



# MPM54524

## Fully Integrated, 16V, Quad 5A Output Power Module with I<sup>2</sup>C Interface

### DESCRIPTION

The MPM54524 is an integrated, quad 5A power module with an I<sup>2</sup>C interface. The device offers a complete power solution with built-in turn-on/off sequencing control, configurable soft start (SS), compensation, and various protection thresholds.

Constant-on-time (COT) control provides ultra-fast transient response. The output voltage ( $V_{OUTx}$ ) (where  $x = A, B, C, \text{ or } D$ ) is adjustable via the I<sup>2</sup>C bus or preset via the multiple-time programmable (MTP) memory. The power-on/off sequence is also configurable via the MTP or can be controlled via the I<sup>2</sup>C.

The MPM54524 offers configurable active voltage positioning (AVP), which generates a droop voltage ( $V_{DROOP}$ ). This allows four channels in parallel with passive current balancing. In addition, buck regulator A (buck A) and buck regulator B (buck B) can operate in parallel for up to 10A in interleaving mode, which enables active current balancing. Full protection features include under-voltage lockout (UVLO), over-current protection (OCP), over-voltage protection (OVP), under-voltage protection (UVP), and thermal shutdown.

The MPM54524 requires a minimal number of external components, and is available in a compact ECLGA (8mmx8mmx2.9mm) package.

### FEATURES

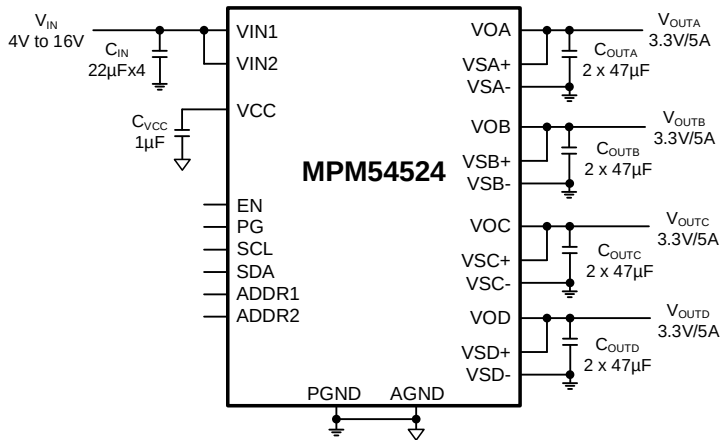
- Wide 4V to 16V Input Voltage ( $V_{INx}$ ) (where  $x = 1 \text{ or } 2$ ) Range
- Adaptive Constant-On-Time (COT) for Ultra-Fast Transient Response
- Parallel Operation with Passive or Active Current Balancing
- I<sup>2</sup>C-Configurable Output Voltage ( $V_{OUTx}$ ) (where  $x = A, B, C, \text{ or } D$ )
- Configurable Switching Frequency ( $f_{SW}$ ): 500kHz to 1000kHz
- Differential  $V_{OUTx}$  Remote Sense (where  $x = A, B, \text{ or } C$ )
- Accurate  $V_{OUTx}$ , Output Current ( $I_{OUTx}$ ) (where  $x = A, B, C, \text{ or } D$ ), and Junction Temperature ( $T_J$ ) Monitoring via the I<sup>2</sup>C
- Open-Drain Power Good (PG) Indication
- Configurable I<sup>2</sup>C Slave Address
- Selectable Pulse-Frequency Modulation (PFM)/Pulse-Width Modulation (PWM) Mode, Adjustable Frequency, and Current Limit via the I<sup>2</sup>C
- Pre-Biased Start-Up
- Protections Include Over-Current Protection (OCP), Under-Voltage Protection (UVP), Under-Voltage Lockout (UVLO), Thermal Shutdown, and Over-Voltage Protection (OVP)
- Available in an ECLGA (8mmx8mmx2.9mm) Package

### APPLICATIONS

- FPGA and ASIC Power Supplies
- Networking and Telecommunications
- Optical Module Power Supplies

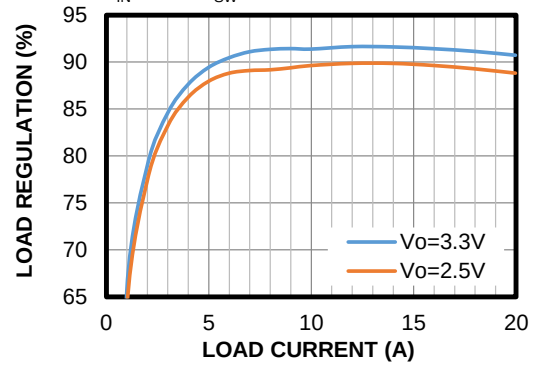
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## TYPICAL APPLICATION



### 4-Phase Paralleled Efficiency vs. Load Current

$V_{IN} = 12V$ ,  $f_{SW} = 1000kHz$



## ORDERING INFORMATION

| Part Number*       | Package                     | Top Marking | MSL Rating |
|--------------------|-----------------------------|-------------|------------|
| MPM54524GCQ-xxxx** | ECLGA-51<br>(8mmx8mmx2.9mm) | See Below   | 3          |
| MPM54524GCQ-0000** | ECLGA-51<br>(8mmx8mmx2.9mm) | See Below   | 3          |

\* For Tray, add suffix -T (e.g. MPM54524GCQ-xxxx-T).

\* For Tape & Reel, add suffix -Z (e.g. MPM54524GCQ-xxxx-Z).

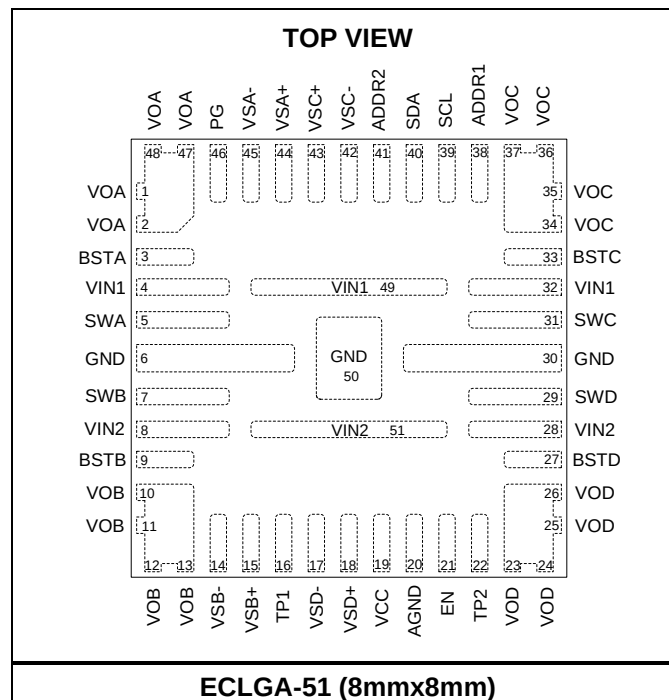
\*\* “xxxx” is the configuration code identifier for the register setting stored in the multiple-time programmable (MTP) memory. The default code is “0000”. Each “x” can be a hexadecimal value between 0 and F. Work with an MPS FAE to create this unique number, even if ordering the “0000” code. See Table 3 on page 51 for the MPM54524GCQ-0000 detailed configuration.

## TOP MARKING

**MPSYYWW**  
**MP54524**  
**LLLLLLLLL**  
**M**

MPS: MPS prefix  
YY: Year code  
WW: Week code  
MP54524: Part number  
LLLLLLLLL: Lot number  
M: Module

## PACKAGE REFERENCE



## PIN FUNCTIONS

| Pin #          | Name  | Description                                                                                                                                                                                                            |
|----------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1, 2, 47, 48   | VOA   | <b>Buck regulator A (buck A) output.</b> The VOA pin is the output of buck A.                                                                                                                                          |
| 3              | BSTA  | <b>Buck A bootstrap.</b> Float the BSTA pin.                                                                                                                                                                           |
| 4, 32, 49      | VIN1  | <b>Supply voltage input of buck A and buck regulator C (buck C).</b> Ceramic capacitors are required to decouple the input rail. Connect the VIN1 and VIN2 pins using a wide PCB trace.                                |
| 5              | SWA   | <b>Buck A switching node.</b> Float the SWA pin.                                                                                                                                                                       |
| 6, 30, 50      | GND   | <b>Power ground.</b> The GND pin requires special consideration during PCB layout. Connect GND using copper traces and vias.                                                                                           |
| 7              | SWB   | <b>Buck B switching output.</b> Float the SWB pin.                                                                                                                                                                     |
| 8, 28, 51      | VIN2  | <b>Supply voltage input of buck regulator B (buck B) and buck regulator D (buck D).</b> Ceramic capacitors are required to decouple the input rail. Connect the VIN1 and VIN2 pins using a wide PCB trace.             |
| 9              | BSTB  | <b>Buck B bootstrap.</b> Float the BSTB pin.                                                                                                                                                                           |
| 10, 11, 12, 13 | VOB   | <b>Buck B output.</b> The VOB pin is the output of buck B.                                                                                                                                                             |
| 14             | VSB-  | <b>Remote-sense ground of buck B.</b> Kelvin connect the VSB- pin to the ground node of the output capacitor (C <sub>OUT</sub> ) for buck B.                                                                           |
| 15             | VSB+  | <b>Positive feedback of buck B.</b> Connect the VSB+ pin to buck B's output.                                                                                                                                           |
| 16             | TP1   | <b>Test pin.</b> Float the TP1 pin.                                                                                                                                                                                    |
| 17             | VSD-  | <b>Ground of buck D.</b> Kelvin connect the VSD- pin to the ground node of C <sub>OUT</sub> for buck D.                                                                                                                |
| 18             | VSD+  | <b>Positive feedback of buck D.</b> Connect the VSD+ pin to buck D's output.                                                                                                                                           |
| 19             | VCC   | <b>Internal 3.3V low-dropout (LDO) output.</b> The driver and control circuits are powered from the VCC pin voltage (V <sub>CC</sub> ). Decouple VCC using a 1μF ceramic capacitor placed as close to VCC as possible. |
| 20             | AGND  | <b>Analog ground.</b> Connect the AGND pin to the power GND pin.                                                                                                                                                       |
| 21             | EN    | <b>Enable control.</b> Pull the EN pin high to enable the module; pull EN low to disable the module.                                                                                                                   |
| 22             | TP2   | <b>Test pin.</b> Float the TP2 pin.                                                                                                                                                                                    |
| 23, 24, 25, 26 | VOD   | <b>Buck D output.</b> The VOD pin is the output of Buck D.                                                                                                                                                             |
| 27             | BSTD  | <b>Buck D bootstrap.</b> Float the BSTD pin.                                                                                                                                                                           |
| 29             | SWD   | <b>Buck D switching output.</b> Float the SWD pin.                                                                                                                                                                     |
| 31             | SWC   | <b>Buck C switching output.</b> Float the SWC pin.                                                                                                                                                                     |
| 33             | BSTC  | <b>Buck C bootstrap.</b> Float the BSTC pin.                                                                                                                                                                           |
| 34, 35, 36, 37 | VOC   | <b>Buck C output.</b> The VOC pin is the output of buck C.                                                                                                                                                             |
| 38             | ADDR1 | <b>I<sup>2</sup>C bus address.</b> There are 9 selectable I <sup>2</sup> C addresses. To select the I <sup>2</sup> C address, pull the ADDR1 pin high, low, or float the pin.                                          |
| 39             | SCL   | <b>I<sup>2</sup>C clock.</b>                                                                                                                                                                                           |
| 40             | SDA   | <b>I<sup>2</sup>C data.</b>                                                                                                                                                                                            |
| 41             | ADDR2 | <b>I<sup>2</sup>C address.</b> There are 9 I <sup>2</sup> C selectable addresses by pulling the ADDR2 pin high, low, or floating the pin.                                                                              |
| 42             | VSC-  | <b>Remote-sense ground of buck C.</b> Kelvin connect the VSC- pin to the ground node of C <sub>OUT</sub> for buck C.                                                                                                   |

## PIN FUNCTIONS *(continued)*

| Pin # | Name | Description                                                                                                                                                                         |
|-------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 43    | VSC+ | <b>Positive feedback of buck C.</b> Connect the VSC+ pin to buck C's output directly.                                                                                               |
| 44    | VSA+ | <b>Positive feedback of buck A.</b> Connect buck A's output to the VSA+ pin directly. In dual-phase interleaving mode, VSA+ must be connected to VSB+.                              |
| 45    | VSA- | <b>Remote-sense ground of buck A.</b> Kelvin connect the VSA- pin to the ground node of C <sub>OUT</sub> for buck A.                                                                |
| 46    | PG   | <b>Open-drain power good output.</b> Pull the PG pin low when any enabled regulator drops below the under-voltage (UV) threshold. Pull PG low when all the regulators are disabled. |

## ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

|                                                                     |                                 |
|---------------------------------------------------------------------|---------------------------------|
| Supply voltage (V <sub>INx</sub> )                                  | 18V                             |
| V <sub>SWx_DC</sub>                                                 | -0.3V to V <sub>IN</sub> + 0.3V |
| V <sub>BSTx</sub>                                                   | V <sub>SW</sub> + 4V            |
| VOA, VOB, VOC, VOD                                                  | 6V                              |
| V <sub>CC</sub>                                                     | 4.5V                            |
| V <sub>CC</sub> , ADDR1, ADDR2, PG (1s) <sup>(2)</sup>              | 6V                              |
| All other pins                                                      | -0.3V to +4.3V                  |
| Continuous power dissipation (T <sub>A</sub> = 25°C) <sup>(6)</sup> | 7.8W                            |
| Junction temperature (T <sub>J</sub> )                              | 150°C                           |
| Storage temperature                                                 | -65°C to +150°C                 |

## ESD Ratings

|                            |      |
|----------------------------|------|
| Human body model (HBM)     | ±2kV |
| Charged-device model (CDM) | ±2kV |

## Recommended Operating Conditions <sup>(3)</sup>

|                                           |                 |
|-------------------------------------------|-----------------|
| Supply voltage (V <sub>INx</sub> )        | 4V to 16V       |
| Output voltage (V <sub>OUTx</sub> )       | 0.4V to 5.5V    |
| Operating junction temp (T <sub>J</sub> ) | -40°C to +125°C |

## Thermal Resistance <sup>(4) (5) (6) (7) (8)</sup>

|                     |         |
|---------------------|---------|
| θ <sub>JA</sub>     | 16°C/W  |
| θ <sub>JC_TOP</sub> | 0.3°C/W |
| θ <sub>JB</sub>     | 4.4°C/W |

### Notes:

- Exceeding these ratings may damage the device.
- Voltage rating during multiple-time programmable (MTP) memory configuring.
- The device is not guaranteed to function outside of its operating conditions.
- θ<sub>JA</sub> is the junction-to-ambient thermal resistance, θ<sub>JC\_TOP</sub> is the junction-to-case top thermal characterization parameter, and θ<sub>JB</sub> is the junction-to-board thermal characterization parameter.
- The thermal parameter is based on testing on the MPS evaluation board, EVM54524-CQ-00A, under no airflow cooling conditions in a standard enclosure. The EVM54524-CQ-00A is a 4-layer, 2oz board (8.1cmx8.1cm).
- The maximum allowable power dissipation is a function of the maximum junction temperature, T<sub>J</sub> (MAX), the junction-to-ambient thermal resistance, θ<sub>JA</sub>, and the ambient temperature, T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX) - T<sub>A</sub>) / θ<sub>JA</sub>. Exceeding the maximum allowable power dissipation produces an excessive die temperature.
- The junction-to-case top thermal characterization parameter, θ<sub>JC\_TOP</sub>, estimates the junction temperature in the real system, based on the equation, T<sub>J</sub> = θ<sub>JC\_TOP</sub> × P<sub>LOSS</sub> + T<sub>CASE\_TOP</sub>, where P<sub>LOSS</sub> is the entire loss of the module in real application, and T<sub>CASE\_TOP</sub> is the case top temperature.
- The junction-to-board thermal characterization parameter, θ<sub>JB</sub>, estimates the junction temperature in the real system, based on the equation, T<sub>J</sub> = θ<sub>JB</sub> × P<sub>LOSS</sub> + T<sub>BOARD</sub>, where P<sub>LOSS</sub> is the entire loss of the module in real application, and T<sub>BOARD</sub> is the board temperature.

## ELECTRICAL CHARACTERISTICS

V<sub>IN</sub> = 12V, T<sub>J</sub> = -40°C to +125°C <sup>(9)</sup>, typical values are tested at T<sub>J</sub> = 25°C, unless otherwise noted.

| Parameter                                                                                         | Symbol                    | Condition                                                                                  | Min  | Typ  | Max  | Units                 |
|---------------------------------------------------------------------------------------------------|---------------------------|--------------------------------------------------------------------------------------------|------|------|------|-----------------------|
| Supply current (no switching)                                                                     | I <sub>IN</sub>           | No switching, FB high, pulse-frequency modulation (PFM), no I <sup>2</sup> C communication |      | 7.24 |      | mA                    |
| Default switching frequency                                                                       | f <sub>SW</sub>           | 0Fh = 0xAA                                                                                 |      | 1000 |      | kHz                   |
| VIN1 or VIN2                                                                                      |                           |                                                                                            |      |      |      |                       |
| V <sub>INx</sub> over-voltage (OV) rising threshold (where x = 1 or 2)                            | V <sub>INx_OV_R</sub>     | 90h, bit[0] = 1'b1                                                                         |      | 15   |      | V                     |
| V <sub>INx</sub> OV hysteresis                                                                    | V <sub>INx_OV_HYS</sub>   |                                                                                            |      | 0.25 |      | V                     |
| V <sub>INx</sub> under-voltage lockout (UVLO) rising threshold                                    | V <sub>INx_UVLO_R</sub>   | 90h, bit[1] = 1'b1, AFh, bits[1:0] = 2'b00                                                 | 2.85 | 3.05 | 3.25 | V                     |
| V <sub>INx</sub> UVLO hysteresis                                                                  | V <sub>INx_UVLO_HYS</sub> |                                                                                            |      | 0.25 |      | V                     |
| Enable (EN)                                                                                       |                           |                                                                                            |      |      |      |                       |
| EN logic high voltage                                                                             | V <sub>EN_H</sub>         |                                                                                            | 1.2  |      |      | V                     |
| EN logic low voltage                                                                              | V <sub>EN_L</sub>         |                                                                                            |      |      | 0.35 | V                     |
| EN internal pull-down resistance                                                                  | R <sub>EN_DOWN</sub>      |                                                                                            |      | 2.7  |      | MΩ                    |
| ADDR1 or ADDR2                                                                                    |                           |                                                                                            |      |      |      |                       |
| ADDR1 or ADDR2 logic high voltage                                                                 | V <sub>ADDRx_H</sub>      |                                                                                            | 1.2  |      |      | V                     |
| ADDR1 or ADDR2 logic low voltage                                                                  | V <sub>ADDRx_L</sub>      |                                                                                            |      |      | 0.35 | V                     |
| Buck Regulators (Buck A, Buck B, Buck C, or Buck D)                                               |                           |                                                                                            |      |      |      |                       |
| Feedback (FB) voltage accuracy                                                                    | V <sub>FBA</sub>          | 25h, bit[3] = 1'b1, 15h = 0x90                                                             | 3.31 | 3.36 | 3.41 | V                     |
|                                                                                                   | V <sub>FBB</sub>          | 25h, bit[2] = 1'b1, 16h = 0x90                                                             | 3.31 | 3.36 | 3.41 | V                     |
|                                                                                                   | V <sub>FBC</sub>          | 25h, bit[1] = 1'b1, 17h = 0x90                                                             | 3.31 | 3.36 | 3.41 | V                     |
|                                                                                                   | V <sub>FBD</sub>          | 25h, bit[0] = 1'b1, 18h = 0x90                                                             | 3.31 | 3.36 | 3.41 | V                     |
| Output voltage (V <sub>OUTx</sub> ) (where X = A, B, C, or D) under-voltage (UV) rising threshold | V <sub>OUTx_UV_R</sub>    |                                                                                            |      | 85   |      | % of V <sub>OUT</sub> |
| V <sub>OUTx</sub> UV falling threshold                                                            | V <sub>OUTx_UV_F</sub>    |                                                                                            |      | 80   |      | % of V <sub>OUT</sub> |
| Low-side (LS) current limit (source)                                                              | I <sub>LS_VALLEY1</sub>   | 26h = 0xAA                                                                                 |      | 5.5  |      | A                     |
| Minimum on time <sup>(10)</sup>                                                                   | t <sub>ON_MIN1</sub>      |                                                                                            |      | 30   |      | ns                    |
| Minimum off time <sup>(10)</sup>                                                                  | t <sub>OFF_MIN1</sub>     |                                                                                            |      | 120  |      | ns                    |
| Output over-voltage protection (OVP) rising threshold                                             | V <sub>OVP1_H</sub>       |                                                                                            |      | 112  |      | % of V <sub>REF</sub> |
| Output OVP recovery threshold                                                                     | V <sub>OVP1_L</sub>       |                                                                                            |      | 109  |      | % of V <sub>REF</sub> |

**ELECTRICAL CHARACTERISTICS (continued)**

**V<sub>IN</sub> = 12V, T<sub>J</sub> = -40°C to +125°C <sup>(9)</sup>, typical values are tested at T<sub>J</sub> = 25°C, unless otherwise noted.**

| Parameter                                         | Symbol               | Condition                                             | Min  | Typ  | Max  | Units                 |
|---------------------------------------------------|----------------------|-------------------------------------------------------|------|------|------|-----------------------|
| Soft-start (SS) time of buck regulator A (buck A) | t <sub>SS_A</sub>    | 12h, bits[7:6] = 2b'10, V <sub>OUT</sub> = 10% to 90% |      | 2    |      | ms                    |
| SS time of buck regulator B (buck B)              | t <sub>SS_B</sub>    | 12h, bits[5:4] = 2b'10, V <sub>OUT</sub> = 10% to 90% |      | 2    |      | ms                    |
| SS time of buck regulator C (buck C)              | t <sub>SS_C</sub>    | 12h, bits[3:2] = 2b'10, V <sub>OUT</sub> = 10% to 90% |      | 2    |      | ms                    |
| SS time of buck regulator D (buck D)              | t <sub>SS_D</sub>    | 12h, bits[1:0] = 2b'10, V <sub>OUT</sub> = 10% to 90% |      | 2    |      | ms                    |
| Discharge resistance                              | R <sub>DIS</sub>     | 0Eh, bits[3:1] = 3b'000/111                           | -40% | 10/2 | +40% | Ω                     |
| <b>Analog-to-Digital Converter (ADC)</b>          |                      |                                                       |      |      |      |                       |
| V <sub>OUTx</sub> readback accuracy               |                      | V <sub>OUTx</sub> = 3.3V                              | 217  | 220  | 223  | LSB                   |
| Output current readback accuracy                  |                      | I <sub>OUT</sub> = 4A                                 |      | 32   |      | LSB                   |
| <b>Power Good (PG)</b>                            |                      |                                                       |      |      |      |                       |
| PG UV rising threshold                            | V <sub>PG_UV_R</sub> | 0Dh, bits[3:0] = 0000                                 |      | 98   |      | % of V <sub>REF</sub> |
| PG UV falling threshold                           | V <sub>PG_UV_F</sub> |                                                       |      | 95   |      | % of V <sub>REF</sub> |
| PG OV rising threshold                            | V <sub>PG_OV_R</sub> |                                                       |      | 105  |      | % of V <sub>REF</sub> |
| PG OV falling threshold                           | V <sub>PG_OV_F</sub> |                                                       |      | 102  |      | % of V <sub>REF</sub> |
| PG output port sink current capability            | V <sub>PG_SINK</sub> | Sink 1mA                                              |      |      | 0.4  | V                     |
| <b>VCC Regulator</b>                              |                      |                                                       |      |      |      |                       |
| V <sub>CC</sub> UVLO rising threshold             | V <sub>CC_R</sub>    |                                                       | 2.5  | 2.7  | 2.9  | V                     |
| V <sub>CC</sub> UVLO hysteresis                   | V <sub>CC_HYS</sub>  |                                                       |      | 300  |      | mV                    |
| V <sub>CC</sub> voltage                           | V <sub>CC</sub>      | I <sub>CC</sub> = 25mA                                |      | 3.3  |      | V                     |
| V <sub>CC</sub> regulation                        | V <sub>CC_RG</sub>   | I <sub>CC</sub> = 0mA to 25mA                         |      | 1    |      | %                     |
| <b>Temperature Protections</b>                    |                      |                                                       |      |      |      |                       |
| Thermal shutdown <sup>(10)</sup>                  | T <sub>OTP_R</sub>   |                                                       |      | 145  |      | °C                    |
| Thermal hysteresis <sup>(10)</sup>                | T <sub>HYS</sub>     |                                                       |      | 20   |      | °C                    |

**Notes:**

9) Not tested in production. Guaranteed by over-temperature correlation.

