



# PTH12040 12Vin Single

## Application Note 193

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## 1. Introduction

The PTH family of non-isolated, wide-output adjust power modules from Artesyn Technologies are optimized for applications that require a flexible, high performance module that is small in size. These products are part of the “Point-of-Load Alliance” (POLA), which ensures compatible footprint, interoperability and true second sourcing for customer design flexibility. The POLA is a collaboration between Artesyn Technologies, Astec Power Texas Instruments and Ericsson Power Modules to offer customers advanced non-isolated modules that provide the same functionality and form factor. Product series covered by the alliance includes the PTHxx050W (6A), PTHxx060W (10A), PTHxx010W (15/12A), PTHxx020W (22/18A), PTHxx030W (30/26A) and the PTHxx040W (50/60A).


From the basic, “Just Plug it In” functionality of the 6A modules, to the 60A rated feature-rich PTHxx040W, series these products were designed to be very flexible, yet simple to use. The features vary with each product series. Table 1 provides a quick reference to the available features by series and input bus voltage.

For simple point-of-use applications, the PTHxx050W series provides operating features such as an ON/OFF inhibit, output voltage trim, pre-bias start-up (3.3/5V input only), and overcurrent protection. The PTHxx060W (10A), and PTHxx010W (15/12A) series add an output voltage sense, and margin up/down controls. The higher output current, PTHxx020W and PTHxx030W series also incorporates overtemperature and shutdown protection. All of the products referenced in Table 1 include Auto-Track™.

This is a feature unique to the PTH family, and was specifically designed to simplify the task of sequencing the supply voltage in a power system. These and other features are described in the following sections.

SERIES	INPUT BUS	I <sub>OUT</sub>	ADJUST TRIM	ON/OFF INHIBIT	OVER-CURRENT	PRE-BIAS START-UP	AUTO-TRACK™*	MARGIN UP/DOWN	OUTPUT SENSE	THERMAL SHUTDOWN
PTHxx050	3.3V	6A	●	●	●	●	●			
	5V	6A	●	●	●	●	●			
	12V	6A	●	●	●	●	●			
PTHxx060	3.3V/5V	10A	●	●	●	●	●	●	●	
	12V	10A	●	●	●	●	●	●	●	
PTHxx010	3.3V/5V	15A	●	●	●	●	●	●	●	
	12V	12A	●	●	●	●	●	●	●	
PTHxx020	3.3V/5V	22A	●	●	●	●	●	●	●	●
	12V	18A	●	●	●	●	●	●	●	●
PTHxx030	3.3V/5V	30A	●	●	●	●	●	●	●	●
	12V	26A	●	●	●	●	●	●	●	●
PTHxx040	3.3V - 5V	60A	●	●	●	●	●	●	●	●
	12V	50A	●	●	●	●	●	●	●	●

Table 1 - Operating Features by Series and Input Bus Voltage

RoHS Compliance Ordering Information	
	PTH12040WAST To order Pb-free (RoHS compatible) surface-mount parts replace the mounting option ‘S’ with ‘Z’, e.g. PTH12040WAZT. To order Pb-free (RoHS compatible) through-hole parts replace the mounting option ‘H’ with ‘D’, e.g. PTH12040WADT.

\*Auto-track™ is a trade mark of Texas Instruments



## 2. System Interface Information

### 2.1 Input Capacitor

The improved transient response of a multi-phase converter places a bigger burden on the transient capability of the input source. The size and value of the input capacitor is therefore determined by this converter's transient performance capability. The minimum amount of input capacitance required is  $560\mu\text{F}^{[3]}$ , with an RMS ripple current rating of 300mA. 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 applications, or wherever the transient performance of the input source is limited,  $1,000\mu\text{F}$  of input capacitance is recommended.

Ripple current, less than  $100\text{m}\Omega$  equivalent series resistance (ESR), and temperature are major considerations when selecting input capacitors. The ripple current reflected from the input of the PTH12040W module is moderate to low. Therefore any good quality, computer-grade electrolytic capacitor, of either value suggested, will have adequate ripple current rating.

Regular tantalum capacitors are not recommended for the input bus. These capacitors require a recommended minimum voltage rating of  $2 \times (\text{max. DC voltage} + \text{AC ripple})$ . This is standard practice to ensure reliability. No tantalum capacitors were found with a sufficient voltage rating to meet this requirement<sup>[1]</sup>. When the operating temperature is below  $0^\circ\text{C}$ , the ESR of aluminum electrolytic capacitors increases. For these applications Os-Con, polyaluminum, and polymer-tantalum types should be considered. Adding one or two ceramic capacitors to the input will reduce high-frequency reflected ripple current<sup>[4]</sup>.

### 2.2 Output Capacitance

For applications with load transients (sudden changes in load current), regulator response will benefit from an external output capacitance. The recommended output capacitance of  $680\mu\text{F}$  will allow the module to meet its transient response specification (refer to the shortform datasheet). For most applications, a high quality computer-grade aluminum electrolytic capacitor is most suitable. These capacitors provide adequate decoupling over the frequency range, 2kHz to 150kHz, and are suitable when ambient temperatures are above  $0^\circ\text{C}$ . For operation below  $0^\circ\text{C}$ , tantalum, ceramic or Os-Con type capacitors are recommended. When using one or more non-ceramic capacitors, the calculated equivalent ESR should be no lower than  $2\text{m}\Omega$  ( $7\text{m}\Omega$  using the manufacturer's maximum ESR for a single capacitor). A list of preferred low-ESR type capacitors are identified in Table 2.

#### 2.2.1 Tantalum Capacitors

Tantalum type capacitors can be used at both the input and output, and are recommended for applications where the ambient operating temperature can be less than  $0^\circ\text{C}$ . The AVX TPS, Sprague 593D/594/595 and Kemet T495/T510 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 considerably higher ESR, reduced power dissipation and lower ripple current capability. These capacitors are also less reliable as they have lower power dissipation and surge current ratings. Tantalum capacitors that do not have a stated ESR or surge current rating are not recommended for power applications. When specifying Os-Con and polymer tantalum capacitors for the output, the minimum ESR limit will be encountered well before the maximum capacitance value is reached.

#### 2.2.2 Ceramic Capacitors

Above 150kHz the performance of aluminum electrolytic capacitors becomes less effective. To further improve the reflected input ripple current or the output transient response, multilayer ceramic capacitors can also be added. Ceramic capacitors have very low ESR and their resonant frequency is higher than the bandwidth of the regulator. When used on the output their combined ESR is not critical as long as the total value of ceramic capacitance, with values between  $10\mu\text{F}$  and  $100\mu\text{F}$ , does not exceed  $400\mu\text{F}$ . Also, to prevent the formation of local resonances, do not place more than five identical ceramic capacitors in parallel with values of  $10\mu\text{F}$  or greater.

#### 2.2.3 Capacitor Table

Table 2 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 100kHz) are critical parameters necessary to insure both optimum regulator performance and long capacitor life.

#### 2.2.4 Designing for Very Fast Load Transients

The transient response of the DC/DC converter has been characterized using a load transient with a  $di/dt$  of  $1\text{A}/\mu\text{s}$ . The typical voltage deviation for this load transient is given in the datasheet specification table using the optional 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 output capacitor decoupling. In these cases special attention must be paid to the type, value and ESR of the capacitors selected.

