

# DC-DC Converter Application Manual

## MPDTH03050W\*\*

### 6-A, 3.3-V Input Non-Isolated Wide-Output Adjust Power Module



#### Features

- Up to 6-A Output Current
- 3.3-V Input Voltage
- Wide-Output Voltage Adjust (0.8 V to 2.5 V)
- Efficiencies up to 94 %
- 103 W/in<sup>3</sup> Power Density
- On/Off Inhibit
- Pre-Bias Startup
- Under-Voltage Lockout
- Auto-Track™ Sequencing
- Output Over-Current Protection (Non-Latching, Auto-Reset)
- Operating Temp: -40 to +85 °C
- Point-of-Load Alliance Compatible

NOMINAL SIZE = 22.1 mm x 12.57 mm

#### Description

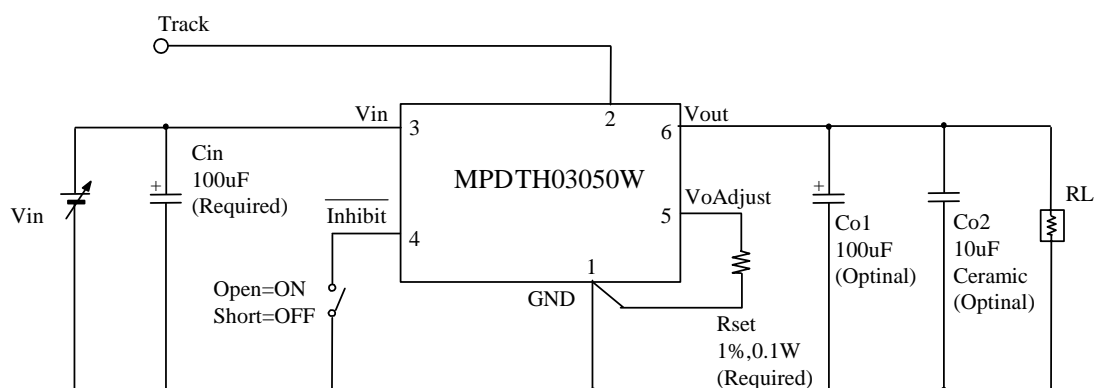
The MPDTH03050 is one of the smallest non-isolated power module from Murata Manufacturing that features Auto-Track™. Auto-Track simplifies supply voltage sequencing in power systems by enabling modules to track each other, or any other external voltage, during power up and power down. Adding to the size advantage (22.1 × 12.57mm), this module is rated for up to 6 A of output current, and is an ideal choice in applications where space, performance, and a power-up sequencing capability are important attributes. The product provides high-performance step-down conversion from a 3.3-V input bus voltage. The output voltage of the MPDTH03050W can be set to any voltage

over the range, 0.8 V to 2.5 V, using a single resistor. Other operating features include an on/off inhibit, output voltage adjust (trim), and output over-current protection. For high efficiency, this product employs a synchronous rectifier output stage, but a pre-bias hold-off 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, ASIC, or FPGA. Package options include both through-hole and surface mount configurations

#### Pin Configuration

| Pin | Function |
|-----|----------|
| 1   | GND      |
| 2   | Track    |
| 3   | Vin      |
| 4   | Inhibit  |
| 5   | VoAdjust |
| 6   | Vout     |

#### Standard Application



Rset = Required to set the output voltage to a value higher than 0.8V. (See spec table)

Cin = Required 100μF

Co1 = Optional 100μF capacitor

Co2 = Optional 10μF ceramic capacitor for reduced output ripple.

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## 6-A, 3.3-V Input Non-Isolated Wide-Output Adjust Power Module

### Ordering Information

#### Output Voltage (MPDTH03050□xx)

#### Package Options (MPDTH03050x□□)

| Code | Voltage               | Code | Description |
|------|-----------------------|------|-------------|
| W    | 0.8V-2.5V(Adjustable) | AH   | Horiz. T/H  |
|      |                       | AS   | SMD(*1)     |

**Notes** (1) Pb free (Sn-Ag-Cu) pin solder material.

### Pin Description

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

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

**GND:** This is the common ground connection for the *Vin* and *Vout* power connections. It is also the 0 VDC reference for the control inputs.

**Vo Adjust:** A 0.1 W 1 % resistor must be directly connected between this pin and *GND* to set the output voltage to a value higher than 0.8 V. The temperature stability of the resistor should be 100 ppm/°C (or better). The set-point range for the output voltage is from 0.8 V to 2.5 V. The resistor value required for a given output voltage can be calculated from the following formula. If this pin is left open circuit, the output voltage will default to its lowest value. For further information on output voltage adjustment see the related application note.

$$R_{set} = 10 \text{ k}\Omega \cdot \frac{0.8\text{V}}{V_{out}-0.8\text{V}} - 2.49 \text{ k}\Omega$$

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

**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 output voltage whenever a valid input source is applied.

**Track:** This is an analog control input that enables the output voltage to follow an external voltage. This pin becomes active typically 20 ms after the input voltage has been applied, and allows direct control of the output voltage from 0 V up to the nominal set-point voltage. Within this range the 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 output voltage is regulated at its set-point voltage. This feature allows the output voltage to rise simultaneously with other modules powered from the same input bus. If unused, the input should be connected to *Vin*.

**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, see the related application note..

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### 6-A, 3.3-V Input Non-Isolated Wide-Output Adjust Power Module

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

| Characteristics             | Symbols             | Conditions                                 | Min                | Typ | Max                  | Units |
|-----------------------------|---------------------|--|--------------------|-----|----------------------|-------|
| Track Input Voltage         | V <sub>track</sub>  |  | -0.3               | -   | V <sub>in</sub> +0.3 | V     |
| Operating Temperature Range | T <sub>a</sub>      | Over V <sub>in</sub> Range                 | -40 <sup>(i)</sup> | -   | 85                   | °C    |
| Storage Temperature         | T <sub>s</sub>      | -  | -40                |     | 125                  | °C    |
| Solder Reflow Temperature   | T <sub>reflow</sub> | Surface temperature of module body or pins |                    |     | 245 <sup>(ii)</sup>  | °C    |

**Notes:** (i) For operation below 0 °C the external capacitors must have stable characteristics. Use either a low ESR tantalum, Os-Con, 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

