V_O = 1.0\text{ V}$			86%	
			$R_{\text{SET}} = \text{open}$, $V_O = 0.7\text{ V}$			83%	
	V_O Ripple (peak-to-peak)	20-MHz bandwidth			10 ⁽¹⁾		mV _{PP}
I_{LIM}	Overcurrent threshold	Reset, followed by auto-recovery			85		A
t_{tr}	Transient response	2.5 A/ μs load step 50 to 100% $I_{O\text{max}}$	w/o TurboTrans $C_O = 660\text{ }\mu\text{F}$, Type C	Recovery time	100		μs
ΔV_{tr}			w/ TurboTrans $C_O = 3300\text{ }\mu\text{F}$, Type C $R_{\text{TT}} = \text{short}$	V_O over/undershoot	160		mV
t_{rTT}				Recovery time	100		μs
ΔV_{rTT}				V_O over/undershoot	45		mV
I_{IL}	Track input current (pin 20)	Pin to GND				-130 ⁽³⁾	μA
dV_{track}/dt	Track slew rate capability	$C_O \leq C_{O\text{max}}$				1	V/ms
$UVLO_{\text{ADJ}}$	Adjustable Under-voltage lockout (pin 21)	V_I increasing, $R_{UVLO} = \text{OPEN}$		4.3	4.45		V
		V_I decreasing, $R_{UVLO} = \text{OPEN}$		4.0	4.2		
		Hysteresis, $R_{UVLO} \leq 127\text{ k}\Omega$			1.0		
	Inhibit control (pin 21)	Input high voltage (V_{IH})				Open ⁽⁴⁾	V
		Input low voltage (V_{IL})		-0.2		0.6	
		Input low current (I_{IL}), Pin 21 to GND			-125		μA
I_{in}	Input standby current	Inhibit (pin 21) to GND, Track (pin 20) open			35		mA
f_s	Switching frequency	Over V_I and I_O ranges, SmartSync (pin 22) to GND			600 ⁽⁵⁾		kHz
f_{SYNC}	Synchronization frequency applied to pin 22			240 ⁽⁵⁾		400 ⁽⁵⁾	kHz
V_{SYNCH}	Synchronization (SYNC) control (pin 22)	SYNC High-Level Input Voltage		2.0		5.5	V
V_{SYNCL}		SYNC Low-Level Input Voltage				0.8	V
t_{SYNC}	SYNC Minimum Pulse Width			200			nSec
C_I	External input capacitance	Nonceramic		1000 ⁽⁶⁾			μF
		Ceramic			22		

- (1) For output voltages less than 1.2 V, the output ripple may increase (up to 2 $\times$) when operating at input voltages greater than ($V_O \times 12$). Adjusting the switching frequency using the SmartSync feature may increase or decrease this ratio. Review the SmartSync section of the Application Information for further guidance.
- (2) The set-point voltage tolerance is affected by the tolerance and stability of R_{SET} . The stated limit is unconditionally met if R_{SET} has a tolerance of 1% with 100 ppm/ $^\circ\text{C}$ or better temperature stability.
- (3) A low-leakage (<100 nA), open-drain device, such as MOSFET or voltage supervisor IC, is recommended to control pin 20. The open-circuit voltage is less than 8 V_{dc} .
- (4) Do not place an external pull-up on this pin. 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 section.
- (5) The PTH08T250W is a two-phase power module. Each phase switches at 300 kHz typical, 180° out-of-phase from one another. The over-all switching frequency is 600 kHz typical. SmartSync controls the frequency of an individual phase. When using SmartSync the external synchronization frequency must be present before a valid input voltage is present, or before the release of inhibit control.
- (6) A 1000 μF electrolytic input capacitor is required for proper operation. When operating at an input voltage greater than 8V the minimum required input capacitance may be reduced to 560 μF . The input capacitor must be rated for a minimum of 600 mA rms of ripple current.

Electrical Characteristics (continued)

 $T_A = 25^\circ\text{C}$, $V_I = 12\text{ V}$, $V_O = 3.3\text{ V}$, $C_I = 1000\text{ }\mu\text{F}$, $C_O = 660\text{ }\mu\text{F}$, and $I_O = I_O\text{ max}$ (unless otherwise stated)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
C_O	w/o TurboTrans	Capacitance Value	Non-ceramic	660 ⁽⁷⁾		8000 ⁽⁸⁾	μF
			Ceramic			1000 ⁽⁹⁾	
		Equivalent series resistance (non-ceramic)		3			$\text{m}\Omega$
	w/ TurboTrans	Capacitance Value	Non-ceramic	660 ⁽⁷⁾ ₍₁₀₎			μF
			Ceramic			1000 ⁽⁹⁾	
		Capacitance $\times$ ESR product ($C_O \times \text{ESR}$)		1000		10000 ₍₁₀₎	$\mu\text{F} \times \text{m}\Omega$
MTBF	Reliability	Per Telcordia SR-332, 50% stress, $T_A = 40^\circ\text{C}$, ground benign		2.79			10^6 Hr

- (7) 660 μF of external **non-ceramic** output capacitance is required for basic operation. Adding additional capacitance at the load further improves transient response. See the Capacitor Application Information section and the TurboTrans Technology section for more guidance.
- (8) This is the calculated maximum when not using *TurboTrans*[™] technology. This value includes both ceramic and non-ceramic capacitors. The minimum ESR requirement often results in a lower value of output capacitance. See the Capacitor Application Information section for more guidance.
- (9) Ceramic output capacitance may be added in addition to the required non-ceramic output capacitance. The amount of ceramic capacitance must be less than the non-ceramic capacitance, not to exceed 1000 μF .
- (10) When using *TurboTrans*[™] technology, a minimum value of output capacitance is required for proper operation. Additionally, low ESR capacitors are required for proper operation. See the TurboTrans Technology section for further guidance.

7.3 Typical Characteristics ($V_I = 12\text{ V}$)

(11)(12)

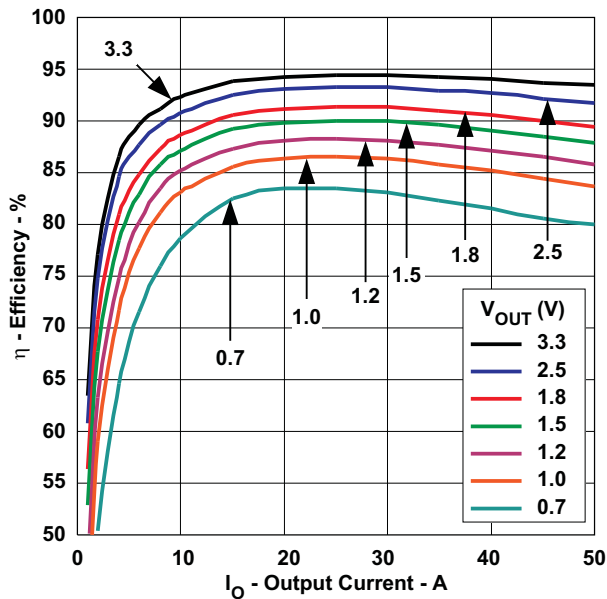


Figure 1. Efficiency vs. Output Current

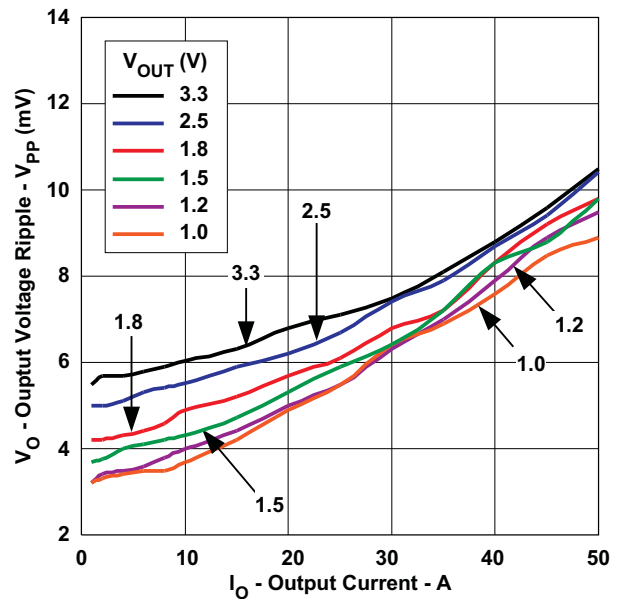


Figure 2. Output Ripple vs. Output Current

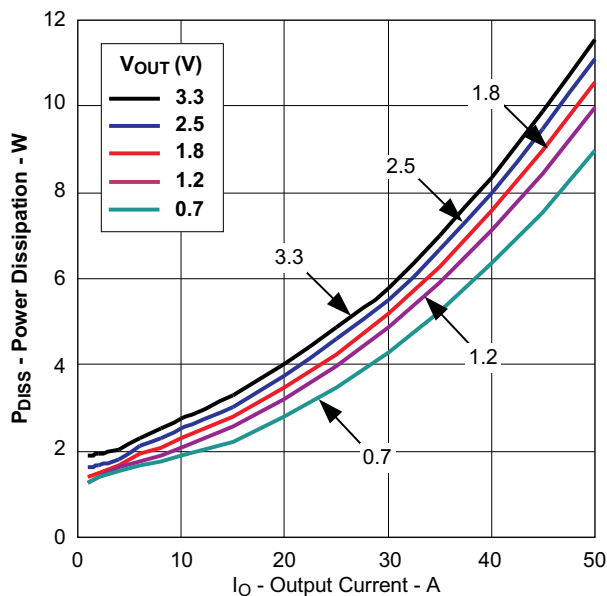


Figure 3. Power Dissipation vs. Output Current

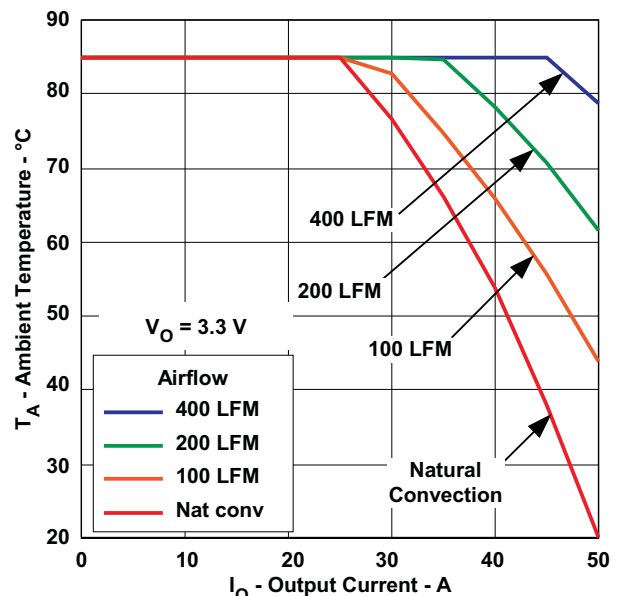


Figure 4. Ambient Temperature vs. Output Current

(11) 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.

(12) 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 × 100 mm double-sided PCB with 2 oz. copper. Applies to Figure 4 and Figure 5.

Typical Characteristics ($V_I = 12\text{ V}$) (continued)

(11) (12)

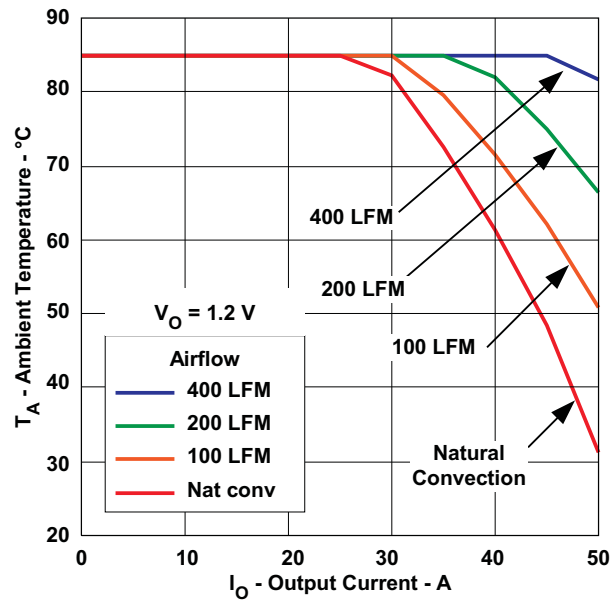


Figure 5. Ambient Temperature vs. Output Current

7.4 Typical Characteristics ($V_I = 5\text{ V}$)

(13)(14)

