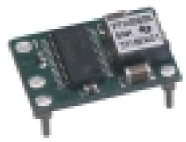
6-A, 5-V Input Non-Isolated Wide-Output Adjust Power Module

SLTS201B – MAY 2003 – REVISED AUGUST 2003



NOMINAL SIZE = 0.75 in x 0.5 in (19,05 mm x 12,7 mm)

Features

- Up to 6-A Output Current
- 5-V Input Voltage
- Wide-Output Voltage Adjust (0.9 V to 3.6 V)
- Efficiencies up to 94 %
- 160 W/in³ Power Density
- On/Off Inhibit
- Under-Voltage Lockout
- Output Current Limit
- Pre-Bias Startup
- Over-Temperature Protection
- Surface Mountable
- Operating Temp: –40 to +85 °C
- DSP Compatible Output Voltages
- IPC Lead Free 2

Description

The PTH05000 series of non-isolated power modules are small in size and high on performance. Using double-sided surface mount construction and synchronous rectification technology, these regulators deliver up to 6 A of output current while occupying a PCB area of about half the size of a standard postage stamp. They are an ideal choice for applications where space, performance and cost are important design constraints.

The series operates from an input voltage of 5 V to provide step-down power conversion to any output voltage over the range, 0.9 V to 3.6 V. The output voltage of the PTH05000W is set within this range using a single resistor.

Operating features include an on/off inhibit, output voltage adjust (trim), an output current limit, and over-temperature protection.

For high efficiency these parts employ a synchronous rectifier output stage. An output pre-bias holdoff capability ensures that the output will not sink current during startup.

Target applications include telecom, industrial, and general purpose circuits, including low-power dual-voltage systems that use a DSP, microprocessor, or ASIC.

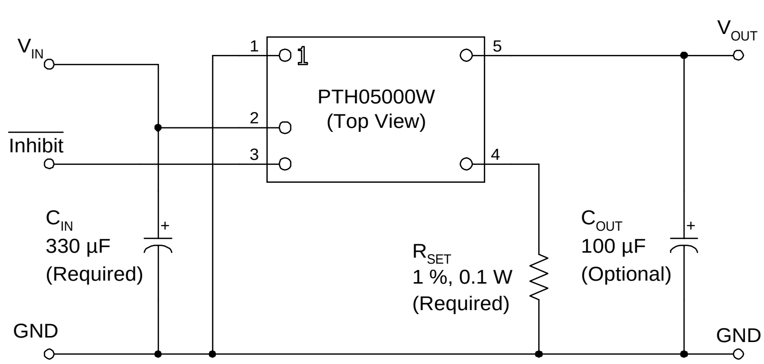
Package options include both through-hole and surface mount configurations.

Pin Configuration

Pin	Function
1	GND
2	V_{in}
3	Inhibit *
4	V_o Adjust
5	V_{out}

* *Denotes negative logic:*
Open = Output On
Ground = Output Off

Standard Application



R_{set} = Reistor to set the desired output voltage (see spec. table for values)
C_{in} = Required electrolytic 330 µF
C_{out} = Recommended 100 µF electrolytic

TEXAS INSTRUMENTS

Ordering Information

Output Voltage (PTH05000❒xx)

Code	Voltage
W	0.9 V – 3.6 V (Adjust)

Package Options (PTH05000x❒❒) (1)

Code	Description	Pkg Ref. (2)
AH	Horiz. T/H	(EUS)
AS	SMD, Standard (3)	(EUT)

Notes: *(1) Add "T" to end of part number for tape and reel on SMD packages only.*
(2) Reference the applicable package reference drawing for the dimensions and PC board layout
(3) "Standard" option specifies 63/37, Sn/Pb pin solder material.

Pin Descriptions

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

GND: This is the common ground connection for the 'V_{in}' and 'V_{out}' power connections. It is also the 0 VDC reference for the 'Inhibit' and 'V_o Adjust' control input.

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

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.

Vo Adjust: A 0.1 W, 1 % 100 ppm/°C resistor must be connected between this pin and the GND pin to set the output voltage to the desired value. The set point range for the output voltage is from 0.9 V to 3.6 V. The resistor required for a given output voltage may be calculated from the following formula. If left open circuit, the module output will default to its lowest output voltage value. For further information on the adjustment and/or trimming of the output voltage, consult the related application note.

$$R_{set} = 10\ \text{k}\Omega \cdot \frac{0.891\ \text{V}}{V_{out} - 0.9\ \text{V}} - 3.24\ \text{k}\Omega$$

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

Environmental & Absolute Maximum Ratings (Voltages are with respect to GND)