10) Not tested in production. Guaranteed by engineering sample characterization.

## I<sup>2</sup>C PORT SIGNAL CHARACTERISTICS <sup>(11)</sup>

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(9)</sup>, typical values are tested at  $T_J = 25^{\circ}C$ , unless otherwise noted.

| Parameter                                                                           | Symbol        | Condition                        | $C_B = 100pF$ |             | $C_B = 400pF$      |     | Units |
|-------------------------------------------------------------------------------------|---------------|----------------------------------|---------------|-------------|--------------------|-----|-------|
|                                                                                     |               |                                  | Min           | Max         | Min                | Max |       |
| SCL clock frequency                                                                 | $f_{SCHL}$    |                                  | 0             | 3.4         | 0                  | 0.4 | MHz   |
| Set-up time for a repeated start command                                            | $t_{SU\_STA}$ |                                  | 160           |             | 600                |     | ns    |
| Hold time (repeated) for a start command                                            | $t_{HD\_STA}$ |                                  | 160           |             | 600                |     | ns    |
| SCL clock low period                                                                | $t_{LOW}$     |                                  | 160           |             | 1300               |     | ns    |
| SCL clock high period                                                               | $t_{HIGH}$    |                                  | 60            |             | 600                |     | ns    |
| Data set-up time                                                                    | $t_{SU\_DAT}$ |                                  | 10            |             | 100                |     | ns    |
| Data hold time                                                                      | $t_{HD\_DAT}$ |                                  | 0             | 70          | 0                  |     | ns    |
| SCL signal rising time                                                              | $t_{R\_CL}$   |                                  | 10            | 40          | $20 \times 0.1C_B$ | 300 | ns    |
| Rising time of the SCL signal after a repeated start command and an acknowledge bit | $t_{F\_CL1}$  |                                  | 10            | 80          | $20 \times 0.1C_B$ | 300 | ns    |
| SCL signal falling time                                                             | $t_{F\_CL}$   |                                  | 10            | 40          | $20 \times 0.1C_B$ | 300 | ns    |
| SDA signal rising time                                                              | $t_{fDA}$     |                                  | 10            | 80          | $20 \times 0.1C_B$ | 300 | ns    |
| SDA signal falling time                                                             | $t_{F\_DA}$   |                                  | 10            | 80          | $20 \times 0.1C_B$ | 300 | ns    |
| Set-up time for stop command                                                        | $t_{SU\_STO}$ |                                  | 160           |             | 600                |     | ns    |
| Bus free time between a stop and start condition                                    | $t_{BUF}$     |                                  | 160           |             | 1300               |     | ns    |
| Data valid time                                                                     | $t_{VD\_DAT}$ |                                  |               | 16          |                    | 90  | ns    |
| Data valid acknowledge time                                                         | $t_{VD\_ACK}$ |                                  |               | 160         |                    | 900 | ns    |
| Capacitive load for each bus line                                                   | $C_B$         | SDA and SCL line                 |               | 100         |                    | 400 | pF    |
|                                                                                     |               | SDAH + SDA line, SCLH + SCL line |               | 400         |                    | 400 | pF    |
| Low-level noise margin                                                              | $C_I$         | For each connected device        |               | $0.1V_{CC}$ | $0.1V_{CC}$        |     | V     |
| High-level noise margin                                                             | $V_{NH}$      | For each connected device        |               | $0.2V_{CC}$ | $0.2V_{CC}$        |     | V     |

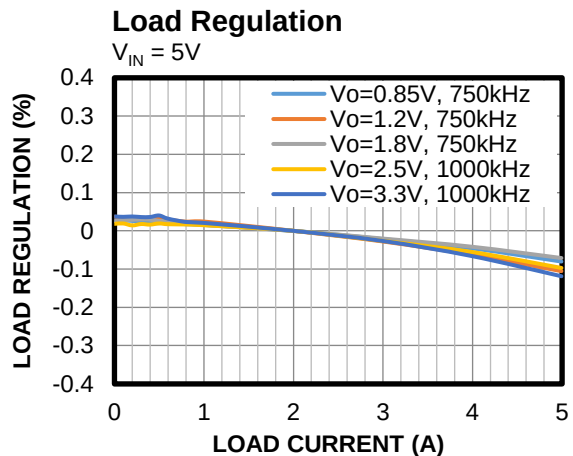
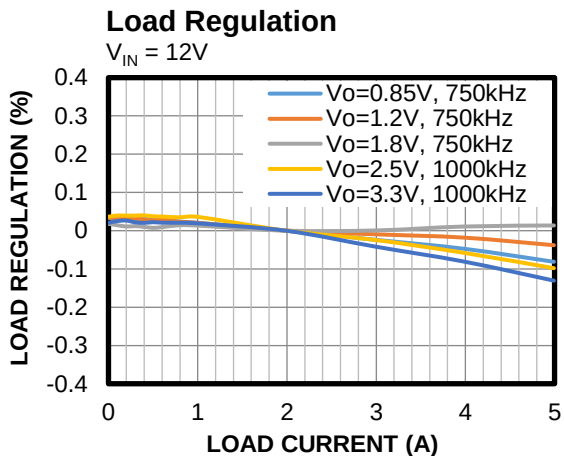
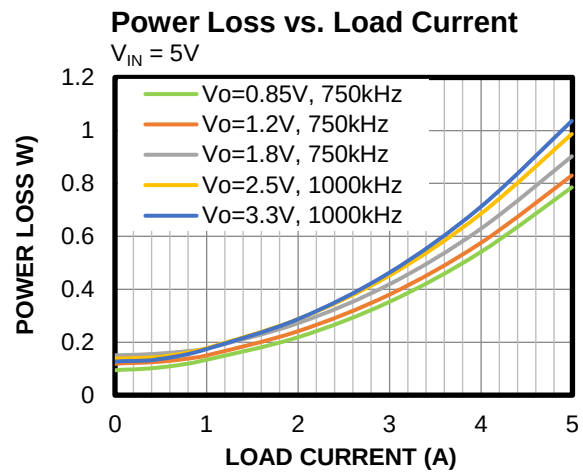
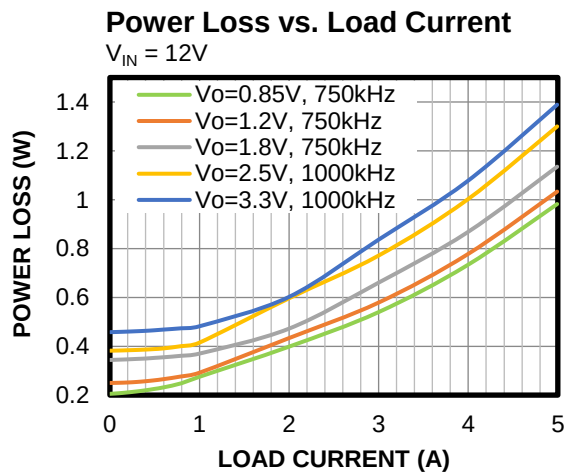
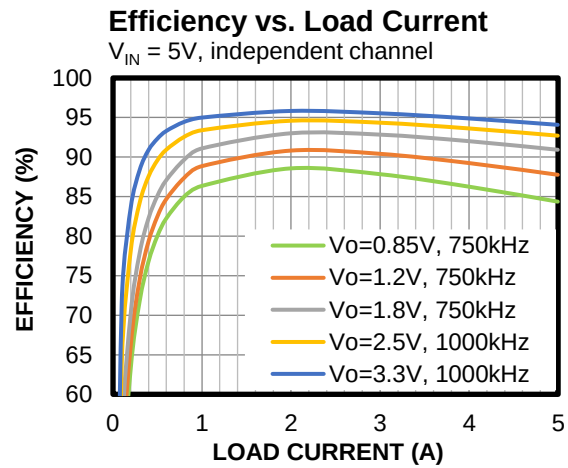
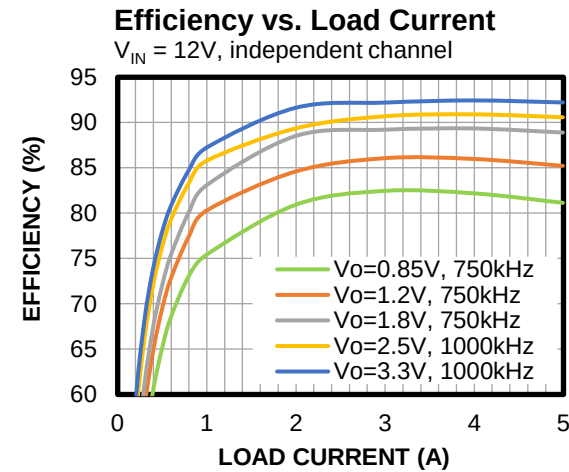
**Note:**

11) The maximum I<sup>2</sup>C bus voltage must be below 4V. A 1.8V or 3.3V typical bus voltage is recommended.



## TYPICAL PERFORMANCE CHARACTERISTICS

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

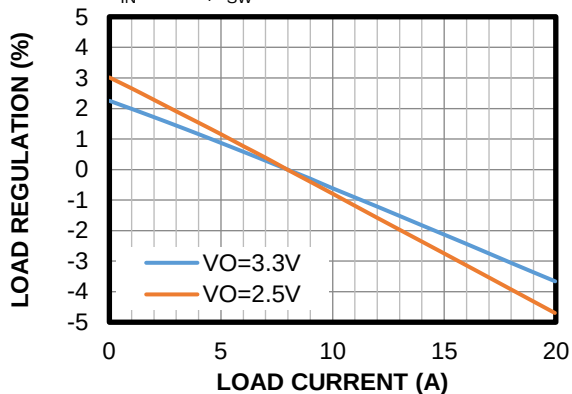


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

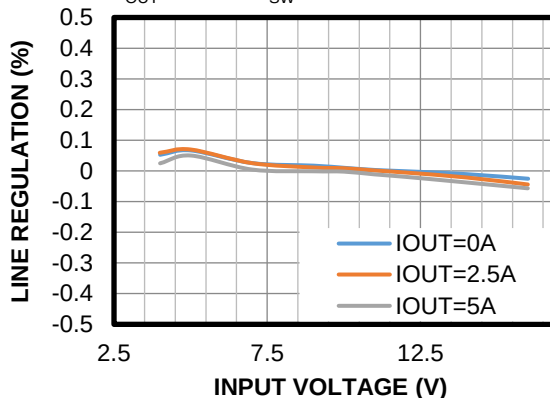
### 4-Phase Paralleled Load Regulation

$V_{IN} = 12V$ ,  $f_{SW} = 1000kHz$



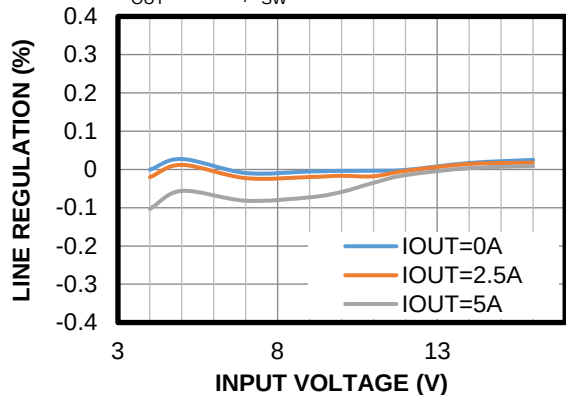
### Line Regulation

$V_{OUT} = 0.85V$ ,  $f_{SW} = 750kHz$



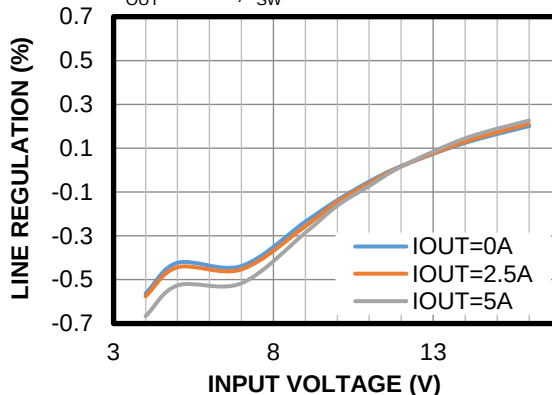
### Line Regulation

$V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$



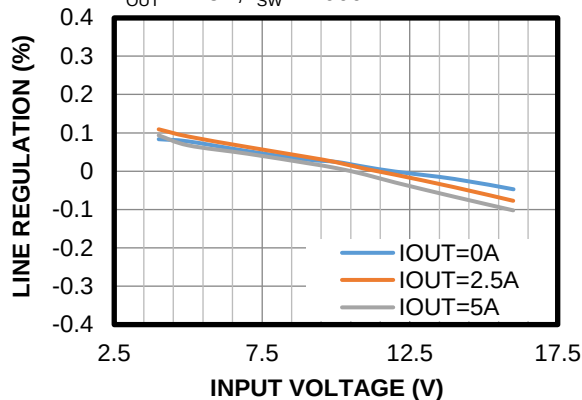
### Line Regulation

$V_{OUT} = 1.8V$ ,  $f_{SW} = 750kHz$



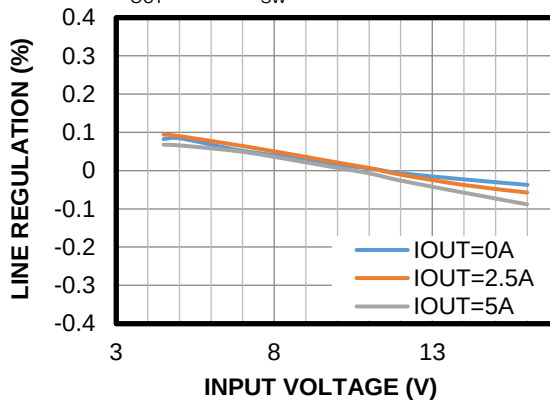
### Line Regulation

$V_{OUT} = 2.5V$ ,  $f_{SW} = 1000kHz$



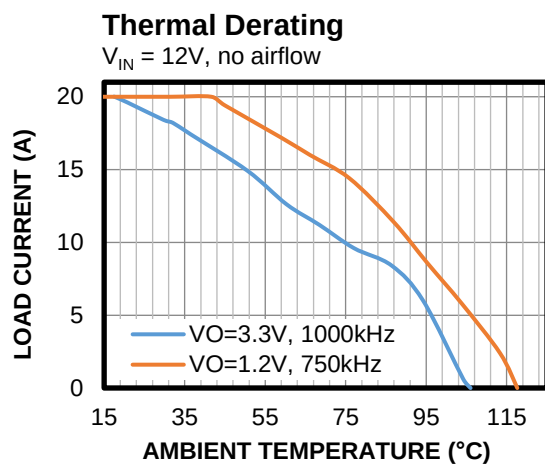
### Line Regulation

$V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$



# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

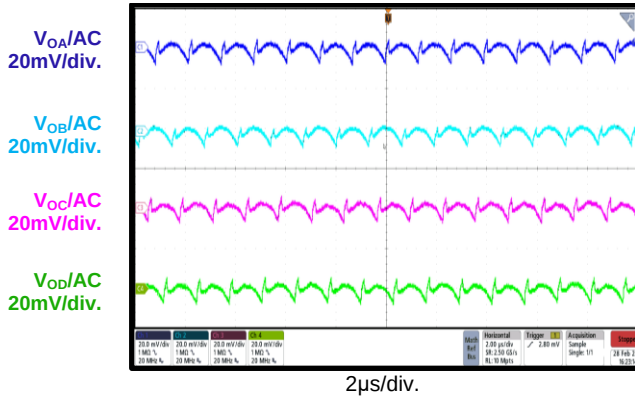


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

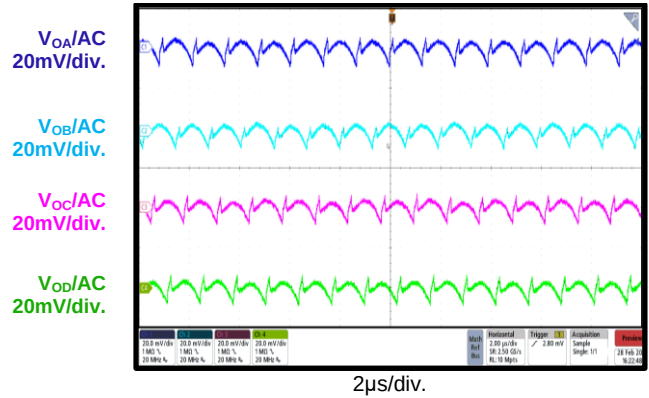
### Steady State

$V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$ ,  
 $I_{OUT} = 0A$ , single channel



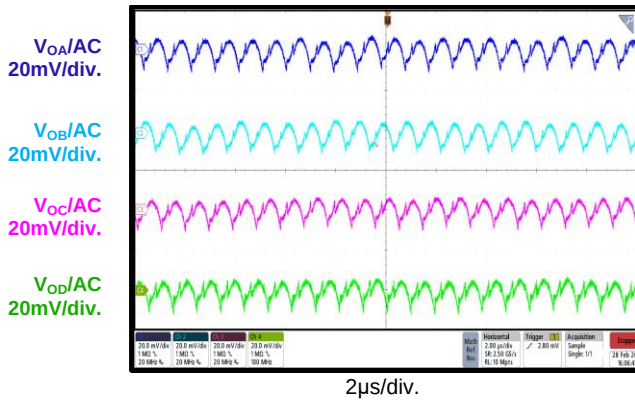
### Steady State

$V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$ ,  
 $I_{OUT} = 5A$ , single channel



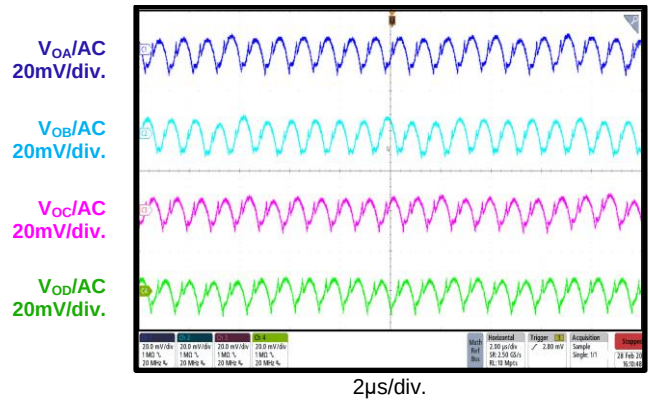
### Steady State

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$ ,  
 $I_{OUT} = 0A$ , single channel



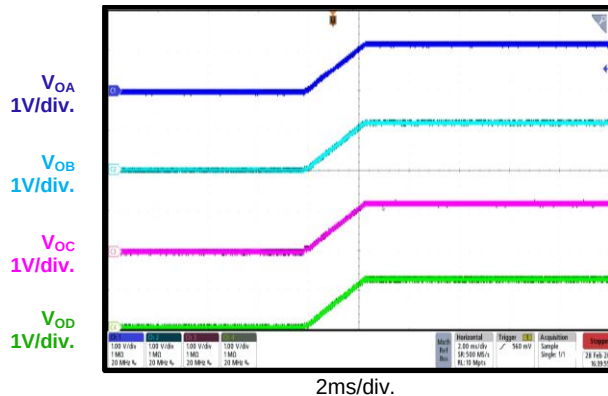
### Steady State

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$ ,  
 $I_{OUT} = 5A$ , single channel



