



# MP7200

## 42V, 1.2A Buck-Boost or 3A Buck Synchronous LED Driver

### DESCRIPTION

The MP7200 is a high-frequency, constant-current, buck-boost LED driver with integrated power MOSFETs. It offers a very compact solution to achieve up to 1.2A of continuous output current, with excellent load and line regulation across a wide input supply range. The MP7200 can also be configured to buck mode to provide up to 3A of constant load current.

Constant frequency hysteretic control mode provides extremely fast transient response without loop compensation. The switching frequency goes up to a fixed 2.3MHz in buck mode to reduce the current ripple and improve EMI, and down to 1.15MHz in buck-boost mode to optimize efficiency and thermal performance.

Full protection features include over-current protection (OCP), output over-voltage (OV) and under-voltage (UV), thermal derating (TD), and thermal shutdown (TSD). The fault indicator outputs an active logic low signal if a fault condition occurs.

The MP7200 requires a minimal number of readily available, standard external components, and is available in a space-saving QFN-19 (3mmx4mm) package.

### FEATURES

- Wide 6V to 42V Operating Input Range
- 44mΩ/40mΩ Low  $R_{DS(ON)}$  Internal Power MOSFETs
- High-Efficiency Synchronous Mode Operation
- Configurable 1.2A Buck-Boost or 3A Buck Mode
- Configurable LED Current without Current-Sense Resistor
- Default 2.3MHz Switching Frequency for Buck Mode and 1.15MHz Switching Frequency for Buck-Boost Mode with Spread Spectrum
- PWM Dimming (Dimming Frequency from 100Hz to 2kHz)
- Internal 500Hz Two-Step Dimming with Configurable Duty Cycle
- Fault Indication for LED Short (to GND and Battery) and Open, Output Over-Voltage, and Thermal Shutdown
- Over-Current Protection (OCP) with Latch-Off Mode
- Configurable Thermal Derating via NTC Remote Temperature Sense
- EMI Reduction Technique
- Available in a QFN-19 (3mmx4mm) Package with Wettable Flanks

### APPLICATIONS

- Turn Indicator Lights
- Daytime Running Lights (DRLs)
- Fog Lights
- Rear Lights

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## TYPICAL APPLICATIONS

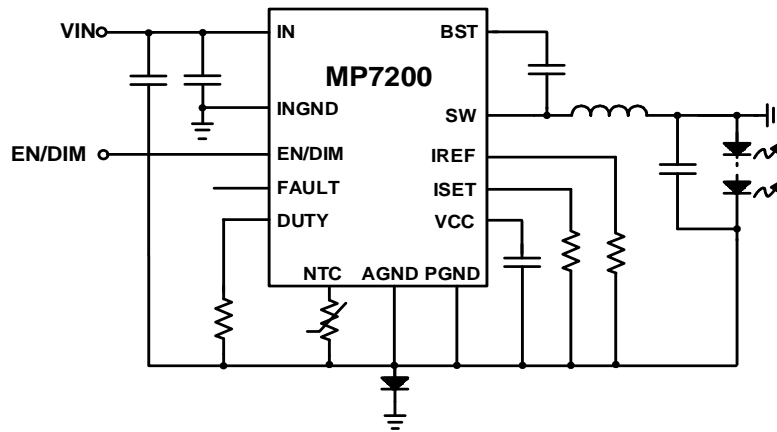


Figure 1: Buck-Boost Topology ( $\leq 9.09k\Omega R_{IREF}$ )

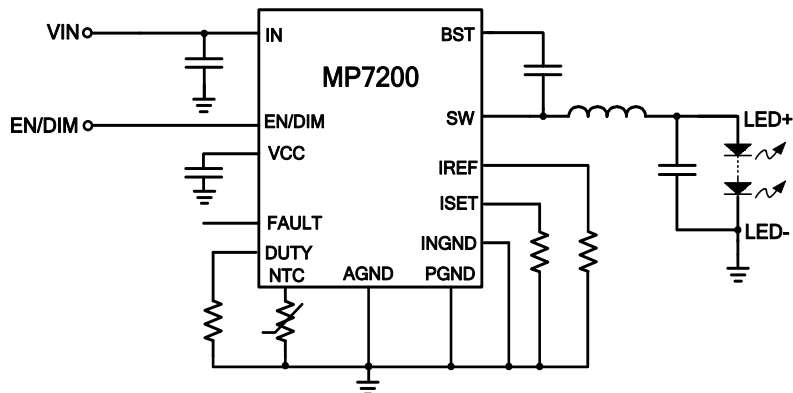


Figure 2: Buck Topology ( $\geq 14.7k\Omega R_{IREF}$ )

## ORDERING INFORMATION

| Part Number* | Package          | Top Marking | MSL Rating** |
|--------------|------------------|-------------|--------------|
| MP7200GLE*** | QFN-19 (3mmx4mm) | See Below   | 1            |

\* For Tape & Reel, add suffix -Z (e.g. MP7200GLE-Z).

\*\* Moisture Sensitivity Level Rating.

\*\*\* Wettable Flank.

## TOP MARKING

**MPYW**

**7200**

**LLL**

**E**

MP: MPS prefix

Y: Year code

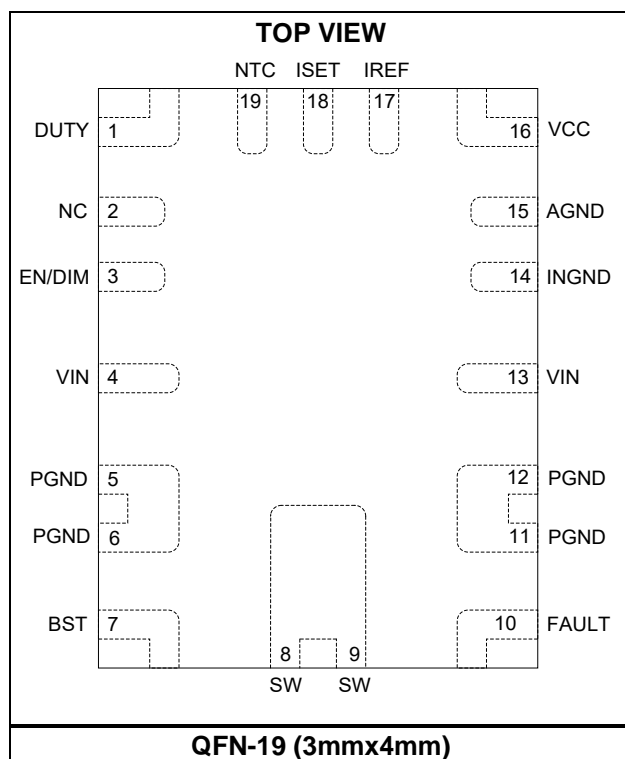
W: Week code

7200: First four digits of the part number

LLL: Lot number

E: Wettable flank

## PACKAGE REFERENCE



## PIN FUNCTIONS

| Pin #        | Name   | Description   |
|--------------|--------|---|
| 1            | DUTY   | <b>Two-step dimming duty setting.</b> Connect a resistor ( $R_{DUTY}$ ) between DUTY and AGND to disable two-step dimming or set the two-step dimming duty cycle. The two-step dimming duty cycle can be set between 5% and 15%, with 1% a step. For more details on the relationship between duty cycle and $R_{DUTY}$ , see the Two-Step Dimming section on page 43. If the DUTY pin is shorted to ground or an open fault is detected before start-up, the part latches off and FAULT is asserted.   |
| 2            | NC     | <b>Not connection.</b> Leave this pin floating.   |
| 3            | EN/DIM | <b>Enable/dimming control.</b> Pull EN high to enable the chip. The part starts to sense the pin's configuration at the first positive edge. Once the configuration is completed, apply a 100Hz to 2kHz external clock to the EN/DIM pin for PWM dimming ( $R_{DUTY} = 4.87K\Omega$ ). EN/DIM can be connected to VIN through a maximum 100k $\Omega$ resistor. In two-step dimming mode, EN is off and the PWM dimming function is deactivated. Pull this pin high for 100% dimming duty, and pull this pin low to set the dimming duty via $R_{DUTY}$ . |
| 4, 13        | VIN    | <b>Supply voltage.</b> The MP7200 operates from a 6V to 42V input rail. VIN requires an input capacitor ( $C_{IN}$ ) to decouple the input rail. Connect VIN to the input rail using a wide PCB trace.  |
| 5, 6, 11, 12 | PGND   | <b>Power ground.</b> PGND is the power device reference ground, including the configuration pins (e.g. NTC), so it requires additional considerations while designing the PCB layout. PGND is also used to dissipate the thermal heat.  |
| 7            | BST    | <b>Bootstrap.</b> Place a capacitor between the SW and BST pins to form a floating supply across the high-side MOSFET driver. Place an optional resistor between the SW and BST capacitors to reduce SW voltage spikes and improve EMI performance.   |
| 8,9          | SW     | <b>Switch output.</b> SW is the middle point between the high-side and low-side MOSFETs. When designing the PCB layout, it is recommended to make the SW node as small as possible with a wide trace. This reduces noise coupling and improves EMI.   |
| 10           | FAULT  | <b>Fault indicator.</b> FAULT is an open-drain output with an internal 300k $\Omega$ pull-up resistor connected to VIN, and a 4M $\Omega$ pull-down resistor connected to INGND. FAULT is pulled low if any of the following occurs: LED short or open, over-temperature protection (OTP), false mode detection, or over-current protection (OCP). FAULT can be continuously connected to VIN with a pull-up resistor.  |
| 14           | INGND  | <b>VIN, EN/DIM, and FAULT ground for buck-boost topology.</b> For a buck topology, connect INGND to PGND and AGND.  |
| 15           | AGND   | <b>Analog ground.</b> Reference ground of the logic circuit. Connect AGND to PGND using an external trace.  |
| 16           | VCC    | <b>Internal bias supply.</b> VCC supplies power to the internal control circuit and gate drivers. Connect a $\geq 3\mu F$ decoupling capacitor to VCC and ground. A 10 $\mu F$ /10V or 16V, X7R capacitor is strongly recommend due to capacitance derating.  |
| 17           | IREF   | <b>Mode selection and NTC reference current setting.</b> Connect a $\leq 9.09k\Omega$ resistor at IREF to select buck-boost mode, or a $\geq 14.7k\Omega$ resistor to select buck mode. The voltage of IREF is 0.57V. Connect a resistor ( $R_{IREF}$ ) from IREF to GND to get a reference current ( $0.57V / R_{IREF}$ ). If the IREF pin is shorted to ground or an open fault is detected, the part is latched off and asserts FAULT. The NTC pin current is 50 (buck mode) or 5 (buck-boost mode) times that of the IREF reference current.          |
| 18           | ISET   | <b>LED current setting.</b> Connect an external resistor from ISET to ground to set the LED average current. If the ISET pin is shorted to ground or an open fault is detected, the part is latched off and asserts FAULT.  |
| 19           | NTC    | <b>Remote temperature sense.</b> Connect NTC to a resistor network to configure the temperature derating starting point. There are protections if NTC is shorted to PGND, AGND, INGND, or the battery.  |

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

|   |                 |
|---|-----------------|
| $V_{IN} - V_{PGND/AGND}$ .....  | -0.3V to +50V   |
| $V_{IN} - V_{INGND}$ .....  | -0.3V to +50V   |
| $V_{INGND} - V_{PGND/AGND}$ .....                                       | -0.3V to +50V   |
| $V_{FAULT} - V_{INGND}$ .....   | -0.3V to +50V   |
| $V_{EN/DIM} - V_{INGND}$ .....  | -0.3V to +5.5V  |
| $V_{SW} - V_{PGND/AGND}$ -0.3V to $V_{IN} - V_{PGND/AGND} + 0.3V$       |                 |
| $V_{BST}$ .....   | $V_{SW} + 5.5V$ |
| $V_{NTC} - V_{PGND/AGND}$ .....   | -0.3V to +50V   |
| All other pins - $V_{PGND/AGND}$ .....                                  | -0.3V to +5.5V  |
| Continuous power dissipation ( $T_A = 25^{\circ}C$ ) <sup>(2) (4)</sup> |                 |
| QFN-19 (3mmx4mm) .....  | 3.9W            |
| Junction temperature .....  | 150°C           |
| Lead temperature .....  | 260°C           |
| Storage temperature .....   | -65°C to +150°C |

## ESD Ratings

|                                  |       |
|----------------------------------|-------|
| Human body model (HBM) .....     | ±2kV  |
| Charged device model (CDM) ..... | ±750V |

## Recommended Operating Conditions

|   |                 |
|---|-----------------|
| Supply voltage ( $V_{IN} - V_{PGND}$ ) .....      | 6V to 42V       |
| LED current ( $I_{LED}$ ) in buck-boost mode..... |                 |
| .....Up to 1.2A                                   |                 |
| LED current ( $I_{LED}$ ) in buck mode .....      | Up to 3A        |
| Operating junction temp ( $T_J$ )....             | -40°C to +125°C |

## Thermal Resistance

$\theta_{JA}$      $\theta_{JC}$

QFN-19 (3mmx4mm)

JESD51-7 <sup>(3)</sup> ..... 48 ..... 11... °C/W

EVQ7200-L-00A <sup>(4)</sup> ..... 32 ..... 6.... °C/W

### Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_J$  (MAX), the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable continuous power dissipation at any ambient temperature is calculated by  $P_D$  (MAX) =  $(T_J$  (MAX) -  $T_A$ ) /  $\theta_{JA}$ . Exceeding the maximum allowable power dissipation can cause excessive die temperature, and the regulator may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 3) Measured on JESD51-7, 4-layer PCB. The value of  $\theta_{JA}$  given in this table is only valid for comparison with other packages and cannot be used for design purposes. These values were calculated in accordance with JESD51-7 and simulated on a specified JEDEC board. They do not represent the performance obtained in an actual application.
- 4) Measured on MPS standard EVB of MP7200, 2oz, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck mode, unless otherwise noted.

| Parameter                                      | Symbol            | Condition  | Min   | Typ                           | Max   | Units      |
|--|-------------------|--|-------|-------------------------------|-------|------------|
| Shutdown supply current                        | $I_{IN}$          | $V_{EN} = 0V$  |       | 30                            | 80    | $\mu A$    |
| Quiescent supply current                       | $I_Q$             | $V_{EN} = 2V$ , no switching, $I_{REF}$ floating (exclude $I_{REF}$ and NTC current) |       | 1.2                           | 2     | mA         |
|  |                   | FAULT latch  |       |                               | 2     | mA         |
| HS-FET on resistance                           | $HS_{RDS(ON)}$    | $V_{BST-SW} = 5V$ , $R_{ISET} = 13.3k\Omega$   |       | 44                            | 75    | m $\Omega$ |
|  |                   | $V_{BST-SW} = 5V$ , $R_{ISET} = 40.2k\Omega$   |       | 85                            | 150   | m $\Omega$ |
| LS-FET on resistance                           | $LS_{RDS(ON)}$    | $V_{CC} = 5.2V$ , $R_{ISET} = 13.3k\Omega$   |       | 40                            | 70    | m $\Omega$ |
|  |                   | $V_{CC} = 5.2V$ , $R_{ISET} = 40.2k\Omega$   |       | 80                            | 140   | m $\Omega$ |
| Switch leakage                                 | $SW_{LKG}$        | $V_{EN} = 0V$ , $V_{SW} = 13.5V$ , $T_J = 25^{\circ}C$                               |       |                               | 1     | $\mu A$    |
|  |                   | $V_{EN} = 0V$ , $V_{SW} = 13.5V$   |       |                               | 5     | $\mu A$    |
| Peak current limit <sup>(6)</sup>              | $I_{LIMIT\_PEAK}$ | $R_{ISET} = 40.2k\Omega$   | 2.65  | 3.15                          | 3.65  | A          |
|  |                   | $R_{ISET} = 13.3k\Omega$   | 5.3   | 6.3                           | 7.3   | A          |
| Zero-current detection <sup>(6)</sup>          |                   |  |       | 50                            |       | mA         |
| Oscillator frequency                           | $f_{SW}$          |  | 2000  | 2300                          | 2600  | kHz        |
| Minimum on time <sup>(6)</sup>                 | $t_{ON\_MIN}$     |  |       | 55                            | 80    | ns         |
| Minimum off time <sup>(6)</sup>                | $t_{OFF\_MIN}$    |  |       | 75                            | 100   | ns         |
| Maximum duty cycle <sup>(6)</sup>              | $D_{MAX}$         | Low dropout  | 95    | 98                            |       | %          |
| Frequency spread spectrum <sup>(6)</sup>       |                   |  |       | 15                            |       | kHz        |
| Frequency spread spectrum range <sup>(6)</sup> |                   |  |       | $\pm 10\%$<br>$\times f_{SW}$ |       | kHz        |
|  |                   |  |       |                               |       |            |
| LED current                                    | $I_{LED}$         | $R_{ISET} = 13.3k\Omega$ , $T_J = 25^{\circ}C$ to $100^{\circ}C$                     | -5%   | 1.2                           | +5%   | A          |
|  |                   | $R_{ISET} = 13.3k\Omega$   | -15%  |                               | +15%  |            |
| LED current threshold for MOSFET cutoff        | $I_{LED\_CUT}$    |  |       | 600                           | 700   | mA         |
| ISET voltage                                   | $V_{ISET}$        | $I_{SET} = 45\mu A$  | 0.578 | 0.592                         | 0.606 | V          |
|  |                   |  |       |                               |       |            |
| ISET current threshold for pin short           |                   | $I_{LED} < I_{LED\_CUT}$   | 80    | 120                           | 160   | $\mu A$    |
|  |                   | $I_{LED} > I_{LED\_CUT}$   | 180   | 220                           | 260   | $\mu A$    |
| ISET current threshold for pin open            |                   |  | 0.5   | 1.4                           | 5     | $\mu A$    |
| EN rising threshold                            | $V_{EN\_RISING}$  | $V_{EN} - V_{INGND}$   | 1.2   | 1.67                          | 2.5   | V          |
| EN falling threshold                           | $V_{EN\_FALLING}$ | $V_{EN} - V_{INGND}$   | 1     | 1.58                          | 2.2   | V          |
| EN threshold hysteresis                        | $V_{EN\_HYS}$     | $V_{EN} - V_{INGND}$   |       | 100                           |       | mV         |
| EN input current                               | $I_{EN}$          | $V_{EN} - V_{INGND} = 2V$  |       | 2                             | 8     | $\mu A$    |
|  |                   | $V_{EN} - V_{INGND} = 0V$  |       | 0                             | 0.2   | $\mu A$    |

**ELECTRICAL CHARACTERISTICS (continued)**

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck mode, unless otherwise noted.

| Parameter   | Symbol            | Condition                                      | Min   | Typ   | Max   | Units      |
|---|-------------------|--|-------|-------|-------|------------|
| EN turn-off delay   | $t_{EN-TD-OFF}$   |  | 10    | 25    | 45    | ms         |
| VIN under-voltage lockout (UVLO) rising threshold           | $INUV_{VTH\_R}$   | $V_{IN} - V_{INGND}$                           | 5.75  | 6     | 6.25  | V          |
| VIN UVLO falling threshold                                  | $INUV_{VTH\_F}$   | $V_{IN} - V_{INGND}$                           | 4.5   | 4.9   | 5.2   | V          |
| VIN UVLO threshold hysteresis                               | $INUV_{HYS}$      | $V_{IN} - V_{INGND}$                           |       | 1.1   |       | V          |
| VCC UVLO rising threshold                                   | $V_{CC\_VTH}$     | $V_{CC} - V_{AGND}$                            | 4.4   | 4.7   | 5     | V          |
| VCC UVLO falling threshold                                  |                   | $V_{CC} - V_{AGND}$                            | 3.4   | 4.05  | 4.7   | V          |
| VCC UVLO threshold hysteresis                               | $V_{CC\_HYS}$     | $V_{CC} - V_{AGND}$                            |       | 650   |       | mV         |
| VCC regulator   | $V_{CC}$          | $I_{CC} = 0mA$                                 | 4.9   | 5.1   | 5.3   | V          |
| VCC load regulation   |                   | $I_{CC} = 20mA$                                | 4.7   |       |       | V          |
| VCC maximum current ability                                 |                   | $V_{CC} = V_{CC\_UVLO} + 100mV$ , no switching | 50    | 80    | 120   | mA         |
| VCC source current ability <sup>(6)</sup>                   |                   | $V_{CC} = V_{CC\_UVLO} + 100mV$ , switching    |       | 25    |       | mA         |
| DUTY source current   | $I_{DUTY}$        | $I_{DUTY1}$                                    | 40    | 45    | 50    | $\mu A$    |
|   |                   | $I_{DUTY2}$                                    | 550   | 600   | 650   | $\mu A$    |
| $V_{DUTY}$ threshold maximum                                |                   | $I_{DUTY1}$ and $I_{DUTY2}$                    | 3.287 | 3.355 | 3.422 | V          |
| $V_{DUTY}$ threshold minimum <sup>(6)</sup>                 |                   | $I_{DUTY1}$ and $I_{DUTY2}$                    | 0.28  | 0.302 | 0.33  | V          |
| Two-step dimming frequency <sup>(6)</sup>                   |                   |  |       | 500   |       | Hz         |
| Output over-voltage (OV) threshold                          | $OV_{VTH}$        |  | 16.5  | 18    | 19    | V          |
| Output under-voltage (UV) threshold                         | $UV_{VTH}$        |  | 0.6   | 1.1   | 1.7   | V          |
| LED low-current threshold                                   |                   | $I_{LED\_SETTING} < I_{LED\_CUT}$              | 45    | 60    | 75    | mA         |
|   |                   | $I_{LED\_SETTING} > I_{LED\_CUT}$              | 100   | 120   | 150   | mA         |
| FAULT assertion delay time during start-up                  | $t_{FT-D\_START}$ |  | 25    | 35    | 40    | ms         |
| FAULT assertion deglitch time after start-up <sup>(6)</sup> | $t_{FT-D}$        |  |       | 20    |       | $\mu s$    |
| FAULT assertion low sink current ability                    | $I_{FAULT\_SINK}$ | $V_{FAULT} = 12V$                              | 10    | 30    | 50    | mA         |
|   |                   | $V_{FAULT} = 0.2V$                             | 5     | 12    |       | mA         |
| FAULT pull-up resistor                                      |                   |  | 100   | 300   | 500   | k $\Omega$ |
| FAULT pull-down resistor                                    |                   |  | 2000  | 4000  | 6000  | k $\Omega$ |
| IREF current for mode detection                             |                   |  | 200   | 240   | 280   | $\mu A$    |

**ELECTRICAL CHARACTERISTICS (continued)**

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck mode, unless otherwise noted.

| Parameter  | Symbol     | Condition                               | Min   | Typ  | Max   | Units       |
|--|------------|---|-------|------|-------|-------------|
| $V_{REF}$ threshold for mode detection               |            |   | 2.6   | 2.7  | 2.8   | V           |
| IREF voltage   | $V_{REF}$  | $I_{REF} = 20\mu A$                     | 0.50  | 0.57 | 0.63  | V           |
| IREF current threshold for pin short detection       |            |   | 60    | 90   | 120   | $\mu A$     |
| IREF current threshold for pin open detection        |            |   |       | 3    | 6     | $\mu A$     |
| NTC source current                                   | $I_{NTC1}$ |   | 4.5   | 7.6  | 10    | $\mu A$     |
|  | $I_{NTC2}$ | $V_{NTC} = 1.25V$ , $I_{REF} = 20\mu A$ | 980   | 1020 | 1060  | $\mu A$     |
| NTC voltage for current derating                     |            | $I_{LED} = 98\%$ of the nominal voltage | -2.5% | 1.25 | +2.5% | V           |
|  |            | $I_{LED} = 58\%$ of the nominal voltage | -2.5% | 0.65 | +2.5% | V           |
| VNTC OV threshold                                    |            | $V_{NTC1}$                              | 1.8   | 2    | 2.2   | V           |
| VNTC threshold for over-temperature protection (OTP) |            | $V_{NTC2}$                              | 0.2   | 0.38 | 0.48  | V           |
| VNTC deglitch time for OTP                           |            | $V_{NTC} = 0.3V$                        | 180   | 256  | 320   | $\mu s$     |
| VNTC UV threshold                                    |            | $V_{NTC2}$                              | 0.14  | 0.18 | 0.22  | V           |
| Thermal shutdown <sup>(6)</sup>                      |            |   | 155   | 170  | 185   | $^{\circ}C$ |



## ELECTRICAL CHARACTERISTICS *(continued)*

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck-boost mode, unless otherwise noted.

| Parameter                                      | Symbol            | Condition   | Min   | Typ                           | Max   | Units      |
|--|-------------------|---|-------|-------------------------------|-------|------------|
| Shutdown supply current                        | $I_{IN}$          | $V_{EN} = 0V$   |       | 30                            | 80    | $\mu A$    |
| Quiescent supply current                       | $I_Q$             | $V_{EN} = 2V$ , no switching, $I_{REF}$ float (exclude $I_{REF}$ and NTC current) |       | 1.2                           | 2     | mA         |
|  |                   | FAULT latch   |       |                               | 2     | mA         |
| HS-FET on resistance                           | $HS_{RDS(ON)}$    | $V_{BST-SW} = 5V$ , $R_{ISET} = 13.3k\Omega$                                      |       | 44                            | 75    | m $\Omega$ |
| LS-FET on resistance                           | $LS_{RDS(ON)}$    | $V_{CC} = 5.2V$ , $R_{ISET} = 13.3k\Omega$  |       | 40                            | 70    | m $\Omega$ |
| Switch leakage                                 | $SW_{LKG}$        | $V_{EN} = 0V$ , $V_{SW} = 13.5V$ , $T_J = 25^{\circ}C$                            |       |                               | 1     | $\mu A$    |
|  |                   | $V_{EN} = 0V$ , $V_{SW} = 13.5V$  |       |                               | 5     | $\mu A$    |
| Peak current limit <sup>(6)</sup>              | $I_{LIMIT\_PEAK}$ |   | 5.3   | 6.3                           | 7.3   | A          |
| Zero-current detection (ZCD) <sup>(5)</sup>    |                   |   |       | 50                            |       | mA         |
| Oscillator frequency                           | $f_{SW}$          |   | 920   | 1150                          | 1380  | kHz        |
| Minimum on time <sup>(6)</sup>                 | $t_{ON\_MIN}$     |   |       | 55                            | 80    | ns         |
| Minimum off time <sup>(6)</sup>                | $t_{OFF\_MIN}$    |   |       | 75                            | 100   | ns         |
| Maximum duty cycle <sup>(6)</sup>              | $D_{MAX}$         | Low dropout   | 95    | 98                            |       | %          |
| Frequency spread spectrum <sup>(6)</sup>       |                   |   |       | 15                            |       | kHz        |
| Frequency spread spectrum range <sup>(6)</sup> |                   |   |       | $\pm 10\%$<br>$\times f_{SW}$ |       | kHz        |
| LED current                                    | $I_{LED}$         | $R_{ISET} = 21.5k\Omega$ , $T_J = 25^{\circ}C$ to $100^{\circ}C$                  | -7%   | 0.75                          | +7%   | A          |
|  |                   | $R_{ISET} = 21.5k\Omega$  | -15%  |                               | +15%  |            |
|  |                   | $R_{ISET} = 13.3k\Omega$ , $T_J = 25^{\circ}C$ to $100^{\circ}C$                  | -5%   | 1.2                           | +5%   | A          |
|  |                   | $R_{ISET} = 13.3k\Omega$  | -15%  |                               | +15%  |            |
| ISET voltage                                   | $V_{ISET}$        | $I_{ISET} = 45\mu A$  | 0.578 | 0.592                         | 0.606 | V          |
| Power derating ratio                           |                   | $V_{IN} = 6.6V$ , $V_{ISET}$ with respect to the nominal voltage                  | 91.5  | 95                            | 98.5  | %          |
|  |                   | $V_{IN} = 5.3V$ , $V_{ISET}$ with respect to the nominal voltage                  | 72.5  | 76                            | 79.5  | %          |
| ISET current threshold for pin short           |                   |   | 90    | 110                           | 130   | $\mu A$    |
| ISET current threshold for pin open            |                   |   | 0.5   | 1.4                           | 5     | $\mu A$    |
| EN rising threshold                            | $V_{EN\_RISING}$  | $V_{EN} - V_{INGND}$  | 1.2   | 1.67                          | 2.5   | V          |
| EN falling threshold                           | $V_{EN\_FALLING}$ | $V_{EN} - V_{INGND}$  | 1.0   | 1.58                          | 2.2   | V          |
| EN threshold hysteresis                        | $V_{EN\_HYS}$     | $V_{EN} - V_{INGND}$  |       | 100                           |       | mV         |

**ELECTRICAL CHARACTERISTICS (continued)**

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck-boost mode, unless otherwise noted.

| Parameter   | Symbol            | Condition                                      | Min   | Typ   | Max   | Units   |
|---|-------------------|--|-------|-------|-------|---------|
| EN input current                                  | $I_{EN}$          | $V_{EN} = 2V$                                  |       | 2     | 8     | $\mu A$ |
|   |                   | $V_{EN} = 0V$                                  |       | 0     | 0.2   | $\mu A$ |
| EN turn-off delay                                 | $t_{EN-TD-OFF}$   |  | 10    | 25    | 45    | ms      |
| VIN UVLO rising threshold                         | $INUV_{VTH\_R}$   | $V_{IN} - V_{INGND}$                           | 5.75  | 6     | 6.25  | V       |
| VIN UVLO falling threshold                        | $INUV_{VTH\_F}$   | $V_{IN} - V_{INGND}$                           | 4.5   | 4.9   | 5.2   | V       |
| VIN UVLO threshold hysteresis                     | $INUV_{HYS}$      | $V_{IN} - V_{INGND}$                           |       | 1.1   |       | V       |
| VCC UVLO rising threshold                         | $V_{CC\_VTH}$     | $V_{CC} - V_{AGND}$                            | 4.4   | 4.7   | 5     | V       |
| VCC UVLO falling threshold                        |                   | $V_{CC} - V_{AGND}$                            | 3.4   | 4.05  | 4.7   | V       |
| VCC UVLO threshold hysteresis                     | $V_{CC\_HYS}$     | $V_{CC} - V_{AGND}$                            |       | 650   |       | mV      |
| VCC regulator                                     | $V_{CC}$          | $I_{CC} = 0mA$                                 | 4.9   | 5.1   | 5.3   | V       |
| VCC load regulation                               |                   | $I_{CC} = 20mA$                                | 4.7   |       |       | V       |
| VCC maximum current ability                       |                   | $V_{CC} = V_{CC\_UVLO} + 100mV$ , no switching | 50    | 80    | 120   | mA      |
| VCC source current ability <sup>(6)</sup>         |                   | $V_{CC} = V_{CC\_UVLO} + 100mV$ , switching    |       | 25    |       | mA      |
| DUTY source current                               | $I_{DUTY}$        | $I_{DUTY1}$                                    | 40    | 45    | 50    | $\mu A$ |
|   |                   | $I_{DUTY2}$                                    | 550   | 600   | 650   | $\mu A$ |
| VDUTY threshold maximum                           |                   | $I_{DUTY1}$ and $I_{DUTY2}$                    | 3.287 | 3.355 | 3.422 | V       |
| VDUTY threshold minimum <sup>(6)</sup>            |                   | $I_{DUTY1}$ and $I_{DUTY2}$                    | 0.28  | 0.302 | 0.33  | V       |
| Two-step dimming frequency <sup>(6)</sup>         |                   |  |       | 500   |       | Hz      |
| Output OV threshold                               | $OV_{VTH}$        | $V_{INGND} - V_{AGND}$                         | 17    | 18    | 19    | V       |
| Output UV threshold                               | $UV_{VTH}$        | $V_{INGND} - V_{AGND}$                         | 1     | 1.35  | 1.7   | V       |
| VIN load dump protection threshold                |                   |  | 38    | 40    | 42    | V       |
| VIN load dump protection falling threshold        |                   |  | 37    | 39    | 41    | V       |
| VIN load dump protection hysteresis               |                   |  |       | 1     |       | V       |
| Output discharge current for load dump protection |                   | $V_{INGND} - V_{PGND} > 5V$                    | 40    | 100   | 180   | mA      |
|   |                   | $V_{INGND} - V_{PGND} = 1V$                    | 20    | 45    | 90    | mA      |
| FAULT assertion delay time when during start-up   | $t_{FT-D\_START}$ |  | 25    | 35    | 40    | ms      |
| FAULT assertion deglitch time after start-up      | $t_{FT-D}$        |  |       | 20    |       | $\mu s$ |

