



## DESCRIPTION

The MPQ7220 is a boost converter with six channel current sources. It is designed for driving automotive tail lights.

The MPQ7220 uses peak current mode as its PWM control architecture. The switching frequency can be programmed by a resistor. It independently regulates the current in each LED string to the value set by an external current-setting resistor.

The device applies six internal current sources, one in each LED string terminal to achieve a current balance with 2.5% current regulation accuracy between strings. The low headroom voltage for LED regulation and on resistance of switching MOSFETs allows for high efficiency.

The MPQ7220 has rich protection modes to guarantee safe operation. Protection modes include OCP (over-current protection), OVP (over-voltage protection), OTP (over-temperature protection), and LED string short and open protection. The LED current decreases at high temperatures.

The MPQ7220 is available in QFN-24 (4mmx4mm) and TSSOP28-EP packages.

## FEATURES

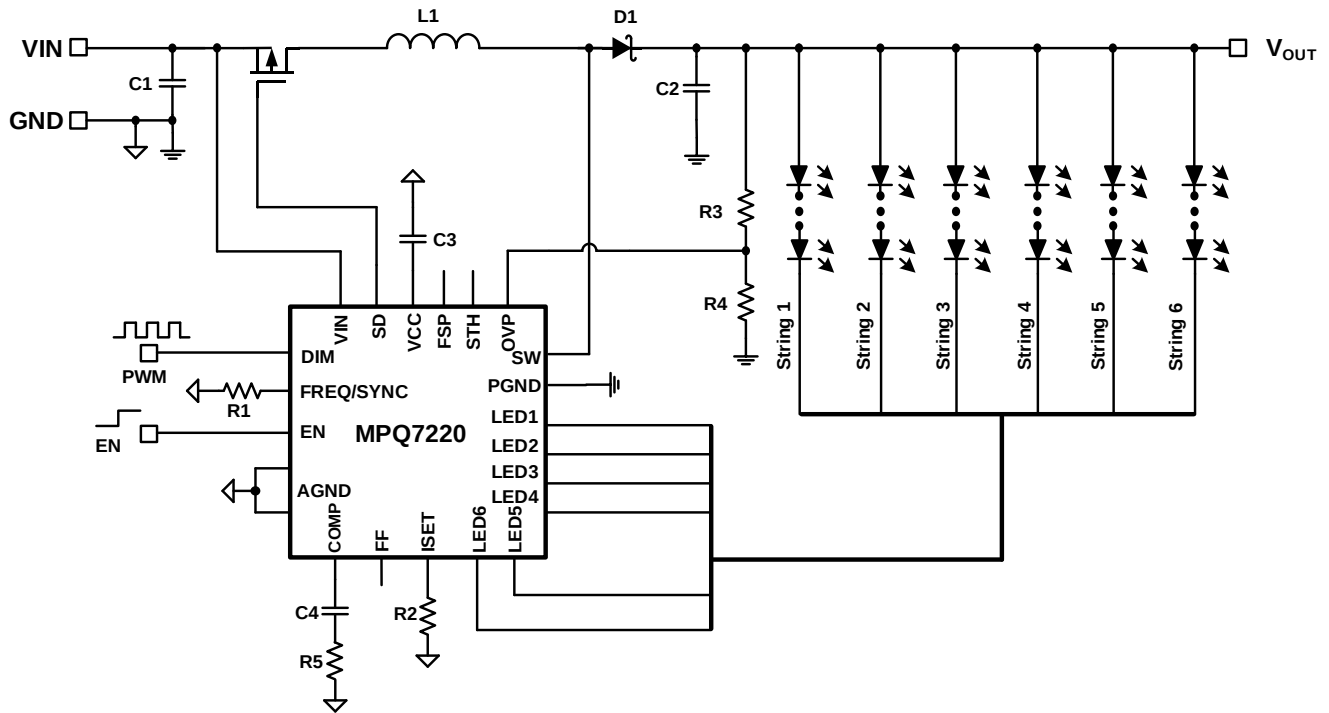
- 3.5V to 36V Input Voltage Range
- Six Channels with Max 100mA per Channel
- Internal 100mΩ, 50V MOSFET
- Programmable Up to 2.2MHz  $f_{sw}$
- External Sync SW Function
- PWM Dimming (Dimming Frequency from 100Hz to 20kHz)
- Excellent EMI Performance, Spread Spectrum
- Disconnect  $V_{OUT}$  from  $V_{IN}$
- 2.5% Current Matching
- Cycle-by-Cycle Current Limiting
- Programmable LED Short Threshold
- Programmable OVP Threshold
- LED Current Auto-Decrement at High Temperatures
- LED Short/Open, OTP, OCP, Inductor Short Protection
- Fault Indicator Signal Output
- Available in QFN-24 (4mmx4mm) and TSSOP28-EP Packages
- AEC-Q100 Grade 1

## APPLICATIONS

- Automotive Tail Lights

All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, please visit the MPS website under Quality Assurance. "MPS", the MPS logo, and "Simple, Easy Solutions" are trademarks of Monolithic Power Systems, Inc. or its subsidiaries.

## TYPICAL APPLICATION



**ORDERING INFORMATION**

| Part Number*   | Package          | Top Marking | MSL Rating** |
|----------------|------------------|-------------|--------------|
| MPQ7220GR-AEC1 | QFN-24 (4mmx4mm) | See Below   | Level 1      |
| MPQ7220GF-AEC1 | TSSOP28-EP       | See Below   | Level 2a     |

\* For Tape &amp; Reel, add suffix -Z (e.g. MPQ7220GR-AEC1-Z).

\*\* Moisture Sensitivity Level Rating.

**TOP MARKING (MPQ7220GF-AEC1)**

MPSYYWW  
MP7220  
LLLLLLLLLL

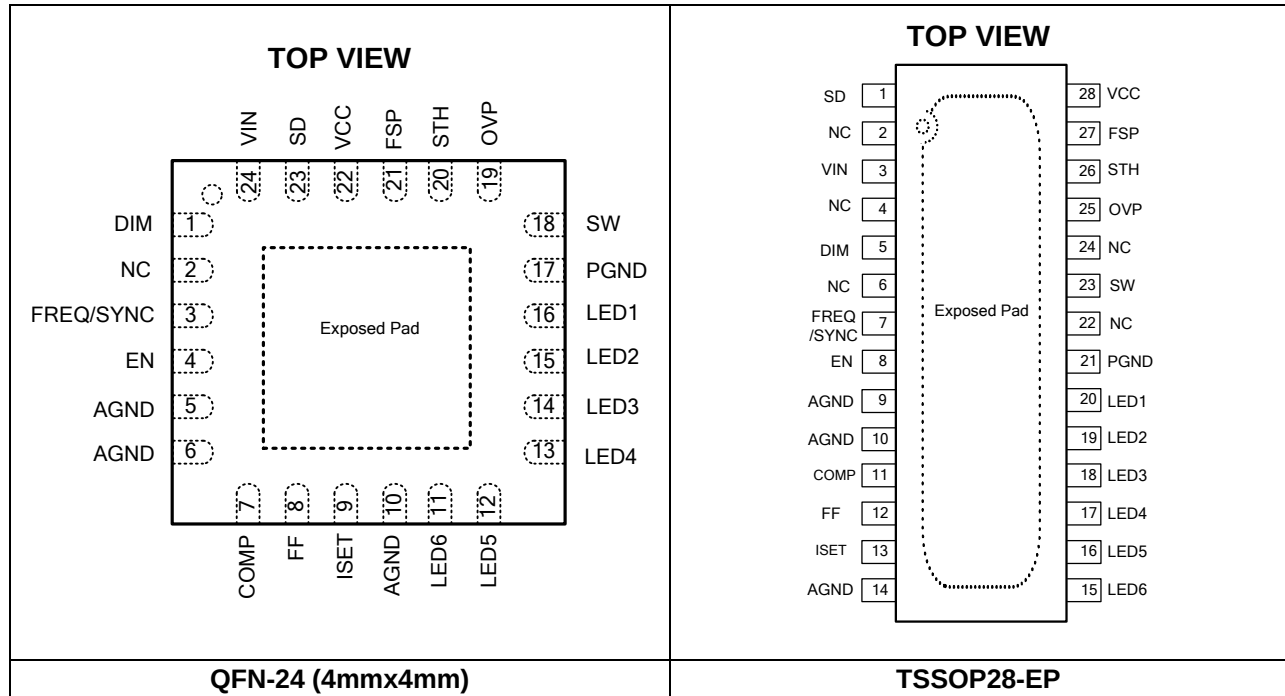
MPS: MPS prefix  
YY: Year code  
WW: Week code  
MP7220: Part number  
LLLLLLLLLL: Lot number

**TOP MARKING (MPQ7220GR-AEC1)**

MPSYWW  
MP7220  
LLLLLL

MPS: MPS prefix  
Y: Year code  
WW: Week code  
MP7220: Part number  
LLLLLL: Lot number

## PACKAGE REFERENCE



## PIN FUNCTIONS

| QFN24 Pin # | TSSOP28-EP Pin # | Name      | Description                                                                                                                                                                                                  |
|-------------|------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1           | 5                | DIM       | <b>DIM signal input.</b> Apply a PWM signal on DIM for brightness control. Pulled low internally. A 100Hz to 20kHz PWM signal is recommended. Pull this pin high if the dimming function not used.           |
| 2           | 2, 4, 6, 22, 24  | NC        | <b>Not connected.</b>                                                                                                                                                                                        |
| 3           | 7                | FREQ/SYNC | <b>Switching frequency setting and SYNC pin.</b> Connect a resistor between this pin and GND to set the converter's switching frequency. Or connect an external clock to sync the boost switching frequency. |
| 4           | 8                | EN        | <b>IC enable pin.</b> Pull this pin to high enable the IC. Pull this pin low to force the IC to enter shutdown mode.                                                                                         |
| 7           | 11               | COMP      | <b>Compensation pin.</b>                                                                                                                                                                                     |
| 8           | 12               | FF        | <b>Fault flag pin.</b> Open drain during normal operation, pulled low in any fault mode. Float FF if not used.                                                                                               |
| 9           | 13               | ISET      | <b>LED current setting.</b> Tie a current-setting resistor from this pin to ground to program the current in each LED string.                                                                                |
| 5, 6, 10    | 9, 10, 14        | AGND      | <b>Analog ground.</b>                                                                                                                                                                                        |
| 11          | 15               | LED6      | <b>LED string 6 current input.</b> Connect the LED string 6 cathode to this pin.                                                                                                                             |
| 12          | 16               | LED5      | <b>LED string 5 current input.</b> Connect the LED string 5 cathode to this pin.                                                                                                                             |
| 13          | 17               | LED4      | <b>LED string 4 current input.</b> Connect the LED string 4 cathode to this pin.                                                                                                                             |
| 14          | 18               | LED3      | <b>LED string 3 current input.</b> Connect the LED string 3 cathode to this pin.                                                                                                                             |
| 15          | 19               | LED2      | <b>LED string 2 current input.</b> Connect the LED string 2 cathode to this pin.                                                                                                                             |

## PIN FUNCTIONS *(continued)*

| QFN24<br>Pin # | TSSOP28-<br>EP Pin # | Name        | Description                                                                                                                                                                                                                                                                                                                                                                             |
|----------------|----------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16             | 20                   | LED1        | <b>LED string 1 current input.</b> Connect the LED string 1 cathode to this pin.                                                                                                                                                                                                                                                                                                        |
| 17             | 21                   | PGND        | <b>Step-up converter power ground.</b>                                                                                                                                                                                                                                                                                                                                                  |
| 18             | 23                   | SW          | <b>Drain for the internal low-side MOSFET switch.</b> Connect the power inductor to SW.                                                                                                                                                                                                                                                                                                 |
| 19             | 25                   | OVP         | <b>Over-voltage protection pin.</b> Use a voltage divider to program the OVP threshold (see the Application Information section on page 20). Do not float this pin.                                                                                                                                                                                                                     |
| 20             | 26                   | STH         | <b>Short LED protection threshold set pin.</b> An 18 $\mu$ A current source flows out of this pin. Connect a resistor from STH to GND to set the protection threshold. The short protection threshold is 5V if this pin is floated.                                                                                                                                                     |
| 21             | 27                   | FSP         | <b>Switching frequency spread spectrum pin.</b> An 18 $\mu$ A current source flows out of this pin. Connect a resistor from FSP to GND to set the voltage. If FSP < 0.4V, the jitter frequency is 1/20 of the central frequency. If FSP = 0.45V to 1.4V, the jitter frequency is 1/32 of the central frequency. If FSP > 1.4V or is floated, the frequency spread spectrum is disabled. |
| 22             | 28                   | VCC         | <b>5V LDO output pin.</b> VCC provides power for the internal logic and gate driver. Place a ceramic capacitor as close as possible to this pin to reduce noise.                                                                                                                                                                                                                        |
| 23             | 1                    | SD          | <b>External disconnect PMOS gate drive pin.</b> Turn off the external PMOS in a fault condition. Float this pin if not used.                                                                                                                                                                                                                                                            |
| 24             | 3                    | VIN         | <b>Power supply input.</b> VIN supplies the power to the IC.                                                                                                                                                                                                                                                                                                                            |
| Exposed pad    | Exposed pad          | Exposed pad | <b>Exposed pad.</b> It has no internal electrical connection to AGND and PGND. Connect exposed pad to external GND plane on board for optimal thermal performance.                                                                                                                                                                                                                      |

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

|                                                                          |                           |
|--------------------------------------------------------------------------|---------------------------|
| $V_{IN}$ .....                                                           | -0.3V to +42V             |
| $V_{SW}$ , $V_{LED1}$ to $V_{LED6}$ .....                                | -0.5V to +50V             |
| $V_{SD}$ .....                                                           | $V_{IN}$ - 6V to $V_{IN}$ |
| All other pins .....                                                     | -0.3V to +6.5V            |
| Junction temperature .....                                               | 150°C                     |
| Lead temperature .....                                                   | 260°C                     |
| Storage temperature .....                                                | -65°C to +150°C           |
| Continuous power dissipation ( $T_A = 25^\circ\text{C}$ ) <sup>(2)</sup> |                           |
| QFN-24 (4mmx4mm) .....                                                   | 2.97W                     |
| TSSOP28-EP .....                                                         | 3.9W                      |

**Electrostatic Discharge (ESD)**

|                                  |       |
|----------------------------------|-------|
| HBM (human body model)           |       |
| LED1-6 .....                     | ±7kV  |
| All other pins .....             | ±2kV  |
| CDM (charged device model) ..... | ±750V |