Characteristics	Symbols	Conditions	Min	Typ	Max	Units
Operating Temperature Range	T_a	Over V_{in} Range	–40 (i)	—	+85	°C
Solder Reflow Temperature	T_{reflow}	Surface temperature of module body or pins			215 (ii)	°C
Storage Temperature	T_s	—	–40	—	+125	°C
Over Temperature Protection	OTP	IC junction temperature	—	150	—	°C
Mechanical Shock		Per Mil-STD-883D, Method 2002.3 1 msec, ½ sine, mounted	—	500	—	G's
Mechanical Vibration		Mil-STD-883D, Method 2007.2 20-2000 Hz	—	20	—	G's
Weight	—		—	2	—	grams
Flammability	—	Meets UL 94V-O				

Notes: (i) *For operation below 0 °C the external capacitors must have stable characteristics. Use either a low ESR tantalum, Oscon®, or ceramic capacitor.*
(ii) *During reflow of SMD package version do not elevate peak temperature of the module, pins or internal components above the stated maximum. For further guidance refer to the application note, "Reflow Soldering Requirements for Plug-in Power Surface Mount Products."*

Electrical Specifications Unless otherwise stated, T_a =25 °C, V_{in} =5 V, V_o =3.3 V, C_{in} =330 µF, C_{out} =0 µF, and I_o =I_o(max)

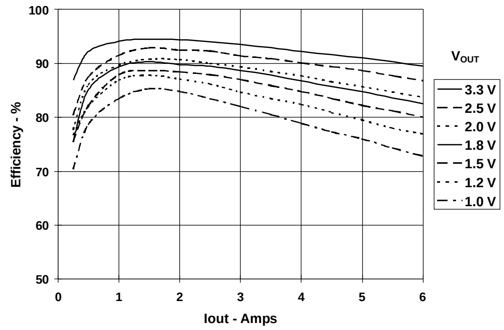
Characteristics	Symbols	Conditions	PTH05000W Min	Typ	Max	Units
Output Current	I_o	0.9 V ≤ V_o ≤3.6 V, T_a =25 °C, natural convection T_a =60 °C, 200LFM	0 0	— —	6 (1) 5.25 (1)	A
Input Voltage Range	V_{in}	Over I_o range	4.5	—	5.5	V
Set-Point Voltage Tolerance	V_o tol		—	—	±2 (2)	$\%V_o$
Temperature Variation	ΔReg_{temp}	–40 °C <T_a < +85 °C	—	±0.5	—	$\%V_o$
Line Regulation	ΔReg_{line}	Over V_{in} range	—	±5	—	mV
Load Regulation	ΔReg_{load}	Over I_o range	—	±5	—	mV
Total Output Variation	ΔReg_{tot}	Includes set-point, line, load, –40 °C ≤ T_a ≤ +85 °C	—	—	±3 (2)	$\%V_o$
Efficiency	η	V_{in} =5 V, I_o =4 A R_{SET} = 475 Ω V_o = 3.3 V R_{SET} = 2.32 kΩ V_o = 2.5 V R_{SET} = 4.87 kΩ V_o = 2.0 V R_{SET} = 6.65 kΩ V_o = 1.8 V R_{SET} = 11.5 kΩ V_o = 1.5 V R_{SET} = 26.1 kΩ V_o = 1.2 V R_{SET} = 84.5 kΩ V_o = 1.0 V	— — — — — — —	92 90 88 87 84 82 79	— — — — — — —	%
V_o Ripple (pk-pk)	V_r	20 MHz bandwidth V_o ≥3.3 V V_o ≤2.5 V	— —	30 25	— —	mVpp
Transient Response	 t_{tr} ΔV_{tr}	1 A/µs load step, 50 to 100 % $I_o$max, V_o =1.8 V, C_{out} =100 µF Recovery time V_o over/undershoot	 — —	 70 100	 — —	 µSec mV
Current Limit	I_{lim}	ΔV_o = –50 mV	—	13	—	A
Under-Voltage Lockout	UVLO	V_{in} increasing V_{in} decreasing	— 3.4	3.8 3.5	4.3 —	V
Inhibit Control (pin 3) Input High Voltage Input Low Voltage	 V_{IH} V_{IL}	Referenced to GND	 V_{in} –0.5 –0.2	 — —	 Open (3) 0.8	V
Input Low Current	I_{IL}	Pin 3 to GND	—	–10	—	µA
Standby Input Current	I_{in} standby	pins 1 & 3 connected	—	1	—	mA
Switching Frequency	f_s	Over V_{in} and I_o ranges	—	700	—	kHz
External Input Capacitance	C_{in}		330 (4)	—	—	µF
External Output Capacitance	C_{out}		0	100 (5)	1,000	µF
Reliability	MTBF	Per Bellcore TR-332 50 % stress, T_a =40 °C, ground benign	28	—	—	10^6 Hrs

