

# IntelliMAX™ 28 V, Over-Voltage, Over-Current Protection Load Switch with Adjustable Current-Limit Control

## FPF2495B

### Description

The FPF2495B advanced load-management switch targets applications requiring a highly integrated solution. It disconnects loads powered from the DC power rail (<6 V) with stringent off-state current targets and high load capacitances (<100  $\mu$ F). The FPF2495B consists of a slew-rate controlled low-impedance MOSFET switch (100 m $\Omega$  maximum) and integrated analog features. The slew-rate controlled turn-on characteristic prevents inrush current and the resulting excessive voltage droop on power rails. FPF2495B has over-voltage protection and over-temperature protection.

The FPF2495B has a Reverse-Current Blocking (RCB) function that obstructs unwanted reverse current from  $V_{OUT}$  to  $V_{IN}$  during OFF states. The exceptionally low off-state current drain (<2  $\mu$ A maximum) facilitates compliance with standby power requirements. The input voltage range operates from 2.5 V to 5.5  $V_{DC}$  to support a wide range of applications in consumer, optical, medical, storage, portable, and industrial-device power management. Switch control is managed by a logic input (active HIGH) capable of interfacing directly with low-voltage control signal / General-Purpose Input / Output (GPIO) without an external pull-down resistor.

The device is packaged in advanced, fully “green” compliant, 1.22 mm x 1.22 mm, Wafer-Level Chip-Scale Package (WLCSP).

### Features

- $V_{IN}$ : 2.5 V~5.5 V
- 28 V Absolute Ratings at  $V_{OUT}$
- Current Capability: 2.8 A
- Adjustable Current Limit: 0.05 A ~ 2.5 A (Typ.)
  - ♦ 0.1 A~2.5 A with 10% Accuracy
  - ♦ < 0.1 A with 15% Accuracy
- $R_{ON}$ : Typ. 70 m $\Omega$  & Max. 100 m $\Omega$  at 5  $V_{IN}$  and 1 A  $I_{OUT}$
- Output OVP: Min. = 5.6 V, Typ. = 5.8 V, Max. = 6 V
- No Output Discharge During Off State
- Open-Drain OCP on FLAGB
- Thermal Shutdown
- Under-Voltage Lockout (UVLO)
- Reverse-Current Blocking (RCB) during OFF
- Logic CMOS IO Meets JESD76 Standard for GPIO Interface and Related Power Supply Requirements
- ESD Protected:
  - ♦ Human Body Model: >2 kV
  - ♦ Charged Device Model: >2.5 kV
  - ♦ IEC 61000-4-2 Air Discharge: >15 kV
  - ♦ IEC 61000-4-2 Contact Discharge: >8 kV



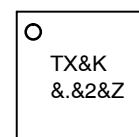
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WLCSP9 1.22x1.22x0.581  
CASE 567SU

### MARKING DIAGRAM



|    |                         |
|----|-------------------------|
| TX | = ON Semiconductor Logo |
|    | = Specific Device Code  |
| &K | = Lot Code              |
| &2 | = Numeric Date Code     |
| &Z | = Assembly Plant Code   |

### ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

### Applications

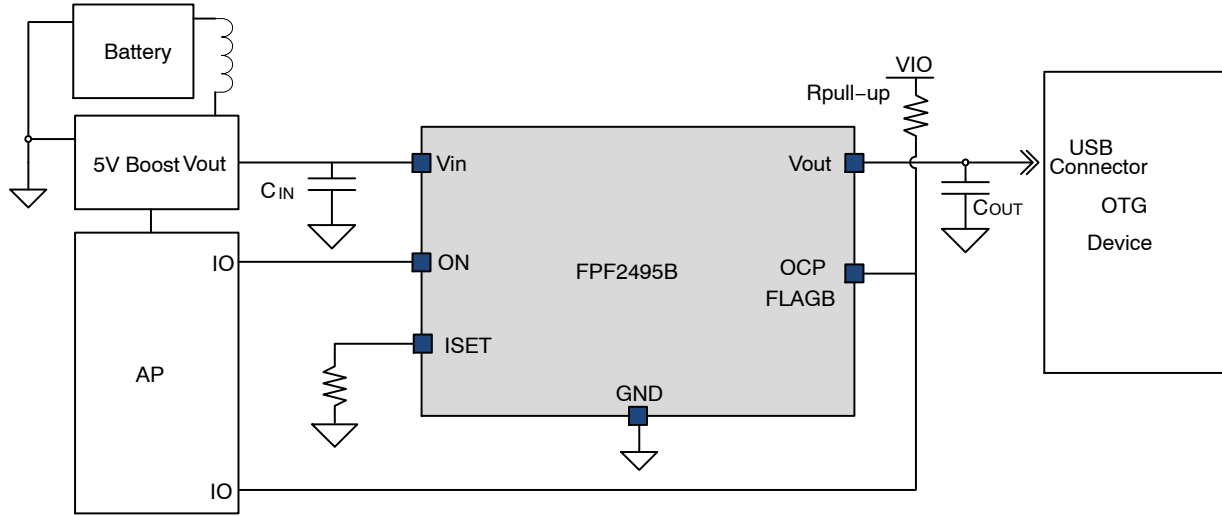
- Smart Phones, Tablet PCs
- Storage, DSLR, and Portable Devices

