



PTH04040 3.3/5 Vin Single

Application Note 192

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POLA
Point-of-Load Alliance



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 (6 A), PTHxx060W (10 A), PTHxx010W (15/12 A), PTHxx020W (22/18 A), PTHxx030W (30/26 A) and the PTHxx040W (50/60 A).


From the basic, “Just Plug it In” functionality of the 6 A modules, to the 60 A 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 (3.3/5 V input only), and overcurrent protection. The PTHxx060W (10 A), and PTHxx010W (15/12 A) 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 _{OUT}	ADJUST TRIM	ON/OFF INHIBIT	OVER-CURRENT	PRE-BIAS START-UP	AUTO-TRACK™*	MARGIN UP/DOWN	OUTPUT SENSE	THERMAL SHUTDOWN
PTHxx050	3.3 V	6 A	●	●	●	●	●			
	5 V	6 A	●	●	●	●	●			
	12 V	6 A	●	●	●	●	●			
PTHxx060	3.3/5 V	10 A	●	●	●	●	●	●	●	
	12 V	10 A	●	●	●	●	●	●	●	
PTHxx010	3.3/5 V	15 A	●	●	●	●	●	●	●	
	12 V	12 A	●	●	●	●	●	●	●	
PTHxx020	3.3/5 V	22 A	●	●	●	●	●	●	●	●
	12 V	18 A	●	●	●	●	●	●	●	●
PTHxx030	3.3/5 V	30 A	●	●	●	●	●	●	●	●
	12 V	26 A	●	●	●	●	●	●	●	●
PTHxx040	3.3 V - 5 V	60 A	●	●	●	●	●	●	●	●
	12 V	50 A	●	●	●	●	●	●	●	●

Table 1 - Operating Features by Series and Input Bus Voltage

RoHS Compliance Ordering Information	
PTH04040WAST 	To order Pb-free (RoHS compatible) surface-mount parts replace the mounting option ‘S’ with ‘Z’, e.g. PTH04040WAZT. To order Pb-free (RoHS compatible) through-hole parts replace the mounting option ‘H’ with ‘D’, e.g. PTH04040WADT.

*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 1,000 μF (or 3 x 330 μF), with an RMS ripple current rating of 400 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 applications, or wherever the transient capability of the input source is limited, 2,200 μF of input capacitance is recommended.

Ripple current and less than 100 m Ω equivalent series resistance (ESR) values are the major considerations, along with temperature, when designing with different types of capacitors. Unlike polymer tantalum, conventional tantalum capacitors have a recommended minimum voltage rating of 2 x (maximum dc voltage + ac ripple). This is standard practice to ensure reliability.

For improved ripple reduction on the input bus, ceramic capacitors may be used to complement electrolytic types and achieve the minimum required capacitance.

2.2 Output Capacitance (Recommended)

For applications with load transients (sudden changes in load current), regulator response will benefit from an external output capacitance. The minimum output capacitance is 660 μF (2 x 330 μF or 1 x 680 μF) with an ESR of a least 2 m Ω . This will allow the module to meet its transient response specification (see product datasheet). For most applications, a high quality computer-grade aluminum electrolytic capacitor is most suitable. These capacitors provide adequate decoupling over the frequency range, 2 kHz to 150 kHz, 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 4 m Ω (7 m Ω 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 150 kHz 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 does not exceed 300 μF . Also, to prevent the formation of local resonances, do not place more than five identical ceramic capacitors in parallel with values of 10 μF 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 100 kHz) 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 A/ μs . 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 μF the selection of output capacitors becomes more important.