Notes: (1) *See SOA curves or consult factory for appropriate derating.*
(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/°C or better temperature stability.*
(3) *The Inhibit control (pin 3) has an internal pull-up to Vin, and if left open-circuit the module will operate when input power is applied. A small low-leakage (<100 nA) MOSFET is recommended to control this input. See application notes for more information.*
(4) *The regulator requires a minimum of 330 µF input capacitor with a minimum 300 mArms ripple current rating. For further information, consult the related application note on Capacitor Recommendations.*
(5) *An external output capacitor is not required for basic operation. Adding 100 µF of distributed capacitance at the load will improve the transient response.*

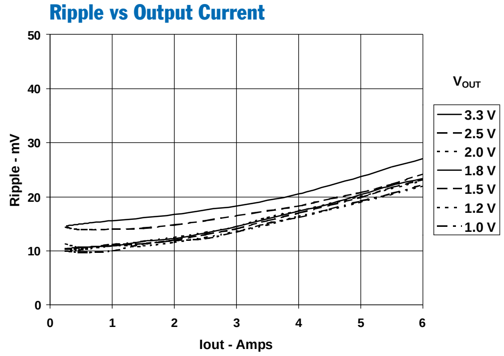
Typical Characteristics

Characteristic Data; V_{in} =5 V *(See Note A)*

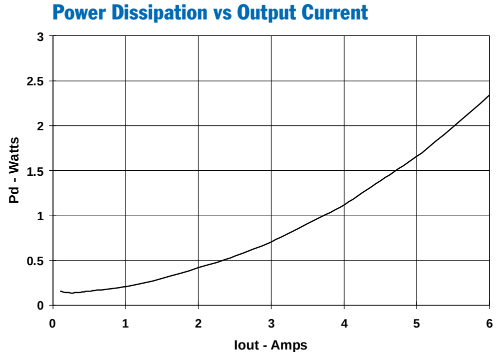
Efficiency vs Output Current



Ripple vs Output Current

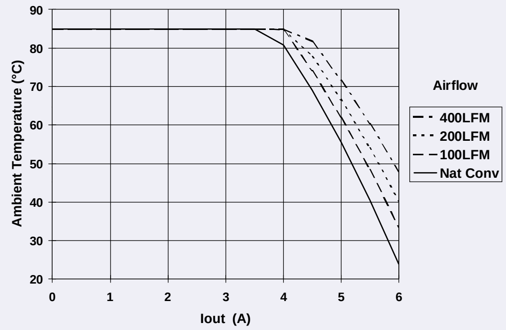


Power Dissipation vs Output Current



Safe Operating Area; V_{in} =5 V *(See Note B)*

Output Voltage =3.3 V



Note A: *Characteristic data has been developed from actual products tested at 25 °C. This data is considered typical data for the Converter.*
Note B: *SOA curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to modules soldered directly to a 4 in. × 4 in. double-sided PCB with 1 oz. copper.*

Adjusting the Output Voltage of the PTH05000W Wide-Output Adjust Power Modules

The V_o *Adjust* control (pin 4) sets the output voltage of the PTH05000Wproduct. The adjustment range is from 0.9 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 [1]. Table 1-1 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 1-2. Figure 1-1 shows the placement of the required resistor.

$$R_{set} = 10\,\text{k}\Omega \cdot \frac{0.891\ \text{V}}{V_{out} - 0.9\ \text{V}} - 3.24\,\text{k}\Omega$$

Table 1-1; Preferred Values of R_{set} for Standard Output Voltages

V_{out} (Standard)	R_{set} (Pref'd Value)	V_{out} (Actual)
3.3 V	475 Ω	3.298V
2.5 V	2.32 kΩ	2.502 V
2 V	4.87 kΩ	1.999 V
1.8 V	6.65 kΩ	1.801 V
1.5 V	11.5 kΩ	1.504 V
1.2 V	26.1 kΩ	1.204 V
1 V	84.5 kΩ	1.001 V
0.9 V	Open	0.9 V