#### Specifications (Unless otherwise stated, T<sub>a</sub> =25°C, V<sub>in</sub> =3.3 V, V<sub>out</sub> =2.5 V, C<sub>in</sub> =100μF, C<sub>o1</sub> =0μF, C<sub>o2</sub> =0μF, and I<sub>o</sub> =I<sub>omax</sub>)

| Characteristics               | Symbols                             | Conditions   | MPDTH03010W                           |                    |                     | Units               |      |
|-------------------------------|-------------------------------------|--|---------------------------------------|--------------------|---------------------|---------------------|------|
|                               |                                     |  | Min                                   | Typ                | Max                 |                     |      |
| Output Current                | I <sub>o</sub>                      | 0.8V ≤ V <sub>o</sub> ≤ 2.5V, 85°C Natural Convection                      | 0                                     | -                  | 6 <sup>(1)</sup>    | A                   |      |
| Input Voltage Range           | V <sub>in</sub>                     | Over I <sub>o</sub> Range  | 2.95 <sup>(2)</sup>                   | -                  | 3.65                | V                   |      |
| Set-Point Voltage Tolerance   | V <sub>o tol</sub>                  |  | -                                     | -                  | ±2 <sup>(3)</sup>   | %V <sub>o</sub>     |      |
| Temperature Variation         | ΔRegtemp                            | -40°C <T <sub>a</sub> < +85°C  | -                                     | ±0.5               | -                   | %V <sub>o</sub>     |      |
| Line Regulation               | ΔRegline                            | Over V <sub>in</sub> Range   | -                                     | ±10                | -                   | mV                  |      |
| Load Regulation               | ΔRegload                            | Over I <sub>o</sub> Range  | -                                     | ±12                | -                   | mV                  |      |
| Total Output Variation        | ΔRegtot                             | Includes set-point, line, load,<br>-40°C <T <sub>a</sub> < +85°C           | -                                     | -                  | ±3 <sup>(3)</sup>   | %V <sub>o</sub>     |      |
| Efficiency                    | η                                   | I <sub>o</sub> =4A   | RSET = 2.21 kΩ V <sub>o</sub> = 2.5 V | -                  | 94                  | -                   | %    |
|                               |                                     |  | RSET = 4.12 kΩ V <sub>o</sub> = 2.0 V | -                  | 92                  | -                   |      |
|                               |                                     |  | RSET = 5.49 kΩ V <sub>o</sub> = 1.8 V | -                  | 91                  | -                   |      |
|                               |                                     |  | RSET = 8.87kΩ V <sub>o</sub> = 1.5 V  | -                  | 90                  | -                   |      |
|                               |                                     |  | RSET = 17.4 kΩ V <sub>o</sub> = 1.2 V | -                  | 88                  | -                   |      |
|                               |                                     | RSET = 36.5 kΩ V <sub>o</sub> = 1.0 V                                      | -                                     | 87                 | -                   |                     |      |
| V <sub>o</sub> Ripple (pk-pk) | V <sub>r</sub>                      | 20 MHz bandwidth, C <sub>o2</sub> =10μF ceramic                            | -                                     | 20 <sup>(4)</sup>  | -                   | mV <sub>pp</sub>    |      |
| Short Circuit Protection      | I <sub>o trip</sub>                 | Reset, Followed by Auto-Recovery   | -                                     | 12                 | -                   | A                   |      |
| Transient Response            | t <sub>tr</sub><br>ΔV <sub>tr</sub> | 1 A/μs load step, 50 to 100 % I <sub>omax</sub><br>C <sub>out</sub> =100μF | Recovery Time                         | -                  | 70                  | -                   | μsec |
|                               |                                     |  | V <sub>o</sub> deviation              | -                  | 100                 | -                   | mV   |
| Track Input Current (pin 2)   | I <sub>IL track</sub>               | Pin to GND   | -                                     | -                  | -130 <sup>(5)</sup> | μA                  |      |
| Track Slew Rate Capability    | dV <sub>track</sub> /dt             | C <sub>out</sub> ≤C <sub>out</sub> (max)                                   | -                                     | -                  | 1                   | V/ms                |      |
| Rising UVLO Threshold         | UVLO <sub>r</sub>                   | V <sub>in</sub> increasing   | -                                     | 2.45               | 2.8                 | V                   |      |
| Falling UVLO Threshold        | UVLO <sub>f</sub>                   | V <sub>in</sub> decreasing   | 1.9                                   | 2.1                | -                   | V                   |      |
| Inhibit Control (pin4)        |                                     | Referenced to GND  |                                       |                    |                     |                     |      |
| Input High Voltage            | V <sub>IH</sub>                     |  | V <sub>in</sub> -0.5                  | -                  | Open <sup>(5)</sup> | V                   |      |
| Input Low Voltage             | V <sub>IL</sub>                     |  | -0.2                                  | -                  | 0.6                 | V                   |      |
| Input Low Current             | I <sub>ILinhibit</sub>              | Pin to GND   | -                                     | -130               | -                   | μA                  |      |
| Input Standby Current         | I <sub>in inh</sub>                 | Inhibit (pin 4) to GND, Track (pin 2) open                                 | -                                     | 10                 | -                   | mA                  |      |
| Switching Frequency           | Frq                                 | Over V <sub>in</sub> and I <sub>o</sub> Ranges                             | 550                                   | 600                | 650                 | kHz                 |      |
| External Input Capacitance    | C <sub>in</sub>                     |  | 100 <sup>(6)</sup>                    | -                  | -                   | μF                  |      |
| External Output Capacitance   | C <sub>out</sub>                    | Capacitance Non-Ceramic(ESR ≥4mΩ)  | 0                                     | 100 <sup>(7)</sup> | 3300 <sup>(8)</sup> | μF                  |      |
|                               |                                     | Ceramic  | 0                                     | -                  | 300                 |                     |      |
| MTBF                          | MTBF                                | Per Bellcore TR-332<br>50 % stress, T <sub>a</sub> =40°C, Ground Benign    | 6                                     | -                  | -                   | 10 <sup>6</sup> Hrs |      |

**Notes:** (1) No derating is required when the module is soldered directly to a 4-layer PCB with 1 oz. copper.

(2) The minimum input voltage is equal to 2.95 V or V<sub>out</sub> + 0.65 V, whichever is greater.

(3) The set-point voltage tolerance is affected by the tolerance and stability of R<sub>SET</sub>. The stated limit is unconditionally met if R<sub>SET</sub> has a tolerance of 1 % with 100 ppm/°C or better temperature stability.

(4) The pk-pk output ripple voltage is measured with an external 10μF ceramic capacitor. See the standard application schematic.

(5) This control pin has an internal pull-up to the input voltage V<sub>in</sub>. 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.

(6) A 100μF input capacitor is required for proper operation. The capacitor must be rated for a minimum of 300 mA rms of ripple current.

