

## 15-A NON-ISOLATED DDR/QDR MEMORY BUS TERMINATION MODULES



### FEATURES

- $V_{TT}$  Bus Termination Output (Output Tracks the System  $V_{REF}$ )
- 15 A Output Current (12 A for 12-V Input)
- 3.3-V, 5-V or 12-V Input Voltage
- DDR and QDR Compatible
- On/Off Inhibit (for  $V_{TT}$  Standby)
- Undervoltage Lockout
- Operating Temperature:  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$

- Efficiencies up to 91%
- Output Overcurrent Protection (Nonlatching, Auto-Reset)
- 62 W/in<sup>3</sup> Power Density
- Safety Agency Approvals UL/cUL60950, EN60950, VDE
- Point-of-Load Alliance (POLA™) Compatible



Nominal Size  
1.37 in x 0.62 in  
34,8 mm x 15,75 mm

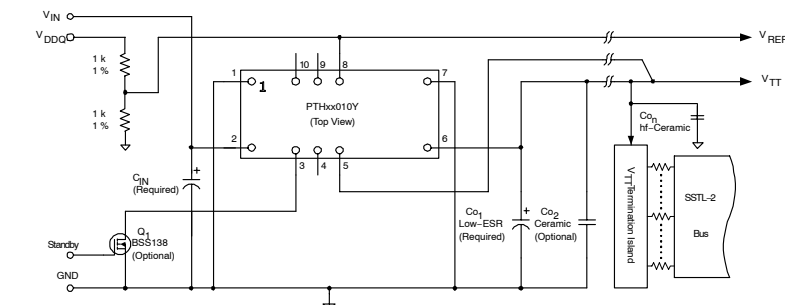
### DESCRIPTION

The PTHxx010Y are a series of ready-to-use switching regulator modules from Texas Instruments designed specifically for bus termination in DDR and QDR memory applications. Operating from either a 3.3-V, 5-V or 12-V input, the modules generate a  $V_{TT}$  output that will source or sink up to 15 A of current (12 A for 12-V input) to accurately track their  $V_{REF}$  input.  $V_{TT}$  is the required bus termination supply voltage, and  $V_{REF}$  is the reference voltage for the memory and chipset bus receiver comparators.  $V_{REF}$  is usually set to half the  $V_{DDQ}$  power supply voltage.

Both the PTHxx010Y series employs an actively switched synchronous rectifier output to provide state-of-the-art stepdown switching conversion. The products are small in size (1.37 in × 0.62 in), and are an ideal choice where space, performance, and high efficiency are desired, along with the convenience of a ready-to-use module.

Operating features include an on/off inhibit and output over-current protection (source mode only). The on/off inhibit feature allows the  $V_{TT}$  bus to be turned off to save power in a standby mode of operation. To ensure tight load regulation, an output remote sense is also provided. Package options include both through-hole and surface mount configurations.

### STANDARD APPLICATION



$C_{IN}$  = Required Capacitor; 470  $\mu\text{F}$  (3.3  $\pm$  5 V Input), 560  $\mu\text{F}$  (12 V Input).  
 $Co_1$  = Required Low-ESR Electrolytic Capacitor; 470  $\mu\text{F}$  (3.3  $\pm$  5 V Input), 940  $\mu\text{F}$  (12 V Input).  
 $Co_2$  = Ceramic Capacitance for Optimum Response to a 3 A ( $\pm$  1.5 A) Load Transient; 200  $\mu\text{F}$  (3.3  $\pm$  5 V Input), 400  $\mu\text{F}$  (12 V Input).  
 $Co_n$  = Distributed hf-Ceramic Decoupling Capacitors for  $V_{TT}$  bus; as Recommended for DDR Memory Applications.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

POLA is a trademark of Texas Instruments.

## ORDERING INFORMATION

| PTHXX010Y (Base Part Number) |                            |                |                    |                                   |
|------------------------------|----------------------------|----------------|--------------------|-----------------------------------|
| Input Voltage                | Part Number <sup>(1)</sup> | DESCRIPTION    | Pb – free and RoHS | Mechanical Package <sup>(2)</sup> |
| 3.3 V                        | PTH03010YAH                | Horizontal T/H | Yes <sup>(3)</sup> | EUH                               |
|                              | PTH03010YAS                | Standard SMD   | No <sup>(4)</sup>  | EUJ                               |
|                              | PTH03010YAZ                | Optional SMD   | Yes <sup>(3)</sup> | EUJ                               |
| 5 V                          | PTH05010YAH                | Horizontal T/H | Yes <sup>(3)</sup> | EUH                               |
|                              | PTH05010YAS                | Standard SMD   | No <sup>(4)</sup>  | EUJ                               |
|                              | PTH05010YAZ                | Optional SMD   | Yes <sup>(3)</sup> | EUJ                               |
| 12 V                         | PTH12010YAH                | Horizontal T/H | Yes <sup>(3)</sup> | EUH                               |
|                              | PTH12010YAS                | Standard SMD   | No <sup>(4)</sup>  | EUJ                               |
|                              | PTH12010YAZ                | Optional SMD   | Yes <sup>(3)</sup> | EUJ                               |

- (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) *Lead (Pb) –free* option specifies Sn/Ag pin solder material.  
(4) *Standard* option specifies 63/37, Sn/Pb pin solder material.

## ENVIRONMENTAL AND ABSOLUTE MAXIMUM RATINGS

voltages are with respect to GND

|                     |                             |   |             | UNIT                            |
|---------------------|-----------------------------|---|-------------|---------------------------------|
| V <sub>REF</sub>    | Control input voltage       |   |             | –0.3 V to V <sub>in</sub> +03 V |
| T <sub>A</sub>      | Operating temperature range | Over V <sub>IN</sub> range                                |             | –40°C to 85°C <sup>(1)</sup>    |
| T <sub>wave</sub>   | Wave solder temperature     | Surface temperature of module body or pins<br>(5 seconds) | PTHXX010YAH | 260°C <sup>(2)</sup>            |
| T <sub>reflow</sub> | Solder reflow temperature   | Surface temperature of module body or pins                | PTHXX010YAS | 235°C <sup>(2)</sup>            |
|                     |                             |   | PTHXX010YAZ | 260°C <sup>(2)</sup>            |
| T <sub>s</sub>      | Storage temperature         |   |             | –40°C to 125°C                  |
|                     | Mechanical shock            | Per Mil-STD-883D, Method 2002.3 1 msec, 1/2 Sine, mounted |             | 500 G                           |
|                     | Mechanical vibration        | Mil-STD-883D, Method 2007.2 20-2000 Hz                    |             | 20 G                            |
|                     | Weight                      |   |             | 3.7 grams                       |
|                     | Flammability                | Meets UL 94V-O  |             |                                 |

- (1) For operation below 0°C the external capacitors must have stable characteristics, use either a low ESR tantalum, Os-Con, or ceramic capacitor.  
(2) During soldering of package version, do not elevate peak temperature of the module, pins or internal components above the stated maximum.