CAPACITOR VENDOR/ SERIES	CAPACITOR CHARACTERISTICS					QUANTITY		VENDOR PART NUMBER
	WORKING VOLTAGE	VALUE (μ F)	MAX. ESR AT 100 kHz	MAX RIPPLE CURRENT AT 85 °C (Irms)	PHYSICAL SIZE (MM) (L X W)	INPUT BUS	OPTIONAL OUTPUT BUS	
Panasonic, FC (Radial) FK (SMD)	10 V 10 V 10 V	1000 1000 1000	0.068 Ω 0.650 Ω 0.080 Ω	1050 mA 1205 mA 850 mA	10.0 x 16.0 12.5 x 16.5 10.0x 10.2	1 1 1	1 1 1	EEUFC1A102 EEVFC1A102LQ EEVFK1A102P
United Chemi-Con FX (Radial) PXA (SMD) PSA (Poly-aluminum) LXZ (Radial)	6.3 V 6.3 V 10 V 10 V	1000 820 680 1000	0.013 Ω 0.010 Ω 0.007 Ω 0.068 Ω	4935 mA 5500 mA >5800 mA 1050 mA	10.0 x 10.5 10.0 x 12.2 10.0 x 11.5 10.0 x 16.0	1 2 3 1	1 1 \leq 3 1	6FX1000M PXA6.3VC820MJ12TP PSA6.3VB680MJ11 LXZ10VB102M10X16LL
Nichicon HD (Radial) PM (Radial)	6.3 V 10 V	1000 1000	0.053 Ω 0.065 Ω	1030 mA 1040 mA	10.0 x 12.5 12.5 x 15.0	1 1	1 1	UHD0J102MPR UPM1A102MHH6
SANYO Os-Con SP (Radial) SVP (SMD)	10 V 6.3 V	470 820	0.015 Ω 0.012 Ω	>4500 mA >5440 mA	10.0 x 10.5 10.0 x 12.7	2 ⁽¹⁾ 2	\leq 5 \leq 3	10SP470M 6SVP820M
Panasonic, Poly-Aluminum S/SE (SMD)	6.3 V	180	0.005 Ω	4000 mA	7.3 x 4.3	N/R	\leq 2	EEFSE0J181R
AVX Tantalum TPS (SMT)	10 V 10 V	470 470	0.045 Ω 0.060 Ω	1723 mA 1826 mA	7.3 x 5.7 7.3 x 5.7	2 ⁽¹⁾ 2 ⁽¹⁾	\leq 7 \leq 7	TPSE477M010R0045 TPSV477M010R0060
Kemet (SMD) T520 Poly-Tant T530 Poly-Tant/ Organic	6.3 V 10 V 6.3 V	470 330 470	0.018 Ω 0.015 Ω 0.012 Ω	>1200 mA >3800 mA 4200 mA	7.3 x 4.3 7.3 x 4.3 7.3 x 4.3	2 ⁽¹⁾ 3 2 ⁽¹⁾	\leq 6 \leq 4 \leq 3	T520X477M006SE018 T530X337M010AS T530X477M006AS
Vishay-Sprague 595D (SMD) 94SA (Radial)	10 V 16 V	470 2200	0.100 Ω 0.015 Ω	1440 mA 9740 mA	7.2 x 6.0 16.0 x 25.0	2 ⁽¹⁾ 1	\leq 7 \leq 4	595D477X0010R2T 94SA108X0016HBP
Kemet, Ceramic X5R (SMD)	16 V 6.3 V	10 47	0.002 Ω 0.002 Ω		1210 case 3225 mm	1 ⁽²⁾ 1 ⁽²⁾	\leq 9 \leq 8	C1210C106M4PAC C1210C476K9PAC
Murata, Ceramic X5R (SMD)	6.3 V 6.3 V 16 V 16 V	100 47 22 10	0.002 Ω		1210 case 3225 mm	1 ⁽²⁾ 1 ⁽²⁾ 1 ⁽²⁾	\leq 4 \leq 8 \leq 8 \leq 9	GRM32ER60J107M GRM32ER60J476M GRM32ER61C226K GRM32DR61C106K
TDK, Ceramic X5R (SMD)	6.3 V 6.3 V 16 V 16 V	100 47 22 10	0.002 Ω		1210 case 3225 mm	1 ⁽²⁾ 1 ⁽²⁾ 1 ⁽²⁾	\leq 4 \leq 8 \leq 8 \leq 9	C3225X5R0J107MT C3225X5R0J476MT C3225X5R1C226MT C3225X5R1C106MT

(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 1000 μ 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.