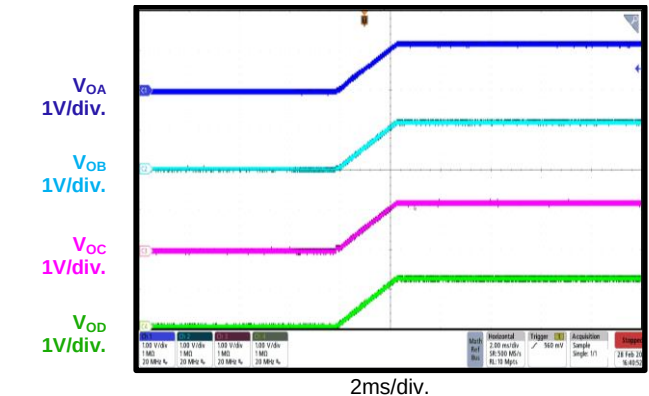
### Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$ ,  
 $I_{OUT} = 0A$ , single channel



### Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$ ,  
 $I_{OUT} = 5A$ , single channel

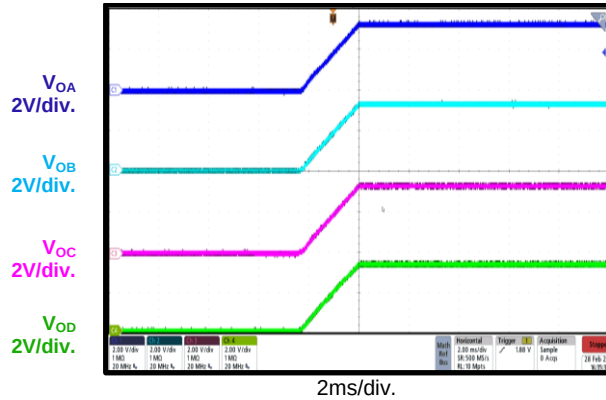


# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

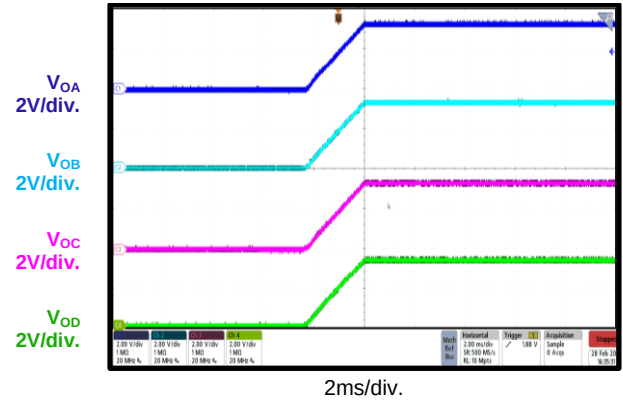
## Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$ ,  
 $I_{OUT} = 0A$ , single channel



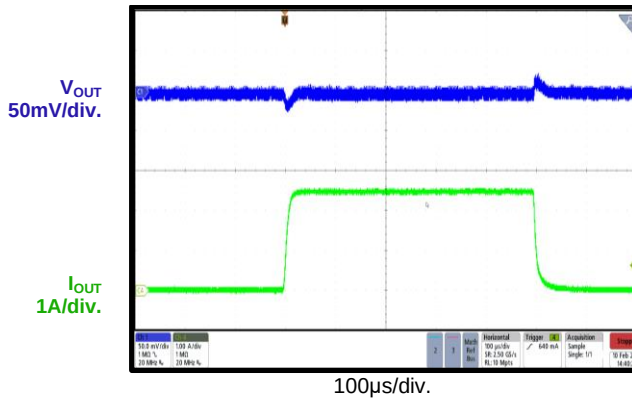
## Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$ ,  
 $I_{OUT} = 5A$ , single channel



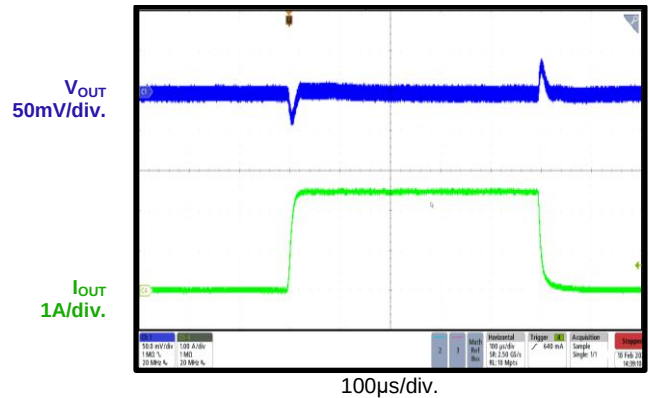
## Load Transient

$V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $f_{SW} = 750kHz$ ,  
 $I_{OUT} = 0A$  to  $2.5A$ ,  $2.5A/\mu s$  e-load, single channel



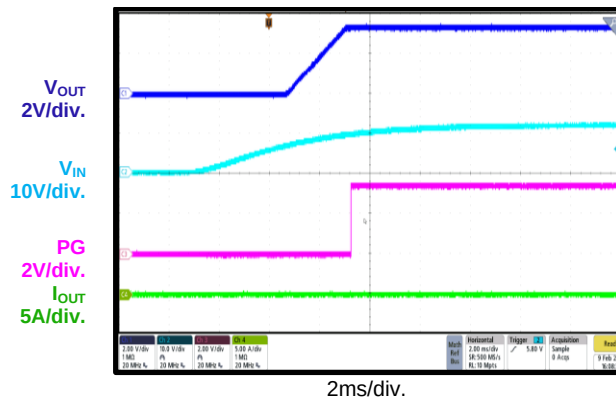
## Load Transient

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $f_{SW} = 1000kHz$ ,  
 $I_{OUT} = 0A$  to  $2.5A$ ,  $2.5A/\mu s$  e-load, single channel



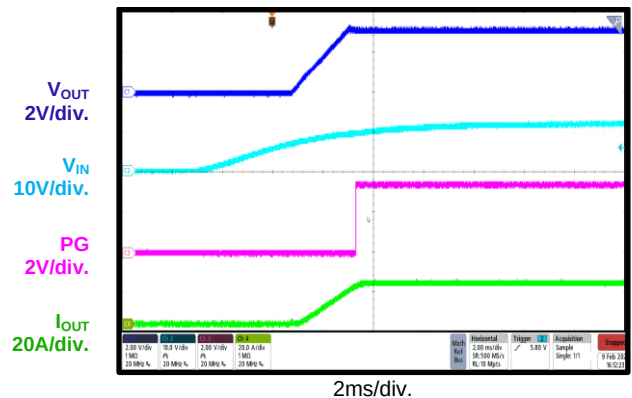
## Start-Up through VIN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 0A$ ,  
4-phase paralleled



## Start-Up through VIN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 20A$ ,  
4-phase paralleled

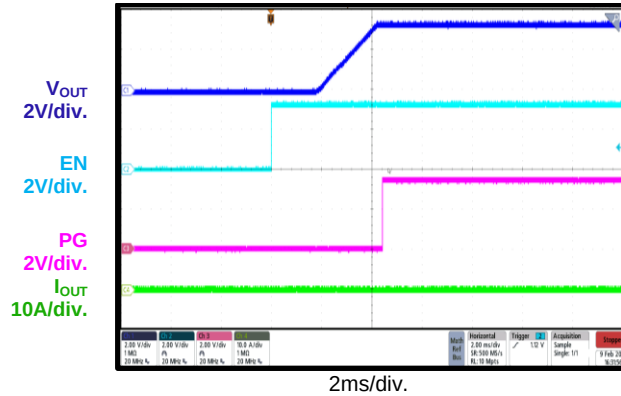


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance curves are tested on the evaluation board.  $V_{IN} = 12V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

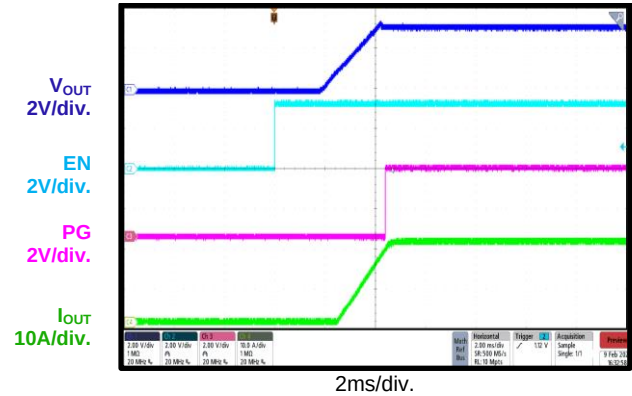
### Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 0A$ ,  
4-phase paralleled



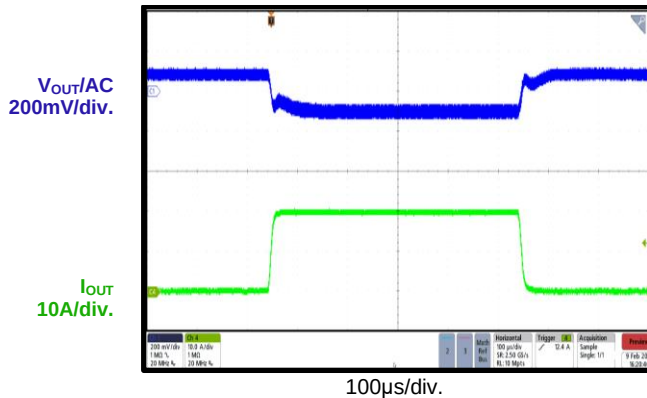
### Start-Up through EN

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 20A$ ,  
4-phase paralleled



### Load Transient

$V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 0A$  to  $20A$ ,  
 $2.5A/\mu s$  e-load, 4-phase paralleled



The schematic diagram illustrates the internal architecture of the PMIC, organized into several functional blocks and their interconnections with external components:

- Input and Reference Section:** Includes **VSD-**, **VSC-**, **VS-**, **VSA+**, and **VSA-** pins. It features a **Bias and Voltage Reference** block connected to **V<sub>REF1</sub>**, a **DAC** connected to **i<sup>2</sup>C Register**, and a **Current Limit** block. A **Slew Rate** control is also present.
- Control and Timing Section:** Contains an **EA** (Error Amplifier), **COMP** (Comparator), **Ramp**, **Over-Voltage Comparator**, **On-Timer**, and **Logic Control** block. A **2 x R** resistor network is connected to **VSA+** and **VSA-** pins, with a current **i<sup>2</sup>C** flowing through it.
- Power Regulation Section:** Includes a **VCC Regulator and UVLO** block, **Buck B** (i<sup>2</sup>C VID, 0.4V to 3.6V), **Buck C** (i<sup>2</sup>C VID, 0.4V to 3.6V), and **Buck D** (i<sup>2</sup>C VID, 0.4V to 3.6V). These are connected to **VIN2** and **VIN1** pins. External capacitors **C6**, **C7**, and **C8** (10000pF) are connected to the input of each buck converter. A **DUAL\_PHASE\_EN** signal is connected to **Interleaving Logic**.
- Switching and Output Section:** Features a **Bootstrap Regulator**, **HS Driver** (High-Side Switch), **LS Driver** (Low-Side Switch), and **Current Modulator**. The output is connected to **V<sub>CC</sub>** and **V<sub>REF0</sub>** pins. External components include capacitors **C1** (0.1μF) and **C5** (10000pF), and inductors **L1** (0.47μH), **L2** (0.47μH), **L3** (0.47μH), and **L4** (0.47μH). The output is connected to **BSTB**, **SWB**, **VOB**, **VS+**, **BSTC**, **SWC**, **VOC**, **VSC+**, **BSTD**, **SWD**, **VOD**, and **VSD+** pins.
- Control and Status Section:** Includes **Control Logic**, **1MHz OSC Phase Shift**, and **Feedback Loop, Current Limit, Mode, SS Control Logic** blocks. These are connected to **TP1**, **EN**, **SCL**, and **SDA** pins. A **i<sup>2</sup>C Register and MTP** block is connected to **SCL** and **SDA** pins. A **PG** (Programmable Gate) block is connected to **PG** pin.
- Protection and Monitoring Section:** Includes a **PG** (Programmable Gate) block, a **PG** (Programmable Gate) block, and a **PG** (Programmable Gate) block. A **PG** (Programmable Gate) block is connected to **PG** pin. A **PG** (Programmable Gate) block is connected to **PG** pin. A **PG** (Programmable Gate) block is connected to **PG** pin.

### Figure 1: Functional Block Diagram



## OPERATION

The MPM54524 is a quad, synchronous, step-down DC/DC power module that offers built-in soft start (SS), compensation, and protections including over-voltage protection (OVP), under-voltage protection (UVP), and over-current protection (OCP). Fixed-frequency constant-on-time (COT) control provides fast transient response.

### Power Supply Input and Under-Voltage Protection (UVP)

The input voltage ( $V_{INx}$ ) (where  $x = 1$  or  $2$ ) is the power module's power supply. If  $V_{INx}$  exceeds the UVP rising threshold and all the other start-up conditions are met, then the four-channel buck regulators start up. The bucks shut down once  $V_{INx}$  drops below the UVP falling threshold.

### Internal VCC Supply

VCC is the internal driver and power supply of the control circuitries. A decoupling capacitor is required to stabilize the regulator and reduce ripple. This regulator takes the  $V_{INx}$  input (where  $x = 1$  or  $2$ ) and operates across the full  $V_{INx}$  range. If  $V_{INx}$  exceeds 3.5V, the regulator's output is in full regulation. If  $V_{INx}$  drops below 3.5V, the regulator's output decreases according to the changes in  $V_{INx}$ .

### Enable (EN)

If  $V_{INx}$  exceeds the under-voltage lockout (UVLO) threshold, pull the EN pin above 1.2V to enable the MPM54524. Float EN or pull the pin down to ground to disable the MPM54524. There is an internal 2.7M $\Omega$  resistor connected between EN and ground.

If EN is pulled high and reaches the  $V_{IN}$  UVLO threshold, BUCKX\_CTRL\_REG (0Ch), bits[7:4] can enable or disable the four channels after the power-on sequence is complete. If the power-on sequence set via 19h to 1Ch, bit[7] = 1'b0, then the outputs of the four channels are disabled by default. Once EN and VIN are ready, 0Ch can enable the four channels.

When the MPM54524 is disabled, the part goes into output discharge or soft shutdown mode if the two functions are enabled.

### Power-On Sequence

Once the  $V_{INx}$  supply is valid and EN is pulled high, the MPM54524 initiates the power-on sequences of configuration 0, configuration 1, configuration 2, and configuration 3 via 19h to 1Fh to enable the corresponding output regulators in the specified sequence. Figure 2 on page 17 shows the power-on sequence. After  $V_{IN}$  reaches the UVLO threshold, EN goes high, and a 2ms system delay, each channel follows the start-up delay time, soft-start time ( $t_{SS_x}$ ) (where  $x = A, B, C,$  or  $D$ ), and PON\_SEQ\_DELAY0 time to execute the power-on sequence. Before enabling each channel, the MPM54524 loads the default voltage of each channel from the multiple-time programmable (MTP) memory registers.

$t_{SS_x}$  for each channel can be configured via 13h.

### Power-Off Sequence

If the EN pin is logic low or  $V_{INx}$  is below its UVLO threshold, the MPM54524 enters the power-off sequence set via 1Dh to 23h. Figure 3 on page 17 shows the power-off sequence. After each channel finishes its off delay, the MPM54524 turns off each channel sequentially with discharge or soft shutdown if the two functions are enabled. The discharge enable/disable function and discharge resistor can be configured via 0Eh. The soft shutdown enable/disable and  $t_{SS_x}$  can be configured via 11h, bits[7:4] and 12h, bits[7:0].

During the power-off sequence at falling UVLO, if rising UVLO is detected again, all the channels continue to execute the power-off sequence, then turn on sequentially based on the new power-on sequence.

### Pre-Biased Start-Up

The MPM54524 is designed for monotonic start-up into pre-biased loads. If the output is pre-biased to a set voltage during start-up, the internal bootstrap (BST) voltage ( $V_{BST}$ ) is refreshed and charged, and the voltage on the internal soft-start capacitor ( $C_{SS}$ ) is charged as well. If  $V_{BST}$  exceeds its rising threshold, and the



$C_{SS}$  voltage exceeds the sensed output voltage ( $V_{OUTx}$ ) (where  $x = A, B, C,$  or  $D$ ) at the feedback pin ( $VSA+, VSB+, VSC+,$  or  $VSD+$ ), then the part starts to work normally.

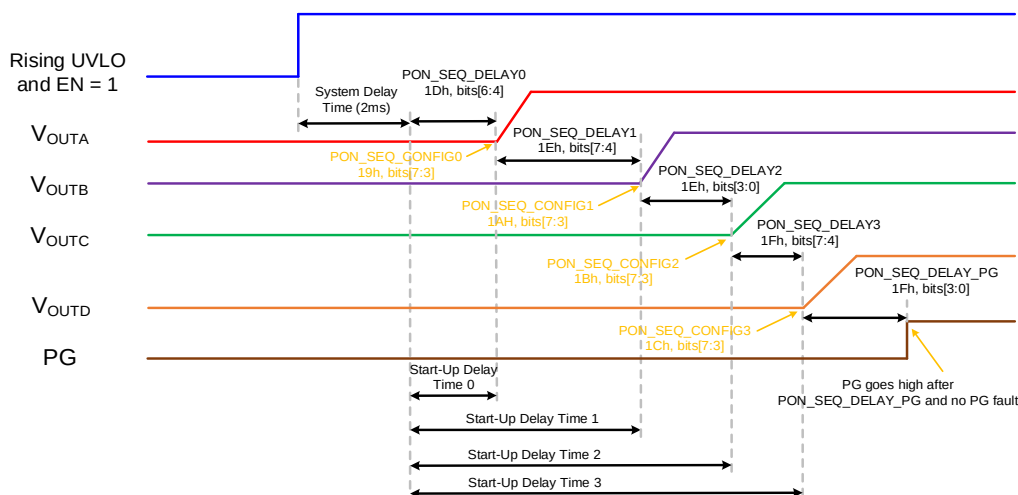
### Power Good (PG)

The MPM54524 provides a power good (PG) output to indicate whether the enabled buck's  $V_{OUTx}$  is ready. The PG pin is an open-drain output. Connect PG to VCC or another voltage source via a pull up resistor (e.g. 10k $\Omega$ ). PG is pulled high after the PON\_SEQ\_DELAY\_PG bit,

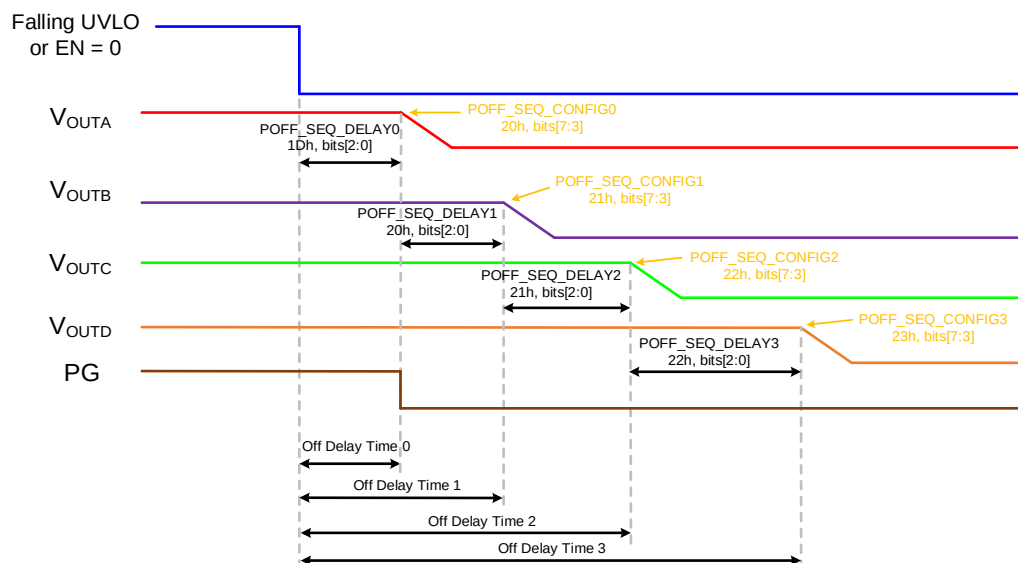
and all the channels finish soft start if they are enabled. During normal operation, PG is pulled low if any fault occurs.

### Output Over-Voltage Protection (OVP)

The MPM54524 monitors  $V_{OUTx}$  and enters OVP latch-off mode once  $V_{OUTx}$  exceeds the output OVP rising threshold ( $V_{OVP1\_H}$ ). After triggering output OVP, all the channels turn off and PG is low. The MPM54524 does not automatically start up again until the OV fault is removed and recycling power on EN is initiated.



**Figure 2: Power-On Sequence**



**Figure 3: Power-Off Sequence**

### V<sub>INX</sub> Over-Voltage Protection (OVP)

If 90h, bit[0] = 1 and V<sub>INX</sub> exceeds 15V for longer than 2μs, then the MPM54524 shuts down and VIN\_OV\_STATUS (00h, bit[1]) is set from 0 to 1. Even when the V<sub>INX</sub> over-voltage (OV) fault is removed, the MPM54524 does not automatically start up until recycling power on EN is initiated. VIN\_OV\_STATUS remains set to 1 until power is recycled on EN, or the host clears the fault by writing the clear bit to 1 in 07h, bit[1].

### Over-Current Protection (OCP) and Short-Circuit Protection (SCP)

The MPM54524 provides valley current limit control. When the low-side MOSFET (LS-FET) is on, the inductor current (I<sub>L</sub>) is monitored. If the sensed I<sub>L</sub> exceeds the valley current limit threshold, the device indicates an over-current (OC) fault via 2Ah. The high-side MOSFET (HS-FET) is not allowed to turn on until the valley current drops below the OC threshold. Meanwhile, V<sub>OUTX</sub> drops until it is below the under-voltage (UV) threshold.

Once the UV and OC conditions are triggered, OCP latches off the device. This means the MPM54524 disables the output power stage and does not automatically turn on again until the UV and OC faults are removed, and recycling power on EN is initiated.

### Output Discharge

To discharge the energy of the output capacitor (C<sub>OUT</sub>) during the power-off sequence, there is a discharge path between the VO<sub>x</sub> pin and ground (where x = A, B, C, or D). The discharge function can be enabled via the MTP interface. The discharge resistor can also be changed via the MTP interface.