# FPF2495B

## ORDERING INFORMATION

| Part Number | Operating Temperature Range | Package                                                      | Packing Method | Top Mark |
|-------------|-----------------------------|--------------------------------------------------------------|----------------|----------|
| FPF2495BUCX | -40 to 85°C                 | 9-Ball, WLCSP, 3x3 Array, 0.4 mm Pitch, Back Side Lamination | Tape & Reel    | TX       |

## Application Diagram



1.  $C_{IN}$  and  $C_{OUT}$  capacitors recommended for improvement of device stability.

Figure 1. Typical Application

## Functional Block Diagram

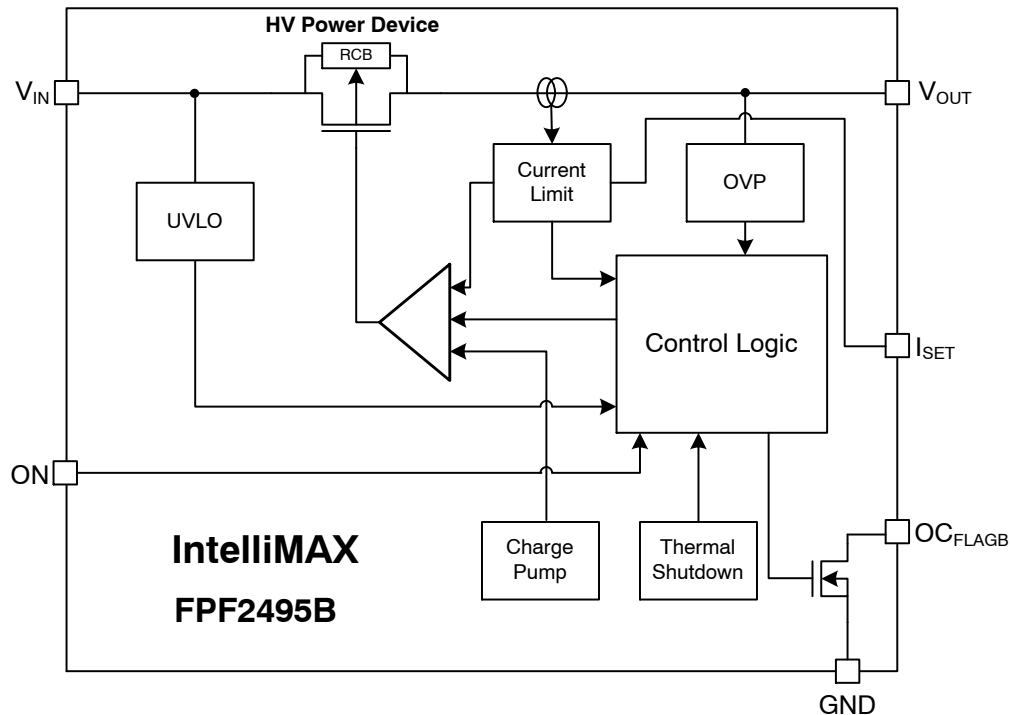


Figure 2. Functional Block Diagram

## Pin Configurations

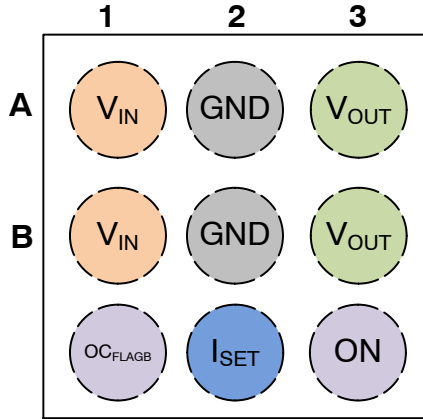


Figure 3. Pin Assignments (Top View)