Figure 1-1; V_o Adjust Resistor Placement

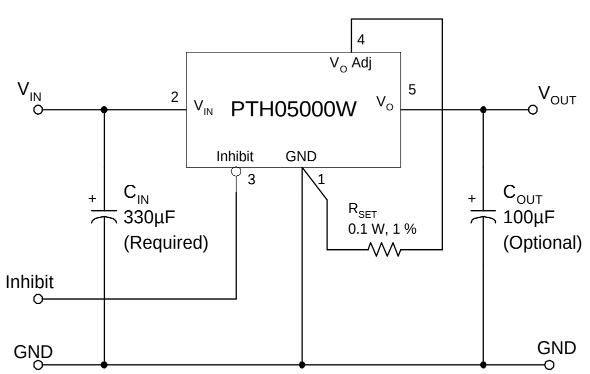


Table 1-2; Output Voltage Set-Point Resistor Values

V_a Req'd	R_{set}	V_a Req'd	R_{set}
0.900	Open	2.00	4.86 kΩ
0.925	353 kΩ	2.05	4.51 kΩ
0.950	175 kΩ	2.10	4.19 kΩ
0.975	116 kΩ	2.15	3.89 kΩ
1.000	85.9 kΩ	2.20	3.61 kΩ
1.025	68.0 kΩ	2.25	3.36 kΩ
1.050	56.2 kΩ	2.30	3.12 kΩ
1.075	47.7 kΩ	2.35	2.90 kΩ
1.100	41.3 kΩ	2.40	2.70 kΩ
1.125	36.4 kΩ	2.45	2.51 kΩ
1.150	32.4 kΩ	2.50	2.33 kΩ
1.175	29.2 kΩ	2.55	2.16 kΩ
1.200	26.5 kΩ	2.60	2.00 kΩ
1.225	24.2 kΩ	2.65	1.85 kΩ
1.250	22.2 kΩ	2.70	1.71 kΩ
1.275	20.5 kΩ	2.75	1.58 kΩ
1.300	19.0 kΩ	2.80	1.45 kΩ
1.325	17.7 kΩ	2.85	1.33 kΩ
1.350	16.6 kΩ	2.90	1.22 kΩ
1.375	15.5 kΩ	2.95	1.11 kΩ
1.400	14.6 kΩ	3.00	1.00 kΩ
1.425	13.7 kΩ	3.05	904 Ω
1.450	13.0 kΩ	3.10	810 Ω
1.475	12.3 kΩ	3.15	720 Ω
1.50	11.6 kΩ	3.20	634 Ω
1.55	10.5 kΩ	3.25	551 Ω
1.60	9.49 kΩ	3.30	473 Ω
1.65	8.64 kΩ	3.35	397 Ω
1.70	7.90 kΩ	3.40	324 Ω
1.75	7.24 kΩ	3.45	254 Ω
1.80	6.66 kΩ	3.50	187 Ω
1.85	6.14 kΩ	3.55	122 Ω
1.90	5.67 kΩ	3.60	60 Ω
1.95	5.25 kΩ		

Notes:

1. Use a 0.1 W resistor. The tolerance should be 1 %, with a temperature stability of 100 ppm/°C (or better). Place the resistor as close to the regulator as possible. Connect the resistor directly between pins 4 and 1 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.

Capacitor Recommendations for the PTH05000 Series of 6-A Power Modules

Input Capacitors

The recommended input capacitance is determined by 300 mA (rms) minimum ripple current rating, less than 300 mΩ equivalent series resistance (ESR) and 330 µF minimum capacitance. The ripple current rating, ESR, and operating temperature are the major considerations when selecting the input capacitor.

It is recommended that tantalum capacitors have a minimum voltage rating of at least twice the working voltage, including the ac ripple. This is necessary to insure reliability with 5-V input voltage bus applications.

Output Capacitors (optional)

The ESR of the output bulk (non-ceramic) capacitance must be between 10 mΩ ≤ESR ≤200 mΩ. Electrolytic capacitors have poor ripple performance at frequencies greater than 400 kHz but excellent low frequency transient response. Above the ripple frequency, ceramic decoupling capacitors are recommended to improve the transient response and reduce any high frequency noise components apparent during higher current excursions. A maximum of 100 µF ceramic capacitance may be added to the output bus.

Tantalum/ Ceramic Capacitors

Tantalum capacitors are acceptable on the output bus. Either tantalum, Os-con®, or ceramic capacitor types are recommended for applications where ambient temperatures fall below 0 °C. Ceramic capacitors may be used instead of electrolytic types on both the input and output bus. The input bus must have at least the minimum amount of capacitance. For the output bus, the total amount of ceramic capacitance should be limited to 100 µF.

Capacitor Table

Table 1-1 identifies capacitors with acceptable ESR and maximum allowable ripple current (rms) ratings. Capacitors recommended for the output are identified under the Output Bus column with the required quantity.

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.