**ELECTRICAL CHARACTERISTICS (continued)**

$V_{IN} = 13.5V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$  <sup>(5)</sup>, typical values are at  $T_J = 25^{\circ}C$ , buck-boost mode, unless otherwise noted.

| Parameter                                      | Symbol            | Condition                                | Min   | Typ  | Max   | Units       |
|--|-------------------|--|-------|------|-------|-------------|
| FAULT assertion low sink current ability       | $I_{FAULT\_SINK}$ | $V_{FAULT} = 12V$                        | 10    | 30   | 50    | mA          |
|  |                   | $V_{FAULT} = 0.2V$                       | 5     | 12   |       | mA          |
| FAULT pull-up resistor                         |                   |  | 100   | 300  | 500   | k $\Omega$  |
| FAULT pull-down resistor                       |                   |  | 2000  | 4000 | 6000  | k $\Omega$  |
| IREF current for mode detection                |                   |  | 200   | 240  | 280   | $\mu A$     |
| VIREF threshold for mode detection             |                   |  | 2.6   | 2.7  | 2.8   | V           |
| IREF voltage                                   | $V_{IREF}$        | $I_{REF} = 20\mu A$                      | 0.50  | 0.57 | 0.63  | V           |
| IREF current threshold for pin short detection |                   |  | 600   | 900  | 1200  | $\mu A$     |
| IREF current threshold for pin open detection  |                   |  |       | 40   | 70    | $\mu A$     |
| NTC source current                             | $I_{NTC1}$        |  | 4.5   | 7.6  | 10    | $\mu A$     |
|  | $I_{NTC2}$        | $V_{NTC} = 1.25V$ , $I_{REF} = 200\mu A$ | 980   | 1020 | 1060  | $\mu A$     |
| NTC voltage for current derating               |                   | $I_{LED} = 98\%$ of the nominal voltage  | -2.5% | 1.25 | +2.5% | V           |
|  |                   | $I_{LED} = 58\%$ of the nominal voltage  | -2.5% | 0.65 | +2.5% | V           |
| $V_{NTC}$ OV threshold                         |                   | $V_{NTC1}$                               | 1.8   | 2    | 2.2   | V           |
| $V_{NTC}$ threshold for OTP                    |                   | $V_{NTC2}$                               | 0.2   | 0.38 | 0.48  | V           |
| $V_{NTC}$ deglitch time for OTP                |                   | $V_{NTC} = 0.3V$                         | 180   | 256  | 320   | $\mu s$     |
| $V_{NTC}$ UV threshold                         |                   | $V_{NTC2}$                               | 0.14  | 0.18 | 0.22  | V           |
| Thermal shutdown <sup>(6)</sup>                |                   |  | 155   | 170  | 185   | $^{\circ}C$ |

**Notes:**

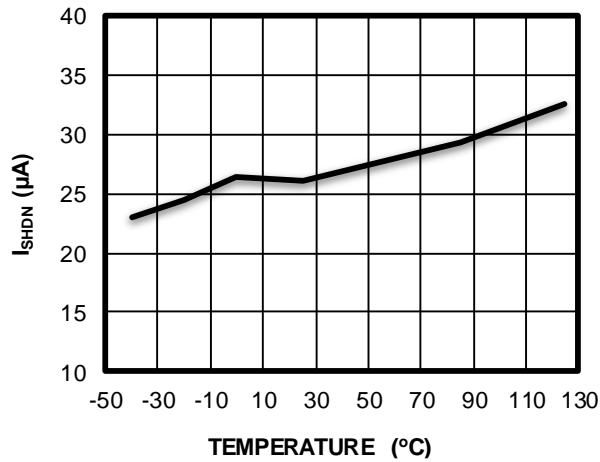
5) Not tested in production. Guaranteed by over-temperature correlation.

6) Not tested in production. Guaranteed by design and characterization.

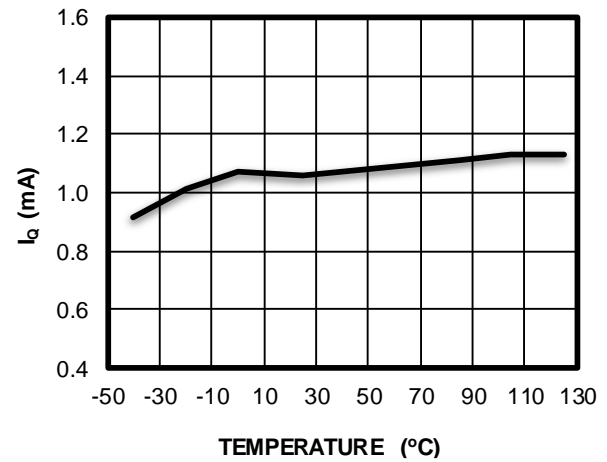
## TYPICAL CHARACTERISTICS

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted.

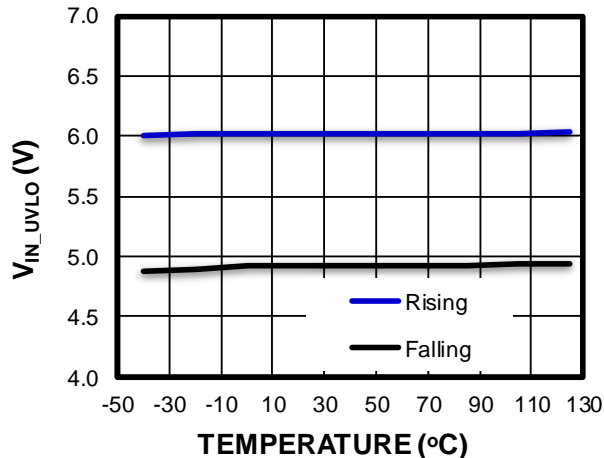
Shutdown Current vs. Temperature



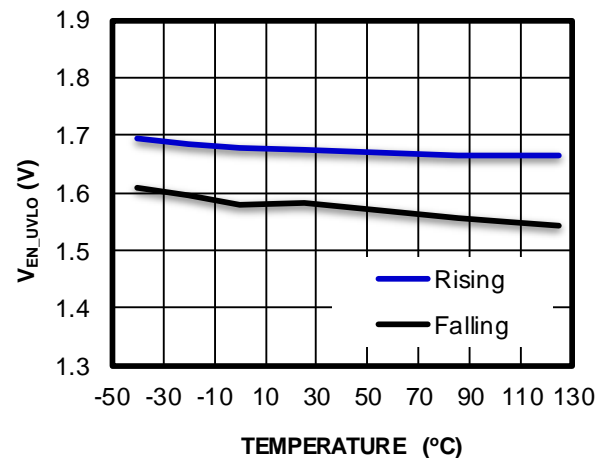
Quiescent Current vs. Temperature



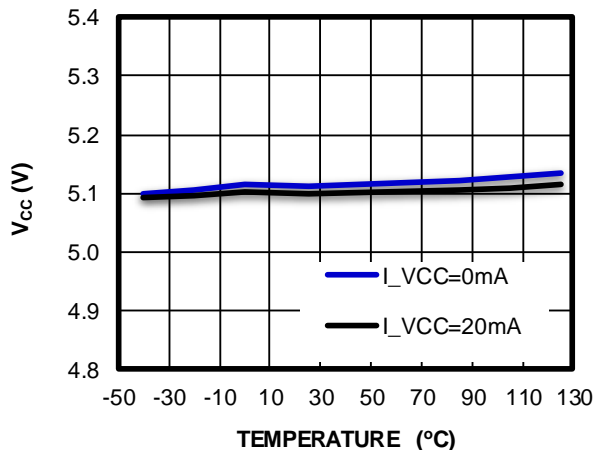
VIN UVLO Threshold vs. Temperature



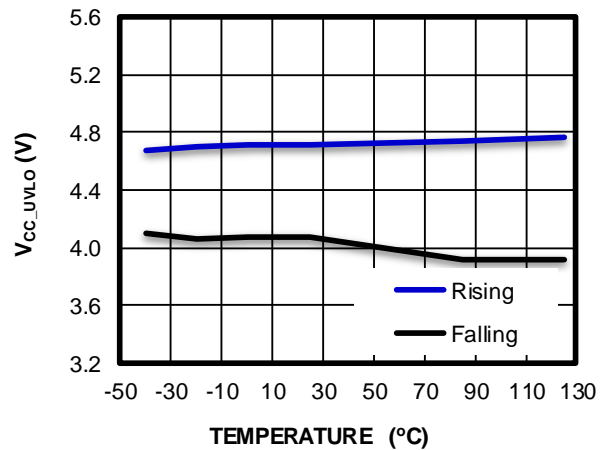
EN UVLO Threshold vs. Temperature



VCC Voltage vs. Temperature



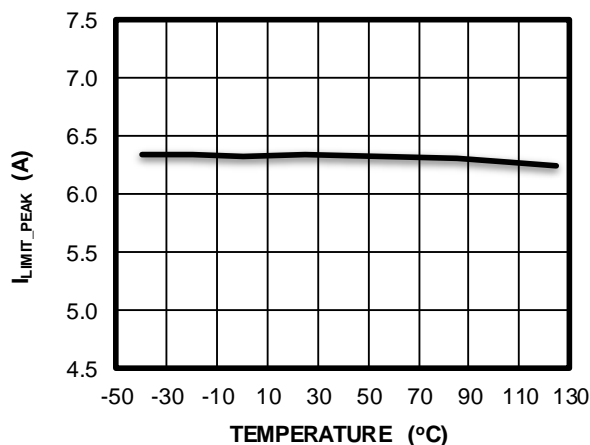
VCC UVLO Threshold vs. Temperature



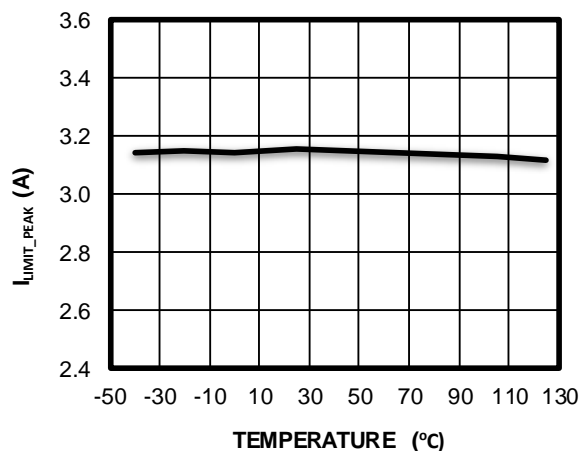
## TYPICAL CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted.

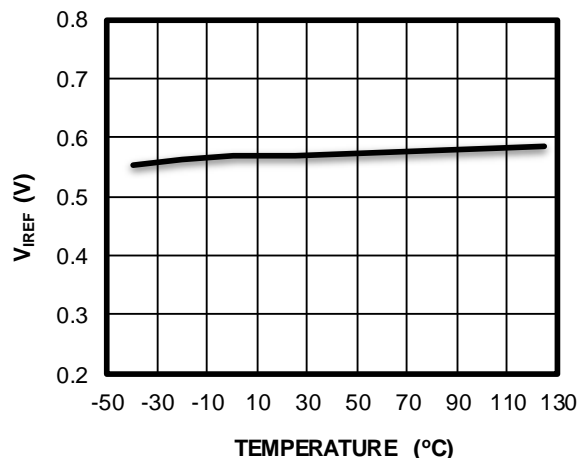
**Current Limit with MOSFETs Fully On vs. Temperature**



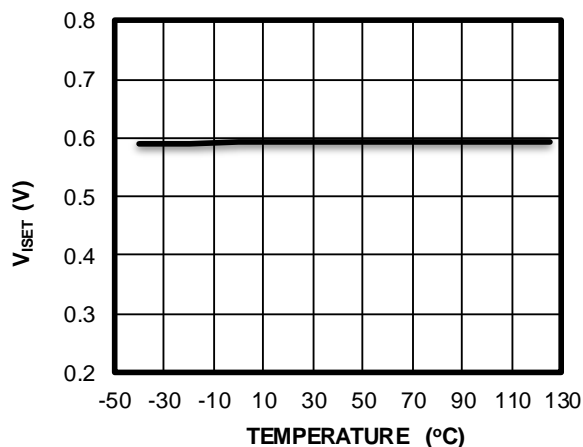
**Current Limit with MOSFETs Half On vs. Temperature**



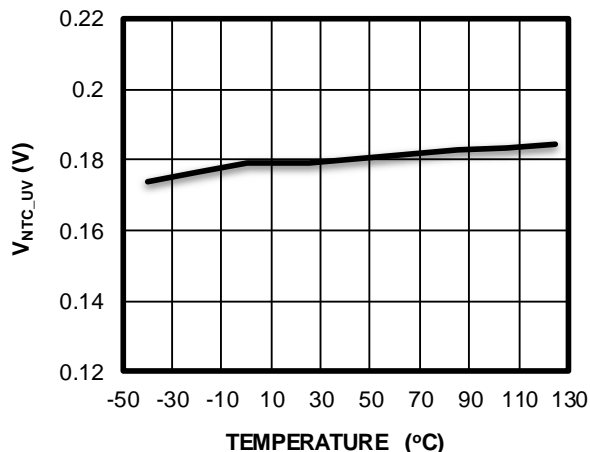
**$V_{IREF}$  vs. Temperature**



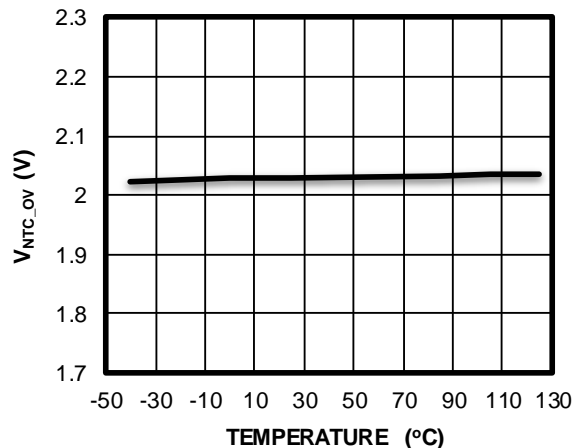
**$V_{ISET}$  vs. Temperature**



**$V_{NTC\_UV}$  Threshold vs. Temperature**



**$V_{NTC\_OV}$  Threshold vs. Temperature**

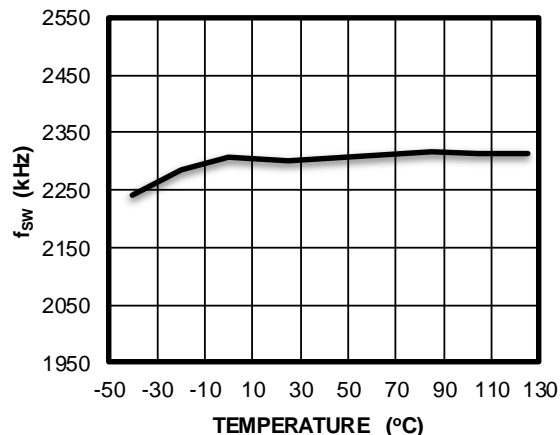


## TYPICAL CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted.

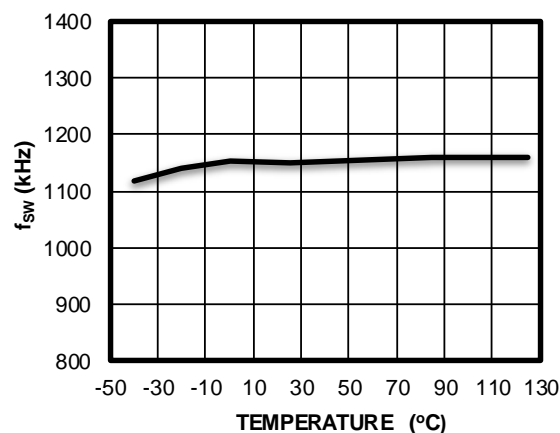
**Switching Frequency vs. Temperature**

Buck mode



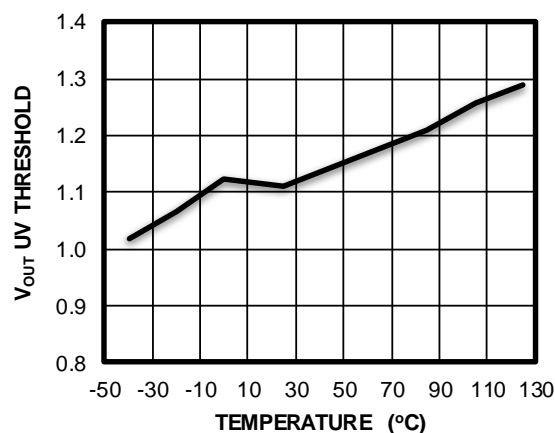
**Switching Frequency vs. Temperature**

Buck-boost mode



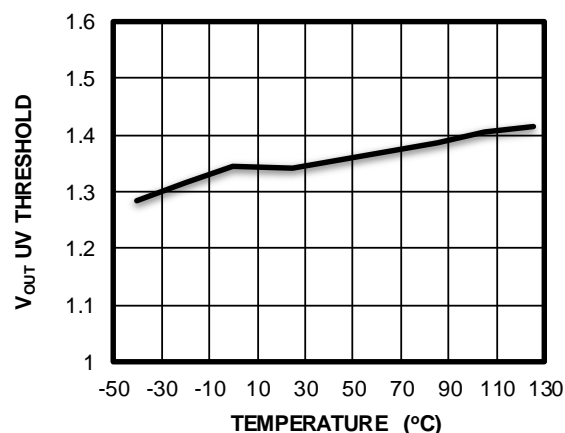
**$V_{OUT}$  UV Threshold vs. Temperature**

Buck mode



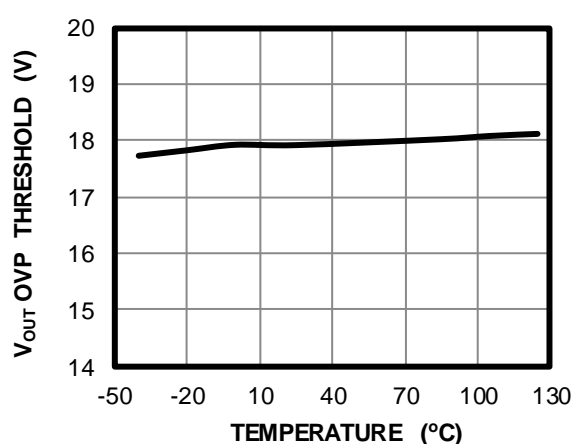
**$V_{OUT}$  UV Threshold vs. Temperature**

Buck-boost mode



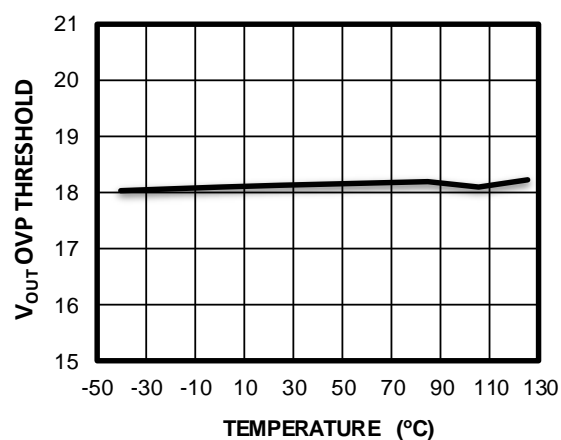
**$V_{OUT}$  OVP Threshold vs. Temperature**

Buck mode



**$V_{OUT}$  OVP Threshold vs. Temperature**

Buck-boost mode

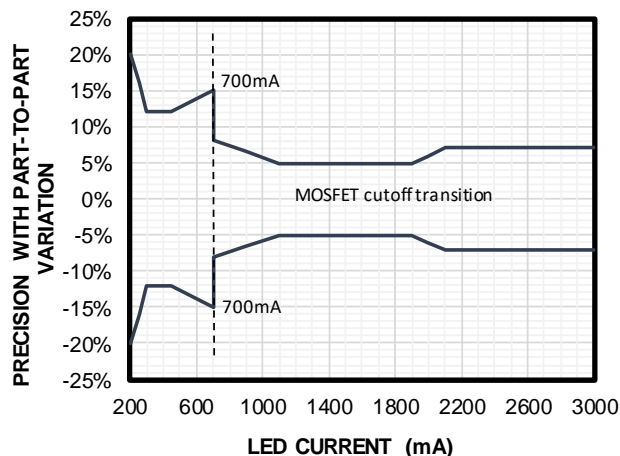


## TYPICAL PERFORMANCE CHARACTERISTICS

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

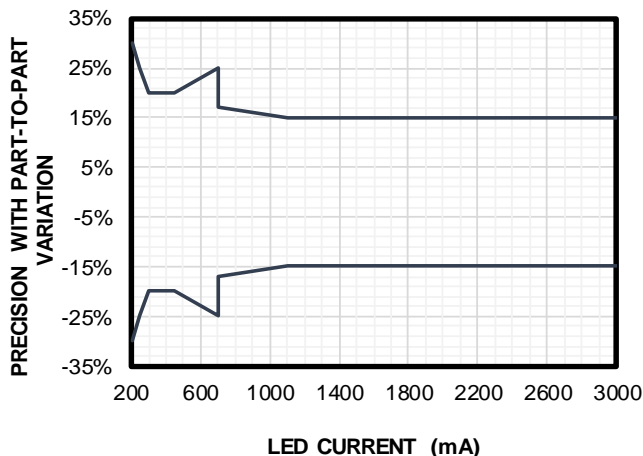
**$I_{LED}$  Part-to-Part Variation**

$T_J = 25^\circ C$  to  $100^\circ C$



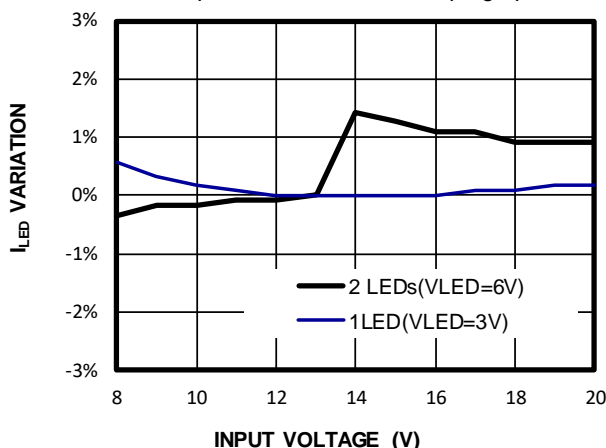
**$I_{LED}$  Part-to-Part Variation**

$T_J = -40^\circ C$  to  $+150^\circ C$



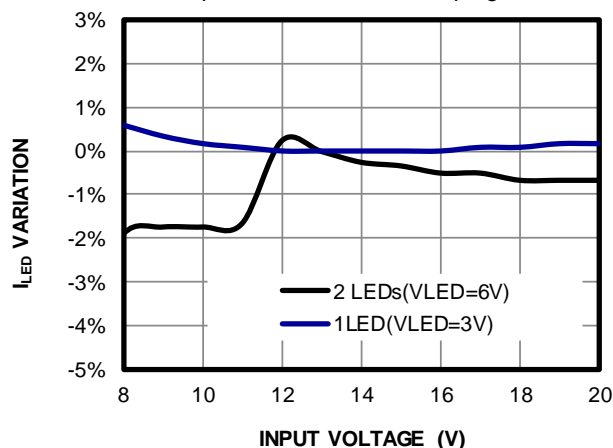
**$I_{LED}$  Precision vs. Input Voltage**

$L = 4.7\mu H$ ,  $I_{LED} = 1.2A$ ,  $V_{IN}$  ramping up



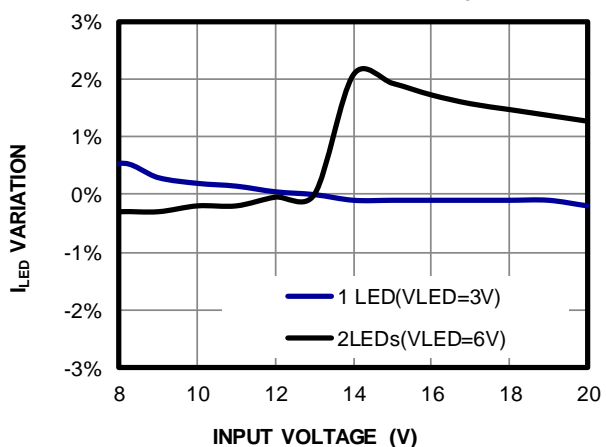
**$I_{LED}$  Precision vs. Input Voltage**

$L = 4.7\mu H$ ,  $I_{LED} = 1.2A$ ,  $V_{IN}$  ramping down



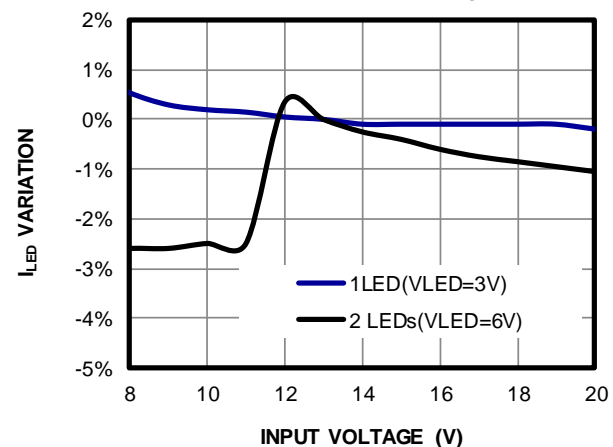
**$I_{LED}$  Precision vs. Input Voltage**

$L = 3.3\mu H$ ,  $I_{LED} = 2A$ ,  $V_{IN}$  ramping up



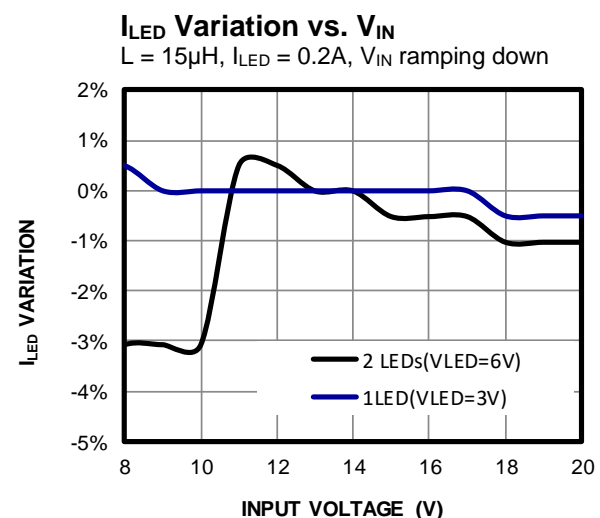
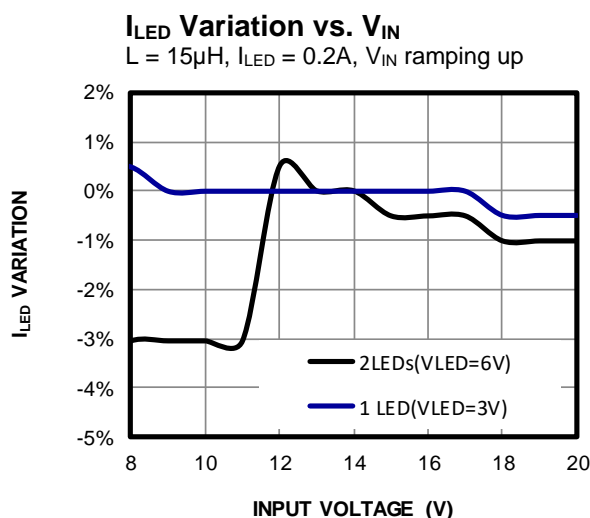
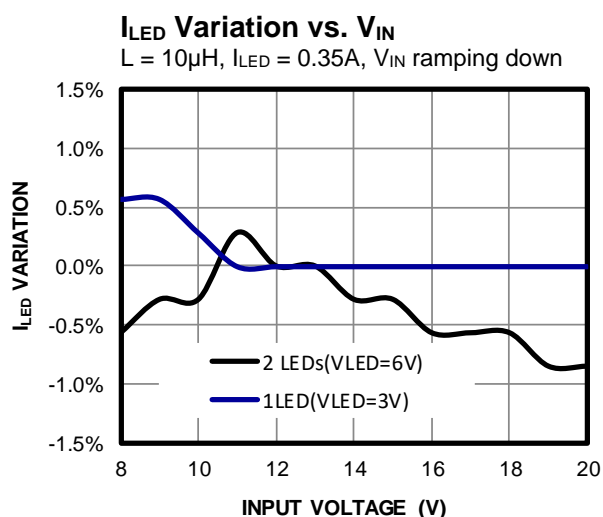
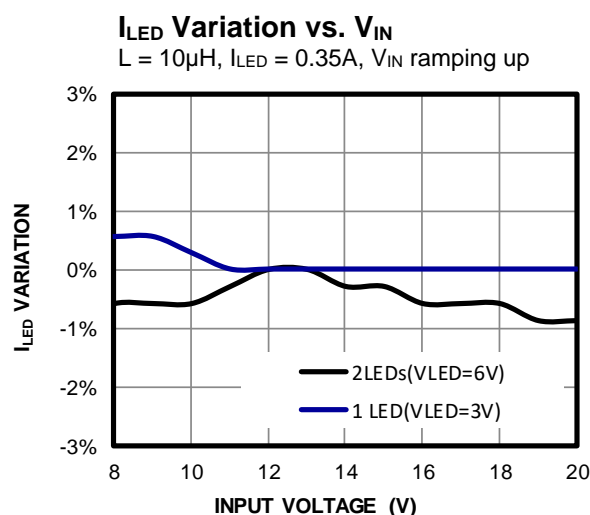
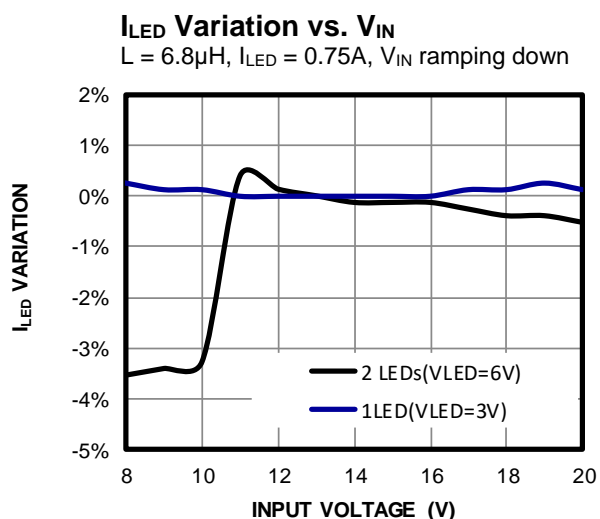
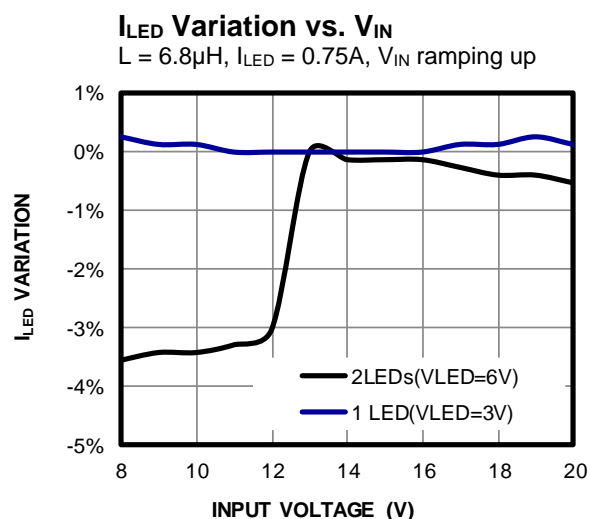
**$I_{LED}$  Precision vs. Input Voltage**

$L = 3.3\mu H$ ,  $I_{LED} = 2A$ ,  $V_{IN}$  ramping down



## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.