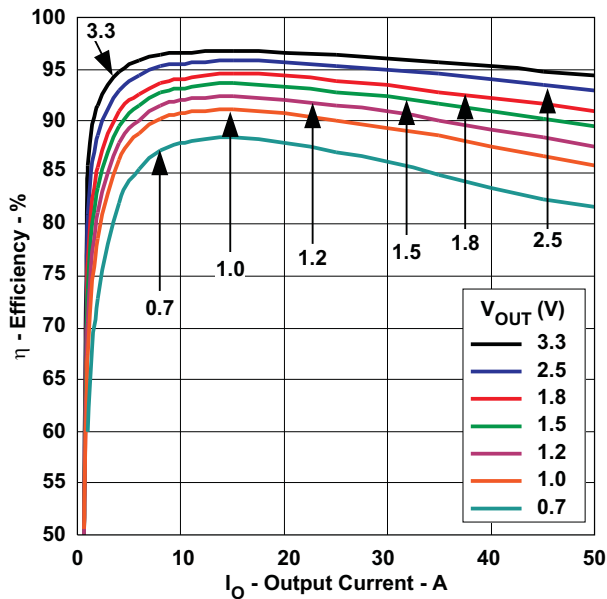


Figure 6. Efficiency vs. Output Current

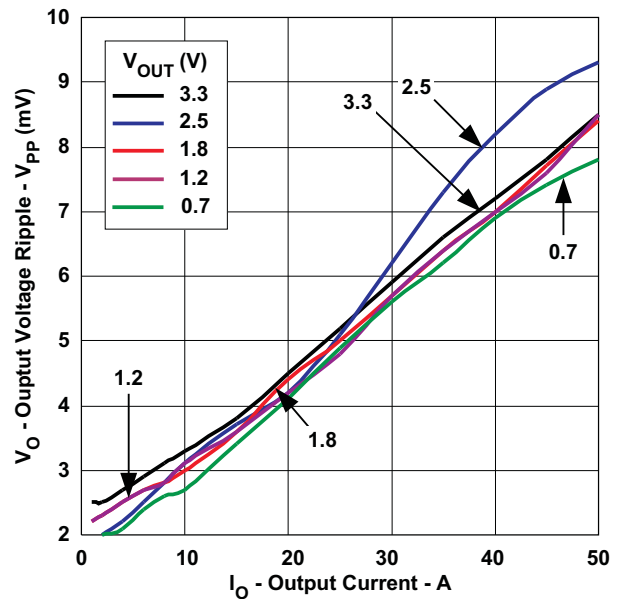


Figure 7. Output Ripple vs. Output Current

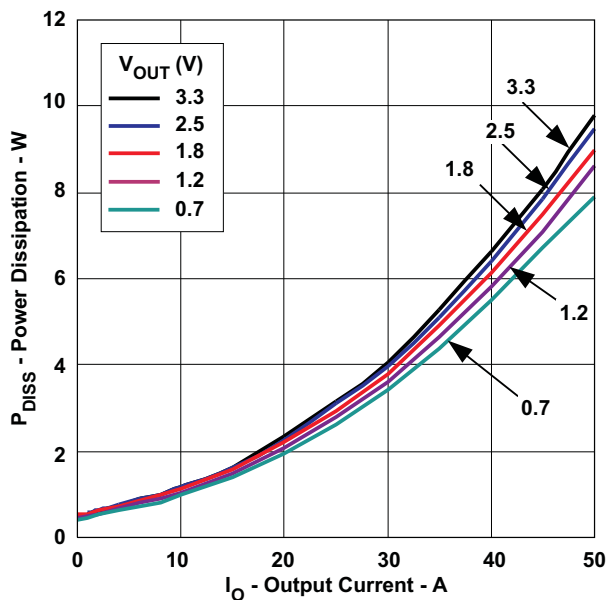


Figure 8. Power Dissipation vs. Output Current

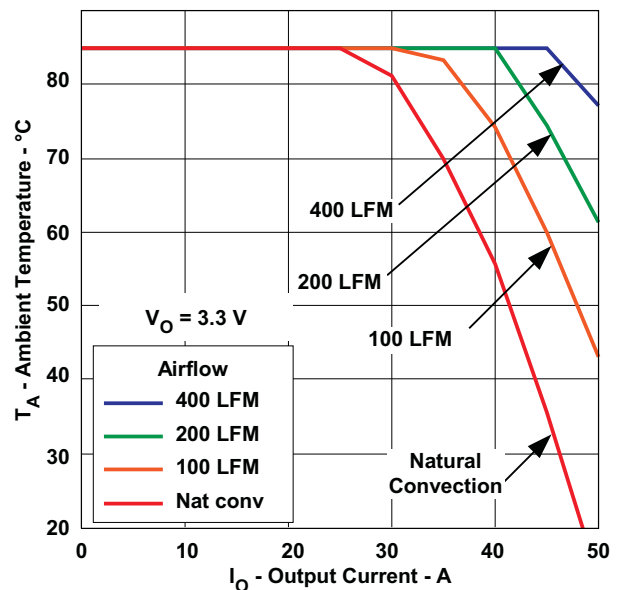


Figure 9. Ambient Temperature vs. Output Current

(13) 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 6](#), [Figure 7](#), and [Figure 8](#).

(14) 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 and the direction of airflow from pin 10 to pin 22. For surface mount packages (AS and AZ suffix), multiple vias must be utilized. Refer to the mechanical specification for more information. Applies to [Figure 9](#) and [Figure 10](#).

Typical Characteristics ($V_I = 5\text{ V}$) (continued)

(13) (14)

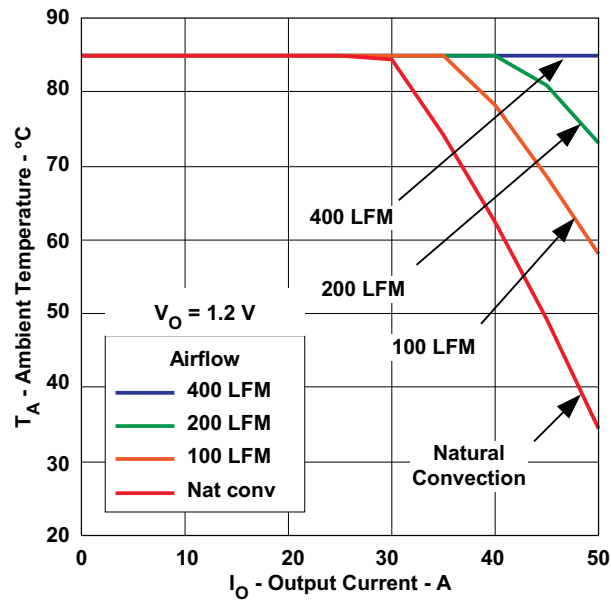


Figure 10. Ambient Temperature vs. Output Current

8 Detailed Description

8.1 Overview: 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 is 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 is reduced. Applications requiring tight transient voltage tolerances and minimized capacitor footprint area benefits greatly from this technology.

8.2 Feature Description

8.2.1 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 11](#)).

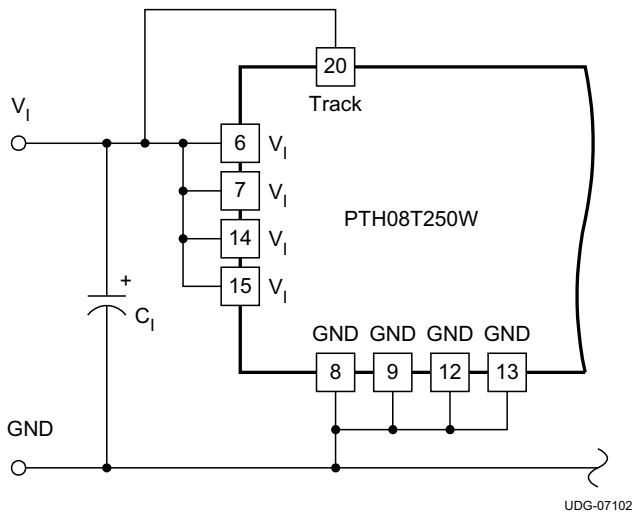


Figure 11. Defeating the Auto-Track Function

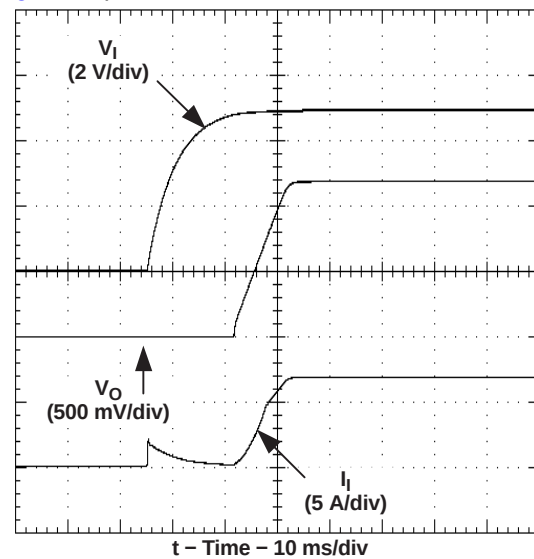


Figure 12. Power-Up Waveform

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 (a period typically between 10 ms and 15 ms) before allowing the output voltage to rise.

The output then progressively rises to the module's setpoint voltage. [Figure 12](#) shows the soft-start power-up characteristic of the PTH08T250W operating from a 5-V input bus and configured for a 1.2-V output. The waveforms were measured with a 25-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 30 ms.

Feature Description (continued)

8.2.2 Differential Output Voltage Remote Sense

Differential remote sense improves the load regulation performance of the module by allowing it to compensate for any IR voltage drop between its output and the load in either the positive or return path. An IR drop is caused by the output current flowing through the small amount of pin and trace resistance. With the sense pins 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.

If the remote sense feature is not used at the load, connect +Sense (pin 17) to V_O (pin 11) and connect –Sense (pin 16) to the module GND (pin 13).

CAUTION

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.

8.2.3 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.

8.2.4 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.

CAUTION

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.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

9.2 Typical Application

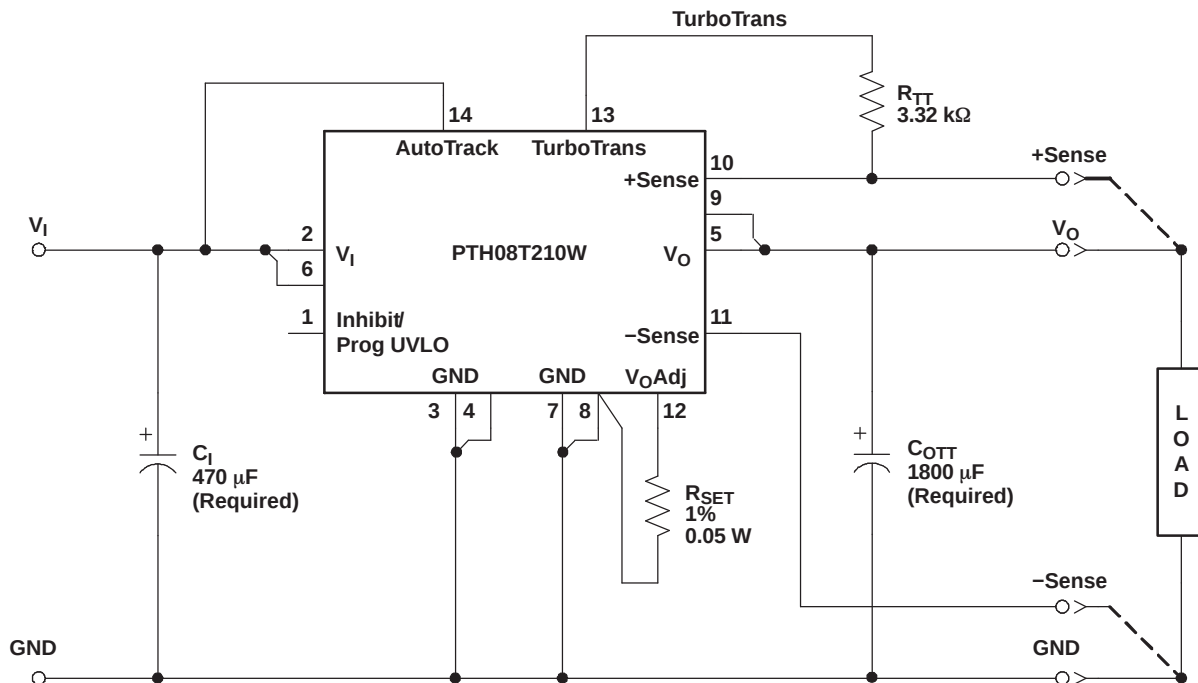


Figure 13. Typical TurboTrans Application Schematic

9.2.1 Detailed Design Procedure

9.2.1.1 Adjusting the Output Voltage

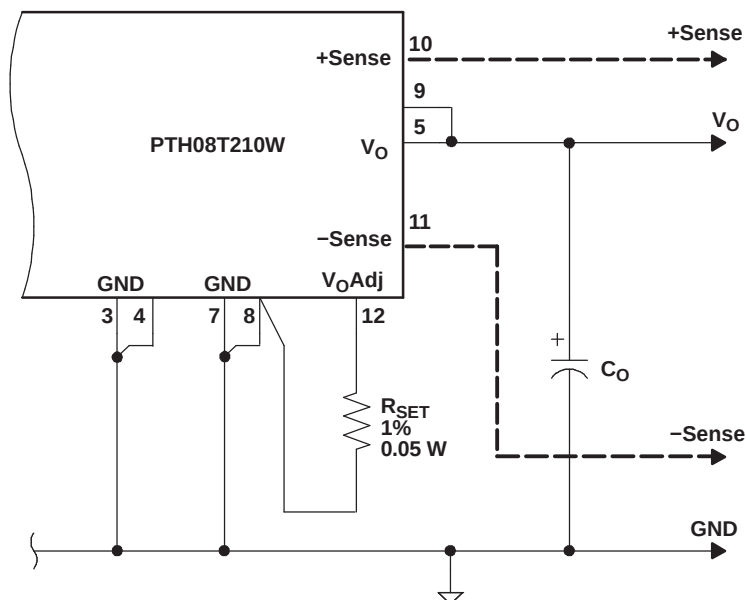
The V_O Adjust control (pin 12) sets the output voltage of the PTH08T210W. The adjustment range of the PTH08T210W is 0.7 V to 3.6 V. The adjustment method requires the addition of a single external resistor, R_{SET}, that must be connected directly between the V_O Adjust and GND pins. [Table 1](#) gives 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 2](#). [Figure 14](#) shows the placement of the required resistor.

$$R_{SET} = 30.1 \text{ k}\Omega \times \frac{0.7}{V_O - 0.7} - 6.49 \text{ k}\Omega \quad (1)$$

Table 1. Preferred Values of R_{SET} for Standard Output Voltages

V_O (Standard) (V)	R_{SET} (Preferred Value) (Ω)	V_O (Actual) (V)
3.3	1.62 k	3.298
2.5	5.23 k	2.498
2	9.76 k	1.997
1.8	12.7 k	1.798
1.5	19.6 k	1.508
1.2	35.7 k	1.199
1	63.4 k	1.001
0.7	Open	0.700



- (1) Use a 0.05 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 12 and 8 using dedicated PCB traces.
- (2) Never connect capacitors from V_O Adjust to either GND or V_O . Any capacitance added to the V_O Adjust pin affects the stability of the regulator.

