MPQ7235

36V, 3A Synchronous Buck Automotive IR LED Driver AEC-Q100 Qualified

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE

DESCRIPTION

The MPQ7235 is a high-frequency, synchronous, rectified, step-down, switch-mode LED driver with built-in power MOSFETs. It offers a very compact solution to achieve 1.5A continuous output current and 3A peak current with low PWM dimming frequency at small dimming duty cycle; it has excellent load and line regulation over a wide input supply range. The MPQ7235 has synchronous mode operation to get high efficiency.

The MPQ7235 can support PWM dimming frequency as low as 10Hz to adjust Infrared Radiation (IR) LED driver application, and it is compatible to 30FPS/60FPS/120FPS dimming.

Current-mode operation provides fast transient response and eases loop stabilization.

Full protection features include over-current protection (OCP) and thermal shut down (TSD).

The MPQ7235 requires a minimal number of readily-available standard external components, and is available in a space-saving QFN-13 (2.5mmx3mm) package.

FEATURES

Built for a wide range of IR LED Application

- Wide 4V to 36V Operating Input Range
- Up to 1.5A continuous LED current; Up to 3A peak LED current with low dimming frequency at small duty.
- Dimming Frequency: 10Hz to 2kHz Compatible to 30FPS/60FPS/120FPS dimming

High Performance for Improved Thermals

- 85mΩ/50mΩ Low $R_{DS(ON)}$ Internal Power MOSFETs
- 0.2V Reference Voltage
- High-Efficiency Synchronous Mode Operation

Optimized for EMC/EMI

- Default 2.2MHz Switching Frequency
- EMI Reduction Technique

Full Protection Features

- LED Short/Open Fault Indication
- Over-Current Protection (OCP) with Valley-Current Detection
- Thermal Shutdown

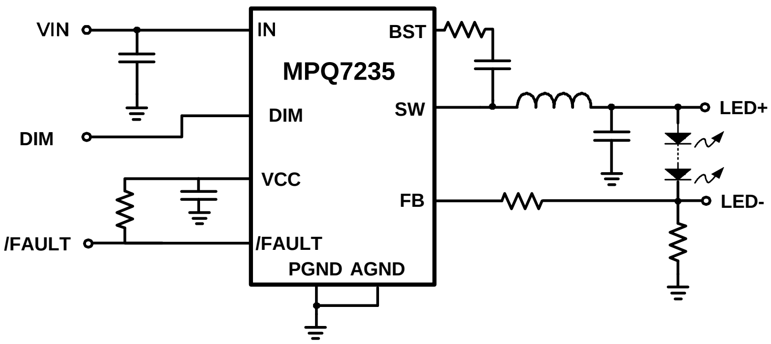
Additional Features

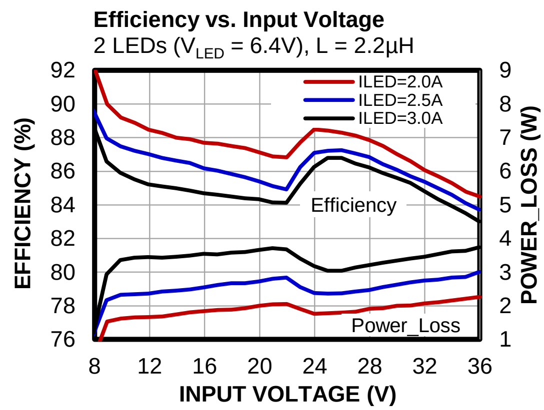
- Forced CCM Mode
- Internal Soft-Start
- Available in a QFN-13 (2.5mmx3mm) Package
- Available in a Wettable Flank Package
- CISPR25 Class 5 Compliant
- Available in AEC-Q100 Grade 1

APPLICATIONS

- Infrared (IR) LED Driver for Driver Monitoring Systems (DMS)
- Infrared (IR) Illumination for Automotive Cameras
- Surveillance Systems

TYPICAL APPLICATION





ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating**
MPQ7235GQBE-AEC1***	QFN-13 (2.5mmx3.0mm)	*See Below*	Level 1

***** For Tape & Reel, add suffix -Z (e.g. MPQ7235GQBE-AEC1-Z)

** Moisture Sensitivity Level Rating

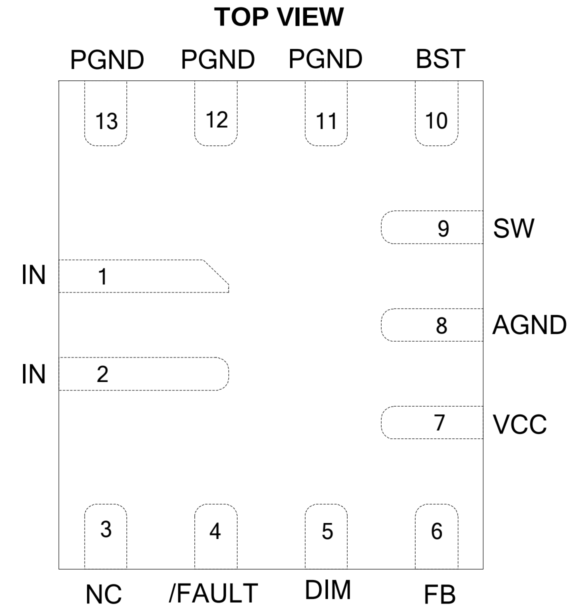
*** Wettable flank

TOP MARKING

BRE
YWW
LLL

BRE: Product code
Y: Year code
WW: Week code
LLL: Lot number

PACKAGE REFERENCE



QFN-13 (2.5mmx3.0mm)

PIN FUNCTIONS

QFN-13 Pin #	Name	Description
1, 2	IN	**Supply Voltage.** The MPQ7235 operates from a 4V to 36V input rail. Requires C_{IN} to decouple the input rail. Connect using a wide PCB trace.
3	NC	**Do not connect.**
4	/FAULT	**Fault indicator.** Open Drain output, pull up to VCC or an external source with a resistor if need indicate fault condition; pull to low when LED short, open or thermal shutdown happening.
5	DIM	**Dimming Control.** Apply a 10Hz to 2kHz external clock to the DIM pin for the PWM dimming. This pin is pulled low with an internal resistor, default off if DIM pin float.
6	FB	**LED Current Feedback Input.**
7	VCC	**Internal bias Supply.** Decouple VCC with a 0.1µF-to-0.22µF capacitor. The capacitance should be no more than 0.22µF.
8	AGND	**Analog ground.** Reference ground of the logic circuit. AGND is connected to PGND internally. External connection on board between AGND and PGND is not a must, but still recommended for better ground connection.
9	SW	**Switch Output.** Connect using a wide PCB trace.
10	BST	**Bootstrap.** Connect a capacitor between SW and BST pins to form a floating supply across the high-side switch driver. A 20Ω resistor placed between SW and BST cap is strongly recommended to reduce SW spike voltage.
11, 12, 13	PGND	**Power Ground.** PGND is the reference ground of the power device and requires careful consideration during PCB layout. For best results, connect PGND with copper pours and vias.