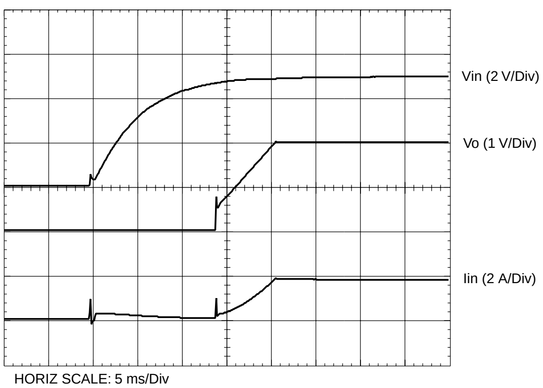
Table 1-1; Recommended Input/Output Capacitors

Capacitor Vendor/ Component Series	Capacitor Characteristics					Quantity		
	Working Voltage	Value (µF)	(ESR) Equivalent Series Resistance	85°C Maximum Ripple Current (Irms)	Physical Size (mm)	Input Bus	Output Bus	Vendor Number
Panasonic WA (SMT) FC	10 V 10 V	330 µF 330 µF	0.035 Ω 0.117 Ω	2800mA 555mA	8×6.9 8×11.5	1 1	1 1	EEFWA1A121P EEUFC1A331
Panasonic FK (SMT)	16 V 25 V	330 µF 330 µF	0.160 Ω 0.160 Ω	600 mA 600 mA	8×10.2 8×10.2	1 1	1 1	EEVFK1C331P EEVFK1E331P
United Chemi–con PXA (SMT) FS LXZ (SMT) MVZ	 10 V 10 V 16 V 25 V	 330 µF 330 µF 330 µF 330 µF	 0.024 Ω 0.025 Ω 0.120 Ω 0.170 Ω	 3770 mA 3500 mA 555 mA 450 mA	 10×7.7 10×10.5 8×12 8×10	 1 1 1 1	 1 1 1 1	 PXA10VC331MJ80TP 10FS330M LXZ16VB331M8x12LL MVZ25VC331MH10TP
Nichicon UWG (SMT) NA PM	 16V 10 V 10 V	 330 µF 470 µF 330 µF	 0.150 Ω 0.018 Ω 0.160 Ω	 670 mA >3100 mA 460 mA	 10x10 10×10 8×11.5	 1 1 1	 1 1 1	 UWG1C331MNR1GS PNA1A471M1 UPM1A331MHH
Sanyo Os-con® SVP (SMT) SP	 10 V 10 V	 330 µF 470 µF	 0.025 Ω 0.015 Ω	 >3700 mA >4500 mA	 10×8 10×10.5	 1 1	 1 1	 10SVP330MX 10SP470M
AVX Tantalum TPS	10 V 10 V	330 µF 330 µF	0.100 Ω 0.060 Ω	>1100 mA >2000 mA	7.3L ×4.3W ×4.1H	1 1	1 1	TPSV337M010R0100 TPSV337M010R0060
Kemet T520 T495	10 V 10 V	330 µF 330 µF	0.035 Ω 0.040 Ω	> 1200 mA >1100 mA	7.3L ×5.7W ×4.0H	1 1	1 1	T510X337M010AS T520X337M010AS
Sprague 594D/595D	10 V 10 V	330 µF 330 µF	0.045 Ω 0.140 Ω	>1400 mA >1000 mA	7.3L ×6.0W ×4.1H	1 1	1 1	594D337X0010R2T 595D337X0010D2T
TDK- Ceramic X5R Murata Ceramic X5R (1210 Case)	6.3 V 6.3 V	47 µF 47 µF	0.002 Ω 0.002 Ω	>1400 mA >1000 mA	3.6L ×2.8W ×2.8H	6 6	2 (max) 2 (max)	C3225X5R0J476KT/MT GRM32ER60J476M/6.3

Power-Up Characteristics

When configured per their standard application, the PTH03000 and PTH05000 series of power modules will produce a regulated output voltage following the application of a valid input source voltage. During power up, internal soft-start circuitry slows the rate that the output voltage rises, thereby limiting the amount of in-rush current that can be drawn from the input source. The soft-start circuitry introduces a short time delay (typically 10 ms) into the power-up characteristic. This is from the point that a valid input source is recognized. Figure 3-1 shows the power-up waveforms for a PTH05000W (5-V input), with the output voltage set point adjusted for a 2-V output. The waveforms were measured with a 5-A resistive load. The initial rise in input current when the input voltage first starts to rise is the charge current drawn by the input capacitors.

Figure 3-1



Current Limit Protection

The PTHxx000W modules protect against load faults with a continuous current limit characteristic. Under a load fault condition the output current cannot exceed the current limit value. Attempting to draw current that exceeds the current limit value causes the output voltage to be progressively reduced. Current is continuously supplied to the fault until it is removed. Upon removal of the fault, the output voltage will promptly recover.

Thermal Shutdown

Thermal shutdown protects the module's internal circuitry against excessively high temperatures. A rise in temperature may be the result of a drop in airflow, a high ambient temperature, or a sustained current limit condition. If the junction temperature of the internal components exceed 150 °C, the module will shutdown. This reduces the output voltage to zero. The module will start up automatically, by initiating a soft-start power up when the sensed temperature decreases 10 °C below the thermal shutdown trip point.