**Recommended Operating Conditions**

|                                                                  |             |
|------------------------------------------------------------------|-------------|
| Supply voltage ( $V_{IN}$ ) .....                                | 3.5V to 36V |
| Operating junction temp ( $T_J$ ) -40°C to +125°C <sup>(3)</sup> |             |

**Thermal Resistance**       $\theta_{JA}$        $\theta_{JC}$ 

|                                    |    |            |
|------------------------------------|----|------------|
| QFN-24 (4mmx4mm)                   |    |            |
| JESD51-7 <sup>(4)</sup> .....      | 42 | 9.....°C/W |
| EVQ7220-R-00A <sup>(5)</sup> ..... | 47 | 8.....°C/W |
| TSSOP28-EP                         |    |            |
| JESD51-7 <sup>(4)</sup> .....      | 32 | 6.....°C/W |
| EVQ7220-F-00A <sup>(5)</sup> ..... | 44 | 7.....°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 will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 3) Operation devices at junction temperature up to 150°C is possible; contact MPS for details.
- 4) Measured on JESD51-7, 4-layer PCB.
- 5) Measured on MPS standard EVB of MPQ7220, 2-layer, 1oz. PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 12V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , typical values at  $T_J = 25^{\circ}C$ , unless otherwise noted.

| Parameter                    | Symbol          | Condition                                                     | Min  | Typ | Max  | Units      |
|------------------------------|-----------------|---------------------------------------------------------------|------|-----|------|------------|
| Operating input voltage      | $V_{IN}$        |                                                               | 3.5  |     | 36   | V          |
| Supply current (quiescent)   | $I_Q$           | No switching                                                  |      | 5   |      | mA         |
| Supply current (shutdown)    | $I_{ST}$        | $V_{EN} = 0V$ , $V_{IN} = 12V$                                |      |     | 1    | $\mu A$    |
| Input UVLO threshold         | $V_{IN\_UVLO}$  | Rising edge                                                   |      | 3.1 |      | V          |
| Input UVLO hysteresis        |                 |                                                               |      | 100 |      | mV         |
| LDO output voltage           | $V_{CC}$        | $V_{EN} = 2V$ , $6V < V_{IN} < 24V$ ,<br>$0 < I_{VCC} < 10mA$ |      | 5   |      | V          |
| EN on threshold              | $V_{EN\_ON}$    | $V_{EN}$ rising                                               | 1.2  |     |      | V          |
| EN off threshold             | $V_{EN\_OFF}$   | $V_{EN}$ falling                                              |      |     | 0.4  | V          |
| EN pull-down resistance      | $R_{EN}$        |                                                               |      | 1   |      | M $\Omega$ |
| <b>Step-Up Converter</b>     |                 |                                                               |      |     |      |            |
| Low-side MOS on resistance   | $R_{DS\_LS}$    | $V_{IN} = 3.7V$                                               |      | 100 |      | m $\Omega$ |
| SW leakage current           | $I_{SW\_LK}$    | $V_{SW} = 45V$                                                |      |     | 1    | $\mu A$    |
| Switching frequency          | $f_{SW}$        | $R_{FREQ} = 10k\Omega$                                        | -10% | 2.2 | +10% | MHz        |
|                              |                 | $R_{FREQ} = 46.8k\Omega$                                      | -10% | 470 | +10% | kHz        |
|                              |                 | FREQ float                                                    | -20% | 400 | +20% | kHz        |
| FREQ voltage                 | $V_{FREQ}$      |                                                               | -5%  | 0.6 | +5%  | V          |
| FSP pull-up current          | $I_{FSP}$       |                                                               |      | 18  |      | $\mu A$    |
| Maximum duty cycle           | $D_{MAX}$       | $f_{SW} = 1MHz$                                               | 90   |     |      | %          |
| Cycle-by-cycle current limit | $I_{SW\_LIMIT}$ | Duty = 90%                                                    | 2.3  | 4   |      | A          |
| Current limit protection     | $I_{CL}$        | To trigger current limit protection                           |      | 8   |      | A          |
| SYNC input low threshold     | $V_{SYNC\_LO}$  | $V_{SYNC}$ falling                                            |      |     | 0.4  | V          |
| SYNC input high threshold    | $V_{SYNC\_HI}$  | $V_{SYNC}$ rising                                             | 1.2  |     |      | V          |
| COMP trans-conductance       | $G_{COMP}$      | $\Delta I_{COMP} \leq 10\mu A$                                |      | 100 |      | $\mu A/V$  |
| COMP source current limit    | $I_{COMP\_SO}$  |                                                               |      | 90  |      | $\mu A$    |
| COMP sink current limit      | $I_{COMP\_SI}$  |                                                               |      | 30  |      | $\mu A$    |
| <b>Current Dimming</b>       |                 |                                                               |      |     |      |            |
| DIM input low threshold      | $V_{DIM\_LO}$   | $V_{DIM}$ falling                                             |      |     | 0.4  | V          |
| DIM input high threshold     | $V_{DIM\_HI}$   | $V_{DIM}$ rising                                              | 1.2  |     |      | V          |

## ELECTRICAL CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $V_{EN} = 2V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , typical values at  $T_J = 25^{\circ}C$ , unless otherwise noted.

| Parameter                                     | Symbol               | Condition                                                                                               | Min   | Typ | Max   | Units |
|-----------------------------------------------|----------------------|---------------------------------------------------------------------------------------------------------|-------|-----|-------|-------|
| Led Current Regulator                         |                      |                                                                                                         |       |     |       |       |
| LEDX regulation voltage                       | V <sub>HD</sub>      | I <sub>LED</sub> = 20mA                                                                                 |       | 300 |       | mV    |
|                                               |                      | I <sub>LED</sub> = 100mA                                                                                | 700   | 850 | 1000  | mV    |
| Current matching <sup>(6)</sup>               |                      | I <sub>LED</sub> = 20mA                                                                                 | -2.5  |     | +2.5  | %     |
|                                               |                      | I <sub>LED</sub> = 100mA                                                                                | -2.5  |     | +2.5  | %     |
| ISET voltage                                  | V <sub>ISET</sub>    |                                                                                                         |       | 1.2 |       | V     |
| LED current                                   | I <sub>LED</sub>     | R <sub>ISET</sub> = 24.9kΩ, T <sub>J</sub> = 25°C                                                       | -2.5% | 50  | +2.5% | mA    |
|                                               |                      | R <sub>ISET</sub> = 24.9kΩ, T <sub>J</sub> = -40°C to +125°C, no over-temperature LED current decrement | -4%   | 50  | +4%   | mA    |
| Protection                                    |                      |                                                                                                         |       |     |       |       |
| Over-voltage protection threshold             | V <sub>OVP</sub>     |                                                                                                         | 1.9   | 2   | 2.1   | V     |
| OVP hysteresis                                |                      |                                                                                                         |       | 200 |       | mV    |
| OVP UVLO threshold                            | V <sub>OVP_UV</sub>  | Step-up converter fails                                                                                 |       | 100 |       | mV    |
| LEDX over-voltage threshold                   | V <sub>LEDX_OV</sub> | STH floating or V <sub>STH</sub> = 0.5V                                                                 | 4.3   | 4.7 | 5.1   | V     |
| LEDX over-voltage fault timer                 |                      |                                                                                                         | 6     | 7.7 | 10    | ms    |
| LEDX UVLO threshold                           | V <sub>LEDX_UV</sub> |                                                                                                         |       | 100 |       | mV    |
| Thermal shutdown threshold <sup>(7)</sup>     | T <sub>ST</sub>      | Rising edge                                                                                             |       | 170 |       | °C    |
|                                               |                      | Hysteresis                                                                                              |       | 20  |       | °C    |
| SD pull-down current                          | I <sub>SD</sub>      |                                                                                                         | 40    | 55  | 70    | μA    |
| SD voltage (with respect to V <sub>IN</sub> ) | V <sub>SD-IN</sub>   | V <sub>IN</sub> = 12V, V <sub>IN</sub> - V <sub>SD</sub>                                                |       | 6   |       | V     |
| STH pull-up current                           | I <sub>STH</sub>     | STH pull-up current                                                                                     |       | 18  |       | μA    |

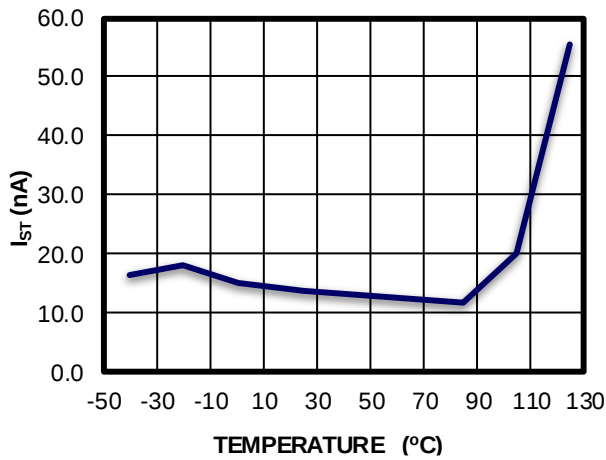
### Notes:

- 6) Matching is defined as the difference of the maximum to minimum current divided by the setting current.  
7) Not tested in production. Guaranteed by design and characterization.

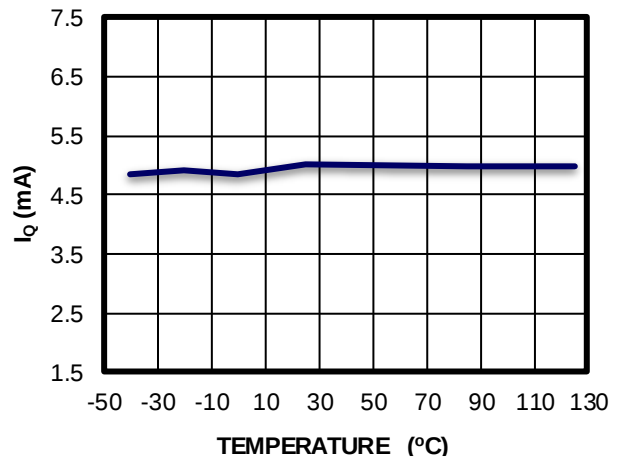
## TYPICAL CHARACTERISTICS

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

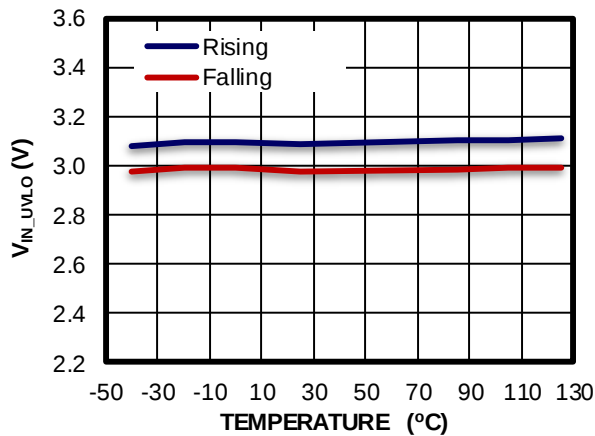
Shutdown Current vs.  
Temperature



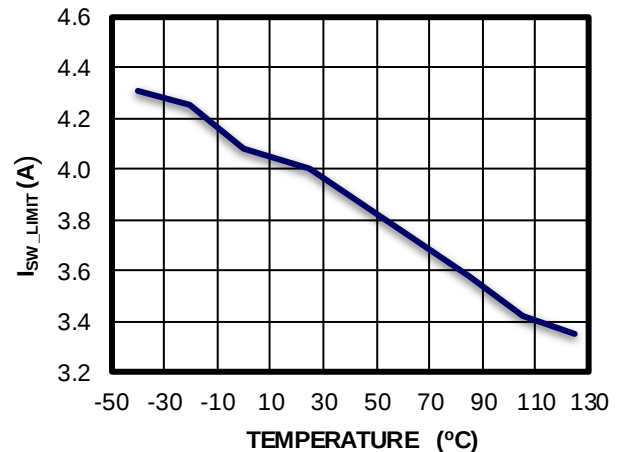
Quiescent Current vs.  
Temperature



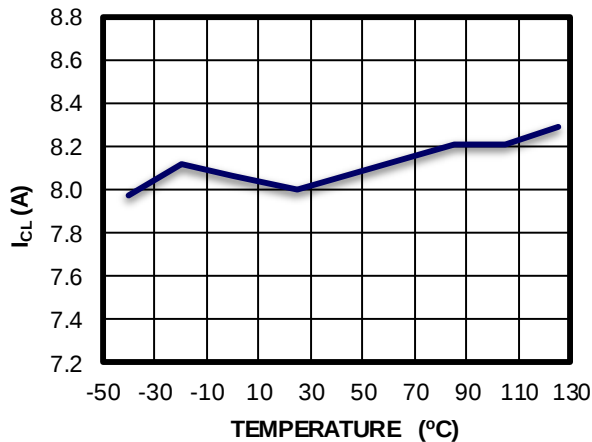
$V_{IN}$  UVLO Threshold vs.  
Temperature



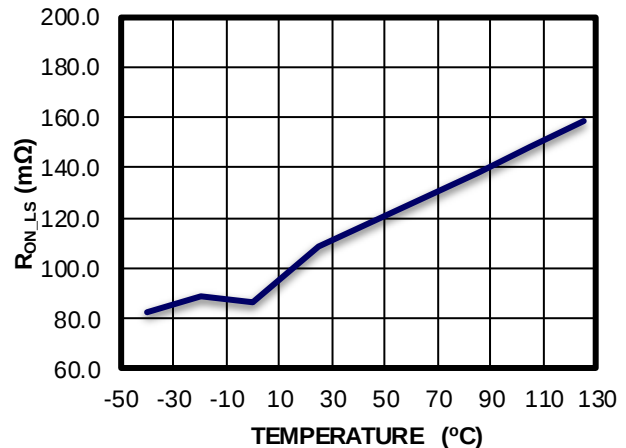
Cycle-by-Cycle Current Limit vs.  
Temperature