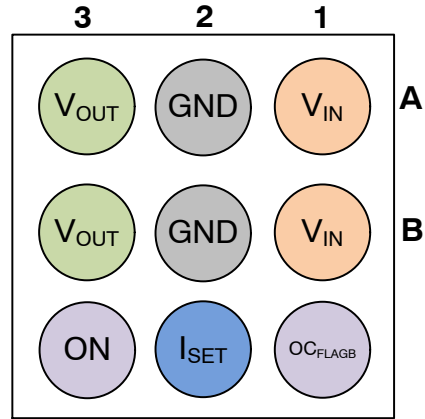


Figure 4. Pin Assignments (Bottom View)

## PIN DESCRIPTION

| Pin #  | Name                | Description                                                                                                                                        |            |                |
|--------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------|
| A3, B3 | V <sub>OUT</sub>    | <b>Switch Output</b>                                                                                                                               |            |                |
| A1, B1 | V <sub>IN</sub>     | <b>Supply Input:</b> Input to the power switch                                                                                                     |            |                |
| A2     | GND                 | <b>Ground</b> (true device ground)                                                                                                                 |            |                |
| B2     |                     |                                                                                                                                                    |            |                |
| C3     | ON                  | <b>ON/OFF Control Input:</b> Active HIGH – GPIO compatible                                                                                         | Logic HIGH | Switch Enable  |
|        |                     |                                                                                                                                                    | Logic LOW  | Switch Disable |
| C1     | OC <sub>FLAGB</sub> | <b>Fault Output:</b> Active LOW, open-drain output that indicates an input over current. External pull-up resistor to V <sub>CC</sub> is required. |            |                |
| C2     | I <sub>SET</sub>    | <b>Current Limit Set Input:</b> A resistor from ISET to ground sets the current limit for the switch.                                              |            |                |

## ABSOLUTE MAXIMUM RATINGS

| Symbol           | Parameters                                                                     |                                                                                 | Min. | Max.            | Unit |
|------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------|-----------------|------|
| V <sub>PIN</sub> | V <sub>OUT</sub> to GND, V <sub>OUT</sub> to V <sub>IN</sub>                   |                                                                                 | –0.3 | 28.0            | V    |
|                  | ON, V <sub>IN</sub> , FLAGB, I <sub>SET</sub> to GND                           |                                                                                 | –0.3 | 6.0             |      |
| I <sub>SW</sub>  | Maximum Continuous Switch Current (Note 1)                                     |                                                                                 |      | 2.8             | A    |
| t <sub>PD</sub>  | Total Power Dissipation at T <sub>A</sub> = 25°C                               |                                                                                 |      | 1.0             | W    |
| T <sub>J</sub>   | Operating Junction Temperature                                                 |                                                                                 | –40  | +150            | °C   |
| T <sub>STG</sub> | Storage Junction Temperature                                                   |                                                                                 | –65  | +150            | °C   |
| θ <sub>JA</sub>  | Thermal Resistance, Junction-to-Ambient<br>(1-inch Square Pad of 2 oz. Copper) |                                                                                 |      | 95<br>(Note 2)  | °C/W |
|                  |                                                                                |                                                                                 |      | 110<br>(Note 3) |      |
| ESD              | Electrostatic Discharge Capability                                             | Human Body Model, JESD22–A114                                                   | 2.0  |                 | kV   |
|                  |                                                                                | Charged Device Model, JESD22–C101                                               | 2.5  |                 |      |
|                  | IEC61000–4–2 System Level                                                      | Air Discharge (V <sub>IN</sub> , V <sub>ON</sub> , V <sub>OUT</sub> to GND)     | 15.0 |                 |      |
|                  |                                                                                | Contact Discharge (V <sub>IN</sub> , V <sub>ON</sub> , V <sub>OUT</sub> to GND) | 8.0  |                 |      |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Maximum Junction Temperature = 85°C.