If the transient performance requirements exceed that specified in the datasheet, or the total amount of load capacitance is above  $3,000\mu\text{F}$  the selection of output capacitors becomes more important.

CAPACITOR VENDOR/ SERIES	CAPACITOR CHARACTERISTICS					QUANTITY		VENDOR PART NUMBER
	WORKING VOLTAGE	VALUE ( $\mu$ F)	MAX. ESR AT 100kHz	MAX RIPPLE CURRENT AT 85°C (Irms)	PHYSICAL SIZE (MM) (L X W)	INPUT BUS	OPTIONAL OUTPUT BUS	
Panasonic, FC (Radial)  FK (SMD)	25V	1000	0.043 $\Omega$	>1690mA	16 x 15.0	1	1	EEUFC1E102S
	25V	560	0.065 $\Omega$	1205mA	12.5 x 15.0	1	1	EEUFC1E561S
	16V	680	0.080 $\Omega$	>850mA	16.0 x 15.0	1	1	EEVFK1C681P
	35V	1000	0.060 $\Omega$	1100mA	12.5 x 13.5	1	1	EEVFK1V102Q
United Chemi-Con MVZ (SMD) LXZ, Aluminum PS, Poly-Aluminum	16V	470	0.090 $\Omega$	670mA	10.0 X 10.0	2	2	MVZ25VC471MJ10TP
	16V	470	0.090 $\Omega$	760mA	10.0 x 12.5	2	2	LXZ16VB471M10X12LL
	25V	680	0.068 $\Omega$	1050mA	10.0 x 16.0	1	1	LXZ16VB681M10X16LL
	16V	330	0.014 $\Omega$	5060mA	10.0 x 12.5	2	$\leq 4$	16PS330MJ12
	16V	330	0.014 $\Omega$	5050mA	10.0 x 12.2	2	$\leq 4$	PXA16VC331MJ12TP
Nichicon HD (Radial) PM (Radial)	25V	560	0.060 $\Omega$	1060mA	12.5 x 15.0	1	2	UPM1E561MHH6
	25V	680	0.038 $\Omega$	1430mA	10.0 x 16.0	1	1	UHD1C681MHR
	35V	560	0.048 $\Omega$	1360mA	16.0 x 15.0	1	2	UPM1V561MHH6
Panasonic, Poly-Aluminum S/SE (SMD)	16V	330	0.022 $\Omega$	4100mA	10.0 x 10.2	2	$\leq 5$	EEFWA1C331P
SANYO Poscap SP, Os-Con (Radial) SVP, Os-Con (SMD)	10V	330	0.025 $\Omega$	3000mA	7.3 x 5.7	N/R <sup>(1)</sup>	$\leq 5$	10TPE330M
	16V	270	0.018 $\Omega$	$\geq 3500$ mA	10.0 x 10.5	3 <sup>(3)</sup>	$\leq 4$	16SP270M
	16V	330	0.016 $\Omega$	4700mA	11.0 x 12.0	2	$\leq 4$	16SVP330M
AVX Tantalum TPS (SMD)	10V	470	0.045 $\Omega$	>1723mA	7.3 x 5.7	N/R <sup>(1)</sup>	$\leq 5$ <sup>(2)</sup>	TPSE477M010R0045 <sup>(5)</sup>
	10V	330	0.045 $\Omega$	>1723mA	7.3 x 5.7	N/R <sup>(1)</sup>	$\leq 5$ <sup>(2)</sup>	TPSV477M010R0060 <sup>(5)</sup>
Kemet Poly-Tantalum T520 (SMD) T530 (SMD)	10V	330	0.040 $\Omega$	1800mA	7.3 x 4.3	N/R <sup>(1)</sup>	2	T520X337M010AS
	10V	330	0.015 $\Omega$	>3800mA	7.3 x 4.3	N/R <sup>(1)</sup>	$\leq 4$	T530X337M010AS
	6.3V	470	0.012 $\Omega$	4200mA	7.3 x 4.3	N/R <sup>(1)</sup>	$\leq 3$	T530X477M006AS <sup>(5)</sup>
Vishay-Sprague 595D, (SMD) 94SA (Radial)	10V	470	0.100 $\Omega$	1440mA	7.2 x 6.0	N/R <sup>(1)</sup>	2 <sup>(2)</sup>	595D477X0010R2T <sup>(5)</sup>
	16V	1000	0.015 $\Omega$	9740mA	16.0 x 25.0	1	$\leq 4$	94SA108X0016HBP
Kemet, Ceramic X5R (SMD)	16V	10	0.002 $\Omega$		3225	1 <sup>(4)</sup>	$\leq 8$	C1210C106M4PAC
	6.3V	47	0.002 $\Omega$			N/R <sup>(1)</sup>	$\leq 8$	C1210C476K9PAC
Murat	6.3V	100	0.002 $\Omega$		3225	N/R <sup>(1)</sup>	$\leq 4$	GRM32ER60J107M
	6.3V	47				N/R <sup>(1)</sup>	$\leq 8$	GRM32ER60J476M
	16V	47				1 <sup>(4)</sup>	$\leq 8$	GRM32ER61C476K
	16V	22				1 <sup>(4)</sup>	$\leq 8$	GRM32ER61C226K
	16V	10				1 <sup>(4)</sup>	$\leq 8$	GRM32DR61C106K
TDK, Ceramic X5R (SMD)	6.3V	100			3225	N/R <sup>(1)</sup>	$\leq 4$	C3225XR0J107MT
	6.3V	47				N/R <sup>(1)</sup>	$\leq 8$	C3225XR0J476MT
	16V	22				1 <sup>(4)</sup>	$\leq 8$	C3225XR1C226MT
	16V	10				1 <sup>(4)</sup>	$\leq 8$	C3225XR1C106MT

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

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

(3) Total capacitance of 540 $\mu$ F is acceptable based on the combined ripple current rating.

(4) Small ceramic capacitors maybe used to complement electrolytic types at the input to further reduce high-frequency ripple current.