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (V_{IN}) .... -0.3V to 40V
Switch voltage (V_{SW}) ....-0.3V to V_{IN} + 0.3V
BST voltage (V_{BST}) .... V_{SW}+6V
All other pins................................-0.3V to 6V (2)
Continuous power dissipation (T_A = 25°C) (3) (8)
QFN-13 (2.5mmx3mm)............................2.98W
Junction temperature .... 150°C
Lead temperature .... 260°C
Storage temperature................-65°C to +150°C

Electrostatic Discharge (ESD) Rating

Human Body Model (HBM) ....Class 2 (4)
Charged Device Model (CDM) ..... Class C2b (5)

Recommended Operating Conditions

Supply voltage (V_{IN}) .... 4V to 36V
Continuous LED current (I_{LED})........... Up to 1.5A
LED peak current (I_{PEAK}) .... Up to 3A
Operating junction temp (T_J) ....
-40°C to +125°C (6)

Thermal Resistance

Thermal Resistance	θ_{JA}	θ_{JC}	
QFN-13 (2.5mmx3mm)			
JESD51-7 (7)	60	13	°C/W
EVQ7235-QB-00A (8)	42	2.5	°C/W

Notes:

1) Absolute maximum ratings are rated under room temperature unless otherwise noted. Exceeding these ratings may damage the device.
2) About the details of DIM pin's ABS MAX rating, please refer to PWM Dimming section.
3) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{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)/θ_{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.
4) Per AEC-Q100-002.
5) Per AEC-Q100-011.
6) Operation devices at junction temperature up to 150°C is possible; please contact MPS for details.
7) Measured on JESD51-7, 4-layer PCB. The value of θ_{JA} given in this table is only valid for comparison with other packages and can't be used for design purposes. These values were calculated in accordance with JESD51-7 and simulated on a specified JEDEC board. The don not represent the performance obtain in an actual application.
8) Measure on MPS standard EVB of MPQ7235, 4-layer PCB, 2-oz, 83mmx83mm.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, V_{DIM} = 2V, T_J = -40°C to +125°C, typical values are at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply current (quiescent)	I_Q	V_{DIM}=2V, V_{FB} = 1V, no switching		0.6	0.8	mA
HS switch-on resistance	HS_{RDS-ON}	V_{BST-SW}=5V		85	150	mΩ
LS switch-on resistance	LS_{RDS-ON}	V_{CC}=5V		50	105	mΩ
Switch leakage	SW_{LKG}	V_{DIM}=0V, V_{SW} =12V			1	μA
Current limit (9)	I_{LIMIT}	Under 40% Duty Cycle	4.8	6	8	A
Reverse current limit				1.2		A
Oscillator frequency	f_{SW}	V_{FB}=100mV	1800	2200	2600	kHz
Maximum duty cycle	D_{MAX}	V_{FB}=100mV	80	87		%
Minimum on time (9)	T_{ON_MIN}			46		ns
Feedback voltage	V_{FB}	T_J=25°C	192	200	208	mV
		T_J=-40°C to +125°C	184	200	216	
Feedback current	I_{FB}	V_{FB}=250mV		30	100	nA
DIM rising threshold	V_{DIM_RISING}		0.65	0.975	1.35	V
DIM falling threshold	$V_{DIM\_FALLING}$		0.5	0.8	1.1	V
DIM threshold hysteresis	V_{DIM_HYS}			175		mV
DIM input current	I_{DIM}	V_{DIM}=2V		4	6	μA
		V_{DIM}=0		0.9	1.5	μA
DIM to 1st SW delay after soft start	t_{DIM-SW}	I_{VCC}=10mA		1.3		μs
VIN under-voltage lockout threshold-rising	$INUV_{Vth}$		3.2	3.5	3.8	V
VIN under-voltage lockout threshold-falling			2.8	3.1	3.5	V
VIN under-voltage lockout threshold-hysteresis	$INUV_{HYS}$			400		mV
Over voltage detection (/FAULT pulled low)	FT_{Vth-Hi}			140%		V_{FB}
Over voltage detection hysteresis				20%		V_{FB}
/FAULT delay	FT_{Td}			10		μs
/FAULT sink current capability	V_{FT}	Sink 4mA			0.4	V
/FAULT leakage current	$I_{FT-LEAK}$				100	nA
VCC regulator	V_{CC}	I_{CC}=0mA	4.6	4.9	5.2	V
VCC load regulation		I_{CC}=5mA		1.5	4	%
VCC source current ability		V_{CC}=$V_{CC\ UVLO}$+100mV, switching		10		mA
Soft-start time (9)	t_{SS}	I_{LED}=3A, L=2.2μH, V_{LED}=6.4V, I_{LED} from 10% to 90%		2		ms

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{DIM} = 2V, T_J = -40°C to +125°C, typical values are at T_J = 25°C, unless otherwise noted.

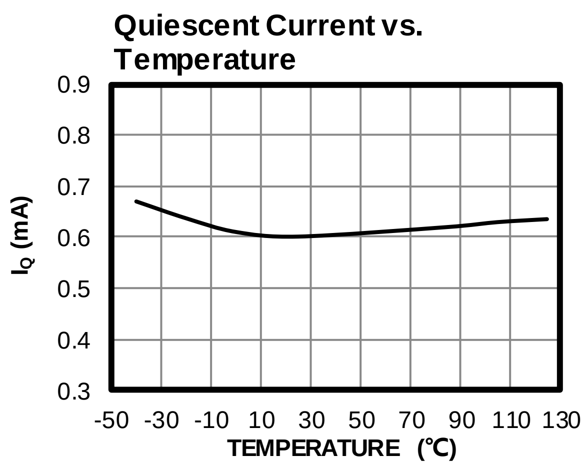
Parameter	Symbol	Condition	Min	Typ	Max	Units
Thermal shutdown (9)	T_{SD}	Rising temperature	150	170		°C
Thermal hysteresis (9)	T_{SD_HYS}			30		°C

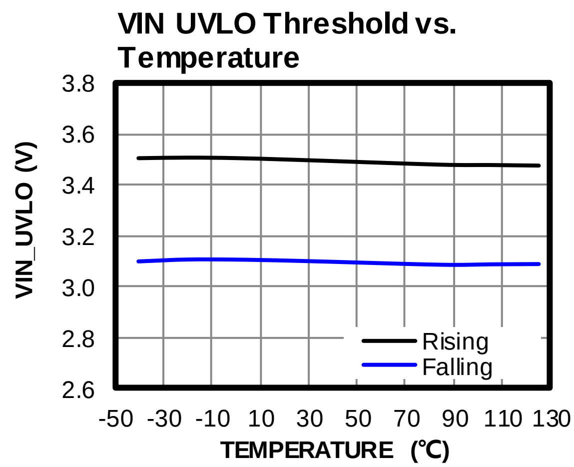
Note:

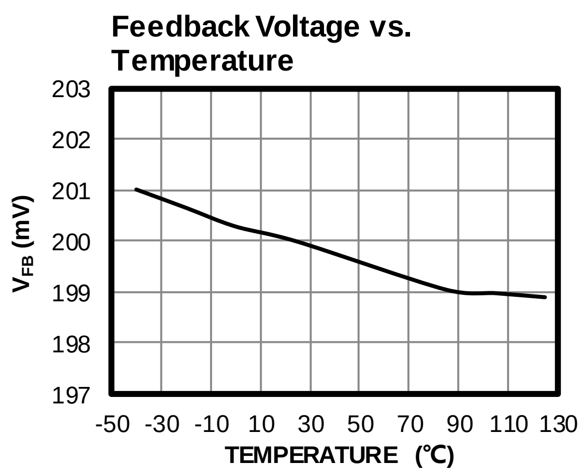
9) Derived from bench characterization. Not tested in production

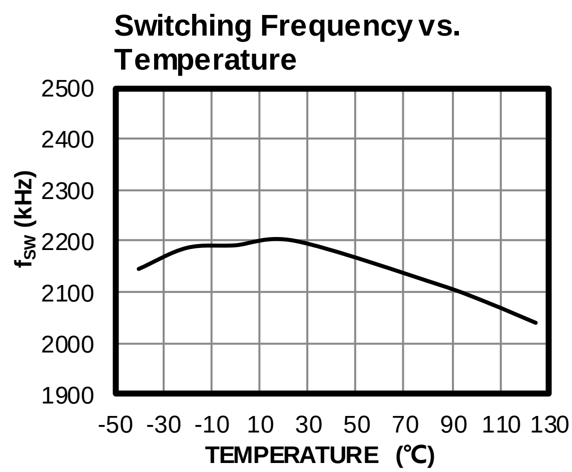
TYPICAL CHARACTERISTICS

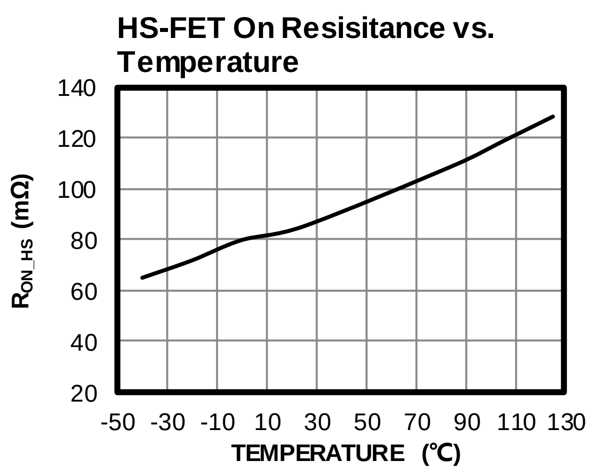
V_{IN} = 12V, T_J = -40°C to +125°C, unless otherwise noted.

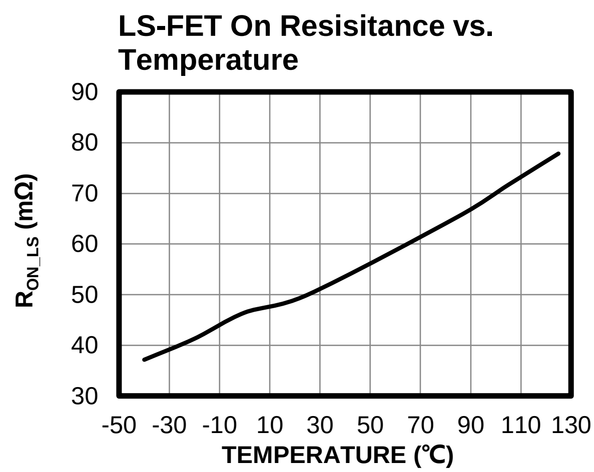






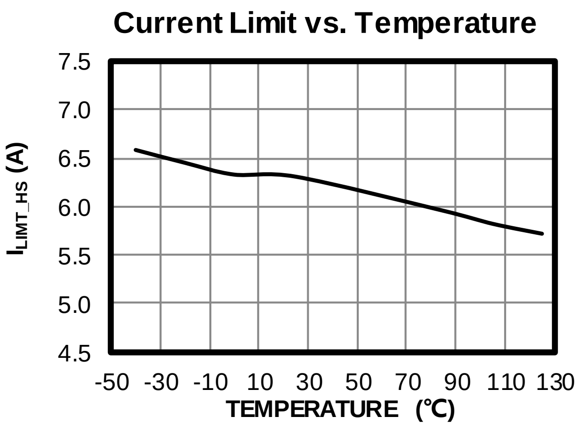


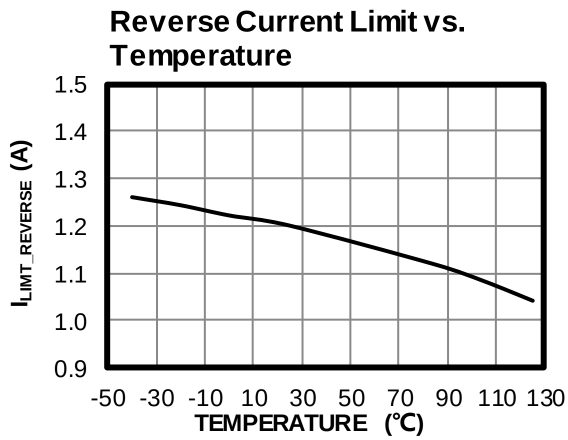




TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, T_J = -40°C to +125°C, unless otherwise noted.