Current Limit Protection vs.  
Temperature

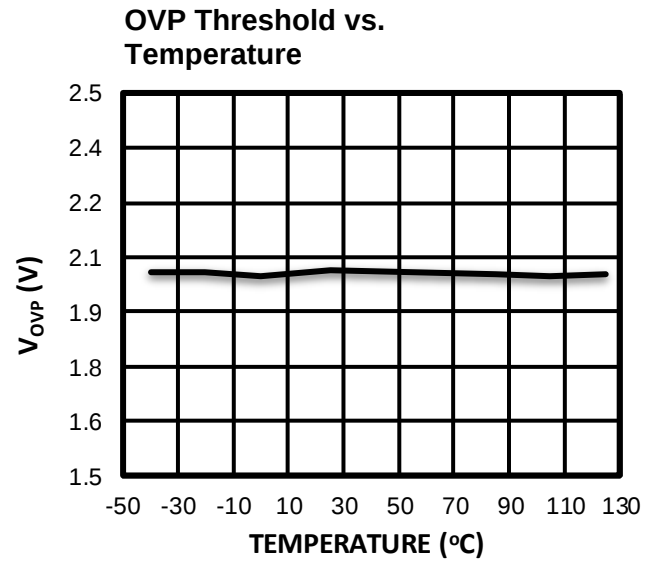
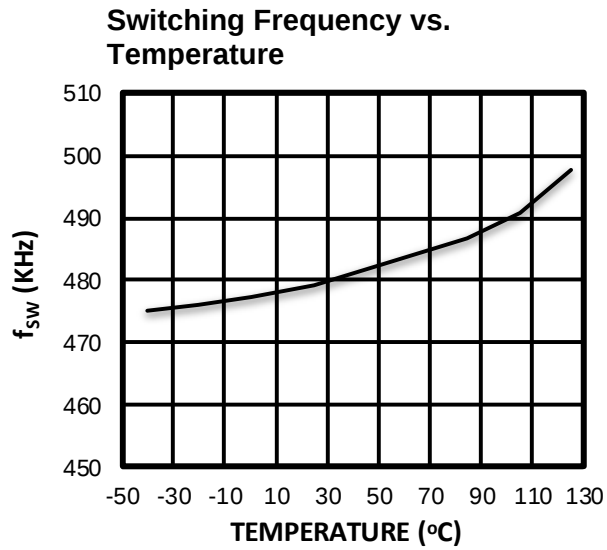


LS-FET On Resistance vs.  
Temperature



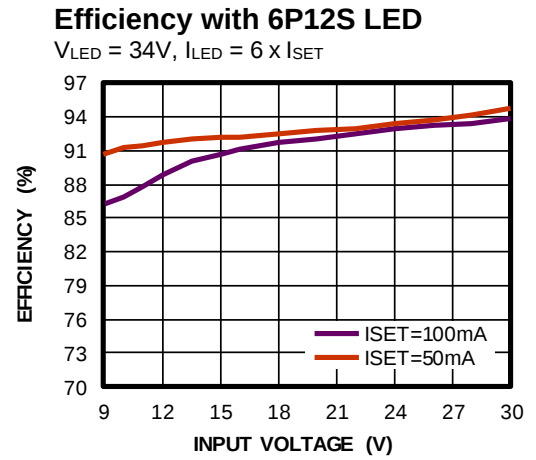
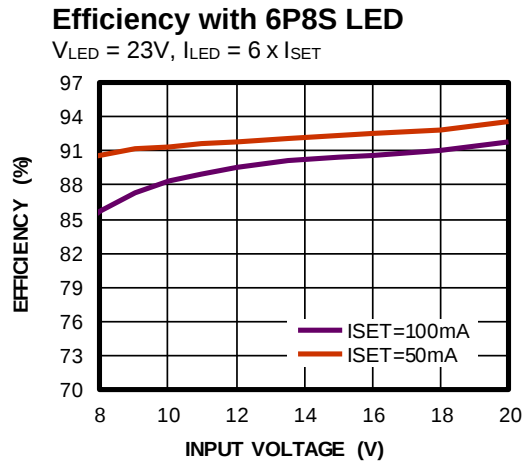
## TYPICAL CHARACTERISTICS

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



## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 12V$ ,  $L = 22\mu H$ , LED = 6P12S,  $f_{SW} = 470kHz$ ,  $I_{SET} = 100mA$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

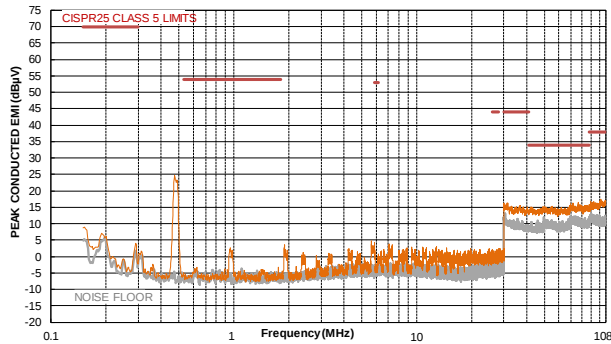


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $L = 15\mu H$ ,  $LED = 6P12S$ ,  $f_{SW} = 450kHz$ ,  $I_{SET} = 100mA$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. (8)

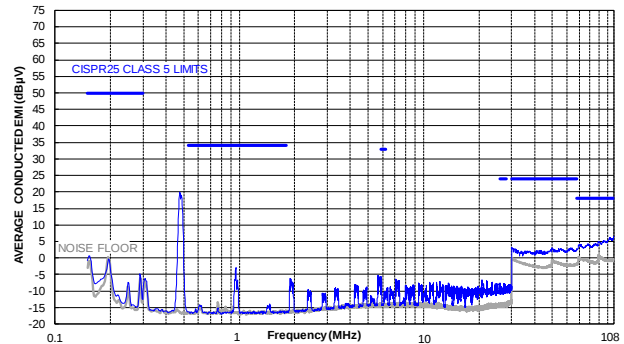
## CISPR25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



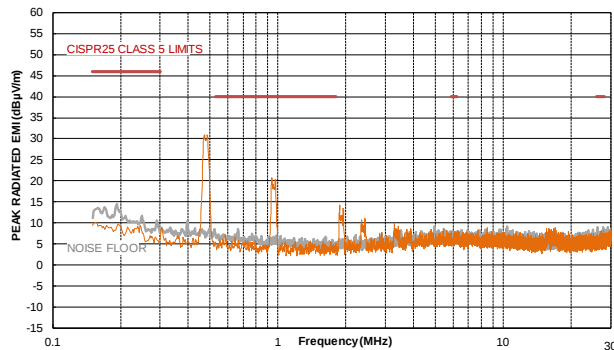
## CISPR25 Class 5 Average Conducted Emissions

150kHz to 108MHz



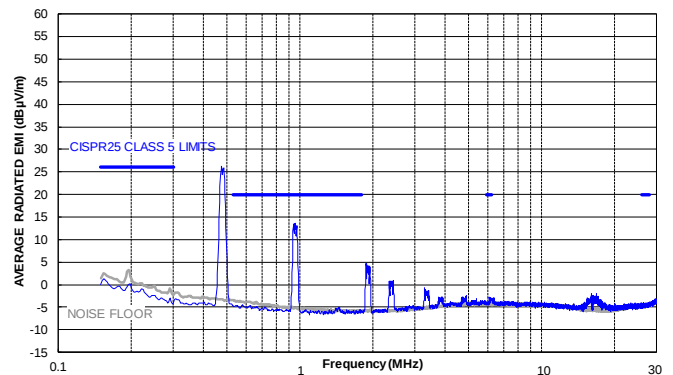
## CISPR25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



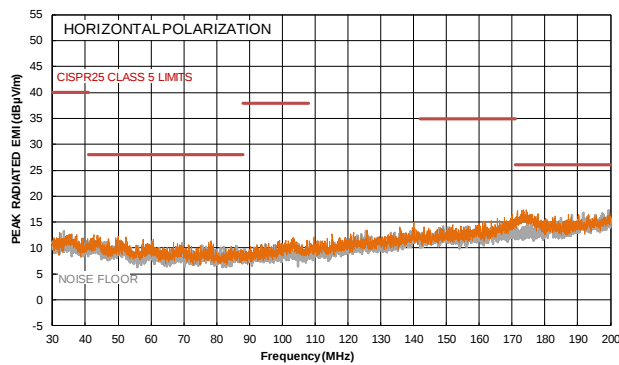
## CISPR25 Class 5 Average Radiated Emissions

150kHz to 30MHz



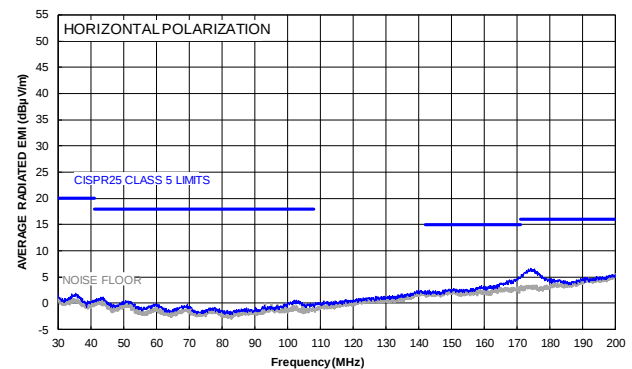
## CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 200MHz



## CISPR25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 200MHz

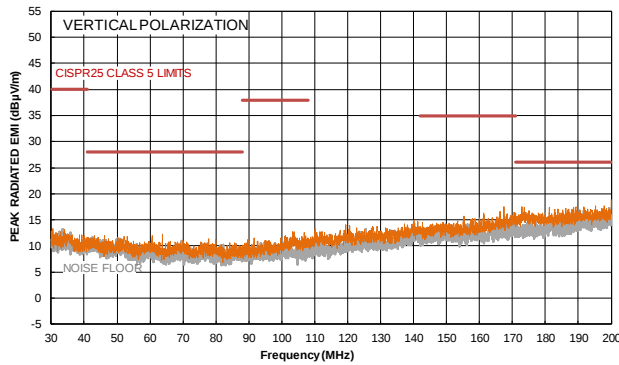


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $L = 15\mu H$ , LED = 6P12S,  $f_{SW} = 450kHz$ ,  $I_{SET} = 100mA$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(8)</sup>

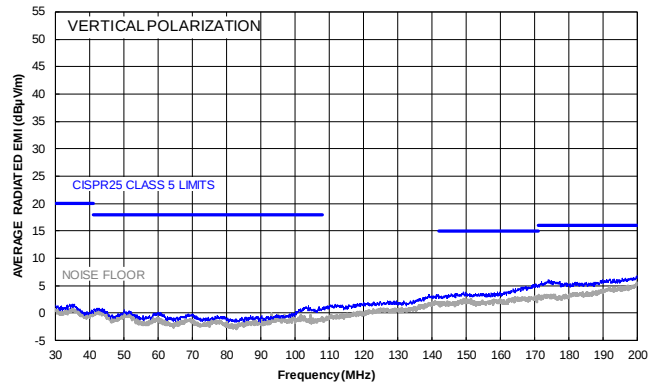
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 200MHz



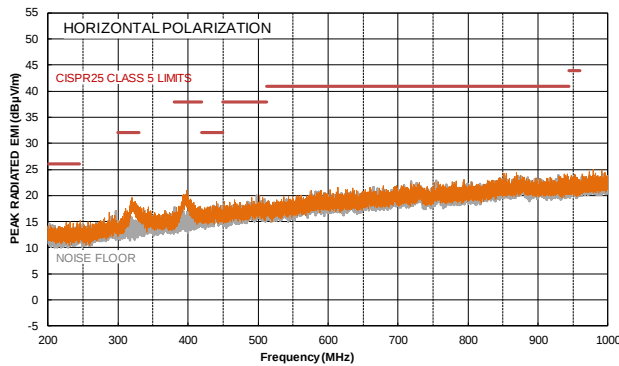
### CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 200MHz



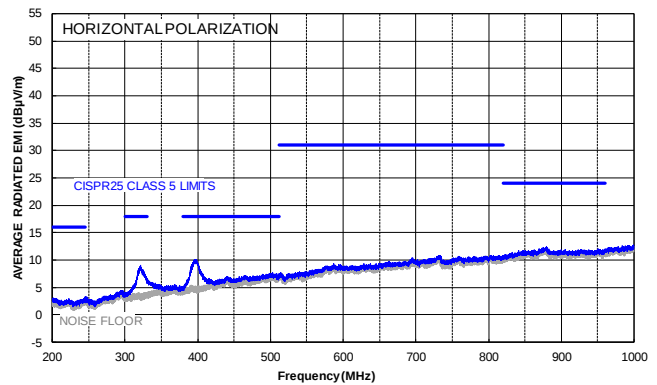
### CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 200MHz to 1GHz



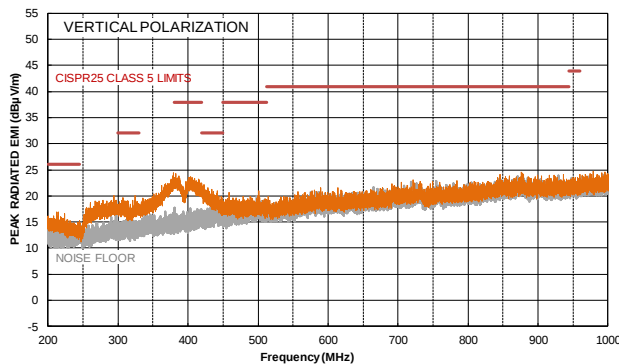
### CISPR25 Class 5 Average Radiated Emissions

Horizontal, 200MHz to 1GHz



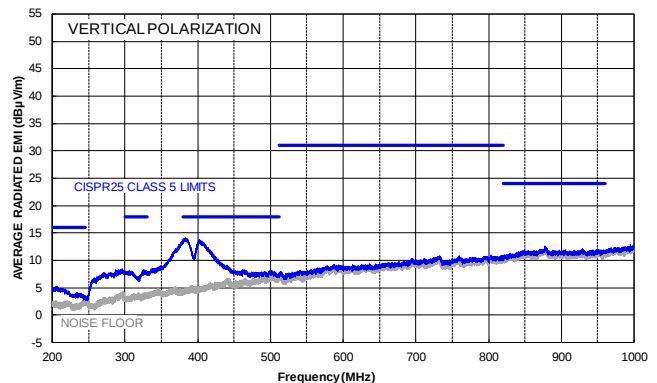
### CISPR25 Class 5 Peak Radiated Emissions

Vertical, 200MHz to 1GHz



### CISPR25 Class 5 Average Radiated Emissions

Vertical, 200MHz to 1GHz



#### Notes:

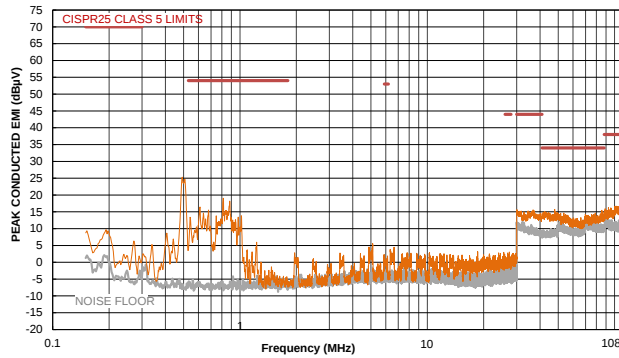
8) The EMC test results are based on the application circuit with EMI filters (see Figure 4 on page 25).

# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $L = 15\mu H$ , LED = 6P12S,  $f_{SW} = 410kHz$ ,  $I_{SET} = 100mA$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(9)</sup>

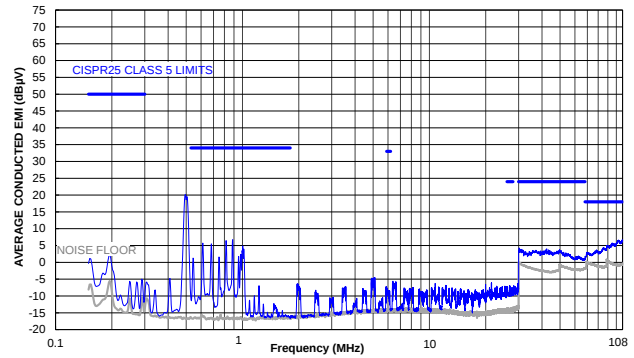
## CISPR25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



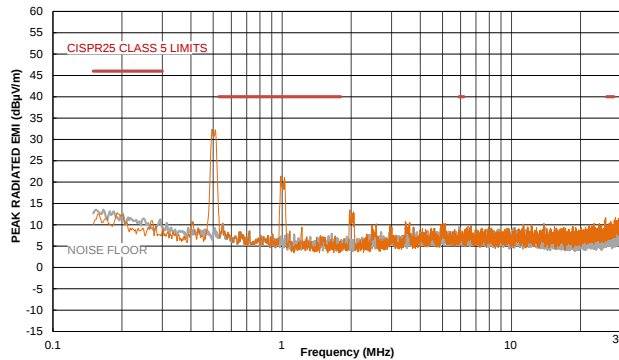
## CISPR25 Class 5 Average Conducted Emissions

150kHz to 108MHz



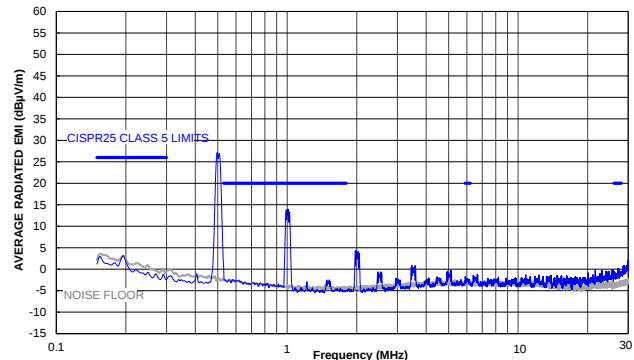
## CISPR25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



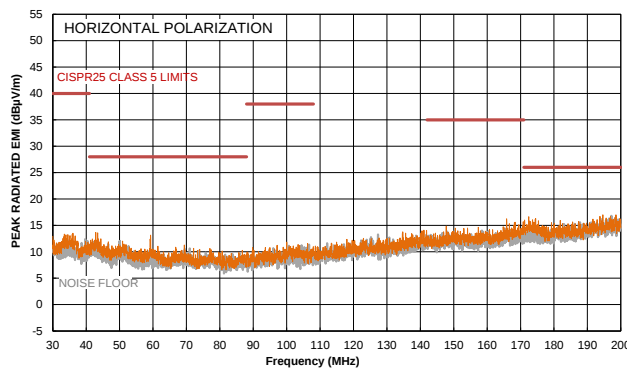
## CISPR25 Class 5 Average Radiated Emissions

150kHz to 30MHz



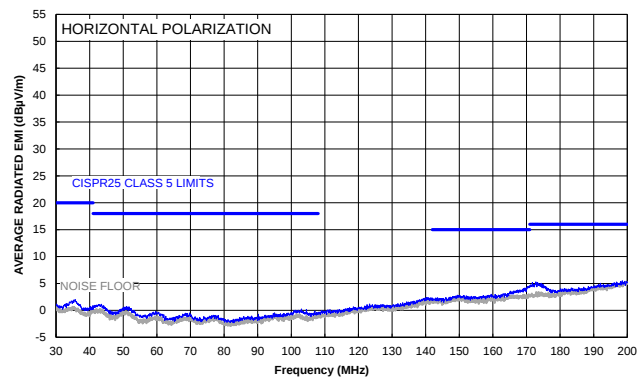
## CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 200MHz



## CISPR25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 200MHz

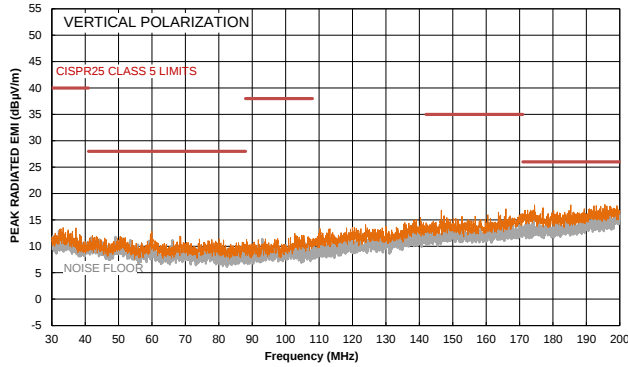


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $L = 15\mu H$ , LED = 6P12S,  $f_{SW} = 410kHz$ ,  $I_{SET} = 100mA$ , with EMI filters,  $T_A = 25^\circ C$ , unless otherwise noted. <sup>(9)</sup>

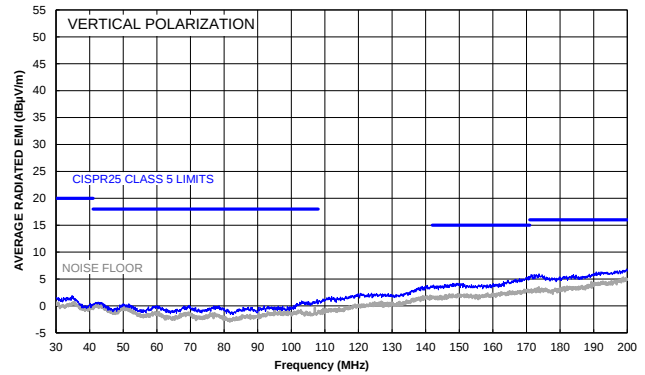
## CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 200MHz



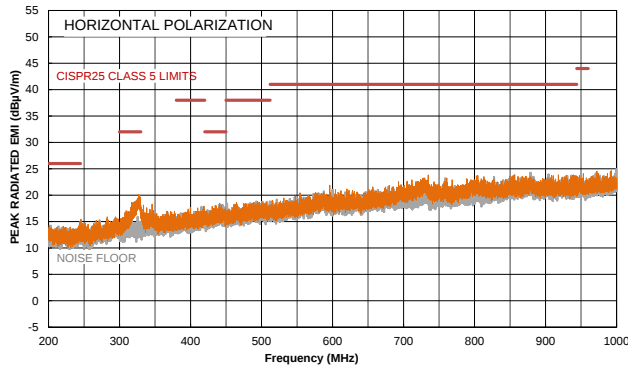
## CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 200MHz



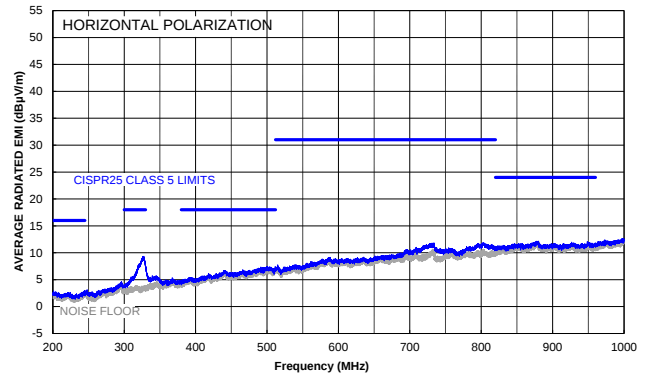
## CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 200MHz to 1GHz



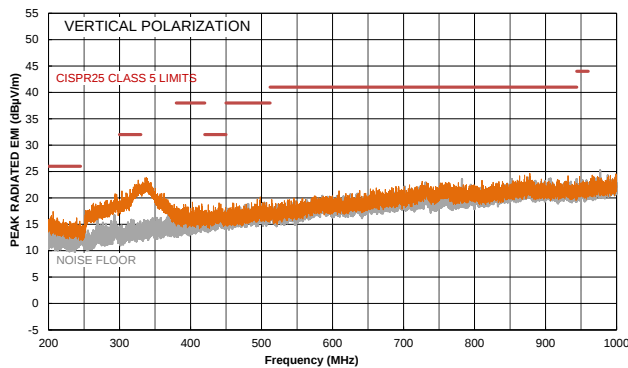
## CISPR25 Class 5 Average Radiated Emissions

Horizontal, 200MHz to 1GHz



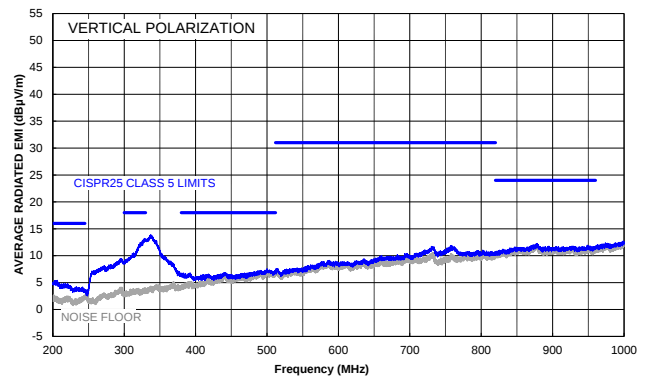
## CISPR25 Class 5 Peak Radiated Emissions

Vertical, 200MHz to 1GHz



## CISPR25 Class 5 Average Radiated Emissions

Vertical, 200MHz to 1GHz



### Notes:

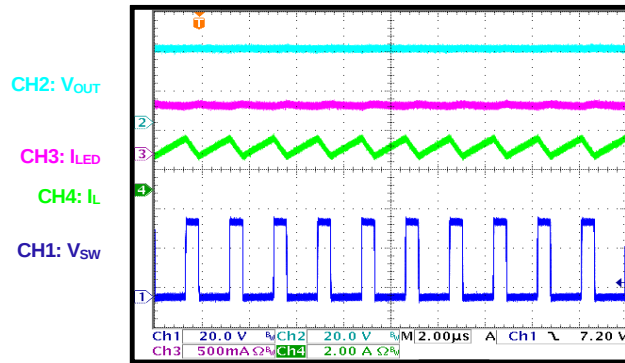
9) The EMC test results are based on the application circuit with EMI filters (see Figure 6 on page 26).

# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $L = 22\mu H$ , LED = 6P12S,  $f_{SW} = 470kHz$ ,  $I_{SET} = 100mA$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