Figure 14. V_O Adjust Resistor Placement

Table 2. Output Voltage Set-Point Resistor Values

V_O Required (V)	R_{SET} (k Ω)	V_O Required (V)	R_{SET} (k Ω)	V_O Required (V)	R_{SET} (k Ω)
0.70	Open	1.50	19.6	2.60	4.64
0.75	412	1.60	16.9	2.70	4.02
0.80	205	1.70	14.7	2.80	3.57
0.85	133	1.80	12.7	2.90	3.09
0.90	97.6	1.90	11.0	3.00	2.67
0.95	78.7	2.00	9.76	3.10	2.26
1.00	63.4	2.10	8.66	3.20	1.96
1.10	46.4	2.20	7.50	3.30	1.62
1.20	35.7	2.30	6.65	3.40	1.30
1.30	28.7	2.40	5.90	3.50	1.02
1.40	23.7	2.50	5.23	3.60	0.768

9.2.1.2 Capacitor Recommendations

9.2.1.2.1 Input Capacitor (Required)

The size and value of the input capacitor is determined by the converter transient performance capability. The minimum amount of required input capacitance is 470 μF , with an RMS ripple current rating of 500 mA. 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.

For high-performance/transient applications, or wherever the input source performance is degraded, 1000 μF of input capacitance is recommended. The additional input capacitance above the minimum level insures an optimized performance.

Ripple current (rms) rating, less than 100 m Ω of equivalent series resistance (ESR), and temperature are the main considerations when selecting input capacitors. The ripple current reflected from the input of the PTH08T210W module is moderate to low. Therefore any good quality, computer-grade electrolytic capacitor will have an adequate ripple current rating.

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°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.

9.2.1.2.2 TurboTrans Output Capacitor

The PTH08T210W requires a minimum output capacitance of 470 μF . The required capacitance above 470 μF 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 (μF) $\times$ ESR (m Ω) 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 680 μF and 5 m Ω ESR, has a $C \times \text{ESR}$ product of 3400 $\mu\text{F} \times \text{m}\Omega$ (680 $\mu\text{F} \times 5 \text{ m}\Omega$).

Using TurboTrans in conjunction with the high quality capacitors (capacitance (μF) $\times$ ESR (m Ω)) reduces the overall capacitance requirement while meeting the minimum transient amplitude level.

[Table 3](#) 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.

9.2.1.2.3 Non-TurboTrans Output Capacitor

The PTH08T210W requires a minimum output capacitance of 470 μF . Non-TurboTrans applications must observe minimum output capacitance ESR limits.

A combination of 200 μF of ceramic capacitors plus low ESR (15 m Ω to 30 m Ω) 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 m Ω to 5 m Ω . (Note: no ceramic capacitors are required). This is necessary for the 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 m Ω (4 m Ω when calculating using the manufacturer's maximum ESR values). A list of preferred low-ESR type capacitors, are identified in [Table 3](#).

9.2.1.2.4 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 5000 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 12,000 μF .

9.2.1.2.5 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.

9.2.1.2.6 Capacitor Table

[Table 3](#) 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.

9.2.1.2.7 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, 3225 case size, plus $10 \times 1 \mu\text{F}$, including numerous high frequency ceramics ($\leq 0.1 \mu\text{F}$) 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.

Table 3. Input/Output Capacitors⁽¹⁾

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 (I _{rms})	Physical Size (mm)	Input Bus	Output Bus		
							No TurboTrans	TurboTrans (Cap Type) ⁽²⁾	
Panasonic	25 V	1000	0.043Ω	>1690 mA	16 × 15	1	≥ 2 ⁽³⁾	N/R ⁽⁴⁾	EEUFC1E102S
FC (Radial)	25 V	1800	0.029Ω	2205 mA	16 × 20	1	≥ 1 ⁽³⁾	N/R ⁽⁴⁾	EEUFC1E182
FC(SMD)	25 V	2200	0.028Ω	>2490 mA	18 × 21,5	1	≥ 1 ⁽³⁾	N/R ⁽⁴⁾	EEVFC1E222N
FK(SMD)	25 V	1000	0.060Ω	1100 mA	12,5×13,5	1	≥ 2 ⁽⁵⁾	N/R ⁽⁴⁾	EEVFK1V102Q
United Chemi-Con									
PTB, Poly-Tantalum(SMD)	6.3 V	470	0.025Ω	2600 mA	7,3x4,3x2.8	N/R ⁽⁶⁾	2 - 4 ⁽³⁾	C ≥ 2 ⁽²⁾	6PTB477MD8TER
LXZ, Aluminum (Radial)	25 V	680	0.068Ω	1050 mA	10 × 16	1	1 - 3 ⁽³⁾	N/R ⁽⁴⁾	LXZ25VB681M10X20LL
PS, Poly-Alum(Radial)	16 V	330	0.014Ω	5060 mA	10 × 12,5	2	2 - 3	B ≥ 2 ⁽²⁾	16PS330MJ12
PXA, Poly-Alum(SMD)	16 V	330	0.014Ω	5050 mA	10 × 12,2	2	2 - 3	B ≥ 2 ⁽²⁾	PXA16VC331MJ12TP
PS, Poly-Alum(Radial)	6.3 V	680	0.010Ω	5500 mA	10 × 12,5	N/R ⁽⁶⁾	1 - 2	C ≥ 1 ⁽²⁾	6PS680MJ12
PXA, Poly-Alum(Radial)	6.3 V	470	0.012Ω	4770 mA	8 × 12,2	N/R ⁽⁶⁾	1 - 2	C ≥ 1 ⁽²⁾	PXA6.3VC471MH12TP
Nichicon, Aluminum	25 V	470	0.070Ω	985 mA	12,5 × 15	1	≥ 2 ⁽³⁾	N/R ⁽⁴⁾	UPM1E471MHH6
HD (Radial)	25 V	470	0.038Ω	1430 mA	10 × 16	1	≥ 2 ⁽³⁾	N/R ⁽⁴⁾	UHD1E471MHR
PM (Radial)	35 V	560	0.048Ω	1360 mA	16 × 15	1	≥ 2 ⁽³⁾	N/R ⁽⁴⁾	UPM1V561MHH6
Panasonic, Poly-Alum	2.0 V	390	0.005Ω	4000 mA	7,3×4,3×4,2	N/R ⁽⁶⁾	N/R ⁽⁶⁾	B ≥ 2 ⁽²⁾	EEFSE0J391R(V _O ≤1.6V) ⁽⁷⁾
Panasonic									
TPE, Poscap (SMD)	6.3 V	470	0.018Ω	3500 mA	7,3 × 4,3	N/R ⁽⁶⁾	1 - 3	C ≥ 1 ⁽²⁾	6TPE470MI
TPE Poscap(SMD)	2.5 V	470	0.007Ω	4400 mA	7,3 × 4,3	N/R ⁽⁶⁾	1 - 2	B ≥ 2 ⁽²⁾	2R5TPE470M7(V _O ≤ 1.8 V) ⁽⁷⁾
TPD Poscap (SMD)	2.5 V	1000	0.005Ω	6100 mA	7,3 × 4,3	N/R ⁽⁶⁾	1	B ≥ 1 ⁽²⁾	2R5TPD1000M5(V _O ≤ 1.8 V) ⁽⁷⁾
SA, Os-Con (Radial)	16 V	470	0.020Ω	>6080 mA	16 × 23	1	1 - 4	N/R ⁽⁴⁾	16SA470M
SP Oscon (Radial)	10 V	470	0.015	>4500 mA	10 × 11,5	N/R ⁽⁶⁾	1 - 3	C ≥ 2 ⁽²⁾	10SP470M
SEPC, Os-Con (Radial)	16 V	470	0.010Ω	>4700 mA	10 × 13	1	1 - 2	B ≥ 1 ⁽²⁾	16SEPC470M
SVPA, Os-Con (SMD)	6.3 V	470	0.020Ω	4700mA	10 × 10,3	N/R ⁽⁶⁾	1 - 4 ⁽³⁾	C ≥ 1 ⁽²⁾ (3)	6SVPA470M

(1) Capacitor Supplier Verification

Be sure to verify the 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) :

- (a) Type A = (100 < capacitance × ESR ≤ 1000)
- (b) Type B = (1,000 < capacitance × ESR ≤ 5,000)
- (c) 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 of this capacitor only allows it to be used for output voltage that is equal to or less than 80% of the working voltage.

Table 3. Input/Output Capacitors⁽¹⁾ (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) ⁽²⁾	
AVX, Tantalum, Series III	6.3 V	680	0.035Ω	>2400 mA	7,3×4,3×4,1	N/R ⁽⁶⁾	2 - 7 ⁽³⁾	N/R ⁽⁴⁾	TPSE477M010R0045
TPM Multianode	6.3 V	470	0.018Ω	>3800 mA	7,3×4,3×4,1	N/R ⁽⁶⁾	2 - 3 ⁽³⁾	C ≥ 2 ⁽²⁾ (3)	TPME687M006#0018
TPS Series III (SMD)	4 V	1000	0.035Ω	2405 mA	7,3 × 5,7	N/R ⁽⁶⁾	2 - 7 ⁽³⁾	N/R ⁽⁴⁾	TPSV108K004R0035 (V _O ≤ 2.2 V) ⁽⁷⁾
Kemet, Poly-Tantalum	6.3 V	470	0.018Ω	2700 mA	7,3×4,3×4	N/R ⁽⁶⁾	1 - 3 ⁽³⁾	C ≥ 2 ⁽²⁾	T520X477M06ASE018
T520 (SMD)	6.3 V	470	0.010Ω	>5200 mA	7,3×4,3×4	N/R ⁽⁶⁾	1 - 2	B ≥ 1 ⁽²⁾	T530X477M006ASE010
T530 (SMD)	6.3 V	470	0.005Ω	7300 mA	7,3×4,3×4	N/R ⁽⁶⁾	1	B ≥ 1 ⁽²⁾	T530X477M006ASE005
T530 (SMD)	2.5 V	1000	0.005Ω	7300 mA	7,3×4,3×4	N/R ⁽⁶⁾	1	B ≥ 1 ⁽²⁾	T530X108M2R5ASE005 (V _O ≤ 2.0 V) ⁽⁷⁾
Vishay-Sprague									
594D, Tantalum (SMD)	6.3 V	1000	0.030Ω	2890 mA	7,2×5,7×4,1	N/R ⁽⁶⁾	1 - 6	N/R ⁽⁴⁾	594D108X06R3R2TR2T
94SA, Os-con (Radial)	16 V	1000	0.015Ω	9740 mA	16 × 25	1	1 - 3	N/R ⁽⁴⁾	94SA108X0016HBP
94SVP Os-Con(SMD)	16 V	330	0.017Ω	>4500 mA	10 × 12,7	2	2 - 3	C ≥ 1 ⁽²⁾	94SVP827X06R3F12
Kemet, Ceramic X5R	16 V	10	0.002Ω	—	3225	1	≥ 1 ⁽⁸⁾	A ⁽²⁾	C1210C106M4PAC
(SMD)	6.3 V	47	0.002Ω			N/R ⁽⁶⁾	≥ 1 ⁽⁸⁾	A ⁽²⁾	C1210C476K9PAC
Murata, Ceramic X5R	6.3 V	100	0.002Ω	—	3225	N/R ⁽⁶⁾	≥ 1 ⁽⁸⁾	A ⁽²⁾	GRM32ER60J107M
(SMD)	6.3 V	47				N/R ⁽⁶⁾	≥ 1 ⁽⁸⁾	A ⁽²⁾	GRM32ER60J476M
	25 V	22				1	≥ 1 ⁽⁸⁾	A ⁽²⁾	GRM32ER61E226K
	16 V	10				1	≥ 1 ⁽⁸⁾	A ⁽²⁾	GRM32DR61C106K
TDK, Ceramic X5R	6.3 V	100	0.002Ω	—	3225	N/R ⁽⁶⁾	≥ 1 ⁽⁸⁾	A ⁽²⁾	C3225X5R0J107MT
(SMD)	6.3 V	47				N/R ⁽⁶⁾	≥ 1 ⁽⁸⁾	A ⁽²⁾	C3225X5R0J476MT
	16 V	10				1	≥ 1 ⁽⁸⁾	A ⁽²⁾	C3225X5R1C106MT0
	16 V	22				1	≥ 1 ⁽⁸⁾	A ⁽²⁾	C3225X5R1C226MT

(8) Maximum ceramic capacitance on the output bus is ≤ 1000 μF. Any combination of the ceramic capacitor values is limited to 1000 μF for non-TurboTrans applications. The total capacitance is limited to 10,000 μF which includes all ceramic and non-ceramic types.

9.2.1.3 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 is 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 is reduced. Applications requiring tight transient voltage tolerances and minimized capacitor footprint area benefits greatly from this technology.

9.2.1.3.1 TurboTrans™ Selection

Utilizing TurboTrans requires connecting a resistor, R_{TT} , between the +Sense pin (pin 17) and the TurboTrans pin (pin 19). 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 PTH08T250W, the minimum required capacitance is 1000 μF . 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 μF) 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 15 thru Figure 18 show the amount of output capacitance required to meet a desired transient voltage deviation with and without TurboTrans for several capacitor types; 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 to 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 15 thru Figure 18 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% (12.5 A), 50% (25 A), and 75% (37.5 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 60 mV deviation during an 15 A load transient. A majority of 470 μF , 10 $\text{m}\Omega$ output capacitors are used. Use the 12 V, Type B capacitor chart, Figure 15. Dividing 60 mV by 15 A gives 4 mV/A transient voltage deviation per amp of transient load step. Select 4 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 1500 μF . The required R_{TT} resistor value for 1500 μF can then be calculated or selected from Table 4. The required R_{TT} resistor is approximately 17.4 k Ω .