(5)  $V_o \leq 5.1V$

**Table 2 - Recommended Input/Output Capacitors**

## 3. Mechanical Information

### 3.1 Mechanical Outline Drawings

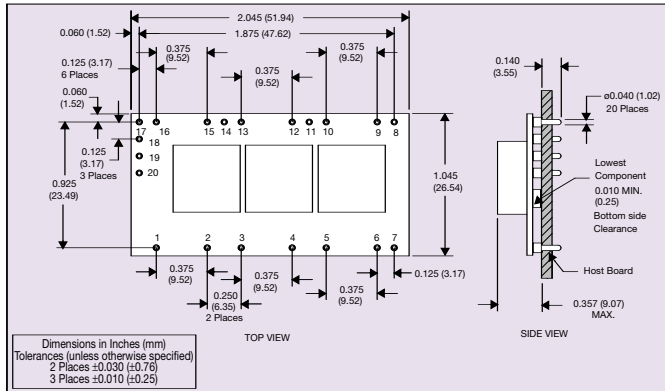


Figure 1 - Plated Through-Hole Mechanical Drawing - Suffix H

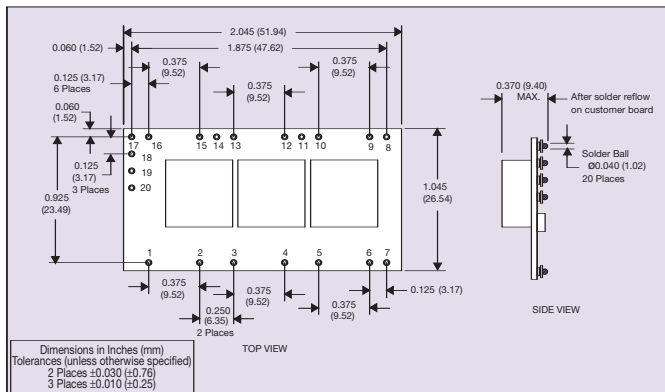


Figure 2 - Surface Mount Mechanical Drawing - Suffix S

### 3.2 Pin-out Table

PIN CONNECTIONS	
PIN NO.	FUNCTION
1	Ground
2	Vin
3	Ground
4	Vin
5	Ground
6	Vin
7	Inhibit
8	UVLO Programming
9	Vout
10	Ground
11	+Vsense
12	Vout
13	Ground
14	-Vsense
15	Vout
16	Ground
17	Adjust
18	Track
19	Margin Up
20	Margin Down

Table 3 - Pin Connections

### 3.3 Pin Description

#### 3.3.1 Ground

This is the common ground connection for the  $V_{in}$  and  $V_{out}$  power connections. It is also the 0VDC reference for the control inputs.

#### 3.3.2 $V_{in}$

The positive input voltage power node to the module, which is referenced to common GND.

#### 3.3.3 Inhibit

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 will produce an output whenever a valid input source is applied.

#### 3.3.4 UVLO Programming

Connecting a resistor from this pin to signal ground allows the 'on' threshold of the input undervoltage lockout (UVLO) to be adjusted higher than the default value. The Hysteresis can also be independently reduced by connecting a second resistor from this pin to  $V_{in}$ . See Section 7.2.

#### 3.3.5 $V_{out}$

The regulated positive power output with respect to the GND node.

**3.3.6 +Sense**

The sense input allows the regulation circuit to compensate for voltage drop between the module and the load. For optimal voltage accuracy  $V_o$  Sense should be connected to  $V_{out}$ . It can also be left disconnected

**3.3.7 -Sense**

For optimal voltage accuracy -Sense should be connected to the ground return at the load. If it is left open, a low value internal resistor ensures that the output remains in regulation.

**3.3.8  $V_o$  Adjust**

A 1% tolerance (or better) resistor must be connected directly between this pin and the output ground (pin 7) to set the output voltage to a value higher than its lowest value. The set point range is from 0.8V to 5.5V. The resistor required for a given output voltage may be calculated from the equations in Section 7.1. If left open-circuit the output voltage will default to its lowest value. For further information on output voltage adjustment please see Section 7.

The specification table gives the preferred resistor values for a number of standard output voltages.

**3.3.9 Track**

This is an analog control input that allows the output voltage to follow another voltage during power up and power down sequences. This pin is active from 0V, up to the nominal set-point voltage. Within this range the module's output will follow 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 nominal output voltage. If unused this input should be connected to  $V_{in}$  for a faster power-up. For further information consult the related application information.

Note: Due to the under-voltage lockout feature, the output of the module cannot follow its own input voltage during power-up. For more information, consult Section 10.

**3.3.10 Margin Down**

When this input is asserted to GND, the output voltage is decreased by 5% from the nominal. The input requires an open-collector (open-drain) interface. It is not TTL compatible. A lower percent change can be accommodated with a series resistor, see Section 7.4.

**3.3.11 Margin Up**

When this input is asserted to GND, the output voltage is increased by 5%. The input requires an open-collector (open-drain) interface. It is not TTL compatible. The percent change can be reduced with a series resistor, see Section 7.4.

**4. Packaging Information**

**4.1 Packaging**

The PTH12040 are available in trays of 12 units.

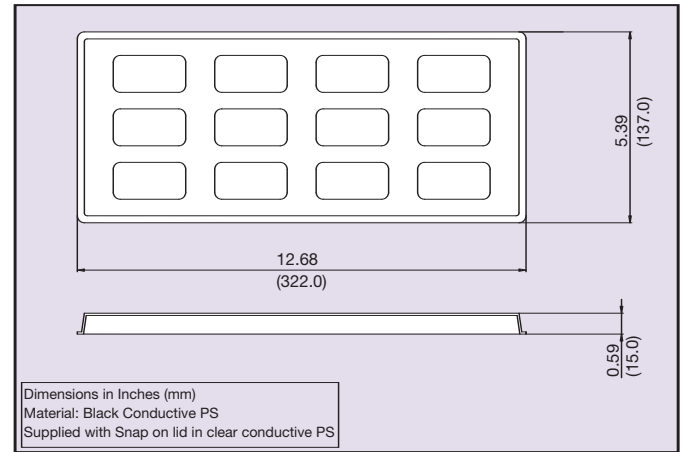


Figure 3 - Tray

**4.2 Labelling and Part Numbering Sequence**

All units in the series will be clearly marked to allow ease of identification for the end user.

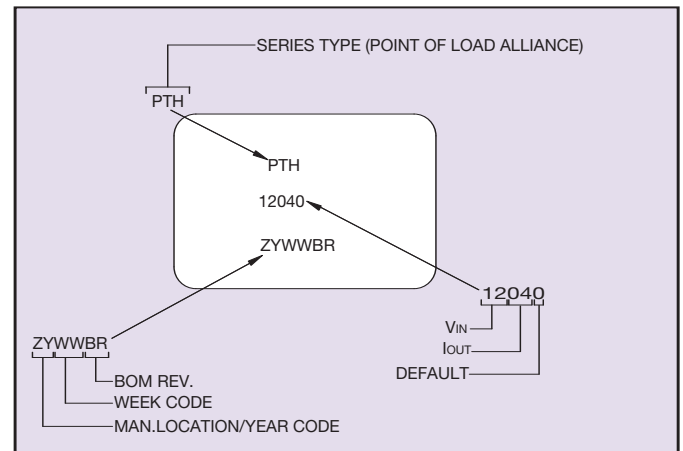


Figure 4 - PTH12040 Part Numbering



## 5. Safety Information

### 5.1 Safety Standards and Approvals

All models will have full international safety approval including EN60950 and UL/cUL1950. Models have been submitted to independent safety agencies for approval.

### 5.2 Fuse Information

Any suitable value fuse (based on the input ratings) maybe used in the unearthed input line. However this is not required for compliance with safety.

### 5.3 Safety Considerations

The converter must be installed as per guidelines outlined by the various safety agency approvals, if safety agency approval is required for the overall system.

## 6. Operating Information

### 6.1 Overtemperature Protection (OTP)

Only the PTHxx020 and PTHxx030 and PTHxx040 series of products have overtemperature protection. These products have an on-board temperature sensor that 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 (see datasheet specifications), the module's Inhibit control is automatically pulled low. This disables the regulator allowing the output voltage to drop to zero. (The external output capacitors will be discharged by the load circuit). The recovery is automatic, and begins with a soft-start power-up. It occurs when the the sensed temperature decreases by about 10°C below the trip point.