# FPF2495B

2. Measured using 2S2P JEDEC std. PCB.
3. Measured using 2S2P JEDEC PCB cold plate method.

## RECOMMENDED OPERATING CONDITIONS

| Symbol   | Parameters                    | Min. | Max. | Unit |
|----------|-------------------------------|------|------|------|
| $V_{IN}$ | Supply Voltage                | 2.5  | 5.5  | V    |
| $T_A$    | Ambient Operating Temperature | -40  | 85   | °C   |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

## ELECTRICAL CHARACTERISTICS

Unless otherwise noted;  $V_{IN} = 2.5$  to  $5.5$  V,  $T_A = -40$  to  $+85$ °C; typical values are at  $V_{IN} = 5$  V and  $T_A = 25$ °C.

| Symbol | Parameters | Condition | Min. | Typ. | Max. | Unit |
|--------|------------|-----------|------|------|------|------|
|--------|------------|-----------|------|------|------|------|

### BASIC OPERATION

|                 |                                   |                                                                    |      |      |      |    |
|-----------------|-----------------------------------|--------------------------------------------------------------------|------|------|------|----|
| $V_{IN}$        | Input Voltage                     |                                                                    | 2.5  |      | 5.5  | V  |
| $I_{Q(OFF)}$    | Off Supply Current                | $V_{ON} = GND, V_{OUT} = Open$                                     |      | 1    | 2    | μA |
| $I_{SD(OFF)}$   | Shutdown Current                  | $V_{IN} = 5.5$ V, $V_{OUT} = 0$ V, $V_{ON} = GND$                  |      | 0.1  | 4.0  | μA |
| $I_Q$           | Quiescent Current                 | $I_{OUT} = 0$ mA                                                   |      | 65   | 100  | μA |
| $R_{ON}$        | On Resistance                     | $V_{IN} = 5.0$ V, $I_{OUT} = 1$ A                                  |      | 70   | 100  | mΩ |
|                 |                                   | $V_{IN} = 3.7$ V, $I_{OUT} = 1$ A                                  |      | 75   | 105  |    |
| $R_{ON}$        | On Resistance <sup>(6)</sup>      | $V_{IN} = 5.0$ V, $I_{OUT} = 1.5$ A                                |      | 70   |      | mΩ |
| $V_{IH}$        | ON Input Logic HIGH Voltage       | $V_{IN} = 2.5$ V to $5.5$ V                                        | 1.15 |      |      | V  |
| $V_{IL}$        | ON Input Logic LOW Voltage        | $V_{IN} = 2.5$ V to $5.5$ V                                        |      |      | 0.65 | V  |
| $V_{IL\_FLAG}$  | FLAGB Output Logic LOW Voltage    | $V_{IN} = 5$ V, $I_{SINK} = 10$ mA                                 |      | 0.1  | 0.2  | V  |
|                 |                                   | $V_{IN} = 2.5$ V, $I_{SINK} = 10$ mA                               |      | 0.15 | 0.30 |    |
| $I_{FLAGB\_LK}$ | FLAGB Output HIGH Leakage Current | $V_{IN} = 5$ V, Switch On                                          |      |      | 1    | μA |
| $I_{ON}$        | On Input Leakage                  | $V_{ON} = 0$ V to $V_{IN}$                                         |      |      | 1.0  | μA |
| $R_{ON\_PD}$    | Pull-Down Resistance at ON Pin    | $V_{IN} = 2.5$ ~ $5.5$ V, $V_{ON} = HIGH$ , $T_A = -40$ to $85$ °C |      | 14   |      | MΩ |

### OVER-VOLTAGE PROTECTION

|                |                                  |                                                                                   |      |      |                  |    |
|----------------|----------------------------------|-----------------------------------------------------------------------------------|------|------|------------------|----|
| $V_{OV\_TRIP}$ | Output OVP Lockout               | $V_{OUT}$ Rising Threshold                                                        | 5.50 | 5.80 | 6.00             | V  |
|                |                                  | $V_{OUT}$ Falling Threshold                                                       |      | 5.50 |                  |    |
| $OUT_{HYS}$    | Output OVP Hysteresis            | $V_{OUT}$ Falling Threshold                                                       |      | 0.3  |                  | V  |
| $t_{OVP}$      | OVP Response Time <sup>(6)</sup> | $I_{OUT} = 0.5$ A, $C_L = 1$ μF, $T_A = 25$ °C, $V_{OUT}$ from $5.5$ V to $6.0$ V | 1    |      | 4 <sup>(6)</sup> | μs |