Table 2 - Recommended Input/Output Capacitors

3. Mechanical Information

3.1 Mechanical Outline Drawings

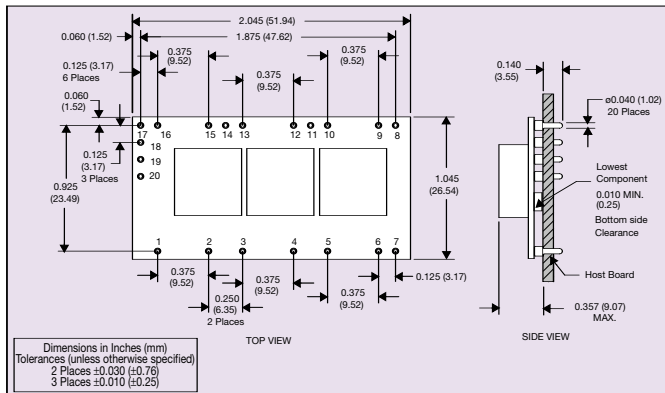


Figure 1 - Plated Through-Hole Mechanical Drawing

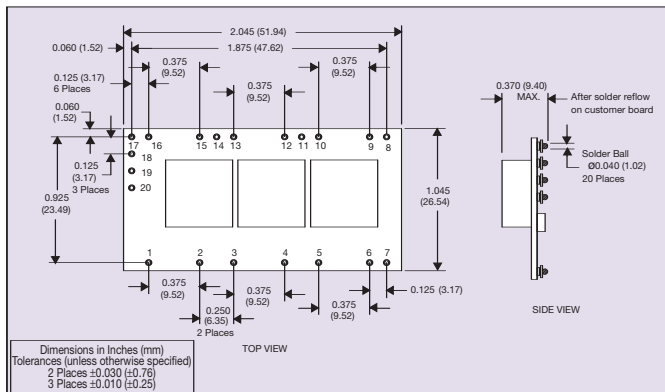


Figure 2 - Surface Mount Mechanical Drawing

3.2 Pin-out Table

PIN CONNECTIONS	
PIN NO.	FUNCTION
1	Ground
2	V _{in}
3	Ground
4	V _{in}
5	Ground
6	V _{in}
7	Inhibit
8	UVLO Programming
9	V _{out}
10	Ground
11	+V _{sense}
12	V _{out}
13	Ground
14	-V _{sense}
15	V _{out}
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 0 Vdc 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 16) to set the output voltage to a value higher than its lowest value. The set point range is from 0.8 Vdc to 3.6 Vdc. 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 0 V, 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 Vin 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 PTH04040 are available in trays of 12 units.

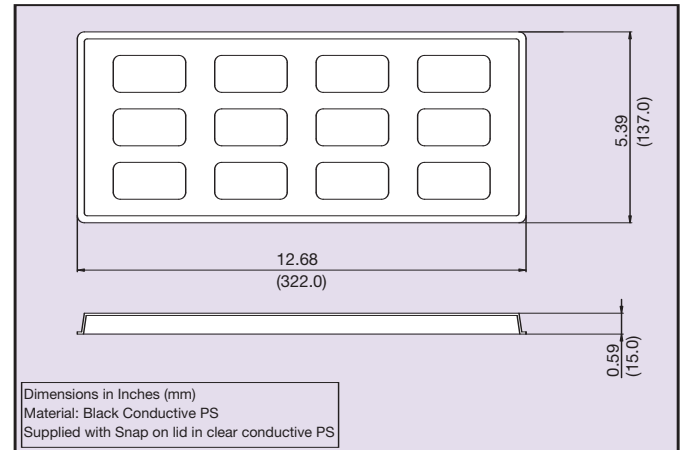


Figure 3 - Tray

4.2 Labeling and Part Numbering Sequence

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

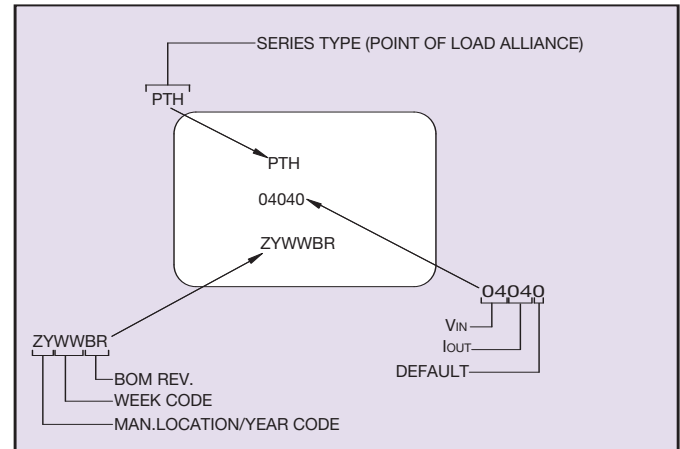


Figure 4 - PTH04040 Part Numbering

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).