## ELECTRICAL SPECIFICATIONS

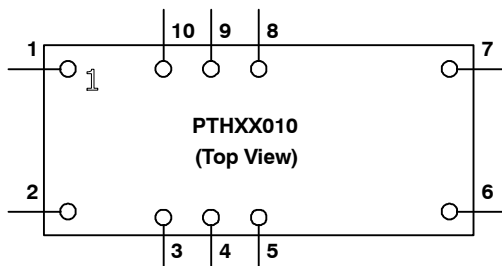
$T_A = 25^\circ\text{C}$ ; nominal  $V_{IN}$ ;  $V_{REF} = 1.25\text{ V}$ ;  $C_{IN}$ ,  $C_{O1}$ , and  $C_{O2}$  = typical values; and  $I_O = I_{Omax}$  (unless otherwise stated)

| PARAMETER            |   | TEST CONDITIONS   |                       | MIN                | TYP                | MAX                 | UNIT            |
|----------------------|---|---|-----------------------|--------------------|--------------------|---------------------|-----------------|
| $I_O$                | Output current                                | Over $\Delta V_{REF}$ range   | PTH03010Y/PTH05010Y   | 0                  |                    | $\pm 15^{(1)}$      | A               |
|                      |   |   | PTH12010Y             |                    |                    | $\pm 12^{(1)}$      |                 |
| $V_{IN}$             | Input voltage range                           | Over $I_O$ range  | PTH03010Y             | 2.95               |                    | 3.65                | V               |
|                      |   |   | PTH05010Y             | 4.5                |                    | 5.5                 |                 |
|                      |   |   | PTH12010Y             | 10.8               |                    | 13.2                |                 |
| $\Delta V_{REF}$     | Tracking range for $V_{REF}$                  |   |                       | 0.55               |                    | 1.8                 | V               |
| $ V_{TT} - V_{REF} $ | Tracking tolerance to $V_{REF}$               | Over line, load and temperature   |                       | -10                |                    | 10                  | mV              |
| $\eta$               | Efficiency                                    | $I_O = 10\text{ A}$   | PTH03010Y             |                    | 88%                |                     |                 |
|                      |   |   | PTH05010Y             |                    | 88%                |                     |                 |
|                      |   |   | PTH12010Y             |                    | 85%                |                     |                 |
| $V_r$                | $V_O$ Ripple (pk-pk)                          | 20 MHz bandwidth  |                       |                    | 20                 |                     | mVpp            |
| $I_O$ trip           | Overcurrent threshold                         | Reset, followed by auto recovery  | PTH03010Y/PTH05010Y   |                    | 27.5               |                     | A               |
|                      |   |   | PTH12010Y             |                    | 20                 |                     |                 |
| $t_{tr}$             | Load transient response                       | 15 A/ $\mu\text{s}$ load step, from -1.5 A to 1.5 A                       | Recovery time         |                    | 30                 |                     | $\mu\text{sec}$ |
| $V_{tr}$             |   |   | $V_O$ over/undershoot |                    | 30                 | 40                  | mV              |
| UVLO                 | Under-voltage lockout                         | $V_{IN}$ Increasing   | PTH03010Y             |                    | 2.45               | 2.8                 | V               |
|                      |   |   | PTH05010Y             |                    | 4.3                | 4.45                |                 |
|                      |   |   | PTH12010Y             |                    | 9.5                | 10.4                |                 |
|                      |   | $V_{IN}$ Decreasing   | PTH03010Y             | 2.0                | 2.40               |                     | V               |
|                      |   |   | PTH05010Y             | 3.4                | 3.7                |                     |                 |
|                      |   |   | PTH12010Y             | 8.8                | 9                  |                     |                 |
| $V_{IH}$             | Inhibit control (pin 4)<br>Input high voltage | Referenced to GND   |                       | $V_{IN} - 0.5$     |                    | Open <sup>(2)</sup> | V               |
| $V_{IL}$             | Inhibit control (pin 4)<br>Input low voltage  |   |                       | -0.2               |                    | 0.6                 | V               |
| $I_{IL}$ inhibit     | Inhibit control (pin 4)<br>Input low current  | Pin to GND  |                       |                    | 130                |                     | $\mu\text{A}$   |
| $I_{IN}$ inh         | Input standby current                         | Inhibit (pin 3) to GND  |                       |                    | 10                 |                     | mA              |
| $f_s$                | Switching frequency                           | Over $V_{IN}$ and $I_O$ ranges  | PTH03010Y/PTH05010Y   | 250                | 300                | 350                 | kHz             |
|                      |   |   | PTH12010Y             | 200                | 250                | 300                 |                 |
| $C_{IN}$             | External input capacitance                    |   | PTH03010Y/PTH05010Y   | 470 <sup>(3)</sup> |                    |                     | $\mu\text{F}$   |
|                      |   |   | PTH12010Y             | 560 <sup>(3)</sup> |                    |                     |                 |
| $C_{O1}$ , $C_{O2}$  | External output capacitance                   | Capacitance value: Nonceramic   | PTH03010Y/PTH05010Y   | 470 <sup>(4)</sup> |                    | 8200 <sup>(5)</sup> | $\mu\text{F}$   |
|                      |   |   | PTH12010Y             | 940 <sup>(4)</sup> |                    | 6600 <sup>(5)</sup> |                 |
|                      |   | Capacitance value: Ceramic  | PTH03010Y/PTH05010Y   |                    | 200 <sup>(4)</sup> | 300                 | $\mu\text{F}$   |
|                      |   |   | PTH12010Y             |                    | 400 <sup>(4)</sup> | 600                 |                 |
|                      |   | Equiv. series resistance (non-ceramic)                                    |                       | 4 <sup>(6)</sup>   |                    |                     | m $\Omega$      |
| MTBF                 | Reliability                                   | Per Bellcore TR-332 50 % stress, $T_A = 40^\circ\text{C}$ , ground benign |                       | 6                  |                    |                     | $10^6$ Hrs      |

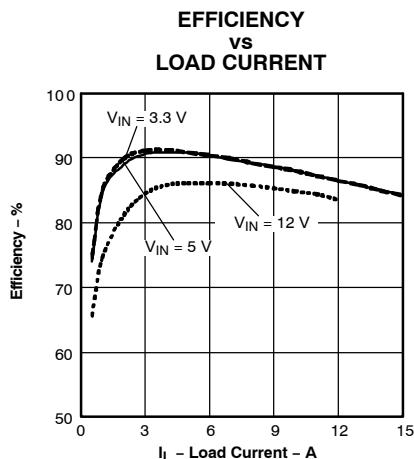
- (1) Rating is conditional on the module being directly soldered to a 4-layer PCB with 1 oz. copper. See the SOA curves or contact the factory for appropriate derating.
- (2) This control pin has an internal pull-up to the input voltage  $V_{IN}$ . If it is left open-circuit the module will operate when input power is applied. A small low-leakage (<100 nA) MOSFET is recommended for control. For further information, consult the related application note.
- (3) An input capacitor is required for proper operation. The capacitor must be rated for a minimum a minimum of 500 mA rms( 750 mA rms for 12-V input) of ripple current.
- (4) The minimum value of external output capacitance ensures that  $V_{TT}$  meets the specified transient performance requirements for the memory bus terminations. Lower values of capacitance may be possible when the *measured* peak change in output current is consistently less than 3 A.
- (5) This is the calculated maximum. The minimum ESR limitation will often result in a lower value. Consult the application notes for further guidance.
- (6) This is the typical ESR for all the electrolytic (non-ceramic) output capacitance. Use 7 m $\Omega$  as the minimum when using max-ESR values to calculate.