To see the benefit of TurboTrans, follow the 4 mV/A marking across to the 'Without TurboTrans' plot. Following that point down shows that you would need a minimum of 7500 μF of output capacitance to meet the same transient deviation limit. This is the benefit of TurboTrans.

9.2.1.3.1.1 PTH08T250W Type B Capacitors

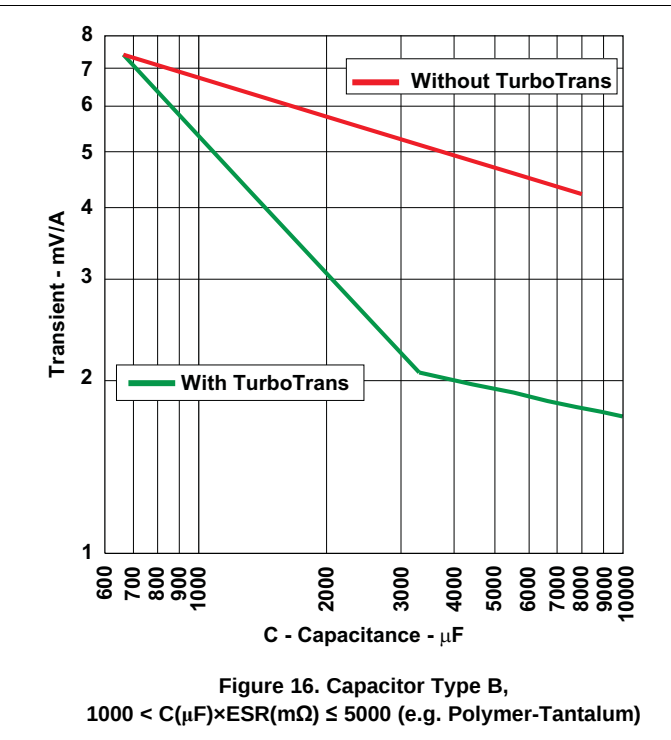
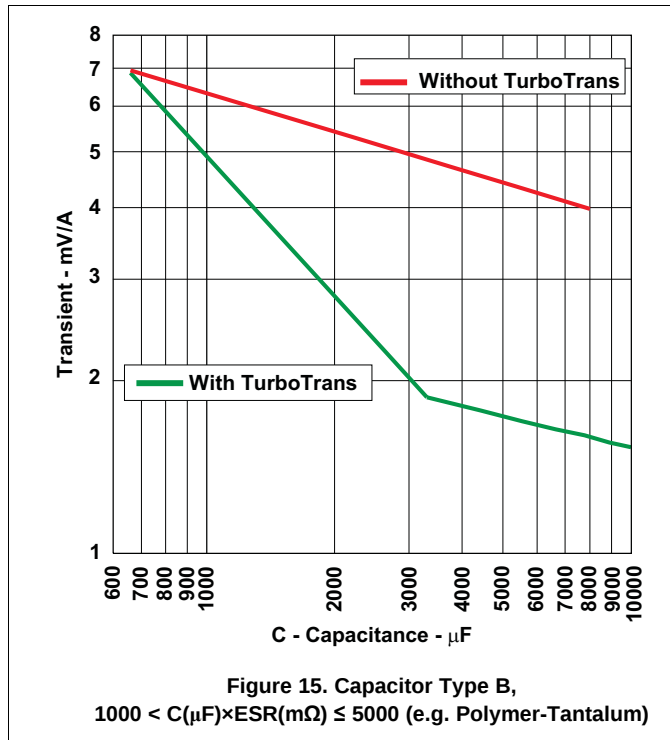


Table 4. Type B TurboTrans C_O Values and Required R_{TT} Selection Table

Transient Voltage Deviation (mV)			12 Volt Input		5 Volt Input	
25% load step (12.5 A)	50% load step (25 A)	75% load step (37.5 A)	C _O Minimum Required Output Capacitance (μF)	R _{TT} Required TurboTrans Resistor (kΩ)	C _O Minimum Required Output Capacitance (μF)	R _{TT} Required TurboTrans Resistor (kΩ)
100	200	300	660	open	660	open
85	170	255	660	open	750	226
75	150	225	800	143	870	93.1
60	120	180	1050	46.4	1150	34.8
50	100	150	1300	24.9	1450	18.7
40	70	105	1750	11.3	1950	8.45
30	60	90	2500	3.48	2800	1.87
25	50	75	3100	0.649	4000	short

9.2.1.3.1.1.1 R_{TT} Resistor Selection

The TurboTrans resistor value, R_{TT} can be determined from the TurboTrans programming [Equation 2](#).

$$R_{TT} = 40 \times \frac{1 - (C_O / 3300)}{(5 \times C_O / 3300) - 1} \text{ (k}\Omega\text{)} \quad (2)$$

Where C_O is the total output capacitance in μF. C_O values greater than or equal to 3300 μF require R_{TT} to be a short, 0Ω. ([Equation 2](#) results in a negative value for R_{TT} when C_O > 3300 μF.)

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 [Figure 15](#) and [Figure 16](#).

9.2.1.3.1.2 PTH08T250W Type C Capacitors

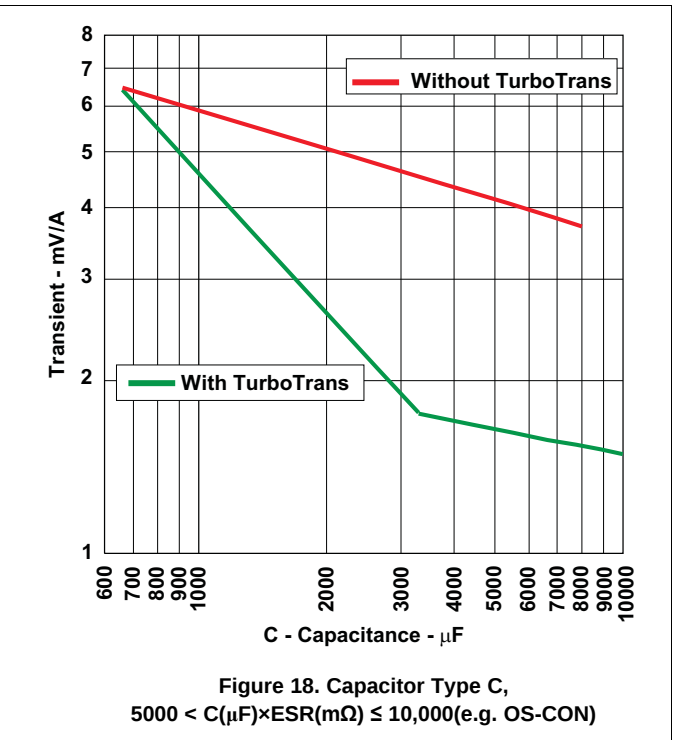
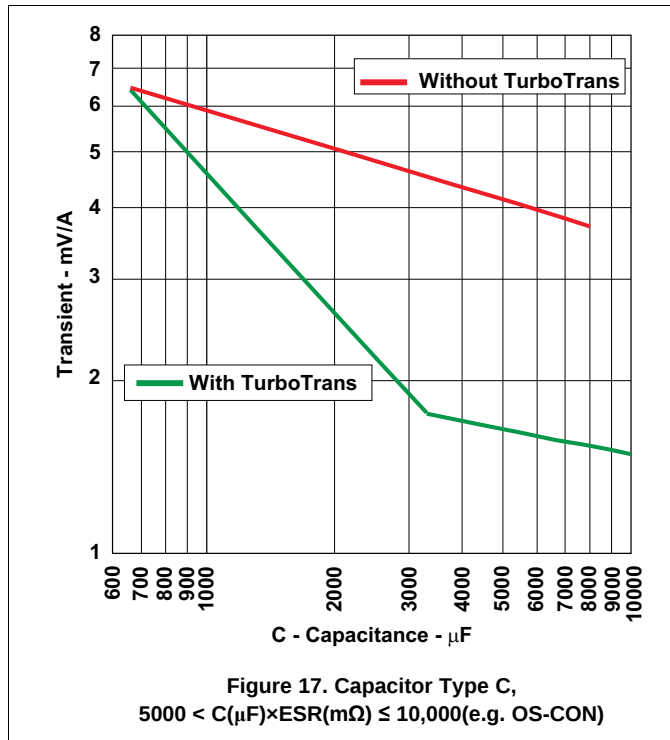


Table 5. Type C TurboTrans C_O Values and Required R_{TT} Selection Table

Transient Voltage Deviation (mV)			12 Volt Input		5 Volt Input	
25% load step (12.5 A)	50% load step (25 A)	75% load step (37.5 A)	C _O Minimum Required Output Capacitance (μF)	R _{TT} Required TurboTrans Resistor (kΩ)	C _O Minimum Required Output Capacitance (μF)	R _{TT} Required TurboTrans Resistor (kΩ)
85	170	255	660	open	660	open
75	150	225	720	340	800	143
60	120	180	950	64.9	1050	46.4
50	100	150	1200	30.9	1350	22.6
40	80	120	1600	14.3	1800	10.5
30	60	90	2250	5.23	2650	2.61
25	50	75	2800	1.87	3850	short
20	40	60	6000	short	-	-

9.2.1.3.1.2.1 R_{TT} Resistor Selection

The TurboTrans resistor value, R_{TT} can be determined from the TurboTrans programming [Equation 3](#).

$$R_{TT} = 40 \times \frac{1 - (C_O / 3300)}{(5 \times C_O / 3300) - 1} \text{ (k}\Omega\text{)} \quad (3)$$

Where C_O is the total output capacitance in μF. C_O values greater than or equal to 3300 μF require R_{TT} to be a short, 0Ω. ([Equation 3](#) results in a negative value for R_{TT} when C_O > 3300 μF). 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 [Figure 17](#) and [Figure 18](#).

9.2.1.4 Undervoltage Lockout (UVLO)

The PTH08T250W 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 500 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.

9.2.1.4.1 UVLO Adjustment

The UVLO feature of the PTH08T250W module allows for limited adjustment of the ON threshold voltage. The adjustment is made via the *Inhibit/UVLO Prog* control pin (pin 11) using a single resistor (see Figure 19). When pin 11 is left open circuit, the ON threshold voltage is internally set to its default value, which is 4.3 volts. The ON threshold might need to be raised if the module is powered from a tightly regulated 12-V bus. Adjusting the threshold prevents the module from operating if the input bus fails to completely rise to its specified regulation voltage.

Equation 4 determines the value of R_{UVLO} 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.

$$R_{UVLO} = \frac{230}{V_I - 4.6} \text{ (k}\Omega\text{)} \quad (4)$$

Table 6 lists the standard resistor values for R_{UVLO} for different values of the on-threshold (V_{THD}) voltage.

Table 6. Standard R_{UVLO} Values for Various V_{THD} Values

V_{THD} (V)	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
R_{UVLO} (k Ω)	255	165	121	95.3	78.7	68.1	59.0	52.3	46.4	42.2	39.2	35.7

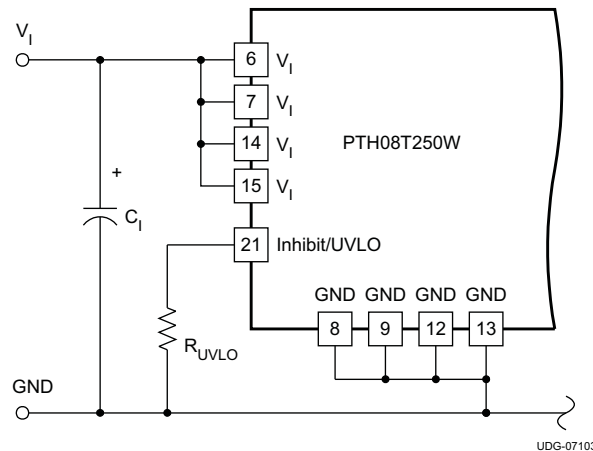


Figure 19. Undervoltage Lockout Adjustment Resistor Placement

9.2.1.5 On/Off Inhibit

For applications requiring output voltage on/off control, the PTH08T250W 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.

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 20 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, V_{INH} . The waveforms were measured with a 25-A constant current load.

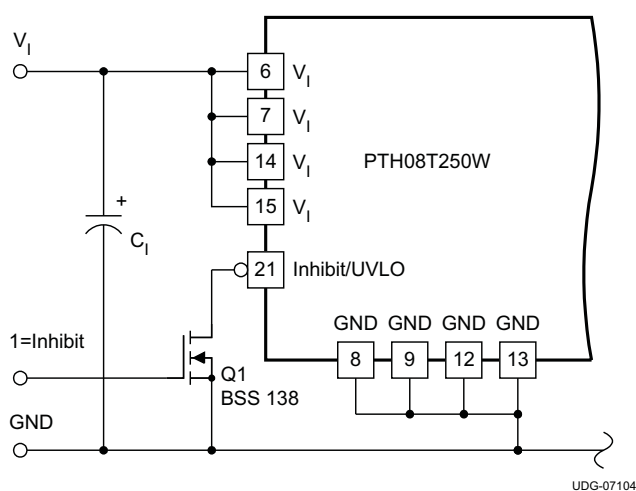


Figure 20. On/Off Inhibit Control Circuit

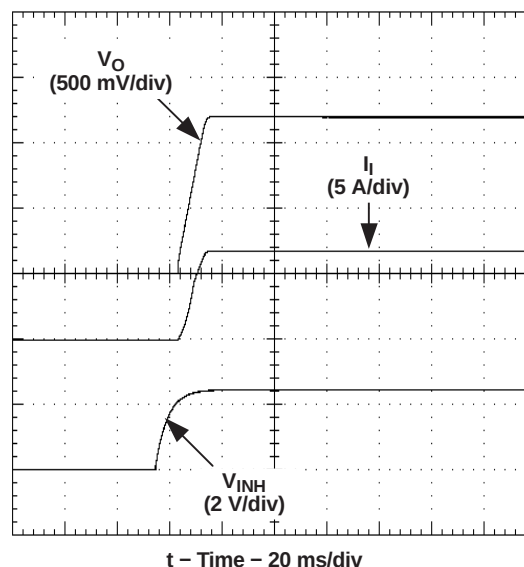


Figure 21. Power-Up Response from Inhibit Control

9.2.1.6 Current Sharing

The PTH08T250W module is capable of being configured in parallel with another PTH08T250W module to share load current. To parallel the two modules, it is necessary to configure one module as the Master and one module as the Slave. To configure a module as the Master, connect the CONFIG pin (pin 1) to GND. The CONFIG pin of the Slave must be connected to V_I . In order to share current, pins 2 thru 5 of both the Master and Slave must be connected between the two modules. See Figure 27 for the recommended layout of pins 2 thru 5. The module that is configured as the MASTER is used to control all of the functions of the two modules including Inhibit ON/OFF control, AutoTrack sequencing, TurboTrans, SmartSync, +/- Remote Sense, and Output Voltage Adjust. See the current sharing diagram in Figure 22 for connections. The MASTER and the SLAVE must be powered from the same input voltage supply.