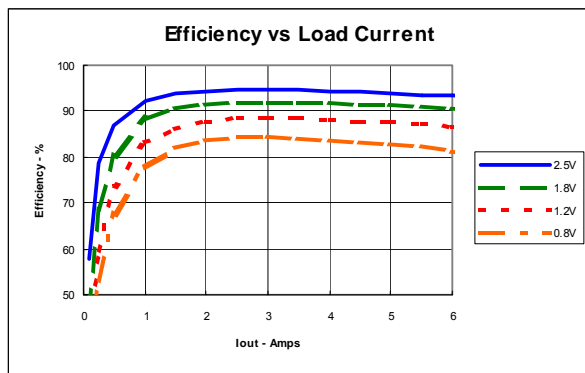
(7) This is the calculated maximum. The minimum ESR limitation will often result in a lower value. Consult the application notes for further guidance.

#### ⚠ Note:

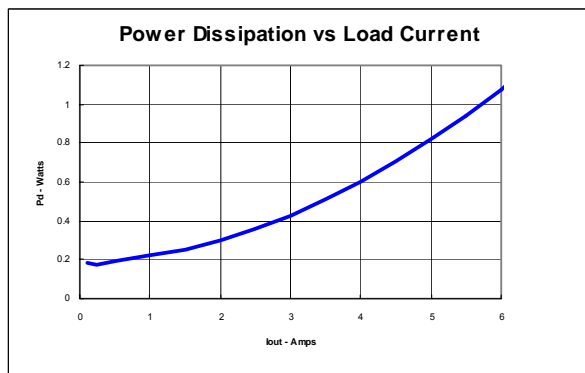
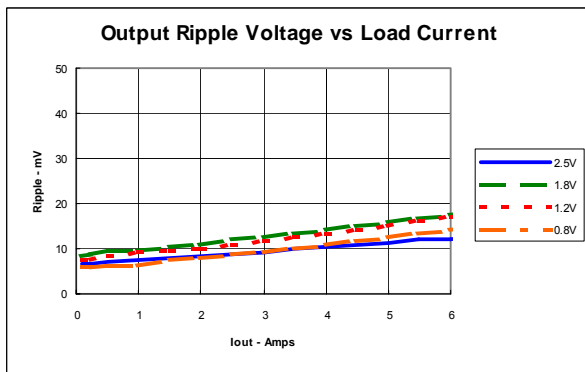
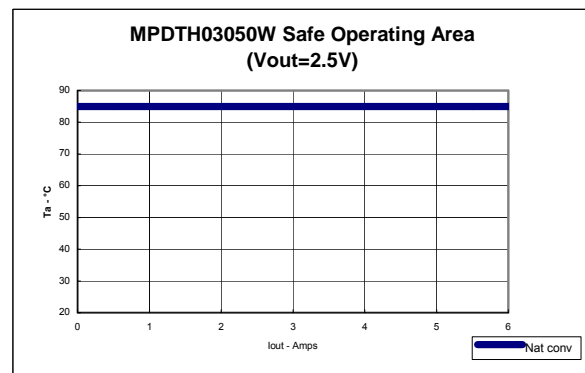
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### 6-A, 3.3-V Input Non-Isolated Wide-Output Adjust Power Module

Characteristic Data;  $V_{in} = 3.3\text{ V}$  (See Note A)



Safe Operating Area;  $V_{in} = 3.3\text{ V}$  (See Note B)



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. 4-layer PCB with 1 oz. copper.

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## MPDTH03050W &amp; MPDTH05050W

**Capacitor Recommendations for the MPDTH03050 & MPDTH05050 Series of Power Modules****Input Capacitor**

The recommended input capacitor(s) is determined by the 100 $\mu$ F [1] minimum capacitance and 300 mArms minimum ripple current rating.

Ripple current, less than 100 m $\Omega$  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 and achieve the minimum required capacitance.

**Output Capacitors (Optional)**

For applications with load transients (sudden changes in load current), regulator response will benefit from an external output capacitance. The recommended output capacitance of 100 $\mu$ F will allow the module to meet its transient response specification (see product data sheet). For most applications, high quality computer-grade aluminum electrolytic capacitors are adequate. These capacitors provide decoupling over the frequency range, 2 kHz to 150 kHz, and are suitable when ambient temperatures above 0°C. For operation below 0°C tantalum, ceramic or Os-Con type capacitors are recommended. When using one or more non-ceramic capacitors, the calculated equivalent ESR should not be 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 listed on Table 1-1.

**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 $\mu$ F. Also, to prevent the formation of local resonance, 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 recommended 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 reduced 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.

**Capacitor Table**

Table 1-1 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 your reference. The RMS ripple current rating and ESR (at 100kHz) are critical parameters necessary to insure both optimum regulator performance and long capacitor life.*

**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 1A/ $\mu$ 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 requirements of transient performance exceed what are specified in the data sheet, or the total amount of load capacitance is above 3,000 $\mu$ F, the selection of output capacitors becomes more important. For further guidance, please consult us.

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## MPDTH03050W &amp; MPDTH05050W