### Soft Start (SS) and Soft Shutdown

The MPM54524 employs a soft start and soft shutdown mechanism to ensure smooth output during start-up and shutdown.

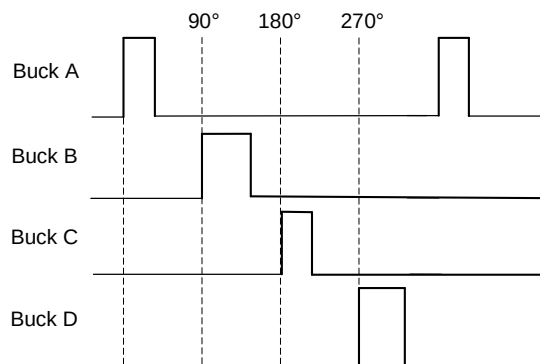
When the MPM54524 is enabled and V<sub>BST</sub> reaches its rising threshold, the internal digital-to-analog converter (DAC) outputs a ramp voltage as the reference voltage (V<sub>REF</sub>). V<sub>OUTX</sub> smoothly ramps up with V<sub>REF</sub>. Once the DAC output reaches the final voltage, it maintains a steady voltage. At this point, soft start finishes and enters steady-state operation.

When the MPM54524 is disabled, the internal DAC ramps down V<sub>REF</sub>. V<sub>OUTX</sub> follows the soft shutdown slew rate with V<sub>REF</sub> until the output drops to 0.15V. Then soft shutdown stops, and the output is discharged via a 30Ω discharge resistor.

The start-up delay, shutdown delay, soft-start and soft shutdown slew rate can be configured via the MTP.

### Out-of-Phase Operation

Figure 4 shows that buck regulator A (buck A), buck regulator B (buck B), buck regulator C (buck C), and buck regulator D (buck D) are frequency-locked with a fixed 90° phase shift, except for during interleaving mode.



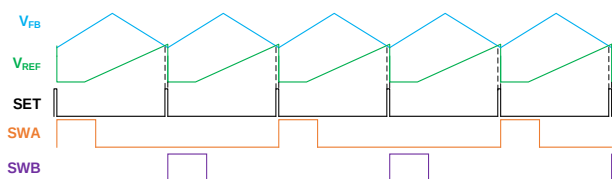
**Figure 4: Phase Shift Functional Diagram**

When buck A and buck B work in interleaving parallel mode, the phase shift between buck A and buck B changes to 180° (see Figure 5 on page 19). Buck C and buck D cannot work in interleaving mode, with the phase shift remaining at 90°.

### Interleaving Mode for Buck A and Buck B

The MPM54524 supports 2-phase interleaving mode for buck A and buck B by setting 14h, bit[5] = 1. VSA+ must be connected to VSB+ in interleaving mode.

Figure 5 on page 19 shows the internal SET signal that is triggered when buck A or buck B's feedback (FB) signal is smaller than the internal REF signal. When the SET signal becomes high, only one phase's pulse-width modulation (PWM) output becomes high; the next time SET goes high, the next phase's PWM output goes high. This achieves automatic interleaving.



**Figure 5: Dual-Phase Interleaving Mode**

When buck A and buck B work in dual phase interleaving mode, the MPM54524 senses two-phase current and automatically tunes the buck's on time ( $t_{ON}$ ) to achieve current balance actively.

### Active Voltage Positioning (AVP)

The MPM54524 supports active voltage positioning (AVP) by setting the AVP\_EN\_X/X bit (where  $x = A/B$  or  $C/D$ ) (71h, bit[7] and 79h, bit[7]) to 1 via the I<sup>2</sup>C. Once enabled,  $V_{OUTx}$  of the corresponding channel drops in proportion with the load current, which is determined using Equation (1) and Equation (2).

The droop voltage ( $V_{DROOP}$ ) can be calculated with Equation (1):

$$V_{DROOP} = I_{OUT} \times R_{DROOP} \quad (1)$$

Where  $R_{DROOP}$  is the droop resistance with a typical value of about 40mΩ.

$V_{OUTx}$  can be calculated with Equation (2):

$$V_{OUTx} = V_{REFx} - V_{DROOP} \quad (2)$$

Where  $V_{REFx}$  is the reference voltage of each channel.

The AVP functions enables on-demand parallel operation, where four outputs, three outputs, or two outputs can be connected in parallel in any combination without pre-setting any registers.

The current of the paralleled channels is inherently balanced by  $V_{DROOP}$ , which is generated by the AVP function.

### Thermal Shutdown

The MPM54524 employs thermal shutdown by internally monitoring the junction temperature ( $T_J$ ). If  $T_J$  exceeds the 145°C threshold, the MPM54524 shuts down based on the soft shutdown ramping down slew rate. This is a non-latch protection. There is a hysteresis of about 20°C. Once  $T_J$  drops to about 125°C, the MPM54524 initiates a soft start.

### Analog-to-Digital Converter (ADC)

The MPM54524 supports the analog-to-digital converter (ADC) to monitor the regulator's  $V_{INx}$ ,  $V_{OUTx}$ , output current ( $I_{OUTx}$ ), and output power ( $P_{OUTx}$ ) (where  $x = A, B, C$ , or  $D$ ).

### Multiple-Time Programmable (MTP) Configuration

After the MPM54524's  $V_{INx}$  starts up, the system-on-chip (SoC) configures the MPM54524's I<sup>2</sup>C register and MTP.

See the I<sup>2</sup>C Interface section on page 20 for more details on identifying a valid slave address. When the SoC writes to the I<sup>2</sup>C register, the I<sup>2</sup>C register takes effect immediately; it can also be burned into the MTP. During the buck's normal operation, the I<sup>2</sup>C master can read and write the register's data online.

## I<sup>2</sup>C INTERFACE

### I<sup>2</sup>C Serial Interface

The I<sup>2</sup>C is a 2-wire, bidirectional, serial interface consisting of a data line (SDA) and a clock line (SCL). The lines are pulled to a bus voltage externally when they are idle. When connecting to the line, a master device generates the SCL signal and device address, then arranges the communication sequence. The MPM54524 interface is an I<sup>2</sup>C slave. The I<sup>2</sup>C interface adds flexibility to the power supply solution.

### I<sup>2</sup>C Address Selection

Two ADDR pins are available to configure bit[0] to bit[3] of the I<sup>2</sup>C slave address according to Table 1, where bit[4] to bit[6] can be modified by writing to 73h, bit[1] to bit[3], respectively. Table 1 shows the I<sup>2</sup>C address setting via the ADDR1 and ADDR2 pins.

**Table 1: I<sup>2</sup>C Address Setting via the ADDR1 and ADDR2 Pins**

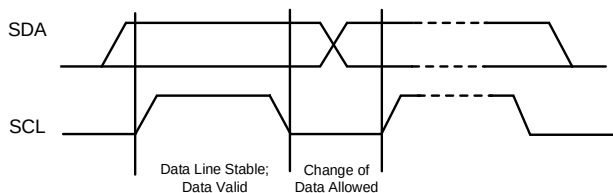
| ADDR1 | ADDR2 | I <sup>2</sup> C Address  |
|-------|-------|---------------------------|
| Low   | Low   | 0XXX 1001 <sup>(12)</sup> |
| Low   | Float | 0XXX 1100 <sup>(12)</sup> |
| Low   | High  | 0XXX 1110 <sup>(12)</sup> |
| Float | Low   | 0XXX 1010 <sup>(12)</sup> |
| Float | Float | 0XXX 1000 <sup>(12)</sup> |
| Float | High  | 0XXX 1111 <sup>(12)</sup> |
| High  | Low   | 0XXX 1011 <sup>(12)</sup> |
| High  | Float | 0XXX 1101 <sup>(12)</sup> |
| High  | High  | 0XXX 0111 <sup>(12)</sup> |

**Note:**

12) "XXX" refers to the portion of the address that can be configured by the customer.

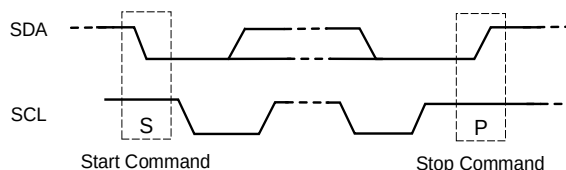
### Data Validity

One clock pulse is generated for each data bit transferred. The data on the SDA line must be stable during the clock's high period. The high or low state of the data line can only change when the clock signal on the SCL line is low (see Figure 6).



**Figure 6: Bit Transfer on the I<sup>2</sup>C Bus**

The start (S) and stop (P) commands are signaled by the master device, which signifies the beginning and the end of the I<sup>2</sup>C transfer. The start command is defined as the SDA signal transitioning from high to low while SCL is high. The stop command is defined as the SDA signal transitioning from low to high while SCL is high (see Figure 7).



**Figure 7: Start and Stop Commands**

Start and stop commands are always generated by the master. The bus is busy after the start condition, and it is considered to be free again a minimum of 4.7μs after the stop command. The bus remains busy if a repeated start (Sr) is generated instead of a stop command. The start and repeated start conditions are functionally identical.

### Transfer Data

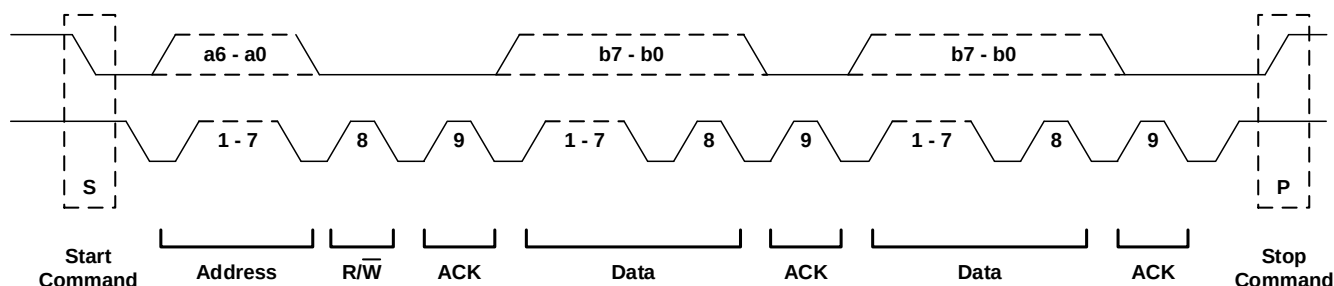
Every byte put on the SDA line must be 8 bits long. Each byte must be followed by an acknowledge (ACK) bit. The acknowledge-related clock pulse is generated by the master. The transmitter releases the SDA line (high) during the acknowledge clock pulse. The receiver must pull down the SDA line during the acknowledge clock pulse so that it remains stable low during the clock pulse's high period.

Figure 8 on page 21 shows the data transfer format. After the start command, a slave address is sent. This address is 7 bits, followed by an 8th data direction bit (R/W). A 0 indicates a transmission (write), and a 1 indicates a request for data (read). A data transfer is always terminated by a stop command, which is generated by the master. If the master still wants to communicate on the bus, it can generate a repeated start command and address another slave without first generating a stop command.

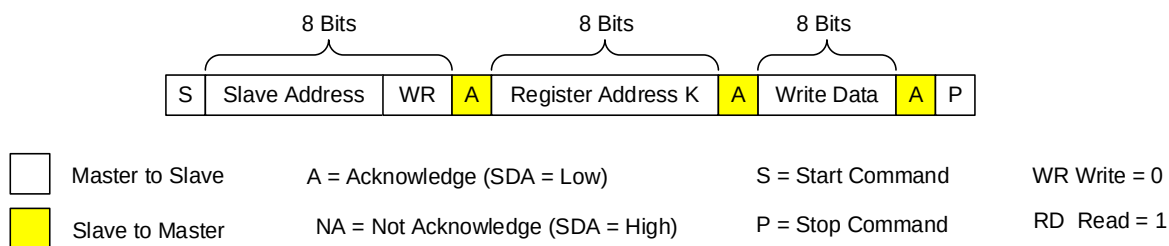
The MPM54524 requires a start command, a valid I<sup>2</sup>C address, register address byte, and data byte for a single data update. After receiving each byte, the MPM54524 acknowledges by pulling the SDA line low during a single clock pulse's high period. A valid I<sup>2</sup>C address selects

the MPM54524. The MPM54524 performs an update on the LSB byte's falling edge.

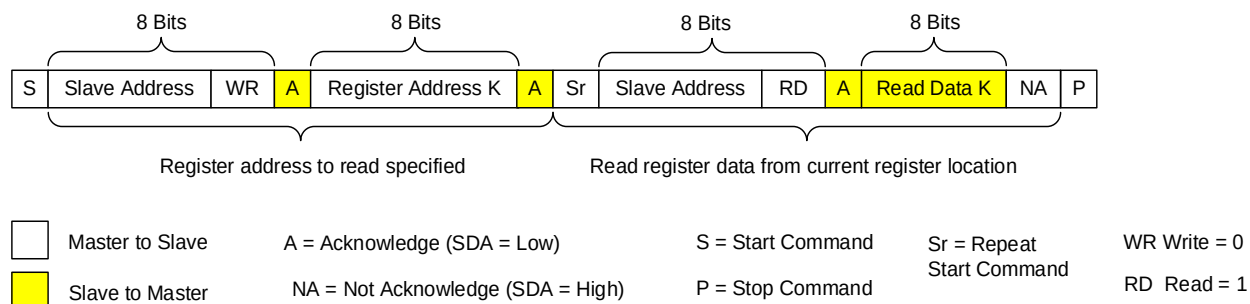
Figure 9 shows an example of writing to a single register. Figure 10 shows an example of reading to a single register.



**Figure 8: Complete Data Transfer**



**Figure 9: I<sup>2</sup>C Write Single Register Example**



**Figure 10: I<sup>2</sup>C Read Single Register Example**

## SUPPORTED PMBUS COMMANDS

| Command Code | Command Name            | Type | Bytes |
|--------------|-------------------------|------|-------|
| 00h          | STATUS_0                | R    | 1     |
| 01h          | STATUS_1                | R    | 1     |
| 02h          | BUCKA_CURRENT/PWR_METER | R    | 1     |
| 03h          | BUCKB_CURRENT/PWR_METER | R    | 1     |
| 04h          | BUCKC_CURRENT/PWR_METER | R    | 1     |
| 05h          | BUCKD_CURRENT/PWR_METER | R    | 1     |
| 06h          | BUCKX_VOLTAGE           | R    | 1     |
| 07h          | CLEAR_0                 | Send | 1     |
| 08h          | CLEAR_1                 | Send | 1     |
| 09h          | MASK_0                  | R/W  | 1     |
| 0Ah          | MASK_1                  | R/W  | 1     |
| 0Bh          | REMOTE_REG              | R/W  | 1     |
| 0Ch          | BUCKX_CTRL_REG          | R/W  | 1     |
| 0Dh          | PG_REG                  | R/W  | 1     |
| 0Eh          | DISCHARGE_R_REG         | R/W  | 1     |
| 0Fh          | SW_FREQ_REG             | R/W  | 1     |
| 10h          | MONITOR_EN_REG          | R/W  | 1     |
| 11h          | SOFT_STOP_EN_REG        | R/W  | 1     |
| 12h          | SOFT_STOP_REG           | R/W  | 1     |
| 13h          | SOFT_START_REG          | R/W  | 1     |
| 14h          | PROTECT_REG             | R/W  | 1     |
| 15h          | BUCKA_VOUT              | R/W  | 1     |
| 16h          | BUCKB_VOUT              | R/W  | 1     |
| 17h          | BUCKC_VOUT              | R/W  | 1     |
| 18h          | BUCKD_VOUT              | R/W  | 1     |
| 19h          | PON_CONFIG_0            | R/W  | 1     |
| 1Ah          | PON_CONFIG_1            | R/W  | 1     |
| 1Bh          | PON_CONFIG_2            | R/W  | 1     |
| 1Ch          | PON_CONFIG_3            | R/W  | 1     |
| 1Dh          | PON_OFF_DELAY0          | R/W  | 1     |
| 1Eh          | PON_SEQ_DELAY_1_2       | R/W  | 1     |
| 1Fh          | PON_SEQ_DELAY_3_PG      | R/W  | 1     |
| 20h          | POFF_SEQ_CONFIG_0       | R/W  | 1     |
| 21h          | POFF_SEQ_CONFIG_1       | R/W  | 1     |
| 22h          | POFF_SEQ_CONFIG_2       | R/W  | 1     |
| 23h          | POFF_SEQ_CONFIG_3       | R/W  | 1     |
| 24h          | ADC_TEMP                | R    | 1     |
| 25h          | VOUT_RANGE_SELECT       | R/W  | 1     |
| 26h          | CLP_BUCKX               | R/W  | 1     |
| 2Ah          | OC_STATUS_CLEAR         | R/W  | 1     |
| 30h          | MTP_AUTO_REG            | R/W  | 1     |

## SUPPORTED PMBUS COMMANDS *(continued)*

| Command Code | Command Name               | Type | Bytes |
|--------------|----------------------------|------|-------|
| 31h          | PART_ID                    | R    | 1     |
| 35h          | CODE_ID                    | R    | 1     |
| 36h          | CODE_VERSION               | R    | 1     |
| 71h          | ACTIVE_POSITION_ENABLE_A/B | R/W  | 1     |
| 73h          | I2C_ADDRESS                | R/W  | 1     |
| 79h          | ACTIVE_POSITION_ENABLE_C/D | R/W  | 1     |
| 90h          | VIN_OV_REG                 | R/W  | 1     |
| AFh          | VIN_UVLO_REG               | R/W  | 1     |



## REGISTER MAP

### Status Registers

The status registers are updated to 1 if an event occurs, and they remain at 1 until the clear command is generated by the host, even if the failing condition is no longer present. In addition, when the input voltage ( $V_{INx}$ ) (where  $x = A, B, C,$  or  $D$ ) drops below its under-voltage lockout (UVLO) threshold, the status register is initialized to 0. The PWR\_GOOD interrupt may be generated by the MPM54524 at the same time, depending on the type of event. The interrupts are only generated if they are not masked.

All read-only (RO) registers are one-time latched registers, meaning that once the MPM54524 sets the register flag, the host must explicitly clear the register. The MPM54524 does not automatically update the registers even if the event that triggered the status is no longer present.

### STATUS\_0 (00h)

**Format:** Unsigned binary

The STATUS\_0 command monitors statuses including over-temperature (OT), buck output power not good, and  $V_{INx}$  over-voltage (OV).

| Bits | Access | Bit Name                    | Default | Description                                                                                           |
|------|--------|-----------------------------|---------|-------------------------------------------------------------------------------------------------------|
| 7    | R      | RESERVED                    | N/A     | Reserved.                                                                                             |
| 6    | R      | OVER_TEMP_STATUS            | 1'b0    | 1'b0: No critical temperature shutdown occurs<br>1'b1: A critical temperature shutdown occurs         |
| 5    | R      | BUCKA_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b0: The buck regulator A (buck A)'s output is power good<br>1'b1: Buck A's output is power not good |
| 4    | R      | BUCKB_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b0: The buck regulator B (buck B)'s output is power good<br>1'b1: Buck B's output is power not good |
| 3    | R      | BUCKC_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b0: The buck regulator C (buck C)'s output is power good<br>1'b1: Buck C's output is power not good |
| 2    | R      | BUCKD_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b0: The buck regulator D (buck D)'s output is power good<br>1'b1: Buck D's output is power not good |
| 1    | R      | VIN_OV_STATUS               | 1'b0    | 1'b0: No $V_{IN}$ OV fault occurs<br>1'b1: A $V_{IN}$ OV fault occurs                                 |
| 0    | R      | RESERVED                    | N/A     | Reserved.                                                                                             |

### STATUS\_1 (01h)

**Format:** Unsigned binary

The STATUS\_1 command monitors buck x output's OV and under-voltage (UV) status (where  $x = A, B, C,$  or  $D$ ).

| Bits | Access | Bit Name        | Default | Description                                                                                |
|------|--------|-----------------|---------|--------------------------------------------------------------------------------------------|
| 7    | R      | BUCKA_OV_STATUS | 1'b0    | 1'b0: Buck A's output indicates no OV fault<br>1'b1: Buck A's output indicates an OV fault |
| 6    | R      | BUCKB_OV_STATUS | 1'b0    | 1'b0: Buck B's output indicates no OV fault<br>1'b1: Buck B's output indicates an OV fault |
| 5    | R      | BUCKC_OV_STATUS | 1'b0    | 1'b0: Buck C's output indicates no OV fault<br>1'b1: Buck C's output indicates an OV fault |
| 4    | R      | BUCKD_OV_STATUS | 1'b0    | 1'b0: Buck D's output indicates no OV fault<br>1'b1: Buck D's output indicates an OV fault |
| 3    | R      | BUCKA_UV_STATUS | 1'b0    | 1'b0: Buck A's output indicates no UV fault<br>1'b1: Buck A's output indicates an UV fault |

|   |   |                 |      |                                                                                            |
|---|---|-----------------|------|--------------------------------------------------------------------------------------------|
| 2 | R | BUCKB_UV_STATUS | 1'b0 | 1'b0: Buck B's output indicates no UV fault<br>1'b1: Buck B's output indicates an UV fault |
| 1 | R | BUCKC_UV_STATUS | 1'b0 | 1'b0: Buck C's output indicates no UV fault<br>1'b1: Buck C's output indicates an UV fault |
| 0 | R | BUCKD_UV_STATUS | 1'b0 | 1'b0: Buck D's output indicates no UV fault<br>1'b1: Buck D's output indicates an UV fault |

### BUCKA\_CURRENT/PWR\_METER (02h)

**Format:** Direct

The BUCKA\_CURRENT/PWR\_METER command monitors buck A's output current ( $I_{OUTA}$ ) and output power ( $P_{OUTA}$ ).