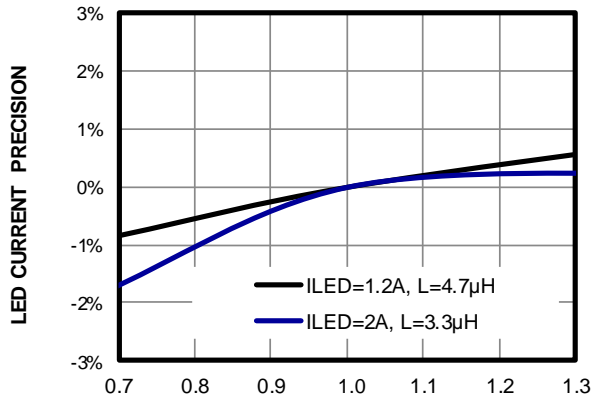


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

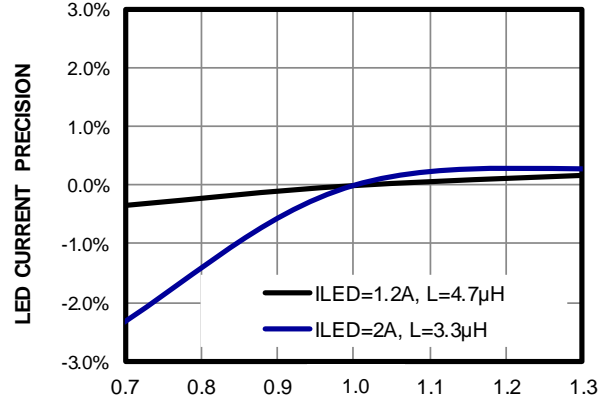
## $I_{LED}$ Precision vs. Inductor Value Variation

$V_{IN} = 13.5V$ , 2 LEDs ( $V_{LED} = 6V$ )



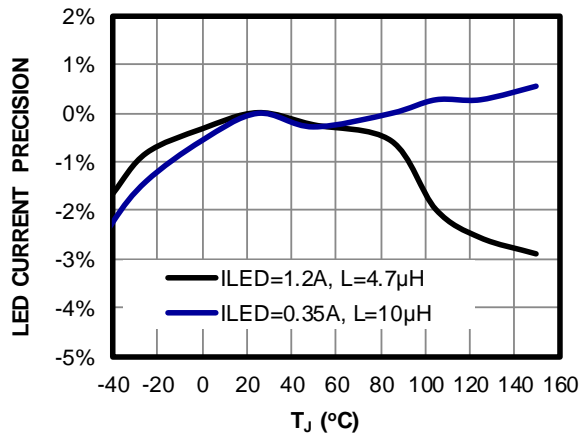
## $I_{LED}$ Precision vs. Inductor Value Variation

$V_{IN} = 13.5V$ , 1 LED ( $V_{LED} = 3V$ )



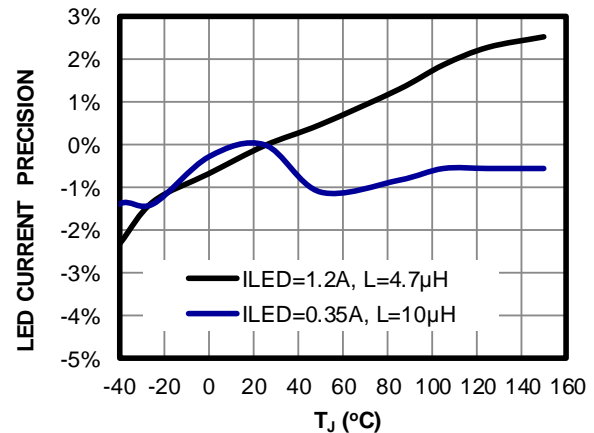
## $I_{LED}$ Precision vs. HS-FET Temperature Sense

2 LEDs ( $V_{LED} = 6V$ )



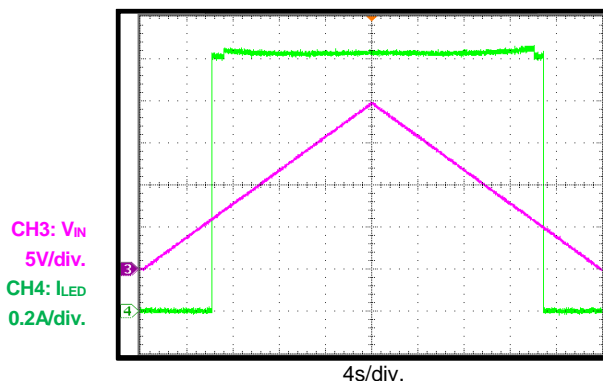
## $I_{LED}$ Precision vs. LS-FET Temperature Sense

2 LEDs ( $V_{LED} = 6V$ )



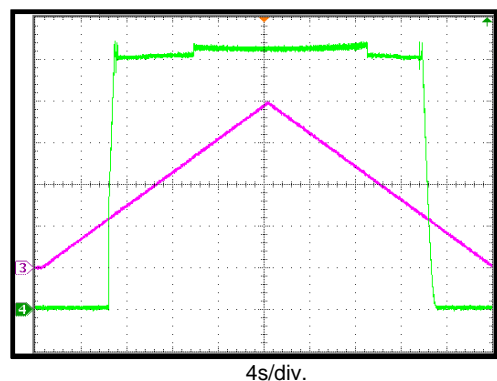
## $V_{IN}$ Slow Ramp Up and Down

2 LEDs ( $V_{LED} = 6V$ ),  $I_{LED} = 1.2A$ ,  
 $V_{IN} = 0V$  to  $20V$ ,  $0.001V/ms$



## $V_{IN}$ Slow Ramp Up and Down

1 LED ( $V_{LED} = 3V$ ),  $I_{LED} = 1.2A$ ,  
 $V_{IN} = 0V$  to  $20V$ ,  $0.001V/ms$

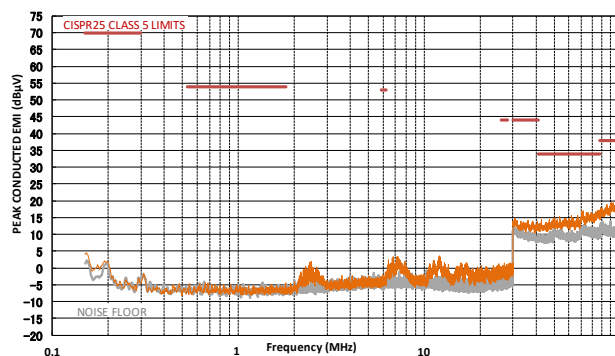


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode,  $V_{IN} = 12V$ , 2 LEDs in series ( $V_{LED} = 6V$ ) when  $I_{LED} = 3A$ ,  $L = 4.7\mu H$ ,  $f_{SW} = 2.3MHz$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(7)</sup>

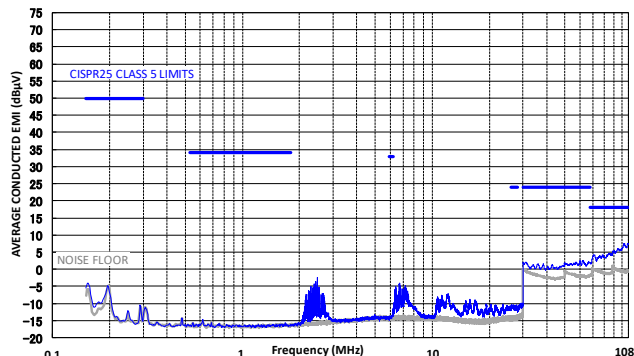
### CISPR25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



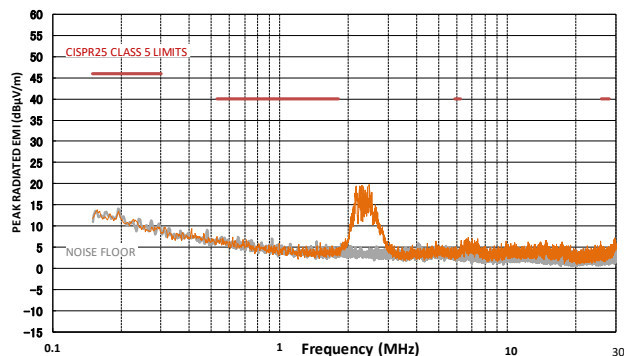
### CISPR25 Class 5 Average Conducted Emissions

150kHz to 108MHz



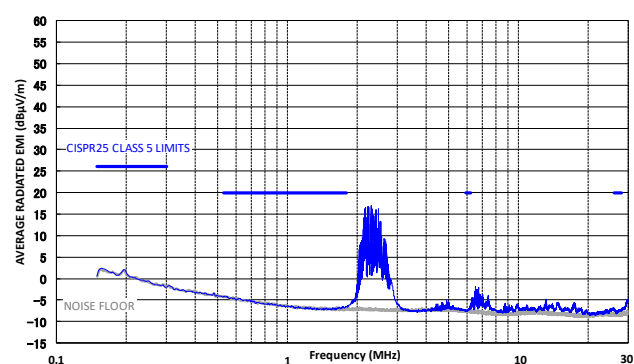
### CISPR25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



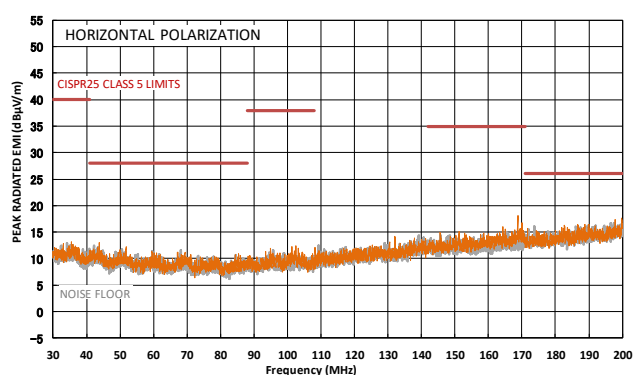
### CISPR25 Class 5 Average Radiated Emissions

150kHz to 30MHz



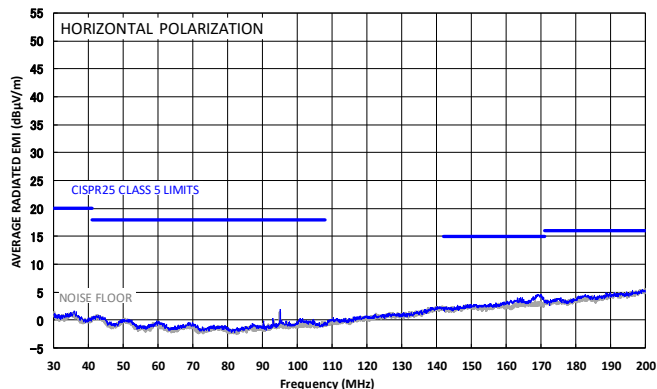
### CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 200MHz



### CISPR25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 200MHz

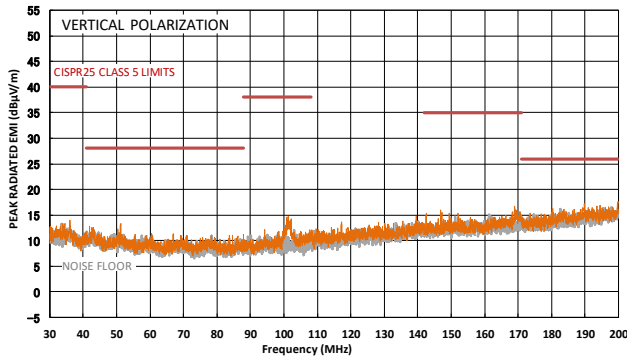


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode,  $V_{IN} = 12V$ , 2 LEDs in series ( $V_{LED} = 6V$ ) when  $I_{LED} = 3A$ ,  $L = 4.7\mu H$ ,  $f_{SW} = 2.3MHz$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(7)</sup>

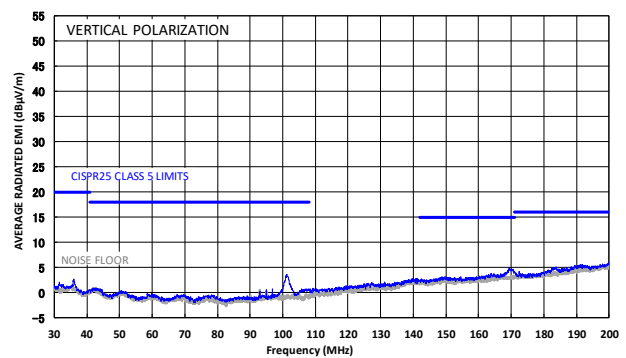
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 200MHz



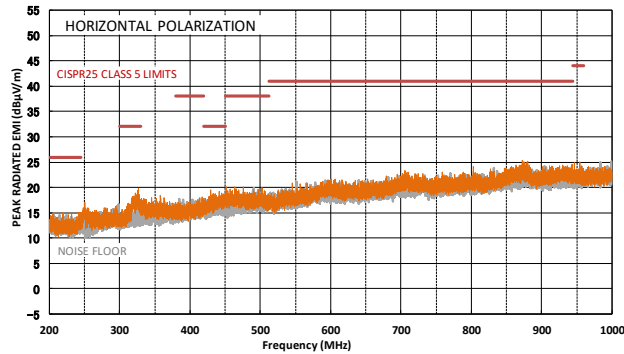
### CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 200MHz



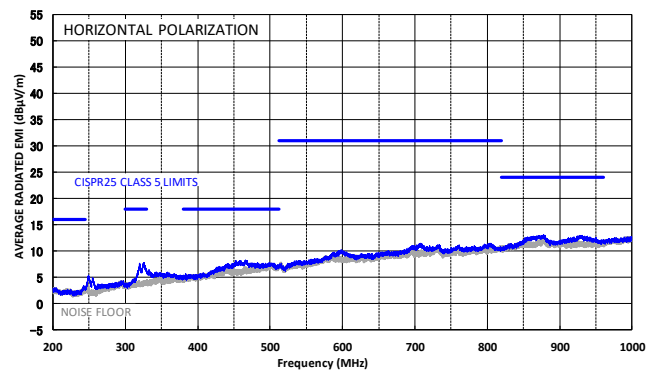
### CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 200MHz to 1GHz



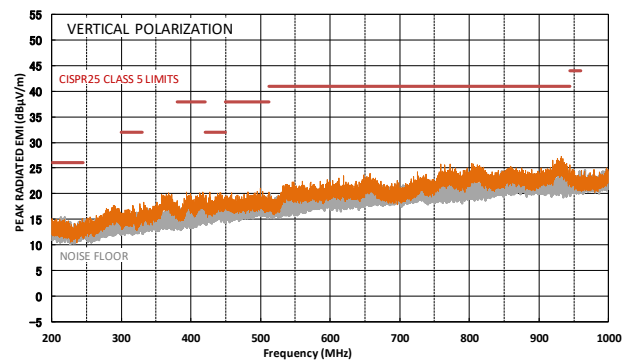
### CISPR25 Class 5 Average Radiated Emissions

Horizontal, 200MHz to 1GHz



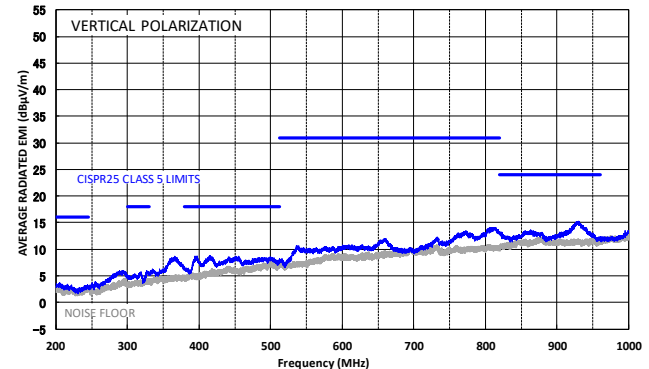
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 200MHz to 1GHz



### CISPR25 Class 5 Average Radiated Emissions

Vertical, 200MHz to 1GHz



#### Note:

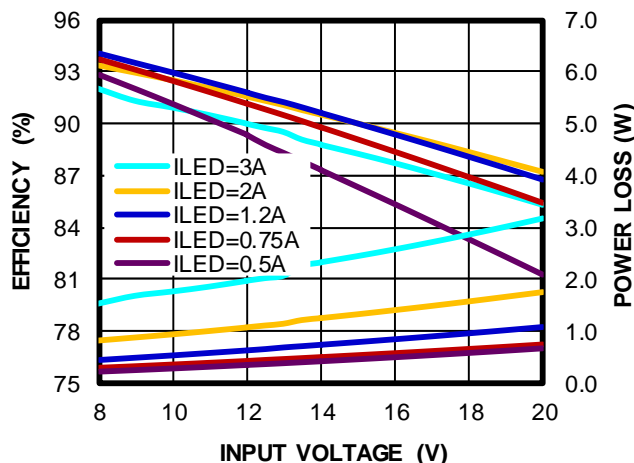
7) Buck mode EMC test results are based on the application circuit with EMI filters (see Figure 11 on page 54).

# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs in series ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

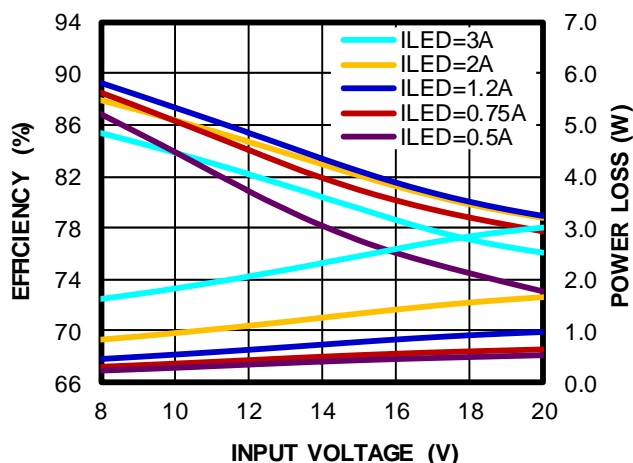
## Efficiency vs. Input Voltage

2 LEDs ( $V_{LED} = 6V$ ), MOSFET Cut-Off when  $I_{LED} = 0.5A$



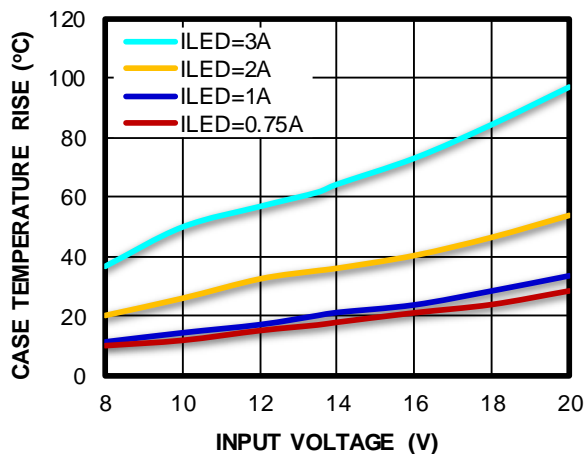
## Efficiency vs. Input Voltage

1 LED ( $V_{LED} = 3V$ ), MOSFET Cut-Off when  $I_{LED} = 0.5A$



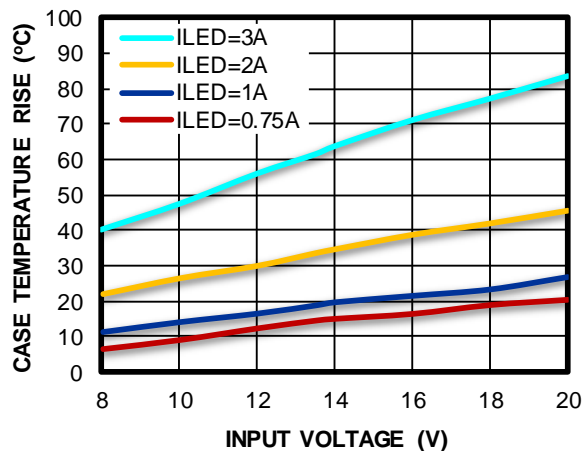
## Case Temperature Rise vs. Input Voltage

2 LEDs ( $V_{LED} = 6V$ )



## Case Temperature Rise with 1 LED

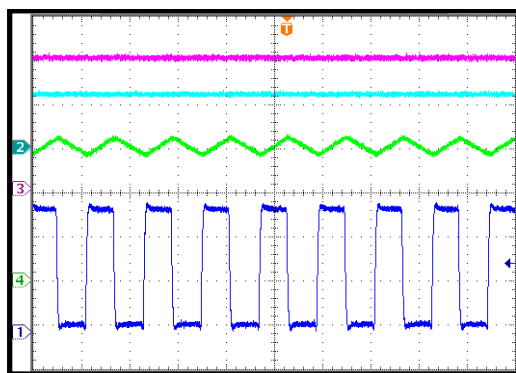
$V_{LED} = 3V$ , MOSFET cut off when  $I_{LED} = 0.5A$



## Steady State

$I_{LED} = 3A$

CH2:  
 $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  
 $I_{LED}$   
1A/div.  
CH4:  $I_L$   
1A/div.  
CH1:  
 $V_{SW}$   
5V/div.

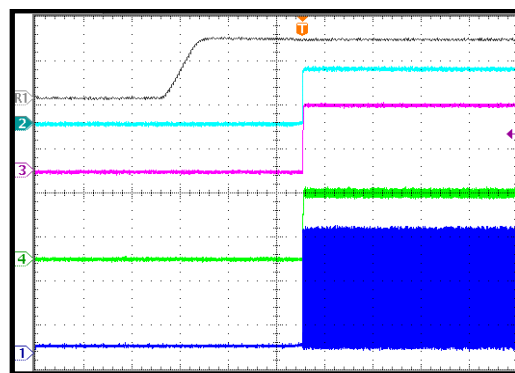


400ns/div.

## Start-Up through VIN

$I_{LED} = 3A$

R1:  $V_{IN}$   
10V/div.  
CH2:  
 $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  
 $V_{SW}$   
5V/div.



2ms/div.

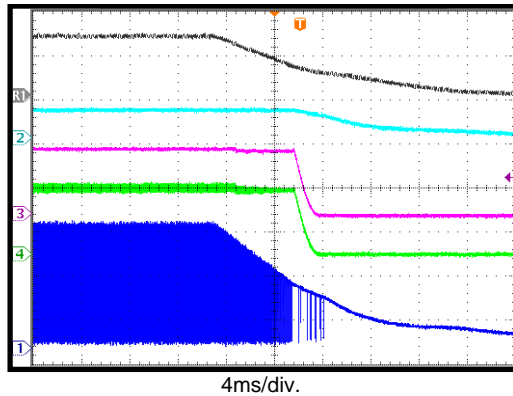
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### Shutdown through VIN

$I_{LED} = 3A$

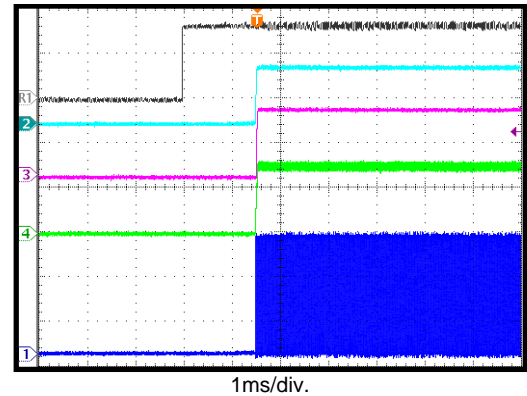
R1:  $V_{IN}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
5V/div.



### Start-Up through EN/DIM

$I_{LED} = 3A$

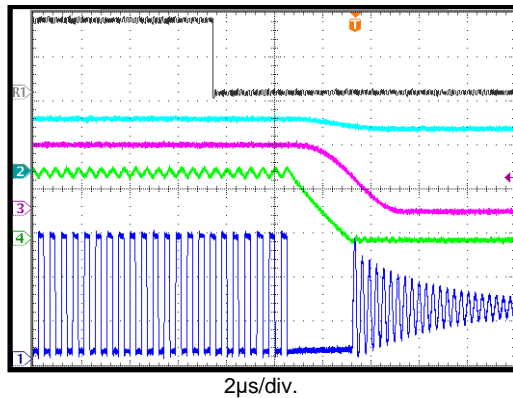
R1:  $V_{EN/DIM}$   
2V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
5V/div.



### Shutdown through EN/DIM

$I_{LED} = 3A$

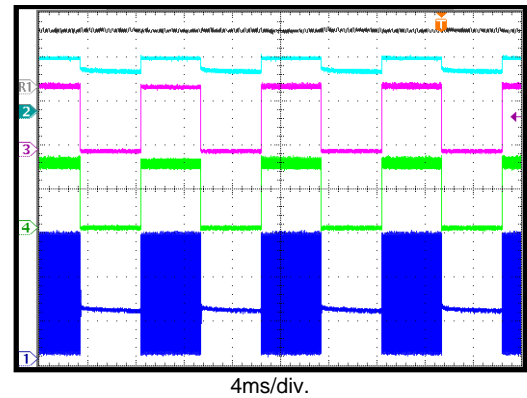
R1:  $V_{EN/DIM}$   
2V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
5V/div.



### PWM Dimming Steady State

Dimming frequency = 100Hz

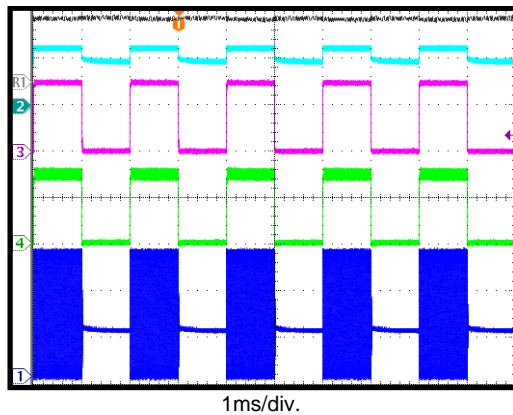
R1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
5V/div.



### PWM Dimming Steady State

Dimming frequency = 500Hz

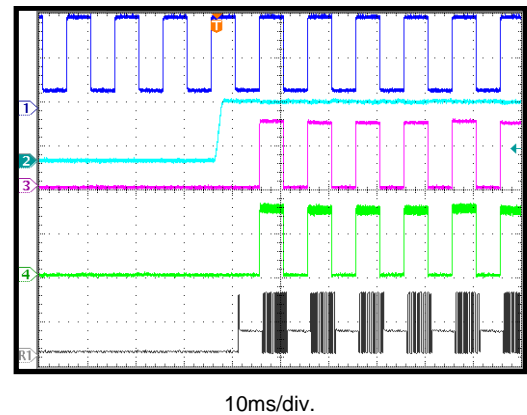
R1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
5V/div.



### PWM Dimming

Start-up through VIN

CH1:  $V_{EN/DIM}$   
2V/div.  
CH2:  $V_{IN}$   
10V/div.  
CH3:  $I_{LED}$   
2A/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
10V/div.