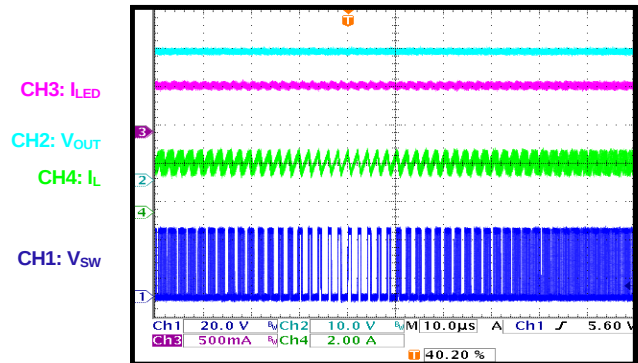
## Steady State

$I_{SET} = 100mA$



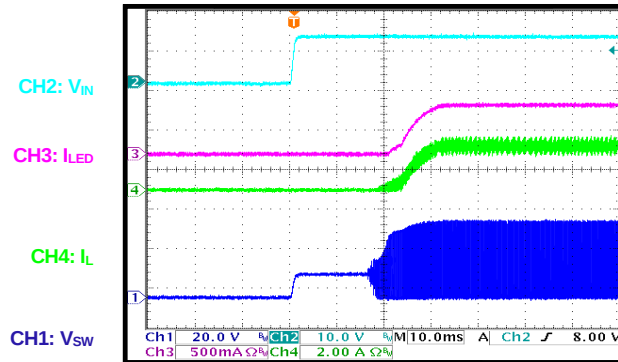
## Frequency Spread Spectrum

1/20 of the center frequency



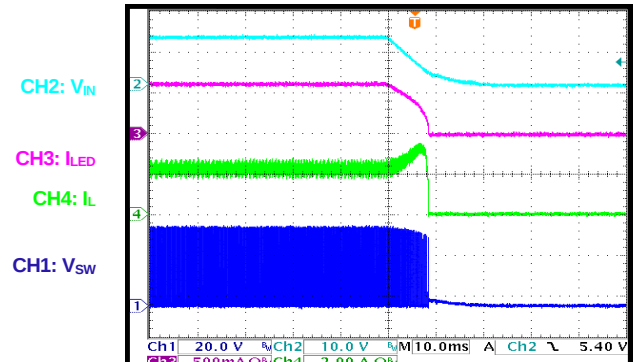
## Start-Up through $V_{IN}$

$I_{SET} = 100mA$



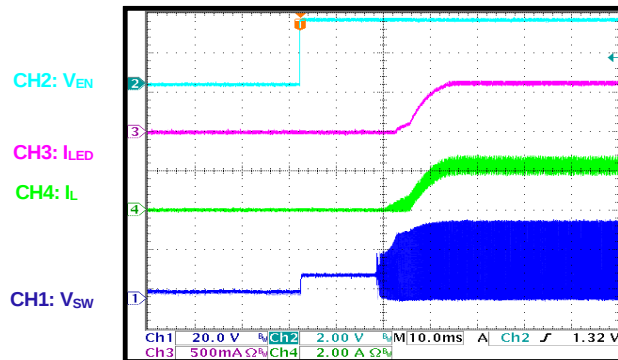
## Shutdown through $V_{IN}$

$I_{SET} = 100mA$



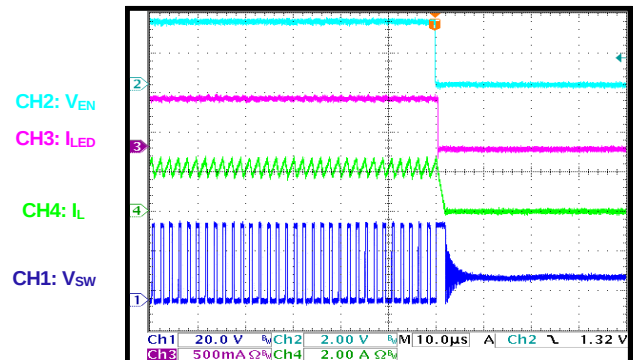
## Start-Up through EN

$I_{SET} = 100mA$



## Start-Up through EN

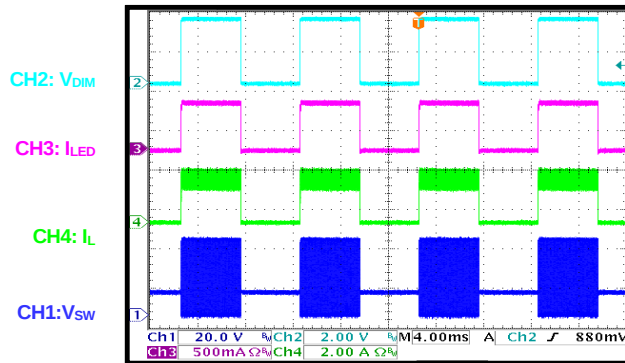
$I_{SET} = 100mA$



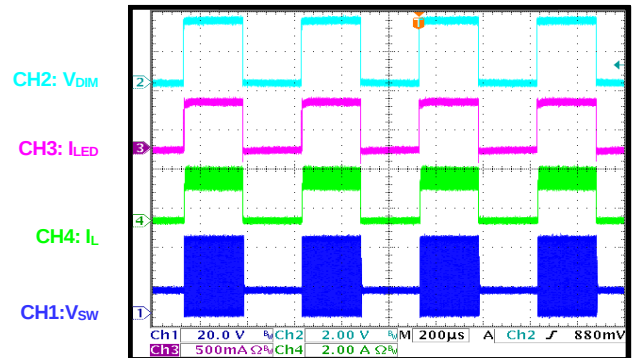
# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $L = 22\mu H$ , LED = 6P12S,  $f_{SW} = 470kHz$ ,  $I_{SET} = 100mA$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

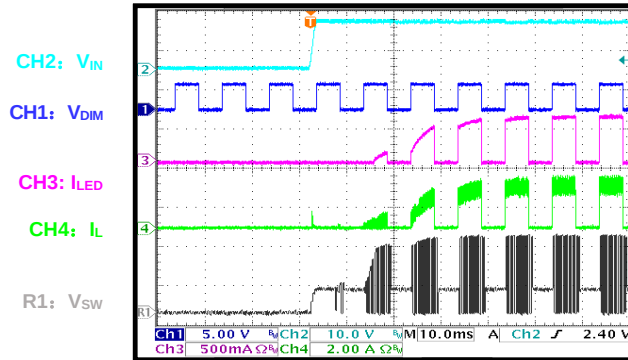
**PWM Dimming Steady State**  
Dimming frequency = 100Hz



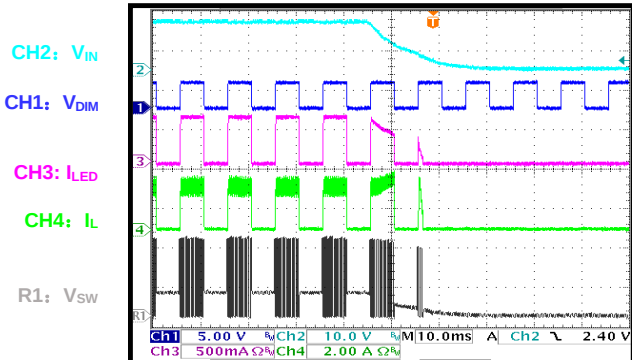
**PWM Dimming Steady State**  
Dimming frequency = 2kHz



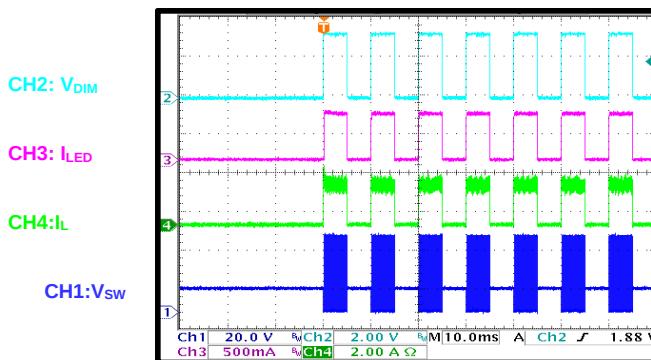
**PWM Dimming Start-Up through  $V_{IN}$**



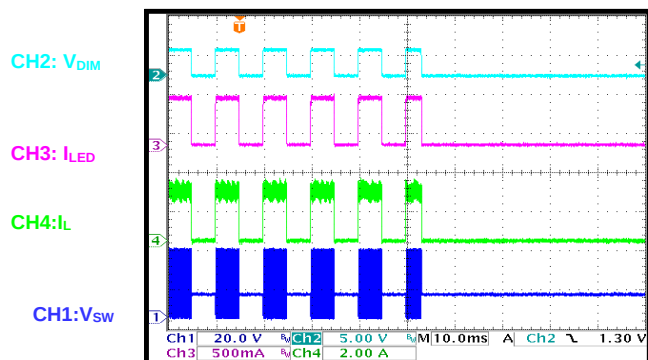
**PWM Dimming Shutdown through  $V_{IN}$**



**PWM Dimming On**



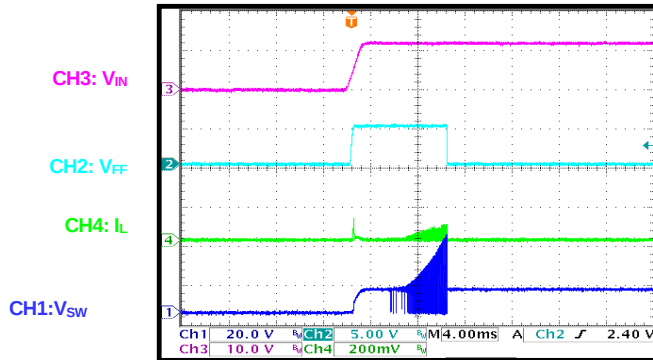
**PWM Dimming Off**



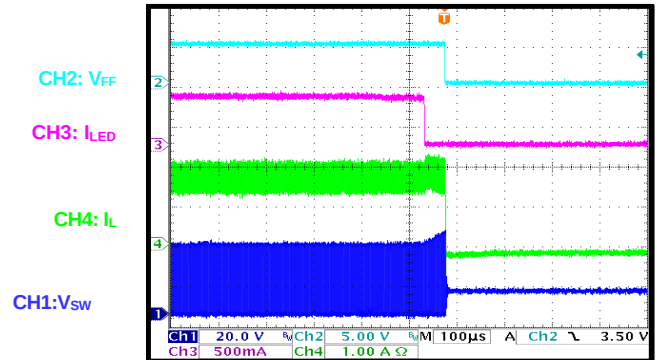
# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $L = 22\mu H$ , LED = 6P12S,  $f_{SW} = 470kHz$ ,  $I_{SET} = 100mA$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

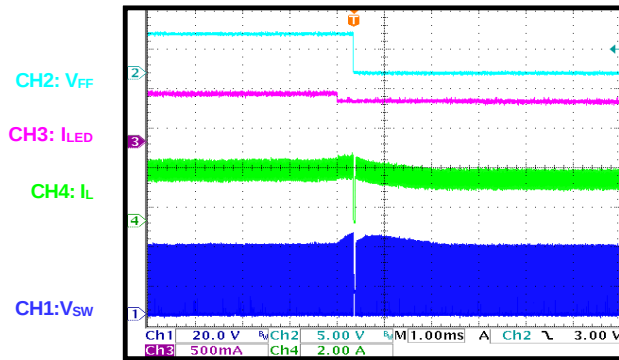
All 6 Strings LED Open Power On



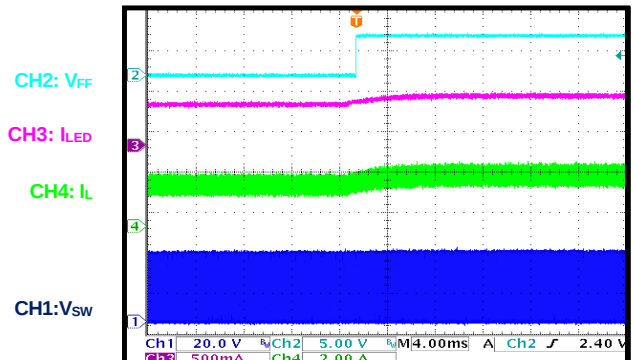
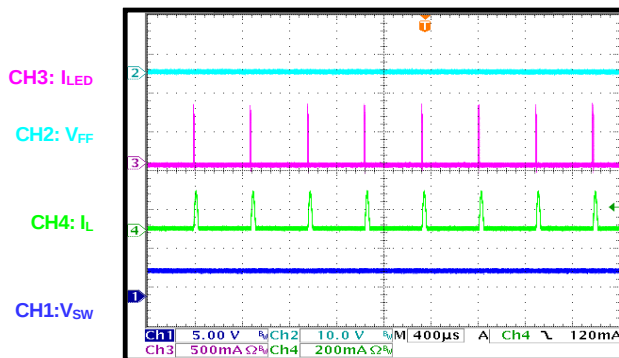
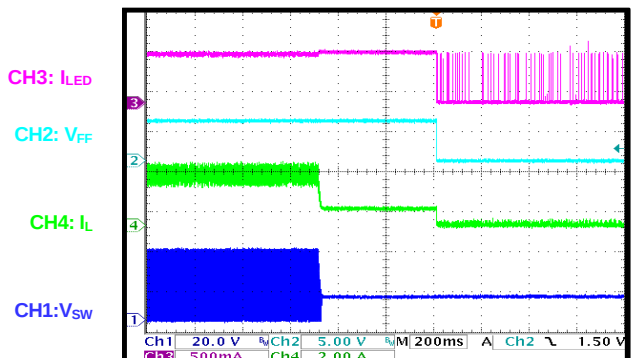
All 6 Strings LED Open Entry



1 String LED Open Entry



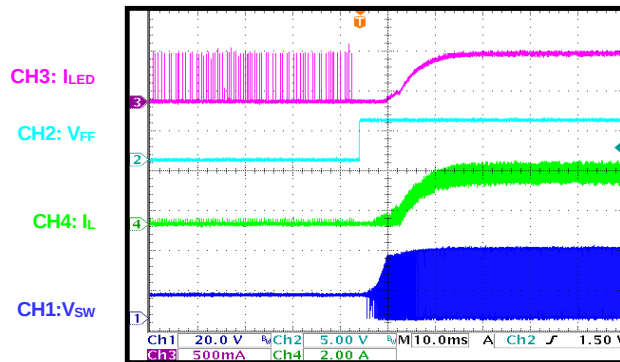
1 String LED Open Recovery


V<sub>OUT</sub> Short to LEDx Steady State

V<sub>OUT</sub> Short to LEDx Entry


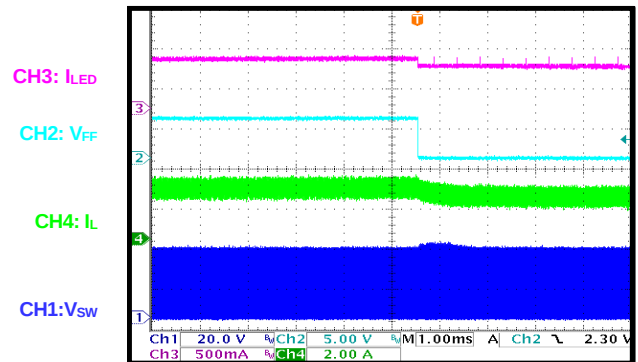
# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $L = 22\mu H$ , LED = 6P12S,  $f_{SW} = 470kHz$ ,  $I_{SET} = 100mA$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