See Figure 22 and Table 7 for a diagram and connection description of each pin when two PTH08T250W modules are being used in a MASTER/SLAVE configuration.

Refer to the application article SLYT320 for more information regarding current sharing PTH08T250W modules.

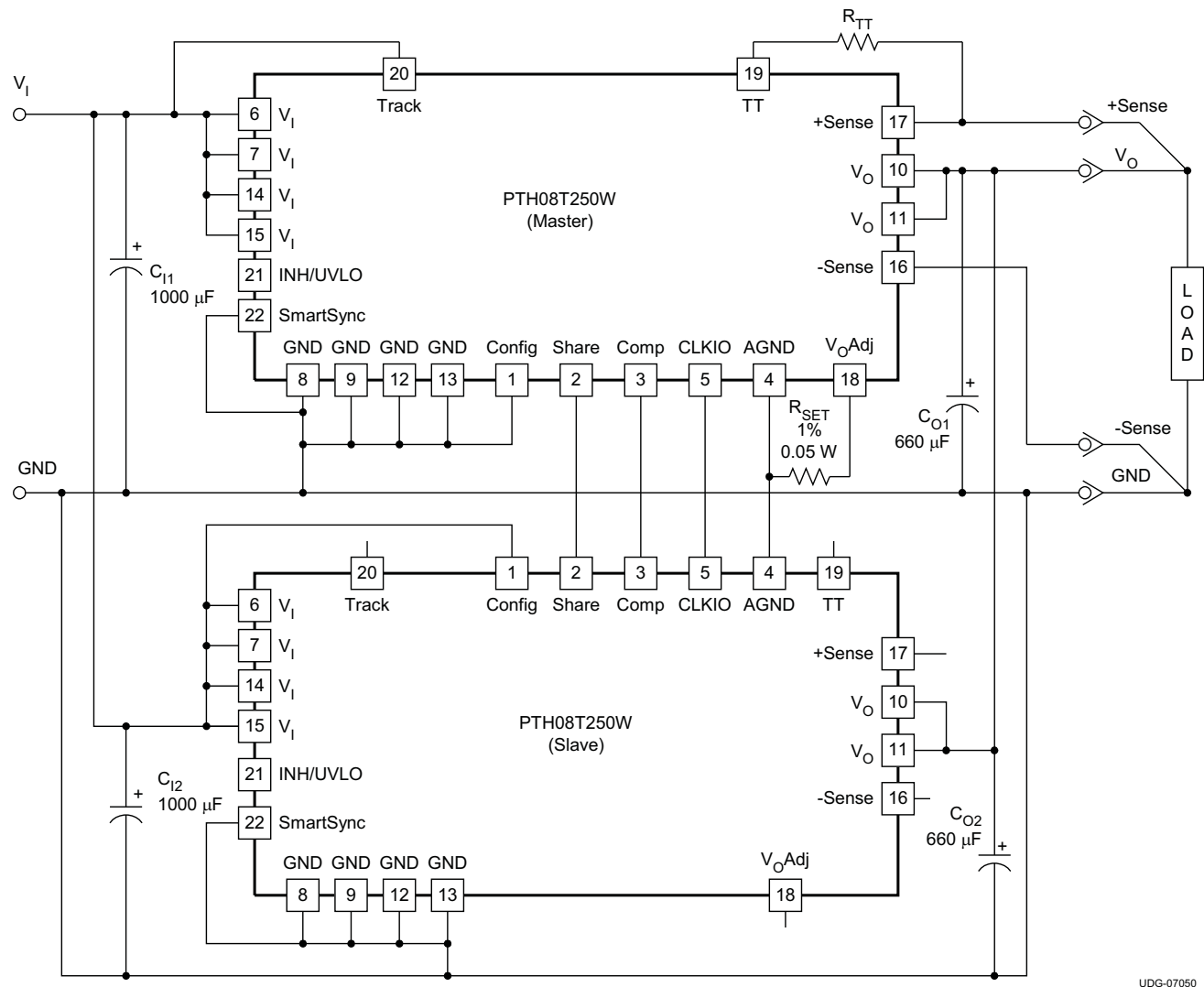


Figure 22. Typical Current Sharing Diagram

Table 7. Required Connections for Current Sharing⁽¹⁾

PIN		MASTER	SLAVE
NAME	NO.		
V _I	6,7,14,15	Connect to the Input Bus.	Connect to the Input Bus.
V _O	10,11	Connect to the Output Bus.	Connect to the Output Bus.
GND	8,9,12,13	Connect to Common Power GND.	Connect to Common Power GND.
Inhibit and UVLO	21	Use for Inhibit control & UVLO adjustments. If unused leave open-circuit.	No Connection. Leave open-circuit.
V _O Adjust	18	Use to set the output voltage. Connect R _{SET} resistor between this pin and AGND (pin 4).	No Connection. Leave open-circuit.
+Sense	17	Connect to the output voltage either at the load or at the module (pin 11).	No Connection. Leave open-circuit.
–Sense	16	Connect to the output GND either at the load or at the module (pin 13).	No Connection. Leave open-circuit.
Track	20	Connect to Track control or to V _I (pin 15).	No Connection. Leave open-circuit.
TurboTrans™	19	Connect TurboTrans resistor, R _{TT} , between this pin and +Sense (pin 17).	No Connection. Leave open-circuit.
SmartSync	22	Connect to an external clock. If unused connect to GND.	Connect to Common Power GND.
CONFIG	1	Connect to GND. ⁽²⁾	Connect to the Input Bus.
Share	2	Connect to pin 2 of Slave. ⁽²⁾	Connect to pin 2 of Master.
Comp	3	Connect to pin 3 of Slave. ⁽²⁾	Connect to pin 3 of Master.
AGND	4	Connect to pin 4 of Slave. ⁽³⁾	Connect to pin 4 of Master.
CLKIO	5	Connect to pin 5 of Slave. ⁽²⁾	Connect to pin 5 of Master.

(1) For more details on the pin descriptions, refer the Pin Functions table.

(2) See Layer A in [Figure 27](#) for recommended layout

(3) See Layer B in [Figure 27](#) for recommended layout

9.2.1.6.1 Current Sharing and TurboTrans™

When using TurboTrans while paralleling two modules, the TurboTrans resistor, R_{TT}, must be connected from the TurboTrans pin (pin 19) of the Master module to the +Sense pin (pin 17) of the Master module. When paralleling modules the procedure to calculate the proper value of output capacitance and R_{TT} is similar to that explained in the [TurboTrans™ Selection](#) section, however the values must be calculated for a single module. Therefore, the total output current load step must be halved before determining the required output capacitance and the R_{TT} value as explained in the [TurboTrans™ Selection](#) section. The value of output capacitance calculated is the minimum required output capacitance per module and the value of R_{TT} must be calculated using this value of output capacitance. The TurboTrans pin of the Slave module must be left open.

As an example, let's look at a 12-V application requiring a 60 mV deviation during an 30 A load transient. A majority of 470 μF, 10 mΩ output capacitors are used. Use the 12 V, Type B capacitor chart, [Figure 15](#). First, halving the load transient gives 15 A. Dividing 60 mV by 15 A gives 4 mV/A transient voltage deviation per amp of transient load step. Select 4 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 1500 μF. This is the minimum required output capacitance per module. Hence, the total minimum output capacitance is 2 × 1500 μF = 3000 μF. The required R_{TT} resistor value for 1500 μF can then be calculated or selected from [Table 4](#). The required R_{TT} resistor is approximately 17.4 kΩ.

9.2.1.6.1.1 Current Sharing Thermal Derating Curves

The temperature derating curves in [Figure 23](#) through [Figure 26](#) represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to two PTH08T250W modules soldered directly to a 100 mm x 200 mm double-sided PCB with 2 oz. copper and the direction of airflow from pins 10 to pins 22. For surface mount packages (AS and AZ suffix), multiple vias must be utilized. Refer to the mechanical specification for more information.

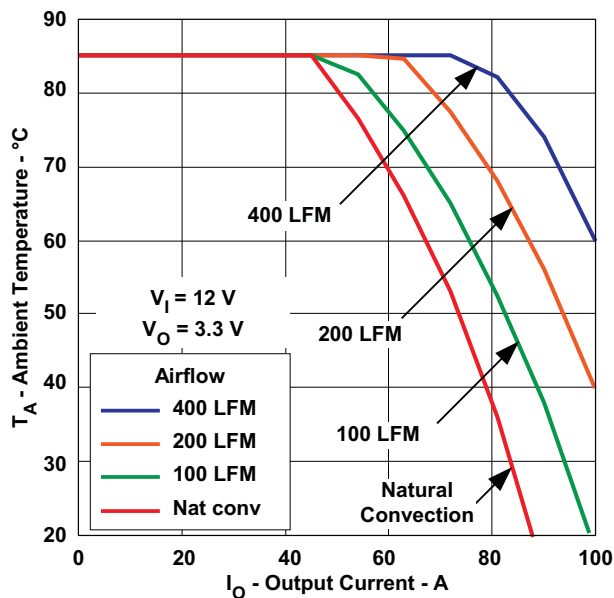


Figure 23. Ambient Temperature vs. Output Current

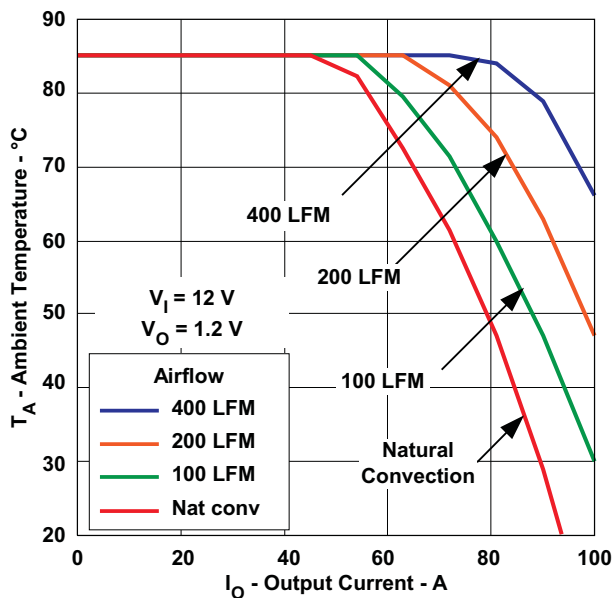


Figure 24. Ambient Temperature vs. Output Current

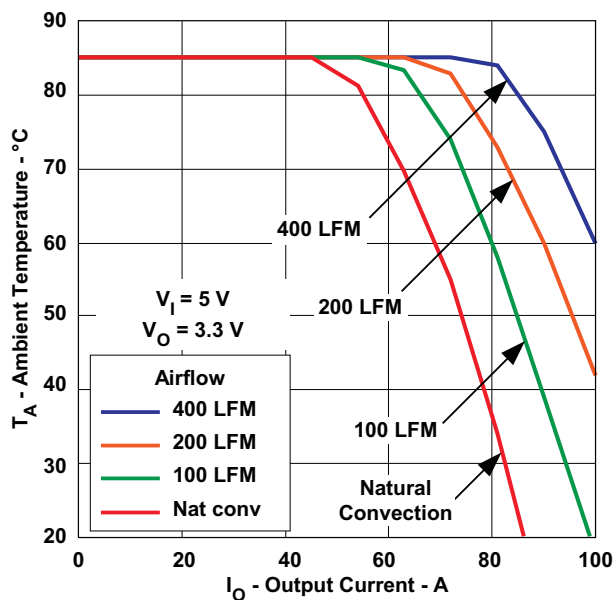


Figure 25. Ambient Temperature vs. Output Current

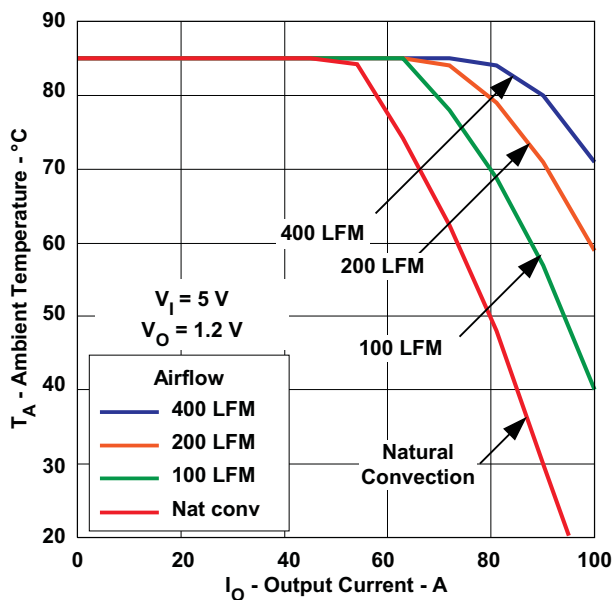


Figure 26. Ambient Temperature vs. Output Current

9.2.1.6.1.2 Current Sharing Layout

In current sharing applications the V_I pins of both modules must be connected to the same input bus. The V_O pins of both modules are connected together to power the load. The GND pins of both modules are connected via the GND plane. Four other inter-connection pins are connected between the modules. [Figure 27](#) shows the required layout of the inter-connection pins for two modules configured to share current. Notice that the Share (pin 2) connection is routed between the Comp (pin 3) and CLKIO (pin 5) connections. AGND (pin 4) should be connected as a thicker trace on an adjacent layer, running parallel to pins 2, 3 and 5. AGND must not be connected to the GND plane.