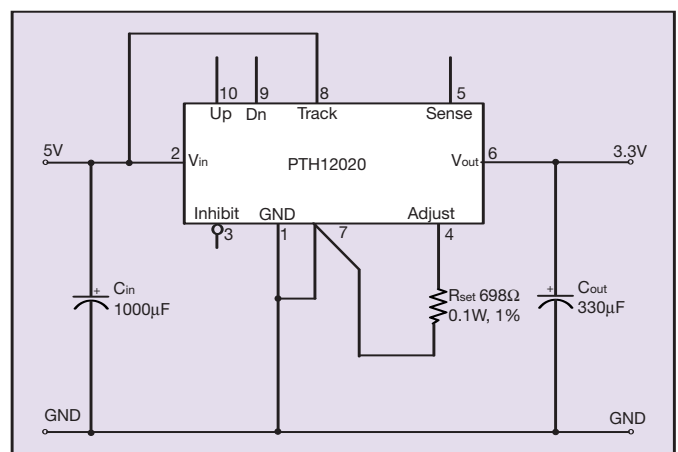
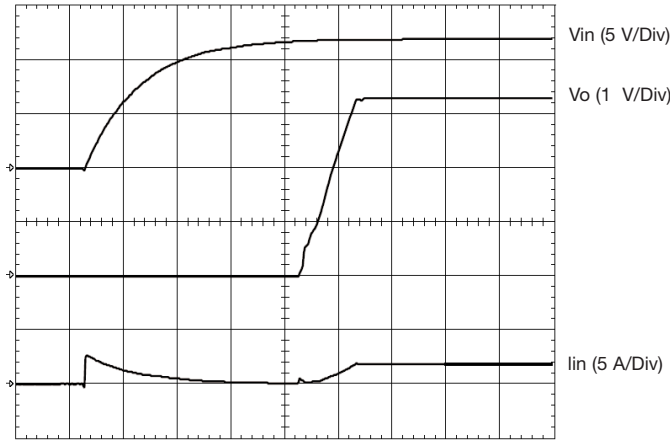


Figure 5 - Soft-start Power-up

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.



HORIZ SCALE: 5 ms/Div

Figure 7 - Power-up Characteristic

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 18 A output product (PTH12020W), operating from a 12 V input bus and configured for a 3.3 V output. The waveforms were measured with a 5 A 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 25 ms.

7. Feature Set

7.1 Adjusting the Output Voltage

The Vo adjust control (pin 17) sets the output voltage of the PTH04040 product. The adjustment range is from 0.8V to 3.6V. The adjustment method requires the addition of a single external resistor¹, R_{set}, that must be connected directly between the Vo Adjust and GND pins². 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 equations, or simply selected from the range of values given in Tables 5. Figure 8 shows the placement of the required resistor.

$$R_{SET} = 10k\Omega \times \frac{0.8V}{V_o - 0.8V} - 2.49 k\Omega$$

Equation 1

V _{out} Standard	R _{set} (Preferred Value)	V _{out} (Actual)
3.3 V	689 Ω	3.309 V
2.5 V	2.21 kΩ	2.502 V
2.0 V	4.12 kΩ	2.010 V
1.8 V	5.49 kΩ	1.803 V
1.5 V	8.87 kΩ	1.504 V
1.2 V	17.4 kΩ	1.202 V
1.0 V	36.5 kΩ	1.005 V
0.8 V	Open	0.8 V