Output On/Off Inhibit

For applications requiring output voltage on/off control, the PTH03000W & PTH05000W power modules incorporate an output on/off *Inhibit* control (pin 3). The inhibit feature can be used wherever there is a requirement for the output voltage from the regulator to be turned off.

The power module functions 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 3-2 shows the typical application of the inhibit function. Note the discrete transistor (Q_1). The *Inhibit* control has its own internal pull-up to V_{in} potential. An open-collector or open-drain device is recommended to control this input.

Turning Q_1 on applies a low voltage to the *Inhibit* control pin and disables the output of the module. If Q_1 is then turned off, the module will execute a soft-start power-up sequence. A regulated output voltage is produced within 20 msec. Figure 3-3 shows the typical rise in the output voltage, following the turn-off of Q_1. The turn off of Q_1 corresponds to the fall in the waveform, Q_1 V_{gs}. The waveforms were measured with a 5-A resistive load.

Figure 3-2

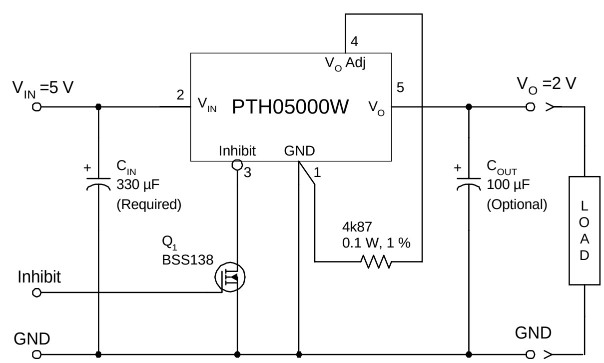
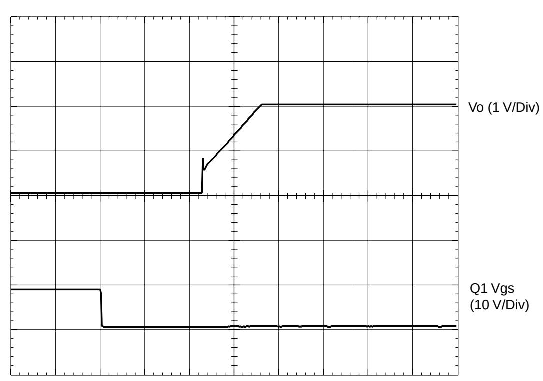


Figure 3-3



PTH05000W Startup with Output Pre-Bias

A pre-bias startup condition occurs as a result of an external voltage being present at the output of the power module prior to its output voltage rising. 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 (to a higher supply voltage) as part of a sequential power-up arrangement.

An output prebias can cause problems with power modules that incorporate synchronous rectifiers. This is because under most operating conditions, they can sink as well as source ouput current. Although the PTH05000W (5-V input) power module can sink current under normal operation, it will not do so during startup. [1] This is true as long as certain conditions are maintained. [2] Figure 3-1 shows an application schematic that demonstrates this capability. Figure 3-2 shows the waveforms of the circuit after input power is applied. Note that the module's output current (I_O) is never negative. Only positive current is sourced. This occurs when the output voltage is raised above that which is backfed from the 5-V input supply, via the diodes D_1 through D_4. [3]

Notes

1. Start up includes both the application of a valid input source voltage, or the removal of a ground signal from the *Inhibit** control (pin 3) with a valid input source applied. The output of the regulator is effectively off (tri-state), during the period that the *Inhibit** control is held low.
2. To ensure that the regulator does not sink current, the input voltage must always be greater or equal to the output voltage throughout the power-up and power-down sequence.
3. If during power up, the backfeeding source is greater than the module's set-point voltage, the module's output voltage will remain higher than its set point. The output will remain out of regulation until the back-feeding source is either reduced in voltage or removed.