## Terminal Functions

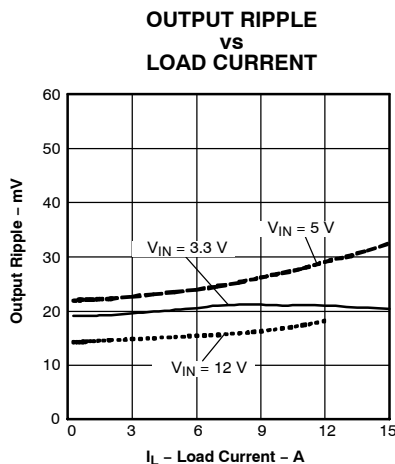
| TERMINAL    |          | DESCRIPTION  |
|-------------|----------|--|
| NAME        | NO.      |  |
| $V_{IN}$    | 2        | The positive input voltage power node to the module, which is referenced to common GND.  |
| GND         | 1, 7     | This is the common ground connection for the $V_{IN}$ and $V_{TT}$ power connections. It is also the 0-VDC reference for the control inputs.   |
| $V_{REF}$   | 8        | The module senses the voltage at this input to regulate the output voltage, $V_{TT}$ . The voltage at $V_{REF}$ is also the reference voltage for the system bus receiver comparators. It is normally set to precisely half the bus driver supply voltage ( $V_{DDQ} \div 2$ ), using a resistor divider. The Thevenin impedance of the network driving the $V_{REF}$ pin should not exceed 500 $\Omega$ . See the Typical DDR Application Diagram in the Application Information section for reference.   |
| $V_{TT}$    | 6        | This is the regulated power output from the module with respect to the GND node, and the tracking termination supply for the application data and address buses. It is precisely regulated to the voltage applied to the module's $V_{REF}$ input, and is active active about 20 ms after a valid input source is applied to the module. Once active it will track the voltage applied at $V_{REF}$ .  |
| $V_o$ Sense | 5        | 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 $V_{TT}$ .   |
| Inhibit     | 3        | 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 turns off the output voltage, $V_{TT}$ . Although the module is inhibited, a voltage, $V_{DDQ}$ will be present at the output terminals, fed through the DDR memory. When the Inhibit 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. See the Typical DDR Application Diagram in the Application Information section for reference. |
| N/C         | 4, 9, 10 | No connection  |



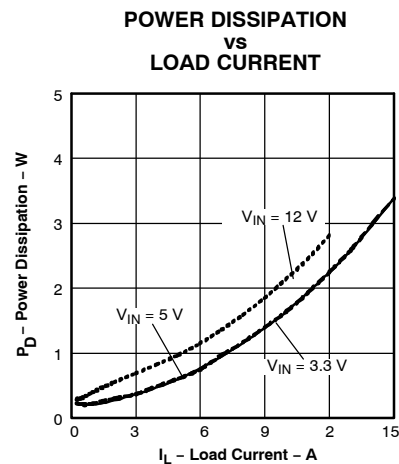
**TYPICAL CHARACTERISTICS ( $V_{REF} = 1.25\text{ V}$ ) <sup>(1) (2)</sup>**



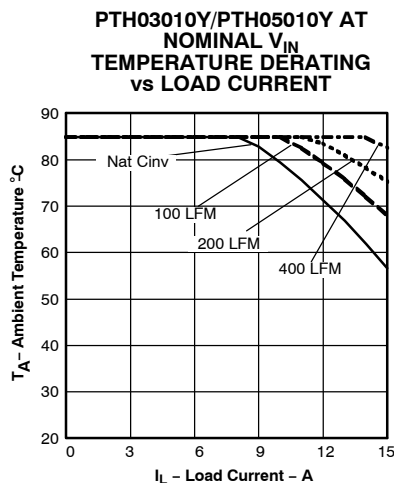
**Figure 1.**



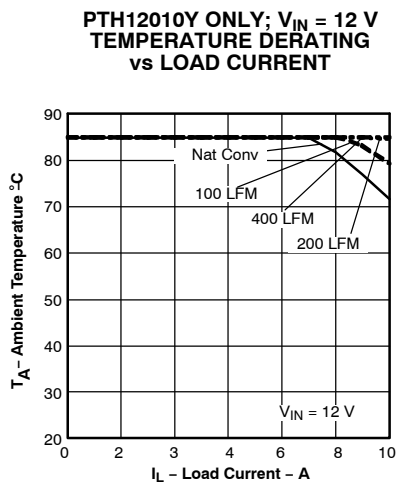
**Figure 2.**



**Figure 3.**



**Figure 4.**



**Figure 5.**

- (1) The electrical characteristic data has been developed from actual products tested at 25°C. This data is considered typical for the converter. Applies to [Figure 1](#), [Figure 2](#), and [Figure 3](#).
- (2) The temperature derating curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures. Derating limits apply to modules soldered directly to a 4 in x 4 in double-sided PCB with 1 oz. copper. For surface mount packages (AS and AZ suffix), multiple vias (plated through holes) are required to add thermal paths around the power pins. Please refer to the mechanical specification for more information. Applies to [Figure 4](#), and [Figure 5](#).

## TYPICAL CHARACTERISTICS

### TRANSIENT PERFORMANCE FOR $\Delta 3$ -A LOAD CHANGE

PTH03010Y/PTH05010Y: SOURCE-SINK-SOURCE  
TRANSIENT

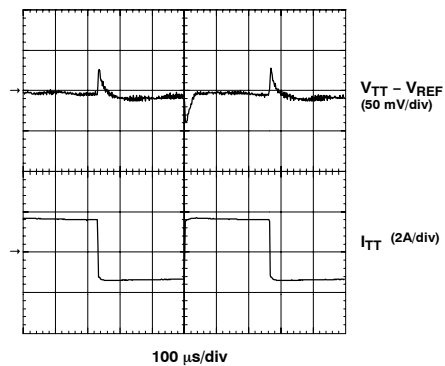


Figure 6.