Table 1-1; Input / Output Capacitors

| Capacitor Vendor,<br>Type Series (Style) | Capacitor Characteristics |            |                     |                                  |                   | Quantity  |            | Vendor Number    |
|--|---------------------------|------------|---------------------|----------------------------------|-------------------|-----------|------------|------------------|
|  | Working Voltage           | Value (uF) | MAX.(ESR) at 100kHz | Max.Ripple at 85°C Current(Irms) | Physical Size(mm) | Input Bus | Output Bus |                  |
| Panasonic<br>FC, Aluminum(SMD)           | 25V                       | 100        | 0.300Ω              | 450 mA                           | 8×10              | 1         | 1          | EEVFC1E101P      |
| WA,Poly-Aluminum(SMD)                    | 10V                       | 120        | 0.035Ω              | 2800 mA                          | 8.3×6.9           | 1         | ≤5         | EEFWA1A121P      |
| Panasonic, Aluminum<br>FC (Radial)       | 16V                       | 220        | 0.150Ω              | 555 mA                           | 10×10.2           | 1         | 1          | EEFC1C221        |
| FK (SMD)                                 | 16V                       | 330        | 0.160Ω              | 600 mA                           | 8×10.2            | 1         | 1          | EEVFK1C331P      |
| United Chemi-Con<br>FS, Os-con(Radial)   | 10V                       | 100        | 0.040Ω              | 2100 mA                          | 6.3×9.8           | 1         | ≤5         | 10FS100M         |
| PXA, Poly-Alum(SMD)                      | 10V                       | 120        | 0.027Ω              | 2430 mA                          | 8×6.7             | 1         | ≤4         | PXA10VC121MH80TP |
| MVZ, Aluminum(SMD)                       | 16V                       | 220        | 0.170Ω              | 450 mA                           | 8×10              | 1         | 1          | MVZ25VC221MH10TP |
| F55, Tantalum(SMD)                       | 10V                       | 100        | 0.024Ω              | 4420 mA                          | 8×11.5            | 1         | ≤4         | 10PS270MH11      |
| Nichicon, Aluminum<br>WG, Aluminum (SMD) | 35V                       | 100        | 0.150Ω              | 670 mA                           | 10×10             | 1         | 1          | UWG1V101MNR1GS   |
| PM, (Radial)                             | 25V                       | 150        | 0.160Ω              | 460 mA                           | 10×11.5           | 1         | 1          | UPM1E151MPH      |
| F55, Tantalum (SMD)                      | 10V                       | 100        | 0.055Ω              | 2000 mA                          | 7.7×4.3           | 1         | 1          | F551A107MN       |
| Sanyo<br>SVP, Os-con(SMD)                | 10V                       | 120        | 0.040Ω              | >2500 mA                         | 7×8               | 1         | ≤5         | 10SVP120M        |
| SP, Os-con(Radial)                       | 16V                       | 100        | 0.025Ω              | >2800 mA                         | 6.3×9.8           | 1         | ≤4         | 16SPS100M        |
| TPE Poscap<br>Polymer(SMD)               | 10V                       | 220        | 0.025Ω              | >2400 mA                         | 7.3×5.7           | 1         | ≤4         | 10TPE220ML       |
| AVX, Tantalum<br>TPS (SMD)               | 10V                       | 100        | 0.100Ω              | >1090 mA                         | 7.3L×             | 1         | ≤5         | TPSD107M010R0100 |
|  | 10V                       | 220        | 0.100Ω              | >1414 mA                         | 4.3W×4.1H         | 1         | ≤5         | TPSV227M010R0100 |
| Kemet<br>T520, Poly-Alum (SMD)           | 10V                       | 100        | 0.080Ω              | 1200 mA                          | 7.3L×             | 1         | 1          | T520D107M010AS   |
| T495, Tantalum(SMD)                      | 10V                       | 100        | 0.100Ω              | >1100 mA                         | 5.7W×4.0H         | 1         | 1          | T495X107M010AS   |
| A700-Poly-Alum.(SMD)                     | 6.3V                      | 100        | 0.018Ω              | 2900 mA                          |                   | 1         | ≤3         | A700D107M006AT   |
| Vishay-Sprague<br>594D, Tantalum (SMD)   | 10V                       | 150        | 0.090Ω              | 1100mA                           | 7.3L×             | 1         | 1          | 594D157X0010C2T  |
| 595D, Tantalum (SMD)                     | 10V                       | 120        | 0.140Ω              | >1000 mA                         | 6.0W×4.1H         | 1         | 1          | 595D127X0010D2T  |
| 94SA, Os-con (Radial)                    | 10V                       | 100        | 0.030Ω              | 2670 mA                          | 8×10.5            | 1         | ≤4         | 94SA107X0010EBP  |
| Kermet, Ceramic<br>X5R(SMD)              | 16V                       | 10         | 0.002Ω              | -                                | 1210case          | 1         | ≤5         | C1210C106M4PAC   |
|  | 6.3V                      | 47         | 0.002Ω              |                                  | 3225mm            | 2[1]      | ≤5         | C1210C476K9PAC   |
| Murata, Ceramic<br>X5R(SMD)              | 6.3V                      | 100        | 0.002Ω              | -                                | 1210case          | 1         | ≤3         | GRM32ER60J107M   |
|  | 6.3V                      | 47         |                     |                                  | 3225mm            | 2[1]      | ≤5         | GRM32ER60J476M   |
|  | 16V                       | 22         |                     |                                  |                   | 5         | ≤5         | GRM32ER61C226K   |
|  | 16V                       | 10         |                     |                                  |                   | 1[2]      | ≤5         | GRM32DR61C106K   |
| TDK, Ceramic X5R(SMD)                    | 6.3V                      | 100        | 0.002Ω              | -                                | 1210case          | 1         | ≤3         | C3225X5R0J107MT  |
|  | 6.3V                      | 47         |                     |                                  | 3225mm            | 2[1]      | ≤5         | C3225X5R0J476MT  |
|  | 16V                       | 22         |                     |                                  |                   | 5         | ≤5         | C3225X5R1C226MT  |
|  | 16V                       | 10         |                     |                                  |                   | 1[2]      | ≤5         | C3225X5R1C106MT  |

[1] Total capacitance of 94μF is acceptable based on the combined ripple current rating.

[2] Small ceramic capacitors may be used to complement electrolytic types at the input to reduce high-frequency ripple current

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## MPDTH03030W &amp; MPDTH05030W

## Adjustment of the Output Voltage of the MPDTH03030W &amp; MPDTH05030W Wide-Output Adjust Power Modules

The *Vo Adjust* control (pin 5) sets the output voltage to a value higher than 0.8 V. The adjustment range of the MPDTH03050W (3.3-V input) is from 0.8 V to 2.5 V<sup>1</sup>, and the MPDTH05050W (5-V input) from 0.8 V to 3.6 V. The adjustment method requires the addition of a single external resistor, *Rset*, that must be connected directly between the *Vo Adjust* and *GND* pins. Table 2-1 shows the preferred value of the external resistor for a number of standard voltages, along with the actual output voltage that this resistance value provides.

For other output voltages the value of the required resistor can either be calculated using the following formula, or simply selected from the range of values given in Table 2-2.

Figure 2-1 shows the placement of the required resistor.

$$R_{set} = 10 \text{ k}\Omega \cdot \frac{0.8\text{V}}{V_{out}-0.8\text{V}} - 2.49 \text{ k}\Omega$$

Table 2-1: Preferred Values of *Rset* for Standard Output Voltages

| Vout(Standard)      | Rset(Pref'd Value) | Vout(Actual) |
|---------------------|--------------------|--------------|
| 3.3V <sup>(1)</sup> | 698Ω               | 3.309V       |
| 2.5V                | 2.21kΩ             | 2.502V       |
| 2.0V                | 4.12kΩ             | 2.010V       |
| 1.8V                | 5.49kΩ             | 1.803V       |
| 1.5V                | 8.87kΩ             | 1.504V       |
| 1.2V                | 17.4kΩ             | 1.202V       |
| 1.0V                | 36.5kΩ             | 1.005V       |
| 0.8V                | Open               | 0.8V         |

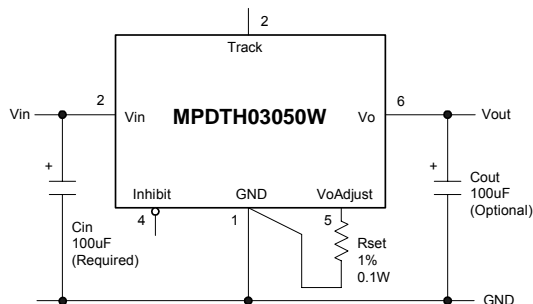
Figure 2-1: *Vo Adjust* Resistor Placement