Note: 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 will reduce 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.

### 6.2 Overcurrent Protection

For protection against load faults, all modules incorporate output overcurrent protection. Applying a load that exceeds the regulator's overcurrent threshold will cause the regulated output to shut down. Following shutdown a module will periodically attempt to recover by initiating a soft-start power-up. This is described as a "hiccup" mode of operation, whereby the module continues in the 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.

### 6.3 Soft-start Power-up

The Auto-Track feature allows the power-up of multiple PTH 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,  $V_{in}$  (see Figure 5).

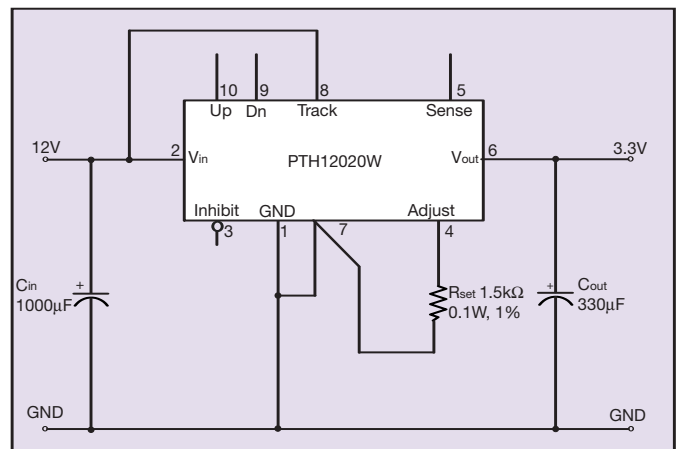
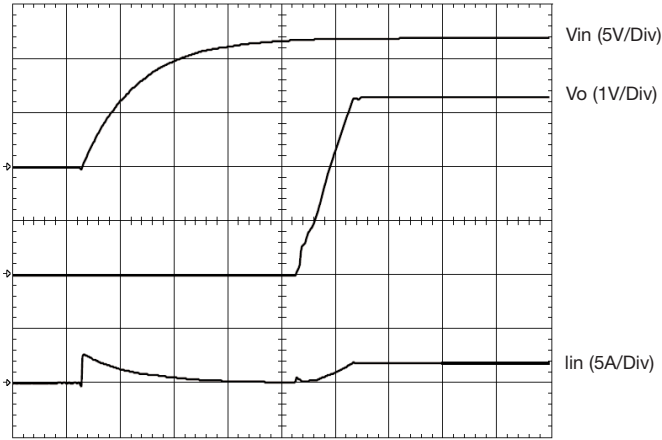


Figure 5 - Soft-start Power-up

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 8ms to 15ms) before allowing the output voltage to rise. The output then progressively rises to the module's setpoint voltage. Figure 7 shows the soft-start power-up characteristic of the 18A output product (PTH12020W), operating from a 12V input bus and configured for a 3.3V output. The waveforms were measured with a 5A resistive load, with Auto-Track 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 25ms.



HORIZ SCALE: 5 ms/Div

Figure 6 - Power-up Characteristic

## 7. Feature Set

### 7.1 Adjusting the Output Voltage

The Vo adjust control (pin 17) sets the output voltage of the PTH12040 product. The adjustment range is from 0.8V to 5.5V. The adjustment method requires the addition of a single external resistor, Rset, that must be connected directly between the Vo Adjust and GND pins<sup>1</sup>. Table 4 gives the preferred value for 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 equation, or simply selected from the range of values given in Tables 5. Figure 7 shows the placement of the required resistor.

$$R_{SET} = 10k\Omega \times \frac{0.8V}{V_o - 0.8V} - 1.696 k\Omega$$

Equation 1

V <sub>out</sub> Standard	R <sub>set</sub> (Preferred Value)	V <sub>out</sub> (Actual)
5.0V	205Ω	5.008V
3.3V	1.5kΩ	3.303V
2.5V	3.01kΩ	2.500V
2.0V	4.99kΩ	1.997V
1.8V	6.34kΩ	1.796V
1.5V	9.76kΩ	1.498V
1.2V	18.2kΩ	1.202V
1.0V	38.3kΩ	1.000V
0.8V	Open	0.800V

Table 4 - Preferred Values of R<sub>set</sub> for Standard Output Voltages

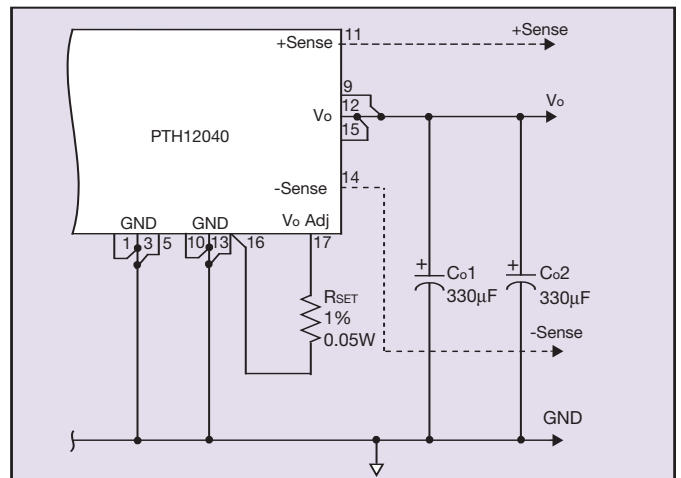


Figure 7 - Adjust Resistor Placement



OUTPUT VOLTAGE SET-POINT RESISTOR VALUES					
V <sub>a</sub> Req'd	R <sub>set</sub>	V <sub>a</sub> Req'd	R <sub>set</sub>	V <sub>a</sub> Req'd	R <sub>set</sub>
0.800	Open	1.60	8.3kΩ	3.10	1.78kΩ
0.825	318kΩ	1.65	7.72kΩ	3.15	1.71kΩ
0.850	158kΩ	1.70	7.19kΩ	3.20	1.64kΩ
0.875	105kΩ	1.75	6.73kΩ	3.25	1.57kΩ
0.900	78.31kΩ	1.80	6.3kΩ	3.30	1.5kΩ
0.925	62.3kΩ	1.85	5.92kΩ	3.35	1.44kΩ
0.950	51.6kΩ	1.90	5.58kΩ	3.40	1.38kΩ
0.975	44.0kΩ	1.95	5.26kΩ	3.50	1.27kΩ
1.000	38.3kΩ	2.00	4.97kΩ	3.60	1.16kΩ
1.025	33.9kΩ	2.05	4.7kΩ	3.70	1.06kΩ
1.050	30.3kΩ	2.10	4.46kΩ	3.80	971Ω
1.075	27.4kΩ	2.15	4.23kΩ	3.90	885Ω
1.100	25.0kΩ	2.20	4.02kΩ	4.00	804Ω
1.125	22.9kΩ	2.25	3.82kΩ	4.10	728Ω
1.150	21.2kΩ	2.30	3.64kΩ	4.20	657Ω
1.175	19.6kΩ	2.35	3.47kΩ	4.30	590Ω
1.200	18.3kΩ	2.40	3.3kΩ	4.40	526Ω
1.225	17.1kΩ	2.45	3.15kΩ	4.50	466Ω
1.250	16.1kΩ	2.50	3.01kΩ	4.60	409Ω
1.275	15.1kΩ	2.55	2.88kΩ	4.70	355Ω
1.300	14.3kΩ	2.60	2.75kΩ	4.80	304Ω
1.325	13.5kΩ	2.65	2.63kΩ	4.90	255Ω
1.350	12.8kΩ	2.70	2.51kΩ	5.00	209Ω
1.375	12.2kΩ	2.75	2.41kΩ	5.10	164Ω
1.400	11.6kΩ	2.80	2.3kΩ	5.20	122Ω
1.425	11.1kΩ	2.85	2.21kΩ	5.30	82Ω
1.450	10.6kΩ	2.90	2.11kΩ	5.40	43Ω
1.475	10.2kΩ	2.95	2.02kΩ	5.50	0Ω
1.50	9.73kΩ	3.00	1.94kΩ		
1.55	8.97kΩ	3.05	1.86kΩ		