PTH12010Y: SOURCE-SINK-SOURCE TRANSIENT

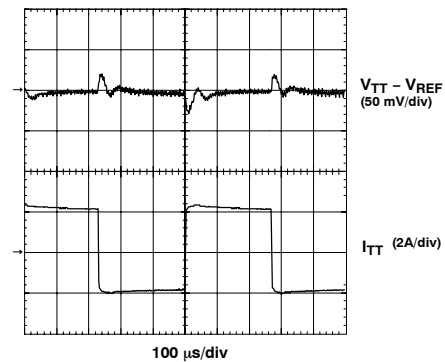
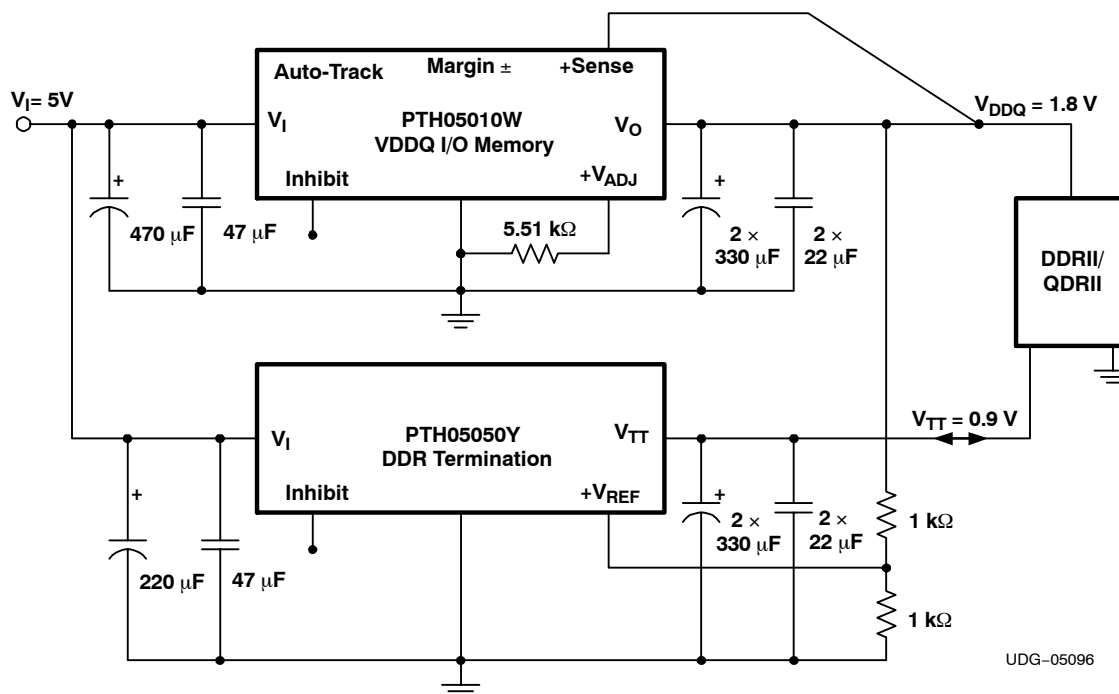


Figure 7.

## APPLICATION INFORMATION

### Typical DDR Application Diagram



### CAPACITOR RECOMMENDATIONS FOR THE PTH03010Y AND PTH05010Y DDR POWER MODULES (3.3-V/5-V OPTION)

#### Input Capacitor

The recommended input capacitor(s) is determined by the 470 μF minimum capacitance and 500 mArms minimum ripple current rating.

Ripple current, less than 160 mΩ equivalent series resistance (ESR), and temperature are the major considerations when selecting input capacitors. Unlike polymer tantalum, regular tantalum capacitors have a recommended minimum voltage rating of  $2 \times$  (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 to achieve the minimum required capacitance.

#### Output Capacitors

For applications with load transients (sudden changes in load current), regulator response benefits from external output capacitance. The recommended output capacitance of 470 μF will allow the module to meet its transient response specification. (See Electrical Specifications table). For most applications, a high quality computer-grade aluminum electrolytic capacitor is adequate. These capacitors provide decoupling over the frequency range, 2 kHz to 150 kHz, and are suitable for ambient temperatures above 0°C. Below 0°C, tantalum, ceramic or Os-Con type capacitors are recommended. When using one or more nonceramic capacitors, the calculated equivalent ESR should be no lower than 4 mΩ (7 mΩ using the manufacturer's maximum ESR for a single capacitor).

A list of preferred low-ESR type capacitors are identified in [Table 1](#). In addition to electrolytic capacitance, adding a 10-μF to 22-μF X5R/X7R ceramic capacitor to the output reduces the output ripple voltage and improves the regulator's transient response. The measurement of both the output ripple and transient response is also best achieved across a 10-μF ceramic capacitor.

## APPLICATION INFORMATION (continued)

### 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 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  $\mu$ F. Also, to prevent the formation of local resonances, do not place more than five identical ceramic capacitors in parallel with values of 10  $\mu$ F or greater.

### 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°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 is encountered before the maximum capacitance value is reached.

### Capacitor Table

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

*This is not an extensive capacitor list. Capacitors from other vendors are available with comparable specifications. Those listed are for guidance. The RMS ripple current rating and ESR (at 100 kHz) are critical parameters necessary to ensure both optimum regulator performance and long capacitor life.*

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

| Capacitor Vendor,<br>Type/Series (Style) | Capacitor Characteristics |                     |                                       |   |                          | Quantity     |               | Vendor<br>Part Number |
|--|---------------------------|---------------------|---------------------------------------|---|--------------------------|--------------|---------------|-----------------------|
|  | Working<br>Voltage<br>(V) | Value<br>( $\mu$ F) | Max ESR<br>at 100 kHz<br>( $\Omega$ ) | Max Ripple<br>Current<br>at 85°C<br>(Irms) (mA) | Physical<br>Size<br>(mm) | Input<br>Bus | Output<br>Bus |                       |
| Panasonic, Aluminum                      |                           |                     |                                       |   |                          |              |               |                       |
| FC (Radial)                              | 10                        | 470                 | 0.117                                 | 555   | 8 × 11,5                 | 1            | 1             | EEUFC1A471            |
| FC (SMD)                                 | 10                        | 470                 | 0.150                                 | 670   | 10 × 10,2                | 1            | 1             | EEUFC1A471P           |
| FK (SMD)                                 | 10                        | 470                 | 0.160                                 | 600   | 8 × 10,2                 | 1            | 1             | EEVFK1A471P           |
| United Chemi-Con                         |                           |                     |                                       |   |                          |              |               |                       |
| PXA, Poly-Aluminum (SMD)                 | 6.3                       | 470                 | 0.020                                 | 4130  | 10 × 7,7                 | 1            | ≤2            | PXA6.3VC471MJ80TP     |
| PS, Poly-Aluminum (Radial)               | 10                        | 470                 | 0.012                                 | 5300  | 10 × 12,5                | 1            | ≤1            | 10PS470MJ12           |
| LXZ, Aluminum (Radial)                   | 16                        | 470                 | 0.120                                 | 555   | 8 × 12                   | 1            | 1             | LXZ10VB471M8X12LL     |
| Nichicon Aluminum                        |                           |                     |                                       |   |                          |              |               |                       |
| WG(SMD)                                  | 10                        | 470                 | 0.150                                 | 670 mA  | 10 × 10                  | 1            | 1             | UWG1A471MNR1GS        |
| HD (Radial)                              | 10                        | 470                 | 0.072                                 | 760   | 8 × 11,5                 | 1            | 1             | UHD1A471MPR           |
| PM (Radial)                              | 10                        | 470                 | 0.130                                 | 600   | 10 × 12,5                | 1            | 1             | UPM1A471MPH6          |