Table 2-2: Output Voltage Set-Point Resistor Values

| Vo Req'd | Rset    | Vo Req'd | Rset    |
|----------|---------|----------|---------|
| 0.800    | Open    | 2.00     | 4.18 kΩ |
| 0.825    | 318 kΩ  | 2.05     | 3.91 kΩ |
| 0.850    | 158 kΩ  | 2.10     | 3.66 kΩ |
| 0.875    | 104 kΩ  | 2.15     | 3.44 kΩ |
| 0.900    | 77.5 kΩ | 2.20     | 3.22 kΩ |
| 0.925    | 61.5 kΩ | 2.25     | 3.03 kΩ |
| 0.950    | 50.8 kΩ | 2.30     | 2.84 kΩ |
| 0.975    | 43.2 kΩ | 2.35     | 2.67 kΩ |
| 1.000    | 37.5 kΩ | 2.40     | 2.51 kΩ |
| 1.025    | 33.1 kΩ | 2.45     | 2.36 kΩ |
| 1.050    | 29.5 kΩ | 2.50     | 2.22 kΩ |
| 1.075    | 26.6 kΩ | 2.55     | 2.08 kΩ |
| 1.100    | 24.2 kΩ | 2.60     | 1.95 kΩ |
| 1.125    | 22.1 kΩ | 2.65     | 1.83 kΩ |
| 1.150    | 20.4 kΩ | 2.70     | 1.72 kΩ |
| 1.175    | 18.8 kΩ | 2.75     | 1.61 kΩ |
| 1.200    | 17.5 kΩ | 2.80     | 1.51 kΩ |
| 1.225    | 16.3 kΩ | 2.85     | 1.41 kΩ |
| 1.250    | 15.3 kΩ | 2.90     | 1.32 kΩ |
| 1.275    | 14.4 kΩ | 2.95     | 1.23 kΩ |
| 1.300    | 13.5 kΩ | 3.00     | 1.15 kΩ |
| 1.325    | 12.7 kΩ | 3.05     | 1.07 kΩ |
| 1.350    | 12.1 kΩ | 3.10     | 988 Ω   |
| 1.375    | 11.4 kΩ | 3.15     | 914 Ω   |
| 1.400    | 10.8 kΩ | 3.20     | 843 Ω   |
| 1.425    | 10.3 kΩ | 3.25     | 775 Ω   |
| 1.450    | 9.82 kΩ | 3.30     | 710 Ω   |
| 1.475    | 9.36 kΩ | 3.35     | 647 Ω   |
| 1.50     | 8.94 kΩ | 3.40     | 587 Ω   |
| 1.55     | 8.18 kΩ | 3.45     | 529 Ω   |
| 1.60     | 7.51 kΩ | 3.50     | 473 Ω   |
| 1.65     | 6.92 kΩ | 3.55     | 419 Ω   |
| 1.70     | 6.40 kΩ | 3.60     | 367 Ω   |
| 1.75     | 5.93 kΩ |          |         |
| 1.80     | 5.51 kΩ |          |         |
| 1.85     | 5.13 kΩ |          |         |
| 1.90     | 4.78 kΩ |          |         |
| 1.95     | 4.47 kΩ |          |         |

## Notes:

- Modules that operate from a 3.3-V input bus should not be adjusted higher than 2.5 V.
- A 0.05-W resistor may be used. The tolerance should be 1%, with temperature stability of 100 ppm/°C (or better). Place the resistor as close to the regulator as possible. Connect the resistor directly between pins 5 and 1 using dedicated PCB traces.
- Never connect capacitors from *Vo Adjust* to either *GND* or *Vout*. Any capacitance added to the *Vo Adjust* pin will affect the stability of the regulator.

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## MPDTH03050W &amp; MPDTH05050W

## Features of the MPDTH Series of Non-Isolated Wide Output Adjust Power Modules

## POLA™ Compatibility

The MPDTH family of non-isolated, wide-output adjust power modules from Murata Manufacturing are optimized for applications that require a flexible and high performance module that is small in size. Each of these products is POLA™ compatible. POLA compatible products are produced by a number of manufacturers, and offer customers advanced and non-isolated modules with the same footprint and form factor. POLA parts are also assured to be interoperable, thereby providing customers with true second-source availability.

From the basic “Just Plug it In” functionality of the 6-A modules to the 30-A rated feature-rich MPDTHxx030, these products were designed to be very flexible, and simple to use. The features vary with each product. Table 3-1 provides a quick reference to the features by product series and input bus voltage.

**Table 3-1: Operating Features by Series and Input Bus Voltage**

| Series     | Input Bus | Output | Adjust(Trim) | On/Off Inhibit | Over-Current | Pre-Bias Startup | Auto-Track™ | Margin Up/Down | Output Sense | Thermal Shutdown |
|------------|-----------|--------|--------------|----------------|--------------|------------------|-------------|----------------|--------------|------------------|
| MPDTHxx050 | 3.3V      | 6A     | o            | o              | o            | o                | o           |                |              |                  |
|            | 5V        | 6A     | o            | o              | o            | o                | o           |                |              |                  |
| MPDTHxx060 | 3.3V/5V   | 10A    | o            | o              | o            | o                | o           | o              | o            |                  |
|            | 12V       | 8A     | o            | o              | o            | o                | o           | o              | o            |                  |
| MPDTHxx010 | 3.3V/5V   | 15A    | o            | o              | o            | o                | o           | o              | o            |                  |
|            | 12V       | 12A    | o            | o              | o            | o                | o           | o              | o            |                  |
| MPDTHxx020 | 3.3V/5V   | 22A    | o            | o              | o            | o                | o           | o              | o            | o                |
|            | 12V       | 18A    | o            | o              | o            | o                | o           | o              | o            | o                |
| MPDTHxx030 | 3.3V/5V   | 30A    | o            | o              | o            | o                | o           | o              | o            | o                |
|            | 12V       | 26A    | o            | o              | o            | o                | o           | o              | o            | o                |

For simple point-of-use applications, the MPDTHxx050 provides operating features such as an on/off inhibit, output voltage trim, pre-bias startup, and over-current protection. The MPDTHxx060 (10 A/8A), and MPDTHxx010 (15/12 A) include an output voltage sense, and margin up/down controls. Then the higher output current MPDTHxx020 and MPDTHxx030 products incorporate over-temperature shutdown protection.

All of the products referenced in Table 3-1 include Auto-Track™. This feature was specifically designed to simplify the task of sequencing the supply voltages in a power system. This and other features are described in the following sections.