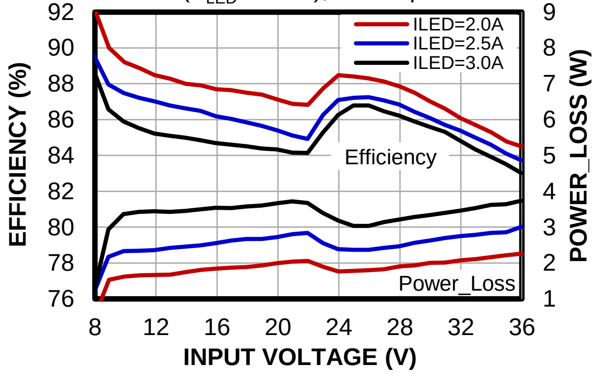


TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

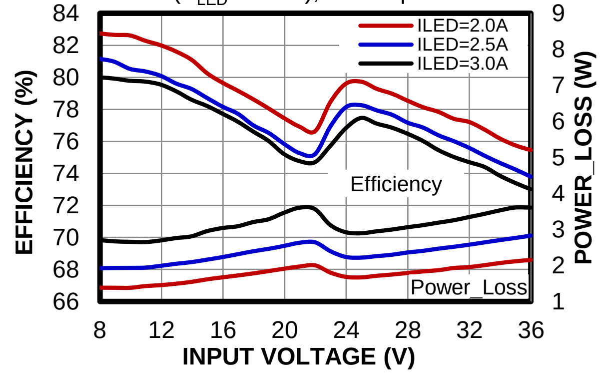
Efficiency vs. Input Voltage

2 LEDs (V_{LED} = 6.4V), L = 2.2µH



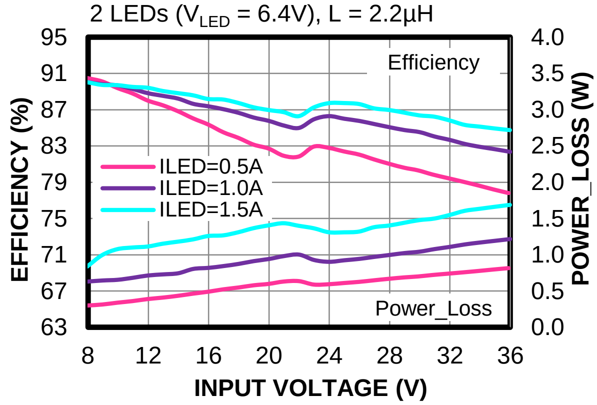
Efficiency vs. Input Voltage

1 LED (V_{LED} = 3.2V), L = 2.2µH



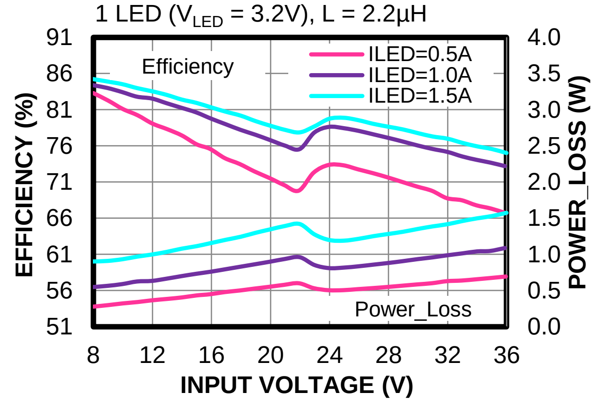
Efficiency vs. Input Voltage

2 LEDs (V_{LED} = 6.4V), L = 2.2µH



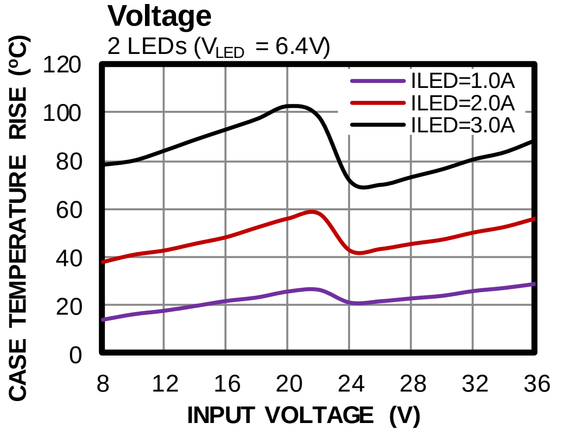
Efficiency vs. Input Voltage

1 LED (V_{LED} = 3.2V), L = 2.2µH



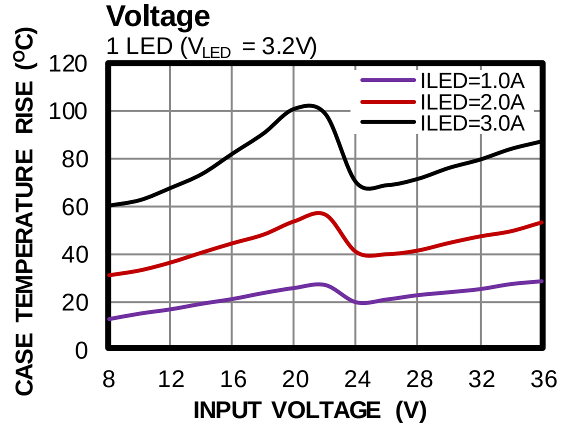
Case Temperature Rise vs. Input Voltage

2 LEDs (V_{LED} = 6.4V)



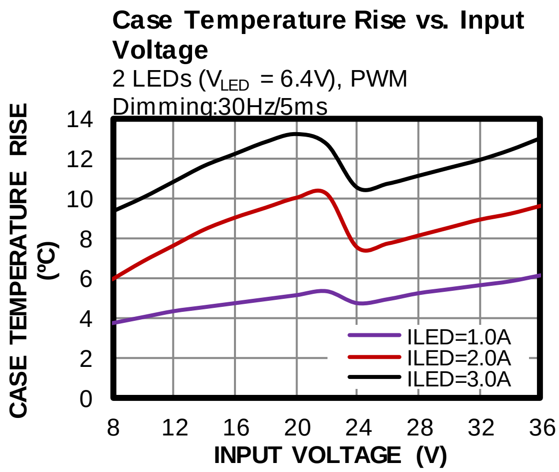
Case Temperature Rise vs. Input Voltage

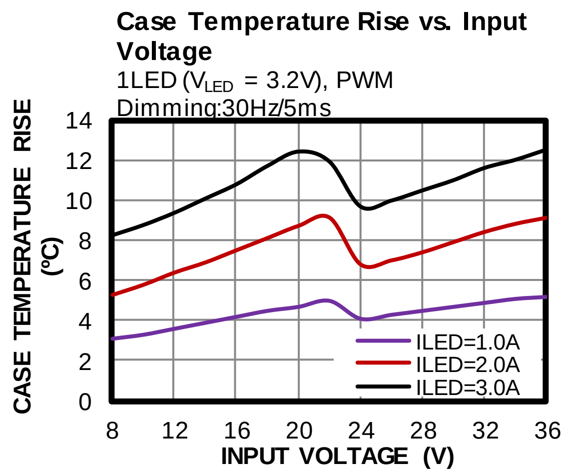
1 LED (V_{LED} = 3.2V)

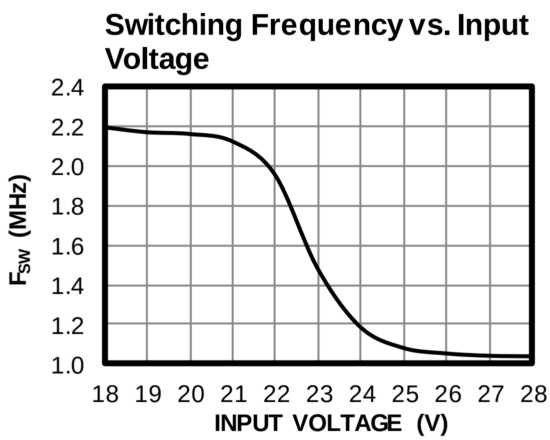


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.