**(1) Capacitor Supplier Verification**

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

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

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



## APPLICATION INFORMATION (continued)

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

| Capacitor Vendor,<br>Type/Series (Style) | Capacitor Characteristics |                     |                                       |   |                          | Quantity         |                    | Vendor<br>Part Number |
|--|---------------------------|---------------------|---------------------------------------|---|--------------------------|------------------|--------------------|-----------------------|
|  | Working<br>Voltage<br>(V) | Value<br>( $\mu$ F) | Max ESR<br>at 100 kHz<br>( $\Omega$ ) | Max Ripple<br>Current<br>at 85°C<br>(Irms) (mA) | Physical<br>Size<br>(mm) | Input<br>Bus     | Output<br>Bus      |                       |
| Panasonic, Poly-Aluminum:<br>S/SE (SMD)  | 6.3                       | 180                 | 0.005                                 | 4000  | 7,3 × 4,3 ×<br>4,2       | 2 <sup>(2)</sup> | N/R <sup>(3)</sup> | EEFSE0J181R           |
| Sanyo                                    |                           |                     |                                       |   |                          |                  |                    |                       |
| SEPC, Os-con (Radial)                    | 6.3                       | 470                 | 0.008                                 | 5700  | 10 × 13                  | 1                | ≤1                 | 6SEPC470M             |
| SVP, (SMD)                               | 6.3                       | 470                 | 0.015                                 | 4200  | 11 × 11,9                | 1                | ≤2                 | 6SVP470M              |
| TPE, Poscap (SMD)                        | 6.3                       | 470                 | 0.018                                 | 3500  | 7,3 × 4,3                | 1                | ≤2                 | 6TPE470MI             |
| AVX, Tantalum TPS (SMD)                  | 10                        | 470                 | 0.045                                 | 1723  | 7,3 L × 5,7 W<br>× 4,1 H | 1                | ≤5                 | TPSE477M010R0045      |
|  | 10                        | 470                 | 0.060                                 | 1826  |                          | 1                | ≤5                 | TPSV477M010R0060      |
| Kemet, Poly-Tantalum                     |                           |                     |                                       |   |                          |                  |                    |                       |
| T520, (SMD)                              | 10                        | 330                 | 0.040                                 | 1800  | 4,3 W × 7,3 L<br>× 4 H   | 2                | ≤5                 | T520X337M010AS        |
| T530, (SMD)                              | 10                        | 330                 | 0.010                                 | 5200  |                          | 2                | ≤1                 | T530X337M010ASE010    |
| Vishay-Sprague                           |                           |                     |                                       |   |                          |                  |                    |                       |
| 595D, Tantalum (SMD)                     | 10                        | 470                 | 0.100                                 | 1440  | 7,2 L × 6 W              | 1                | ≤5                 | 595D477x0010r2t       |
| 94SP, Poly Aluminum (Radial)             | 10                        | 470                 | 0.015                                 | 4510  | 10 × 10                  | 1                | ≤2                 | 94SP477X0010FBP       |
| 94SVP, Poly-Aluminum (SMD)               | 6.3                       | 470                 | 0.017                                 | 3960  | 8 × 12                   | 1                | ≤3                 | 94SVP477X06R3E12      |
| Kemet, Ceramic X5R (SMD)                 | 16                        | 10                  | 0.002                                 | —   | 3225 mm                  | 1                | ≤5                 | C1210C106M4PAC        |
|  | 6.3                       | 47                  |                                       |   | 3225 mm                  | 1                | ≤5                 | C1210C476K9PAC        |
| Murata, Ceramic X5R (SMD)                | 6.3                       | 100                 | 0.002                                 | —   | 3225 mm                  | 1 <sup>(4)</sup> | ≤3                 | GRM32ER60J107M        |
|  | 6.3                       | 47                  |                                       |   | 3225 mm                  | 1 <sup>(4)</sup> | ≤5                 | GRM32ER60J476M        |
|  | 16                        | 22                  |                                       |   |                          | 1 <sup>(4)</sup> | ≤5                 | GRM32ER61C226K        |
|  | 16                        | 10                  |                                       |   |                          | 1 <sup>(4)</sup> | ≤5                 | GRM32DR61C106K        |
| TDK, Ceramic X5R (SMD)                   | 6.3                       | 100                 | 0.002                                 | —   | 3225 mm                  | 1 <sup>(4)</sup> | ≤3                 | C3225X5R0J107MT       |
|  | 6.3                       | 47                  |                                       |   | 3225 mm                  | 1 <sup>(4)</sup> | ≤5                 | C3225X5R0J476MT       |
|  | 16                        | 22                  |                                       |   |                          | 1 <sup>(4)</sup> | ≤5                 | C3225X5R1C226MT       |
|  | 16                        | 10                  |                                       |   |                          | 1 <sup>(4)</sup> | ≤5                 | C3225X5R1C106MT       |

(2) A total capacitance of 360  $\mu$ F is acceptable based on the combined ripple current rating.

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

(4) A ceramic capacitor is recommended to complement electrolytic types at the input to further reduce high-frequency ripple current.

### 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/ $\mu$ s. The typical voltage deviation for this load transient is given in the data sheet 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 data sheet, or the total amount of load capacitance is above 8200  $\mu$ F, the selection of output capacitors becomes more important.

## CAPACITOR RECOMMENDATIONS FOR THE PTH12010Y DDR POWER MODULES (12-V OPTION)

### INPUT CAPACITOR

The recommended input capacitance is determined by the 560  $\mu\text{F}$  minimum capacitance and 750 mArms minimum ripple current rating. A 10- $\mu\text{F}$  X5R/X7R ceramic capacitor may also be added to reduce the reflected input ripple current. The ceramic capacitor should be located between the input electrolytic and the module.

Ripple current, less than 100 m $\Omega$  equivalent series resistance (ESR) and temperature are major considerations when selecting input capacitors. Unlike polymer-tantalum capacitors, regular tantalum capacitors have a recommended minimum voltage rating of  $2 \times$  (max dc voltage + ac ripple). This is standard practice to ensure reliability. No tantalum capacitors were found with sufficient voltage rating to meet this requirement. At temperatures below 0°C, the ESR of aluminum electrolytic capacitors increases. For these applications, Os-Con, polymer-tantalum, and polymer-aluminum types should be considered.

### OUTPUT CAPACITORS

For applications with load transients (sudden changes in load current), regulator response benefits from external output capacitance. The recommended output capacitance of 940  $\mu\text{F}$  will allow the module to meet its transient response specification. (See Electrical Specifications table). For most applications, a high quality computer-grade aluminum electrolytic capacitor is adequate. These capacitors provide decoupling over the frequency range, 2 kHz to 150 kHz, and are suitable for ambient temperatures above 0°C. Below 0°C, tantalum, ceramic or Os-Con type capacitors are recommended. When using one or more nonceramic capacitors, the calculated equivalent ESR should be no lower than 4 m $\Omega$  (7 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](#).

In addition to electrolytic capacitance, adding a 10- $\mu\text{F}$  to 22- $\mu\text{F}$  X5R/X7R ceramic capacitor to the output reduces the output ripple voltage and improve the regulator's transient response. The measurement of both the output ripple and transient response is also best achieved across a 10- $\mu\text{F}$  ceramic capacitor.

### CERAMIC CAPACITORS

Above 150 kHz the performance of aluminum electrolytic capacitors is less effective. Multilayer ceramic capacitors have very low ESR and a resonant frequency higher than the bandwidth of the regulator. They can be used to reduce the reflected ripple current at the input as well as improve the transient response of the output. When used on the output, their combined ESR is not critical as long as the total value of ceramic capacitance does not exceed 300  $\mu\text{F}$ . 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.

### TANTALUM CAPACITORS

Tantalum type capacitors are most suited for use on the output bus, and are recommended for applications where the ambient operating temperature can be less than 0°C. The AVX TPS, Sprague 593D/594/595 and Kemet T495/T510 capacitor series are suggested over 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 are encountered well before the maximum capacitance value is reached.