Table 4 - Preferred Values of R_{set} for Standard Output Voltages

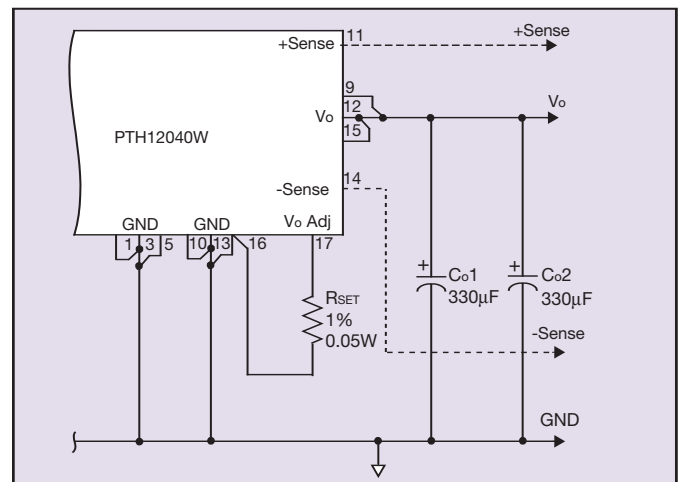


Figure 8 - Adjust Resistor Placement

OUTPUT VOLTAGE SET-POINT RESISTOR VALUES					
V _a Req'd	R _{set}	V _a Req'd	R _{set}	V _a Req'd	R _{set}
0.800	Open	1.400	10.8 kΩ	2.50	2.22 kΩ
0.825	318 kΩ	1.425	10.3 kΩ	2.55	2.08 kΩ
0.850	158 kΩ	1.450	9.82 kΩ	2.60	1.95 kΩ
0.875	104 kΩ	1.475	9.36 kΩ	2.65	1.83 kΩ
0.900	77.5 kΩ	1.50	8.94 kΩ	2.70	1.72 kΩ
0.925	61.5 kΩ	1.55	8.18 kΩ	2.75	1.61 kΩ
0.950	50.8 kΩ	1.60	7.51 kΩ	2.80	1.51 kΩ
0.975	43.2 kΩ	1.65	6.92 kΩ	2.85	1.41 kΩ
1.000	37.5 kΩ	1.70	6.4 kΩ	2.90	1.32 kΩ
1.025	33.1 kΩ	1.75	5.93 kΩ	2.95	1.23 kΩ
1.050	29.5 kΩ	1.80	5.51 kΩ	3.00	1.15 kΩ
1.075	26.6 kΩ	1.85	5.13 kΩ	3.05	1.07 kΩ
1.100	24.2 kΩ	1.90	4.78 kΩ	3.10	988 Ω
1.125	22.1 kΩ	1.95	4.47 kΩ	3.15	914 Ω
1.150	20.4 kΩ	2.00	4.18 kΩ	3.20	843 Ω
1.175	18.8 kΩ	2.05	3.91 kΩ	3.25	775 Ω
1.200	17.5 kΩ	2.10	3.66 kΩ	3.30	710 Ω
1.225	16.3 kΩ	2.15	3.44 kΩ	3.35	647 Ω
1.250	15.3 kΩ	2.20	3.22 kΩ	3.40	587 Ω
1.275	14.4 kΩ	2.25	3.03 kΩ	3.45	529 Ω
1.300	13.5 kΩ	2.30	2.84 kΩ	3.50	473 Ω
1.325	12.7 kΩ	2.35	2.67 kΩ	3.55	419 Ω
1.350	12.1 kΩ	2.40	2.51 kΩ	3.60	367 Ω
1.375	11.4 kΩ	2.45	2.36 kΩ		

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_o Adjust to either GND or V_{out}. Any capacitance added to the V_o Adjust pin will affect the stability of the regulator.

7.2 Adjusting the Under-Voltage Lockout (UVLO)

The PTH04040W 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 monotonic powerup for the load circuit, and also limits the magnitude of current drawn from the module's input source during the powerup sequence.

The UVLO characteristic is defined by the on-threshold (V_{THD}) and hysteresis (V_{HYS}) 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. 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 PTH04040W gives the user the option of adjusting the on-threshold voltage higher than the default value. This might be desirable if the module is powered from a +5 V input bus. This would prevent the module from operating until the input bus has risen closer to its regulation voltage.

The adjustment method uses the 'UVLO Prog' control (pin 8). If the UVLO Prog pin is left open circuit, the on-threshold voltage remains at its nominal value of 2.63 V (refer to the shortform datasheet). This ensures that the unadjusted module will produce a regulated output when the minimum input voltage is applied. The hysteresis voltage is approximately 0.62 V, which correlates to an off-threshold voltage of about 2 V. The magnitude of the hysteresis is automatically set to about 22% of the on-threshold. So if the on-threshold voltage is increased, then the hysteresis will also increase slightly.

7.2.2 Adjustment Method

Figure 8 shows the placement of the resistor, R_{THD}, for adjusting the UVLO on-threshold voltage. It connects from the UVLO Prog control pin to GND. Equation 2 A determines the value of R_{THD} required to adjust V_{THD} to a new value. The default value is 2.63 V, and it can only be adjusted higher. Once the value of R_{THD} has been set, equation Equation 2B may be used to determine the new hysteresis voltage.