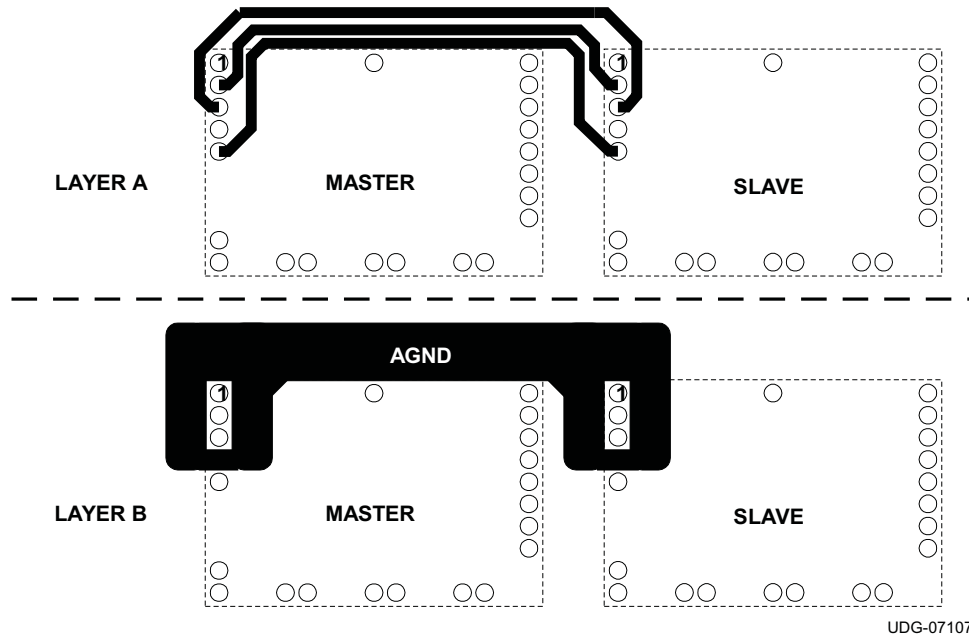


Figure 27. Recommended Layout of Inter-Connection Pins Between Two Current Sharing Modules

9.2.1.7 Prebias Startup Capability

A prebias startup condition occurs as a result of an external voltage being present at the output of a power module prior to its output becoming active. This often occurs in complex digital systems when current from another power source is backfed through a dual-supply logic component, such as an FPGA or ASIC. Another path might be via clamp diodes as part of a dual-supply power-up sequencing arrangement. A prebias can cause problems with power modules that incorporate synchronous rectifiers. This is because under most operating conditions, these types of modules can sink as well as source output current.

The PTH family of power modules incorporate synchronous rectifiers, but does not sink current during startup⁽¹⁾, or whenever the Inhibit pin is held low. However, to ensure satisfactory operation of this function, certain conditions must be maintained⁽²⁾. [Figure 29](#) shows an application demonstrating the prebias startup capability. The startup waveforms are shown in [Figure 28](#). Note that the output current (I_O) is negligible until the output voltage rises above the voltage backfed through the intrinsic diodes.

The prebias start-up feature is not compatible with Auto-Track. When the module is under Auto-Track control, it sinks current if the output voltage is below that of a back-feeding source. To ensure a pre-bias hold-off one of two approaches must be followed when input power is applied to the module. The Auto-Track function must either be disabled⁽³⁾, or the module's output held off (for at least 50 ms) using the Inhibit pin. Either approach ensures that the Track pin voltage is above the set-point voltage at start up.

1. Startup includes the short delay (approximately 10 ms) prior to the output voltage rising, followed by the rise of the output voltage under the module's internal soft-start control. Startup is complete when the output voltage has risen to either the set-point voltage or the voltage at the Track pin, whichever is lowest.
2. To ensure that the regulator does not sink current when power is first applied (even with a ground signal applied to the Inhibit control pin), the input voltage must always be greater than the output voltage *throughout* the power-up and power-down sequence.
3. The Auto-Track function can be disabled at power up by immediately applying a voltage to the module's Track pin that is greater than its set-point voltage. This can be easily accomplished by connecting the Track pin to V_I .

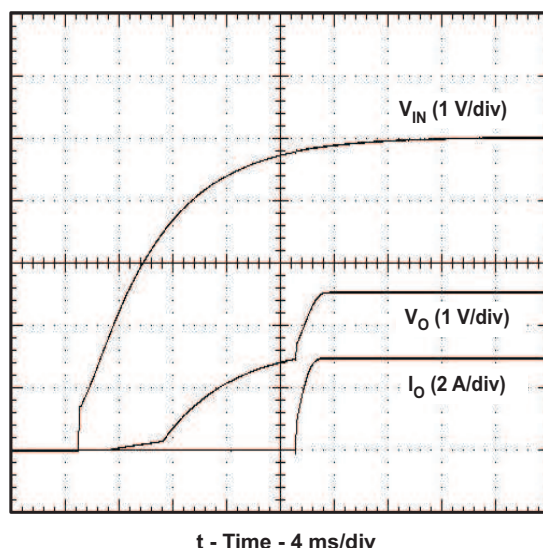


Figure 28. Prebias Startup Waveforms

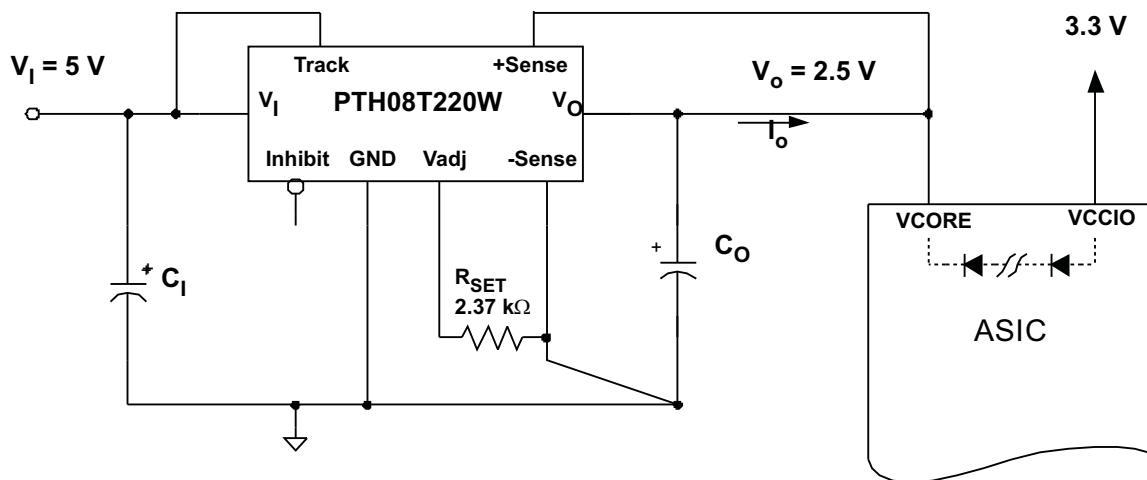


Figure 29. Application Circuit Demonstrating Pre-Bias Startup

9.2.1.8 SmartSync Technology

SmartSync technology allows multiple power modules to be synchronized to a common frequency. When not used, this pin must be connect to GND. Driving the SmartSync 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. Eliminating the low beat frequencies (usually <10 kHz) allows the EMI filter to be designed to attenuate only the synchronization frequency. Power modules can also be synchronized out-of-phase to minimize ripple current and reduce input capacitance requirements.

NOTE

The PTH08T250W requires that the external synchronization frequency be present before a valid input voltage is present or before release of the inhibit control.

Figure 30 shows a standard circuit with two modules synchronized 180° out-of-phase using a D flip-flop circuit.

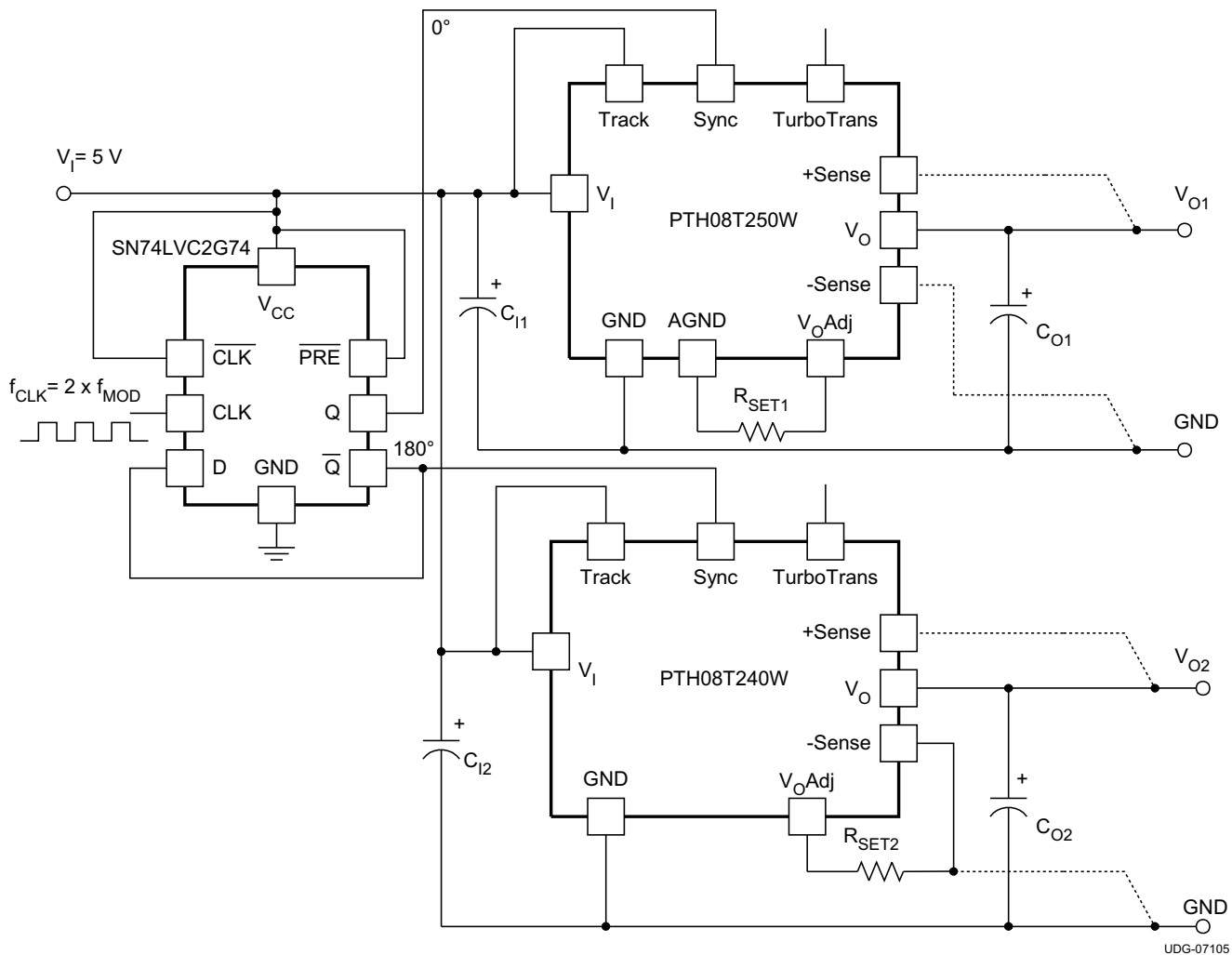


Figure 30. Typical SmartSync Schematic

Operating the PTH08T250W with a low duty cycle may increase the output voltage ripple. When operating at the nominal switching frequency, input voltages greater than ($V_O \times 12$) may cause the output voltage ripple to increase (up to 2×).

When using Smart Sync, the minimum duty cycle varies as a function of output voltage and switching frequency. Synchronizing to a higher frequency causes greater restrictions on the duty cycle range. For a given switching frequency, [Figure 31](#) shows the operating region where the output voltage ripple meets the electrical specifications. Operation above a given curve may cause the output voltage ripple to increase (up to 2×). For example, a module operating at 400 kHz and an output voltage of 1.2 V, the maximum input voltage that meets the output voltage ripple specification is 11 V. Exceeding 11 V may cause in an increase in output voltage ripple. As shown in [Figure 31](#), operating below 6 V allows operation down to the minimum output voltage over the entire synchronization frequency range without affecting the output voltage ripple. See the Electrical Characteristics table for the synchronization frequency range limits.

The maximum output current that a single module can deliver may also be affected by the synchronization frequency. See [Figure 32](#) below for load current derating when synchronizing at frequencies greater than 330 kHz. First consult the temperature derating graphs in the Typical Characteristics section to determine the maximum output current based on operating conditions. Any derating due to the SmartSync frequency is in addition to the temperature derating.