### 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.*

**Table 2. Input/Output Capacitors<sup>(1)</sup>**

| CAPACITOR VENDOR,<br>TYPE/SERIES, (STYLE) | CAPACITOR CHARACTERISTICS |                     |                        |   |                       | QUANTITY           |                           | VENDOR PART<br>NUMBER |
|---|---------------------------|---------------------|------------------------|---|-----------------------|--------------------|---------------------------|-----------------------|
|   | WORKING<br>VOLTAGE        | VALUE<br>( $\mu$ F) | MAX. ESR<br>AT 100 kHz | MAX RIPPLE<br>CURRENT AT<br>85°C (Irms) | PHYSICAL<br>SIZE (mm) | INPUT<br>BUS       | OPTIONAL<br>OUTPUT<br>BUS |                       |
| Panasonic, Aluminum (FC)                  | 25 V                      | 560                 | 0.065 $\Omega$         | 1205 mA                                 | 12,5 x 15             | 1                  | 1                         | EEUFC1E561S           |
| FC, Radial                                | 25 V                      | 1000                | 0.060 $\Omega$         | 1100 mA                                 | 12,5 x 13,5           | 1                  | 1                         | EEVFK1E102Q           |
| FK, (SMD)                                 | 35 V                      | 680                 | 0.060 $\Omega$         | 1100 mA                                 | 12,5 x 13,5           | 1                  | 1                         | EEVFK1V681Q           |
| United Chemi-Con                          |                           |                     |                        |   |                       |                    |                           |                       |
| PS, Poly-Aluminum (Radial)                | 16 V                      | 330                 | 0.014 $\Omega$         | 5050 mA                                 | 10 x 12,5             | 2                  | $\leq 2$                  | 16PS330MJ12           |
| LXZ, Aluminium (Radial)                   | 16 V                      | 680                 | 0.068 $\Omega$         | 1050 mA                                 | 10 x 16               | 1                  | 1                         | LXZ16VB681M10X16LL    |
| PXA, Poly-Aluminum (SMD)                  | 16 V                      | 330                 | 0.014 $\Omega$         | 5050 mA                                 | 10 x 12,2             | 2                  | $\leq 2$                  | PXA16VC331MJ12TP      |
| Nichicon, Aluminum (PM)                   | 25 V                      | 560                 | 0.060 $\Omega$         | 1060 mA                                 | 12,5 x 15             | 1                  | 1                         | UPM1E561MHH6          |
| HD, (Radial)                              | 16 V                      | 680                 | 0.038 $\Omega$         | 1430 mA                                 | 10 x 16               | 1                  | 1                         | UHD1C681MPR           |
| PM, (Radial)                              | 35 V                      | 560                 | 0.048 $\Omega$         | 1360 mA                                 | 16 x 15               | 1                  | 1                         | UPM1V561MHH6          |
| Sanyo                                     |                           |                     |                        |   |                       |                    |                           |                       |
| TPE Poscap (SMD)                          | 10 V                      | 330                 | 0.025 $\Omega$         | 3000 mA                                 | 7,3 L x 5,7 W         | N/R <sup>(2)</sup> | $\leq 3$                  | 10TPE330M             |
| SEQP, Os-Con (Radial)                     | 16 V                      | 330                 | 0.016 $\Omega$         | >4720 mA                                | 10 x 13               | 2                  | $\leq 2$                  | 16SEQP330M            |
| SVP, Os-Con (SMD)                         | 16 V                      | 330                 | 0.016 $\Omega$         | 4700 mA                                 | 11 x 12               | 2                  | $\leq 2$                  | 16SVP330M             |
| AVX, Tantalum Series III<br>TPS (SMD)     | 10 V                      | 470                 | 0.045 $\Omega$         | >1723 mA                                | 7,3L x 5,7W           | N/R <sup>(2)</sup> | $\leq 5$ <sup>(3)</sup>   | TPSE477M010R0045      |
|   | 10 V                      | 330                 | 0.045 $\Omega$         | >1723 mA                                | x 4,1H                | N/R <sup>(2)</sup> | $\leq 5$ <sup>(3)</sup>   | TPSE377M010R0045      |
| Kemet                                     |                           |                     |                        |   |                       |                    |                           |                       |
| T520, Poly-Tantalum (SMD)                 | 10 V                      | 330                 | 0.040 $\Omega$         | 1800 mA                                 | 7,3 L                 | N/R <sup>(2)</sup> | $\leq 5$                  | T520X337M010AS        |
| T530, Poly-Tant/Organic                   | 10 V                      | 330                 | 0.010 $\Omega$         | >3800 mA                                | x 4,3 W               | N/R <sup>(2)</sup> | $\leq 1$                  | T530X337M010ASE010    |
|   | 6.3 V                     | 470                 | 0.005 $\Omega$         | 4200 mA                                 | x 4 H                 | N/R <sup>(2)</sup> | $\leq 1$ <sup>(3)</sup>   | T530X477M006AS E005   |
| Vishay-Sprague                            |                           |                     |                        |   |                       |                    |                           |                       |
| 595D, Tantalum (SMD)                      | 10 V                      | 470                 | 0.100 $\Omega$         | 1440 mA                                 | 7,2L x 6W x<br>4,1H   | N/R <sup>(2)</sup> | $\leq 5$ <sup>(3)</sup>   | 595D477X0010R2T       |
| 94SA, Os-con (Radial)                     | 16 V                      | 1000                | 0.015 $\Omega$         | 9750 mA                                 | 16 x 25               | 1                  | $\leq 2$                  | 94SA108X0016HBP       |
| 94SVP, Os-CON(SMD)                        | 16V                       | 330                 | 0.017 $\Omega$         | 4580 mA                                 | 10 x 12,7             | 2 <sup>(4)</sup>   | $\leq 2$                  | 94SVP337X0016F12      |
| Kemet, Ceramic X5R<br>(SMD)               | 16 V                      | 10                  | 0.002 $\Omega$         | -                                       | 3225 mm               | 1 <sup>(5)</sup>   | $\leq 5$                  | C1210C106M4PAC        |
|   | 6.3 V                     | 47                  | 0.002 $\Omega$         |   | 3225 mm               | N/R <sup>(2)</sup> | $\leq 5$                  | C1210C476K9PAC        |
| Murata, Ceramic X5R<br>(SMD)              | 6.3 V                     | 100                 | 0.002 $\Omega$         | -                                       | 3225 mm               | N/R <sup>(2)</sup> | $\leq 3$                  | GRM32ER60J107M        |
|   | 16 V                      | 47                  |                        |   | 3225 mm               | 1 <sup>(5)</sup>   | $\leq 5$                  | GRM32ER61CJ476K       |
|   | 16 V                      | 22                  |                        |   |                       | 1 <sup>(5)</sup>   | $\leq 5$                  | GRM32ER61C226K        |
|   | 16 V                      | 10                  |                        |   |                       | 1 <sup>(5)</sup>   | $\leq 5$                  | GRM32DR61C106K        |
| TDK, Ceramic X5R (SMD)                    | 6.3 V                     | 100                 | 0.002 $\Omega$         | -                                       | 3225 mm               | N/R <sup>(2)</sup> | $\leq 3$                  | C3225X5R0J107MT       |
|   | 6.3 V                     | 47                  |                        |   | 3225 mm               | N/R <sup>(2)</sup> | $\leq 5$                  | C3225X5R0J476MT       |
|   | 16 V                      | 22                  |                        |   |                       | 1 <sup>(5)</sup>   | $\leq 5$                  | C3225X5R1C226MT       |
|   | 16 V                      | 10                  |                        |   |                       | 1 <sup>(5)</sup>   | $\leq 5$                  | C3225X5R1C106MT       |

**(1) Capacitor Supplier Verification**

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

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

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

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

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

(4) A total capacitance of 540  $\mu$ F is acceptable based on the combined ripple current rating.