The recommended adjustment method requires that any change to the hysteresis be determined first. If the hysteresis is changed, then a value for R_{THD} must also be calculated. This is irrespective of whether a change is required to the value of V_{THD}. If there is no change to V_{HYS}, then a resistor should not be placed in the R_{HYS} location. R_{HYS} should then be assigned an infinite value for calculating the value of R_{THD}.

$$R_{THD} = \frac{12.9}{V_{THD} - 2.63} \quad k\Omega$$

Equation 2A

$$V_{HYS} = 2.191 \left(\frac{1}{R_{THD}} + 0.283 \right) V$$

Equation 2B

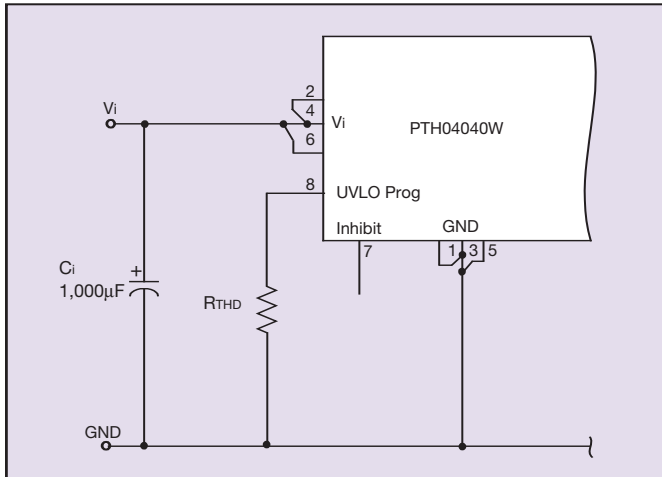


Figure 9 - UVLO Program Resistor Placement

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 10 shows the typical application of the inhibit function. Note the discrete transistor (Q1). The Inhibit control has its own internal pull-up to $+V_{in}$ potential. The input is not compatible with TTL logic devices. An open-collector (or open-drain) discrete transistor is recommended for control.

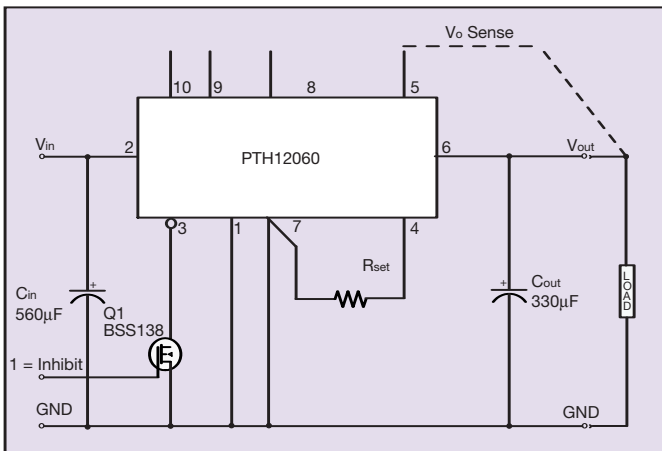


Figure 10 - Typical Application of the Inhibit Function

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 25 ms. Figure 11 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 5 A load.

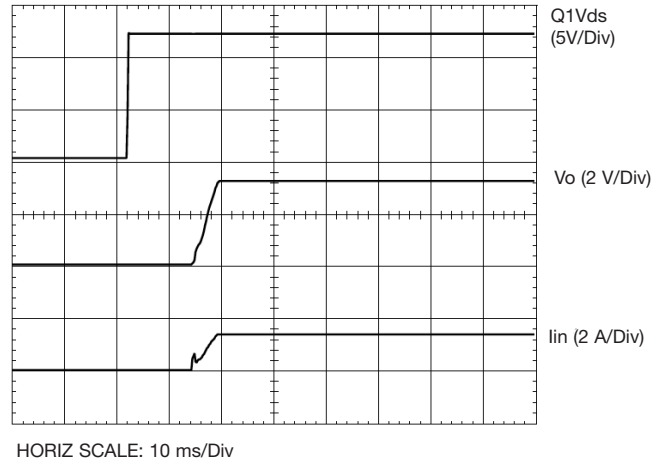


Figure 11 - Typical Rise in Output Voltage and Input Current

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⁽¹⁾, 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⁽²⁾. 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 11). 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 μA when grounded, and has an open-circuit voltage of 0.8 V.