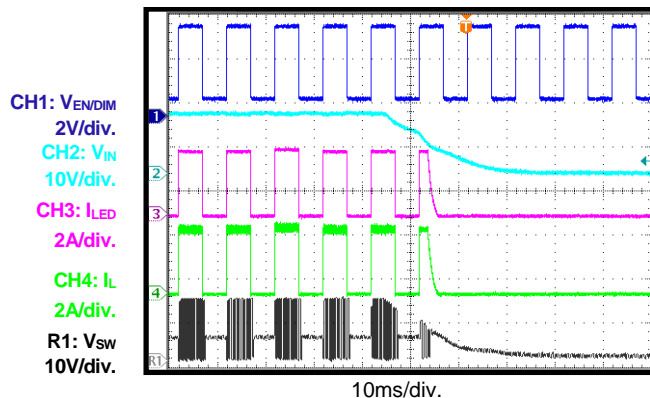


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

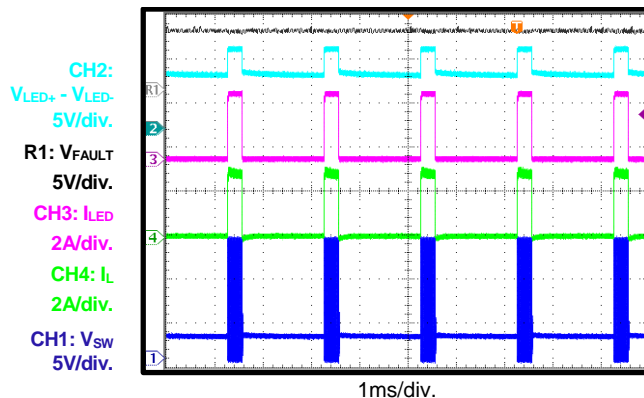
### PWM Dimming

Shutdown through VIN



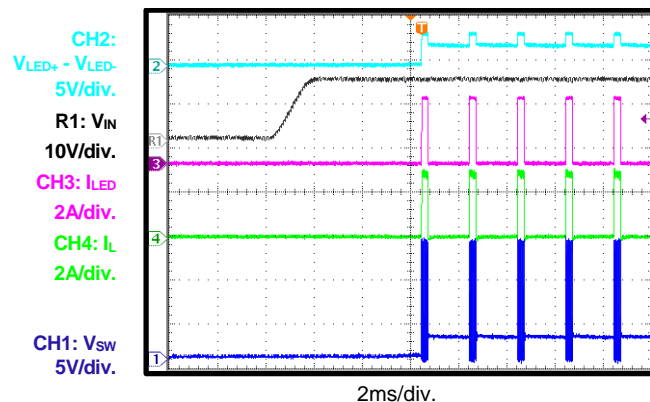
### Two-Step Dimming

Steady state



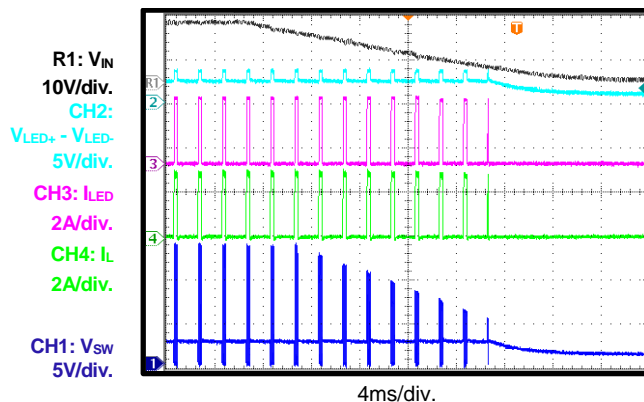
### Two-Step Dimming

Start-up through VIN



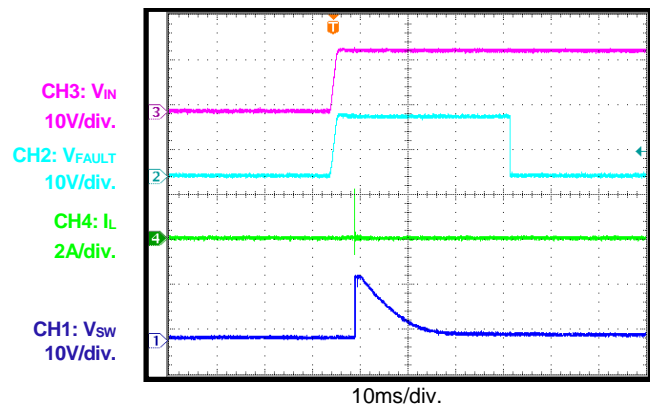
### Two-Step Dimming

Shutdown through VIN



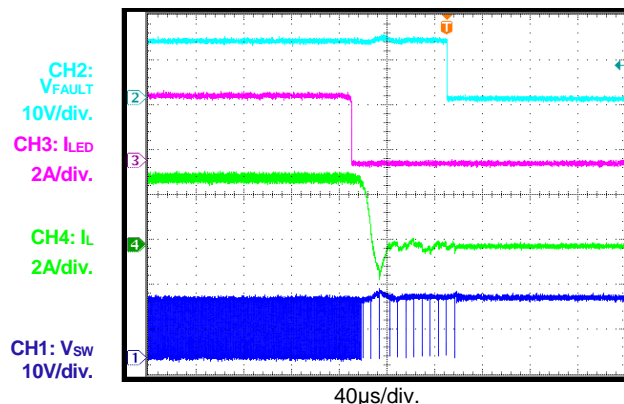
### No Dimming

LED open start-up



### No Dimming

LED open entry

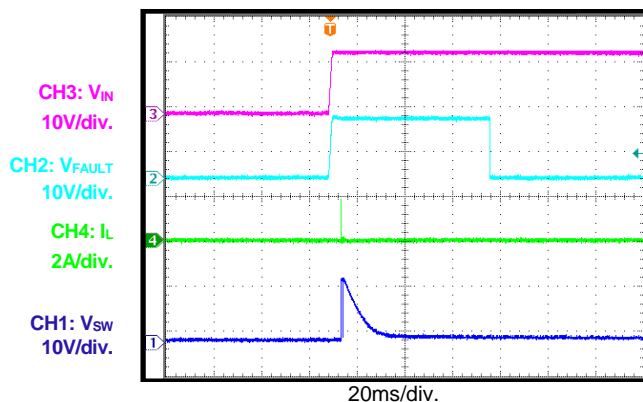


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

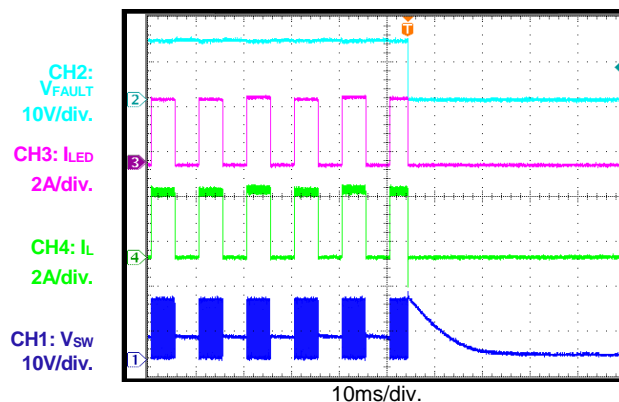
### PWM Dimming

LED open start-up



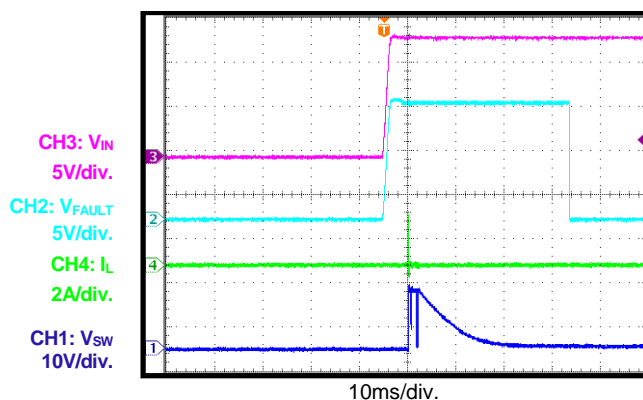
### PWM Dimming

LED open entry



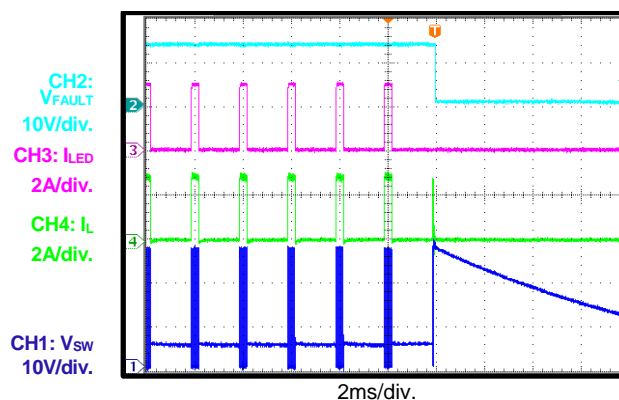
### Two-Step Dimming

LED open start-up



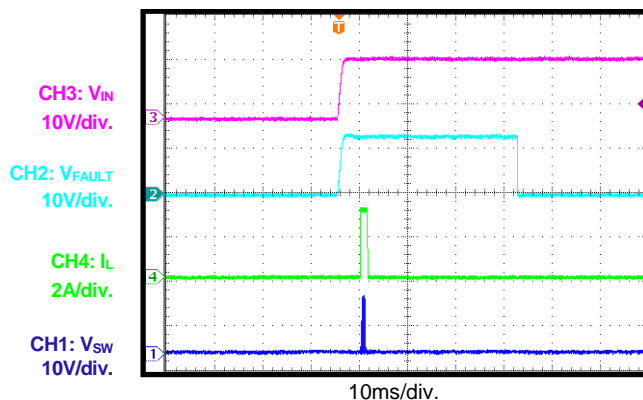
### Two-Step Dimming

LED open entry



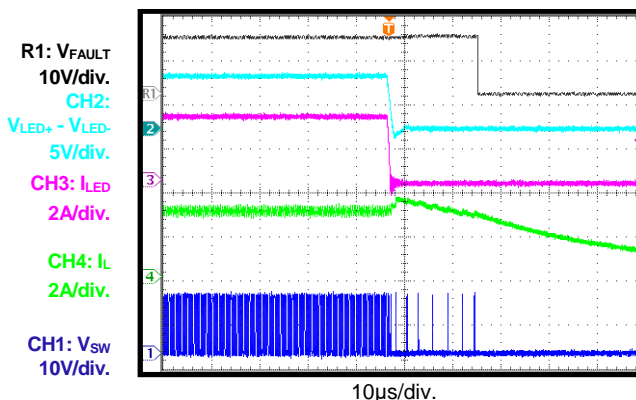
### No Dimming

LED+ short to LED- start-up



### No Dimming

LED+ short to LED- entry



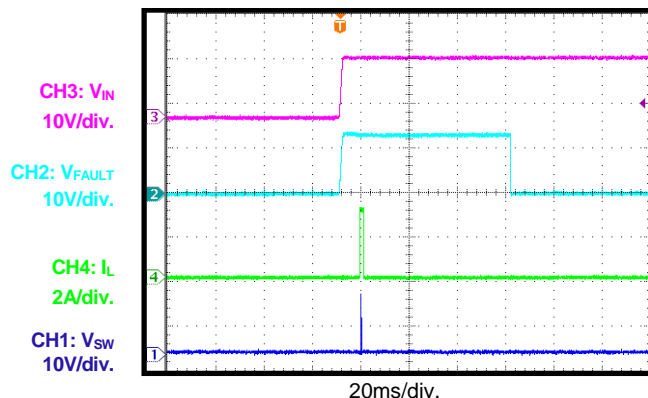


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

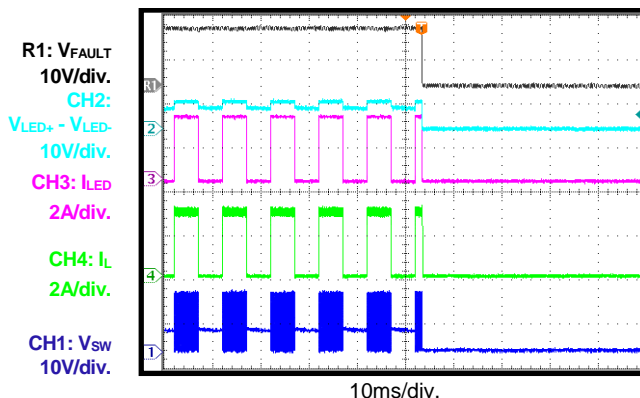
### PWM Dimming

LED+ short to LED- start-up



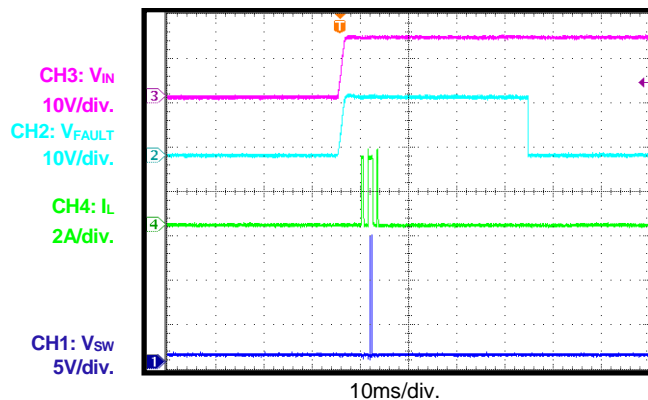
### PWM Dimming

LED+ short to LED- entry



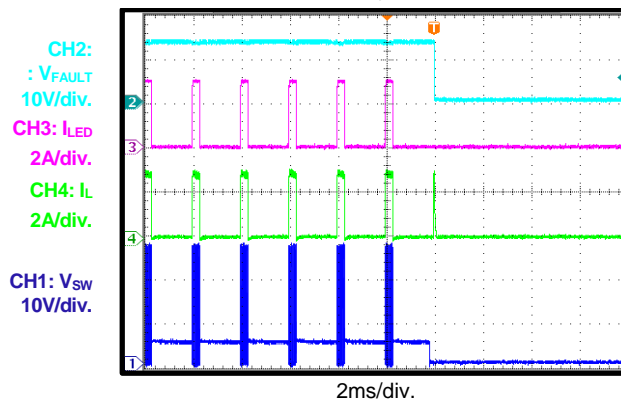
### Two-Step Dimming

LED+ short to LED- start-up

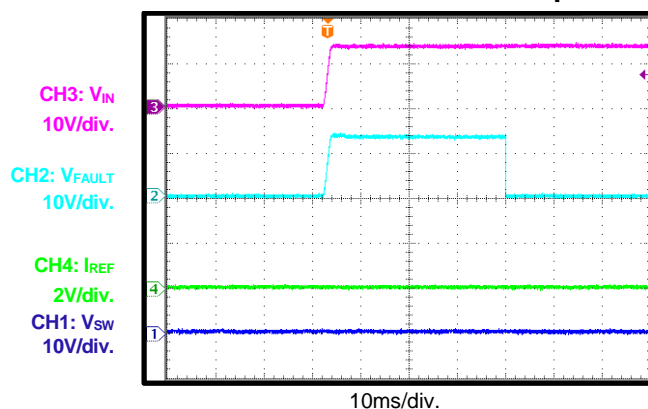


### Two-Step Dimming

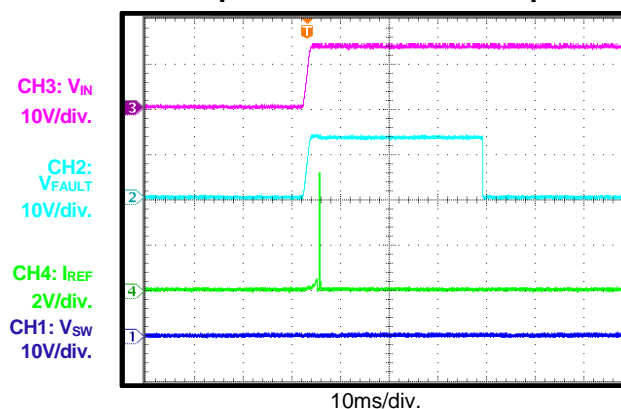
LED+ short to LED- entry



### IREF Short Before IC Starts Up



### IREF Open Before IC Starts Up

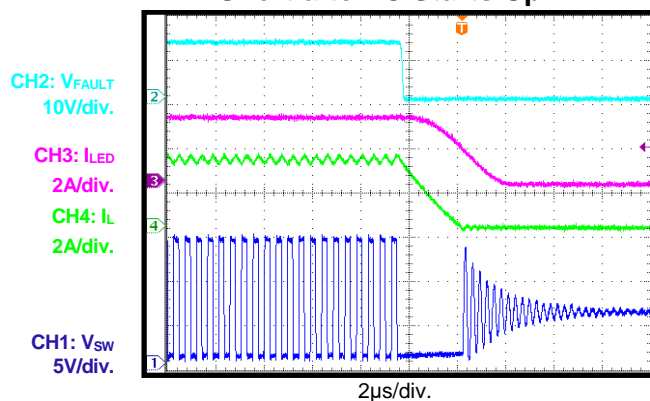




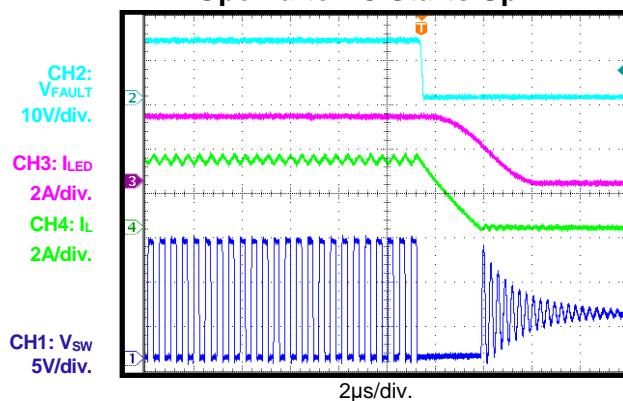
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

**IREF Short after IC Starts Up**

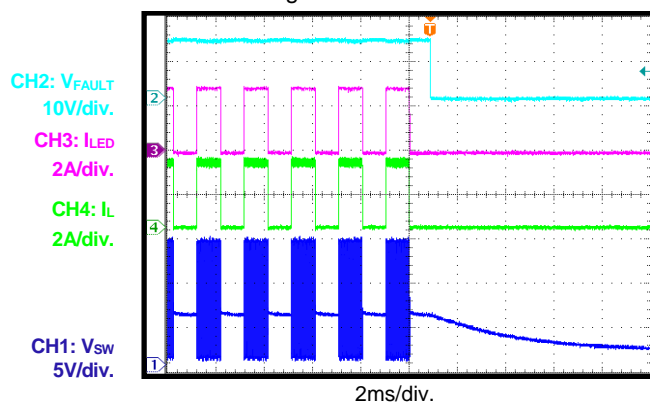


**IREF Open after IC Starts Up**



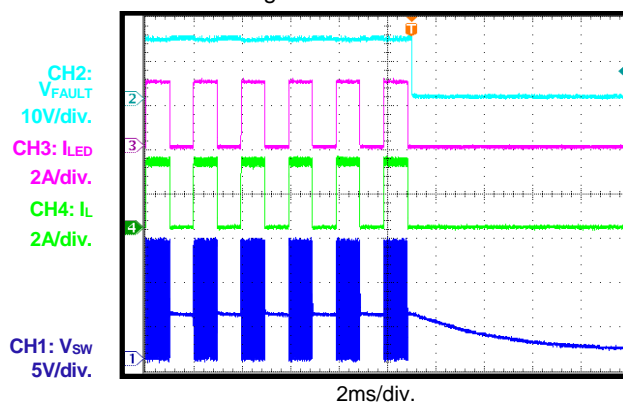
**IREF Short after IC Starts Up**

PWM dimming



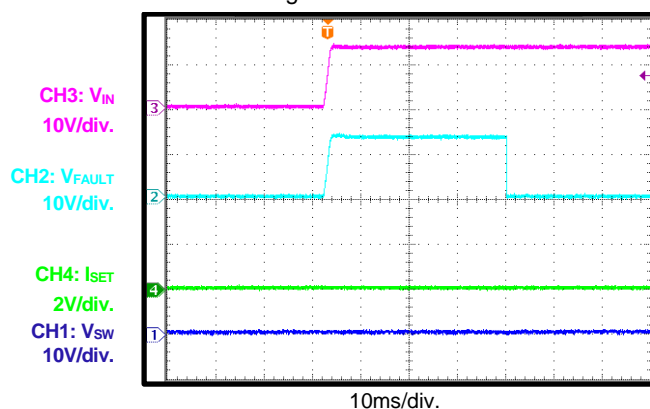
**IREF Open after IC Starts Up**

PWM dimming



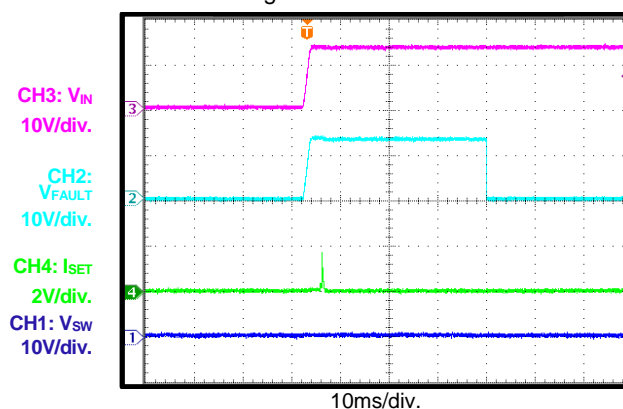
**ISET Short Before IC Starts Up**

PWM dimming



**ISET Open Before IC Starts Up**

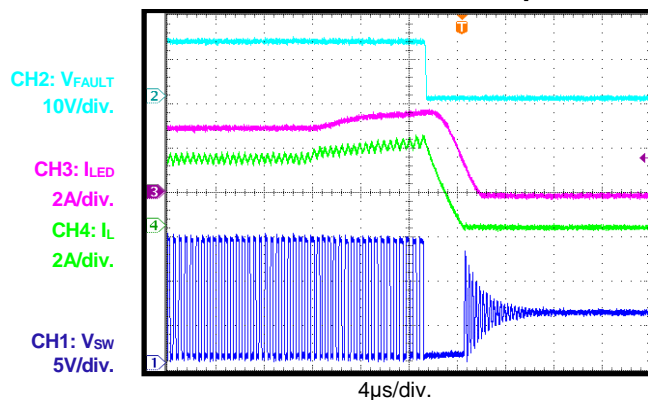
PWM dimming



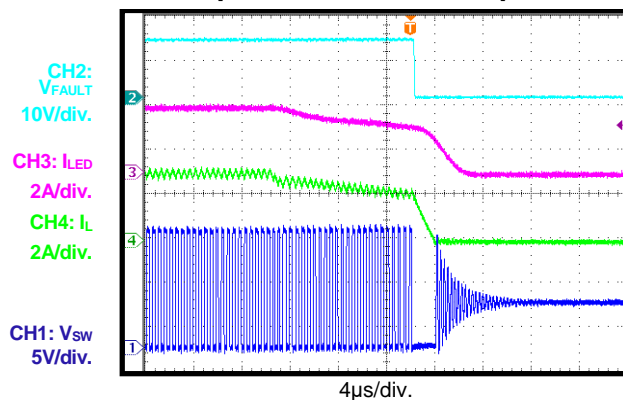
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

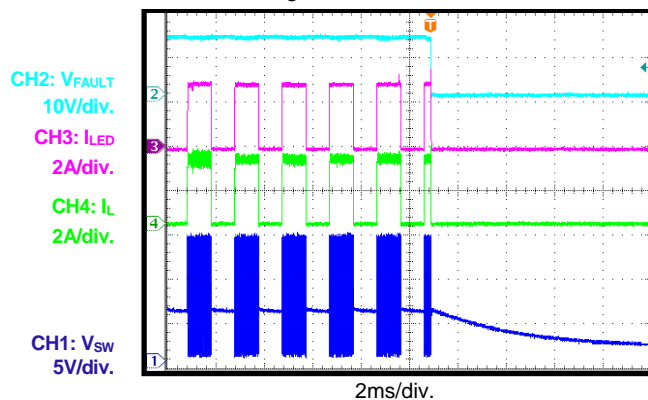
**ISET Short after IC Starts Up**



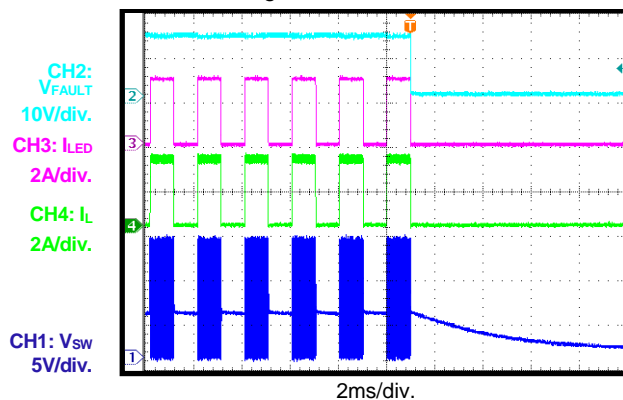
**ISET Open after IC Starts Up**



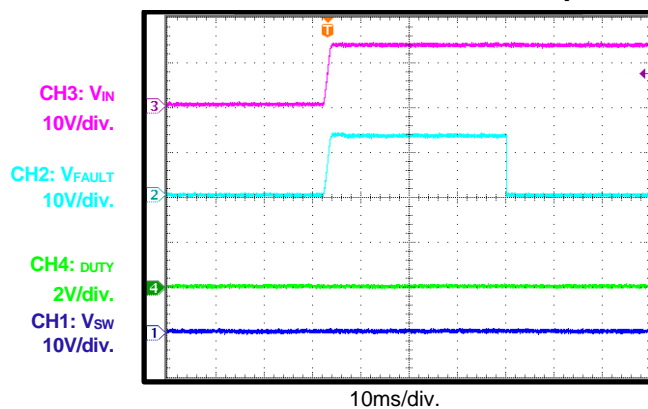
**ISET Short after IC Starts Up**  
PWM dimming



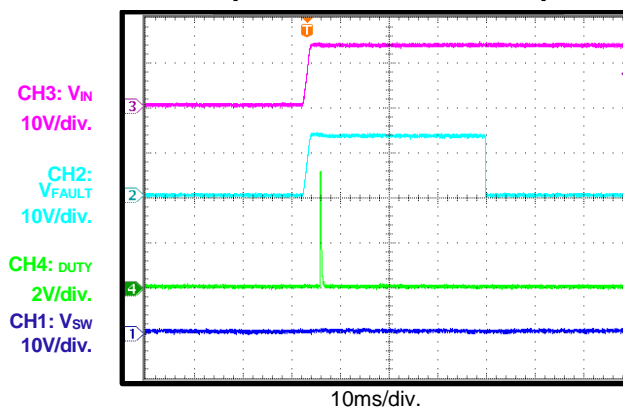
**ISET Open after IC Starts Up**  
PWM dimming



**DUTY Short before IC Starts Up**



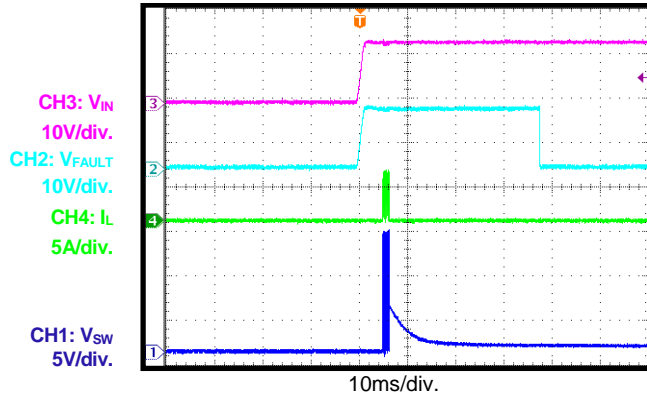
**DUTY Open before IC Starts Up**



## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck mode, 2 LEDs ( $V_{LED} = 6V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 2.3MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