### OVER-CURRENT PROTECTION

|                 |                                 |                                                                                           |     |      |      |    |
|-----------------|---------------------------------|-------------------------------------------------------------------------------------------|-----|------|------|----|
| $I_{LIM}$       | Current Limit                   | $V_{IN} = 5$ V, $R_{SET} = 20000$ Ω, $V_{OUT} = 1.68$ to $5$ V with 15% Accuracy (Note 4) | 42  | 50   | 58   | mA |
|                 |                                 | $V_{IN} = 5$ V, $R_{SET} = 2100$ Ω, $V_{OUT} = 1.68$ to $5$ V with 10% Accuracy (Note 4)  | 450 | 500  | 550  |    |
|                 |                                 | $V_{IN} = 5$ V, $R_{SET} = 1070$ Ω, $V_{OUT} = 1.68$ to $5$ V with 10% Accuracy (Note 4)  | 900 | 1000 | 1100 |    |
| $V_{UVLO}$      | Under-Voltage Lockout           | $V_{IN}$ Increasing                                                                       |     | 2.4  |      | V  |
|                 |                                 | $V_{IN}$ Decreasing                                                                       |     | 2.2  |      |    |
| $V_{UVLO\_HYS}$ | UVLO Hysteresis                 |                                                                                           |     | 200  |      | mV |
| $I_{RCB}$       | RCB Current                     | $V_{ON} = 0$ V, $V_{OUT} = 5.5$ V,                                                        |     | 7    |      | μA |
| $t_{HOCP}$      | Hard Over-Current Response Time | Moderate Over-Current Condition, $I_{OUT} \geq I_{LIM}$ , $V_{OUT} = 0$ V                 |     | 6    |      | μs |

**ELECTRICAL CHARACTERISTICS** (continued)

Unless otherwise noted;  $V_{IN} = 2.5$  to  $5.5$  V,  $T_A = -40$  to  $+85^\circ\text{C}$ ; typical values are at  $V_{IN} = 5$  V and  $T_A = 25^\circ\text{C}$ .

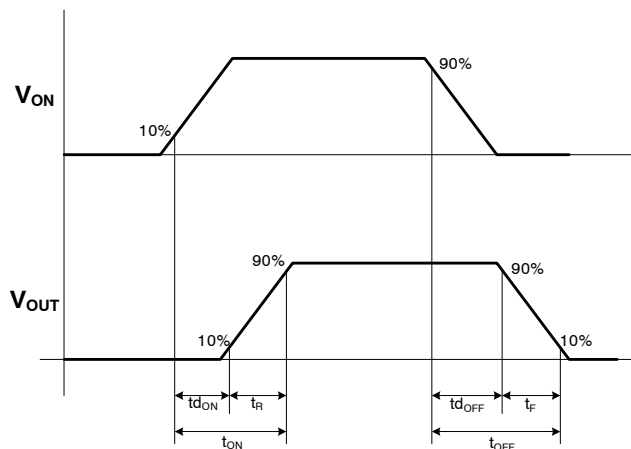
| Symbol                         | Parameters                      | Condition                                                                        | Min. | Typ. | Max. | Unit             |
|--------------------------------|---------------------------------|----------------------------------------------------------------------------------|------|------|------|------------------|
| <b>OVER-CURRENT PROTECTION</b> |                                 |                                                                                  |      |      |      |                  |
| $t_{OCP}$                      | Over-Current Response Time      | Moderate Over-Current Condition,<br>$I_{OUT} \geq I_{LIM}$ $V_{OUT} \leq V_{IN}$ |      | 7    |      | $\mu\text{s}$    |
| $t_{OC\_FLAG}$                 | Over-Current Flag Response Time | When Over-Current Occurs to Flag Pulling LOW                                     |      | 8    |      | ms               |
| TSD                            | Thermal Shutdown                | Shutdown Threshold                                                               |      | 150  |      | $^\circ\text{C}$ |
|                                |                                 | Return from Shutdown                                                             |      | 130  |      |                  |
|                                |                                 | Hysteresis                                                                       |      | 20   |      |                  |