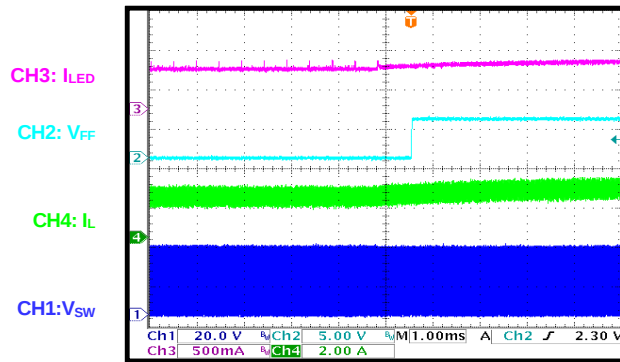
## $V_{OUT}$ Short to LEDx Recovery



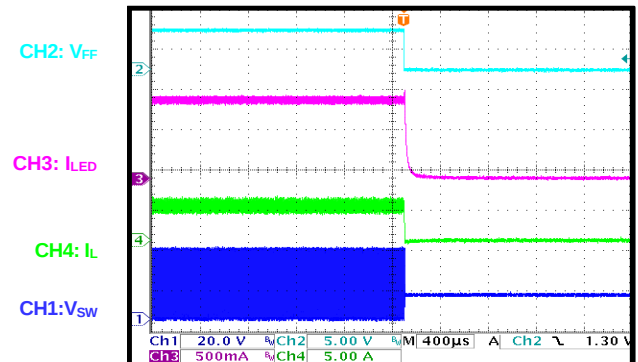
## Short 1 String at Working



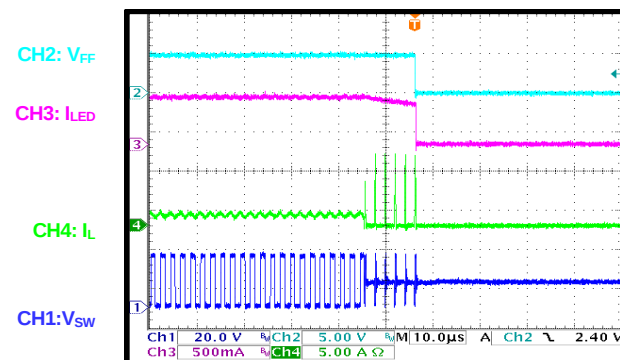
## Short 1 String Recovery



## LEDx Short to GND Entry



## Inductor Short Entry



## FUNCTIONAL BLOCK DIAGRAM

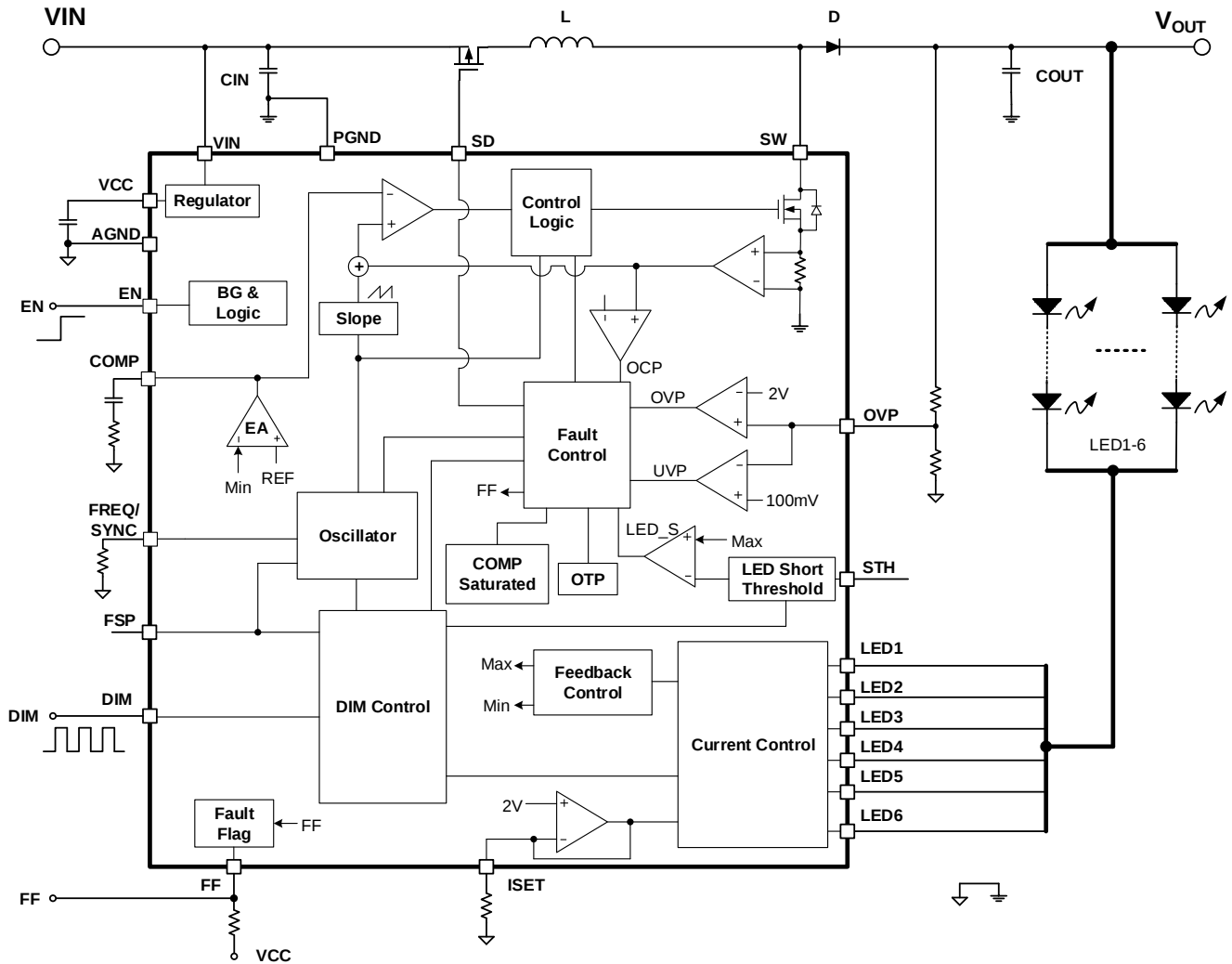


Figure 1: Functional Block Diagram

## OPERATION

The MPQ7220 employs a programmable, constant-frequency, peak current mode, step-up converter with up to six channels of regulated current sources to drive the array of white LEDs.

### Internal 5V Regulator

The MPQ7220 includes an internal linear regulator (VCC). When  $V_{IN}$  exceeds 6V, this regulator outputs a 5V power supply to the internal MOSFET switch gate driver and the internal control circuitry. The VCC voltage drops to 0V when the chip shuts down. The chip remains disabled until VCC exceeds the UVLO threshold.

### System Start-Up

If both  $V_{IN}$  and EN exceed their respective thresholds, the IC starts up. The IC pulls ( $V_{IN} - V_{SD}$ ) to 6V to turn on the external disconnect PMOS (if this PMOS is used). After a 500 $\mu$ s delay, the IC monitors the OVP pin to determine whether the output is shorted to GND. If the OVP pin voltage drops below 100mV for 10 $\mu$ s, then the IC latches off and the SD pin is pulled to  $V_{IN}$  to turn the PMOS off. Then the MPQ7220 continues to check other safety limits (e.g. LED open and over-voltage protection). If the device passes all of the protection tests, the IC starts to boost the step-up converter with an internal soft start.

The recommended start-up sequence is listed below:

1.  $V_{IN}$  starts up
2. EN starts up
3. PWM dimming signal starts up

### Step-Up Converter

The MPQ7220 employs peak current mode control to regulate the output energy. At the beginning of each switching cycle, the internal clock turns on the internal MOSFET (in normal operation, the minimum on time is about 100ns). A stabilizing ramp added to the output of the current-sense amplifier prevents sub-harmonic oscillations for duty cycles greater than 50%. This result is fed into the PWM comparator. When the summed voltage reaches the output voltage of the error amplifier, the internal MOSFET turns off.

The output voltage of the internal error amplifier is an amplified signal of the difference between the reference voltage and the feedback voltage. The converter automatically chooses the lowest active LEDx pin voltage to provide a high enough output voltage to power all the LED arrays.

If the feedback voltage drops below the reference, the output of the error amplifier increases. This results in more current flowing through the MOSFET, thus increasing the power delivered to the output. This forms a closed loop that regulates the output voltage.

Under light-load conditions, especially in the case of  $V_{OUT} \approx V_{IN}$ , the converter runs in pulse-skipping mode where the MOSFET turns on for a minimum on time, and then the converter discharges the power to the output for the remaining period. The internal MOSFET remains off until the output voltage needs to be boosted again.

### LED Current Setting

The LED current amplitude is set by an external resistor from ISET to GND. The LED current amplitude setting follows Equation (1):

$$I_{LED} (mA) = \frac{1245}{R_{ISET} (k\Omega)} \quad (1)$$

For  $R_{ISET} = 12.4k\Omega$ , the LED current is 100mA.

### PWM Dimming Control

Applying an external 100Hz to 20kHz PWM waveform to DIM pin for PWM dimming. During PWM dimming, the part stops switching when DIM is below 0.4V and the LED current is zero. The part resumes normal operation with a nominal LED current when DIM exceeds 1.2V.

### Unused LED Channel Setting

The MPQ7220 automatically detects the unused LED string and removes it from the control loop during start-up by connecting the LEDx pin of an unused channel to GND. If employing 5 strings, connect the LED6 to GND. If using 4 strings, connect the LED5 and LED6 to GND, and so on.

### Frequency Spread Spectrum

The MPQ7220 uses switching frequency jitter to spread the switching frequency spectrum. It

reduces the spectrum spike around the switching frequency and its harmonic frequencies.

The FSP pin can program the dithering range, and the modulation frequency is fixed to 1/150 of the switching frequency. FSP is a current-source output (18μA). Connect a resistor to program its voltage.

If  $FSP < 0.4V$ , the jitter frequency is 1/20 of the central frequency.

If  $FSP = 0.45V$  to  $1.4V$ , the jitter frequency is 1/32 of the central frequency.

If  $FSP > 1.4V$  or is left floating, the frequency spread spectrum is disabled.

### Programming and Synchronizing the Switching Frequency

The switching frequency is programmed through an external resistor or an external clock on the **FREQ/SYNC** pin. The switching frequency can be determined with Equation (2):

$$F_{SW}(\text{kHz}) = \frac{22000}{R_{FRE}(\text{k}\Omega)} \quad (2)$$

For  $R_{OSC} = 46.4\text{k}\Omega$ , the switching frequency is set to 470kHz.

Synchronize the switching frequency using an external clock to improve EMI, efficiency, and thermal performance.

### Protection

The MPQ7220 includes open string protection, short string protection, short LEDx to GND protection, over-current protection, short out to GND protection, and thermal protection. Once the protection is triggered, the fault flag (FF) pin pulls to GND. FF is released to high with a 750μs delay after the IC recovering from protection.

### Open String Protection

Open string protection is achieved through detecting the voltage of the OVP pin and the LED1-6 pins. During operation, if one string is open, the respective LEDx pin voltage is pulled low to ground. The IC keeps charging the output voltage until it reaches the over-voltage protection (OVP) threshold. If the OVP point has been triggered, the chip stops switching and marks off the fault string that has a LEDx

pin voltage below 100mV. Once marked, the remaining LED strings force the output voltage back into normal regulation. The string with the largest voltage drop determines the output regulation value. The marked-off string sends a 10μs pulse current to check whether an open fault is removed after every 500μs delay, so open string protection is recoverable.

### Short String Protection

The MPQ7220 monitors the LEDx pin voltages to determine whether a short string fault has occurred. If one or more strings are shorted, the respective LEDx pins tolerate high voltage stress. If an LEDx pin voltage exceeds the protection threshold, an internal counter is started. If this fault condition lasts for 7.7ms, the fault string is marked off and disabled. Once a string is marked off, it disconnects from the output voltage loop until the short is removed.

The short protection threshold is set by the external **STH** pin. An 18μA current flows out of the pin. Connect a resistor from **STH** to **AGND** to get a voltage ( $V_{STH}$ ). The threshold is 10 times  $V_{STH}$  when  $V_{STH} < 1.4V$ . When **STH** is floating or  $V_{STH} > 1.4V$ , the short protection threshold is set to 5V.

When all LEDx voltages exceed the threshold for 480ms, all strings are marked off. The IC is on standby until the strings release from shorting.

### Short LEDx to GND Protection

When LEDx shorts to GND, the COMP voltage increases and saturates. When the COMP saturated time lasts for 20ms, protection is triggered, the FF pin pulls low, and the SD pin is pulled high to turn off the external PMOS. The IC also latches off.

### Short $V_{OUT}$ to GND Protection

If  $V_{OUT}$  shorts to GND, the OVP voltage decreases and triggers the OVP UVLO threshold (100mV) for 10μs. Then the OVP UVLO protection is triggered. The SD pin is pulled up to  $V_{IN}$  to turn the external PMOS off,  $V_{OUT}$  is disconnected from  $V_{IN}$ , and the IC latches off. The OVP voltage should be below 100mV; otherwise, the protection cannot be triggered. Caution should be taken if a  $V_{OUT}$  short to GND occurs during start-up, since there is a 500μs delay before OVP pin detection is

active (see the System Start-Up section). If a  $V_{OUT}$  short to GND occurs before OVP detection is active, the output current may rise too high and damage the PMOS and diode.

### Cycle-by-Cycle Current Limit

To prevent the external components from exceeding the current stress rating, the IC has cycle-by-cycle current limit protection. When the current exceeds the current limit value, the IC stops switching until the next clock cycle.

### Latch-Off Current Limit Protection

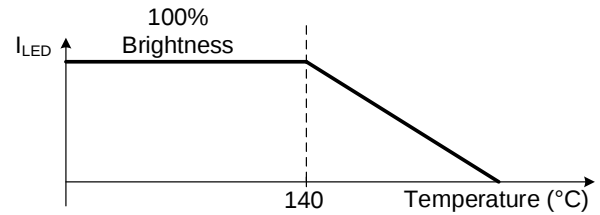
Extreme conditions like excess current or an inductor short may cause device damage. Therefore, the MPQ7220 provides a latch-off current limit protection when the current flowing through an internal MOSFET reaches the threshold (8A) and lasts for five switching cycles.

### Thermal Protection

To prevent the IC from damage when operating at exceedingly high temperatures, thermal protection is implemented in this chip by detecting the silicon die temperature.

### Over-Temperature LED Current Decrement

When the die temperature exceeds 140°C, the MPQ7220 automatically decreases the LED current amplitude.



**Figure 2:  $I_{LED}$  Decreases with Temperature**

### Thermal Shutdown

When the die temperature exceeds the upper threshold ( $T_{ST}$ ), the IC shuts down. It recovers to normal operation when the die temperature drops below the lower threshold. The hysteresis value is typically 20°C.

## APPLICATION INFORMATION

### LED Current Setting

The LED current amplitude is set by an external resistor connected from ISET to GND. The LED current amplitude setting is determined with Equation (3):

$$I_{LED} (mA) = \frac{1245}{R_{ISET} (k\Omega)} \quad (3)$$

For  $R_{ISET} = 12.4k\Omega$ , the LED current is 100mA.

### Setting the Over-Voltage Protection (OVP)

The voltage divider sets the over-voltage protection (OVP) point (see Figure 3). Calculate  $V_{OVP}$  with Equation (4):

$$V_{OVP} (V) = 2V \times \frac{R_3 + R_4}{R_4} \quad (4)$$

Normally, the OVP point is set about 10% to 30% higher than the LED voltage.

### Switching Frequency

The frequency can be programmed by an external resistor or an external clock on the FREQ/SYNC pin. Calculate the switching frequency using Equation (5):

$$f_{sw} (kHz) = \frac{22000}{R_{FRE} (k\Omega)} \quad (5)$$

For  $R_{FRE} = 46.4k\Omega$ , the switching frequency is set to 470kHz.

Synchronize the switching frequency using an external clock to improve EMI, efficiency, and thermal performance.

### Selecting the Input Capacitor

The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent the high-frequency switching current from passing through to the input. Use ceramic capacitors with X5R or X7R dielectrics for their low ESR and small temperature coefficients.