**Table 5 - Output Voltage Set-point Resistor Values**

**Notes:**

- 1 Use a resistor with a tolerance of 1% (or better). Place the resistor as close to the regulator as possible. Connect the resistor directly between pins 17 and nearest ground pin (16) using dedicated PCB traces.
- 2 Never connect capacitors from V<sub>o</sub> Adjust to either GND or V<sub>out</sub>. Any capacitance added to the V<sub>o</sub> Adjust pin will affect the stability of the regulator.

**7.2 Adjusting the Under-Voltage Lockout (UVLO)**

The PTH12040W power modules incorporate an input under-voltage 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 power-up 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<sub>THD</sub>) and Hysteresis (V<sub>HYS</sub>) voltages. Below the 'on' threshold, the Inhibit control is overridden, and the module will not produce an output. The Hysteresis voltage is the difference between the 'on' and 'off' threshold voltages. It ensures a clean power-up, even when the input voltage is rising slowly. 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.

**7.2.1 UVLO Adjustment**

The UVLO feature of the PTH12040W module allows for limited adjustment of both the on-threshold and Hysteresis voltages. The adjustment is made via the 'UVLO Prog' control pin. When the UVLO Prog pin is left open circuit the on-threshold and Hysteresis voltages are internally set to their default values. The 'on' threshold has a nominal voltage of 7.5V, and the Hysteresis 1V. This ensures that the module will produce a regulated output when the minimum input voltage is applied (see specifications). The combination correlates to an 'off' threshold of approximately 6.5V. The adjustments are limited. The on-threshold can only be adjusted higher, and the Hysteresis voltage can only be reduced in magnitude.

The 'on' threshold might need to be raised if the module is powered from a tightly regulated 12V bus. This would prevent it from operating if the input bus failed to completely rise to its specified regulation voltage. The Hysteresis shouldn't be changed unless absolutely necessary. A generous amount of Hysteresis ensures that the module exhibits a clean startup. Therefore adjustment of the Hysteresis should only be considered if there is a system requirement to specifically set the off-threshold voltage (in addition to the on-threshold). Depending on the load regulation of the input source, the Hysteresis should not be adjusted below 0.5V without careful consideration.

**7.2.2 Adjustment Method**

The resistors R<sub>THD</sub>, and R<sub>HYS</sub> (see Figure 8), provide the adjustment of the on-threshold and Hysteresis voltages. R<sub>THD</sub> connects between the UVLO Prog control pin and VI. R<sub>THD</sub> alone can be used to adjust the on-threshold voltage higher. However, to adjust the hysteresis to a lower value requires both the R<sub>HYS</sub> and R<sub>THD</sub> resistors to be placed in the circuit.

The recommended adjustment method requires that any change to the Hysteresis be determined first. If the Hysteresis is changed, then a value for R<sub>THD</sub> must also be calculated. This is irrespective of whether a change is required to the value of V<sub>THD</sub>. If there is no change to V<sub>HYS</sub>, then a resistor should not be placed in the R<sub>HYS</sub> location. R<sub>HYS</sub> should then be assigned an infinite value for calculating the value of R<sub>THD</sub>.

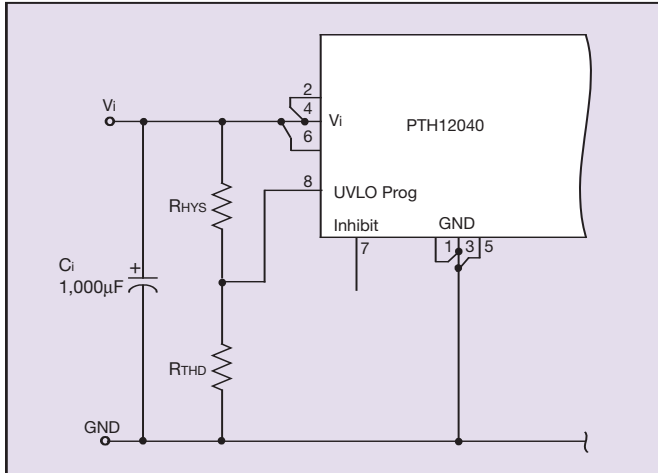


Figure 8 - UVLO Program Resistor Placement

**7.2.3 Hysteresis Adjust**

The Hysteresis voltage,  $V_{HYS}$ , is the difference between the ‘on’ and ‘off’ threshold values. The default value is 1V and it can only be adjusted to a lower value.

! Caution should be used when changing the Hysteresis voltage to a lower value, as it could induce start-up oscillations.

Any change in the Hysteresis voltage will require both  $R_{HYS}$  and  $R_{THD}$  resistors be in place. Adding  $R_{HYS}$  alone will not have the desired effect. The value for  $R_{HYS}$  must first be calculated using Equation 2. The value identified for  $R_{HYS}$  must then be used to determine a value for  $R_{THD}$ , using Equation 3.

$$R_{HYS} = \frac{26.1 \times V_{HYS}}{0.365 \times (1 - V_{HYS})} \quad k\Omega$$

Equation 2

**7.2.4 Threshold Adjust**

Equation 3 determines the value of  $R_{THD}$  required to adjust  $V_{THD}$  to a new value. The default value is 7.5V, and it may only be adjusted to a higher value. If the Hysteresis value has been adjusted, then a value for  $R_{THD}$  must also be calculated. (This is irrespective of whether  $V_{THD}$  is being adjusted.) If there has been no adjustment for the hysteresis voltage, the term ‘ $1/R_{HYS}$ ’ in Equation 3 may be assigned the value, ‘0’.

$$R_{THD} = \frac{39.2k\Omega}{39.2 \left[ \left( \frac{1}{R_{HYS}} + 0.014 \right) \left( \frac{V_{THD}}{2.5} - 1 \right) - 0.0027 \right] - 1}$$

Equation 3

**7.2.5 Calculated Values**

Table 6 shows a matrix of standard resistor values for  $R_{HYS}$  and  $R_{THD}$ , for different options of the on-threshold ( $V_{THD}$ ) and Hysteresis ( $V_{HYS}$ ) voltages. For most applications, only the on-threshold voltage should need to be adjusted. In this case select only a value for  $R_{THD}$  from far right-hand column.