## ⚠ Note:

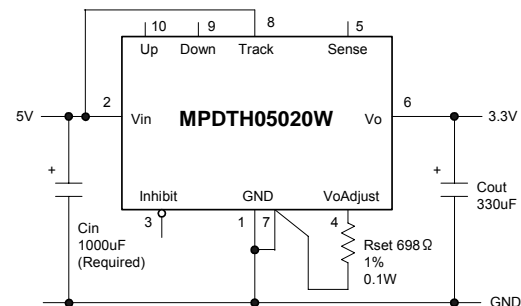
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## Soft-Start Power Up

The Auto-Track feature allows the power-up of multiple modules to be directly controlled from their *Track* pin.

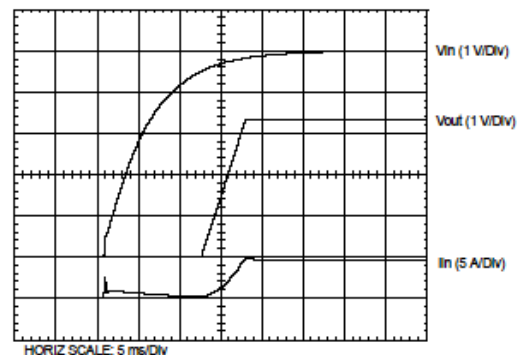
However in a stand-alone configuration, or when the Auto-Track feature is not being used, the *Track* pin should be directly connected to the input voltage,  $V_{in}$  (see Figure 3-1).

**Figure 3-1**



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.

**Figure 3-2**





## MPDTH03050W & MPDTH05050W

From the moment a valid input voltage is applied, the soft-start control introduces a short time delay (typically 5 ms-10 ms) before allowing the output voltage to rise. The output then progressively rises to the module's setpoint voltage. Figure 3-2 shows the soft-start power-up characteristic of the 22-A output product (MPDTH05020W), operating from a 5-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 completed within 15 ms.

### Over-Current Protection

For protection against load faults, all modules incorporate output over-current protection. Applying a load that exceeds the regulator's over-current threshold will cause the regulated output to shutdown. 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 a cycle of successive shutdown and power up until the load fault is removed. During this period, the average current flowing into the fault is significantly reduced. Once the fault is removed, the module automatically recovers and returns to normal operation.

### Over-Temperature Protection

The MPDTHxx020 and MPDTHxx030 series of products have over-temperature protection. These products have an on-board temperature sensor that protects the module's internal circuitry against excessively high temperatures. A rise of the internal temperature may be the result of a drop in airflow, or a high ambient temperature. If the internal temperature exceeds the OTP threshold, the module's *Inhibit* control is automatically pulled low. This turns off the output. The output voltage will drop as the external output capacitors are discharged by the load circuit. The recovery is automatic, and begins with a soft-start power up. It occurs when the sensed temperature decreases by about 10 °C below the trip point.

*Note: The over-temperature 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.*

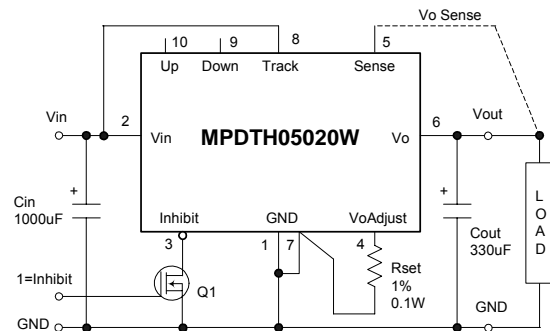
### Output On/Off Inhibit

For applications requiring output voltage on/off control, each series of the MPDTH 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 *Vin* with respect to *GND*.

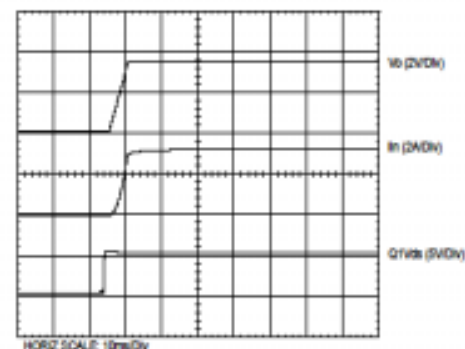
Figure 3-3 shows the typical application of the inhibit function. Note the discrete transistor (Q1). The *Inhibit* control has its own internal pull-up to *Vin* potential. The input is not compatible with TTL logic devices. An open collector (or open-drain) discrete transistor is recommended for control.

Figure 3-3



Turning Q1 on applies a low voltage to the *Inhibit* control and disables the output of the module. If Q1 is then turned off, the module will execute a soft-start power-up. A regulated output voltage is produced within 20 msec. Figure 3-4 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 Vds. The waveforms is measured with a 5-A load.

Figure 3-4



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## MPDTH03050W & MPDTH05050W

### Auto-Track™ Function

The Auto-Track function is unique to the MPDTH family, and is available with the all POLA-compatible 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.

#### 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 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. For 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. 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.

#### Typical Application

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 3-5.

To initiate a power-up sequence the Track control must be pulled first to ground potential. This should be done at or before input power is applied to the modules, and then held for at least 10 ms 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. 10 ms 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 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 3-6 shows the output voltage waveforms from the circuit of Figure 3-5 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 3-5 limit the rate at which Q1 can pull down the Track control voltage. The values of 100 k-ohm and 0.1 μF 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 3-7 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.