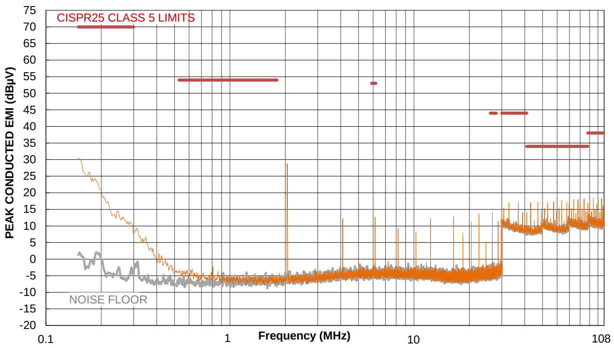




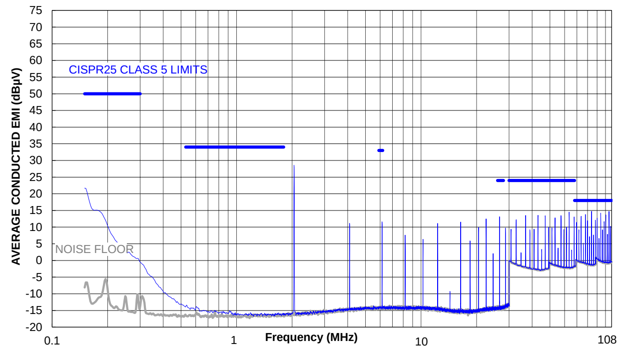
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 3A, L = 2.2µH, f_{SW} = 2.2MHz, with EMI filters, T_A = 25°C, unless otherwise noted. (10)

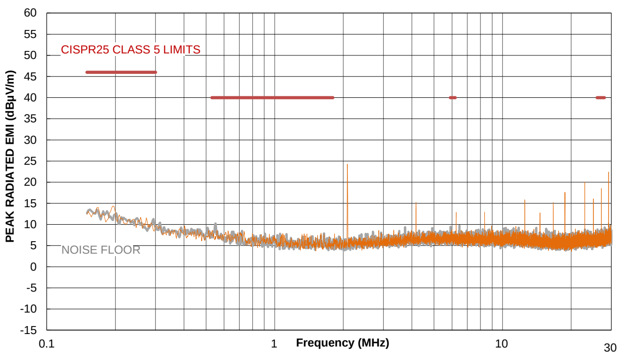
CISPR25 Class 5 Peak Conducted Emissions
150kHz to 108MHz



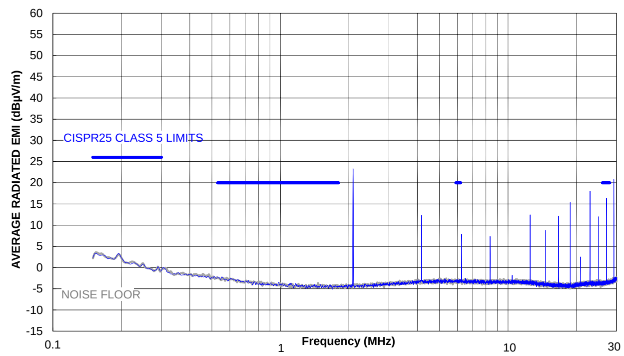
CISPR25 Class 5 Average Conducted Emissions
150kHz to 108MHz



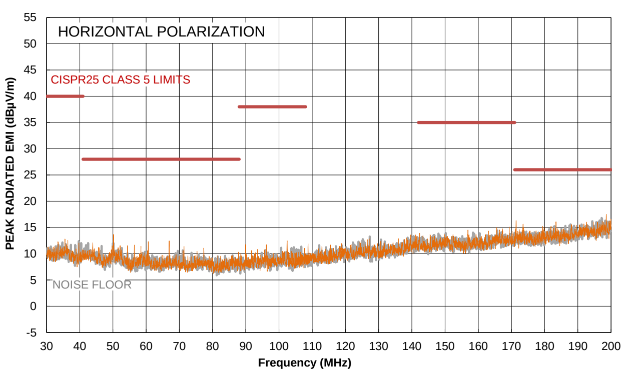
CISPR25 Class 5 Peak Radiated Emissions
150kHz to 30MHz



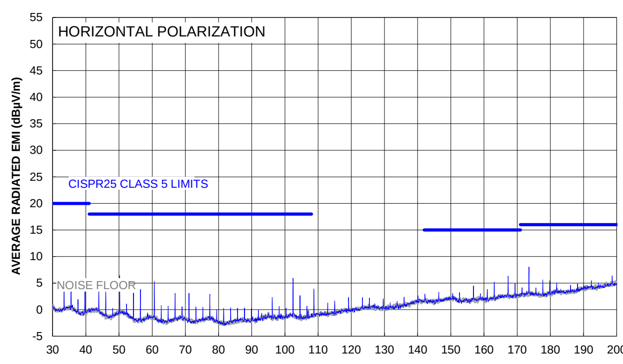
CISPR25 Class 5 Average Radiated Emissions
150kHz to 30MHz



CISPR25 Class 5 Peak Radiated Emissions
Horizontal, 30MHz to 200MHz



CISPR25 Class 5 Average Radiated Emissions
Horizontal, 30MHz to 200MHz

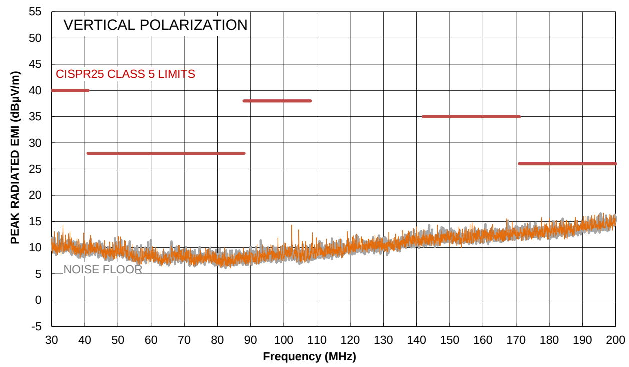


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 3A, L = 2.2μH, f_{SW} = 2.2MHz, with EMI filters, T_A = 25°C, unless otherwise noted. (10)