The Hysteresis should only be adjusted if there is a specific requirement to independently adjust the off-threshold, separately from the on-threshold voltage. In this case, a value for both  $R_{HYS}$  and  $R_{THD}$  must be selected from the table. This is irrespective of whether the on-threshold voltage is being adjusted.

		$V_{HYS}$	0.5V	0.6V	0.7V	0.8V	0.9V	1V (Default)
$V_{THD}$	$R_{HYS}$	71.5k $\Omega$	107k $\Omega$	165k $\Omega$	287k $\Omega$	649k $\Omega$	N/A	
8.0V	$R_{THD}$	30.1k $\Omega$	43.2k $\Omega$	63.4k $\Omega$	97.6k $\Omega$	169k $\Omega$	402k $\Omega$	
8.5V	$R_{THD}$	25.5k $\Omega$	36.5k $\Omega$	51.1k $\Omega$	73.2k $\Omega$	110k $\Omega$	187k $\Omega$	
9.0V	$R_{THD}$	23.2k $\Omega$	30.9k $\Omega$	42.2k $\Omega$	57.6k $\Omega$	82.5k $\Omega$	124k $\Omega$	
9.5V	$R_{THD}$	20k $\Omega$	27.4k $\Omega$	36.5k $\Omega$	48.7k $\Omega$	64.9k $\Omega$	90.9k $\Omega$	
10V	$R_{THD}$	18.2k $\Omega$	24.3k $\Omega$	31.6k $\Omega$	41.2k $\Omega$	54.9k $\Omega$	73.2k $\Omega$	
10.5V	$R_{THD}$	16.2k $\Omega$	21.5k $\Omega$	28k $\Omega$	36.5k $\Omega$	46.4k $\Omega$	60.4k $\Omega$	
11V	$R_{THD}$	15k $\Omega$	19.6k $\Omega$	25.5k $\Omega$	32.4k $\Omega$	41.2k $\Omega$	52.3k $\Omega$	
11.5V	$R_{THD}$	14k $\Omega$	18.2k $\Omega$	23.2k $\Omega$	28k $\Omega$	36.5k $\Omega$	45.3k $\Omega$	
12V	$R_{THD}$	12.7k $\Omega$	16.5k $\Omega$	21k $\Omega$	26.1k $\Omega$	32.4k $\Omega$	40.2k $\Omega$	

Table 6 - Calculated Values of  $R_{HYS}$  and  $R_{THD}$  for Various Values of  $V_{HYS}$  and  $V_{THD}$

**7.3 Output ON/OFF Inhibit**

For applications requiring output voltage ON/OFF control, each series of the PTH family incorporates an output 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  $V_{in}$  with respect to GND. Figure 9 shows the typical application of the inhibit function. Note the discrete transistor (Q1). The Inhibit control has its own internal pull-up to +Vin potential. The input is not compatible with TTL logic devices. An open-collector (or open-drain) discrete transistor is recommended for control.

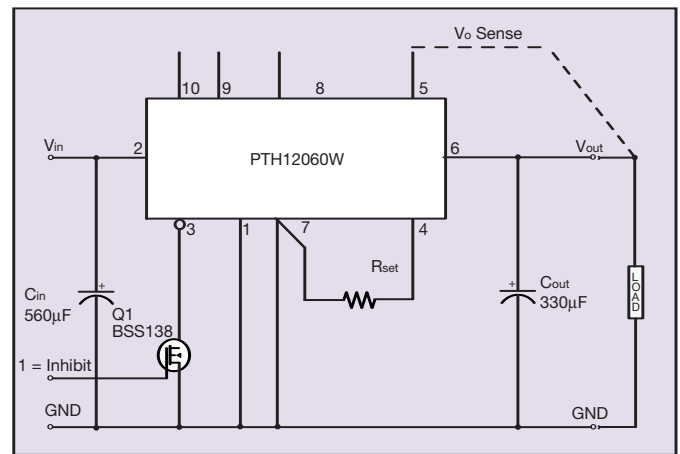
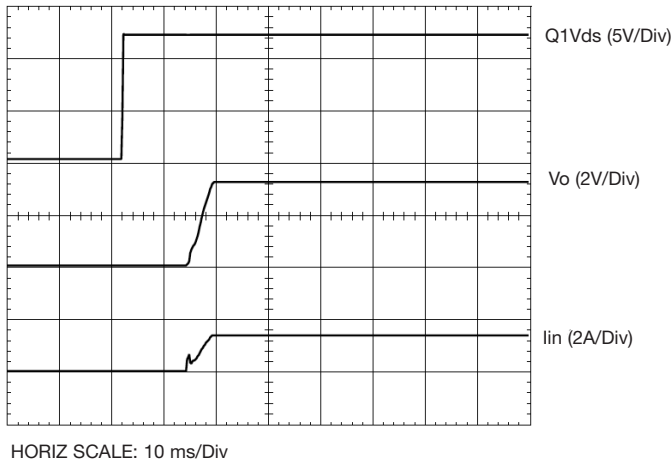


Figure 9 - Typical Application of the Inhibit Function

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 will execute a soft-start power-up sequence. A regulated output voltage is produced within 25ms. Figure 10 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 5A load.



**Figure 10 - Typical Rise in Output Voltage and Input Current**

### 7.4 Margin Up/Down Controls

The PTHxx060W, PTHxx010W, PTHxx020W, PTHxx030W and PTHxx040W module series incorporate Margin Up and Margin Down control inputs. These controls allow the output voltage set point to be momentarily adjusted<sup>(1)</sup>, either up or down, by a nominal 5%. This provides a convenient method for dynamically testing the operation of the load circuit over its power supply margin or range. The  $\pm 5\%$  change is applied to the adjusted output voltage as set by the external resistor,  $R_{Set}$  at the  $V_O$  Adjust pin.

The 5% adjustment is made by driving the appropriate margin control input directly to the GND terminal<sup>(2)</sup>. A low-leakage open-drain device, such as a MOSFET or p-channel JFET is recommended for this purpose. Adjustments of less than 5% can also be accommodated by adding series resistors to the control inputs (See Figure 11). The value of the resistor can be selected from Table 6 or calculated using the following formula.

#### 7.4.1 Up/Down Adjust Resistance Calculation

To reduce the margin adjustment to something less than 5%, series resistors are required (See  $R_D$  and  $R_U$  in Figure 15). For the same amount of adjustment, the resistor value calculated for  $R_D$  and  $R_U$  will be the same. The formula is as follows.

$$R_u \text{ or } R_d = \frac{499}{\Delta\%} - 99.8 \text{ k}\Omega$$

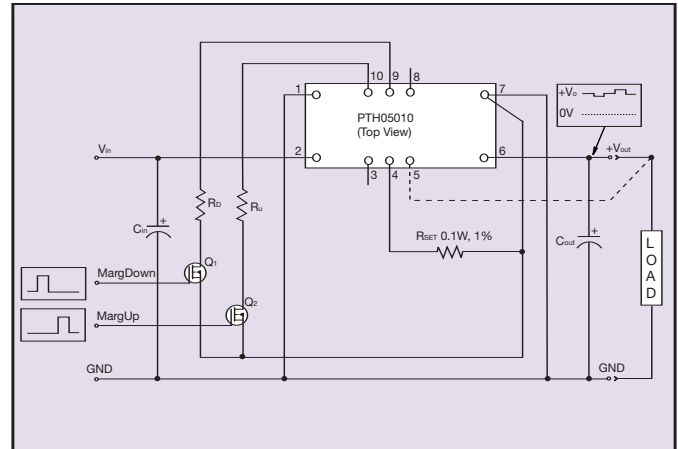
Where  $\Delta\%$  = The desired amount of margin adjust in percent.