Figure 3-2; Start-up with Output Pre-Bias

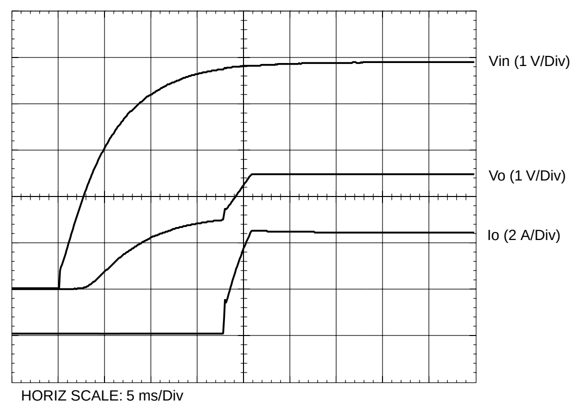
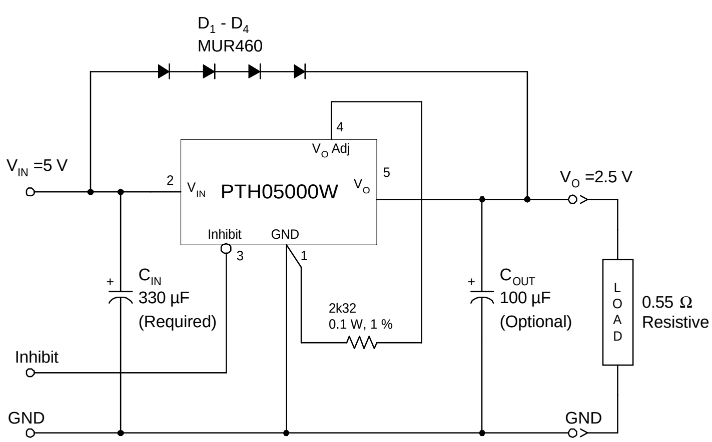
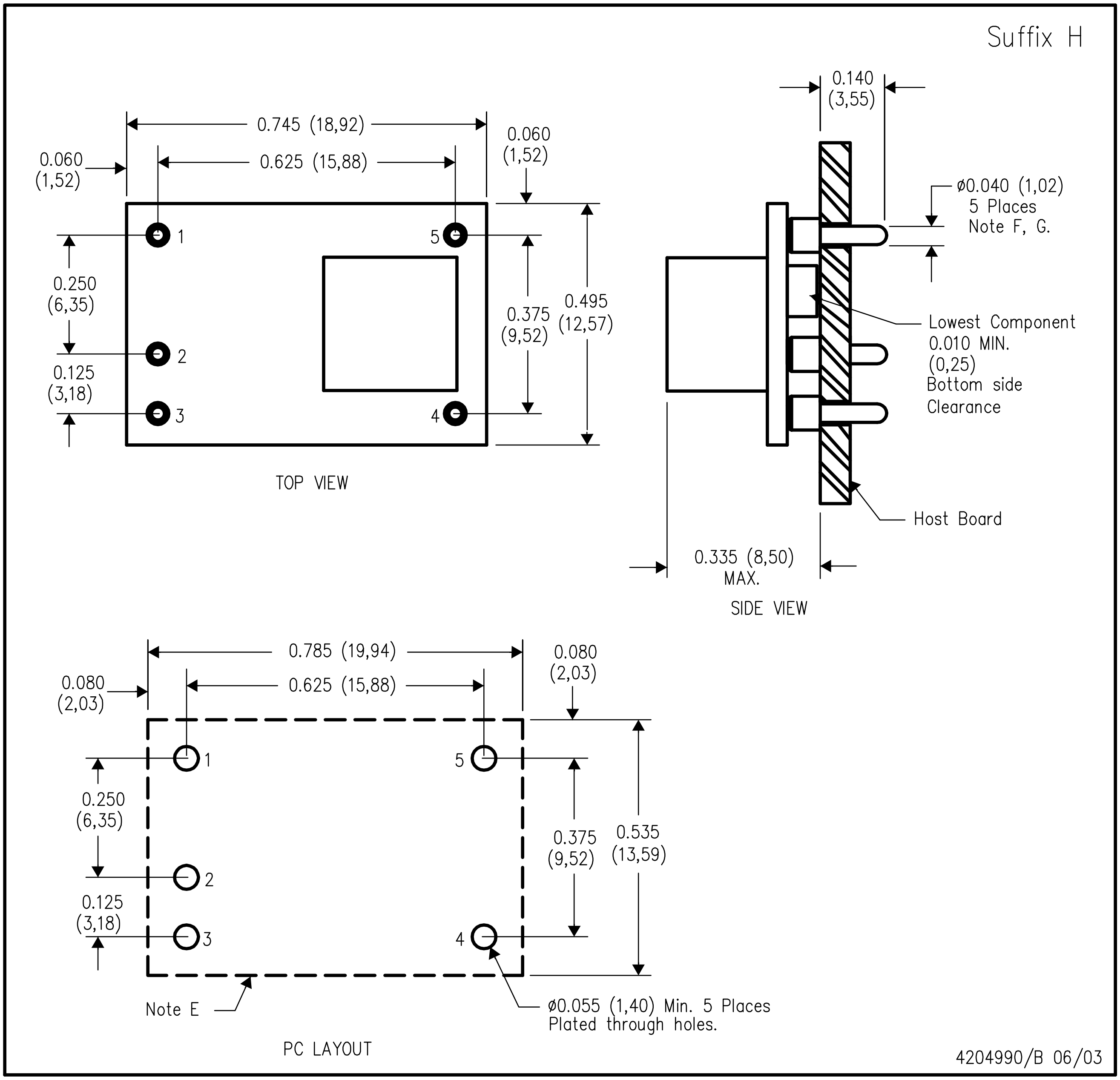