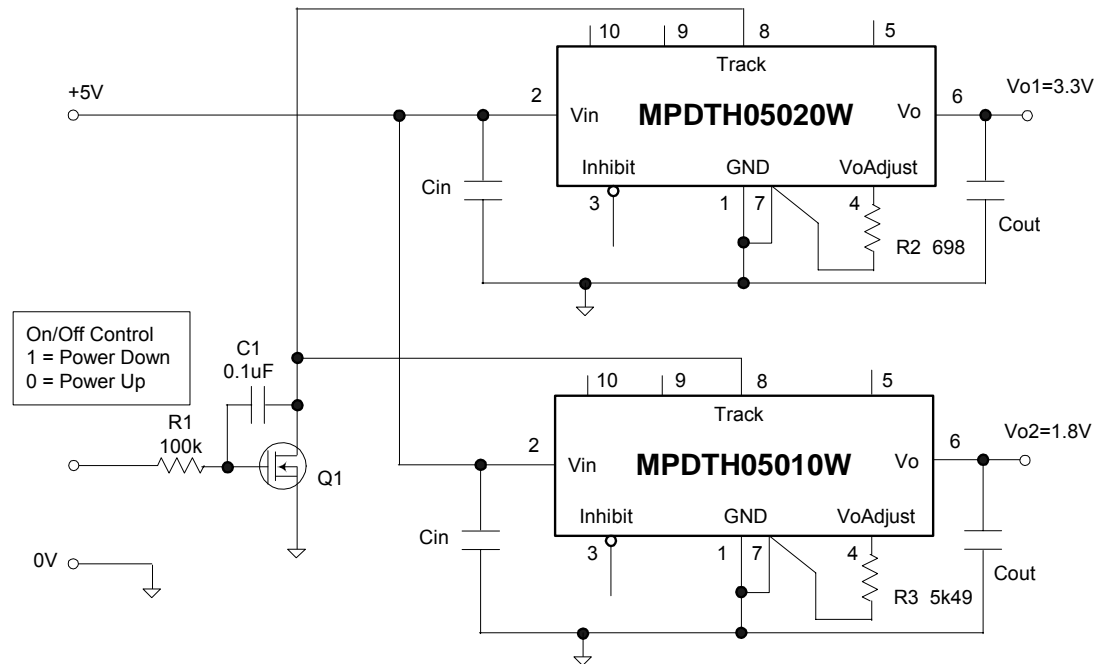
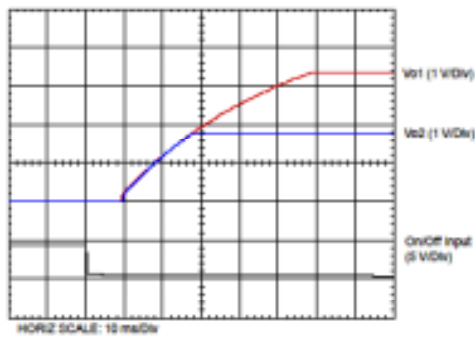
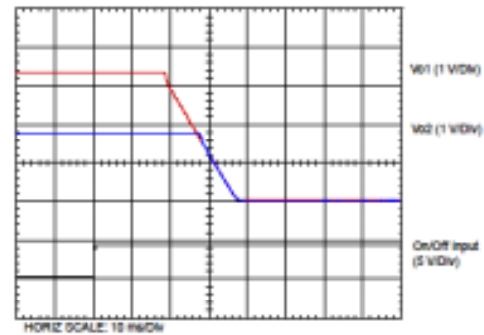
#### Notes on Use of Auto-Track™

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 speed 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 at 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.

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## MPDTH03030W &amp; MPDTH05030W

**Figure 3-5: Sequenced Power Up & Power Down Using Auto-Track****Figure 3-6: Simultaneous Power Up with Auto-Track Control****Figure 3-7: Simultaneous Power Down with Auto-Track Control****Note:**

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## MPDTH03030W & MPDTH05030W

### Margin Up/Down Controls

The MPDTHxx060, MPDTHxx010, MPDTHxx020, and MPDTHxx030 products incorporate *Margin Up* and *Margin Down* control inputs. These controls allow the output voltage to be momentarily adjusted  $\pm 1$ , either up or down, by a nominal 5%. This provides a convenient method for dynamic testing of the operation of the load circuit over its supply margin or range. It can also be used to verify the function of supply voltage supervisors. 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 pulling the appropriate margin control input directly to the  $GND$  terminal. A low-leakage open-drain device, such as an n-channel 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. The value of the resistor can be selected from Table 3-2, or calculated using the following formula.

#### Up/Down Adjust Resistance Calculation

To reduce the margin adjustment to a value less than 5%, series resistors are required (See  $R_D$  and  $R_U$  in Figure 3-8). For the same amount of adjustment, the resistor value calculated for  $R_U$  and  $R_D$  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.

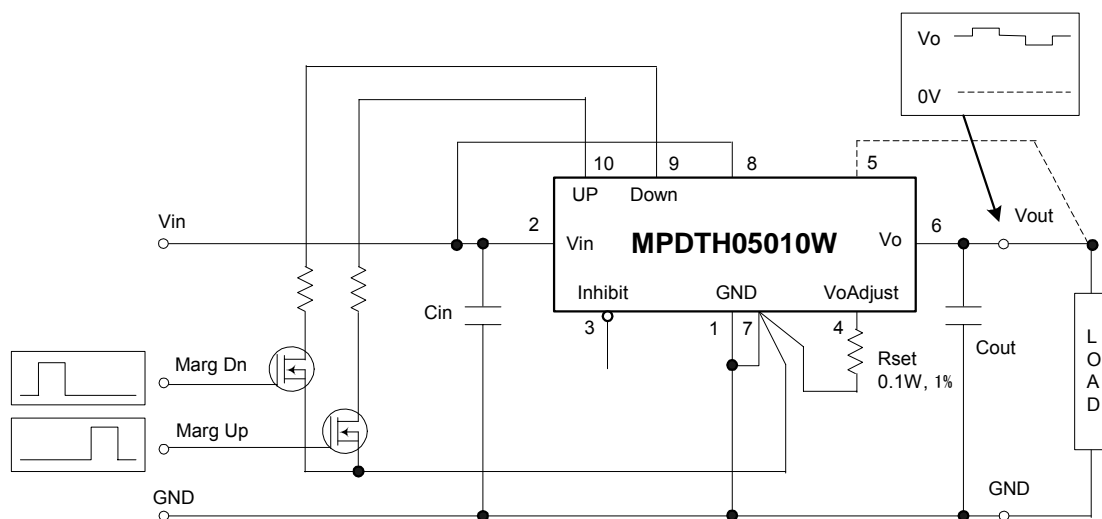
#### Notes:

1. The *Margin Up\** and *Margin Dn\** controls were not intended to be activated simultaneously. If their effects on the output voltage may not be completely canceled, 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  $GND$  at pin 7 (pin 1 for the MPDTHxx050). 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 by a true open-drain device (preferably a discrete MOSFET transistor). The selected device should have low off-state leakage current. Each input sources  $8\mu A$  when grounded, and has an open-circuit voltage of 0.8 V.

**Table 3-2: Margin Up/Down Resistor Values**

| %Adjust | $R_U / R_D$    |
|---------|----------------|
| 5       | 0.0k $\Omega$  |
| 4       | 24.9k $\Omega$ |
| 3       | 66.5k $\Omega$ |
| 2       | 150k $\Omega$  |
| 1       | 397k $\Omega$  |

**Figure 3-8: Margin Up/Down Application Schematic**



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## MPDTH03030W &amp; MPDTH05030W