| Bits | Access | Bit Name                | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------|--------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R      | BUCKA_ADC_CURRENT/POWER | <p>If 10h, bit[3] = 0, this measures buck A's <math>I_{OUTA}</math> or <math>P_{OUTA}</math>. The <math>I_{OUTA}</math> analog-to-digital converter (ADC) report values are listed below:</p> <p>8'b 0000 0000: Reserved<br/> 8'b 0000 0001: 0.125A or 125mW<br/> 8'b 0000 0010: 0.25A or 250mW<br/> 8'b 0000 0011: 0.375A or 375mW<br/> .....<br/> 8'b 0011 1100 = 7.5A or 7500mW<br/> 8'b 0011 1101 = 7.625A or 7625mW<br/> 8'b 0011 1110 = 7.75A or 7750mW<br/> 8'b 0011 1111 <math>\geq</math> 7.875A or 7875mW</p> <p>If 10h, bit[3] = 1, this indicates the sum of <math>P_{OUTA}</math>, buck B's output power (<math>P_{OUTB}</math>), buck C's output power (<math>P_{OUTC}</math>), and buck D's output power (<math>P_{OUTD}</math>).</p> <p>8'b 0000 0000: Reserved<br/> 8'b 0000 0001: 125mW<br/> 8'b 0000 0010: 250mW<br/> 8'b 0000 0011: 375mW<br/> .....<br/> 8'b 1111 1100 = 31500mW<br/> 8'b 1111 1101 = 31625mW<br/> 8'b 1111 1110 = 31750mW<br/> 8'b 1111 1111 <math>\geq</math> 31875mW</p> |

### BUCKB\_CURRENT/PWR\_METER (03h)

**Format:** Direct

The BUCKB\_CURRENT/PWR\_METER command monitors buck B's output current ( $I_{OUTB}$ ) and  $P_{OUTB}$ .

| Bits | Access | Bit Name                | Description                                                                                                                                                                                                                                                                                                                                                                                                             |
|------|--------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R      | BUCKB_ADC_CURRENT/POWER | <p>The <math>I_{OUTB}</math> or <math>P_{OUTB}</math> ADC report values are listed below:</p> <p>8'b 0000 0000: Reserved<br/> 8'b 0000 0001: 0.125A or 125mW<br/> 8'b 0000 0010: 0.25A or 250mW<br/> 8'b 0000 0011: 0.375A or 375mW<br/> .....<br/> 8'b 0011 1100 = 7.5A or 7500mW<br/> 8'b 0011 1101 = 7.625A or 7625mW<br/> 8'b 0011 1110 = 7.75A or 7750mW<br/> 8'b 0011 1111 <math>\geq</math> 7.875A or 7875mW</p> |

**BUCKC\_CURRENT/PWR\_METER (04h)****Format:** DirectThe BUCKC\_CURRENT/PWR\_METER command monitors buck C's output current ( $I_{OUTC}$ ) and  $P_{OUTC}$ .

| Bits | Access | Bit Name                | Description                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------|--------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R      | BUCKC_ADC_CURRENT/POWER | <p>The <math>I_{OUTC}</math> or <math>P_{OUTC}</math> ADC report values are listed below:</p> <p>8'b 0000 0000: Reserved</p> <p>8'b 0000 0001: 0.125A or 125mW</p> <p>8'b 0000 0010: 0.25A or 250mW</p> <p>8'b 0000 0011: 0.375A or 375mW</p> <p>.....</p> <p>8'b 0011 1100 = 7.5A or 7500mW</p> <p>8'b 0011 1101 = 7.625A or 7625mW</p> <p>8'b 0011 1110 = 7.75A or 7750mW</p> <p>8'b 0011 1111 <math>\geq</math> 7.875A or 7875mW</p> |

**BUCKD\_CURRENT/PWR\_METER (05h)****Format:** DirectThe BUCKD\_CURRENT/PWR\_METER command monitors buck D's output current ( $I_{OUTD}$ ) and  $P_{OUTD}$ .

| Bits | Access | Bit Name                | Description                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------|--------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R      | BUCKD_ADC_CURRENT/POWER | <p>The <math>I_{OUTD}</math> or <math>P_{OUTD}</math> ADC report values are listed below:</p> <p>8'b 0000 0000: Reserved</p> <p>8'b 0000 0001: 0.125A or 125mW</p> <p>8'b 0000 0010: 0.25A or 250mW</p> <p>8'b 0000 0011: 0.375A or 375mW</p> <p>.....</p> <p>8'b 0011 1100 = 7.5A or 7500mW</p> <p>8'b 0011 1101 = 7.625A or 7625mW</p> <p>8'b 0011 1110 = 7.75A or 7750mW</p> <p>8'b 0011 1111 <math>\geq</math> 7.875A or 7875mW</p> |

**BUCKX\_VOLTAGE (06h)****Format:** DirectThe BUCKX\_VOLTAGE command monitors  $V_{OUTX}$ .

| Bits | Access | Bit Name          | Description                                                                                                                                                                                                       |
|------|--------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R      | BUCKX_ADC_VOLTAGE | <p>Changes <math>V_{OUTX}</math> based on 10h, bits[6:5].</p> <p>8'b 0000 0000 = Undefined</p> <p>8'b 0000 0001 = 15mV</p> <p>8'b 0000 0010 = 30mV</p> <p>.....</p> <p>8'b 1111 1111 <math>\geq</math> 3825mV</p> |

**Clear Registers**

For each real-time status register (00h and 01h), the MPM54524 offers a way to clear the status of events. All clear registers are write-1-to-clear (W1C) registers. If 1 is written to any of the clear registers, the MPM54524 updates the status registers to the default state and removes the interrupt condition on the PWR\_GOOD output signal, assuming that the event is no longer present. If the failing condition is still present, the status register remains at 1. Note that the PWR\_GOOD interrupt is only applicable if the event is not masked.

The MPM54524 offers a global clear command by writing 1 to 07h, bit[0]. This command works the same way as the individual clear command. This command can be used by the host if more than one clear command is required to different registers.

**CLEAR\_0 (07h)**

**Format:** Unsigned binary

The CLEAR\_0 command clears the buck's output power not good and V<sub>INx</sub> over-voltage protection (OVP) status, in addition to providing a global clear.

| Bits | Access | Bit Name                          | Default | Description                                  |
|------|--------|-----------------------------------|---------|----------------------------------------------|
| 7:6  | R      | RESERVED                          | N/A     | Reserved.                                    |
| 5    | R/W    | CLEAR_BUCKA_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Clears the status of 00h, bit[5]       |
| 4    | R/W    | CLEAR_BUCKB_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Clears the status of 00h, bit[4]       |
| 3    | R/W    | CLEAR_BUCKC_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Clears the status of 00h, bit[3]       |
| 2    | R/W    | CLEAR_BUCKD_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Clears the status of 00h, bit[2]       |
| 1    | R/W    | CLEAR_VIN_OVP_STATUS              | 1'b0    | 1'b1: Clears the status of 00h, bit[1]       |
| 0    | R/W    | CLEAR_GLOBAL                      | 1'b0    | 1'b1: Clears all the statuses of 00h and 01h |

**CLEAR\_1 (08h)**

**Format:** Unsigned binary

The CLEAR\_1 command clears the buck x's OV and UV status (where x = A, B, C, or D).

| Bits | Access | Bit Name              | Default | Description                            |
|------|--------|-----------------------|---------|----------------------------------------|
| 7    | R/W    | CLEAR_BUCKA_OV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[7] |
| 6    | R/W    | CLEAR_BUCKB_OV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[6] |
| 5    | R/W    | CLEAR_BUCKC_OV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[5] |
| 5    | R/W    | CLEAR_BUCKD_OV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[4] |
| 3    | R/W    | CLEAR_BUCKA_UV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[3] |
| 2    | R/W    | CLEAR_BUCKB_UV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[2] |
| 1    | R/W    | CLEAR_BUCKC_UV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[1] |
| 0    | R/W    | CLEAR_BUCKD_UV_STATUS | 1'b0    | 1'b1: Clears the status of 01h, bit[0] |

## Mask Registers

For each real-time status register, the MPM54524 offers a way to mask the status of events.

### **MASK\_0 (09h)**

**Format:** Unsigned binary

The MASK\_0 command masks buck x's output power not good and the V<sub>INx</sub> OVP status.

| Bits | Access | Bit Name                         | Default | Description                           |
|------|--------|----------------------------------|---------|---------------------------------------|
| 7:6  | R      | RESERVED                         | N/A     | Reserved.                             |
| 5    | R/W    | MASK_BUCKA_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Masks the status of 00h, bit[5] |
| 4    | R/W    | MASK_BUCKB_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Masks the status of 00h, bit[4] |
| 3    | R/W    | MASK_BUCKC_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Masks the status of 00h, bit[3] |
| 2    | R/W    | MASK_BUCKD_POWER_NOT_GOOD_STATUS | 1'b0    | 1'b1: Masks the status of 00h, bit[2] |
| 1    | R/W    | MASK_VIN_OVP_STATUS              | 1'b0    | 1'b1: Masks the status of 00h, bit[1] |
| 0    | R      | RESERVED                         | N/A     | Reserved.                             |

### **MASK\_1 (0Ah)**

**Format:** Unsigned binary

The MASK\_1 command masks buck x's output OV and over-current (OC) status.

| Bits | Access | Bit Name             | Default | Description                           |
|------|--------|----------------------|---------|---------------------------------------|
| 7    | R/W    | MASK_BUCKA_OV_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[7] |
| 6    | R/W    | MASK_BUCKB_OV_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[6] |
| 5    | R/W    | MASK_BUCKC_OV_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[5] |
| 4    | R/W    | MASK_BUCKD_OV_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[4] |
| 3    | R/W    | MASK_BUCKA_OC_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[3] |
| 2    | R/W    | MASK_BUCKB_OC_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[2] |
| 1    | R/W    | MASK_BUCKC_OC_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[1] |
| 0    | R      | MASK_BUCKD_OC_STATUS | 1'b0    | 1'b1: Masks the status of 01h, bit[0] |

## Threshold and Configuration Registers

### REMOTE\_REG (0Bh)

**Format:** Unsigned binary

The REMOTE\_REG command sets buck x's remote sensing.

| Bits | Access | Bit Name        | Default | Description                                                                                       |
|------|--------|-----------------|---------|---------------------------------------------------------------------------------------------------|
| 7    | R/W    | BUCKA_REMOTE_EN | 1'b0    | Selects buck A's remote sensing.<br>1'b0: Disables remote sensing<br>1'b1: Enables remote sensing |
| 6    | R/W    | BUCKB_REMOTE_EN | 1'b0    | Selects buck's B remote sensing.<br>1'b0: Disables remote sensing<br>1'b1: Enables remote sensing |
| 5    | R/W    | BUCKC_REMOTE_EN | 1'b0    | Selects buck C's remote sensing.<br>1'b0: Disables remote sensing<br>1'b1: Enables remote sensing |
| 4:0  | R      | RESERVED        | N/A     | Reserved.                                                                                         |

### BUCKX\_CTRL\_REG (0Ch)

**Format:** Unsigned binary

The BUCKx\_CTRL\_REG command sets buck x's output regulator in pulse-frequency modulation (PFM) or pulse-width modulation (PWM) mode.

| Bits | Access | Bit Name  | Default | Description                                                                                  |
|------|--------|-----------|---------|----------------------------------------------------------------------------------------------|
| 7    | R/W    | BUCKA_EN  | 1'b1    | Enables buck A's output regulator.<br>1'b 0: Disabled<br>1'b 1: Enabled                      |
| 6    | R/W    | BUCKB_EN  | 1'b1    | Enables buck B's output regulator.<br>1'b0: Disabled<br>1'b1: Enabled                        |
| 5    | R/W    | BUCKC_EN  | 1'b1    | Enables buck C's output regulator.<br>1'b0: Disabled<br>1'b1: Enabled                        |
| 4    | R/W    | BUCKD_EN  | 1'b1    | Enables buck D's output regulator.<br>1'b0: Disabled<br>1'b1: Enabled                        |
| 3    | R/W    | PWM_BUCKA | 1'b0    | Sets buck A's automatic mode or forced PWM mode.<br>1'b0: Forced PWM<br>1'b1: Automatic mode |
| 2    | R/W    | PWM_BUCKB | 1'b0    | Sets buck B's automatic mode or forced PWM mode.<br>1'b0: Forced PWM<br>1'b1: Automatic mode |
| 1    | R/W    | PWM_BUCKC | 1'b0    | Sets buck C's automatic mode or forced PWM mode.<br>1'b0: Forced PWM<br>1'b1: Automatic mode |

|   |     |           |      |                                                                                              |
|---|-----|-----------|------|----------------------------------------------------------------------------------------------|
| 0 | R/W | PWM_BUCKD | 1'b0 | Sets buck D's automatic mode or forced PWM mode.<br>1'b0: Forced PWM<br>1'b1: Automatic mode |
|---|-----|-----------|------|----------------------------------------------------------------------------------------------|

### PG\_REG (0Dh)

**Format:** Unsigned binary

The PG\_REG command sets buck x's power good (PG) threshold.

| Bits | Access | Bit Name   | Default | Description                                                 |
|------|--------|------------|---------|-------------------------------------------------------------|
| 7    | R      | RESERVED   | N/A     | Reserved.                                                   |
| 6    | R      | RESERVED   | N/A     | Reserved.                                                   |
| 5    | R      | RESERVED   | N/A     | Reserved.                                                   |
| 4    | R      | RESERVED   | N/A     | Reserved.                                                   |
| 3    | R/W    | PG_%_BUCKA | 1'b0    | Sets the PG threshold for buck A.<br>1'b0 = 5%<br>1'b1 = 7% |
| 2    | R/W    | PG_%_BUCKB | 1'b0    | Sets the PG threshold for buck B.<br>1'b0 = 5%<br>1'b1 = 7% |
| 1    | R/W    | PG_%_BUCKC | 1'b0    | Sets the PG threshold for buck C.<br>1'b0 = 5%<br>1'b1 = 7% |
| 0    | R/W    | PG_%_BUCKD | 1'b0    | Sets the PG threshold for buck D<br>1'b0 = 5%<br>1'b1 = 7%  |

### DISCHARGE\_R\_REG (0Eh)

**Format:** Unsigned binary

The DISCHARGE\_R\_REG command sets buck x's automatic discharge mode and discharge resistance.

| Bits | Access | Bit Name  | Default | Description                                                                               |
|------|--------|-----------|---------|-------------------------------------------------------------------------------------------|
| 7    | R/W    | AUTODIS_1 | 1'b1    | Sets the automatic discharge mode for buck A.<br>1'b 0: No discharge<br>1'b 1: Discharges |
| 6    | R/W    | AUTODIS_2 | 1'b1    | Sets the automatic discharge mode for buck B.<br>1'b 0: No discharge<br>1'b 1: Discharges |
| 5    | R/W    | AUTODIS_3 | 1'b1    | Sets the automatic discharge mode for buck C.<br>1'b 0: No discharge<br>1'b 1: Discharges |
| 4    | R/W    | AUTODIS_4 | 1'b1    | Sets the automatic discharge mode for buck D.<br>1'b 0: No discharge<br>1'b 1: Discharges |
| 3    | R/W    | DIS_R_1   | 1'b1    | Sets the discharge resistance for buck A.<br>1'b0: 10Ω<br>1'b1: 2Ω                        |



|   |     |         |      |                                                                    |
|---|-----|---------|------|--------------------------------------------------------------------|
| 2 | R/W | DIS_R_2 | 1'b1 | Sets the discharge resistance for buck B.<br>1'b0: 10Ω<br>1'b1: 2Ω |
| 1 | R/W | DIS_R_3 | 1'b1 | Sets the discharge resistance for buck C.<br>1'b0: 10Ω<br>1'b1: 2Ω |
| 0 | R/W | DIS_R_4 | 1'b1 | Sets the discharge resistance for buck D.<br>1'b0: 10Ω<br>1'b1: 2Ω |

### SW\_FREQ\_REG (0Fh)

**Format:** Unsigned binary

The SW\_FREQ\_REG command sets buck x's switching frequency ( $f_{sw}$ ).

| Bits | Access | Bit Name                                   | Default | Description                                                                                                     |
|------|--------|--------------------------------------------|---------|-----------------------------------------------------------------------------------------------------------------|
| 7:6  | R/W    | BUCKA_OUTPUT_REGULATOR_SWITCHING_FREQUENCY | 2'b10   | Sets buck A's output regulator $f_{sw}$ .<br>2'b00: 500kHz<br>2'b01: 750kHz<br>2'b10: 1000kHz<br>2'b11: 1250kHz |
| 5:4  | R/W    | BUCKB_OUTPUT_REGULATOR_SWITCHING_FREQUENCY | 2'b10   | Sets buck B's output regulator $f_{sw}$ .<br>2'b00: 500kHz<br>2'b01: 750kHz<br>2'b10: 1000kHz<br>2'b11: 1250kHz |
| 3:2  | R/W    | BUCKC_OUTPUT_REGULATOR_SWITCHING_FREQUENCY | 2'b10   | Sets buck C's output regulator $f_{sw}$ .<br>2'b00: 500kHz<br>2'b01: 750kHz<br>2'b10: 1000kHz<br>2'b11: 1250kHz |
| 1:0  | R/W    | BUCKD_OUTPUT_REGULATOR_SWITCHING_FREQUENCY | 2'b10   | Sets buck D's output regulator $f_{sw}$ .<br>2'b00: 500kHz<br>2'b01: 750kHz<br>2'b10: 1000kHz<br>2'b11: 1250kHz |

### MONITOR\_EN\_REG (10h)

**Format:** Unsigned binary

The MONITOR\_EN\_REG command enables  $V_{OUTx}$  and  $I_{OUTx}$  monitoring.

| Bits | Access | Bit Name  | Default | Description                                                                                        |
|------|--------|-----------|---------|----------------------------------------------------------------------------------------------------|
| 7    | R/W    | MON_V_EN  | 1'b1    | Enables $V_{OUTx}$ monitoring.<br>1'b0: Disabled<br>1'b1: Enabled                                  |
| 6:5  | R/W    | MON_V_SEL | 2'b00   | Selects $V_{OUTx}$ monitoring.<br>2'b00: Buck A<br>2'b01: Buck B<br>2'b10: Buck C<br>2'b11: Buck D |

|   |     |            |      |                                                                                                             |
|---|-----|------------|------|-------------------------------------------------------------------------------------------------------------|
| 4 | R/W | MON_IP_SEL | 1'b0 | Selects I <sub>OUTx</sub> or the power.<br>1'b0: Buck x's I <sub>OUTx</sub><br>1'b1: Buck x's power         |
| 3 | R/W | MON_TP_SEL | 1'b0 | Selects buck A's power or the total power.<br>1'b0: Buck A's I <sub>OUT</sub> or power<br>1'b1: Total power |
| 2 | R/W | MON_I_EN   | 1'b1 | Enables I <sub>OUTx</sub> monitoring.<br>1'b0: Disabled<br>1'b1: Enabled                                    |
| 1 | R   | RESERVED   | N/A  | Reserved.                                                                                                   |
| 0 | R   | RESERVED   | N/A  | Reserved.                                                                                                   |

### SOFT\_STOP\_EN\_REG (11h)

**Format:** Unsigned binary

The SOFT\_STOP\_EN\_REG command enables buck x's soft shutdown.

| Bits | Access | Bit Name        | Default | Description                                                          |
|------|--------|-----------------|---------|----------------------------------------------------------------------|
| 7    | R/W    | SOFT_STOP_BUCKA | 1'b0    | Enables soft shutdown for buck A.<br>1'b0: Disabled<br>1'b1: Enabled |
| 6    | R/W    | SOFT_STOP_BUCKB | 1'b0    | Enables soft shutdown for buck B.<br>1'b0: Disabled<br>1'b1: Enabled |
| 5    | R/W    | SOFT_STOP_BUCKC | 1'b0    | Enables soft shutdown for buck C.<br>1'b0: Disabled<br>1'b1: Enabled |
| 4    | R/W    | SOFT_STOP_BUCKD | 1'b0    | Enables soft shutdown for buck D.<br>1'b0: Disabled<br>1'b1: Enabled |
| 3:0  | R      | RESERVED        | N/A     | Reserved.                                                            |

### SOFT\_STOP\_REG (12h)

**Format:** Unsigned binary

The SOFT\_STOP\_REG command sets buck x's soft shutdown time.

| Bits | Access | Bit Name             | Default | Description                                                                                 |
|------|--------|----------------------|---------|---------------------------------------------------------------------------------------------|
| 7:6  | R/W    | SOFT_STOP_TIME_BUCKA | 2'b00   | Sets buck A's soft shutdown time.<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 2ms<br>2'b11: 4ms |
| 5:4  | R/W    | SOFT_STOP_TIME_BUCKB | 2'b00   | Sets buck B's soft shutdown time.<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 2ms<br>2'b11: 4ms |

|     |     |                      |       |                                                                                             |
|-----|-----|----------------------|-------|---------------------------------------------------------------------------------------------|
| 3:2 | R/W | SOFT_STOP_TIME_BUCKC | 2'b00 | Sets buck C's soft shutdown time.<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 2ms<br>2'b11: 4ms |
| 1:0 | R/W | SOFT_STOP_TIME_BUCKD | 2'b00 | Sets buck D's soft shutdown time.<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 2ms<br>2'b11: 4ms |

### SOFT\_START\_REG (13h)

**Format:** Unsigned binary

The SOFT\_START\_REG command sets buck x's soft-start time ( $t_{ss\_x}$ ).

| Bits | Access | Bit Name              | Default | Description                                                                                                |
|------|--------|-----------------------|---------|------------------------------------------------------------------------------------------------------------|
| 7:6  | R/W    | SOFT_START_TIME_BUCKA | 2'b11   | Sets buck A's soft-start time ( $t_{ss\_A}$ ).<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 1.5ms<br>2'b11: 2ms |
| 5:4  | R/W    | SOFT_START_TIME_BUCKB | 2'b11   | Sets buck B's soft-start time ( $t_{ss\_B}$ ).<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 1.5ms<br>2'b11: 2ms |
| 3:2  | R/W    | SOFT_START_TIME_BUCKC | 2'b11   | Sets buck C's soft-start time ( $t_{ss\_C}$ ).<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 1.5ms<br>2'b11: 2ms |
| 1:0  | R/W    | SOFT_START_TIME_BUCKD | 2'b11   | Sets buck D's soft-start time ( $t_{ss\_D}$ ).<br>2'b00: 0.5ms<br>2'b01: 1ms<br>2'b10: 1.5ms<br>2'b11: 2ms |