For most applications, a 10μF ceramic capacitor is sufficient.

### Selecting the Inductor

The MPQ7220 requires an inductor to supply a higher output voltage while being driven by the input voltage. A larger-value inductor results in less ripple current, lower peak inductor current, and less stress on the internal MOSFET. However, the larger-value inductor has a larger physical size, higher series resistance, and lower saturation current.

Choose an inductor that does not saturate under worst-case load conditions. Select the minimum inductor value to ensure that the boost converter works in continuous conduction mode with high efficiency and good EMI performance.

Calculate the required inductance value using Equation (6) and Equation (7):

$$L \geq \frac{\eta \times V_{OUT} \times D \times (1-D)^2}{2 \times f_{sw} \times I_{LOAD}} \quad (6)$$

$$D = 1 - \frac{V_{IN}}{V_{OUT}} \quad (7)$$

Where  $V_{IN}$  and  $V_{OUT}$  are the input and output voltages, respectively.  $f_{sw}$  is the switching frequency,  $I_{LOAD}$  is the LED load current, and  $\eta$  is the efficiency.

With the given inductor value, the inductor DC current rating is at least 40% greater than the maximum input peak inductor current for most applications. The inductor's DC resistance should be as small as possible for higher efficiency.

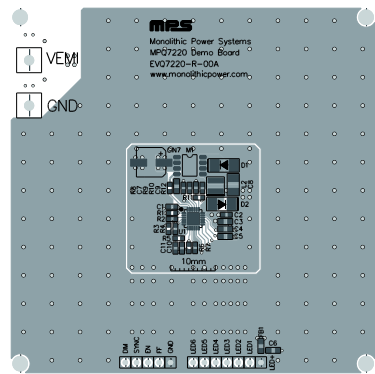
### Selecting the Output Capacitor

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. The output capacitor impedance must be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. For most applications, a 10μF ceramic capacitor is sufficient.

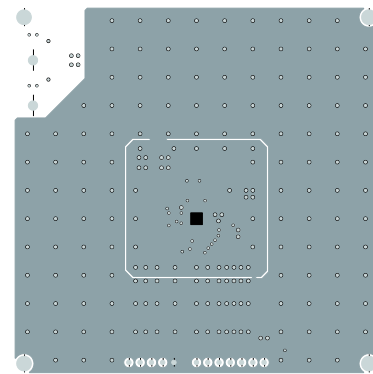
### PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. A 4-layer layout is strongly recommended to improve thermal performance. For the best results, refer to Figure 3 and Figure 4, and follow the guidelines below:

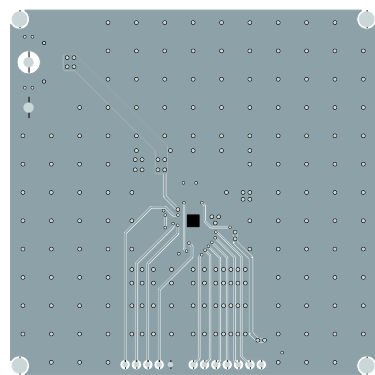
1. Use a large ground plane to connect PGND directly.
2. If the bottom layer is a ground plane, add vias near PGND.
3. Connect the high-current paths at PGND and VIN using short, direct, and wide traces.
4. Place the ceramic input capacitor, especially the input bypass capacitor in a small package (0603), as close to the VIN and PGND pins as possible to minimize high-frequency noise.
5. Make the connection between the input capacitor and VIN as short and wide as possible.
6. Place the VCC capacitor as close to the VCC and PGND pins as possible.
7. Use an internal PCB layer for the GND plane to keep radiated noise away from the device to reduce EMI.
8. Route the high-speed switching nodes away from the sensitive analog areas.
9. Use multiple vias to connect the power planes to the internal layers.



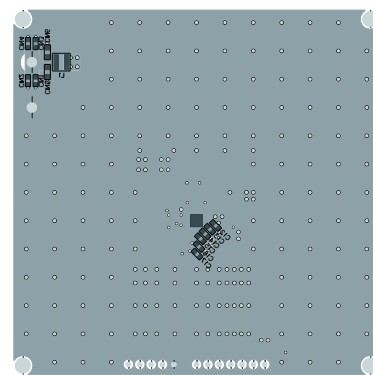
**Top Layer**



**Mid-Layer 1**



**Mid-Layer 2**

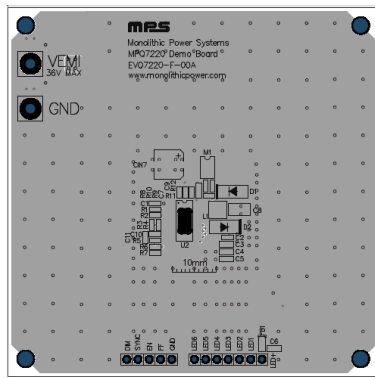


**Bottom Layer**

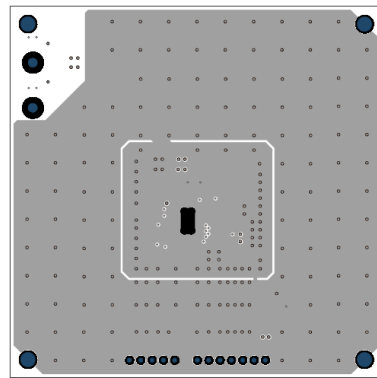
**Figure 3: Recommended PCB Layout for the QFN-24 Package <sup>(10)</sup>**

**Note:**

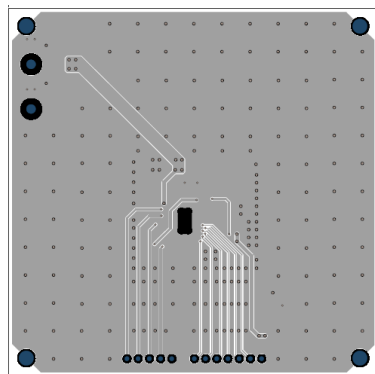
10) The recommended PCB layout is based on Figure 6 on page 27.



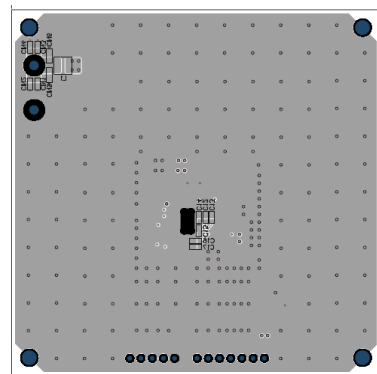
Top Layer



Mid-Layer 1



Mid-Layer 2



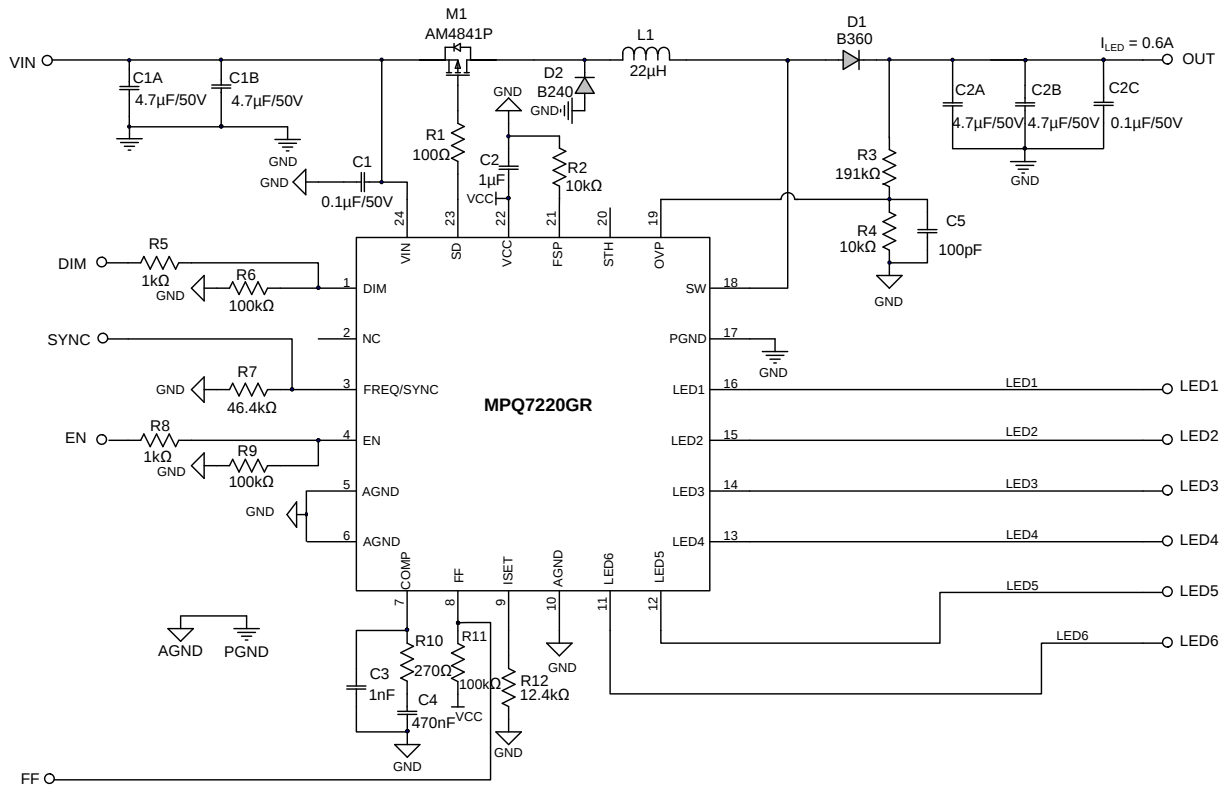
Bottom Layer

Figure 4: Recommended PCB Layout for the TSSOP-28 Package <sup>(11)</sup>

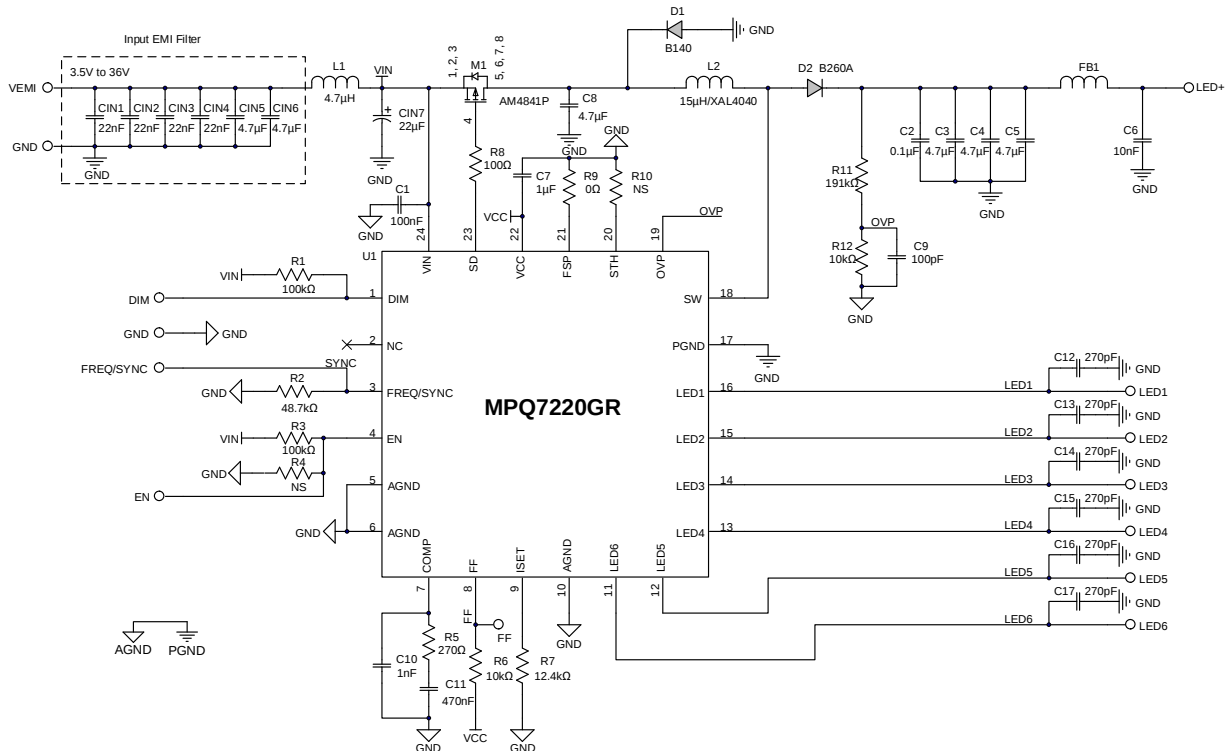
**Note:**

11) The recommended PCB layout is based on Figure 8 on page 28.