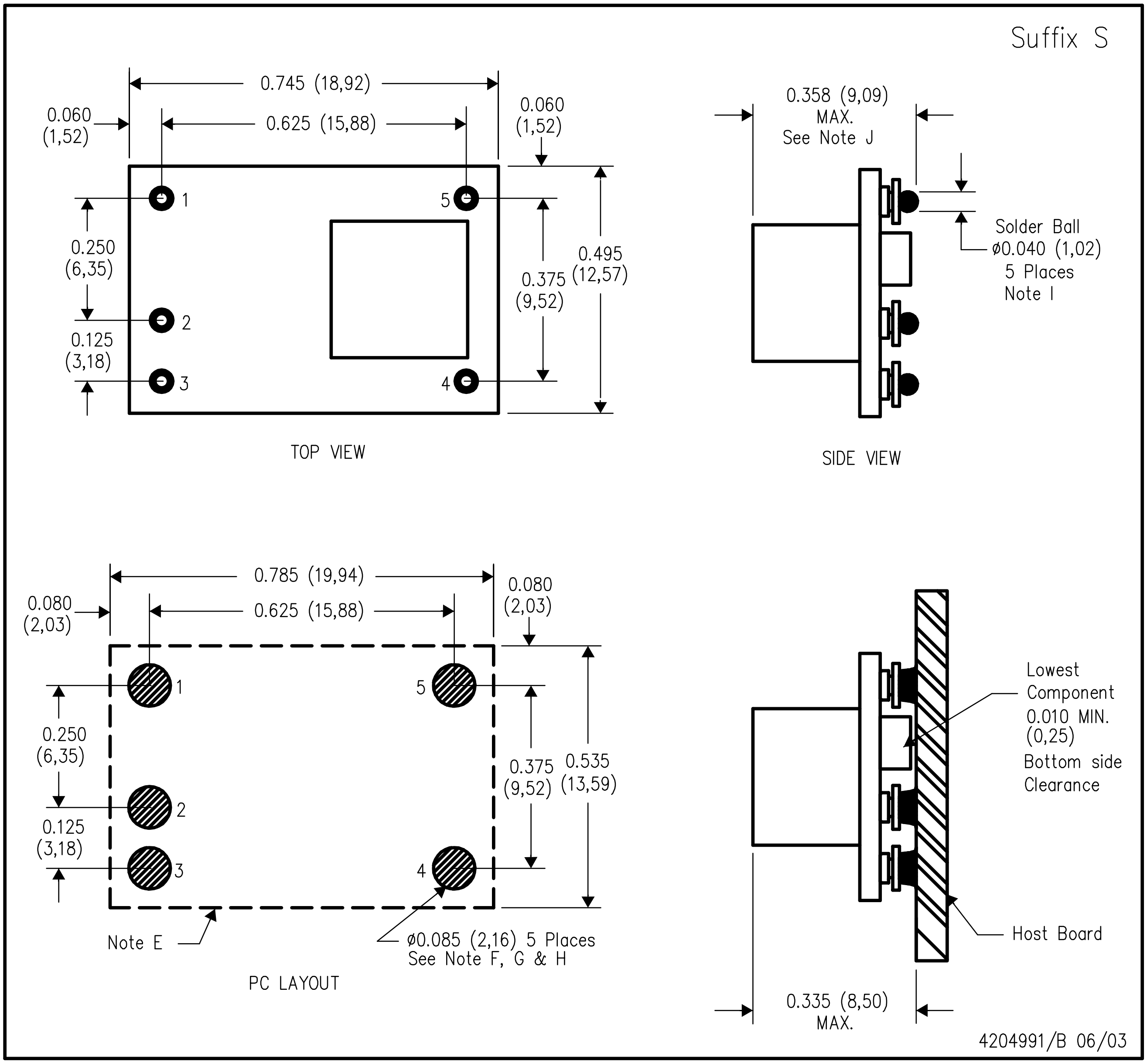
Figure 3-1; Schematic Demonstrating Startup with Output Pre-Bias





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 (±0,76mm).
- D. 3 place decimals are ±0.010 (±0,25mm).
- 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

EUT (R–PDSS–B5) 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 (±0,76mm).
- D. 3 place decimals are ±0.010 (±0,25mm).
- E. Recommended keep out area for user components.
- F. Power pin connection should utilize two or more vias to the interior power plane of 0.025 (0,63) I.D. per input, ground and output pin (or the electrical equivalent).
- G. Paste screen opening: 0.080 (2,03) to 0.085 (2,16). Paste screen thickness: 0.006 (0,15).
- H. Pad type: Solder mask defined.
- I. All pins: Material – Copper Alloy
  Finish – Tin (100%) over Nickel plate
  Solder Ball – See product data sheet.
- J. Dimension prior to reflow solder.

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