**PROTECT\_REG (14h)**
**Format:** Unsigned binary

The PROTECT\_REG command sets the protection functions and phase regulator mode for buck A or buck B.

| Bits | Access | Bit Name        | Default | Description                                                                                                       |
|------|--------|-----------------|---------|-------------------------------------------------------------------------------------------------------------------|
| 7    | R      | RESERVED        | N/A     | Reserved.                                                                                                         |
| 6    | R/W    | MTP_W           | 1'b0    | Sets the multiple-time programmable (MTP) memory write.<br>1'b0: Disabled<br>1'b1: Enabled                        |
| 5    | R/W    | BUCKA/B_DUAL_EN | 1'b0    | Selects phase regulator mode for buck A and buck B.<br>1'b0: Single-phase regulator<br>1'b1: Dual-phase regulator |
| 4:0  | R      | RESERVED        | N/A     | Reserved.                                                                                                         |

**BUCKA\_VOUT (15h)**
**Format:** Direct

The BUCKA\_VOUT command sets buck A's output voltage ( $V_{OUTA}$ ).

| Bits | Access | Bit Name           | Default | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------|--------|--------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R/W    | BUCKA_VOUT_SETTING | 0x8F    | <p>Sets <math>V_{OUTA}</math>. Note that the <math>V_{OUTA}</math> change slew rate is 1mV/<math>\mu</math>s.</p> <p>If 25h, bit[3] = 0, then buck A outputs a dynamic voltage scaling (DVS) range between 0.4V and 1.2V.</p> <p>0x00: 0.4V<br/> 0x01: 0.41V<br/> 0x02: 0.42V<br/> 0x03: 0.43V<br/> .....<br/> 0x4D: 1.17V<br/> 0x4E: 1.18V<br/> 0x4F: 1.19V<br/> 0x50: 1.2V<br/> Others are reserved (0x51 to 0xFF)</p> <p>If 25h, bit[3] = 1, then buck A outputs a DVS range between 1.2V and 3.6V.</p> <p>0x00: 1.2V<br/> 0x01: 1.215V<br/> 0x02: 1.23V<br/> 0x03: 1.245V<br/> .....<br/> 0x8C: 3.3V<br/> 0x8D: 3.315V<br/> 0x8E: 3.33V<br/> .....<br/> 0x9F: 3.585V<br/> 0xA0: 3.6V<br/> Others are reserved (0xA1 to 0xFF)</p> |

**BUCKB\_VOUT (16h)**
**Format:** Direct

The BUCKB\_VOUT command sets buck B's output voltage ( $V_{OUTB}$ ).

| Bits | Access | Bit Name           | Default | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------|--------|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R/W    | BUCKB_VOUT_SETTING | 0x8F    | <p>Sets <math>V_{OUTB}</math>. Note that the <math>V_{OUTB}</math> change slew rate is 1mV/<math>\mu</math>s.</p> <p>If 25h, bit[2] = 0, then buck B outputs a DVS range between 0.4V and 1.2V.</p> <p>0x00: 0.4V<br/> 0x01: 0.41V<br/> 0x02: 0.42V<br/> 0x03: 0.43V<br/> .....<br/> 0x4D: 1.17V<br/> 0x4E: 1.18V<br/> 0x4F: 1.19V<br/> 0x50: 1.2V<br/> Others are reserved (0x51 to 0xFF)</p> <p>If 25h, bit[2] = 1, then buck B outputs a DVS range between 1.2V and 3.6V.</p> <p>0x00: 1.2V<br/> 0x01: 1.215V<br/> 0x02: 1.23V<br/> 0x03: 1.245V<br/> .....<br/> 0x8C: 3.3V<br/> 0x8D: 3.315V<br/> 0x8E: 3.33V<br/> .....<br/> 0x9F: 3.585V<br/> 0xA0: 3.6V<br/> Others are reserved (0xA1 to 0xFF)</p> |

**BUCKC\_VOUT (17h)**
**Format:** Direct

The BUCKC\_VOUT command sets buck C's output voltage ( $V_{OUTC}$ ).

| Bits | Access | Bit Name           | Default | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------|--------|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R/W    | BUCKC_VOUT_SETTING | 0x8F    | <p>Sets <math>V_{OUTC}</math>. Note that the <math>V_{OUTC}</math> change slew rate is 1mV/<math>\mu</math>s.</p> <p>If 25h, bit[1] = 0, then buck C outputs a DVS range between 0.4V and 1.2V.</p> <p>0x00: 0.4V<br/> 0x01: 0.41V<br/> 0x02: 0.42V<br/> 0x03: 0.43V<br/> .....<br/> 0x4D: 1.17V<br/> 0x4E: 1.18V<br/> 0x4F: 1.19V<br/> 0x50: 1.2V<br/> Others are reserved (0x51 to 0xFF)</p> <p>If 25h, bit[1] = 1, then buck C outputs a DVS range between 1.2V and 3.6V.</p> <p>0x00: 1.2V<br/> 0x01: 1.215V<br/> 0x02: 1.23V<br/> 0x03: 1.245V<br/> .....<br/> 0x8C: 3.3V<br/> 0x8D: 3.315V<br/> 0x8E: 3.33V<br/> .....<br/> 0x9F: 3.585V<br/> 0xA0: 3.6V<br/> Others are reserved (0xA1 to 0xFF)</p> |

**BUCKD\_VOUT (18h)**
**Format:** Direct

The BUCKD\_VOUT command sets buck D's output voltage ( $V_{OUTD}$ ).

| Bits | Access | Bit Name           | Default | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------|--------|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | R/W    | BUCKD_VOUT_SETTING | 0x8F    | <p>Sets <math>V_{OUTD}</math>. Note that the <math>V_{OUTD}</math> change slew rate is 1mV/<math>\mu</math>s.</p> <p>If 25h, bit[0] = 0, then buck D outputs a DVS range between 0.4V and 1.2V.</p> <p>0x00: 0.4V<br/> 0x01: 0.41V<br/> 0x02: 0.42V<br/> 0x03: 0.43V<br/> .....<br/> 0x4D: 1.17V<br/> 0x4E: 1.18V<br/> 0x4F: 1.19V<br/> 0x50: 1.2V<br/> Others are reserved (0x51 to 0xFF)</p> <p>If 25h, bit[0] = 1, then buck D outputs a DVS range between 1.2V and 3.6V.</p> <p>0x00: 1.2V<br/> 0x01: 1.215V<br/> 0x02: 1.23V<br/> 0x03: 1.245V<br/> .....<br/> 0x8C: 3.3V<br/> 0x8D: 3.315V<br/> 0x8E: 3.33V<br/> .....<br/> 0x9F: 3.585V<br/> 0xA0: 3.6V<br/> Others are reserved (0xA1 to 0xFF)</p> |

**PON\_CONFIG\_0 (19h)**
**Format:** Unsigned binary

The PON\_CONFIG\_0 command sets the power-on sequence for configuration 0.

| Bits | Access | Bit Name              | Default | Description                                                                                                                              |
|------|--------|-----------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | PON_SEQ_CONFIG0       | 1'b1    | <p>Sets the power-on sequence for configuration 0.</p> <p>1'b0: Does not execute configuration 0<br/> 1'b1: Executes configuration 0</p> |
| 6    | R/W    | PON_SEQ_CONFIG0_BUCKA | 1'b1    | <p>Enables buck A's output regulator.</p> <p>1'b0: Disables buck A's output regulator<br/> 1'b1: Enables buck A's output regulator</p>   |
| 5    | R/W    | PON_SEQ_CONFIG0_BUCKB | 1'b1    | <p>Enables buck B's output regulator.</p> <p>1'b0: Disables buck B's output regulator<br/> 1'b1: Enables buck B's output regulator</p>   |
| 4    | R/W    | PON_SEQ_CONFIG0_BUCKC | 1'b1    | <p>Enables buck C's output regulator.</p> <p>1'b0: Disables buck C's output regulator<br/> 1'b1: Enables buck C's output regulator</p>   |



|     |     |                       |      |                                                                                                                           |
|-----|-----|-----------------------|------|---------------------------------------------------------------------------------------------------------------------------|
| 3   | R/W | PON_SEQ_CONFIG0_BUCKD | 1'b1 | Enables buck D's output regulator.<br>1'b0: Disables buck D's output regulator<br>1'b1: Enables buck D's output regulator |
| 2:0 | R   | RESERVED              | N/A  | Reserved.                                                                                                                 |

### PON\_CONFIG\_1 (1Ah)

**Format:** Unsigned binary

The PON\_CONFIG\_1 command sets the power-on sequence for configuration 1.

| Bits | Access | Bit Name              | Default | Description                                                                                                                 |
|------|--------|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | PON_SEQ_CONFIG1       | 1'b0    | Sets the power-on sequence for configuration 1.<br>1'b0: Does not execute configuration 1<br>1'b1: Executes configuration 1 |
| 6    | R/W    | PON_SEQ_CONFIG1_BUCKA | 1'b0    | Enables buck A's output regulator.<br>1'b0: Disables buck A's output regulator<br>1'b1: Enables buck A's output regulator   |
| 5    | R/W    | PON_SEQ_CONFIG1_BUCKB | 1'b0    | Enables buck B's output regulator.<br>1'b0: Disables buck B's output regulator<br>1'b1: Enables buck B's output regulator   |
| 4    | R/W    | PON_SEQ_CONFIG1_BUCKC | 1'b0    | Enables buck C's output regulator.<br>1'b0: Disables buck C's output regulator<br>1'b1: Enables buck C's output regulator   |
| 3    | R/W    | PON_SEQ_CONFIG1_BUCKD | 1'b0    | Enables buck D's output regulator.<br>1'b0: Disables buck D's output regulator<br>1'b1: Enables buck D's output regulator   |
| 2:0  | R      | RESERVED              | N/A     | Reserved.                                                                                                                   |

### PON\_CONFIG\_2 (1Bh)

**Format:** Unsigned binary

The PON\_CONFIG\_2 command sets the power-on sequence for configuration 2.

| Bits | Access | Bit Name              | Default | Description                                                                                                                 |
|------|--------|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | PON_SEQ_CONFIG2       | 1'b0    | Sets the power-on sequence for configuration 2.<br>1'b0: Does not execute configuration 2<br>1'b1: Executes configuration 2 |
| 6    | R/W    | PON_SEQ_CONFIG2_BUCKA | 1'b0    | Enables buck A's output regulator.<br>1'b0: Disables buck A's output regulator<br>1'b1: Enables buck A's output regulator   |
| 5    | R/W    | PON_SEQ_CONFIG2_BUCKB | 1'b0    | Enables buck B's output regulator.<br>1'b0: Disables buck B's output regulator<br>1'b1: Enables buck B's output regulator   |
| 4    | R/W    | PON_SEQ_CONFIG2_BUCKC | 1'b0    | Enables buck C's output regulator.<br>1'b0: Disables buck C's output regulator<br>1'b1: Enables buck C's output regulator   |
| 3    | R/W    | PON_SEQ_CONFIG2_BUCKD | 1'b0    | Enables buck D's output regulator.<br>1'b0: Disables buck D's output regulator<br>1'b1: Enables buck D's output regulator   |

|     |   |          |     |           |
|-----|---|----------|-----|-----------|
| 2:0 | R | RESERVED | N/A | Reserved. |
|-----|---|----------|-----|-----------|

### PON\_CONFIG\_3 (1Ch)

**Format:** Unsigned binary

The PON\_CONFIG\_3 command sets the power-on sequence for configuration 3.

| Bits | Access | Bit Name              | Default | Description                                                                                                                 |
|------|--------|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | PON_SEQ_CONFIG3       | 1'b0    | Sets the power-on sequence for configuration 3.<br>1'b0: Does not execute configuration 3<br>1'b1: Executes configuration 3 |
| 6    | R/W    | PON_SEQ_CONFIG3_BUCKA | 1'b0    | Enables buck A's output regulator.<br>1'b0: Disables buck A's output regulator<br>1'b1: Enables buck A's output regulator   |
| 5    | R/W    | PON_SEQ_CONFIG3_BUCKB | 1'b0    | Enables buck B's output regulator.<br>1'b0: Disables buck B's output regulator<br>1'b1: Enables buck B's output regulator   |
| 4    | R/W    | PON_SEQ_CONFIG3_BUCKC | 1'b0    | Enables buck C's output regulator.<br>1'b0: Disables buck C's output regulator<br>1'b1: Enables buck C's output regulator   |
| 3    | R/W    | PON_SEQ_CONFIG3_BUCKD | 1'b0    | Enables buck D's output regulator.<br>1'b0: Disables buck D's output regulator<br>1'b1: Enables buck D's output regulator   |
| 2:0  | R      | RESERVED              | N/A     | Reserved.                                                                                                                   |

### PON\_OFF\_DELAY0 (1Dh)

**Format:** Unsigned binary

The PON\_OFF\_DELAY0 command sets power-on/-off delay 0.

| Bits | Access | Bit Name        | Default | Description                                                                                                                                                                                                                                                   |
|------|--------|-----------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R      | RESERVED        | N/A     | Reserved.                                                                                                                                                                                                                                                     |
| 6:4  | R/W    | PON_SEQ_DELAY0  | 3'b000  | Sets power-on delay 0, which defines the time between V <sub>IN</sub> UVLO rising or EN high and the first channel starting to rise.<br>3'b000: 0ms<br>3'b001: 1ms<br>3'b010: 2ms<br>3'b011: 3ms<br>3'b100: 4ms<br>3'b101: 5ms<br>3'b110: 8ms<br>3'b111: 10ms |
| 3    | R      | RESERVED        | N/A     | Reserved.                                                                                                                                                                                                                                                     |
| 2:0  | R/W    | POFF_SEQ_DELAY0 | 3'b000  | Sets power-off delay 0, which defines the time between V <sub>IN</sub> UVLO falling or EN low and the first channel starting to fall.<br>3'b000: 0ms<br>3'b001: 1ms<br>3'b010: 2ms<br>3'b011: 4ms<br>3'b100: 6ms<br>Others are reserved.                      |

**PON\_SEQ\_DELAY\_1\_2 (1Eh)**
**Format:** Unsigned binary

The PON\_SEQ\_DELAY\_1\_2 command sets power-on sequence delay 1 and delay 2.

| Bits | Access | Bit Name       | Default | Description                                                                                                                                                                                                                              |
|------|--------|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:4  | R/W    | PON_SEQ_DELAY1 | 4'b0000 | Sets power-on sequence delay 1.<br>4'b0000: 0ms<br>4'b0001: 1ms<br>4'b0010: 2ms<br>4'b0011: 3ms<br>4'b0100: 4ms<br>4'b0101: 5ms<br>4'b0110: 6ms<br>4'b0111: 7ms<br>4'b1000: 8ms<br>4'b1001: 9ms<br>4'b1010: 10ms<br>Others are reserved. |
| 3:0  | R/W    | PON_SEQ_DELAY2 | 4'b0000 | Sets power-on sequence delay 2.<br>4'b0000: 0ms<br>4'b0001: 1ms<br>4'b0010: 2ms<br>4'b0011: 3ms<br>4'b0100: 4ms<br>4'b0101: 5ms<br>4'b0110: 6ms<br>4'b0111: 7ms<br>4'b1000: 8ms<br>4'b1001: 9ms<br>4'b1010: 10ms<br>Others are reserved. |

**PON\_SEQ\_DELAY\_3\_PG (1Fh)**
**Format:** Unsigned binary

The PON\_SEQ\_DELAY\_3\_PG command sets power-on sequence delay 3 and the PG delay.

| Bits | Access | Bit Name       | Default | Description                                                                                                                                                                                                                              |
|------|--------|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:4  | R/W    | PON_SEQ_DELAY3 | 4'b0000 | Sets power-on sequence delay 3.<br>4'b0000: 0ms<br>4'b0001: 1ms<br>4'b0010: 2ms<br>4'b0011: 3ms<br>4'b0100: 4ms<br>4'b0101: 5ms<br>4'b0110: 6ms<br>4'b0111: 7ms<br>4'b1000: 8ms<br>4'b1001: 9ms<br>4'b1010: 10ms<br>Others are reserved. |

|     |     |                  |         |                                                                                                                                                                                                                                                      |
|-----|-----|------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3:0 | R/W | PON_SEQ_DELAY_PG | 4'b0000 | Sets the PG delay of the power-on sequence.<br>4'b0000: 0ms<br>4'b0001: 1ms<br>4'b0010: 2ms<br>4'b0011: 3ms<br>4'b0100: 4ms<br>4'b0101: 5ms<br>4'b0110: 6ms<br>4'b0111: 7ms<br>4'b1000: 8ms<br>4'b1001: 9ms<br>4'b1010: 10ms<br>Others are reserved. |
|-----|-----|------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### POFF\_SEQ\_CONFIG\_0 (20h)

**Format:** Unsigned binary

The POFF\_SEQ\_CONFIG\_0 command sets the power-off sequence for configuration 0.

| Bits | Access | Bit Name               | Default | Description                                                                                                                         |
|------|--------|------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | POFF_SEQ_CONFIG0       | 1'b1    | Sets the power-off sequence for configuration 0.<br>1'b0: Does not execute configuration 0<br>1'b1: Executes configuration 0        |
| 6    | R/W    | POFF_SEQ_CONFIG0_BUCKA | 1'b1    | Disables buck A's output regulator.<br>1'b0: Does not disable buck A's output regulator<br>1'b1: Disables buck A's output regulator |
| 5    | R/W    | POFF_SEQ_CONFIG0_BUCKB | 1'b1    | Disables buck B's output regulator.<br>1'b0: Does not disable buck B's output regulator<br>1'b1: Disables buck B's output regulator |
| 4    | R/W    | POFF_SEQ_CONFIG0_BUCKC | 1'b1    | Disables buck C's output regulator.<br>1'b0: Does not disable buck C's output regulator<br>1'b1: Disables buck C's output regulator |
| 3    | R/W    | POFF_SEQ_CONFIG0_BUCKD | 1'b1    | Disables buck D's output regulator.<br>1'b0: Does not disable buck D's output regulator<br>1'b1: Disables buck D's output regulator |
| 2:0  | R/W    | POFF_SEQ_DELAY1        | 3'b000  | Sets power delay 1.<br>3'b000: 0ms<br>3'b001: 1ms<br>3'b010: 2ms<br>3'b011: 4ms<br>3'b100: 6ms<br>Others are reserved.              |

**POFF\_SEQ\_CONFIG\_1 (21h)**
**Format:** Unsigned binary

The POFF\_SEQ\_CONFIG\_1 command sets the power-off sequence for configuration 1.

| Bits | Access | Bit Name               | Default | Description                                                                                                                         |
|------|--------|------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | POFF_SEQ_CONFIG1       | 1'b0    | Sets the power-off sequence for configuration 1.<br>1'b0: Does not execute configuration 1<br>1'b1: Executes configuration 1        |
| 6    | R/W    | POFF_SEQ_CONFIG1_BUCKA | 1'b1    | Disables buck A's output regulator.<br>1'b0: Does not disable buck A's output regulator<br>1'b1: Disables buck A's output regulator |
| 5    | R/W    | POFF_SEQ_CONFIG1_BUCKB | 1'b1    | Disables buck B's output regulator.<br>1'b0: Does not disable buck B's output regulator<br>1'b1: Disables buck B's output regulator |
| 4    | R/W    | POFF_SEQ_CONFIG1_BUCKC | 1'b1    | Disables buck C's output regulator.<br>1'b0: Does not disable buck C's output regulator<br>1'b1: Disables buck C's output regulator |
| 3    | R/W    | POFF_SEQ_CONFIG1_BUCKD | 1'b1    | Disables buck D's output regulator.<br>1'b0: Does not disable buck D's output regulator<br>1'b1: Disables buck D's output regulator |
| 2:0  | R/W    | POFF_SEQ_DELAY2        | 3'b000  | Sets power delay 2.<br>3'b000: 0ms<br>3'b001: 1ms<br>3'b010: 2ms<br>3'b011: 4ms<br>3'b100: 6ms<br>Others are reserved.              |

**POFF\_SEQ\_CONFIG\_2 (22h)**
**Format:** Unsigned binary

The POFF\_SEQ\_CONFIG\_2 command sets the power-off sequence for configuration 2.

| Bits | Access | Bit Name               | Default | Description                                                                                                                         |
|------|--------|------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | POFF_SEQ_CONFIG2       | 1'b0    | Sets the power-off sequence for configuration 2.<br>1'b0: Does not execute configuration 2<br>1'b1: Executes configuration 2        |
| 6    | R/W    | POFF_SEQ_CONFIG2_BUCKA | 1'b1    | Disables buck A's output regulator.<br>1'b0: Does not disable buck A's output regulator<br>1'b1: Disables buck A's output regulator |
| 5    | R/W    | POFF_SEQ_CONFIG2_BUCKB | 1'b1    | Disables buck B's output regulator.<br>1'b0: Does not disable buck B's output regulator<br>1'b1: Disables buck B's output regulator |
| 4    | R/W    | POFF_SEQ_CONFIG2_BUCKC | 1'b1    | Disables buck C's output regulator<br>1'b0: Does not disable buck C's output regulator<br>1'b1: Disables buck C's output regulator  |

|     |     |                        |        |                                                                                                                                     |
|-----|-----|------------------------|--------|-------------------------------------------------------------------------------------------------------------------------------------|
| 3   | R/W | POFF_SEQ_CONFIG2_BUCKD | 1'b1   | Disables buck D's output regulator.<br>1'b0: Does not disable buck D's output regulator<br>1'b1: Disables buck D's output regulator |
| 2:0 | R/W | POFF_SEQ_DELAY3        | 3'b000 | Sets power delay 3.<br>3'b000: 0ms<br>3'b001: 1ms<br>3'b010: 2ms<br>3'b011: 4ms<br>3'b100: 6ms<br>Others are reserved.              |

### POFF\_SEQ\_CONFIG\_3 (23h)

**Format:** Unsigned binary

The POFF\_SEQ\_CONFIG\_3 command sets the power-off sequence for configuration 3.