**Pre-Bias Startup Capability**

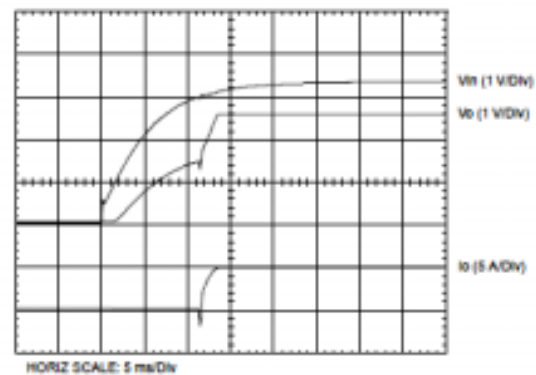
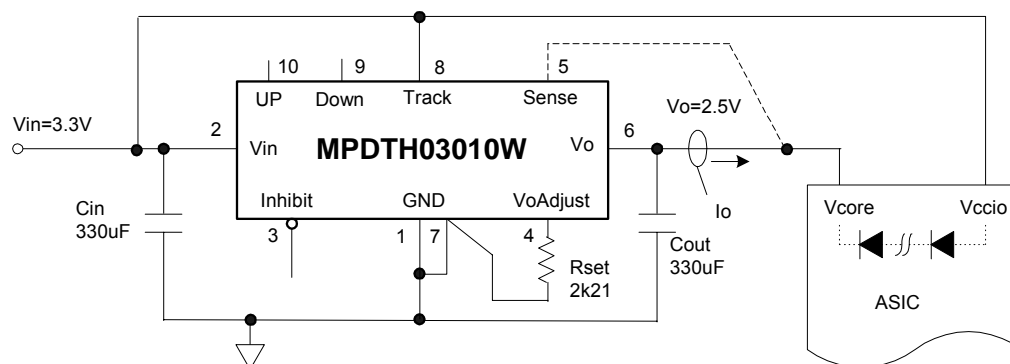
A pre-bias startup condition occurs as a result of an external voltage being present at the output of a power module prior to its output becoming active. This often occurs in complex digital systems when current from another power source is backed through a dual-supply logic component, such as an FPGA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

The MPDTH family of power modules incorporate synchronous rectifiers, but will not sink current during startup 1, or whenever the *Inhibit* pin is held low. However, to ensure satisfactory operation of this function, certain conditions must be maintained. 2 Figure 3-9 shows an application demonstrating the pre-bias startup capability. The start-up waveforms are shown in Figure 3-10. Note that the output current from the MPDTH03010W ( $I_o$ ) shows negligible current until its output voltage rises above that backed through diodes D1 and D2.

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

**Notes**

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

**Figure 3-10; Pre-Bias Startup Waveforms****Figure 3-9; Application Circuit Demonstrating Pre-Bias Startup****Note:**

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## MPDTH03030W & MPDTH05030W

### Remote Sense

Products with this feature incorporate an output voltage sense pin, *Vo Sense*. 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. To use this feature simply connect the *Vo Sense* pin to the *Vout* node, close to the load circuit (see data sheet standard application). If not used, the *Vo Sense* pin can be left open-circuit. An internal low-value resistor (15-Ω or less) is connected between the *Vo Sense* and *Vout*. This ensures the output voltage remains in regulation.

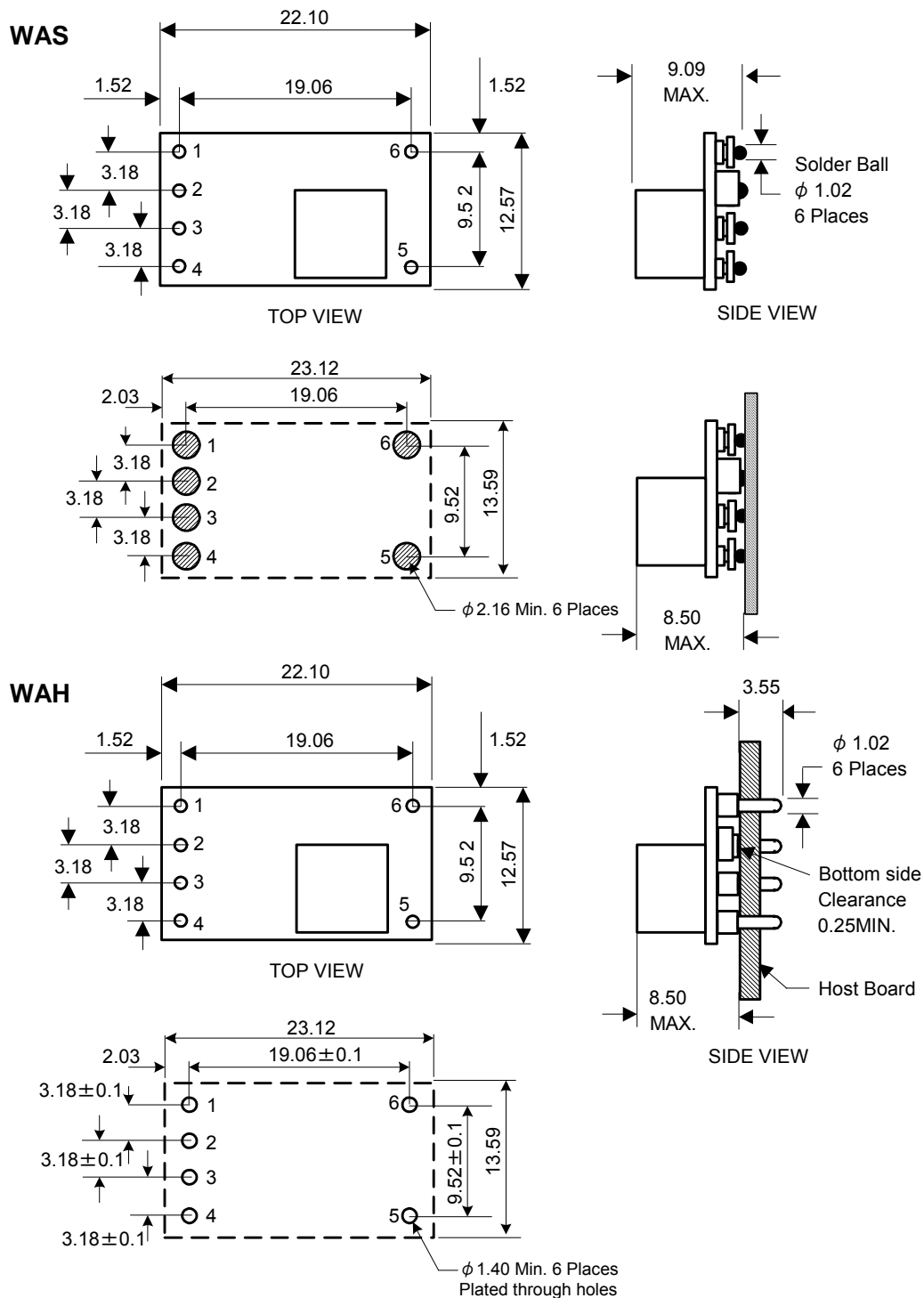
With the sense pin connected, the difference between the voltage measured directly between the *Vout* and *GND* pins, and that measured from *Vo Sense* to *GND*, is the amount of IR drop being compensated by the regulator. This should be limited to a maximum of 0.3 V.

*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.*

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## MPDTH03030W &amp; MPDTH05030W



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