**False Mode Detection during VIN Start-Up**

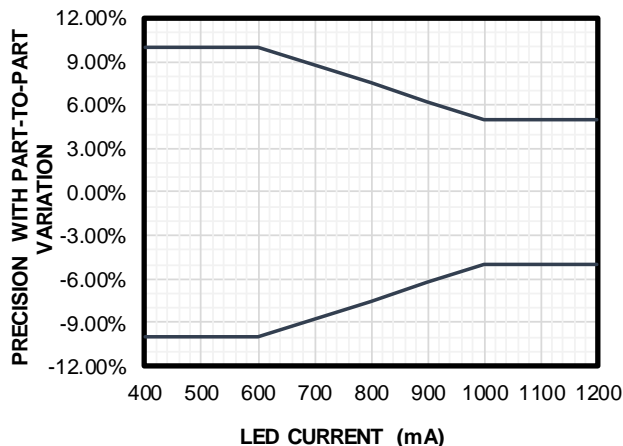


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

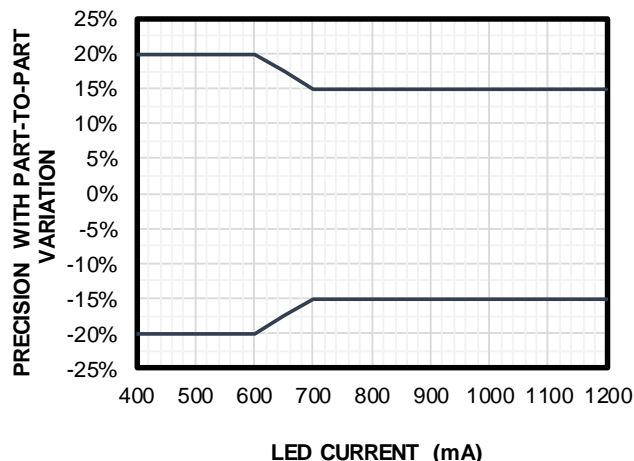
**$I_{LED}$  Part-to-Part Variation**

$T_J = 25^{\circ}C$  to  $100^{\circ}C$



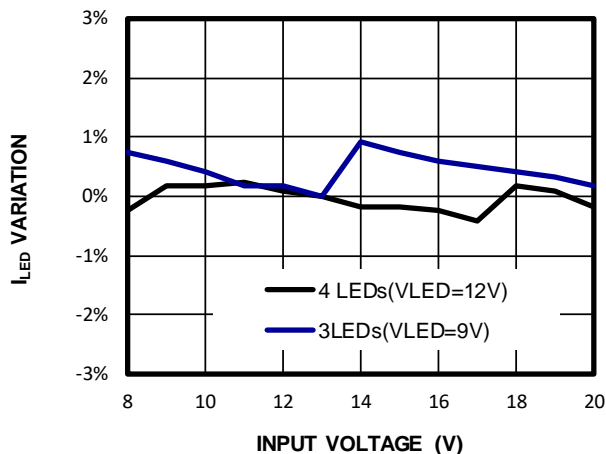
**$I_{LED}$  Part-to-Part Variation**

$T_J = -40^{\circ}C$  to  $+150^{\circ}C$



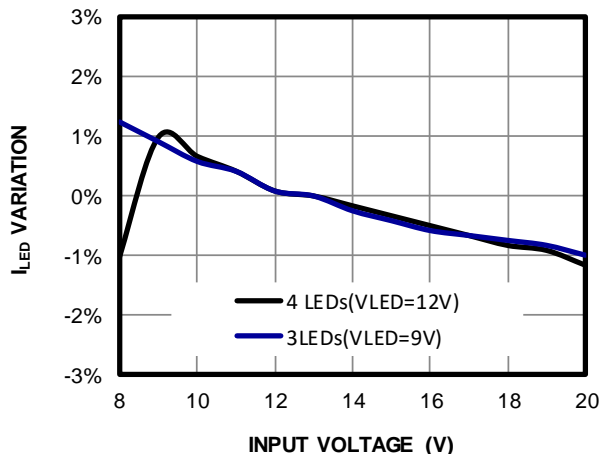
**$I_{LED}$  Variation vs.  $V_{IN}$**

$L = 3.3\mu H$ ,  $I_{LED} = 1.2A$ ,  $V_{IN}$  ramping up



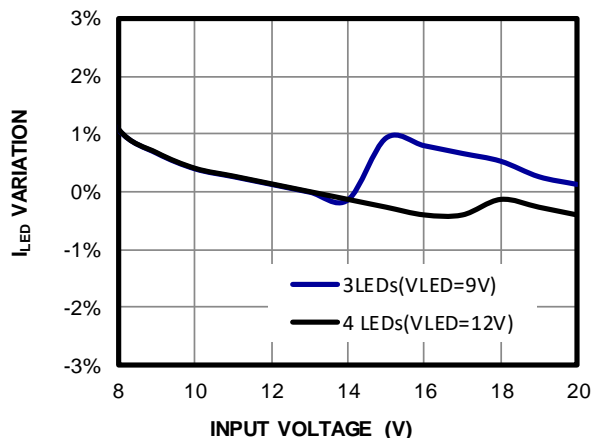
**$I_{LED}$  Variation vs.  $V_{IN}$**

$L = 3.3\mu H$ ,  $I_{LED} = 1.2A$ ,  $V_{IN}$  ramping down



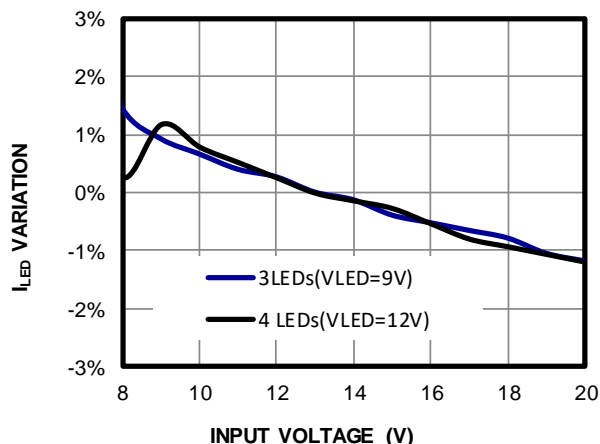
**$I_{LED}$  Variation vs.  $V_{IN}$**

$L = 6.8\mu H$ ,  $I_{LED} = 0.75A$ ,  $V_{IN}$  ramping up



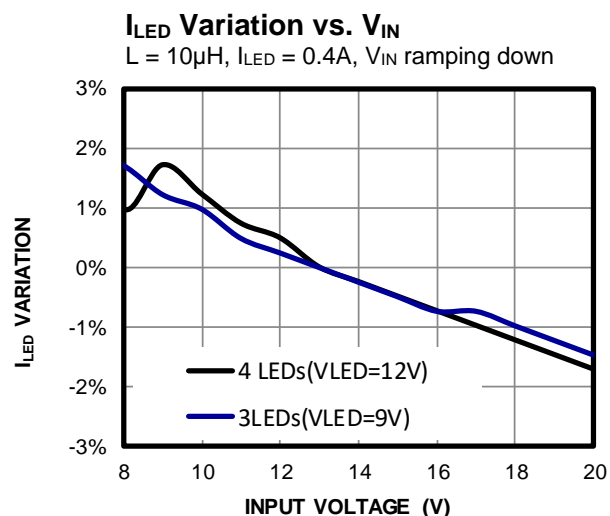
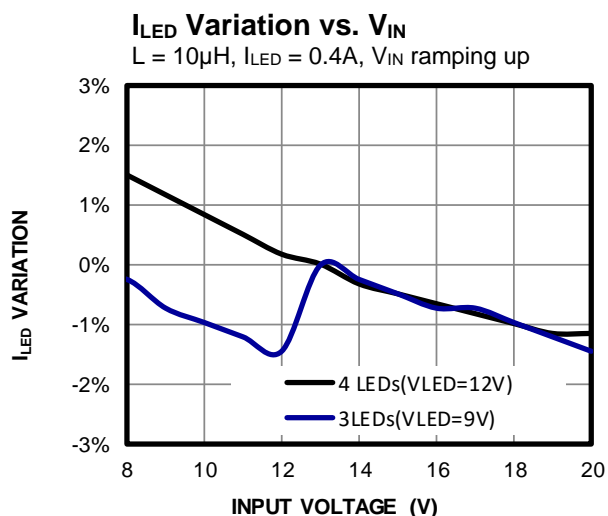
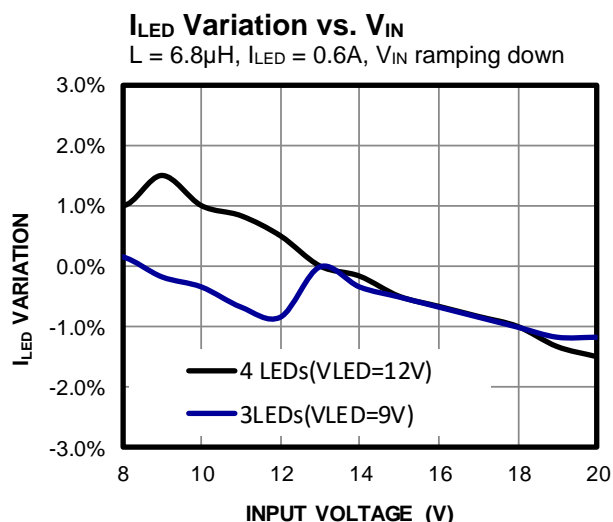
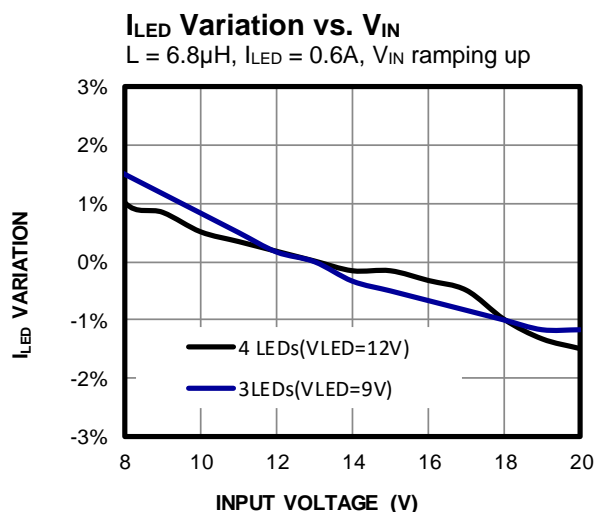
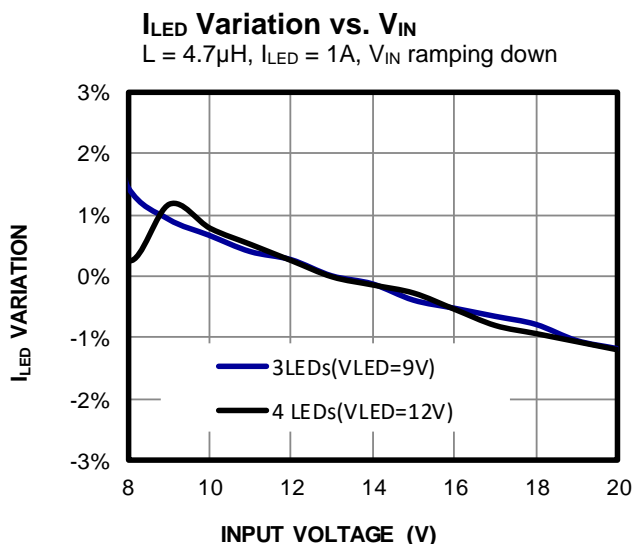
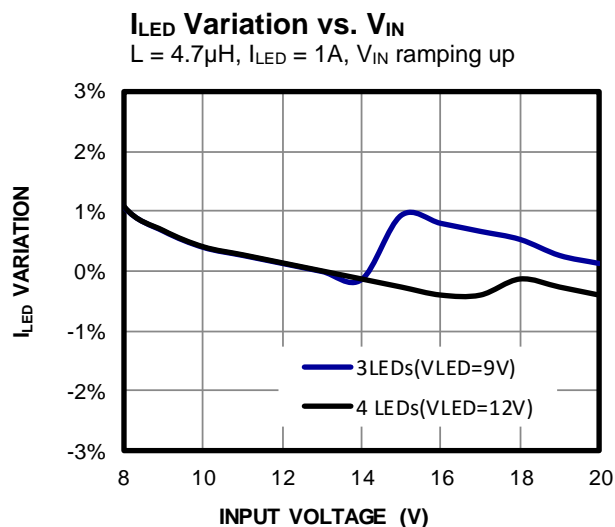
**$I_{LED}$  Variation vs.  $V_{IN}$**

$L = 6.8\mu H$ ,  $I_{LED} = 0.75A$ ,  $V_{IN}$  ramping down



## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

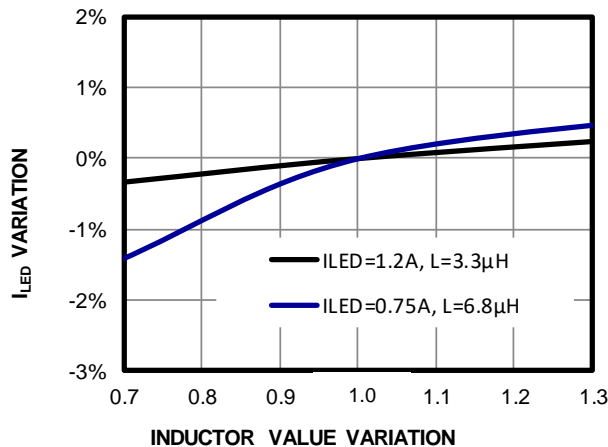


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

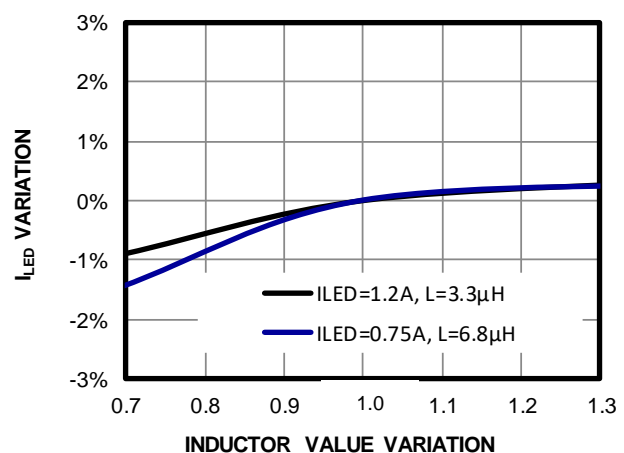
## LED Current Precision vs. Inductor Value Variation

$V_{IN} = 13.5V$ , 4 LEDs ( $V_{LED} = 12V$ )



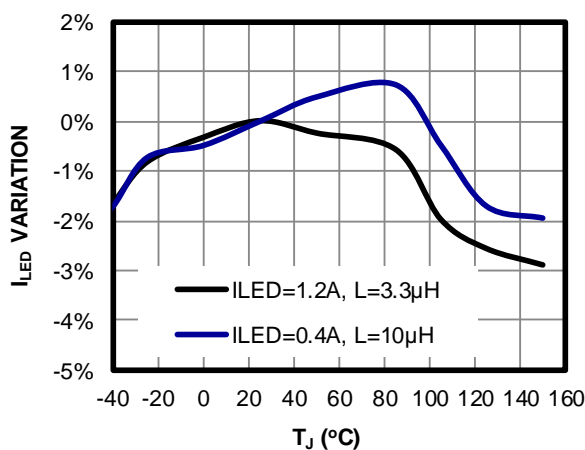
## LED Current Precision vs. Inductor Value Variation

$V_{IN} = 13.5V$ , 3 LEDs ( $V_{LED} = 9V$ )



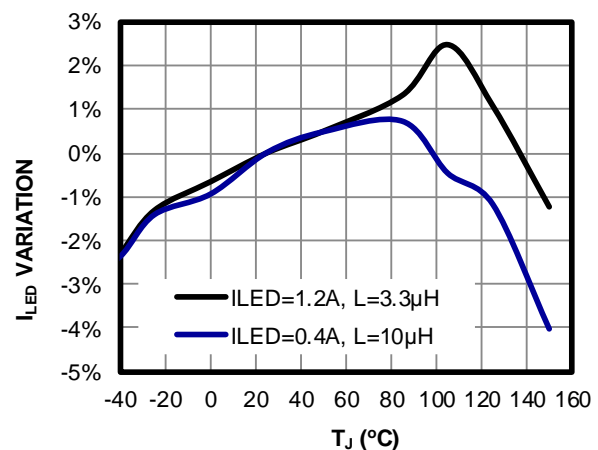
## I\_LED Precision vs. Temperature HS-FET Sense

4 LEDs ( $V_{LED} = 12V$ )



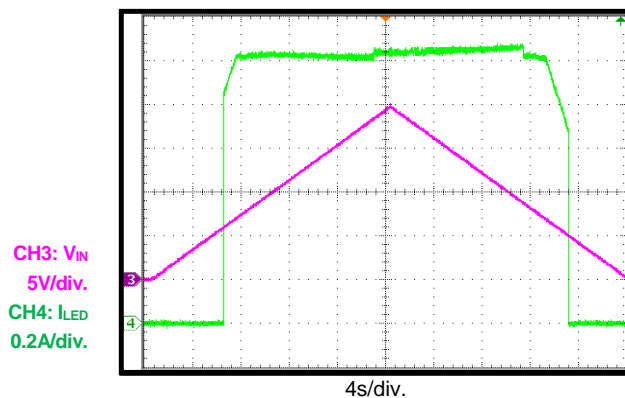
## I\_LED Precision vs. Temperature LS-FET Sense

4 LEDs ( $V_{LED} = 12V$ )



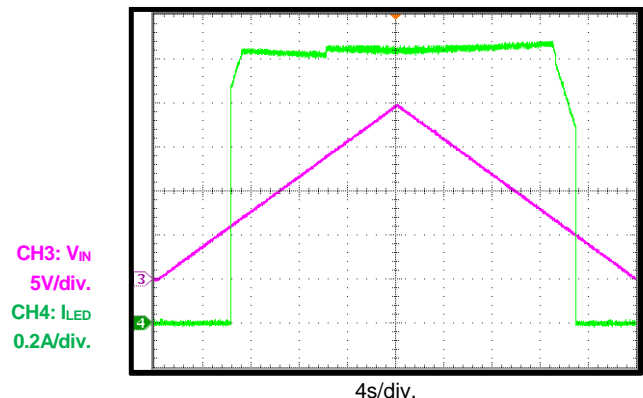
## V\_IN Slow Ramp Up and Down

4 LEDs ( $V_{LED} = 12V$ ),  $I_{LED} = 1.2A$ ,  
 $V_{IN} = 0V$  to  $20V$ ,  $0.001V/ms$



## V\_IN Slow Ramp Up and Down

3 LEDs ( $V_{LED} = 9V$ ),  $I_{LED} = 1.2A$ ,  
 $V_{IN} = 0V$  to  $20V$ ,  $0.001V/ms$

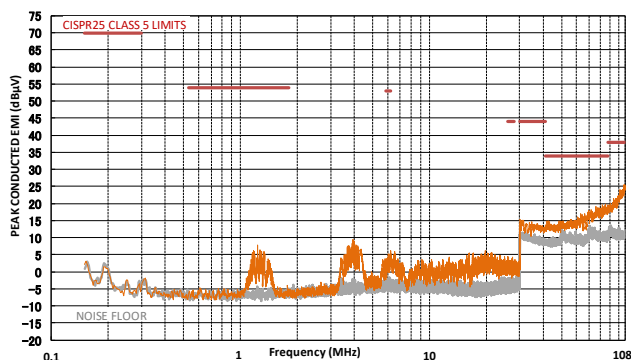


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode,  $V_{IN} = 12V$ , 4 LEDs in series ( $V_{LED} = 12V$ ) when  $I_{LED} = 1.2A$ ,  $L = 4.7\mu H$ ,  $f_{SW} = 1.15MHz$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(8)</sup>

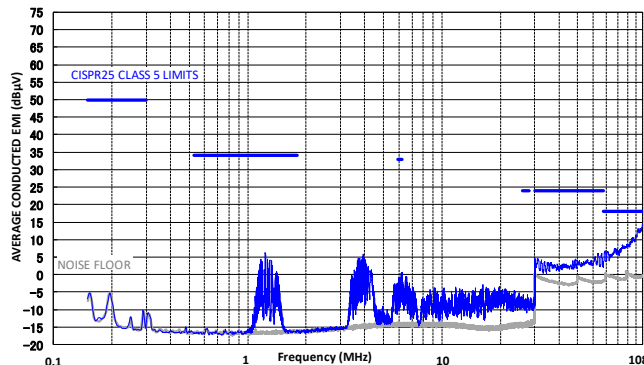
### CISPR25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



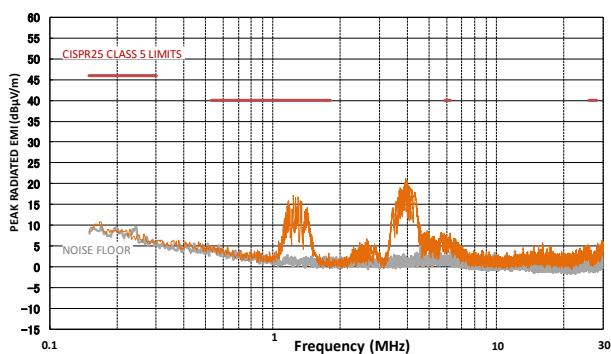
### CISPR25 Class 5 Average Conducted Emissions

150kHz to 108MHz



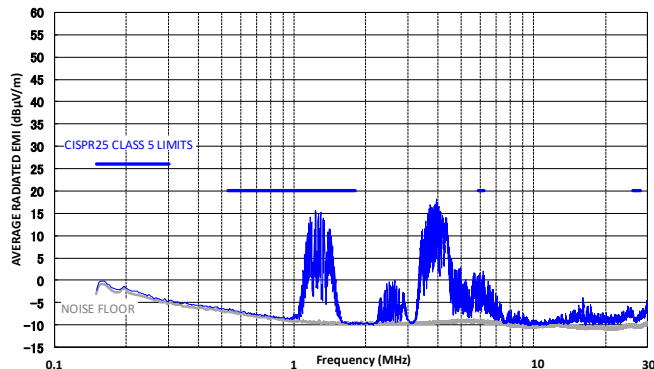
### CISPR25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



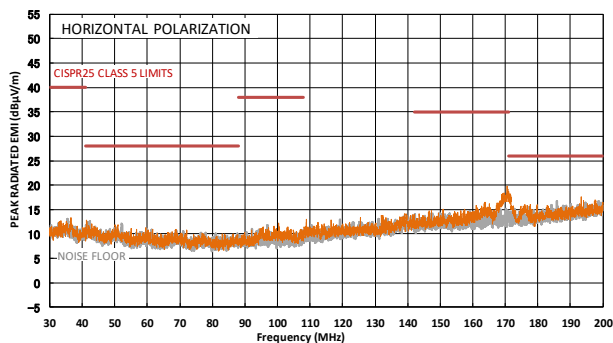
### CISPR25 Class 5 Average Radiated Emissions

150kHz to 30MHz



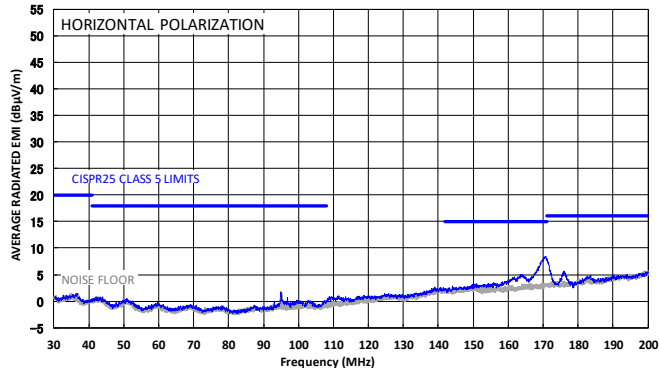
### CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 200MHz



### CISPR25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 200MHz

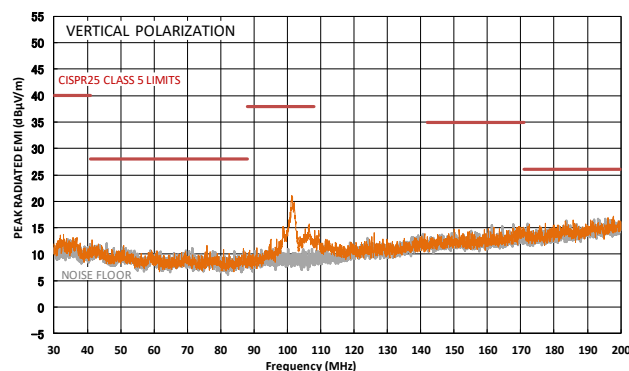


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode,  $V_{IN} = 12V$ , 4 LEDs in series ( $V_{LED} = 12V$ ) when  $I_{LED} = 1.2A$ ,  $L = 4.7\mu H$ ,  $f_{SW} = 1.15MHz$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(8)</sup>

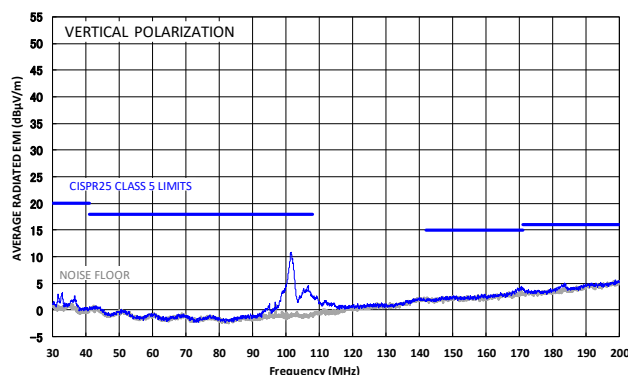
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 200MHz



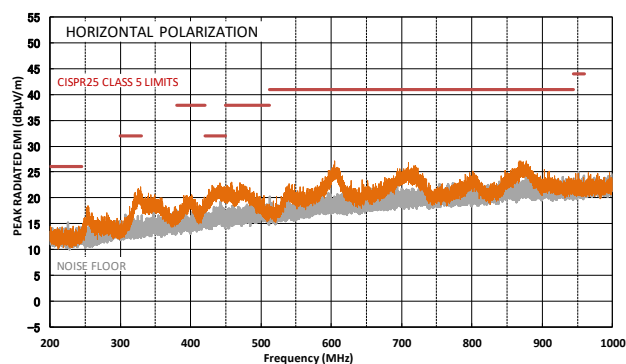
### CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 200MHz



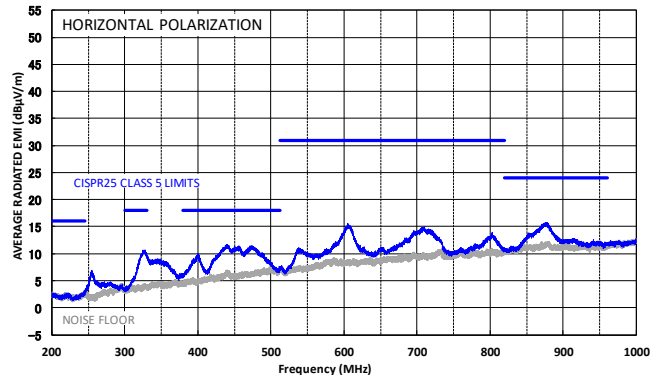
### CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 200MHz to 1GHz



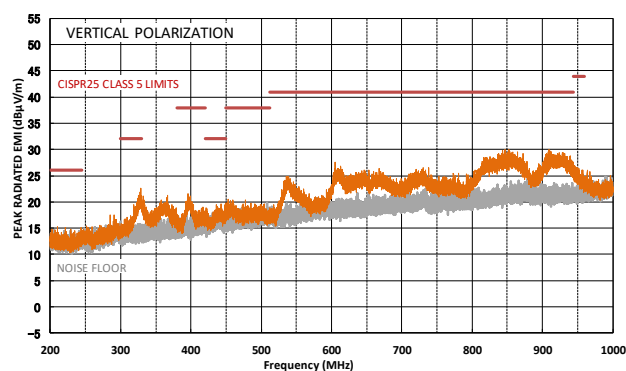
### CISPR25 Class 5 Average Radiated Emissions

Horizontal, 200MHz to 1GHz



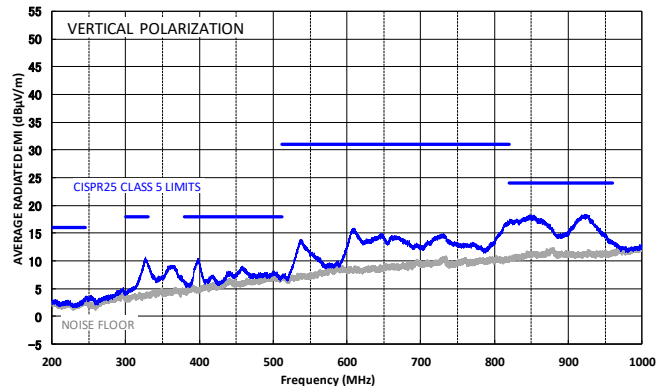
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 200MHz to 1GHz



### CISPR25 Class 5 Average Radiated Emissions

Vertical, 200MHz to 1GHz



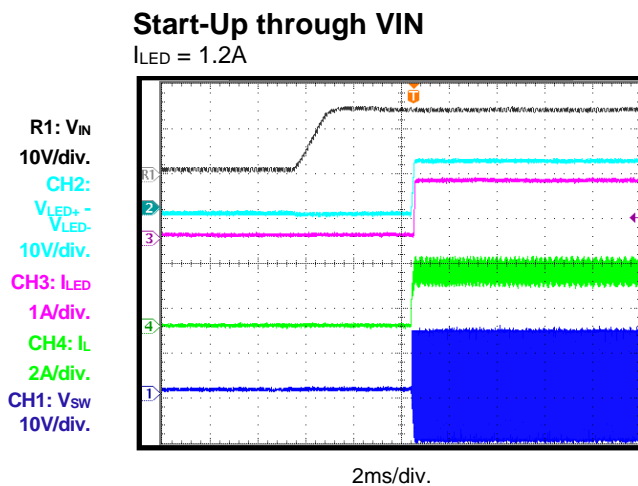
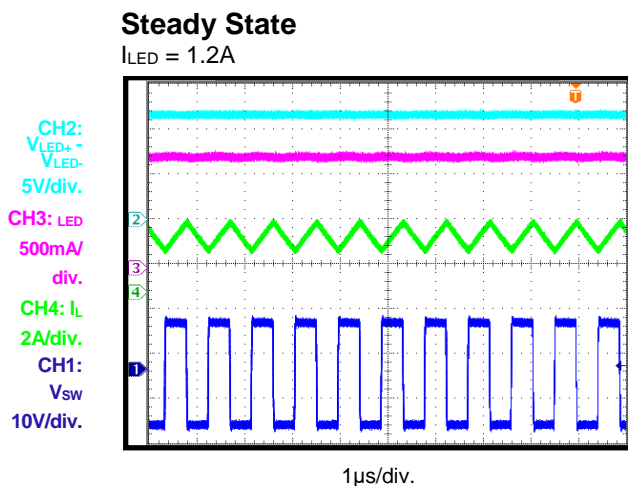
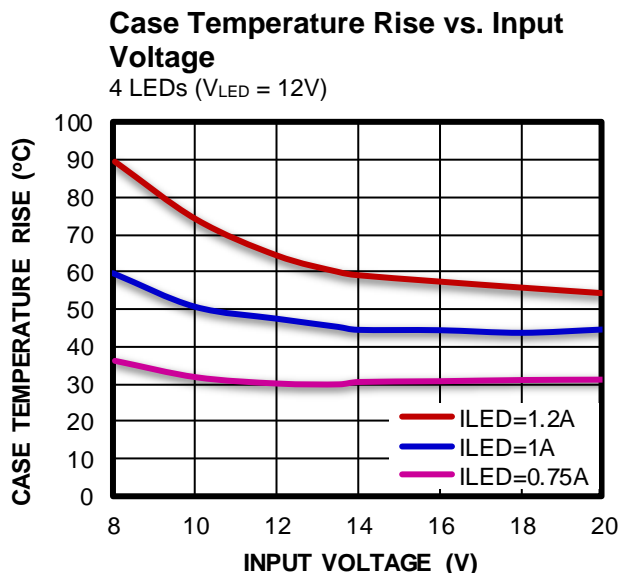
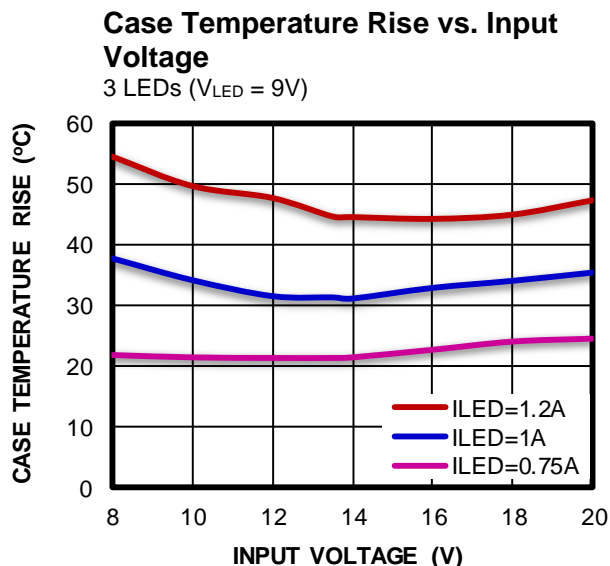
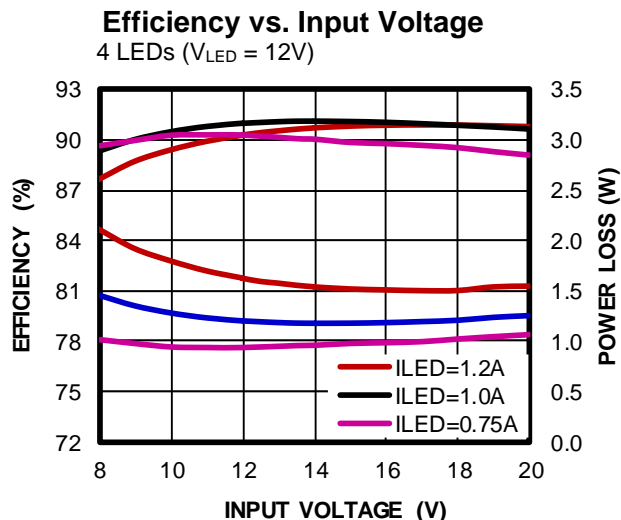
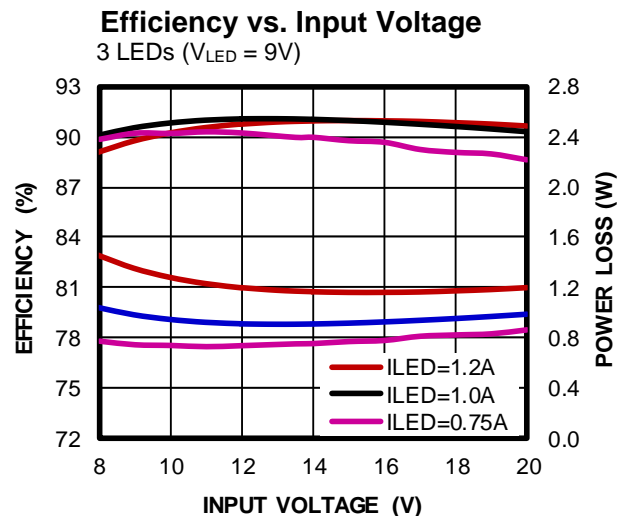
#### Note:

- 8) The MP7200 buck-boost mode EMC test results are based on the application circuit with EMI filters (see Figure 12 on page 54).



## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.