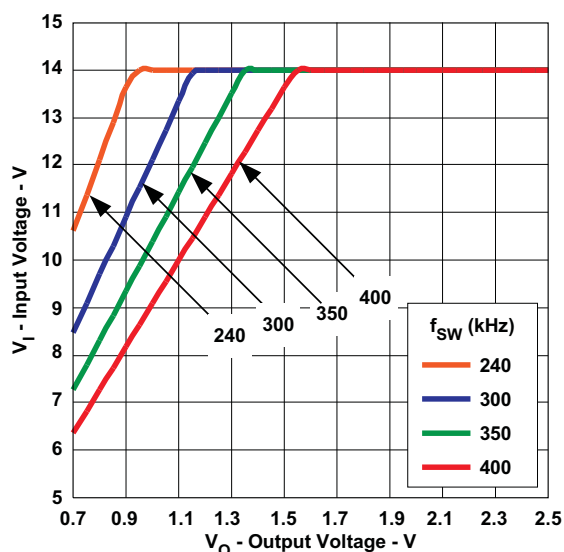


Figure 31. Output Voltage Ripple Limits

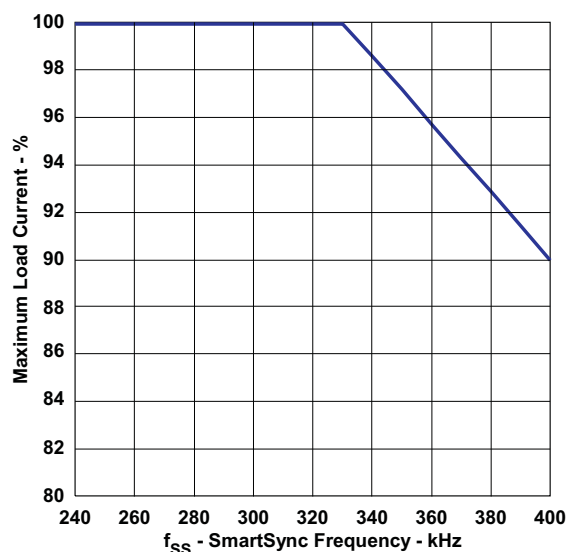


Figure 32. Maximum Load Current vs. SmartSync Frequency

9.2.1.9 Auto-Track™ Function

The Auto-Track function is unique to the PTH and PTV device families, 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.

9.2.1.9.1 How Auto-Track™ Works

Auto-Track works by forcing the module output voltage to follow a voltage presented at the *Track* control pin ⁽¹⁾. 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 ⁽²⁾. 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 ⁽³⁾. 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.

9.2.1.9.2 Typical Auto-Track 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 33](#).

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 ⁽⁴⁾, enabling them to produce an output voltage. A low-cost supply voltage supervisor IC, with a built-in time delay, is an ideal component for automatically controlling the Track inputs at power up.

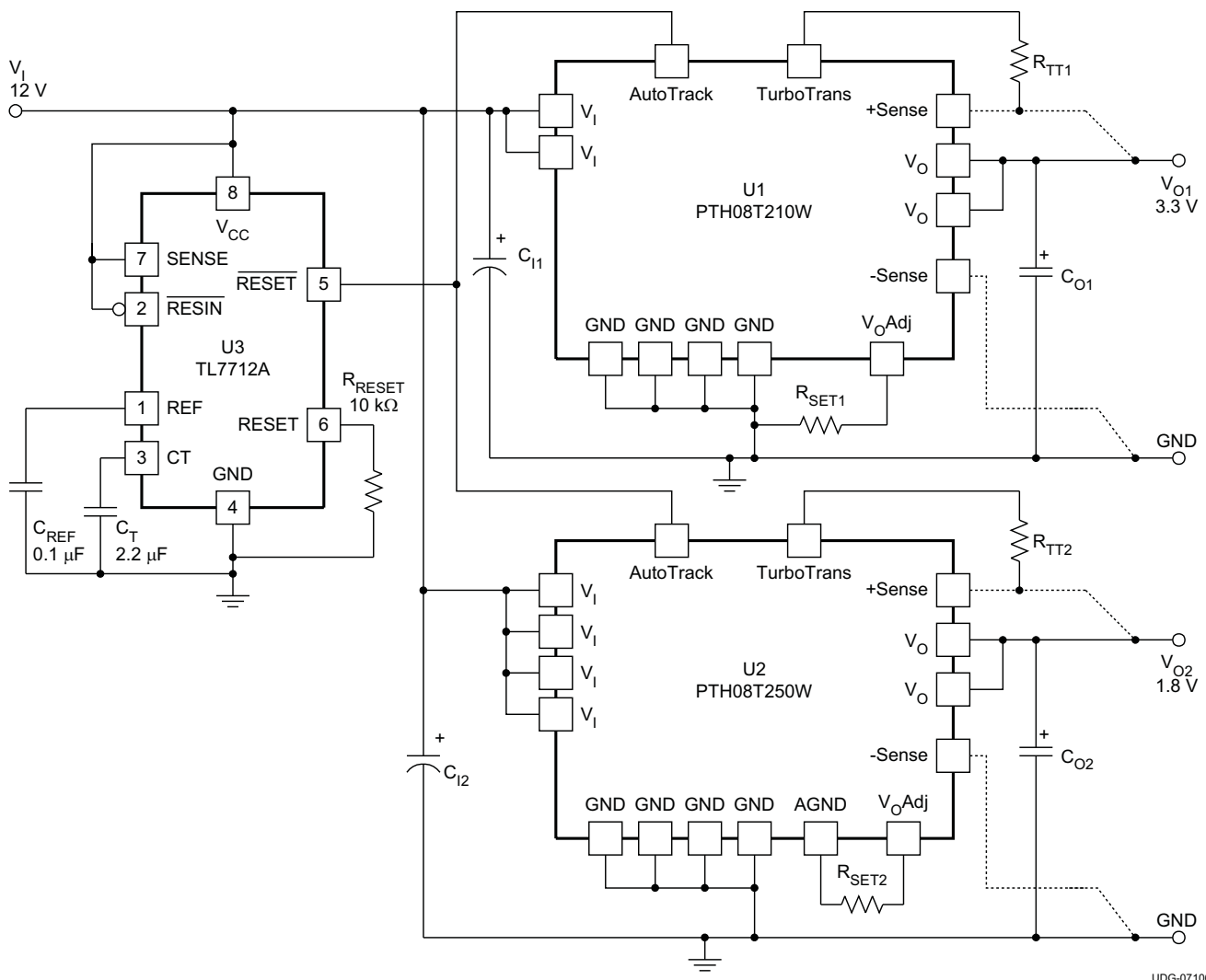
[Figure 33](#) shows how the TL7712A supply voltage supervisor IC (U3) can be used to coordinate the sequenced power up of PTH08T250W modules. The output of the TL7712A supervisor becomes active above an input voltage of 3.6 V, enabling it to assert a ground signal to the common track control well before 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 C_T . The value of 2.2 μ 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 34](#) 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 35](#). 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.

9.2.1.9.3 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.



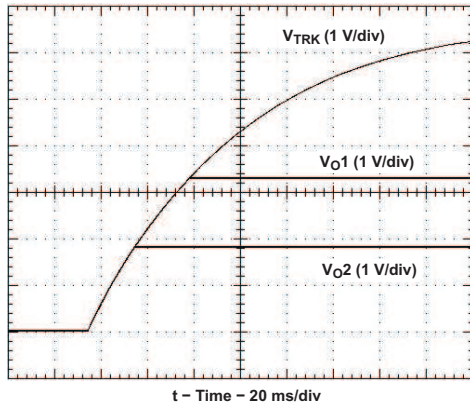
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Figure 33. Sequenced Power Up and Power Down Using Auto-Track

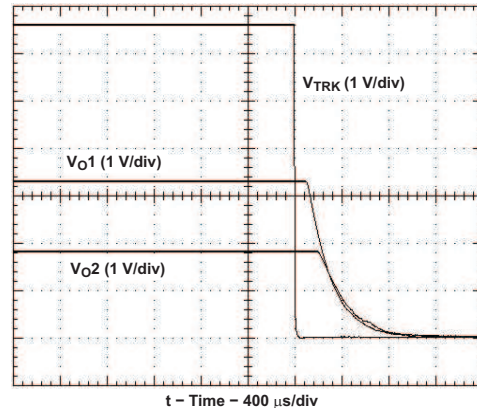
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**Figure 34. Simultaneous Power Up
With Auto-Track Control**



**Figure 35. Simultaneous Power Down
With Auto-Track Control**

10 Device and Documentation Support

10.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

10.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

10.3 Trademarks

Auto-Track, TurboTrans, TMS320, E2E are trademarks of Texas Instruments. All other trademarks are the property of their respective owners.

10.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

10.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

PTH08T250W

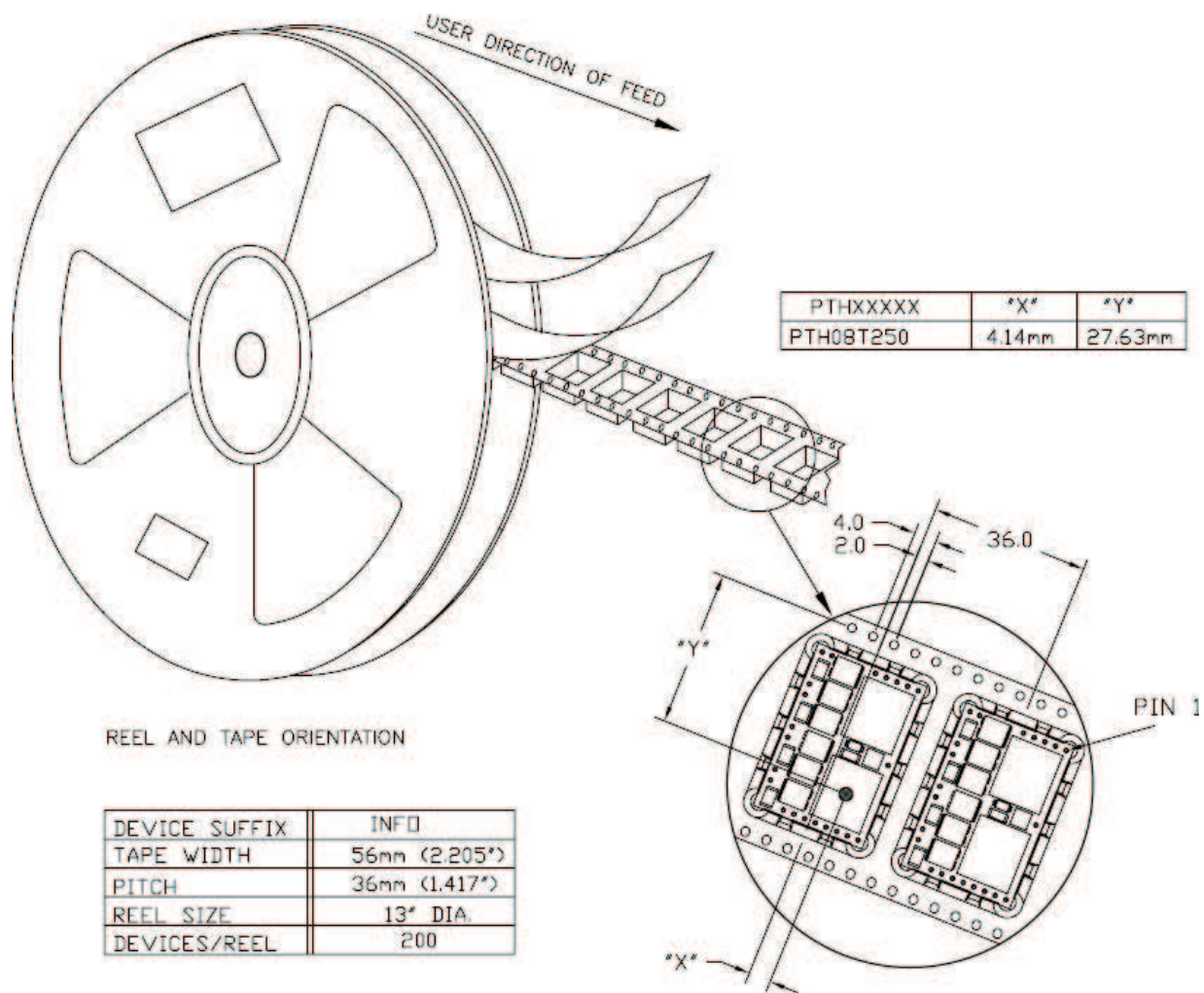
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11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

11.1 Tape, Reel and Tray Drawings



207.96
203.84

Y
PITCH

B

0.000

A

X
PITCH

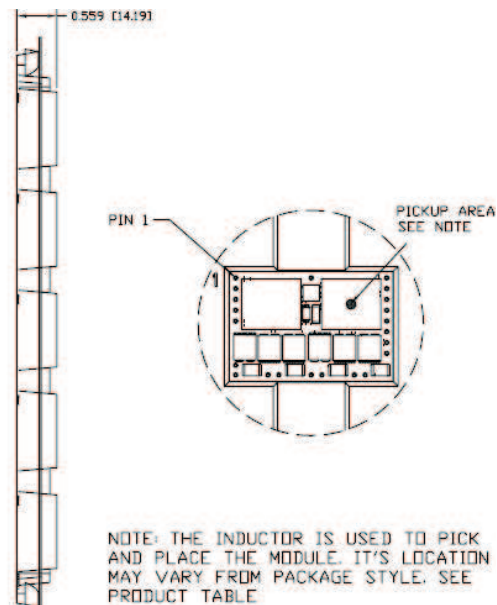
PTHXXXXX

	A	*B*	*X*	*Y*
PTH08T250	40.36	36.43	47.63	35.56

ALL DIMENSIONS ARE IN MILLIMETER.