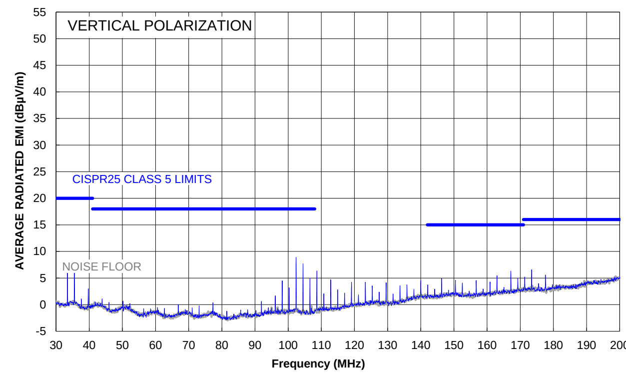
CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 200MHz



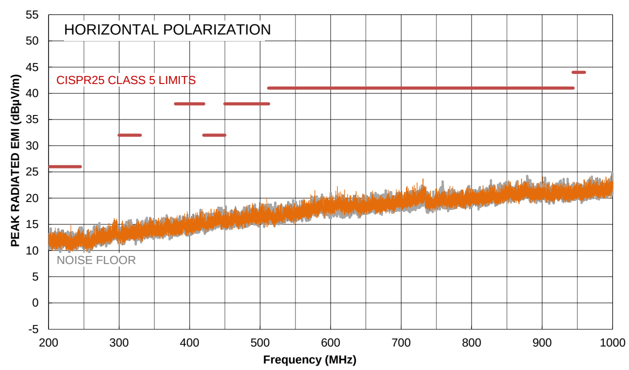
CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 200MHz



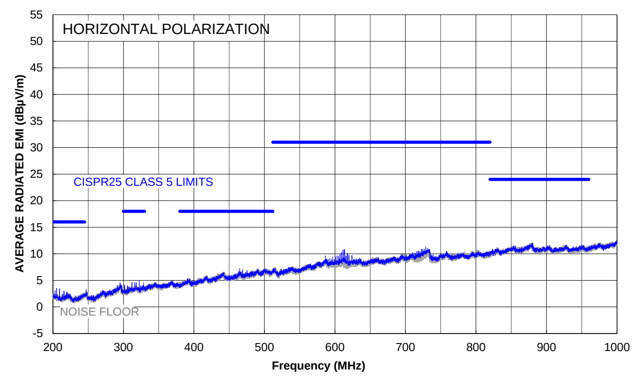
CISPR25 Class 5 Peak Radiated Emissions

Horizontal, 200MHz to 1GHz



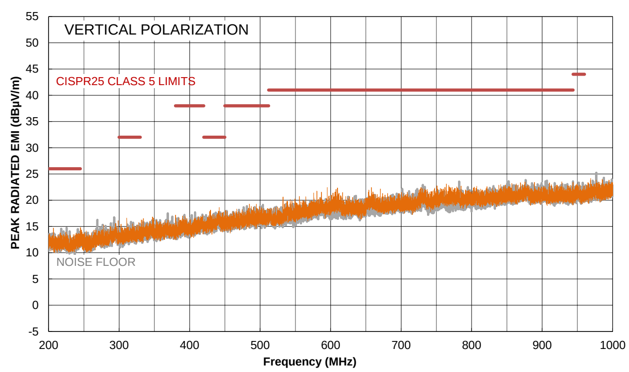
CISPR25 Class 5 Average Radiated Emissions

Horizontal, 200MHz to 1GHz



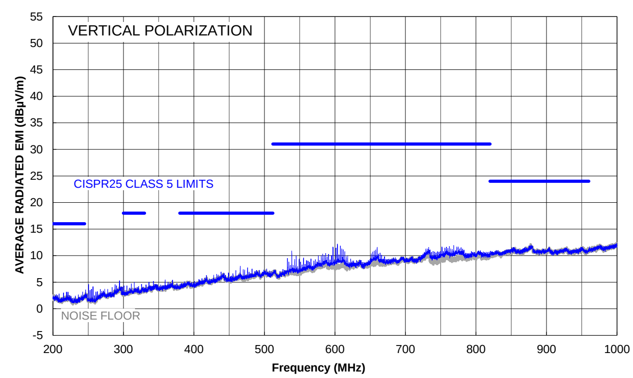
CISPR25 Class 5 Peak Radiated Emissions

Vertical, 200MHz to 1GHz



CISPR25 Class 5 Average Radiated Emissions

Vertical, 200MHz to 1GHz



Note:

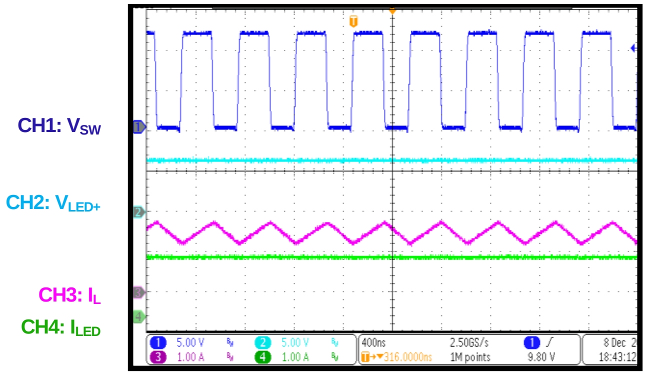
10) The MPQ7235 EMI test results are based on the application circuit with EMI filters in Figure 9.