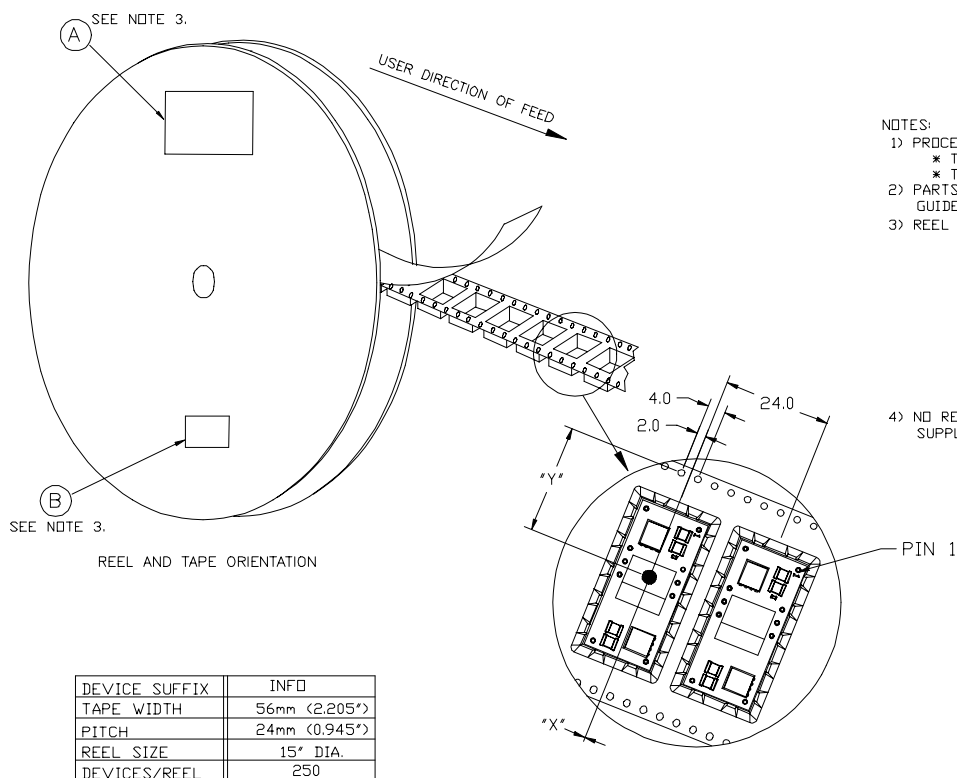
(5) A ceramic capacitor can be used to complement electrolytic types at the input further reduce high-frequency ripple current.

## 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 data sheet 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 data sheet, or the total amount of load capacitance is above  $6600\text{ }\mu\text{F}$ , the selection of output capacitors becomes more important.

## TAPE AND REEL SPECIFICATION



### NOTES:

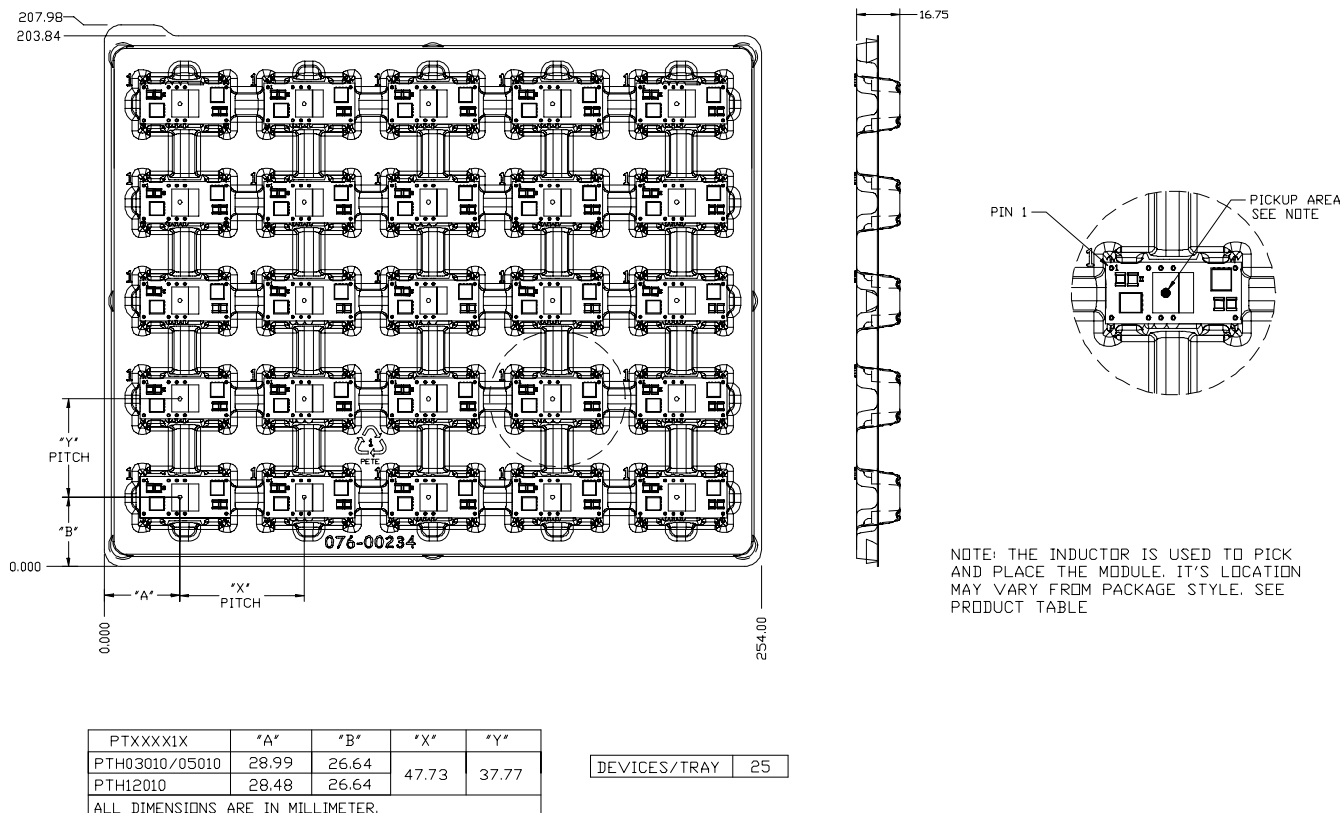
- 1) PROCESS IN ACCORDANCE WITH EIA-481-2
  - \* TAPE LEADER DIMENSION 15.30" MIN.
  - \* TAPE TRAILER DIMENSION 6.30" MIN.
- 2) PARTS SHOULD BE PACKAGED IN ACCORDANCE WITH ESD GUIDELINES IN EIA-541.
- 3) REEL LABEL: "A"— \* TI PART NUMBER.  
 \* QUANTITY  
 \* DATE CODE  
 \* LOT NUMBER  
 \* MSL DATA  
 \* MADE IN  
 \* ASSY SITE ORIGIN  
 \* COUNTRY OF ORIGIN  
 \* SUPPLIER

\*B"— ANTI-STATIC CAUTION LABEL

- 4) NO REQUIREMENT FOR TAPE DIRECTION OF FEED FROM SUPPLIER REEL.