#### Notes:

- 1 The Margin Up and Margin Down controls were not intended to be activated simultaneously. If they are their effects on the output voltage may not completely cancel, resulting in the possibility of a slightly higher error in the output voltage set point.
- 2 The ground reference should be a direct connection to the module GND. This will produce a more accurate adjustment at the load circuit terminals. The transistors Q1 and Q2 should be located close to the regulator.
- 3 The Margin Up and Margin Dn control inputs are not compatible with devices that source voltage. This includes TTL logic. These are analog inputs and should only be controlled with a true open-drain device (preferably a discrete MOSFET transistor). The device selected should have low off-state leakage current. Each input sources  $8\mu A$  when grounded, and has an open-circuit voltage of 0.8V.

% ADJUST	$R_U/R_D$
5	0.0k $\Omega$
4	24.9k $\Omega$
3	66.5k $\Omega$
2	150.0k $\Omega$
1	397.0k $\Omega$

**Table 6 - Margin Up/Down Resistor Values**



**Figure 11 - Margin Up/Down Application Schematic**

### 7.5 Remote Sense

The  $V_O$  Sense pin should be connected to  $V_{out}$  at the load circuit (see datasheet standard application). A remote sense improves the load regulation performance of the module by allowing it to compensate for any 'IR' voltage drop between itself and the load. An IR drop is caused by the high output current flowing through the small amount of pin and trace resistance. Use of the remote sense is optional. If not used, the  $V_{out}$  Sense pin can be left open-circuit. An internal low-value resistor ( $15\Omega$  or less) is connected between the  $V_O$  Sense and  $V_{out}$ , ensures that the output voltage remains in regulation.

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

Note: The remote sense feature is not designed to compensate for the forward drop of non-linear 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. Thermal Information

### 8.1 Thermal Reference Points

The electrical operating conditions namely:

- Input voltage,  $V_{in}$
- Output voltage,  $V_o$
- Output current,  $I_o$

determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

### 8.2 Safe Operating Area Curve

Thermal characterization data is presented in the datasheet in a safe operating area curve format which is repeated here in Figure 12. This SOA curve shows the load current versus the ambient air temperature and velocity.

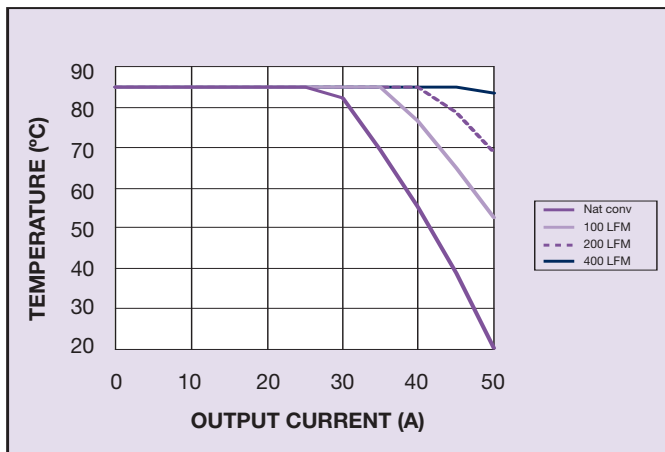


Figure 12 - Safe Operating Curve  
PTH12040W  $V_{out} = 3.3V$

### 8.3 Thermal Test Set-up

All of the data was taken with the converter soldered to a test board which closely represents a typical application. The test board is a 1.6mm, eight layer FR4 PCB with the inner layers consisting of 2oz power and ground planes. The top and bottom layers contain a minimal amount of metalization. A board to board spacing of 1 inch was used. The data represented by the 0m/s curve indicate a natural convection condition i.e. no forced air. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperatures are kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using either AWG #36 or #40 gauge thermocouples or an IR camera. In order to comply with stringent Artesyn derating criteria, the ambient temperature should never exceed 85°C. Please contact Artesyn Technologies for further support.

## 9. Use in a Manufacturing Environment

### 9.1 Recommended Land Pattern

It is recommended that the customer uses a solder mask defined land pattern similar to that shown in Figures 13 and 14.

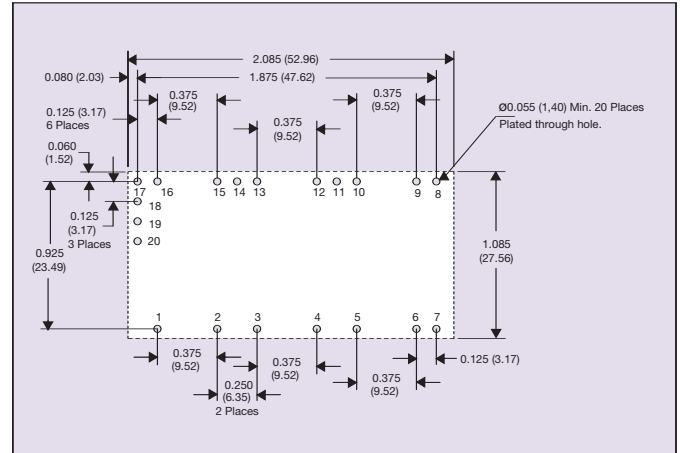


Figure 13 - Recommended Land Pattern (Through - Hole Model)

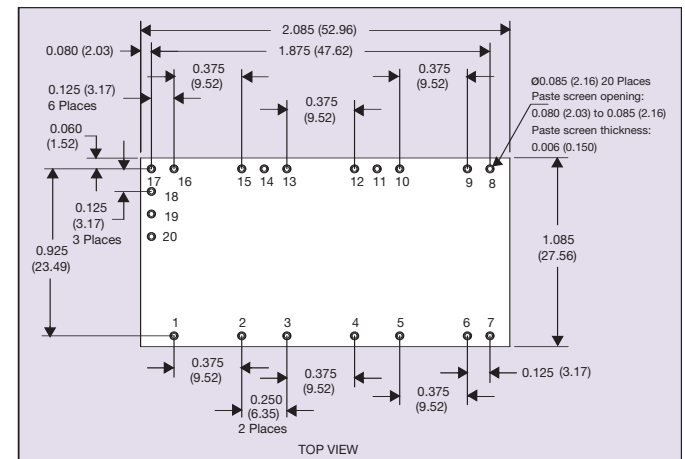


Figure 14 - Recommended Land Pattern (Surface Mount Model)

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). All power pins need to be connected.