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

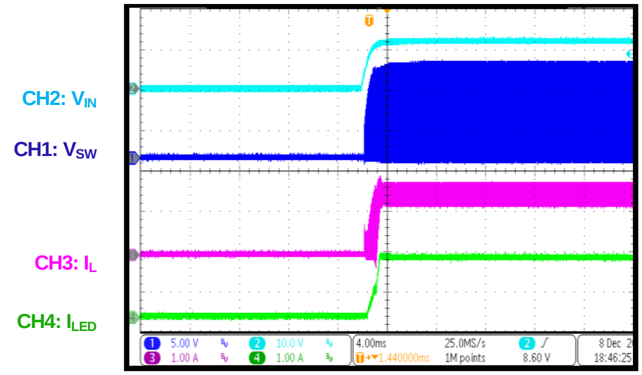
Steady State

I_{LED} = 1.5A



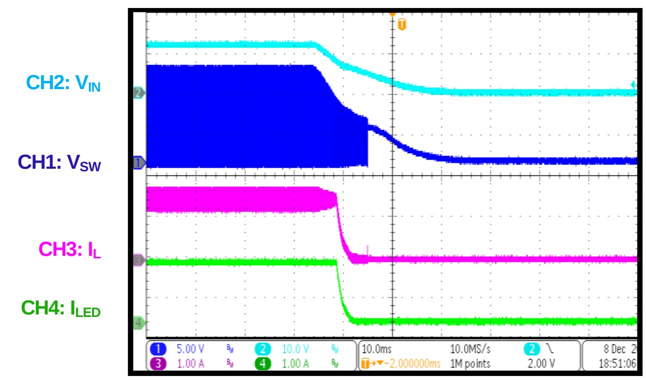
Start-Up through V_{IN}

I_{LED} = 1.5A



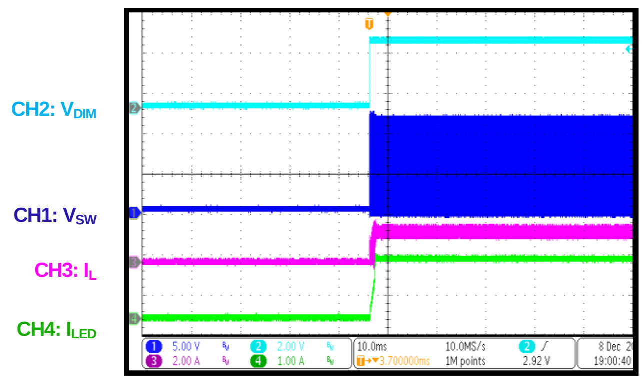
Shutdown through V_{IN}

I_{LED} = 1.5A



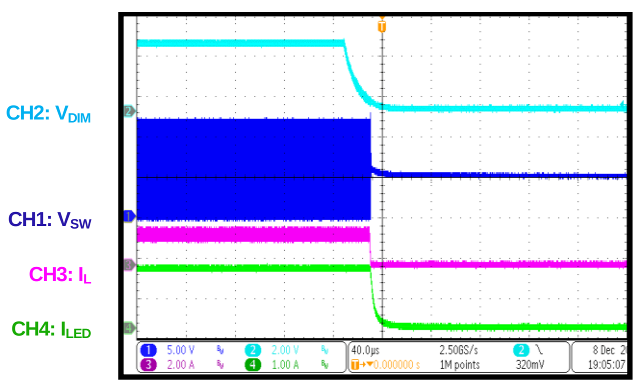
Start-Up through DIM

I_{LED} = 1.5A



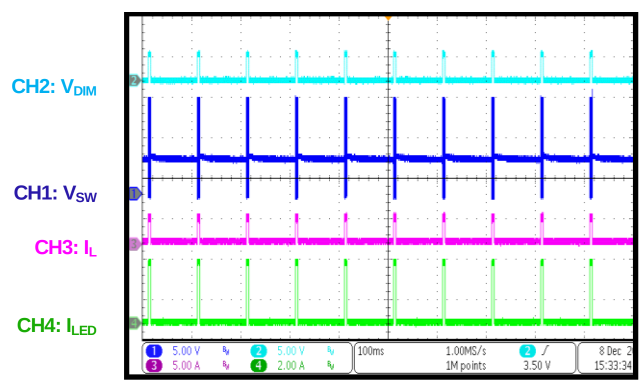
Shutdown through DIM

I_{LED} = 1.5A



PWM Dimming Steady State

Dimming Frequency = 10Hz/5ms, I_{PEAK} = 3A

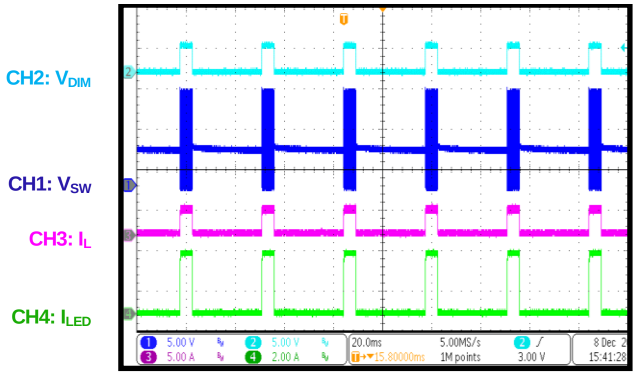


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

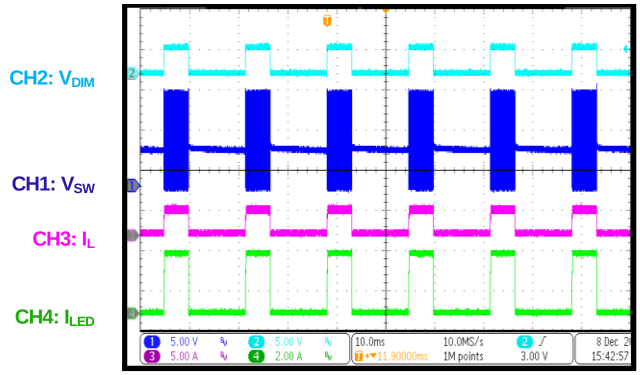
PWM Dimming Steady State

Dimming Frequency = 30Hz/5ms, I_{PEAK} = 3A



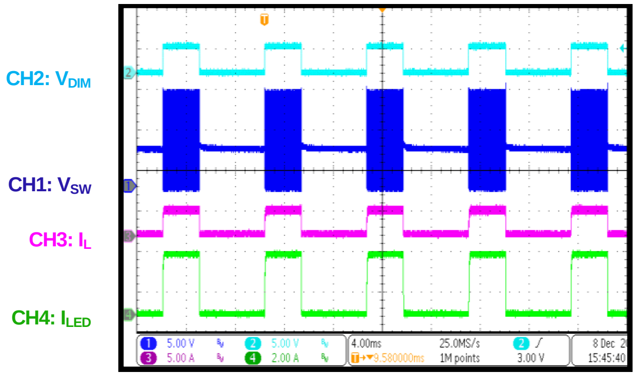
PWM Dimming Steady State