**DYNAMIC CHARACTERISTICS**

|            |                                 |                                                                                                                                |  |      |      |               |
|------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------|--|------|------|---------------|
| $t_{DON}$  | Turn-On Delay (Note 5, 6)       | $V_{IN} = 5$ V, $R_L = 100\ \Omega$ , $C_L = 1\ \mu\text{F}$ ,<br>$T_A = 25^\circ\text{C}$ , $R_{SET} = 2040\ \Omega$          |  | 0.67 |      | ms            |
| $t_R$      | $V_{OUT}$ Rise Time (Note 5, 6) |                                                                                                                                |  | 0.69 |      | ms            |
| $t_{ON}$   | Turn-On Time (Note 5, 7)        |                                                                                                                                |  | 1.36 |      | ms            |
| $t_{DOFF}$ | Turn-Off Delay (Note 6, 5)      |                                                                                                                                |  | 0.01 |      | ms            |
| $t_F$      | $V_{OUT}$ Fall Time (Note 6, 5) |                                                                                                                                |  | 0.22 |      | ms            |
| $t_{OFF}$  | Turn-Off Time (Note 8, 5)       |                                                                                                                                |  | 0.23 |      | ms            |
| $t_{DON}$  | Turn-On Delay (Note 6, 9)       | $V_{IN} = 5$ V, $R_L = 3.8\ \Omega$ , $C_L = 10\ \mu\text{F}$ ,<br>$T_A = -40$ to $85^\circ\text{C}$ , $R_{SET} = 634\ \Omega$ |  | 0.65 | 0.78 | ms            |
| $t_R$      | $V_{OUT}$ Rise Time (Note 6, 9) |                                                                                                                                |  | 0.65 | 0.82 | ms            |
| $t_{ON}$   | Turn-On Time (Note 7, 9)        |                                                                                                                                |  | 1.3  | 1.6  | ms            |
| $t_{DOFF}$ | Turn-Off Delay (Note 6, 9)      |                                                                                                                                |  | 4    | 10   | $\mu\text{s}$ |
| $t_F$      | $V_{OUT}$ Fall Time (Note 6, 9) |                                                                                                                                |  | 76   | 120  | $\mu\text{s}$ |
| $t_{OFF}$  | Turn-Off Time (Note 8, 9)       |                                                                                                                                |  | 80   | 130  | $\mu\text{s}$ |

4. Characterization based on 1% tolerance resistor.
5. This parameter is guaranteed by design and characterization; not production tested.
6.  $t_{DON}/t_{DOFF}/t_R/t_F$  are defined in Figure 5 below.
7.  $t_{ON} = t_R + t_{DON}$ .
8.  $t_{OFF} = t_F + t_{DOFF}$ .
9. This parameter is guaranteed by design.

**TIMING DIAGRAM**



where:

$t_{DON}$  = Delay On Time  
 $t_R$  =  $V_{OUT}$  Rise Time  
 $t_{ON}$  = Turn-On Time  
 $t_{DOFF}$  = Delay Off Time  
 $t_F$  =  $V_{OUT}$  Fall Time  
 $t_{OFF}$  = Turn Off Time

Figure 5. Timing Diagram

## OPERATION AND APPLICATION DESCRIPTION

### Input Capacitor

To limit the voltage drop on the input supply caused by transient inrush current when the switch turns on into discharge load capacitor; a capacitor must be placed in between the  $V_{IN}$  and GND pins. A high-value capacitor on  $C_{IN}$  can be used to reduce the voltage drop in high-current applications.

### Output Capacitor

An output capacitor should be placed between the  $V_{OUT}$  and GND pins. This capacitor prevents parasitic board inductance from forcing  $V_{OUT}$  below GND when the switch is on. This capacitor also prevents reverse inrush current from creating a voltage spike that could damage the device in the case of a  $V_{OUT}$  short.

### Fault Reporting

Upon the detection of an over-current, OC\_FLAGB signal the fault by activating LOW.

### Current Limiting

The current limit ensures that the current through the switch does not exceed the maximum set value, while not limiting the minimum value. The current at which the part's limit is adjustable through the selection of the external resistor connected to the ISET pin. Information for selecting the resistor is found in the section below. The device acts as a constant-current source when the load draws more than the maximum value set by the device until thermal shutdown occurs. The device recovers if the die temperature drops below the threshold temperature.

### Under-Voltage Lockout (UVLO)

The under-voltage lockout turns the switch off if the input voltage drops below the lockout threshold. With the ON pin active, the input voltage rising above the UVLO threshold releases the lockout and enables the switch.

### Reverse-Current Blocking

The reverse-current blocking feature protects the input source against current flow from output to input when the load switch is off.

### Thermal Shutdown

The thermal shutdown protects the die from internally or externally generated excessive temperature. During an over-temperature condition, the switch is turned off. The switch automatically turns on again if the temperature of the die drops below the threshold temperature.