| PTXXXXIX       | "X"   | "Y"    |
|----------------|-------|--------|
| PTH03010/05010 | 0.0mm | 24.3mm |
| PTH12010       | 0.0mm | 23.8mm |

## TRAY SPECIFICATION



**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| PTH03010YAD      | ACTIVE                | DIP MOD ULE  | EUH             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | N / A for Pkg Type           |
| PTH03010YAH      | ACTIVE                | DIP MOD ULE  | EUH             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | N / A for Pkg Type           |
| PTH03010YAS      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH03010YAST     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH03010YAZ      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |
| PTH03010YAZT     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |
| PTH05010YAH      | ACTIVE                | DIP MOD ULE  | EUH             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | N / A for Pkg Type           |
| PTH05010YAS      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH05010YAST     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH05010YAZ      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |
| PTH05010YAZT     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |
| PTH12010YAH      | ACTIVE                | DIP MOD ULE  | EUH             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | N / A for Pkg Type           |
| PTH12010YAS      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH12010YAST     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | TBD                     | Call TI          | Level-1-235C-UNLIM           |
| PTH12010YAZ      | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 25          | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |
| PTH12010YAZT     | ACTIVE                | DIP MOD ULE  | EUJ             | 10   | 250         | Pb-Free (RoHS)          | Call TI          | Level-3-260C-168 HR          |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

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

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

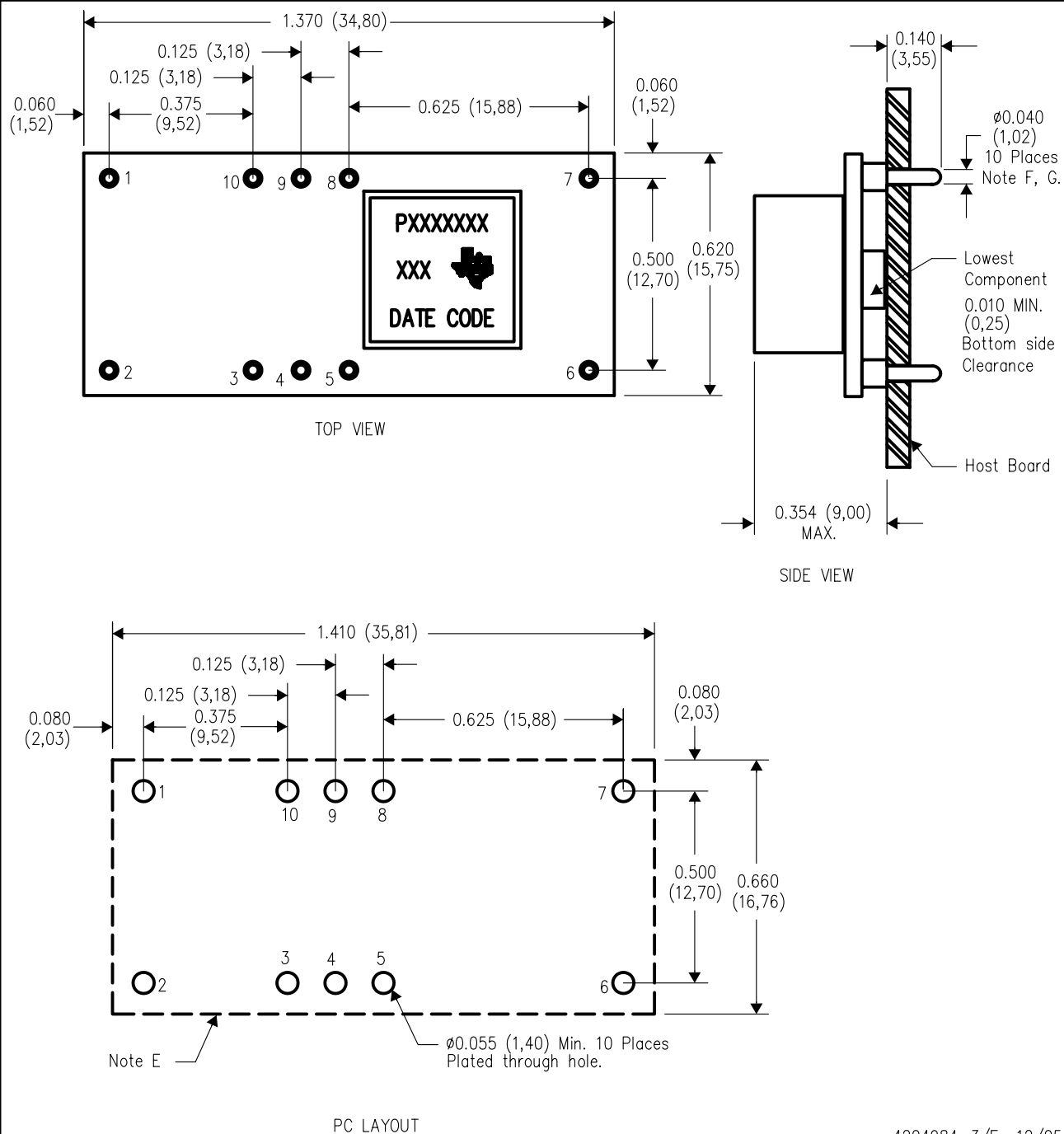
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## MECHANICAL DATA

## EUH (R-PDSS-T10)

DOUBLE SIDED MODULE



NOTES:

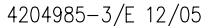
- A. All linear dimensions are in inches (mm).
- B. This drawing is subject to change without notice.
- C. 2 place decimals are  $\pm 0.030$  ( $\pm 0,76\text{mm}$ ).
- D. 3 place decimals are  $\pm 0.010$  ( $\pm 0,25\text{mm}$ ).
- E. Recommended keep out area for user components.

F. Pins are 0.040" (1,02) diameter with  
0.070" (1,78) diameter standoff shoulder.

G. All pins: Material - Copper Alloy  
Finish - Tin (100%) over Nickel plate



## DOUBLE SIDED MODULE



- NOTES:
- |  |  |
|--|--|
| A. All linear dimensions are in inches (mm).                 | G. Paste screen opening: 0.080 (2,03) to 0.085 (2,16). |
| B. This drawing is subject to change without notice.         | Paste screen thickness: 0.006 (0,15).                  |
| C. 2 place decimals are $\pm 0.030$ ( $\pm 0,76\text{mm}$ ). | H. Pad type: Solder mask defined.                      |
| D. 3 place decimals are $\pm 0.010$ ( $\pm 0,25\text{mm}$ ). | I. All pins: Material – Copper Alloy                   |
| E. Recommended keep out area for user components.            | Finish – Tin (100%) over Nickel plate                  |
| F. Power pin connection should utilize two or more vias      | Solder Ball – See product data sheet.                  |
| to the interior power plane of 0.025 (0,63) I.D. per input,  | J. Dimension prior to reflow solder.                   |
| ground and output pin (or the electrical equivalent).        |  |

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| DSP                | <a href="http://dsp.ti.com">dsp.ti.com</a>                         |
| Interface          | <a href="http://interface.ti.com">interface.ti.com</a>             |
| Logic              | <a href="http://logic.ti.com">logic.ti.com</a>                     |
| Power Mgmt         | <a href="http://power.ti.com">power.ti.com</a>                     |
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| RFID               | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>               |
| Low Power Wireless | <a href="http://www.ti.com/lpw">www.ti.com/lpw</a>                 |

### Applications

|                    |  |
|--------------------|--|
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