076-00295

252.43



DEVICES/TRAY	42
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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTH08T250WAD	ACTIVE	Through-Hole Module	ECT	22	25	RoHS (In Work) & Green (In Work)	SN	N / A for Pkg Type	-40 to 85		Samples
PTH08T250WAS	ACTIVE	Surface Mount Module	ECU	22	25	RoHS (In Work) & Green (In Work)	SNPB	Level-1-235C-UNLIM/ Level-3-260C-168HRS	-40 to 85		Samples
PTH08T250WAST	ACTIVE	Surface Mount Module	ECU	22	200	RoHS (In Work) & Green (In Work)	SNPB	Level-1-235C-UNLIM/ Level-3-260C-168HRS	-40 to 85		Samples
PTH08T250WAZ	ACTIVE	Surface Mount Module	BCU	22	25	RoHS (In Work) & Green (In Work)	SNAGCU	Level-3-260C-168 HR	-40 to 85		Samples
PTH08T250WAZT	ACTIVE	Surface Mount Module	BCU	22	200	RoHS (In Work) & Green (In Work)	SNAGCU	Level-3-260C-168 HR	-40 to 85		Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

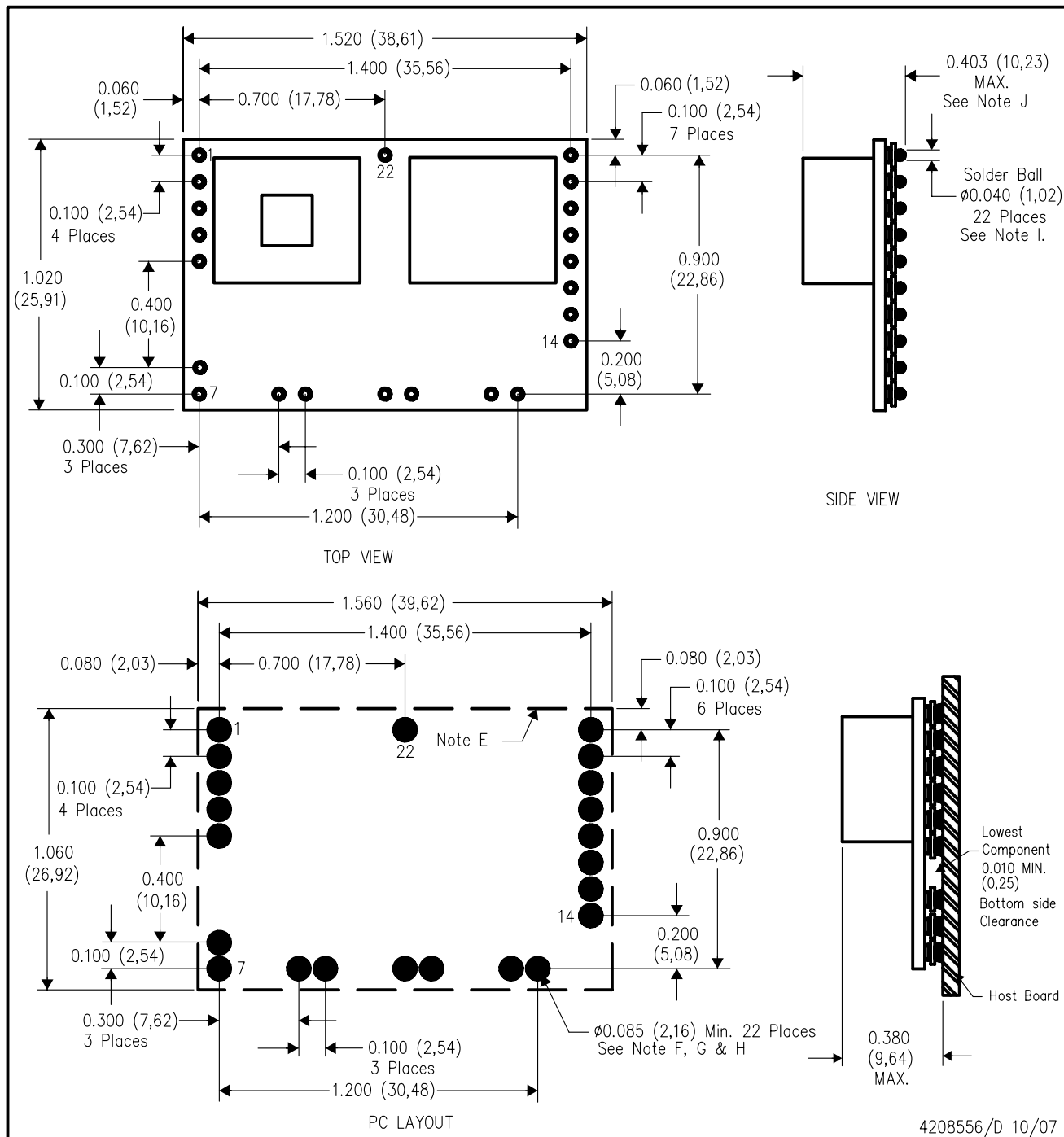
⁽⁶⁾ Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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BCU (R-PDSS-B22)

DOUBLE SIDED MODULE

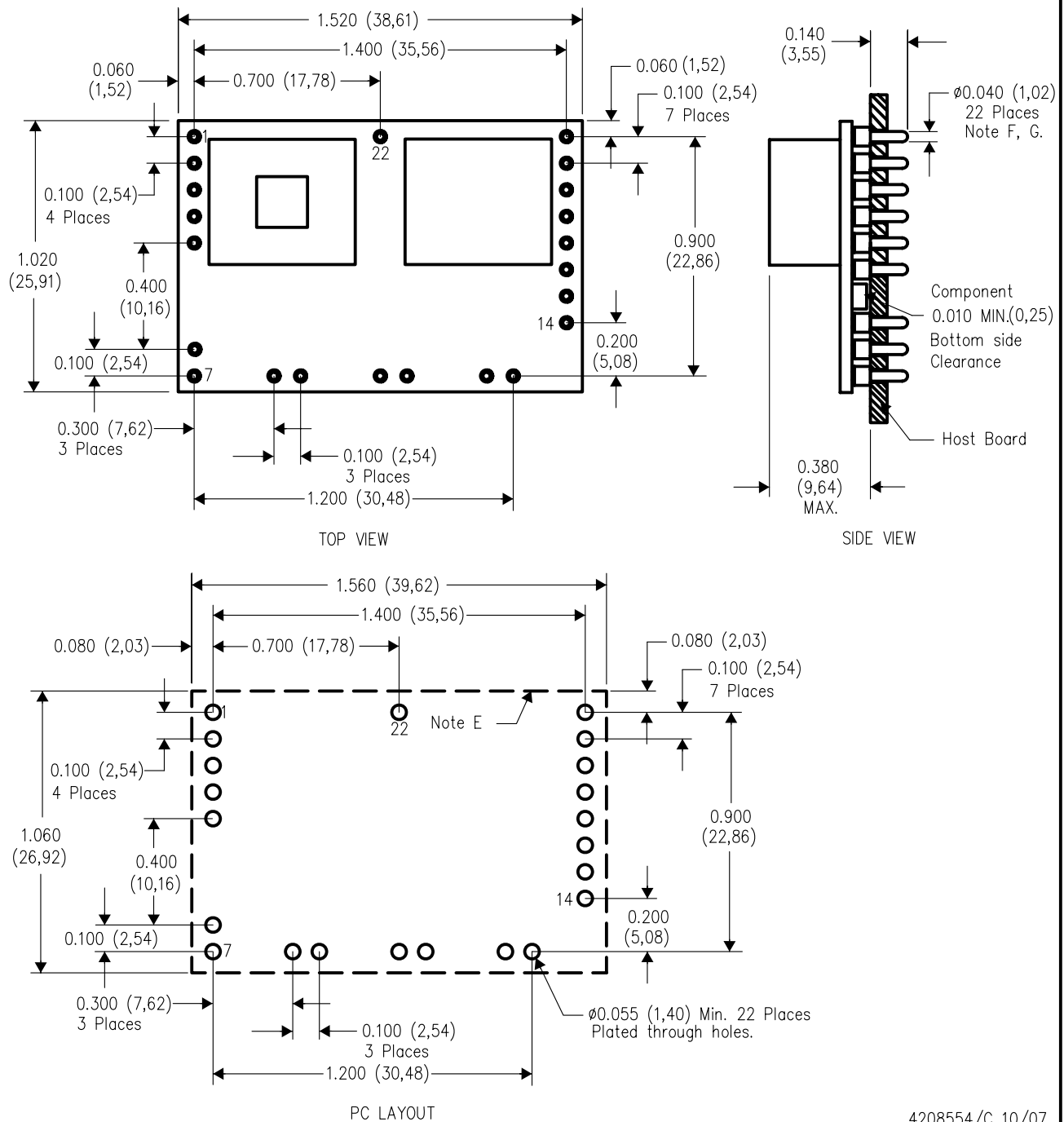


- NOTES:
- A. All linear dimensions are in inches (mm).
 - B. This drawing is subject to change without notice.
 - C. 2 place decimals are ± 0.030 ($\pm 0,76\text{mm}$).
 - D. 3 place decimals are ± 0.010 ($\pm 0,25\text{mm}$).
 - E. Recommended keep out area for user components.
 - F. Power pin connection should utilize four 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. This is a lead-free solder ball design.
Finish: Tin (100%) over Nickel plate
Solder ball: 96.5 Sn/3.0 Ag/0.5 Cu
- J. Dimension prior to reflow solder.

ECT (R-PDSS-T22)

DOUBLE SIDED MODULE

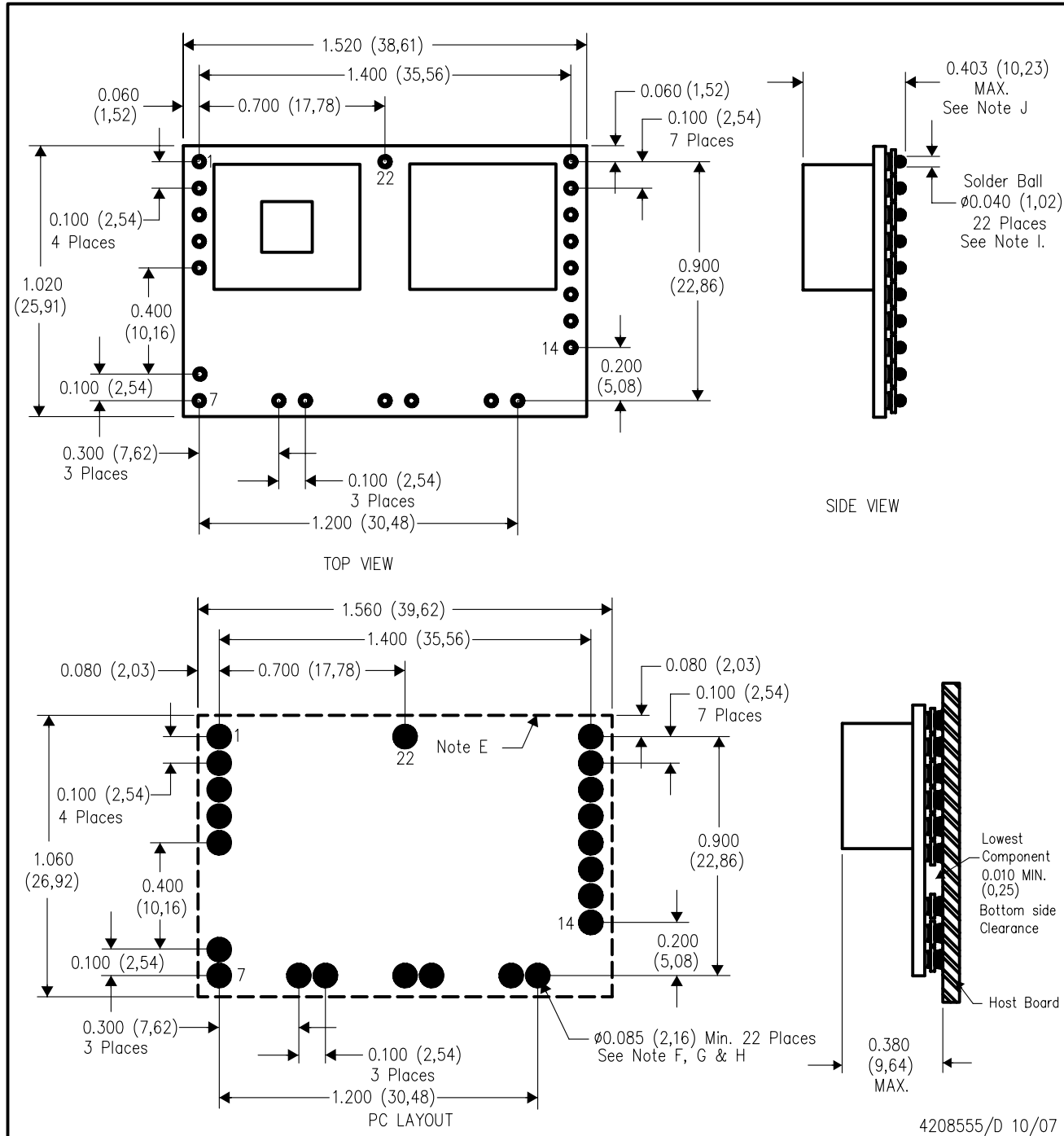


- NOTES:
- A. All linear dimensions are in inches (mm).
 - B. This drawing is subject to change without notice.
 - C. 2 place decimals are ± 0.030 (± 0.76 mm).
 - D. 3 place decimals are ± 0.010 (± 0.25 mm).
 - E. Recommended keep out area for user components.

- 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

ECU (R-PDSS-B22)

DOUBLE SIDED MODULE



4208555/D 10/07

- NOTES:
- All linear dimensions are in inches (mm).
 - This drawing is subject to change without notice.
 - 2 place decimals are ± 0.030 ($\pm 0,76$ mm).
 - 3 place decimals are ± 0.010 ($\pm 0,25$ mm).
 - Recommended keep out area for user components.
 - Power pin connection should utilize four 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).

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

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