### Setting Current Limit

The current limit is set with an external resistor connected between the  $I_{SET}$  and GND pins. The resistor is selected

using Table 1. Resistor tolerance of 1% or less is recommended.

**Table 1. CURRENT LIMIT SETTINGS BY RSET** (Note10)

| $R_{SET}\Omega$ | Min. Current Limit (mA) | Typ. Current Limit (mA) | Max. Current Limit (mA) |
|-----------------|-------------------------|-------------------------|-------------------------|
| 420             | 2250                    | 2500                    | 2750                    |
| 469             | 2025                    | 2250                    | 2475                    |
| 528             | 1800                    | 2000                    | 2200                    |
| 604             | 1570                    | 1750                    | 1920                    |
| 680             | 1350                    | 1500                    | 1650                    |
| 866             | 1125                    | 1250                    | 1375                    |
| 1070            | 900                     | 1000                    | 1100                    |
| 1200            | 810                     | 900                     | 990                     |
| 1330            | 720                     | 800                     | 880                     |
| 1500            | 630                     | 700                     | 770                     |
| 1740            | 540                     | 600                     | 660                     |
| 2100            | 450                     | 500                     | 550                     |
| 2320            | 405                     | 450                     | 495                     |
| 2550            | 360                     | 400                     | 440                     |
| 2940            | 315                     | 350                     | 385                     |
| 3400            | 270                     | 300                     | 330                     |
| 4020            | 225                     | 250                     | 275                     |
| 4990            | 180                     | 200                     | 220                     |
| 6490            | 135                     | 150                     | 165                     |
| 9530            | 90                      | 100                     | 110                     |
| 20000           | 42                      | 50                      | 58                      |

10. Table values based on 1% tolerance resistor.

11. For 50 mA setting, tolerance is  $\pm 15\%$  with 1%.

If current limit is not used it is OK for the  $I_{SET}$  pin to be connected with GND, but the maximum current must be less than the maximum current capability of 2.8 A.

## BOARD LAYOUT

For best performance, all traces should be as short as possible. To be most effective, the input and output capacitors should be placed close to the device to minimize the effect that parasitic trace inductance may have on normal and short-circuit operation. Using wide traces for  $V_{IN}$ ,  $V_{OUT}$ , GND helps minimize parasitic electrical effects along with minimizing the case-to-ambient thermal impedance.

# FPF2495B

## TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25^\circ\text{C}$



Figure 1.  $t_{ON}$  Response



Figure 2. OVP Response (Increase  $V_{OUT}$  to OVP Trip Point)

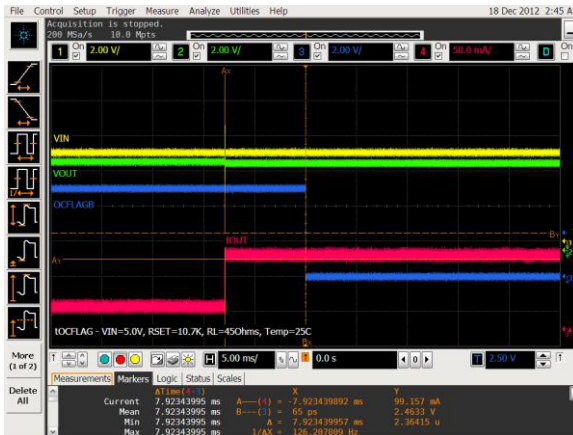


Figure 3. OC\_FLAGB Response Time (Toggle  $R_{LOAD}$  from High to Low Resistance)