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

Table 6 - Margin Up/Down Resistor Values

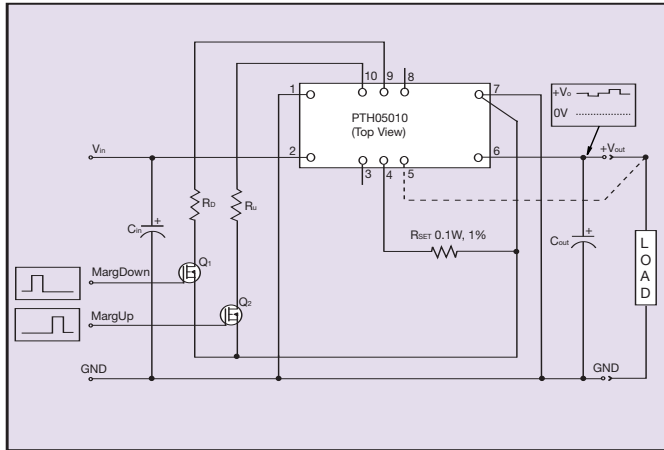


Figure 12 - Margin Up/Down Application Schematic

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 Ω 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 0.3 V.

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:

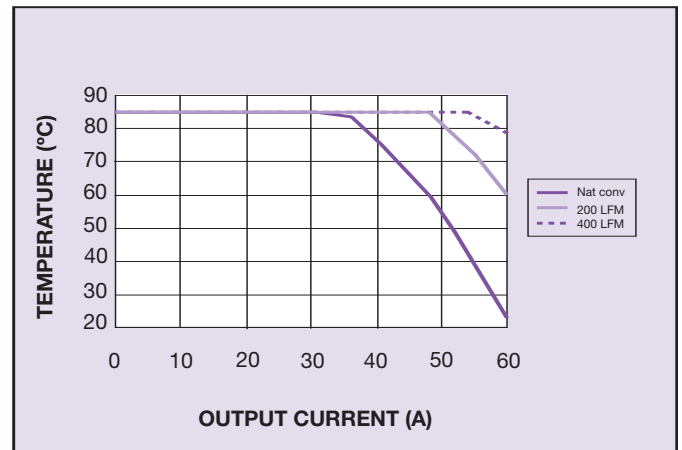
- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

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 13. This SOA curve shows the load current versus the ambient air temperature and velocity.



**Figure 13 - Safe Operating Curve
PTH04040W $V_{out} = 5$ V**

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 1.6 mm, eight layer FR4 PCB with the inner layers consisting of 2 oz power and ground planes. The top and bottom layers contain a minimal amount of metalisation. A board to board spacing of 1 inch was used. The data represented by the 0 m/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 14 and 15.

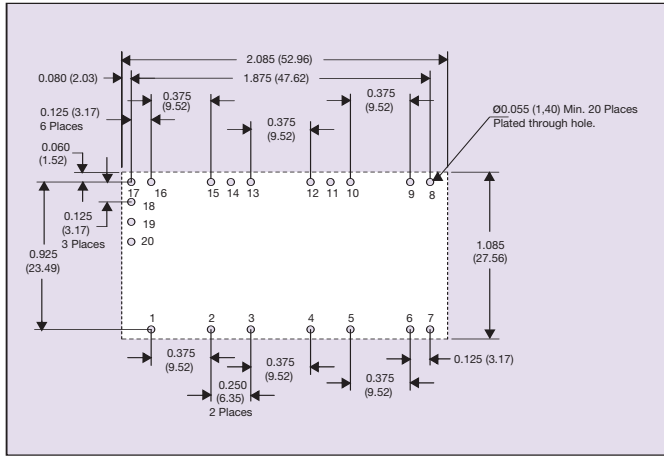


Figure 14 - Recommended Land Pattern (Through - Hole Model)

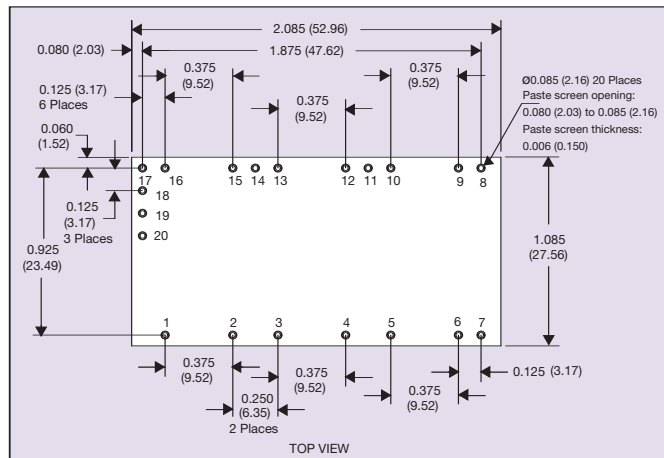


Figure 15 - Recommended Land Pattern (Surface Mount Model)

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 0 V 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⁽¹⁾. As an example, if the Track pin of a 2.5 V regulator is at 1 V, the regulated output will be 1 V. But if the voltage at the Track pin rises to 3 V, the regulated output will not go higher than 2.5 V.