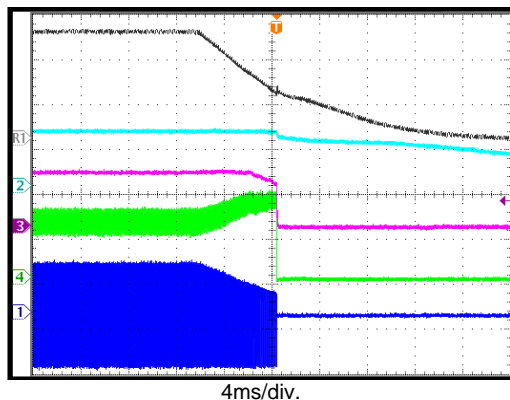
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

**Shutdown through VIN**

$I_{LED} = 1.2A$

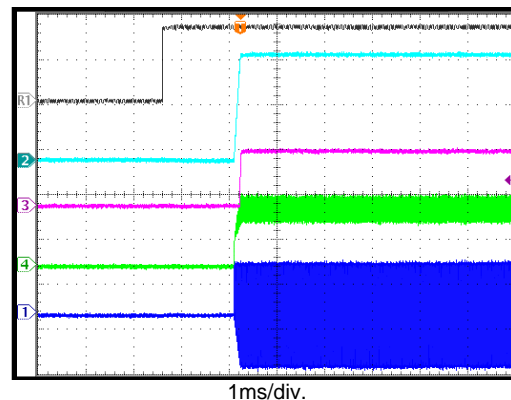
R1:  $V_{IN}$   
5V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



**Start-Up through EN/DIM**

$I_{LED} = 1.2A$

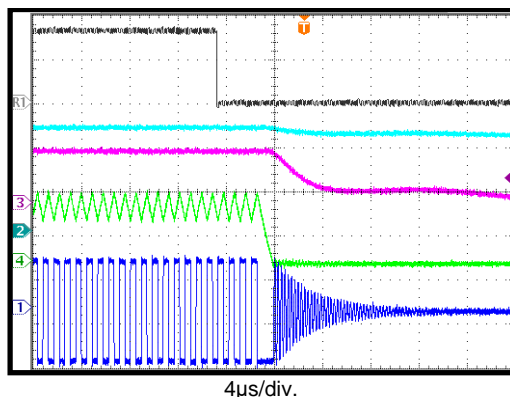
R1:  $V_{EN/DIM}$   
2V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



**Shutdown through EN/DIM**

$I_{LED} = 1.2A$

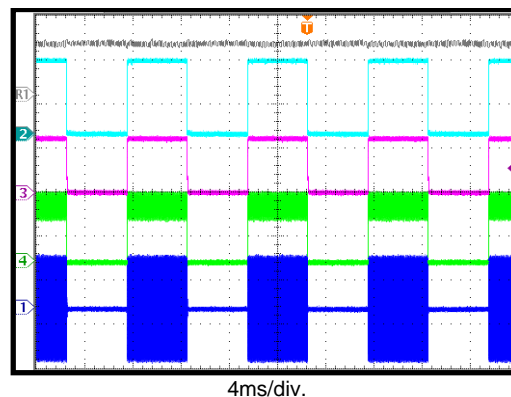
R1:  $V_{EN/DIM}$   
2V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH2:  $V_{LED+} - V_{LED-}$   
5V/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



**PWM Dimming Steady State**

Dimming frequency = 100Hz

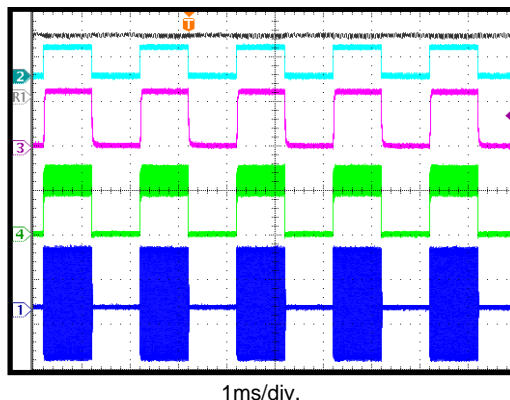
R1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
2V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



**PWM Dimming Steady State**

Dimming frequency = 500Hz

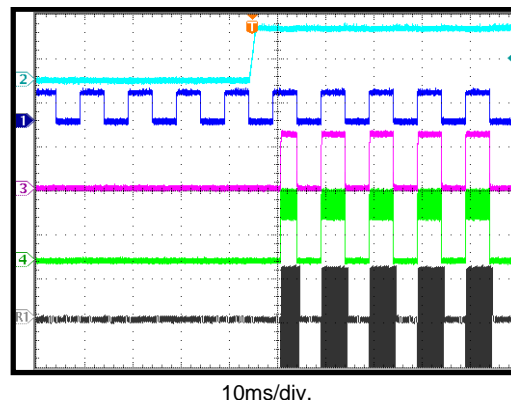
CH2:  $V_{EN/DIM}$   
5V/div.  
R1:  $V_{FAULT}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



**PWM Dimming**

Start-up through VIN

CH2:  $V_{IN}$   
10V/div.  
CH1:  $V_{EN/DIM}$   
5V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
10V/div.



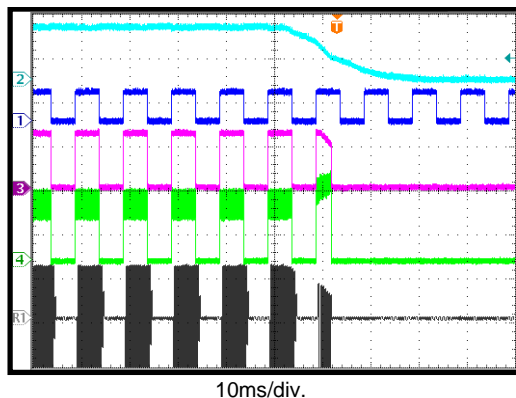
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### PWM Dimming

Shutdown through VIN

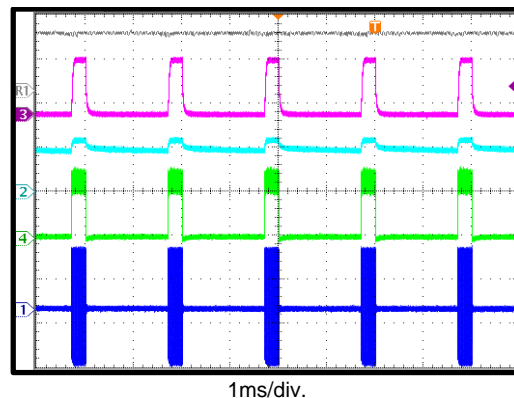
CH2:  $V_{IN}$   
10V/div.  
CH1:  $V_{EN/DIM}$   
5V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
10V/div.



### Two-Step Dimming

Steady state

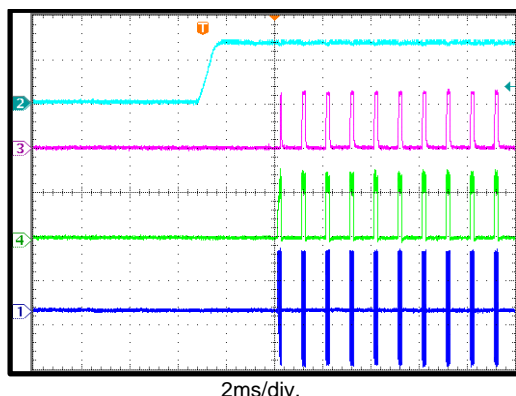
R1:  $V_{FAULT}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



### Two-Step Dimming

Start-up through VIN

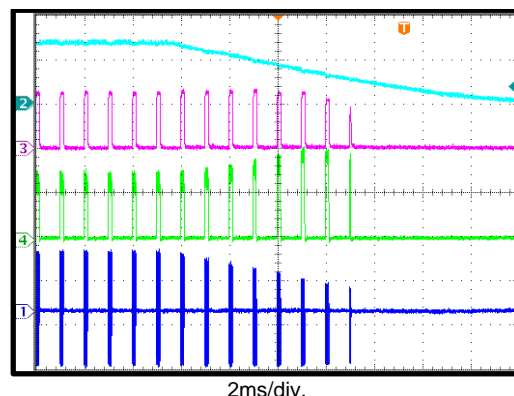
CH2:  $V_{IN}$   
5V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



### Two-Step Dimming

Shutdown through VIN

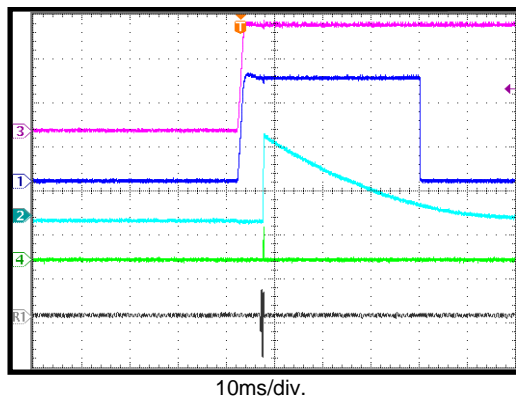
CH2:  $V_{IN}$   
5V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



### No Dimming

LED open, start-up through VIN

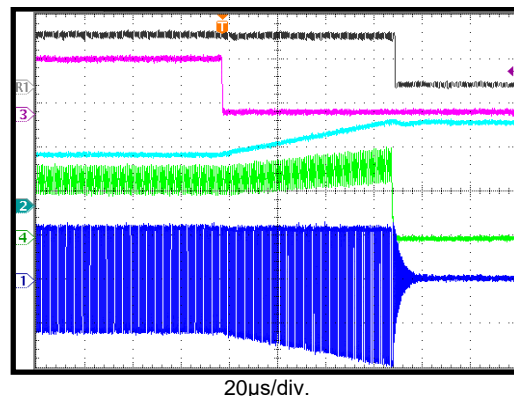
CH3:  $V_{IN}$   
5V/div.  
CH1:  $V_{FAULT}$   
5V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH4:  $I_L$   
5A/div.  
R1:  $V_{SW}$   
20V/div.



### No Dimming

LED open entry

R1:  $V_{FAULT}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



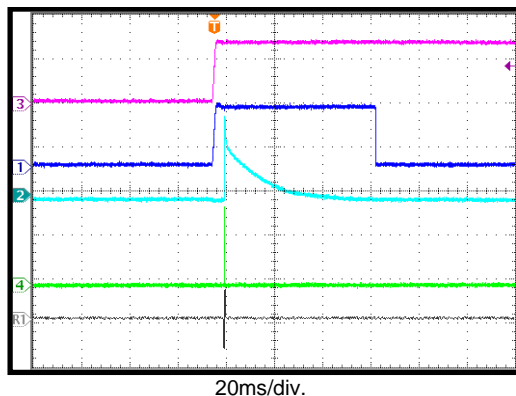
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### PWM Dimming

LED open during VIN start-up

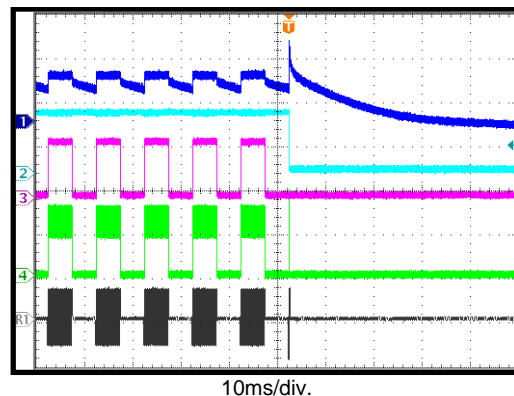
CH3:  $V_{IN}$   
10V/div.  
CH1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
20V/div.



### PWM Dimming

LED open entry

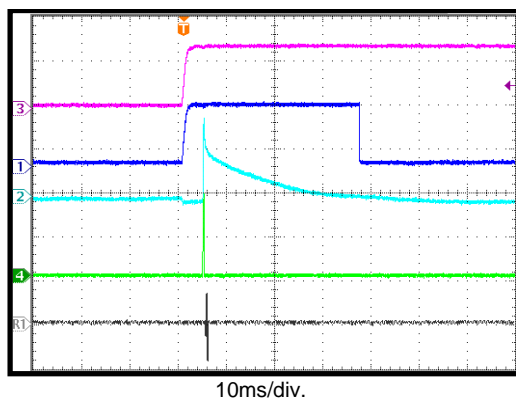
CH1:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH2:  $V_{FAULT}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
20V/div.



### Two-Step Dimming

LED open during VIN start-up

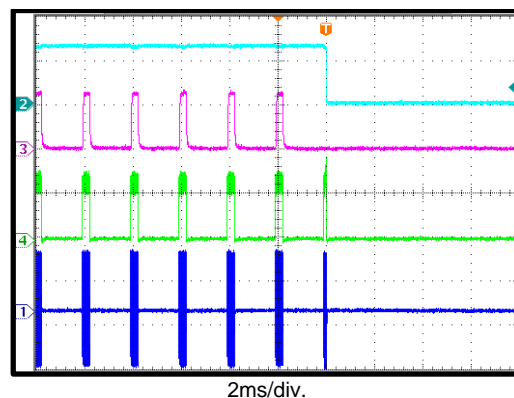
CH3:  $V_{IN}$   
10V/div.  
CH1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH4:  $I_L$   
2A/div.  
R1:  $V_{SW}$   
20V/div.



### Two-Step Dimming

LED open entry

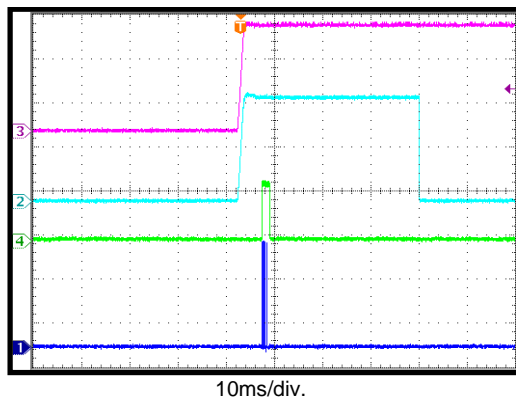
CH2:  $V_{FAULT}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{LED+} - V_{LED-}$   
10V/div.



### No Dimming

LED+ short to LED- during VIN start-up

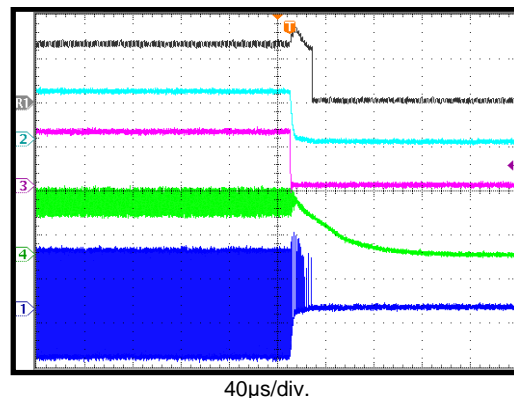
CH3:  $V_{IN}$   
5V/div.  
CH2:  $V_{FAULT}$   
5V/div.  
CH4:  $I_L$   
1A/div.  
CH1:  $V_{SW}$   
5V/div.



### No Dimming

LED+ short to LED- entry

R1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



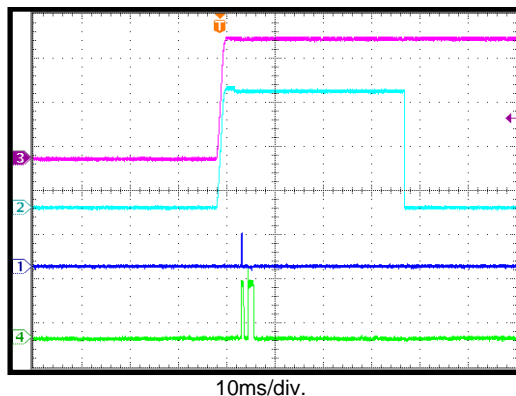
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### PWM Dimming

LED+ short to LED- during VIN start-up

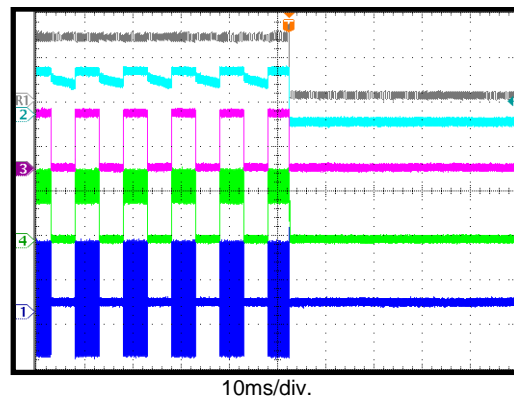
CH3:  $V_{IN}$   
5V/div.  
CH2:  $V_{FAULT}$   
5V/div.  
CH1:  $V_{SW}$   
5V/div.  
CH4:  $I_L$   
1A/div.



### PWM Dimming

LED+ short to LED- entry

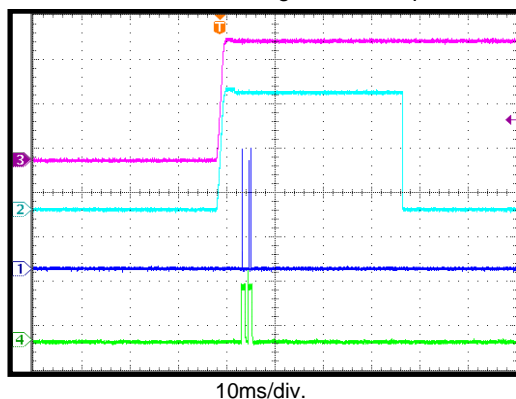
R1:  $V_{FAULT}$   
10V/div.  
CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



### Two-Step Dimming

LED+ short to LED- during VIN start-up

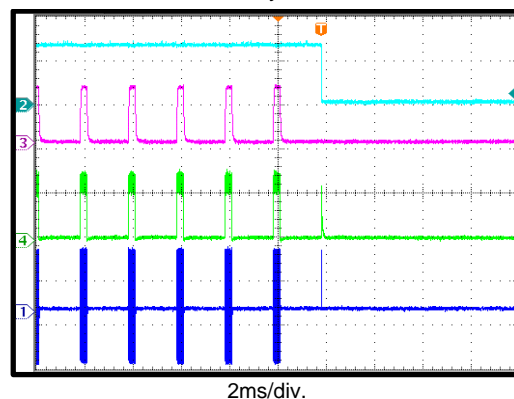
CH3:  $V_{IN}$   
5V/div.  
CH2:  $V_{FAULT}$   
5V/div.  
CH1:  $V_{SW}$   
5V/div.  
CH4:  $I_L$   
1A/div.



### Two-Step Dimming

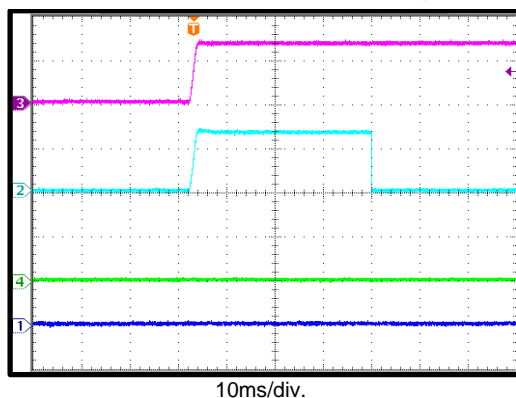
LED+ short to LED- entry

CH2:  $V_{LED+} - V_{LED-}$   
10V/div.  
CH3:  $I_{LED}$   
1A/div.  
CH4:  $I_L$   
2A/div.  
CH1:  $V_{SW}$   
10V/div.



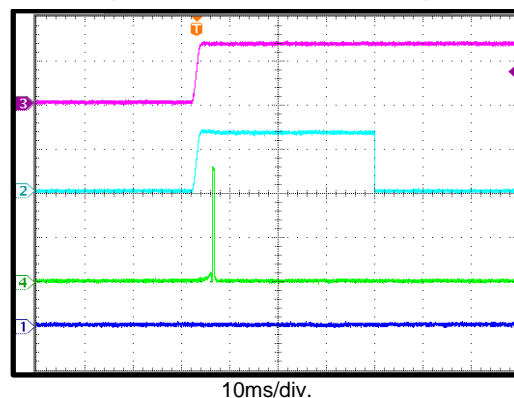
### IREF Short before VIN Start-Up

CH3:  $V_{IN}$   
10V/div.  
CH2:  $V_{FAULT}$   
10V/div.  
CH4:  $I_{REF}$   
2V/div.  
CH1:  $V_{SW}$   
10V/div.



### IREF Open before VIN Start-Up

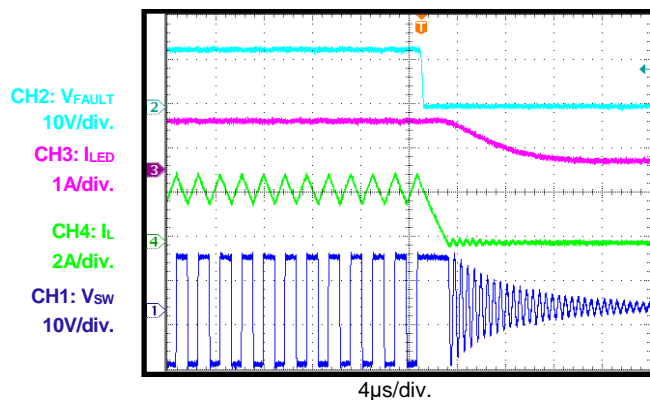
CH3:  $V_{IN}$   
10V/div.  
CH2:  $V_{FAULT}$   
10V/div.  
CH4:  $I_{REF}$   
2V/div.  
CH1:  $V_{SW}$   
10V/div.



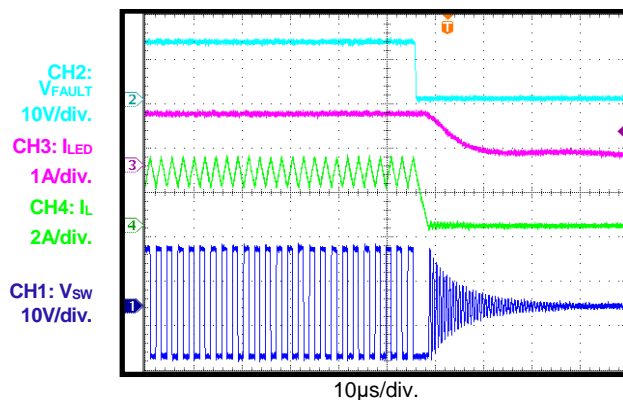
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

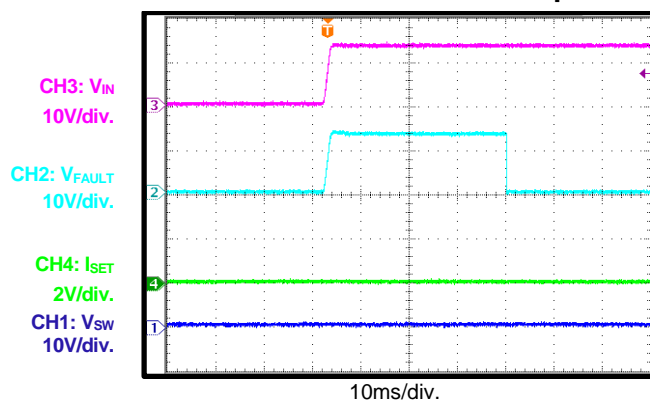
**IREF Short after VIN Start-Up**



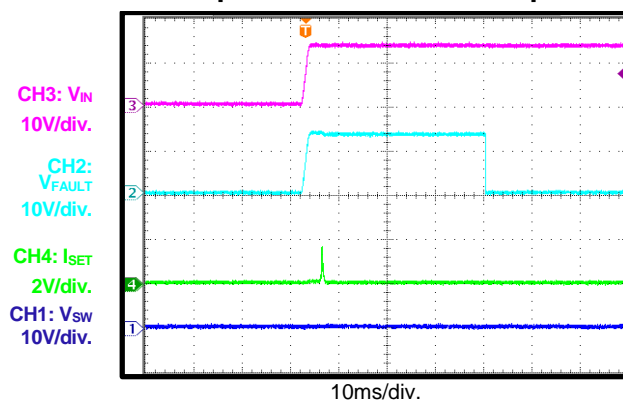
**IREF Open after VIN Start-Up**



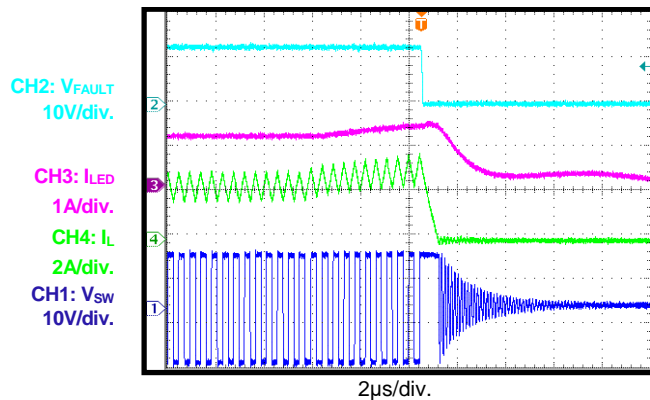
**ISET Short before VIN Start-Up**



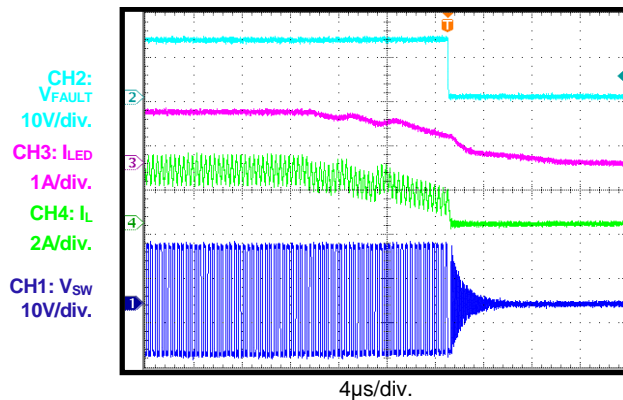
**ISET Open before VIN Start-Up**



**ISET Short after VIN Start-Up**



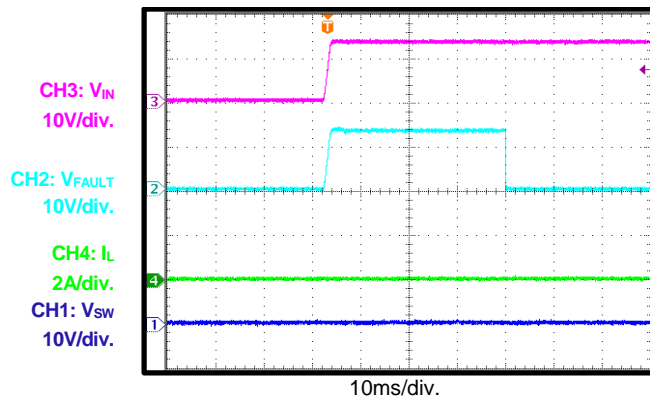
**ISET Open after VIN Start-Up**



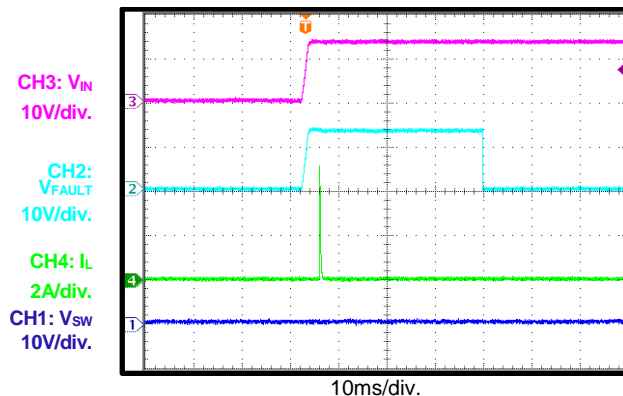
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Buck-boost mode, 4 LEDs ( $V_{LED} = 12V$ ),  $V_{IN} = 13.5V$ ,  $f_{SW} = 1.15MHz$ ,  $L = 4.7\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

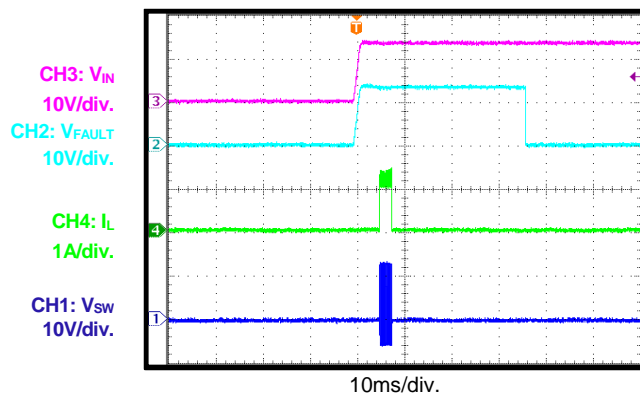
**IDUTY Short before VIN Start-Up**



**IDUTY Open before VIN Start-Up**



**False Mode Detection during VIN Start-Up**



## FUNCTIONAL BLOCK DIAGRAM

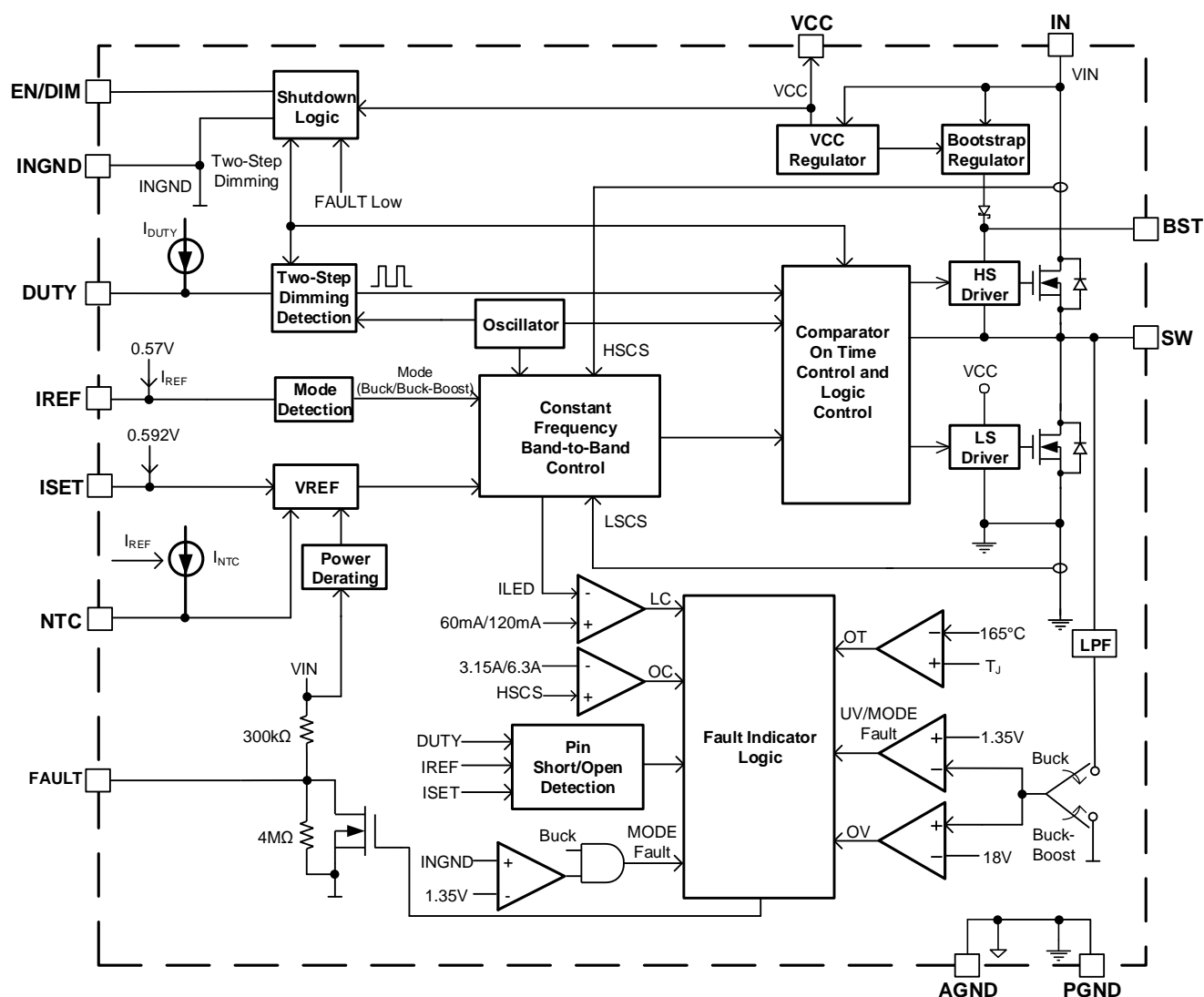


Figure 3: Functional Block Diagram



## OPERATION

The MP7200 is a high-frequency, synchronous, rectified, buck-boost or buck switch-mode LED driver with built-in power MOSFETs. It offers a very compact solution to achieve up to 1.2A of continuous output current in a buck-boost topology (or 3A in a buck topology), with excellent load and line regulation across a 6V to 42V input supply range.