Figure 4.  $t_{OFF}$  Response



Figure 5.  $t_{OCP}$  Response Time

## FPF2495B

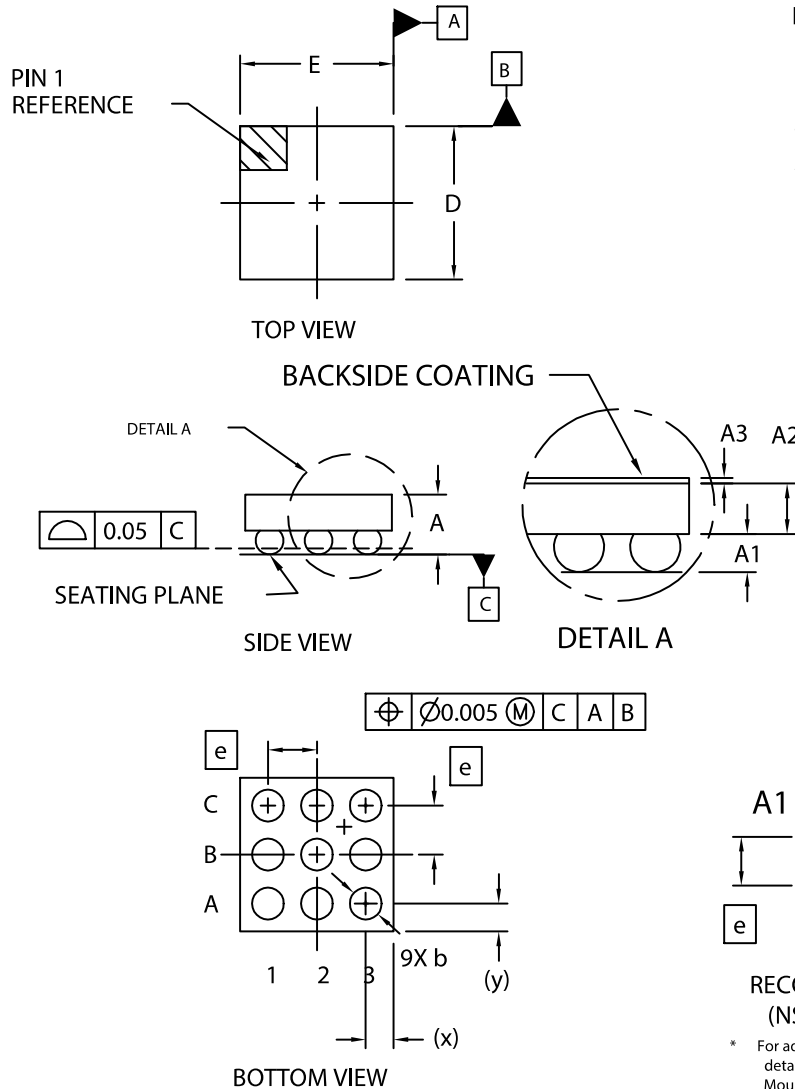
### PRODUCT-SPECIFIC DIMENSIONS

| Parts       | D                                         | E                                         | X                 | Y                 |
|-------------|-------------------------------------------|-------------------------------------------|-------------------|-------------------|
| FPF2495BUCX | 1220 $\mu\text{m}$ $\pm$ 30 $\mu\text{m}$ | 1220 $\mu\text{m}$ $\pm$ 30 $\mu\text{m}$ | 210 $\mu\text{m}$ | 210 $\mu\text{m}$ |



**WLCSP9 1.22x1.22x0.581**  
CASE 567SU  
ISSUE A

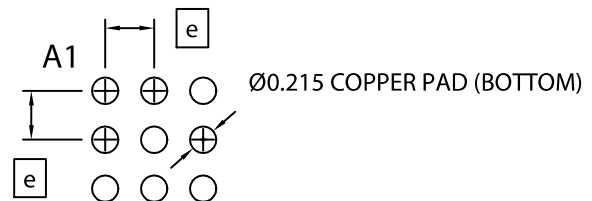
DATE 22 APR 2020



### NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2009.
2. CONTROLLING DIMENSION: MILLIMETERS
3. DATUM C APPLIES TO THE SPHERICAL CROWN OF THE SOLDER BALLS

| DIM | MILLIMETERS |       |       |
|-----|-------------|-------|-------|
|     | MIN.        | NOM.  | MAX.  |
| A   | 0.543       | 0.581 | 0.619 |
| A1  | 0.183       | 0.203 | 0.223 |
| A2  | 0.338       | 0.353 | 0.368 |
| A3  | 0.022       | 0.025 | 0.028 |
| b   | 0.240       | 0.260 | 0.280 |
| D   | 1.19        | 1.22  | 1.25  |
| E   | 1.19        | 1.22  | 1.25  |
| e   | 0.40 BSC    |       |       |
| x   | 0.195       | 0.210 | 0.225 |
| y   | 0.195       | 0.210 | 0.225 |



### RECOMMENDED MOUNTING FOOTPRINT\* (NSMD PAD TYPE)

\* For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

|                         |                               |                                                                                                                                                                                     |
|-------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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| <b>DESCRIPTION:</b>     | <b>WLCSP9 1.22x1.22x0.581</b> | <b>PAGE 1 OF 1</b>                                                                                                                                                                  |

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