As a surface-mount power component, interconnection to internal power planes will typically be required. This is accomplished by placing a number of vias between the SMT pad and the relevant plane. The number and exact location of these vias should be determined based on electrical resistivity, current flow and thermal requirements.

## 10. Auto-Track™

### 10.1 Auto-Track™ Function

The Auto-Track™ function is unique to the PTH family, and is available with the all “Point-of-Load Alliance” (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 DSPs, micro-processors, and ASICs.

### 10.2 How Auto-Track™ Works

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

When under 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 will 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 control incorporates an internal RC charge circuit. This operates off the module's input voltage to provide a suitable rising voltage ramp waveform.

### 10.3 Typical Applications

The basic implementation of Auto-Track allows for simultaneous voltage sequencing of a number of Auto-Track compliant modules. Connecting the Track control pins of two or more modules forces the Track control of all modules to follow the same collective RC ramp waveform, and allows them to be controlled through a single transistor or switch; Q1 in Figure 15.

To initiate a power-up sequence the Track control pin must first be pulled to ground potential. This should be done at or before input power is applied to the modules, and then held for at least 10ms thereafter. This brief period gives the modules time to complete their internal soft-start initialization, which enables them to produce an output voltage.

Applying a logic-level high signal to the circuit's On/Off Control turns Q1 on and applies a ground signal to the Track control. After completing their internal soft-start initialization, the output of all modules will remain at zero volts while Q1 is on. 10ms after a valid input voltage has been applied to all modules, Q1 can be turned off. This allows the track control voltage to automatically rise toward to the modules' input voltage. During this period the output voltage of each module will rise in unison with other modules, to its respective set-point voltage.

Figure 16 shows the output voltage waveforms from the circuit of Figure 15 after the On/Off Control is set from a high to a low-level voltage. The waveforms, Vo1 and Vo2 represent the output voltages from the two power modules, U1 (3.3V) and U2 (2V) respectively. Vo1 and Vo2 are shown rising together to produce the desired simultaneous power-up characteristic.

The same circuit also provides a power-down sequence. Power-down is the reverse of power-up, and is accomplished by lowering the track control voltage back to zero volts. The important constraint is that a valid input voltage must be maintained until the power-down is complete. It also requires that Q1 be turned off relatively slowly. This is so that the Track control voltage does not fall faster than Auto-Track's slew rate capability, which is 1V/ms. The components R1 and C1 in Figure 15 limit the rate at which Q1 can pull down the Track control voltage. The values of 100kΩ and 0.1μF correlate to a decay rate of about 0.17V/ms.

The power-down sequence is initiated with a low-to-high transition at the On/Off Control input to the circuit. Figure 17 shows the power-down waveforms. As the Track control voltage falls below the nominal set-point voltage of each power module, then its output voltage decays with all the other modules under Auto-Track™ control.

### Notes on the Use of Auto-Track™

- 1 The Track pin voltage must be allowed to rise above the module's set-point voltage before the module can regulate at its adjusted set-point voltage.
- 2 The Auto-Track™ function will track almost any voltage ramp during power-up, and is compatible with ramp speeds of up to 1V/ms.
- 3 The absolute maximum voltage that may be applied to the Track pin is  $V_{in}$ .
- 4 The module will not follow a voltage at its Track control input until it has completed its soft-start initialization. This takes about 10 ms from the time that the module has sensed that a valid voltage has been applied its input. During this period, it is recommended that the Track pin be held at ground potential.
- 5 The module is capable of both sinking and sourcing current when following a voltage at its Track pin. Therefore startup into an output prebias is not supported during Auto-Track control. Note: A pre-bias holdoff is not necessary when all supply voltages rise simultaneously under the control of Auto-Track.
- 6 The Auto-Track function can be disabled by connecting the Track pin to the input voltage ( $V_{in}$ ). With Auto-Track disabled, the output voltage will rise at a quicker and more linear rate after input power is applied.

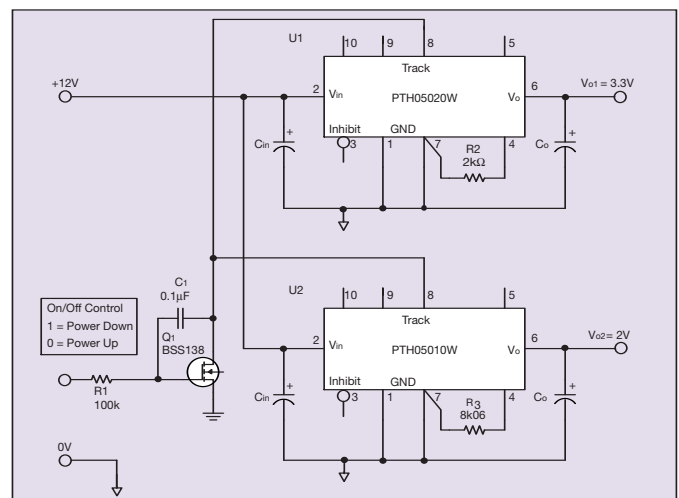
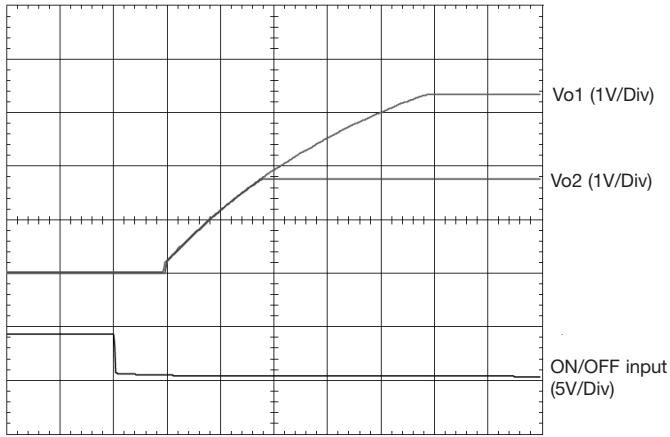
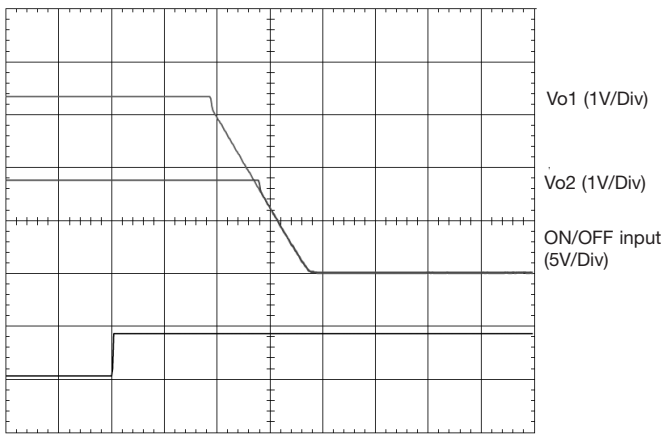


Figure 15 - Sequenced Power-up and Power-down Using Auto-Track™



HORIZ SCALE: 10 ms/Div

**Figure 16 - Power-up with Auto-Track Control**



HORIZ SCALE: 10 ms/Div

**Figure 17 - Power-down with Auto-Track Control**

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