### Fixed-Frequency Band-to-Band Control

The MP7200 uses fixed-frequency band-to-band control, plus spread spectrum, to reduce electromagnetic interference (EMI) noise. Compared to fixed-frequency PWM control, band-to-band control offers a simpler control loop and faster transient response. The loop is stable without an output capacitor. Band-to-band control compares the inductor current to the internal thresholds ( $I_{BANDPEAK}$  and  $I_{BANDVALLEY}$ ).

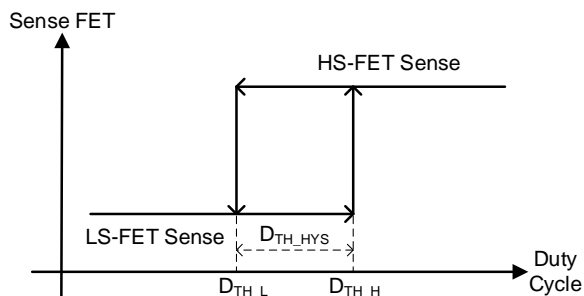
When the inductor current ( $I_L$ ) exceeds  $I_{BANDPEAK}$ , the high-side MOSFET (HS-FET) turns off. When  $I_L$  drops below  $I_{BANDVALLEY}$ , the HS-FET turns on.  $(I_{BANDPEAK} + I_{BANDVALLEY}) / 2$  is controlled by a PID loop to regulate the LED current.  $I_{BANDPEAK} - I_{BANDVALLEY}$  is controlled by a PLL loop to regulate the switching frequency to be 2.3MHz in buck mode, and 1.15MHz in buck-boost mode. If the minimum on time ( $t_{ON\_MIN}$ ) or minimum off time ( $t_{OFF\_MIN}$ ) is triggered, the switching frequency is extended. The real switching frequency is  $(D / t_{ON\_MIN})$  or  $(1 - D) / t_{OFF\_MIN}$ , where  $D$  is the required duty cycle, and  $t_{ON\_MIN}$  and  $t_{OFF\_MIN}$  are both 80ns maximum.

The spread spectrum function uses a 15kHz modulation frequency with a triangular profile to spread the internal oscillator frequency across a  $\pm 10\%$  nominal switching frequency window (1.15MHz in buck mode, and 2.3MHz in buck-boost mode).

### Middle-Point Inductor Current Sense

The MP7200 senses the LED current by sensing the inductor current middle point ( $I_{LMID}$ ).  $I_{LMID}$  is sensed through the sensing FET.  $I_{LMID}$  is sensed through the HS-FET when the duty cycle exceeds  $D_{TH\_H}$  (55% in buck mode or 60% in buck-boost mode), and is sensed through the LS-FET when the duty cycle is below  $D_{TH\_L}$  (45% in buck mode or 40% in buck-boost mode).

A duty cycle hysteresis ( $D_{TH\_HYS}$ ) (10% in buck mode and 20% in buck-boost mode) is used to prevent frequent current-sense switches between the HS-FET and LS-FET at the critical duty cycle (see Figure 4).



**Figure 4: Current-Sense MOSFET vs. Duty Cycle**

In buck mode, the LED current is equal to  $I_{LMID}$ . In buck-boost mode, it is equal to  $I_{LMID} \times V_{IN} / (V_{IN} + V_{OUT})$ .

### Buck and Buck-Boost Mode Selection

The MP7200 can be configured to buck or buck-boost mode by connecting a different resistor ( $R_{IREF}$ ) at the IREF pin.

Mode detection starts when VCC reaches its under-voltage lockout (UVLO) threshold of about 4.7V. There is a 240 $\mu$ A current source ( $I_{REF\_DET}$ ) flowing out of the IREF pin to detect the resistor voltage value at the pin during start-up. If the voltage generated by  $I_{REF\_DET} \times R_{IREF}$  is below 2.6V, buck-boost mode is selected. If  $I_{REF\_DET} \times R_{IREF}$  exceeds 2.8V, buck mode is selected. The corresponding  $R_{IREF}$  is  $\leq 9.09k\Omega$  for buck-boost mode, and  $\geq 14.7k\Omega$  for buck mode.

Certain resistors are recommended to avoid an IREF short fault in buck-boost mode, and an IREF open fault in buck mode. In buck mode,  $R_{IREF}$  should be set between 1.05k $\Omega$  and 9.09k $\Omega$ . In buck-boost mode,  $R_{IREF}$  should be set between 14.7k $\Omega$  and 80.6k $\Omega$ . Once the resistor has been detected, the mode is latched and  $I_{REF}$  becomes  $0.57V / R_{IREF}$ , which is the reference for the NTC pin current. The latched mode signal is reset by VCC UVLO; it cannot be reset by pulling EN/DIM low.

An internal 1MHz filter works with a 250 $\mu$ s deglitch time to protect the part from false mode detection caused by noise coupling at the pin. To ensure that the detected mode is consistent with the real topology connection,  $V_{INGND} - V_{PGND}$  is

monitored. If buck mode is detected when  $(V_{INGND} - V_{PGND}) > 1.35V$ , or buck-boost mode is detected when  $(V_{INGND} - V_{PGND}) < 1.35V$  (detected as output under-voltage [UV] condition), the part latches off and asserts FAULT low.

### Internal Regulator

The 5.1V internal regulator (VCC) powers most of the internal circuitries. VCC rises once  $V_{IN}$  reaches its rising UVLO threshold, regardless of whether EN is high or low. VCC is a reference to PGND and AGND, but not INGND. This means that in buck-boost mode, VCC cannot have the same ground level as INGND. In buck-boost mode, the regulator uses either  $V_{IN}$  or  $V_{INGND}$  as the input: When  $(V_{INGND} - V_{PGND}) < 5.1V$ , VCC is powered from  $V_{IN}$ . When  $(V_{INGND} - V_{PGND}) > 5.1V$ , the VCC regulator input switches to  $V_{INGND}$  to reduce power loss. Once this switch occurs,  $V_{IN}$  does not power VCC until  $V_{INGND} - V_{PGND}$  drops below 4.8V.

A smaller-value VCC capacitor can cause VCC voltage ringing and can make the switch unstable. A  $\geq 3\mu F$  decoupling ceramic capacitor is needed at the VCC pin. When selecting a VCC capacitor, consider the capacitance derating to ensure that the real capacitance  $\geq 3\mu F$ . A  $10\mu F$ , X7R capacitor with a  $\geq 10V$  DC rated voltage is recommended. VCC has its own UVLO with a 4.7V rising threshold and a 4.05V falling threshold. In addition to powering internal circuitries, VCC also powers external circuitries in the system, with a current capability of 25mA.

### CCM Operation and DCM Operation

The MP7200 uses continuous conduction mode (CCM) to ensure that the part works with fixed frequency across the full load range. The advantage of CCM is the controllable frequency and lower output ripple at light loads. When  $I_{BANDVALLEY} = 0A$ , the MP7200 enters discontinuous conduction mode (DCM), in which the LS-FET acts as an ideal diode. Use an inductor that can ensure that the part does not enter DCM, even during a power or thermal derating. Otherwise, LED current precision cannot be guaranteed.

### Enable Control (EN)

When the two-step dimming function is not active (see the Two-Step Dimming section on page 43), EN/DIM is a control pin that turns the LED driver on and off. Drive  $V_{EN/DIM} - V_{INGND}$  above 1.67V to turn the part on. Drive  $V_{EN/DIM} - V_{INGND}$  below 1.58V for longer than 25ms to turn the part off and reset FAULT. When two-step dimming is active, the part automatically turns on while  $V_{IN}$  and VCC exceed their UVLO thresholds, and EN is configured to be the two-step dimming control pin. Drive EN/DIM high to select a 100% dimming duty. Drive EN/DIM low to select the dimming duty via the DUTY pin. EN cannot reset FAULT in two-step dimming mode.

Connect EN/DIM to  $V_{IN}$  through a resistor in both buck and buck-boost mode (it can also be connected to VCC in buck mode) if the EN/DIM pin is not used to control whether the part is on or off. In this scenario, the part always delivers the full configured current (no dimming). If two-step dimming is deactivated, connect an internal  $1M\Omega$  resistor from EN/DIM to INGND to float EN/DIM and shut down the chip. Place an integrated Zener diode in parallel with the EN/DIM pin to clamp  $V_{EN/DIM} - V_{INGND}$  to about 7V. This internal Zener diode can handle a 1mA current for a load dump voltage up to 100V when a  $100k\Omega$  resistor is connected between  $V_{IN}$  and EN/DIM.

### ISET

The LED average current can be configured by connecting a resistor ( $R_{ISET}$ ) at the ISET pin. The LED current can be calculated with Equation (1):

$$I_{LED} (A) = 16 / R_{ISET} (k\Omega) \quad (1)$$

The ISET pin nominal voltage ( $V_{ISET}$ ) is 0.592V.  $V_{ISET}$  can be set below 0.592V to decrease the LED current in the event of power derating or thermal derating.

During the mode detection period during start-up while the device is in buck mode, the ISET current is monitored to detect if the LED current is set above or below 600mA. If  $I_{ISET} > 22.2\mu A$  during this period, then the LED current setting is detected as  $> 600mA$  and the MOSFETs turn fully on.

If the LED current setting is detected to be  $< 600mA$ , half of the HS-FETs and LS-FETs are cut off to improve current-sense accuracy. After

this cutoff, the current limit drops from 6.3A to 3.15A. The signal to indicate whether the LED current is above or below 600mA is latched once detection finishes, and only can be reset by VCC UVLO. After LED current detection, the MOSFET's  $R_{DS(ON)}$  does not change, even if the current setting exceeds or falls below 600mA.

During normal operation, the ISET pin is continuously monitored to detect the occurrence of an open or short to GND condition. If the ISET current is above its specific value, the device detects a pin short to ground. In buck-boost mode, the MOSFET is always on, regardless of the current.

If the LED current ( $I_{LED}$ ) is set below 600mA, the ISET current threshold for short detection is 120 $\mu$ A (with the 4.9k $\Omega$  resistor, or 3.24A  $I_{LED}$ ). If  $I_{LED}$  is set above 600mA, the threshold is 220 $\mu$ A (with a 2.7k $\Omega$  resistor, or 5.9A  $I_{LED}$ ). When the ISET current is below 1.4 $\mu$ A (with a 428k $\Omega$  resistor, or 37.3mA  $I_{LED}$ ), a pin open fault is detected.

The part latches off if the ISET pin detects a short or open fault, regardless of whether FAULT is asserted. If there is an ISET pin short or open fault after start-up, FAULT is pulled low immediately. There is a 25ms to 40ms delay for FAULT assertion if a short or open fault is detected during start-up.

## IREF

The IREF pin configures the device to buck or buck-boost mode. Afterward, it sets the current in the external NTC. After mode detection finishes, the IREF pin voltage ( $V_{IREF}$ ) is set to 0.57V with a 10.5% tolerance. Connect a resistor ( $R_{IREF}$ ) between IREF and AGND to get a current ( $I_{REF}$ ) equal to  $0.57V / R_{IREF}$ . This current is used as a reference current for the NTC's current source. The NTC current is 50 times that of  $I_{REF}$  in buck mode, and 5 times that of  $I_{REF}$  in buck-boost mode. The IREF current is continuously monitored to detect if the IREF pin open and short to GND conditions occur.

If the IREF current exceeds 90 $\mu$ A in buck mode (with a 6.3k $\Omega$  resistor) or 900 $\mu$ A in buck-boost mode (with a 0.63k $\Omega$  resistor), a short-to-GND fault is detected. If the IREF current drops below 3 $\mu$ A in buck mode (with a 190k $\Omega$  resistor) or

below 40 $\mu$ A in buck-boost mode (with a 14.3k $\Omega$  resistor), an open fault is detected.

The part latches off if a short or open fault is detected on IREF, regardless of whether FAULT asserts. If there is an IREF pin short or open fault after start-up, FAULT is pulled low immediately. There is a 25ms to 40ms delay for FAULT assertion if a short or open fault is detected during start-up.

## PWM Dimming

When two-step dimming is inactive ( $R_{DUTY} = 4.87k\Omega$ ), an external 100Hz to 2kHz PWM waveform can be applied to the EN/DIM pin. In external PWM dimming mode, the part stops switching when EN/DIM drops below 1.58V and  $I_{LED}$  is 0A. The part resumes normal operation with the nominal LED current, and when EN/DIM exceeds 1.67V. The average LED current is proportional to the PWM duty, and its accuracy can be up to  $\pm 15\%$  when  $V_{IN} = 13.5V \pm 0.5V$  and  $T_J$  is between 25°C and 100°C.

Note that the EN/DIM high-voltage period should always be longer than 100 $\mu$ s. Otherwise, the part can stop switching, and an LED open fault may not be detected. To prevent the part from shutting down, the EN/DIM low-voltage period should not be longer than 10ms (EN turn-off delay).

## Two-Step Dimming

When VCC reaches its UVLO rising threshold (4.7V), two-step dimming detection is activated on the DUTY pin. A 45 $\mu$ A current source ( $I_{DUTY1}$ ) with a  $\pm 11\%$  tolerance flows through the resistor between the DUTY pin and GND.

If the generated voltage ( $V_{DUTY}$ ) exceeds 3.347V, an open fault is detected, the part latches off, and FAULT asserts. If  $0.302V < V_{DUTY} < 3.347V$ , the two-step dimming function is activated and the two-step dimming duty cycle is selected using Table 1. If  $V_{DUTY}$  is below 0.302V, the DUTY current source rises to 600 $\mu$ A ( $I_{DUTY2}$ ) with a  $\pm 8.75\%$  tolerance to detect  $V_{DUTY}$  again.

If  $V_{DUTY} > 2.235V$  at this point, two-step dimming is disabled. Then the part can be turned on/off through EN/DIM, or can work in normal PWM dimming by applying a dimming signal at EN/DIM. If  $V_{DUTY} < 0.302V$ , a short fault is detected, the part latches off, and FAULT

asserts. If  $0.302V < V_{DUTY} < 2.235V$ , two-step dimming is reactivated and the two-step dimming duty cycle is determined by  $V_{DUTY}$ . After this detection, the duty is not affected by changing  $V_{DUTY}$ , even if the DUTY pin is opened or shorted to GND.

Once two-step dimming is activated, PWM dimming is deactivated. The EN/DIM pin is used as the input pin to select no dimming or low dimming. When the EN/DIM pin is high, a 100% dimming duty cycle is selected. When EN/DIM is low, the dimming duty cycle is determined by  $I_{DUTY}$  and  $V_{DUTY}$ . The part can switch between dimming values in less than 20ms.

Configurable dimming is implemented as PWM dimming, but not analog dimming. When two-step dimming is activated at  $I_{DUTY1}$ , the dimming duty can be set between 15% and 10% with a 1% step. The corresponding typical  $V_{DUTY}$  is between 3.347V and 0.302V, with a 33% decrement for each step. When two-step dimming is activated at  $I_{DUTY2}$ , the dimming duty can be set between 9% and 5% with a 1% step. The corresponding  $V_{DUTY}$  is between 2.235V and 0.302V, with a 33% decrement for each step. Table 1 shows the relationship between the two-step dimming duty and  $V_{DUTY}$  window when considering different  $V_{DUTY}$  threshold tolerances.

**Table 1: Two-Step Dimming Duty vs.  $V_{DUTY}$  Window**

| Two-Step Dimming Duty |                  | Corresponding $V_{DUTY}$ Window |       |       |               |       |       |
|-----------------------|------------------|---------------------------------|-------|-------|---------------|-------|-------|
|                       |                  | $V_{DUTY\_H}$                   |       |       | $V_{DUTY\_L}$ |       |       |
| $I_{DUTY1}$           | $I_{DUTY2}$      | Min                             | Typ   | Max   | Min           | Typ   | Max   |
| Latch                 | No two-step dim. | 4.018                           | 4.100 | 4.182 | 3.280         | 3.347 | 3.414 |
| 15%                   |                  | 3.280                           | 3.347 | 3.414 | 2.190         | 2.235 | 2.279 |
| 14%                   |                  | 2.190                           | 2.235 | 2.279 | 1.460         | 1.489 | 1.519 |
| 13%                   |                  | 1.460                           | 1.489 | 1.519 | 0.969         | 0.989 | 1.009 |
| 12%                   | 7%               | 0.969                           | 0.989 | 1.009 | 0.634         | 0.653 | 0.673 |
| 11%                   | 6%               | 0.634                           | 0.653 | 0.673 | 0.407         | 0.428 | 0.449 |
| 10%                   | 5%               | 0.407                           | 0.428 | 0.449 | 0.28          | 0.302 | 0.33  |
| To $I_{DUTY2}$        | Latch            | 0.28                            | 0.302 | 0.33  | -             |       |       |

To prevent errors while selecting the two-step dimming duty, ensure that the  $V_{DUTY}$  window is between the minimum  $V_{DUTY\_H}$  and maximum  $V_{DUTY\_L}$  values when selecting  $R_{DUTY}$ . An E96 series resistor is recommend to select precise dimming values. Table 2 shows the proposed  $R_{DUTY}$  in E96 series for different two-step dimming duties, while considering the  $I_{DUTY}$  tolerance and a  $\pm 3\%$  resistor tolerance

If  $V_{CC}$  drops below 4.05V before two-step dimming detection finishes, two-step dimming detection stops and does not restart until  $V_{CC}$  returns to 4.7V. The two-step dimming signal, together with the two-step dimming duty, is latched once detection finishes. It only can be reset by  $V_{CC}$  UVLO, and not an EN shutdown.

The two-step dimming frequency is typically 500Hz, within  $\pm 50\text{Hz}$ .

**Table 2: Two-Step Dimming Duty vs.  $R_{DUTY}$**

| Two-Step Dimming Duty                      | $R_{DUTY} (\Omega)$ |
|--|---------------------|
| 15%  | 61900               |
| 14%  | 41200               |
| 13%  | 27400               |
| 12%  | 18200               |
| 11%  | 12100               |
| 10%  | 7870                |
| PWM dimming (two-step dimming inactivated) | 4870                |
| 9%   | 3090                |
| 8%   | 2050                |
| 7%   | 1370                |
| 6%   | 887                 |
| 5%   | 576                 |



## Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. Both ( $V_{IN} - V_{INGND}$ ) and  $V_{CC}$  have UVLO thresholds. The  $V_{IN} - V_{INGND}$  UVLO rising threshold is 6V, with a 1.1V hysteresis. The  $V_{CC}$  UVLO rising threshold is 4.7V, with a 0.65V hysteresis. Neither of these UVLOs triggers a fault.

## Fault Detection and Indication

The MP7200 has fault indication. The FAULT pin is the open drain of a MOSFET. FAULT is internally pulled up to  $V_{IN}$  through a 300k $\Omega$  resistor, and pulled down with a 4M $\Omega$  resistor connected to INGND. The FAULT pin is pulled high during normal operation. It pulls low to indicate a fault status if any of the following events occur:

- An LED short or open fault
- Thermal shutdown
- False mode detection
- Over-current protection (OCP)

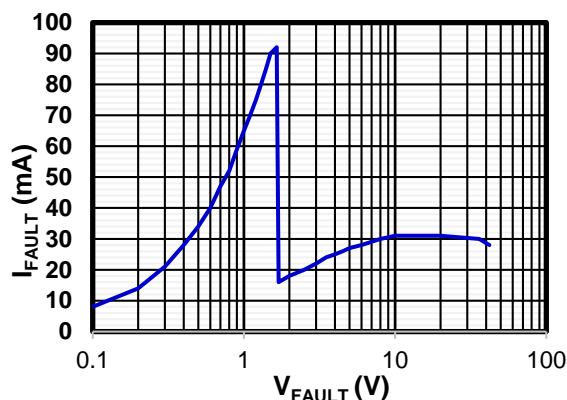
An ISET or IREF pin short/open fault during (or after) start-up can assert FAULT. An IDUTY pin short/open fault can only assert FAULT if it is detected before start-up. The MP7200 senses the output by monitoring the average SW voltage in buck mode, or the INGND voltage in buck-boost mode. If LED+ shorts to LED- or PGND,  $V_{OUT}$  drops below its under-voltage (UV) threshold, a short-circuit is detected, and FAULT asserts. If an LED open or output over-voltage (OV) fault is detected in buck-boost mode, or the high-side MOSFET current is detected in buck mode, then FAULT asserts. The low-current threshold is 60mA when the LED current is set below 600mA, or 120mA when the LED current is set above 600mA.

To prevent the part from latching due to cold crank conditions while in buck mode, low-current detection is disabled when  $V_{IN}$  drops below 7.5V. If LED+ (INGND) shorts to the battery,  $V_{IN} - V_{INGND}$  falls below its UV threshold in buck-boost mode, and FAULT cannot assert. If LED- (PGND) shorts to INGND,  $V_{INGND}$  drops below its UV threshold and FAULT asserts. If an LED open fault occurs,  $V_{INGND}$  exceeds its OV threshold and FAULT asserts.

At high temperatures, the part operates with a reduced current level. The device only stops if the internal temperature reaches the 170°C over-temperature (OTP) threshold and FAULT asserts. If any fault occurs, the part stops switching, the FAULT output asserts in 20 $\mu$ s, and then the part latches. While latched,  $V_{CC}$  is still present, and the part's consumption current is <2mA. FAULT can be reset by  $V_{CC}$  UVLO. EN shutdown (EN going low longer than 25ms) can also reset FAULT if two-step dimming is not selected.

At start-up, the FAULT pin is not activated, and remains inactive for at least 25ms. FAULT is active within 40ms. In PWM dimming mode, the FAULT counter works only when the dimming signal is high, which makes the inactive time 30ms/PWM dimming duty. This avoids any false functions from the system when multiple parts have connected FAULT pins and share the same EN signal. Individual parts are self-protected and latch off immediately if a fault condition is detected, regardless of whether FAULT asserts.

The FAULT pin can withstand a 30mA current and protects itself if the pin shorts to a high voltage (e.g.  $V_{BATT}$ ). If FAULT is low (<1.6V), the FAULT sink current increases to enhance the pull-down capability. Figure 5 shows the detailed FAULT sink current when the FAULT pin is pulled low at different voltages.



**Figure 5: FAULT Sink Current vs. FAULT Voltage**

In PWM dimming and two-step dimming, fault conditions may not be detected when the dimming on time is below 100 $\mu$ s. Ensure that the dimming on time exceeds 100 $\mu$ s for normal fault detection operation. Table 3 shows the fault detection options.

**Table 3: Fault Detection** <sup>(9)</sup>

| Fault Conditions           | Detection  |   |
|----------------------------|--|---|
|                            | Buck Mode  | Buck-Boost Mode   |
| LED+ short to LED-         | $V_{OUT}$ UV ( $V_{OUT} < 1.1V$ )  | INGND UV ( $V_{INGND} - V_{PGND} < 1.35V$ ) <sup>(10)</sup> |
| LED+ short to PGND         | $V_{OUT}$ UV ( $V_{OUT} < 1.1V$ )  | INGND UV ( $V_{INGND} - V_{PGND} < 1.35V$ )                 |
| LED+ short to INGND        | $V_{OUT}$ UV ( $V_{OUT} < 1.1V$ )  | Normal condition  |
| LED+ short to battery      | Low LED current<br>( $I_{HS} < 60mA$ when $I_{LED\_SETTING} < 600mA$ )<br>( $I_{HS} < 120mA$ when $I_{LED\_SETTING} > 600mA$ ) | Cannot assert FAULT due to<br>$V_{IN} - V_{INGND}$ UVLO     |
| LED- short to INGND        | Normal conditions  | INGND UV ( $INGND - PGND < 1.35V$ )                         |
| LED- short to battery      | Cannot assert FAULT due to<br>$V_{IN} - V_{INGND}$ UVLO  | Cannot assert FAULT due to<br>$V_{IN} - V_{INGND}$ UVLO     |
| LED open                   | Low LED current<br>( $I_{HS} < 60mA$ when $I_{LED\_SETTING} < 600mA$ )<br>( $I_{HS} < 120mA$ when $I_{LED\_SETTING} > 600mA$ ) | INGND OV<br>( $V_{INGND} - V_{PGND} > 18V$ )                |
| MODE detection wrong       | $V_{INGND} - V_{PGND} > 1.35V$   | INGND UV ( $V_{INGND} - V_{PGND} < 1.35V$ )                 |
| OTP                        | $T_J > 170^{\circ}C$ , or $0.18V < V_{NTC} < 0.38V$ for $>256\mu s$  |   |
| ISET short <sup>(11)</sup> | ( $I_{SET} > 120\mu A$ when<br>$I_{LED\_SETTING} < 600mA$ ), or<br>( $I_{SET} > 220\mu A$ when<br>$I_{LED\_SETTING} > 600mA$ ) | $I_{SET} > 110\mu A$  |
| ISET open <sup>(11)</sup>  | $I_{SET} < 1.4\mu A$   |   |
| IREF short <sup>(11)</sup> | $I_{REF} > 90\mu A$  | $I_{REF} > 900\mu A$  |
| IREF open <sup>(11)</sup>  | $I_{REF} < 3\mu A$   | $I_{REF} < 40\mu A$   |
| DUTY open <sup>(12)</sup>  | $V_{DUTY1} > 3.355V$   |   |
| DUTY short <sup>(12)</sup> | $V_{DUTY2} < 0.302V$   |   |
| OCP                        | Current limit triggered three continuous times   |   |

**Notes:**

9) If a fault mentioned in this table is detected, the part latches off and FAULT is asserted.

10) The FAULT pin may not work correctly if  $V_{INGND} - V_{PGND}$  is pulled below  $-0.3V$ , or if an LED+ short to LED- occurs with a long cable.

11) If the ISET or IREF pins experience a short or open fault before or after start-up, the part latches off and FAULT asserts.

12) If an IDUTY pin short or open fault occurs before start-up, the part latches off and FAULT asserts. After start-up, an IDUTY short or open fault cannot be detected.

### Over-Current Protection (OCP)

The MP7200 has cycle-by-cycle peak current limit protection.  $I_L$  is monitored while the HS-FET is on. If  $I_L$  exceeds the current limit value (6.3A when  $I_{LED}$  is set above 600mA, or 3.15A when  $I_{LED}$  is set below 600mA), the HS-FET turns off immediately. Then the LS-FET turns on to discharge the energy, and  $I_L$  decreases. The HS-FET remains off until  $I_L$  drops to 0A, at which point another HS-FET on cycle starts. If the over-current (OC) condition still remains after three consecutive retries, the part latches off, reports a failure, and the FAULT pin is asserted.

### Load Dump Protection

The MP7200's internal MOSFETs have a 50V absolute maximum rating and a maximum 42V operating voltage. In buck topologies, the maximum voltage can handle load dump conditions up to 42V. In buck-boost topologies, the voltage difference between  $V_{IN}$  and PGND is the sum of the car battery's voltage plus the LED voltage. Under load dump conditions, the MP7200 can exceed its maximum value.

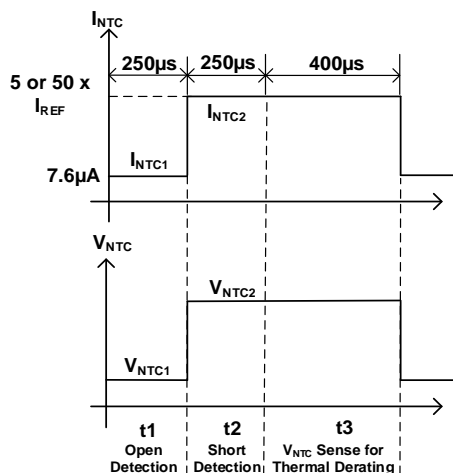
To protect the part from load dump conditions in buck-boost mode, the MP7200 stops switching if  $V_{IN} - V_{PGND}$  exceeds 40V. A 100mA sink current at INGND is activated to discharge the output voltage, so the MOSFET only detects the  $V_{IN}$  voltage stress. Once  $V_{IN} - V_{PGND}$  drops back to 39V, the part automatically restarts. Load dump protection does not always trigger a fault, and it is not active in buck mode. Load dump protection can reset the FAULT status caused by other fault conditions, but it cannot reset the MP7200 if the part is latched.

### Power Derating

If  $V_{IN}$  falls below a specific voltage (typically 7V) in buck-boost mode, power derating starts.  $I_{LED}$  drops linearly with  $V_{IN}$  due to analog dimming. Derating continues until  $V_{IN}$  reaches the UVLO threshold, then  $I_{LED}$  drops by 29%. Power derating is enabled during start-up in buck-boost mode, but it is disabled during start-up in buck mode.

### NTC Thermal Derating

Connect an NTC resistor network to the NTC pin to reduce the output current via analog dimming. This is especially useful when the sensed temperature exceeds the configured value.  $I_{LED}$  drops as the temperature rises. The activation of NTC and the dimming ratio are determined by the three-step NTC voltage ( $V_{NTC}$ ) detection (see Figure 6).



**Figure 6:  $I_{NTC}$  Timing**

At  $t_1$  and  $t_2$ , the voltage on the NTC pin is detected to determine if the NTC is enabled.  $t_1$  and  $t_2$  both last for 250µs. At  $t_3$ ,  $V_{NTC}$  is sensed. The dimming ratio is generated at the end of  $t_3$ .  $t_3$  lasts for 400µs.

During  $t_1$ , the detection current ( $I_{NTC1}$ ) is 7.6µA; during  $t_2$ , it is 50 times  $I_{REF}$  (in buck mode) or 5 (in buck-boost mode) times  $I_{REF}$  ( $I_{NTC2}$ ). To activate NTC thermal derating,  $V_{NTC}$  should be below 2V (with a <263kΩ resistor) during  $t_1$  ( $V_{NTC1}$ ), and above 0.38V (with a resistor that is based on the values of  $V_{NTC2}$  and  $I_{NTC2}$ ) during  $t_2$ . If  $V_{NTC1}$  exceeds 2V during  $t_1$ , an open pin fault is detected. If  $V_{NTC2}$  falls below 0.18V during  $t_2$ , a short fault is detected. An open or short fault deactivates NTC thermal derating.

$V_{NTC1}$  must be below 2V (even if the NTC value is large at low temperatures) to avoid triggering an open fault.  $V_{NTC2}$  must exceed 0.18V (even if the NTC resistor is small) at high temperatures to avoid triggering a short fault.

If NTC thermal derating is activated at the end of  $t_2$ ,  $V_{NTC2}$  is sensed during  $t_3$  to indicate the real temperature and determine the dimming ratio. The dimming ratio decreases as  $V_{NTC2}$  decreases, starting when  $V_{NTC2}$  drops below 1.25V. The dimming ratio decreases by a step of 2% if  $V_{NTC2}$  drops by 30mV. If  $V_{NTC2}$  falls to 0.5V, the dimming ratio decreases to 50%. This means the LED average current also falls to 50% of the set LED current.