| Bits | Access | Bit Name               | Default | Description                                                                                                                         |
|------|--------|------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------|
| 7    | R/W    | POFF_SEQ_CONFIG3       | 1'b0    | Sets the power-off sequence for configuration 3.<br>1'b0: Does not execute configuration 3<br>1'b1: Executes configuration 3        |
| 6    | R/W    | POFF_SEQ_CONFIG3_BUCKA | 1'b0    | Disables buck A's output regulator.<br>1'b0: Does not disable buck A's output regulator<br>1'b1: Disables buck A's output regulator |
| 5    | R/W    | POFF_SEQ_CONFIG3_BUCKB | 1'b0    | Disables buck B's output regulator.<br>1'b0: Does not disable buck B's output regulator<br>1'b1: Disables buck B's output regulator |
| 4    | R/W    | POFF_SEQ_CONFIG3_BUCKC | 1'b0    | Disables buck C's output regulator.<br>1'b0: Does not disable buck C's output regulator<br>1'b1: Disables buck C's output regulator |
| 3    | R/W    | POFF_SEQ_CONFIG3_BUCKD | 1'b0    | Disables buck D's output regulator.<br>1'b0: Does not disable buck D's output regulator<br>1'b1: Disables buck D's output regulator |
| 2:0  | R      | RESERVED               | N/A     | Reserved.                                                                                                                           |

### ADC\_TEMP (24h)

**Format:** Unsigned binary

The ADC\_TEMP command monitors the junction temperature (T<sub>J</sub>) of the IC.

| Bits | Access | Bit Name         | Description                                                                                                                                                                                                           |
|------|--------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:5  | R      | ADC_TEMP_READOUT | Measures T <sub>J</sub> .<br>3'b000: <85°C<br>3'b001: 85°C to 95°C<br>3'b010: 95°C to 105°C<br>3'b011: 105°C to 115°C<br>3'b100: 115°C to 125°C<br>3'b101: 125°C to 135°C<br>3'b110: 135°C to 145°C<br>3'b111: >145°C |
| 4:0  | R/W    | RESERVED         | Reserved.                                                                                                                                                                                                             |

**VOUT\_RANGE\_SELECT (25h)**
**Format:** Unsigned binary

The VOUT\_RANGE\_SELECT command selects the V<sub>OUTx</sub> range.

| Bits | Access | Bit Name                | Default | Description                                                                                                    |
|------|--------|-------------------------|---------|----------------------------------------------------------------------------------------------------------------|
| 7:4  | R      | RESERVED                | N/A     | Reserved.                                                                                                      |
| 3    | R/W    | BUCKA_VOUT_RANGE_SELECT | 1'b1    | Selects the V <sub>OUTA</sub> range.<br>1'b0: 0.4V to 1.2V with 10mV/step<br>1'b1: 1.2V to 3.6V with 15mV/step |
| 2    | R/W    | BUCKB_VOUT_RANGE_SELECT | 1'b1    | Selects the V <sub>OUTB</sub> range.<br>1'b0: 0.4V to 1.2V with 10mV/step<br>1'b1: 1.2V to 3.6V with 15mV/step |
| 1    | R/W    | BUCKC_VOUT_RANGE_SELECT | 1'b1    | Selects the V <sub>OUTC</sub> range.<br>1'b0: 0.4V to 1.2V with 10mV/step<br>1'b1: 1.2V to 3.6V with 15mV/step |
| 0    | R/W    | BUCKD_VOUT_RANGE_SELECT | 1'b1    | Selects the V <sub>OUTD</sub> range.<br>1'b0: 0.4V to 1.2V with 10mV/step<br>1'b1: 1.2V to 3.6V with 15mV/step |

**CLP\_BUCKX (26h)**
**Format:** Unsigned binary

The CLP\_BUCKX command sets buck x's current limit (I<sub>LIMITx</sub>) threshold (where x = A, B, C, or D).

| Bits | Access | Bit Name  | Default | Description                                                                                            |
|------|--------|-----------|---------|--------------------------------------------------------------------------------------------------------|
| 7:6  | R/W    | CLP_BUCKA | 2'b10   | Sets buck A's valley current limit (I <sub>LIMITA</sub> ).<br>00: 4.5A<br>01: 5A<br>10: 5.5A<br>11: 6A |
| 5:4  | R/W    | CLP_BUCKB | 2'b10   | Sets buck B's valley current limit (I <sub>LIMITB</sub> ).<br>00: 4.5A<br>01: 5A<br>10: 5.5A<br>11: 6A |
| 3:2  | R/W    | CLP_BUCKC | 2'b10   | Sets buck C's valley current limit (I <sub>LIMITC</sub> ).<br>00: 4.5A<br>01: 5A<br>10: 5.5A<br>11: 6A |
| 1:0  | R/W    | CLP_BUCKD | 2'b10   | Sets buck D's valley current limit (I <sub>LIMITD</sub> ).<br>00: 4.5A<br>01: 5A<br>10: 5.5A<br>11: 6A |

**OC\_STATUS\_CLEAR (2Ah)****Format:** Unsigned binary

The OC\_STATUS\_CLEAR command monitors the OC status and clear register.

| Bits | Access | Bit Name              | Default | Description                                                                                        |
|------|--------|-----------------------|---------|----------------------------------------------------------------------------------------------------|
| 7    | R/W    | CLEAR_BUCKA_OC_STATUS | 1'b0    | 1'b1: Clears the status of 2Ah, bit[3]                                                             |
| 6    | R/W    | CLEAR_BUCKB_OC_STATUS | 1'b0    | 1'b1: Clears the status of 2Ah, bit[2]                                                             |
| 5    | R/W    | CLEAR_BUCKC_OC_STATUS | 1'b0    | 1'b1: Clears the status of 2Ah, bit[1]                                                             |
| 4    | R/W    | CLEAR_BUCKD_OC_STATUS | 1'b0    | 1'b1: Clears the status of 2Ah, bit[0]                                                             |
| 3    | R      | BUCKA_OC_STATUS       | 1'b0    | 1'b0: Indicates no OC fault for buck A's output<br>1'b1: Indicates an OC fault for buck A's output |
| 2    | R      | BUCKB_OC_STATUS       | 1'b0    | 1'b0: Indicates no OC fault for buck B's output<br>1'b1: Indicates an OC fault for buck B's output |
| 1    | R      | BUCKC_OC_STATUS       | 1'b0    | 1'b0: Indicates no OC fault for buck C's output<br>1'b1: Indicates an OC fault for buck C's output |
| 0    | R      | BUCKD_OC_STATUS       | 1'b0    | 1'b0: Indicates no OC fault for buck D's output<br>1'b1: Indicates an OC fault for buck D's output |

**MTP\_AUTO\_REG (30h)****Format:** Unsigned binary

The MTP\_AUTO\_REG command controls MTP automatic write. The steps of MTP write operation are described below:

1. Configure all the MTP registers.
2. Write 14h, bit[6] from 0 to 1 to disable write protection.
3. Ensure that buck x is off before configuring MTP. It is recommended to pull down the external EN pin.
4. Write 30h, bit[7] from 0 to 1 to enable MTP automatic write.
5. Wait about 2s.
6. Read 30h to 0x5A to indicate that MTP configuring is finished.

| Bits | Access | Bit Name       | Default | Description                                                |
|------|--------|----------------|---------|------------------------------------------------------------|
| 7    | R/W    | MTP_AUTO_WRITE | 1'b0    | If 1'b0 changes to 1'b1, this enables MTP automatic write. |
| 6    | R      | MTP_WRITE_DONE | 1'b0    | If 1'b0 changes to 1'b1, MTP finishes.                     |
| 5:0  | R      | RESERVED       | N/A     | Reserved.                                                  |

**PART\_ID (31h)****Format:** Unsigned binary

The PART\_ID command sets the MPM54524's ID number.

| Bits | Access | Bit Name | Default | Description                    |
|------|--------|----------|---------|--------------------------------|
| 7:0  | R      | PART_ID  | 0x24    | Sets the MPM54524's ID number. |



**CODE\_ID (35h)****Format:** Unsigned binary

The CODE\_ID command sets the code ID number.

| Bits | Access | Bit Name | Default | Description              |
|------|--------|----------|---------|--------------------------|
| 7:0  | R      | CODE_ID  | 0x00    | Sets the code ID number. |

**CODE\_VERSION (36h)****Format:** Unsigned binary

The CODE\_VERSION command sets the code version number.

| Bits | Access | Bit Name     | Default | Description                   |
|------|--------|--------------|---------|-------------------------------|
| 7:0  | R      | CODE_VERSION | 0x00    | Sets the code version number. |

**ACTIVE\_POSITION\_ENABLE\_A/B (71h) <sup>(12) (13)</sup>****Format:** Unsigned binary

The ACTIVE\_POSITION\_ENABLE\_A/B command enables the active voltage positioning (AVP) function of buck A and buck B.

| Bits | Access | Bit Name   | Default | Description                                                                       |
|------|--------|------------|---------|-----------------------------------------------------------------------------------|
| 7    | R/W    | AVP_EN_A/B | 1'b1    | Enables the AVP function of buck A and buck B.<br>1'b0: Disabled<br>1'b1: Enabled |
| 6:0  | R      | RESERVED   | N/A     | Reserved.                                                                         |

**I2C\_ADDRESS (73h) <sup>(12) (13)</sup>****Format:** Unsigned binaryThe I2C\_ADDRESS command sets the I<sup>2</sup>C address.

| Bits | Access | Bit Name     | Default | Description                                                                                                                                         |
|------|--------|--------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:4  | R      | RESERVED     | N/A     | Reserved.                                                                                                                                           |
| 3:1  | R/W    | ADDRESS_BITS | 3'b 000 | Defines the I <sup>2</sup> C address, bits [6:4]. The I <sup>2</sup> C address can be modified via the MTP and is changed during the next power-on. |
| 0    | R      | RESERVED     | N/A     | Reserved.                                                                                                                                           |

**ACTIVE\_POSITION\_ENABLE\_C/D (79h) <sup>(13) (14)</sup>****Format:** Unsigned binary

The ACTIVE\_POSITION\_ENABLE\_C/D command enables the AVP function of buck C or buck D.

| Bits | Access | Bit Name   | Default | Description                                                                 |
|------|--------|------------|---------|-----------------------------------------------------------------------------|
| 7    | RW     | AVP_EN_C/D | 1'b1    | Enables the AVP function of buck C or D.<br>1'b0: Disabled<br>1'b1: Enabled |
| 6:0  | R      | RESERVED   | N/A     | Reserved.                                                                   |

**Notes:**

- 13) To operate 71h, 73h, and 79h, a password must be written to the device following the steps below:
- Write C1h to 95h.
  - Write C1h to 63h.
- 14) To write the register to the MTP, follow the steps below:
- Configure 71h, 73h, and 79h.
  - Write 87h to 80h.
  - Wait about 1s, then read 87h. If 87h is at 00h, writing to the MTP was successful; otherwise, writing to the MTP has failed.

**VIN\_OV\_REG (90h)**
**Format:** Unsigned binary

The VIN\_OV\_REG command sets V<sub>INx</sub> UVLO hysteresis and V<sub>INx</sub> OVP.

| Bits | Access | Bit Name            | Default | Description                                                              |
|------|--------|---------------------|---------|--------------------------------------------------------------------------|
| 7:2  | R      | RESERVED            | N/A     | Reserved.                                                                |
| 1    | R/W    | VIN_UVLO_HYSTERESIS | 1'b0    | Selects V <sub>INx</sub> UVLO hysteresis.<br>1'b0: 0.125V<br>1'b1: 0.25V |
| 0    | R/W    | VIN_OVP             | 1'b0    | Enables V <sub>INx</sub> OVP.<br>1'b0: Disabled<br>1'b1: Enabled         |

**VIN\_UVLO\_REG (AFh)**
**Format:** Unsigned binary

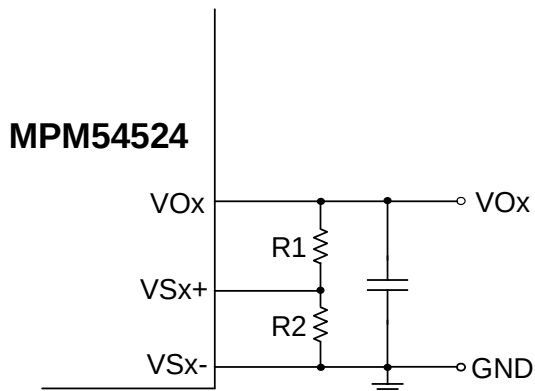
The VIN\_UVLO\_REG command sets V<sub>INx</sub> UVLO.

| Bits | Access | Bit Name | Default | Description                                                                 |
|------|--------|----------|---------|-----------------------------------------------------------------------------|
| 7:2  | R      | RESERVED | N/A     | Reserved.                                                                   |
| 1:0  | R/W    | VIN_UVLO | 2'b00   | Selects V <sub>INx</sub> UVLO.<br>00: 3V<br>01: 3.5V<br>10: 3.75V<br>11: 4V |

## APPLICATION INFORMATION

### Setting the Output Voltage with an External Divider

The MPM54524 can also set  $V_{OUTx}$  via an external resistor divider (see Figure 11).



**Figure 11: Feedback Network**

The FB voltage ( $V_{FB}$ ) is determined by the  $V_{OUTx}$  configuration registers. For example, set 25h to 00h and the  $V_{OUTx}$  register to 14h to generate a 0.6V  $V_{FB}$ . After using an external divider to set  $V_{OUTx}$ , the ADC readback voltage is  $V_{FB}$ , not  $V_{OUTx}$ .

Consider the tradeoff between stability and dynamic response to select a feedback resistor ( $R1$ ) that is not too large or too small.  $R2$  can be calculated with Equation (3):

$$R2 = \frac{R1}{\frac{V_{OUTx}}{V_{REF}} - 1} \quad (3)$$

Table 2 lists the recommended resistances for common  $V_{OUTx}$  values with 0.6V  $V_{FB}$ .

**Table 2: Resistances for Common  $V_{OUTx}$  Values**

| $V_{OUTx}$ (V) | $R1$ (k $\Omega$ ) | $R2$ (k $\Omega$ ) |
|----------------|--------------------|--------------------|
| 1              | 10                 | 15                 |
| 1.2            | 10                 | 10                 |
| 1.8            | 10                 | 5                  |
| 2.5            | 10                 | 3.15               |
| 3.3            | 10                 | 2.2                |
| 5.5            | 10                 | 1.23               |

### Selecting the Input Capacitor

The step-down converter has a discontinuous input current ( $I_{IN}$ ), and requires a capacitor to supply AC current to the converter while maintaining the DC  $V_{IN}$ . For the best performance, it is recommended to use low-ESR capacitors. Ceramic capacitors with X5R or X7R dielectrics are recommended for the best results due to their low ESR and small temperature coefficients. For most applications, use a 22 $\mu$ F capacitor.

Since  $C1$  absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor ( $C_{IN}$ ) ( $I_{C1}$ ) can be estimated with Equation (4):

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (4)$$

The worse-case condition occurs at  $V_{IN} = 2 \times V_{OUT}$ , where  $I_{C1}$  can be calculated with Equation (5):

$$I_{C1} = \frac{I_{LOAD}}{2} \quad (5)$$

For simplification, choose  $C_{IN}$  with an RMS current rating exceeding half of the maximum load current.

$C_{IN}$  can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, add a small, high-quality ceramic capacitor (e.g. 0.1 $\mu$ F) placed as close to the IC as possible. When using ceramic capacitors, ensure they have enough capacitance to provide sufficient charge, which prevents excessive voltage ripple at the input. The input voltage ripple ( $\Delta V_{IN}$ ) caused by the capacitance can be estimated with Equation (6):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_{SW} \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (6)$$

### Selecting the Output Capacitor for the Step-Down Regulator

The output capacitor ( $C_{OUT}$ ) for the step-down regulator maintains the DC  $V_{OUT}$ . Use ceramic, tantalum, or low-ESR electrolytic capacitors. For the best results, use low-ESR capacitors to keep the output voltage ripple ( $\Delta V_{OUT}$ ) low.  $\Delta V_{OUT}$  can be estimated by Equation (7):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{SW} \times C2}\right) \quad (7)$$

Where  $L1$  is the inductance, and  $R_{ESR}$  is the equivalent series resistance (ESR) of  $C_{OUT}$ .

For ceramic capacitors, the capacitance dominates the impedance at the  $f_{SW}$ , and the

capacitance causes the majority of  $\Delta V_{OUT}$ . For simplification,  $\Delta V_{OUT}$  can be estimated with Equation (8):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (8)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at  $f_{SW}$ . For simplification,  $\Delta V_{OUT}$  can be estimated with Equation (9):

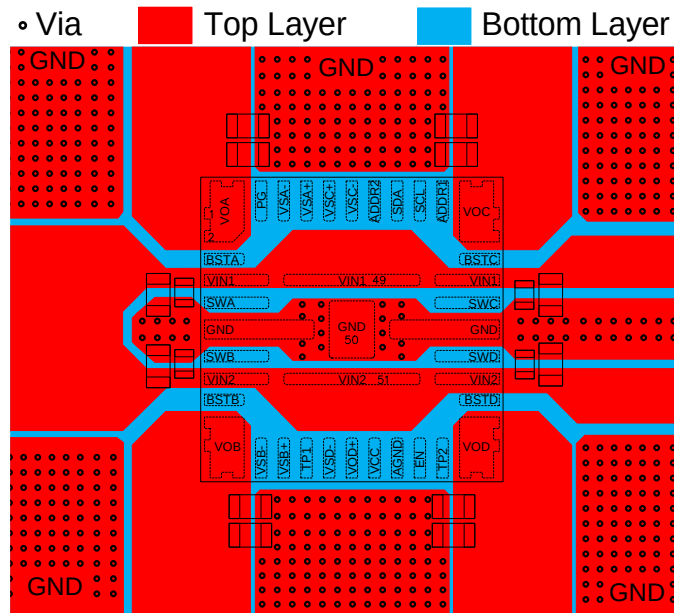
$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \quad (9)$$

The  $C_{OUT}$  characteristics also affect the stability of the regulation system.

## PCB Layout Guidelines

Efficient PCB layout is very critical for stable operation. For the best results, refer to Figure 12 and follow the guidelines.

1. Connect the input ground to the GND pin using the shortest and widest trace possible.
2. Connect  $C_{IN}$  to the VINx pin using the shortest and widest trace possible.
3. Connect the input ground to the GND pin using the shortest and widest trace possible.
4. Route SWx (where x = A, B, C, or D) away from sensitive analog areas such as FB.



### Figure 12: Recommended PCB Layout

## MULTIPLE-TIME PROGRAMMABLE (MTP) CONFIGURATION

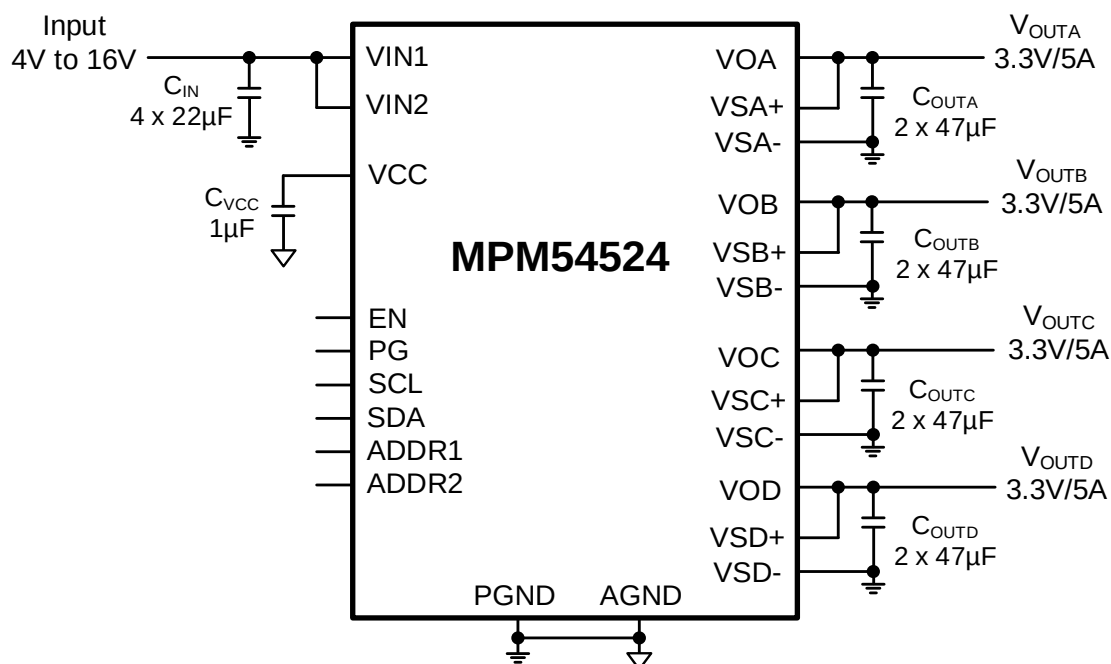
**Table 3: -0000 Suffix Code Configuration**

| MTP Parameters                                           | VOA      | VOB      | VOC      | VOD      |
|----------------------------------------------------------|----------|----------|----------|----------|
| Output voltage (V <sub>OUT</sub> )                       | 3.345V   | 3.345V   | 3.345V   | 3.345V   |
| Mode                                                     | FCCM     | FCCM     | FCCM     | FCCM     |
| Bits[6:4] of the I <sup>2</sup> C address                | 000      |          |          |          |
| Soft-start time (t <sub>SS_x</sub> )                     | 2ms      | 2ms      | 2ms      | 2ms      |
| Soft shutdown time enable/disable                        | Disabled | Disabled | Disabled | Disabled |
| Soft shutdown time                                       | -        | -        | -        | -        |
| Switching frequency (f <sub>sw</sub> )                   | 1000kHz  | 1000kHz  | 1000kHz  | 1000kHz  |
| Valley current limit                                     | 5.5A     | 5.5A     | 5.5A     | 5.5A     |
| Buck output discharge enable                             | Enabled  | Enabled  | Enabled  | Enabled  |
| Buck output discharge resistor                           | 2Ω       | 2Ω       | 2Ω       | 2Ω       |
| Power good (PG) threshold                                | 95%      | 95%      | 95%      | 95%      |
| VOA and VOB interleaving enable/disable                  | Disabled |          | Disabled |          |
| VOA start-up delay time 0                                | 0ms      |          |          |          |
| VOB start-up delay time 1                                | 0ms      |          |          |          |
| VOC start-up delay time 2                                | 0ms      |          |          |          |
| VOD start-up delay time 3                                | 0ms      |          |          |          |
| PG start-up delay time 4                                 | 0ms      |          |          |          |
| VOA off delay time 0                                     | 0ms      |          |          |          |
| VOB off delay time 1                                     | 0ms      |          |          |          |
| VOC off delay time 2                                     | 0ms      |          |          |          |
| VOD off delay time 3                                     | 0ms      |          |          |          |
| Active voltage positioning (AVP) function enable/disable | Enabled  |          |          |          |
| Current monitor enable/disable                           | Enabled  |          |          |          |
| Voltage monitor enable/disable                           | Enabled  |          |          |          |
| Load line                                                | 40mV/A   |          |          |          |