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⁽³⁾. 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 16.

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 17 shows the output voltage waveforms from the circuit of Figure 16 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 (3.3 V) and U2 (1.8 V) 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 1 V/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 100 k Ω and 0.1 μ F correlate to a decay rate of about 0.17 V/ms.

The power-down sequence is initiated with a low-to-high transition at the On/Off Control input to the circuit. Figure 18 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 1 V/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.

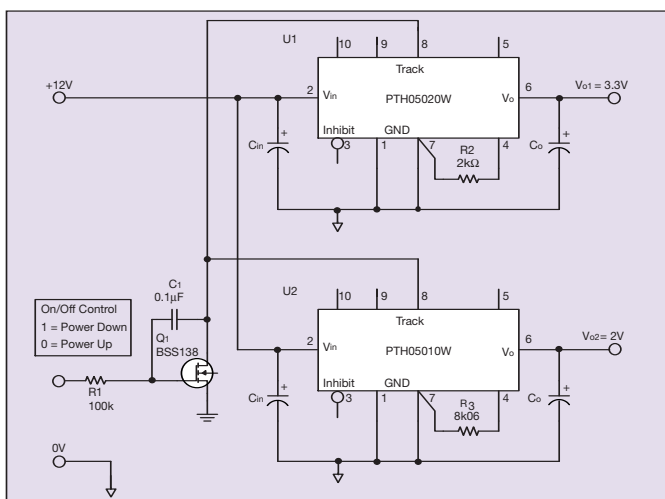
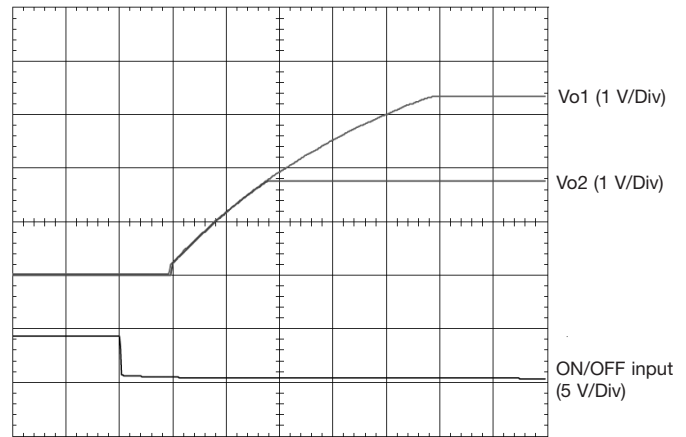
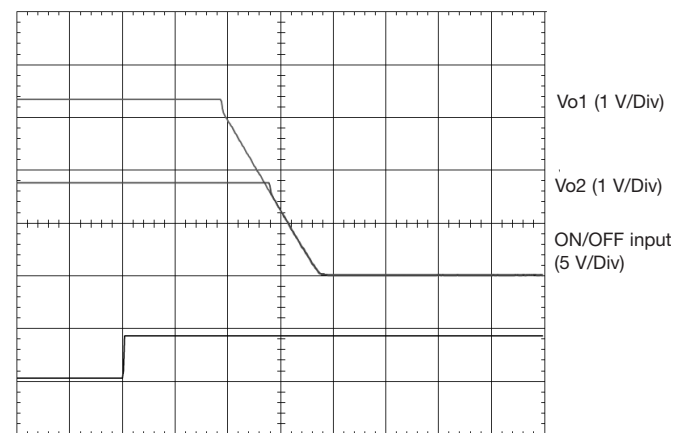


Figure 16 - Sequenced Power-up and Power-down Using Auto-Track™



HORIZ SCALE: 10 ms/Div

Figure 17 - Power-up with Auto-Track Control



HORIZ SCALE: 10 ms/Div

Figure 18 - Power-down with Auto-Track Control

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