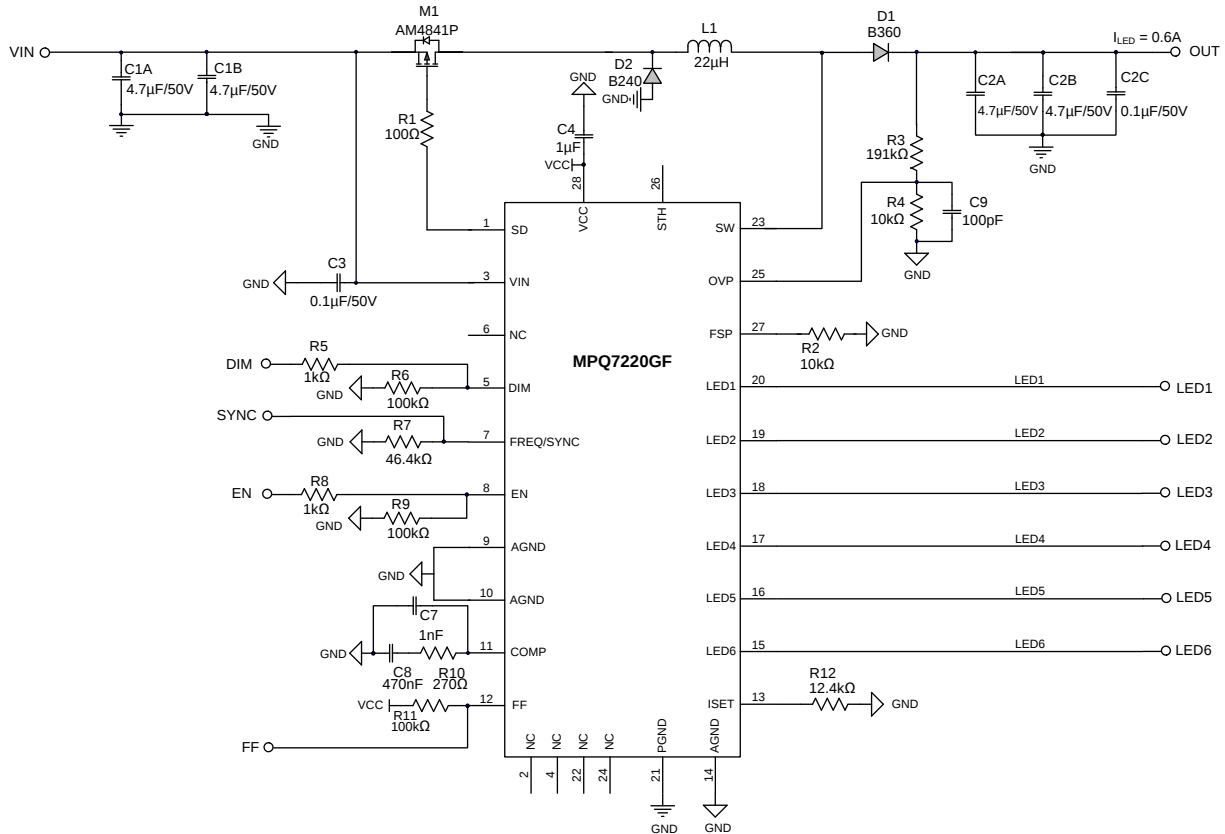
## TYPICAL APPLICATION CIRCUITS



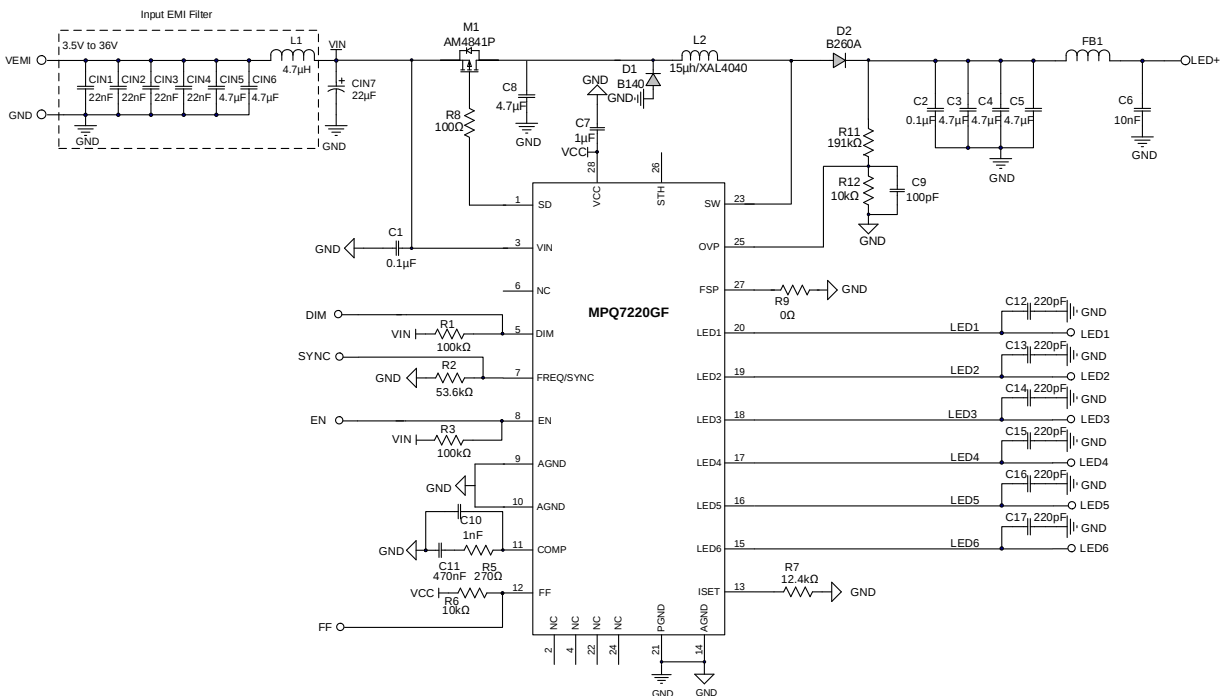
**Figure 5: Typical Application Circuit for the QFN-24 Package (I<sub>SET</sub> = 100mA, f<sub>sw</sub> = 470kHz)**



**Figure 6: Typical Application Circuit for the QFN-24 Package with EMI Filters (I<sub>SET</sub> = 100mA, f<sub>sw</sub> = 450kHz)**



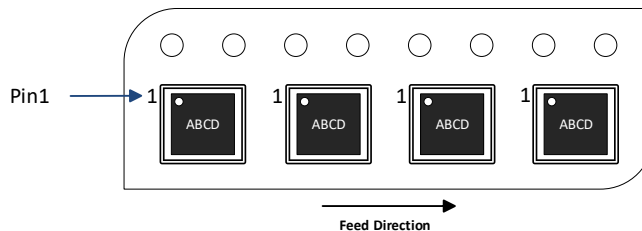
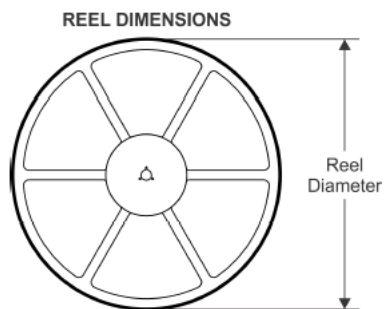
**Figure 7: Typical Application Circuit for the TSSOP-28 Package ( $I_{SET} = 100\text{mA}$ ,  $f_{sw} = 470\text{kHz}$ )**



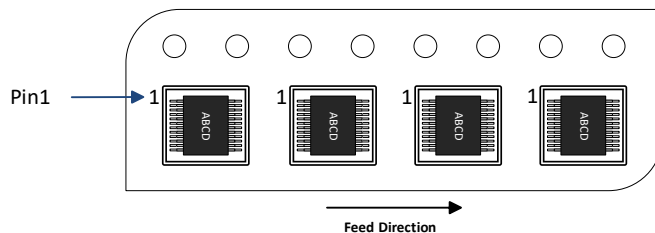
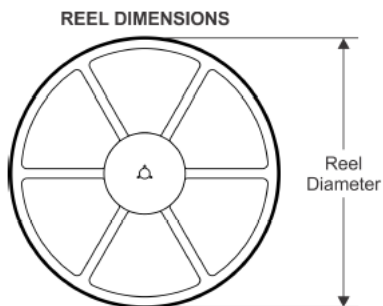
**Figure 8: Typical Application Circuit for the TSSOP-28 Package with EMI Filters ( $I_{SET} = 100\text{mA}$ ,  $f_{sw} = 410\text{kHz}$ )**

## CARRIER INFORMATION

### QFN-24 (4mmx4mm)



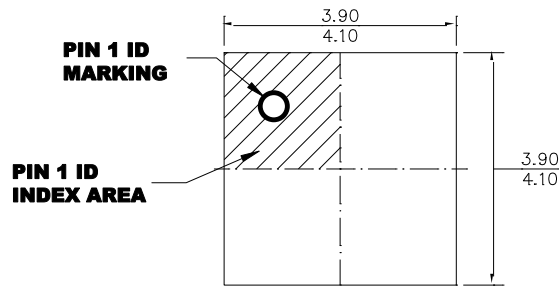
### TSSOP28-EP



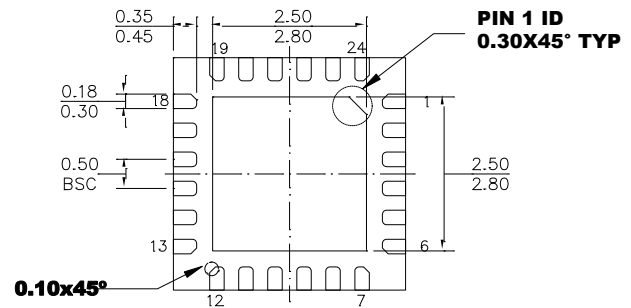
| Part Number | Package Description | Quantity/Reel | Quantity/Tube | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|-------------|---------------------|---------------|---------------|---------------|--------------------|--------------------|
| MPQ7220GR   | QFN-24 (4mmx4mm)    | 2500          | NA            | 13in          | 12mm               | 8mm                |
| MPQ7220GF   | TSSOP28-EP          | 2500          | 50            | 13in          | 16mm               | 8mm                |

# PACKAGE INFORMATION

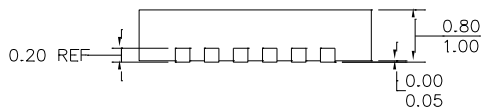
## QFN-24 (4mmx4mm)



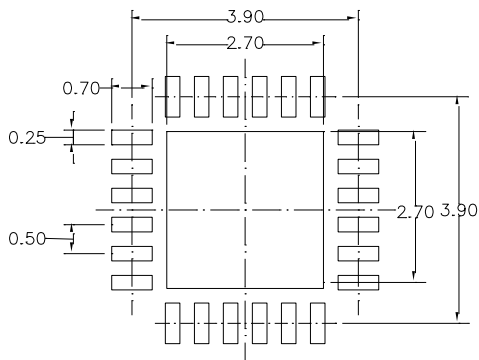
**TOP VIEW**



**BOTTOM VIEW**



**SIDE VIEW**



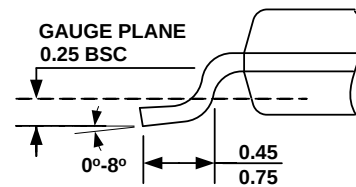
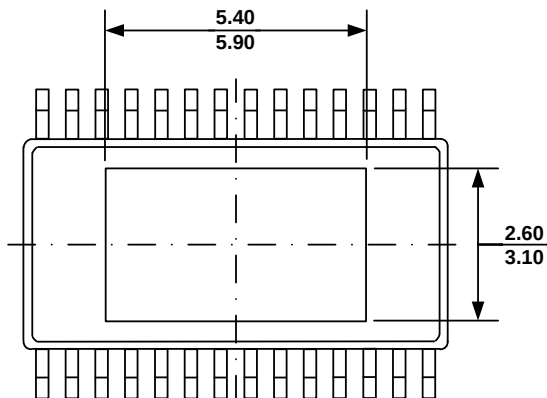
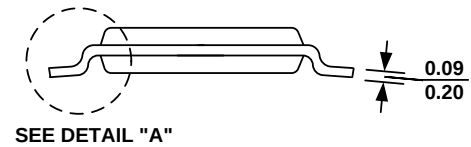
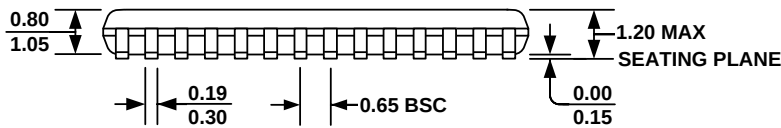
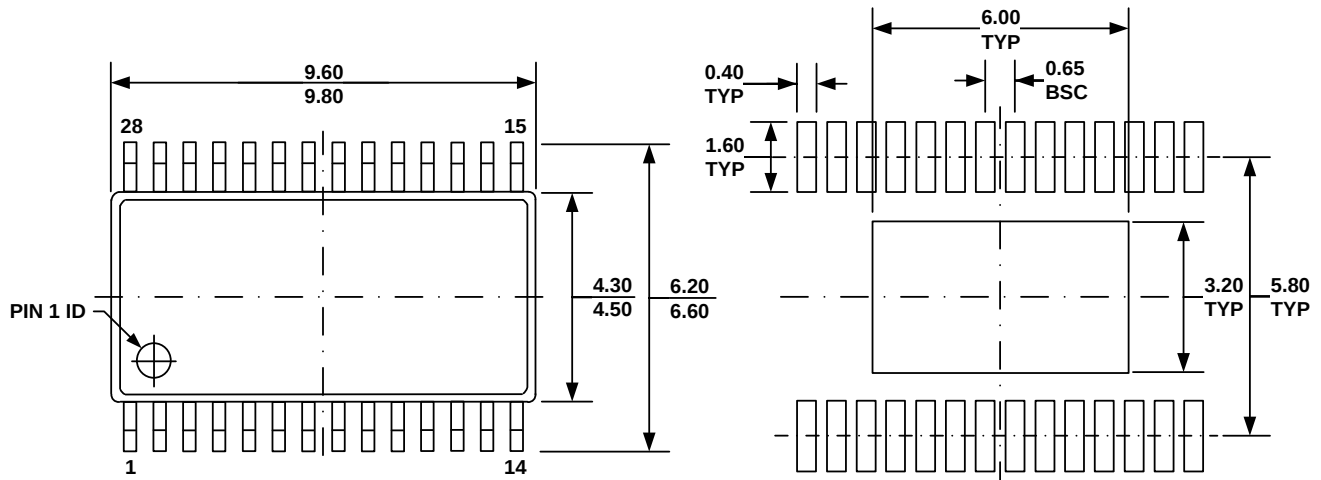
**RECOMMENDED LAND PATTERN**

### 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.

# PACKAGE INFORMATION

## TSSOP28-EP



### NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
- 5) DRAWING CONFORMS TO JEDEC MO-153, VARIATION AET.
- 6) DRAWING IS NOT TO SCALE.

## REVISION HISTORY

| Revision # | Revision Date | Description                                                                            | Pages Updated |
|------------|---------------|----------------------------------------------------------------------------------------|---------------|
| 1.0        | 07/30/2019    | Initial Release                                                                        | -             |
| 1.1        | 11/3/2022     | Removed the qualification and updated “-Z” to “-Z” in the Ordering Information section | 3             |
|            |               | Added EMI test results                                                                 | 12–15         |
|            |               | Updated the System Start-Up section                                                    | 21            |
|            |               | Updated the Short V <sub>OUT</sub> to GND Protection section                           | 22            |
|            |               | Added the PCB Layout Guidelines section                                                | 25            |
|            |               | Added Figure 6 and Figure 8; updated figure titles                                     | 27–28         |
|            |               | Updated Figure 4                                                                       | 28            |
|            |               | Updated the Carrier Information section                                                | 29            |
|            |               | Updated header and footer formatting                                                   | All           |

**Notice:** The information in this document is subject to change without notice. Please contact MPS for current specifications. Users should warrant and guarantee that third-party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.