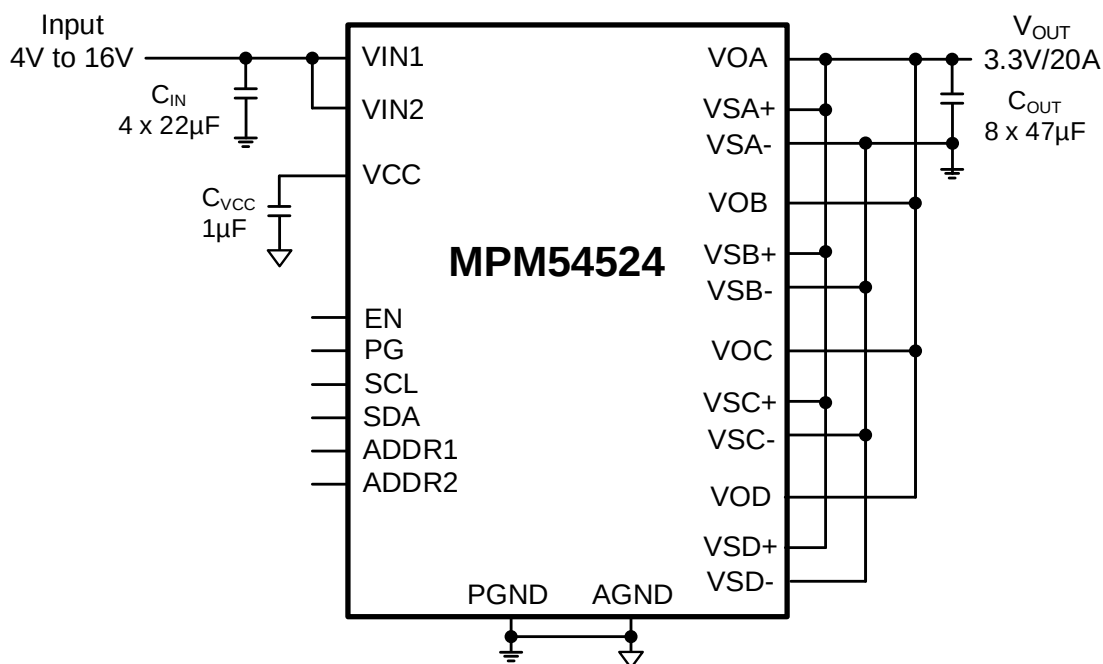
**Table 4: -0000 Suffix Code Register Values**

| Register | Hex Value | Register | Hex Value | Register | Hex Value |
|----------|-----------|----------|-----------|----------|-----------|
| 09h      | 0x00      | 17h      | 0x8F      | 26h      | 0xAAh     |
| 0Ah      | 0x00      | 18h      | 0x8F      | 27h      | 0x00h     |
| 0Bh      | 0xE0      | 19h      | 0xF8      | 28h      | 0x00h     |
| 0Ch      | 0x00      | 1Ah      | 0x00      | 29h      | 0x00h     |
| 0Dh      | 0x00      | 1Bh      | 0x00      | 2Ah      | 0x00h     |
| 0Eh      | 0xFF      | 1Ch      | 0x00      | 31h      | 0x24h     |
| 0Fh      | 0xAA      | 1Dh      | 0x00      | 35h      | 0x00h     |
| 10h      | 0x84      | 1Eh      | 0x00      | 36h      | 0x00h     |
| 11h      | 0x00      | 1Fh      | 0x00      | 71h      | 0x80h     |
| 12h      | 0x00      | 20h      | 0xF8      | 73h      | 0x00h     |
| 13h      | 0xFF      | 21h      | 0x78      | 79h      | 0x80h     |
| 14h      | 0x00      | 22h      | 0x78      | -        | -         |
| 15h      | 0x8F      | 23h      | 0x00      | -        | -         |
| 16h      | 0x8F      | 25h      | 0x0F      | -        | -         |

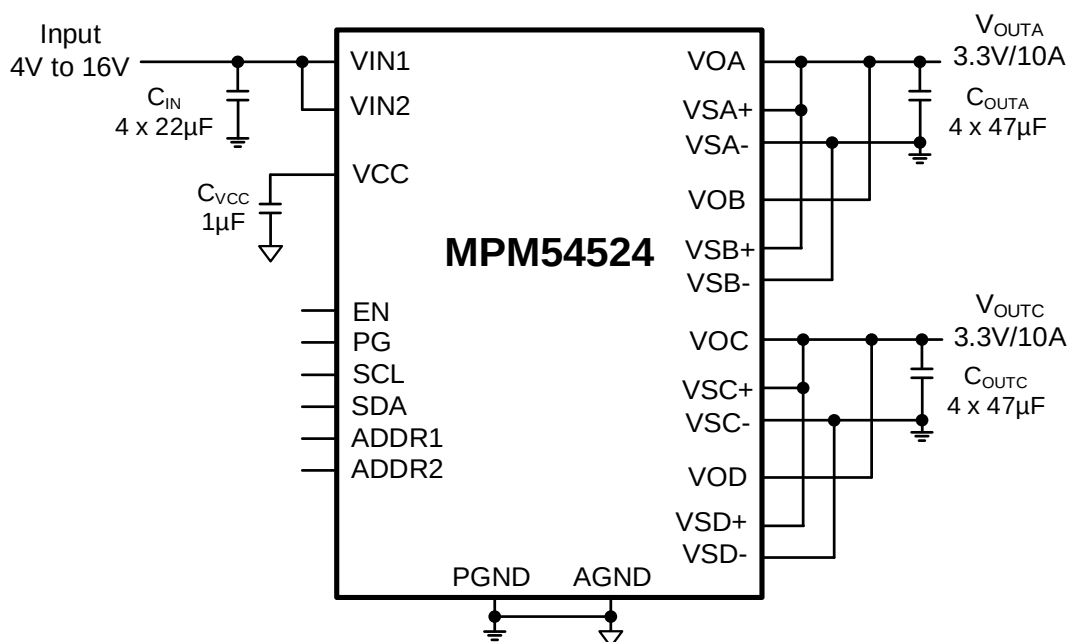
## TYPICAL APPLICATION CIRCUITS



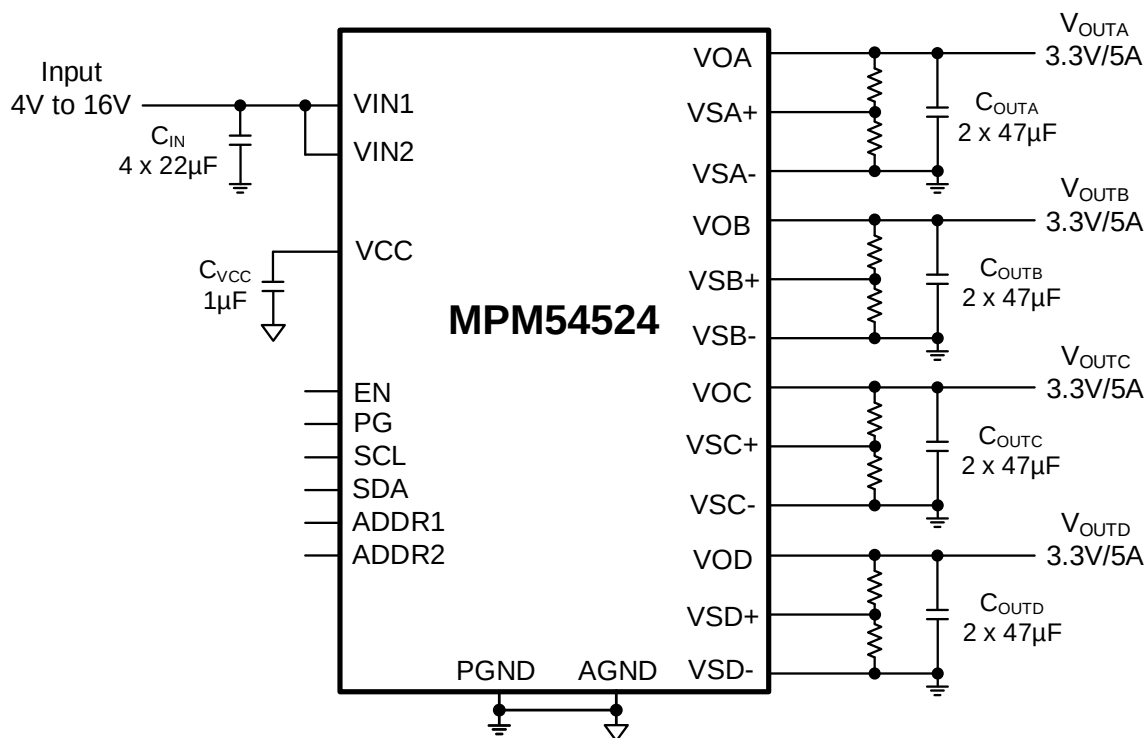
**Figure 13: Typical Application Circuit (Quad 5A Outputs with an Internal Divider)**



**Figure 14: Typical Application Circuit (4-Phase, Single 20A Output with an Internal Divider)**

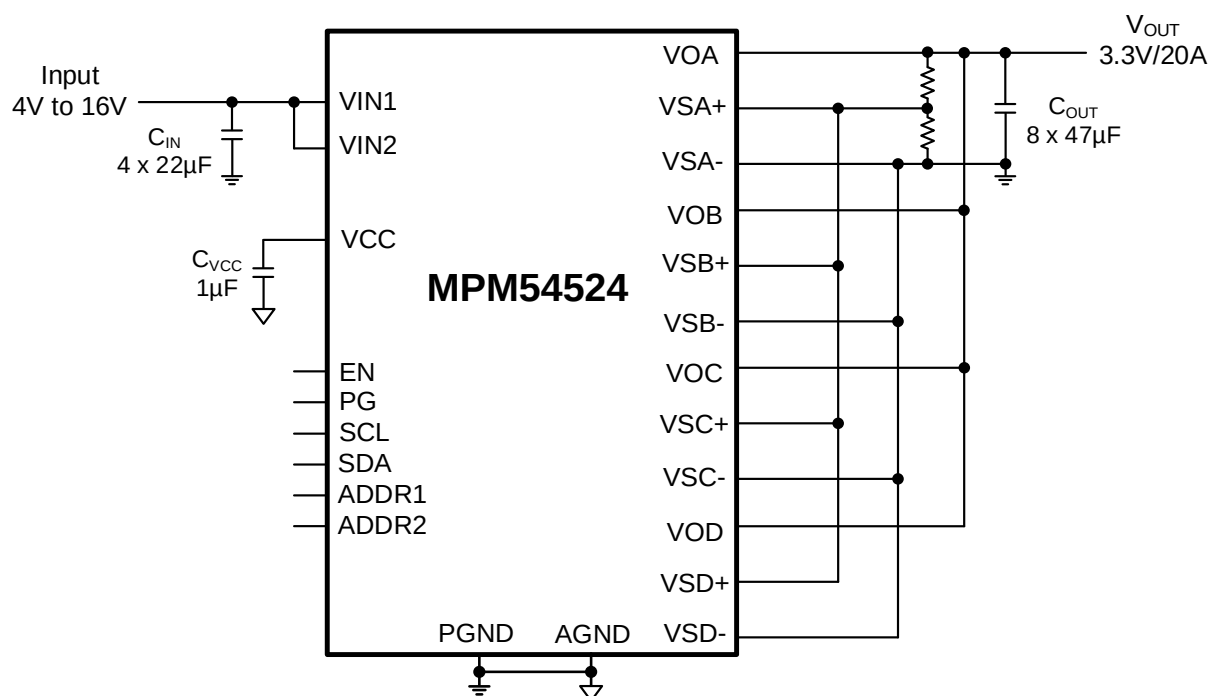
**TYPICAL APPLICATION CIRCUITS (continued)**


**Figure 15: Typical Application Circuit (Dual 10A Outputs with an Internal Divider)**

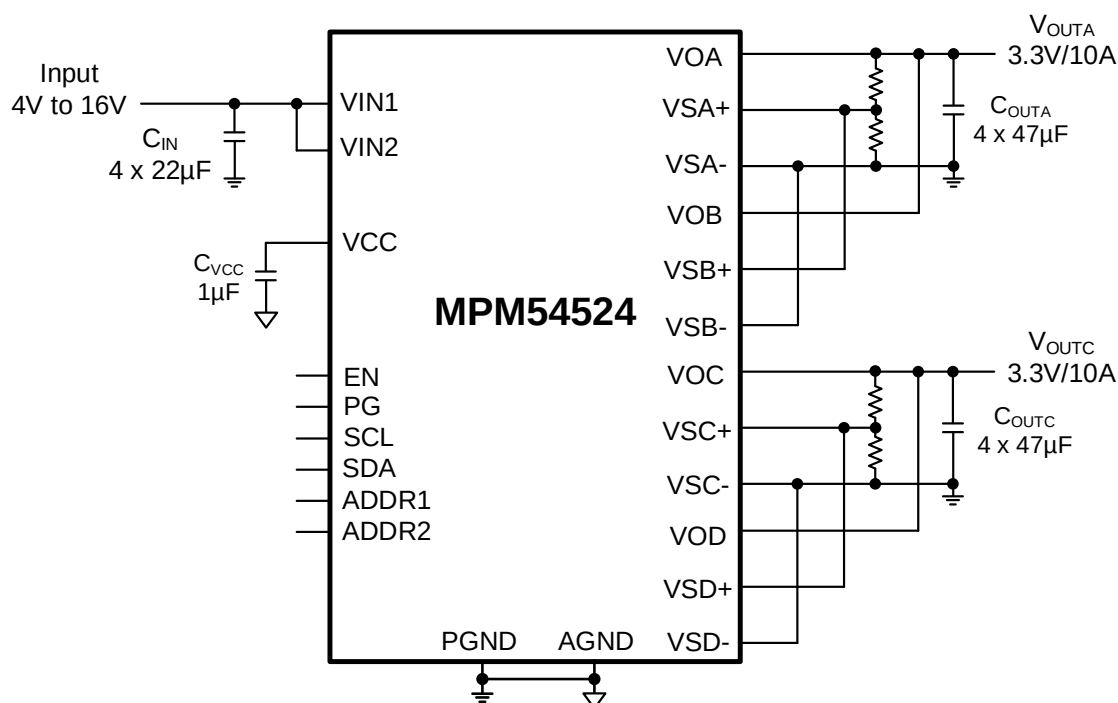


**Figure 16: Typical Application Circuit (Quad 5A Outputs with an External Divider)**



**TYPICAL APPLICATION CIRCUITS (continued)**


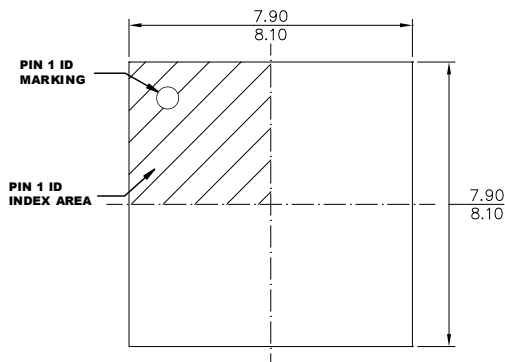
**Figure 17: Typical Application Circuit (4-Phase, Single 20A Output with an External Divider)**



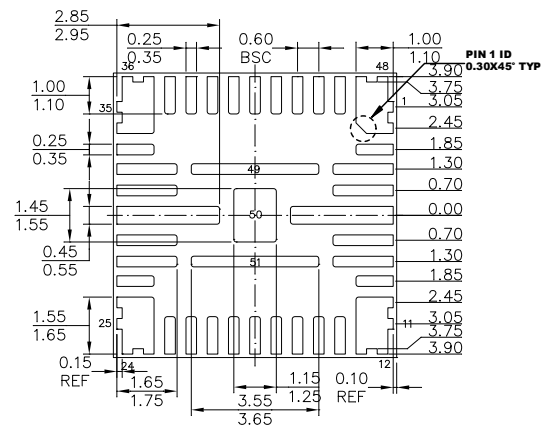
**Figure 18: Typical Application Circuit (Dual 10A Outputs with an External Divider)**

## PACKAGE INFORMATION

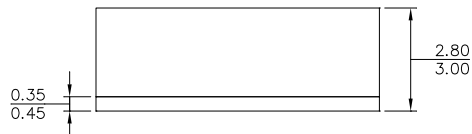
### ECLGA-51 (8mmx8mmx2.9mm)



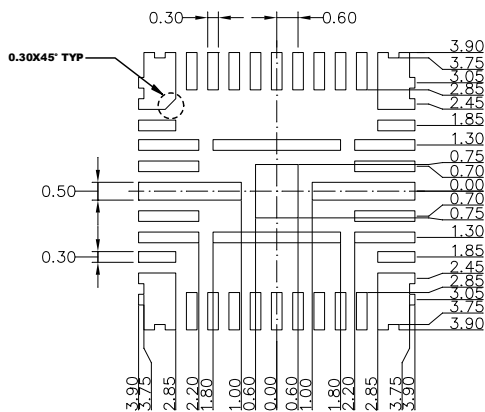
**TOP VIEW**



**BOTTOM VIEW**



### SIDE VIEW

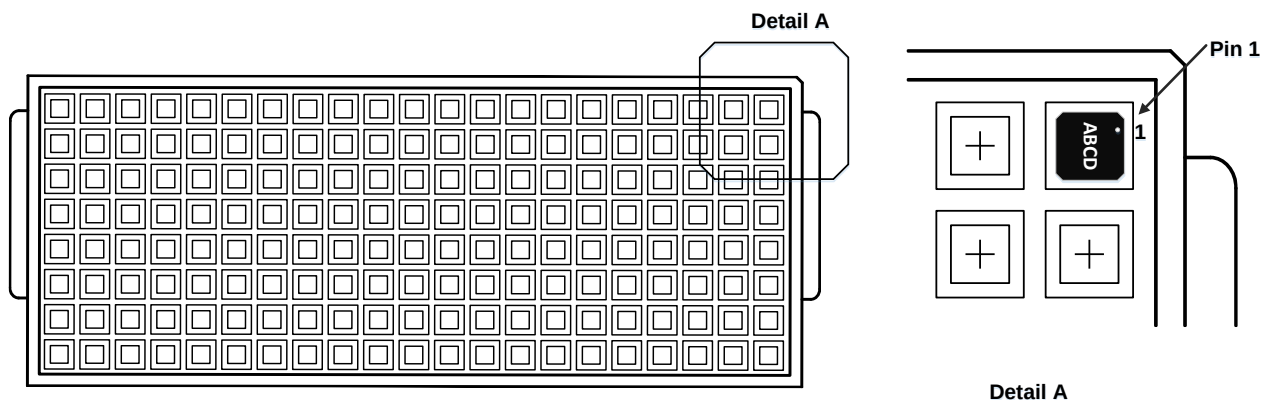


### **RECOMMENDED LAND PATTERN**

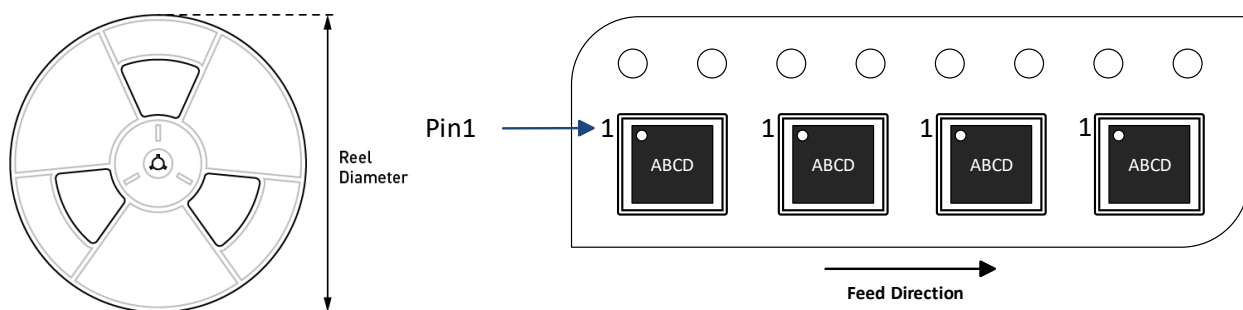
**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.  
2) LEAD COPLANARITY SHALL BE 0.10  
MILLIMETERS MAX.  
3) JEDEC REFERENCE IS MO-303.  
4) DRAWING IS NOT TO SCALE.

# CARRIER INFORMATION <sup>(15)</sup>



| Part Number        | Package Description       | Quantity/ Reel | Quantity/ Tube | Quantity/ Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|--------------------|---------------------------|----------------|----------------|----------------|---------------|--------------------|--------------------|
| MPM54524GCQ-xxxx-T | ECLGA-51 (8mmx8mmx 2.9mm) | N/A            | N/A            | 260            | N/A           | N/A                | N/A                |



| Part Number        | Package Description       | Quantity/ Reel | Quantity/ Tube | Quantity/ Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|--------------------|---------------------------|----------------|----------------|----------------|---------------|--------------------|--------------------|
| MPM54524GCQ-xxxx-Z | ECLGA-51 (8mmx8mmx 2.9mm) | 1000           | N/A            | N/A            | 13in          | 16mm               | 12mm               |

## Note:

15) The schematic diagrams of Tray (-T) and Reel (-Z), respectively, where different packages correspond to different lengths, widths, and heights.



## REVISION HISTORY

| Revision # | Revision Date | Description     | Pages Updated |
|------------|---------------|-----------------|---------------|
| 1.0        | 4/15/2024     | Initial Release | -             |

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