If  $V_{NTC2}$  continues to drop to between 0.5V and 0.38V, the thermal derating remains at 50%. If  $V_{NTC2}$  is between 0.38V and 0.18V, the part latches off due to a thermal shutdown event and FAULT is asserted. The device can restart only after it is turned off then on again, or if EN is reset. If the voltage falls below 0.18V, the NTC pin is considered shorted to PGND, and the NTC circuitry is deactivated.

### Thermal Shutdown (TSD)

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. If the die temperature exceeds 170°C, the entire chip shuts down and FAULT is asserted. The device restarts only after being turned off and on again, or after EN is reset.

### Floating Driver and Bootstrap Charging

An external bootstrap capacitor powers the floating power MOSFET driver. The bootstrap capacitor voltage is charged to about 5V from VCC through a pass transistor while the LS-FET is on.

This floating driver has its own UVLO protection, with a rising threshold of 2.5V and hysteresis of 700mV. If the BST-to-SW voltage drops to 2.2V, the LS-FET turns on to refresh the BST voltage. It is recommended to use a 47nF to 220nF ceramic capacitor for the bootstrap capacitor. Consider the capacitor's DC voltage and temperature derating when selecting the capacitor to ensure that the real capacitance is between 47nF and 200nF. A maximum 22Ω resistor can be placed in series with the bootstrap capacitor to reduce SW voltage spikes.

The part integrates BST capacitor open-detection functionality. When VIN and VCC reach their UVLO rising thresholds, the BST capacitor is charged after the 1ms thermal derating finishes. If the voltage on the BST capacitor reaches the UVLO rising threshold within 45μs, the part detects a BST open fault and latches off. If VIN restarts frequently, the BST capacitor may not be able to discharge sufficiently, and an open fault may be mistriggered.

To avoid a mistrigger, place a small BST capacitor and a bleeding resistor in parallel with the BST capacitor. This ensures that the BST capacitor voltage is sufficiently low after a restart. It is recommended to use a 22nF capacitor and 15kΩ resistor.



## APPLICATION INFORMATION

### Selecting Buck or Buck-Boost Mode

The device can be configured for buck or buck-boost mode by connecting a different resistor at the IREF pin ( $R_{IREF}$ ). Select a  $1.05k\Omega \leq R_{IREF} \leq 9.09k\Omega$  resistor for buck-boost mode, and a  $14.7k\Omega \leq R_{IREF} \leq 80.6k\Omega$  resistor for buck mode.

### Dimming Mode Selection

The dimming mode can be configured by connecting a different resistor at the IDUTY pin ( $R_{IDUTY}$ ). Select a  $4.87k\Omega$  resistor to disable the internal PWM dimming function and enable external PWM dimming. Table 2 on page 44 lists resistors for two-step dimming, if that function is required.

### Setting the LED Current

The external resistor connected to the ISET pin sets the LED current. The value of the external resistor can be calculated with Equation (2):

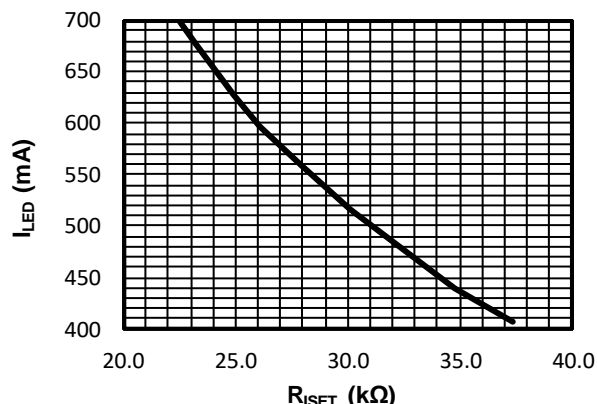
$$R_3 = \frac{16}{I_{LED} (A)} (k\Omega) \quad (2)$$

If  $I_{LED}$  is below 0.7A in buck-boost mode, certain LED setting resistors are recommended (see Table 4).

**Table 4: Resistor Selection when  $I_{LED} \leq 700mA$  in Buck-Boost Mode**

| $I_{LED} (A)$ | $R_{ISET} (k\Omega)$ |
|---------------|----------------------|
| 0.7           | 22.6                 |
| 0.65          | 24.2                 |
| 0.6           | 26.1                 |
| 0.55          | 23.2                 |
| 0.5           | 30.9                 |
| 0.45          | 34.0                 |
| 0.4           | 37.4                 |

Figure 7 shows the relationship between  $I_{LED}$  and  $R_{ISET}$  in buck-boost mode.



**Figure 7:  $I_{LED}$  vs.  $R_{ISET}$  when  $I_{LED} \leq 700mA$  in Buck-Boost Mode**

### Selecting the Inductor

For most applications, it is recommended to use an inductor between  $2.2\mu H$  and  $33\mu H$  with a DC current rating that exceeds the maximum inductor current. Include the inductor's DC resistance when estimating the output current and the inductor's power consumption.

For buck mode, the required inductance value can be estimated with Equation (3):

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{SW}} \quad (3)$$

Choose an inductor ripple current that exceeds 20% of the LED current. The peak inductor current can be calculated with Equation (4):

$$I_{L\_PEAK} = I_{L\_AVG} + \frac{\Delta I_L}{2} \quad (4)$$

Where  $I_{L\_AVG}$  is the average current through the inductor. In buck mode,  $I_{L\_AVG}$  is equal to the output load current (LED current).

Under light-load conditions, use a larger-value inductor to improve efficiency and current precision. Table 5 lists the recommended inductor values for common LED currents in buck mode.

**Table 5: Buck Mode Inductor Values for Common LED Currents**

| $I_{LED} (A)$ | Recommend Inductor Value ( $\mu H$ ) |
|---------------|--------------------------------------|
| [2A, 3A]      | 3.3                                  |
| [0.8A, 2A]    | 4.7                                  |
| [0.4A, 0.8A]  | 6.8                                  |
| [0.3A, 0.4A]  | 10                                   |

For buck-boost applications, estimate the required inductance value with Equation (5):

$$L = \frac{V_{OUT} \times V_{IN}}{(V_{OUT} + V_{IN}) \times \Delta I_L \times f_{SW}} \quad (5)$$

Where  $\Delta I_L$  is the inductor's peak-to-peak current ripple.

$\Delta I_L$  should exceed 25% of the inductor average current when  $I_{LED} > 0.7A$ . Select  $\Delta I_L$  to exceed 20% of the inductor average current when  $I_{LED} < 0.7A$ .  $I_{L\_AVG}$  can be calculated with Equation (6):

$$I_{L\_AVG} = I_{LED} \times (1 + \frac{V_{OUT}}{V_{IN}}) \quad (6)$$

The peak inductor current can be calculated with Equation (7):

$$I_{L\_PEAK} = I_{L\_AVG} + \frac{\Delta I_L}{2} \quad (7)$$

Under light-load conditions, use a larger-value inductor to improve efficiency and current precision. Table 6 lists the recommended inductor values for common LED currents in buck-boost mode.

**Table 6: Buck-Boost Mode Inductor Values for Common LED Currents**

| $I_{LED}$ (A) | Recommend Inductor Value ( $\mu H$ ) |
|---------------|--------------------------------------|
| (1A, 1.2A]    | 3.3                                  |
| (0.8A, 1A]    | 4.7                                  |
| (0.6A, 0.8A]  | 6.8                                  |
| [0.4A, 0.6A]  | 10                                   |

### Selecting the Input Capacitor

The device has a discontinuous input current in both buck and buck-boost mode, and requires a capacitor to supply AC current to the converter while maintaining the DC input voltage. For the best performance, use low-ESR capacitors. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients.

For most applications, it is recommended to use a 4.7 $\mu F$  to 22 $\mu F$  capacitor. The input capacitor can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, it is strongly recommended to use an additional, lower-value capacitor (e.g. 0.1 $\mu F$ ) with a small

package size (0603) to absorb high-frequency switching noise. Place the smaller capacitor as close to VIN and GND (INGND = PGND in buck mode, for both INGND and PGND in buck-boost mode) as possible.

Since the input capacitor absorbs the input switching current in buck mode, the device requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (8):

$$I_{CIN} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})} \quad (8)$$

The worst-case condition occurs at  $V_{IN} = 2V_{OUT}$ , calculated with Equation (9):

$$I_{CIN} = \frac{I_{LOAD}}{2} \quad (9)$$

For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current. The input voltage ripple caused by the capacitance can be estimated with Equation (10):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_{SW} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (10)$$

If  $I_{BANDVALLEY} \geq I_{LED}$  in buck-boost mode, the capacitance can be calculated with Equation (11):

$$\Delta V_{IN} = \frac{I_{LED} \times V_{OUT}}{(V_{IN} + V_{OUT}) \times f_{SW} \times C_{IN}} \quad (11)$$

In buck-boost mode, consider the capacitor between VIN and PGND for VCC regulator stability and improved EMC performance. If  $(V_{INGND} - V_{PGND}) > 5.1V$ , then the VCC regulator input switches to  $V_{INGND}$  to reduce power loss. Place a 0.44 $\mu F$  to 1.2 $\mu F$  ceramic capacitor between VIN and PGND to stabilize VCC when the VCC charging source changes from VIN to INGND. Two symmetric (0.1 $\mu F$  + 0.47 $\mu F$ ) /50V X7R ceramic capacitors can be placed between VIN and PGND.

### Selecting the Output Capacitor

The output capacitor maintains the DC output voltage. Ceramic, tantalum, or low-ESR electrolytic capacitors are recommended. For the best results, use low-ESR capacitors to keep the output voltage ripple low.

In buck mode, the output voltage ripple can be estimated with Equation (12):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{SW} \times C_{OUT}}\right) \quad (12)$$

Where L is the inductor value, and  $R_{ESR}$  is the output capacitor's equivalent series resistance (ESR) value.

For ceramic capacitors, the capacitance dominates the impedance at the switching frequency and causes the majority of the output voltage ripple. For simplification, the output voltage ripple can be estimated with Equation (13):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L \times C_{OUT}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (13)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be estimated with Equation (14):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \quad (14)$$

If  $I_{BANDVALLEY} \geq I_{LED}$  in buck-boost applications, the output capacitance can be calculated with Equation (15):

$$\Delta V_{OUT} = I_{LED} \times \left(R_{ESR} + \frac{V_{OUT}}{f_{SW} \times C_{OUT} \times (V_{IN} + V_{OUT})}\right) \quad (15)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be estimated with Equation (16):

$$\Delta V_{OUT} = I_{LED} \times R_{ESR} \quad (16)$$

A 10μF to 22μF ceramic capacitor is sufficient for most applications. Place a symmetric 4.7μF / 25V X7R ceramic capacitor between LED+ and LED-.

### Selecting the Diode from PGND to INGND in Buck-Boost Mode

If the device is operating in buck-boost mode, place a Schottky diode between INGND and PGND to direct the charge current of the capacitor connected between VIN and PGND, especially when the VIN slew rate is high. When  $(V_{INGND} - V_{PGND}) < 5.1V$ , VCC is powered by VIN. The VCC charge current flows from the VCC

capacitor to PGND, then back to INGND and the car battery. It is recommended to use a Schottky diode with a low forward voltage ( $V_F$ ) of about 0.32V, with a 1A current rating and >20V VVRRM voltage. A PMEG2010EPAS Schottky diode is recommended.

### Selecting the VCC Capacitor

A small VCC capacitor causes ringing on VCC, and makes the MOSFET unstable. It is recommended to place a ≥3μF decoupling ceramic capacitor at the VCC pin. When selecting a capacitor, consider the capacitance derating to ensure that the real capacitance is at least 3μF. A 10μF X7R with a ≥10V DC rated voltage capacitor is recommended. VCC is the reference to PGND/AGND.

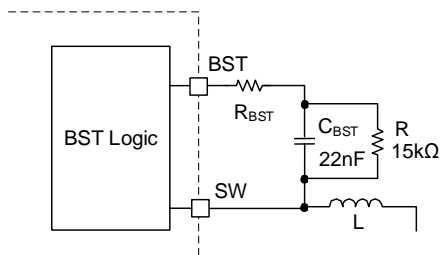
### BST Resistor and Capacitor

It is recommended to place a resistor in series with the BST capacitor to reduce the SW spike voltage. A higher resistance reduces SW spikes, but also reduces efficiency. It is recommended to use a 22nF to 220nF ceramic capacitor with a 10/16V DC derating.

Consider efficiency and EMI performance when choosing a resistor. Choose a maximum 22Ω resistor with a 0603/0402 package, as a large package is not required. During normal operation, the average current flowing through  $R_{BST}$  is about 20mA in buck mode and 10mA in buck-boost mode. If the capacitor is shorted, the current in the resistor is limited by the internal LDO. The device can quickly detect a failure if the LED current falls below its low limit. Then the part latches off and current is no longer sourced to the resistor. A 0402 package can handle power dissipation on  $R_{BST}$ .

The part integrates BST capacitor open-detection functionality. When VIN and VCC reach their UVLO rising thresholds, the BST capacitor is charged after the 1ms thermal derating finishes. If the voltage on the BST capacitor reaches the UVLO rising threshold within 45μs, the part detects a BST open fault and latches off. If VIN restarts frequently, the BST capacitor may not be able to discharge sufficiently, and an open fault may be mistriggered. To avoid a mistrigger, place a small BST capacitor and a bleeding resistor in parallel with the BST capacitor. This ensures that

the BST capacitor voltage is sufficiently low after a restart. It is recommended to use a 22nF capacitor and a 15k $\Omega$  resistor (see Figure 8).

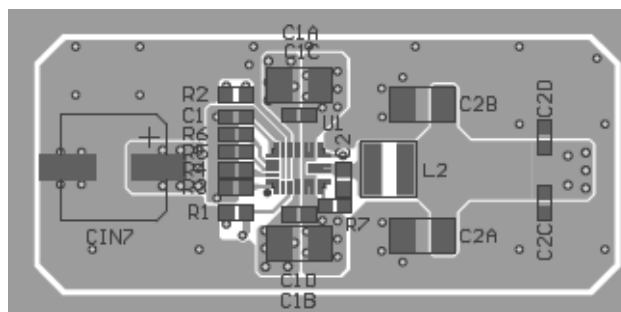


**Figure 8: BST Recommend Circuitry in VIN Hot-Plug Application**

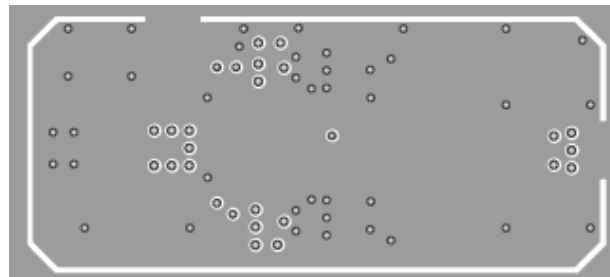
### PCB Layout Guidelines <sup>(13)</sup> <sup>(14)</sup>

Efficient PCB layout, especially input capacitor placement, is critical for stable operation. A 4-layer layout is strongly recommended to improve thermal performance. For the best results, refer to Figure 9 and Figure 10, and follow the guidelines below:

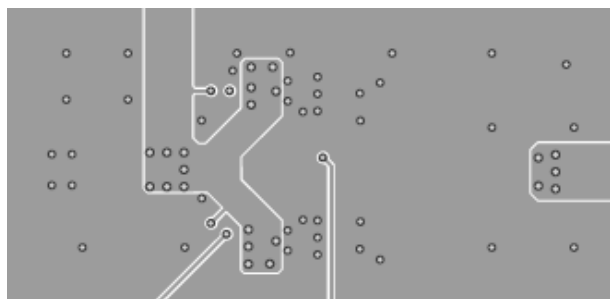
1. Place symmetric input capacitors as close to VIN and GND as possible. For buck-boost mode, connect the symmetric capacitors as close to VIN and PGND as possible.
2. connect the PGND pin directly to a large ground plane on the PCB.
3. If the bottom layer is a ground plane, add vias near PGND.
4. Ensure that the high-current paths at PGND and VIN have short, direct, and wide traces.
5. Place the ceramic input capacitor (especially the 0603small package size capacitor) as close to VIN and PGND as possible to minimize high-frequency noise.
6. Make the connection between the input capacitor and VIN as short and wide as possible.
7. Place the VCC capacitor as close to VCC and PGND as possible.
8. Route SW and BST away from sensitive analog areas.
9. Use multiple vias to connect the power planes to the internal layers.



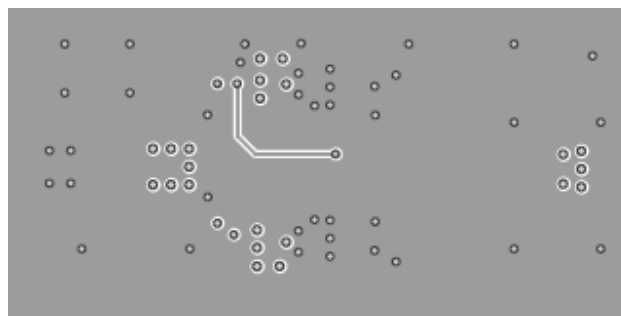
**Top Layer**



**Inner Layer 1**

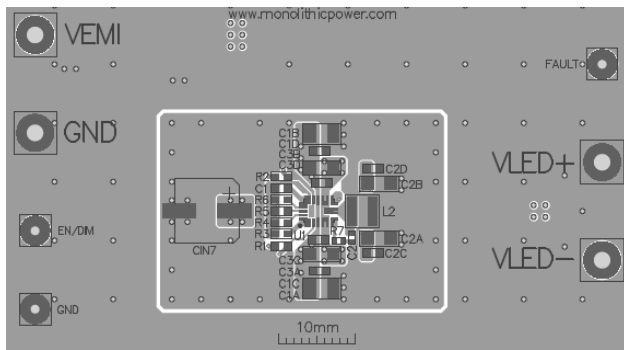


**Inner Layer 2**

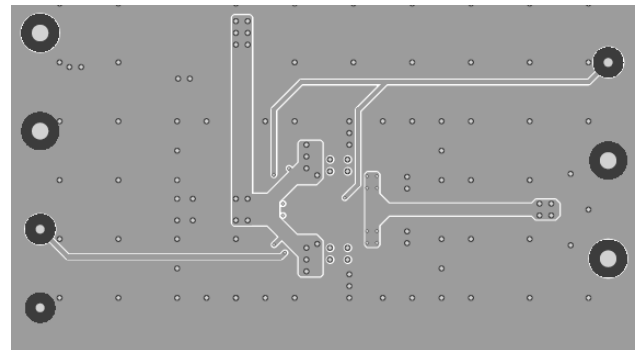


**Bottom Layer**

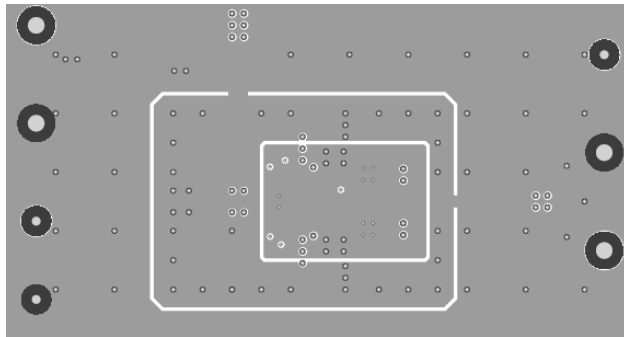
**Figure 9: Recommended PCB Layout for Buck Mode <sup>(13)</sup>**



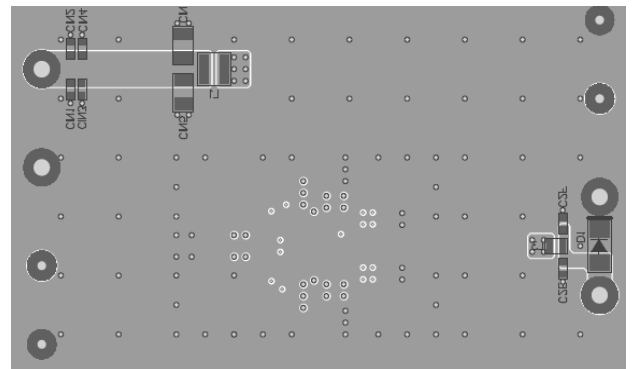
**Top Layer**



**Inner Layer 2**



**Inner Layer 1**



**Bottom Layer**

**Figure 10: Recommended PCB Layout for Buck-Boost Mode <sup>(14)</sup>**

**Notes:**

- 13) The recommended layout is based on Figure 11.
- 14) The recommended layout is based on Figure 12.

## TYPICAL APPLICATION CIRCUITS

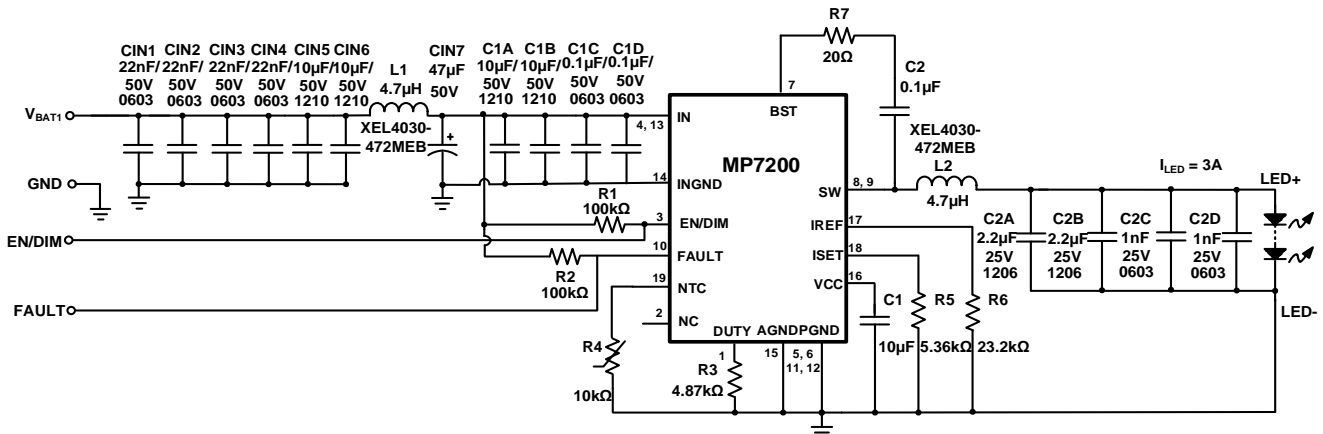


Figure 11:  $I_{LED} = 3A$  Buck Application Circuit with No Two-Step Dimming

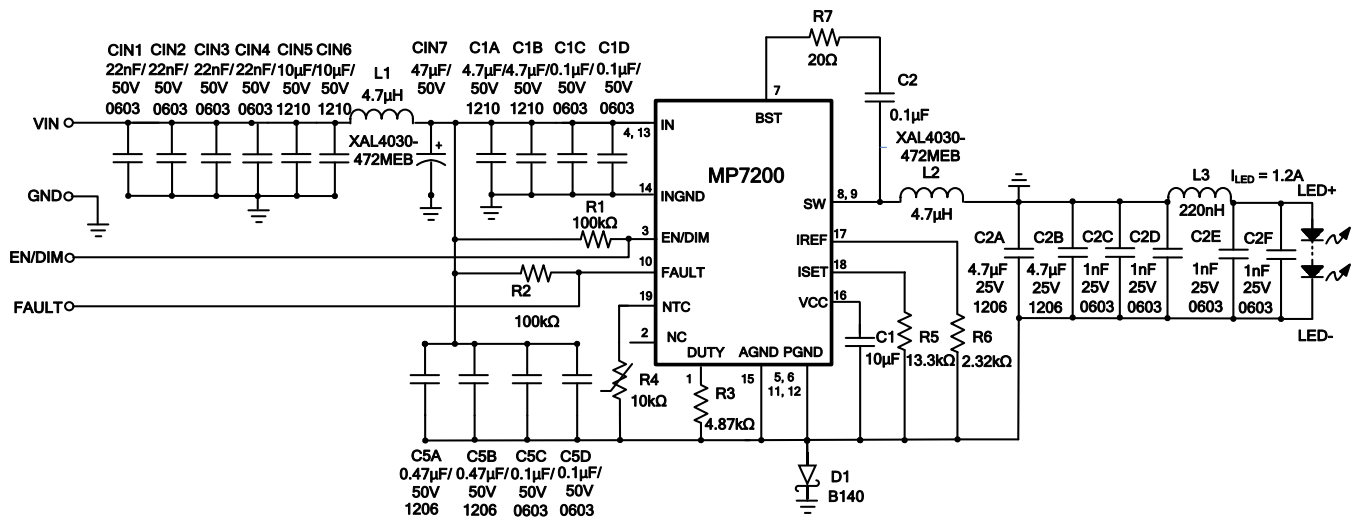


Figure 12:  $I_{LED} = 1.2A$  Buck-Boost Application Circuit with No Two-Step Dimming

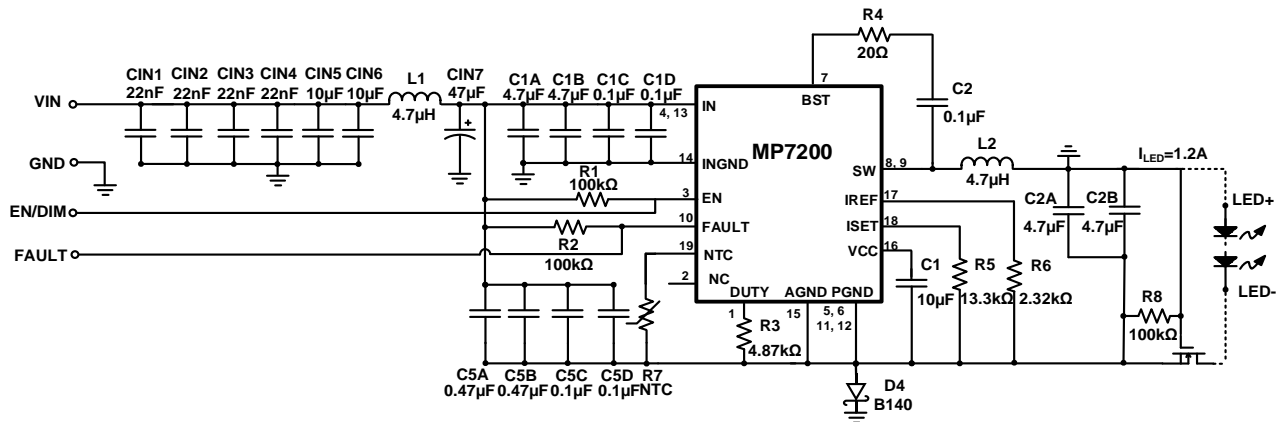


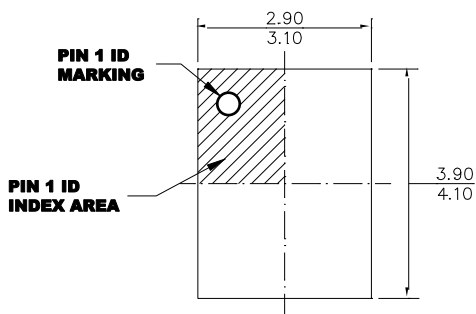
Figure 13:  $I_{LED} = 1.2A$  Buck-Boost Application Circuit with LED+ Short to Battery Protection



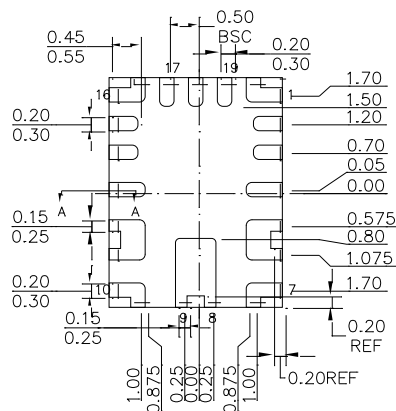
## PACKAGE INFORMATION

### QFN-19 (3mmx4mm)

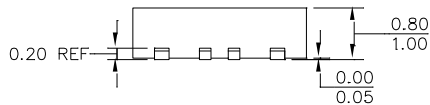
## Wettable Flank



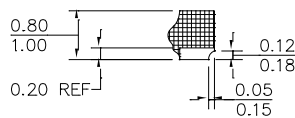
### TOP VIEW



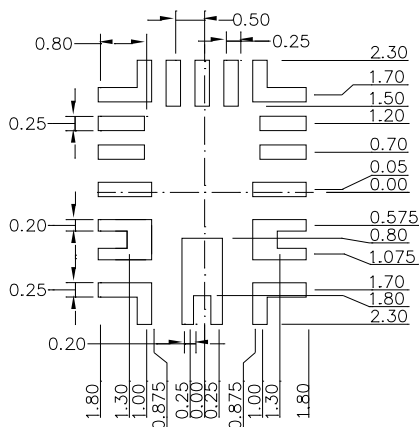
### BOTTOM VIEW



### SIDE VIEW



**SECTION A-A**



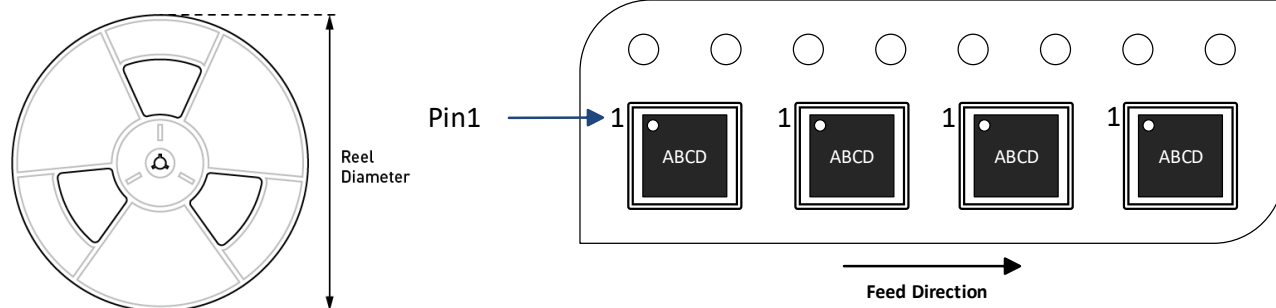
## **RECOMMENDED LAND PATTERN**

**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
- 3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
- 4) JEDEC REFERENCE IS MO-220.
- 5) DRAWING IS NOT TO SCALE.



## CARRIER INFORMATION



| Part Number | Package Description | Quantity/Reel | Quantity /Tube | Quantity /Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|-------------|---------------------|---------------|----------------|----------------|---------------|--------------------|--------------------|
| MP7200GLE-Z | QFN-19<br>(3mmx4mm) | 5000          | N/A            | N/A            | 13in          | 12mm               | 8mm                |

## REVISION HISTORY

| Revision # | Revision Date | Description     | Pages Updated |
|------------|---------------|-----------------|---------------|
| 1.0        | 1/21/2021     | Initial Release | -             |

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[AP5726FDCG-7](#) [SLG7NT4082V](#) [SLG7NT4082VTR](#) [BD1604MVV-E2](#) [MAX16840ATB+](#) [CAT4004BHU2-GT3](#) [TLE4242EJ](#)  
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