Dimming Frequency = 60Hz/5ms, I_{PEAK} = 3A



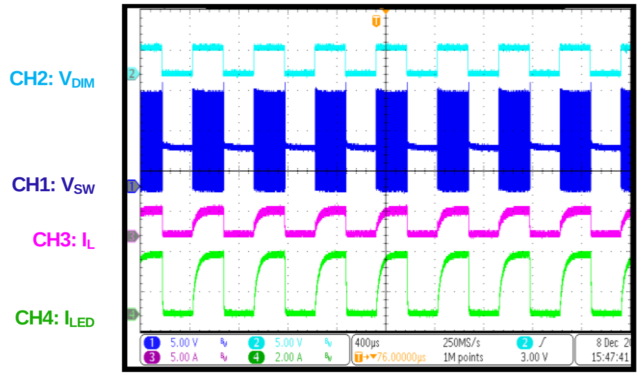
PWM Dimming Steady State

Dimming Frequency = 120Hz/3ms, I_{PEAK} = 3A



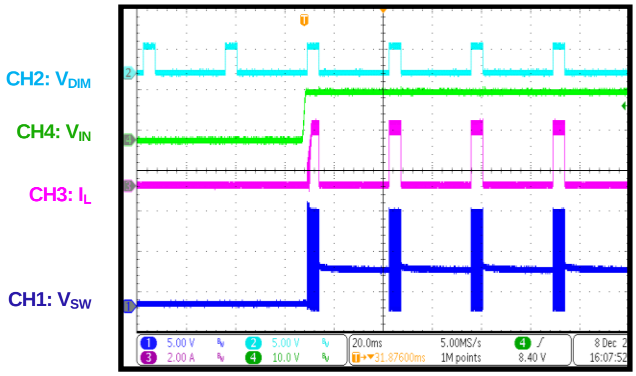
PWM Dimming Steady State

Dimming Frequency = 2kHz/50%, I_{PEAK} = 3A



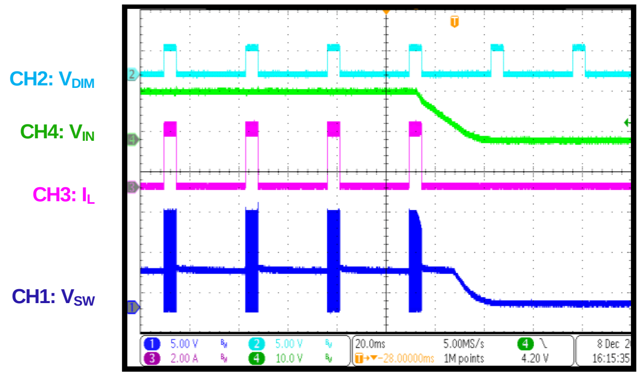
PWM Dimming

Start-Up through V_{IN}, I_{PEAK} = 3A



PWM Dimming

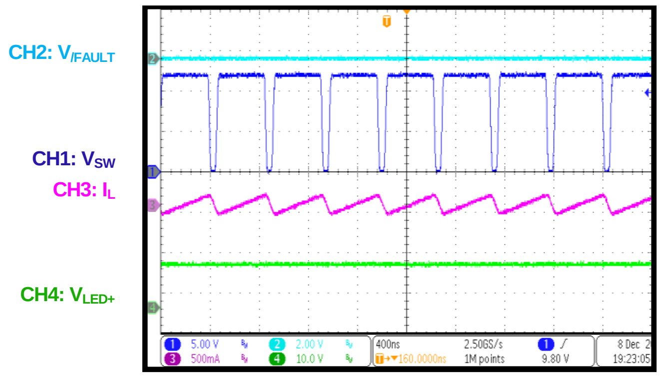
Shutdown through V_{IN}, I_{PEAK} = 3A



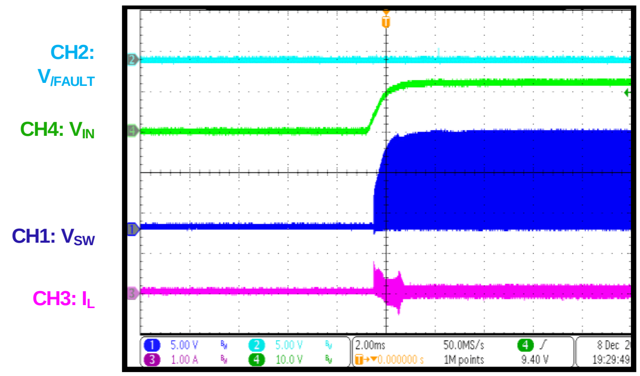
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

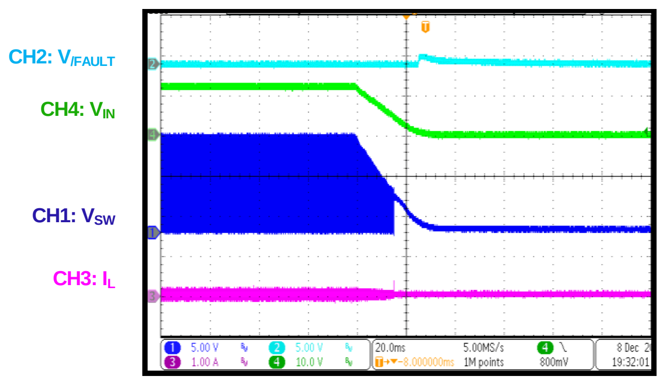
LED Open Steady State



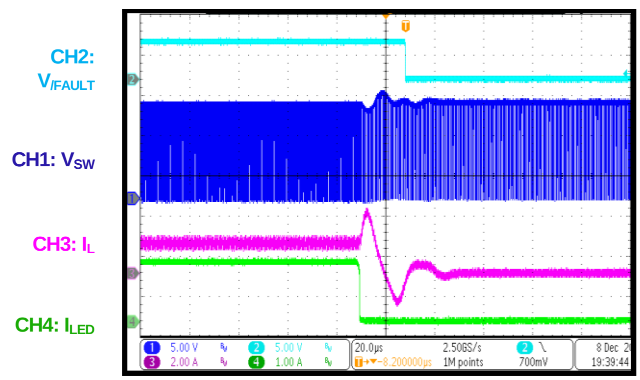
LED Open Input Power-On



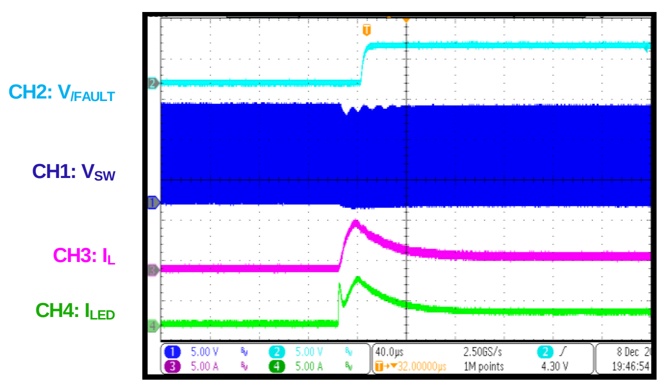
LED Open Input Power-Off



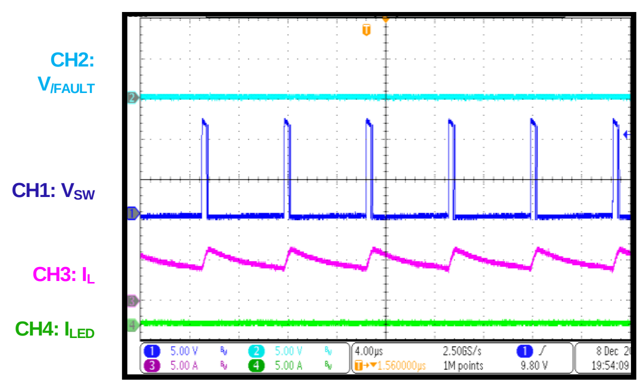
LED Open Entry



LED Open Recovery



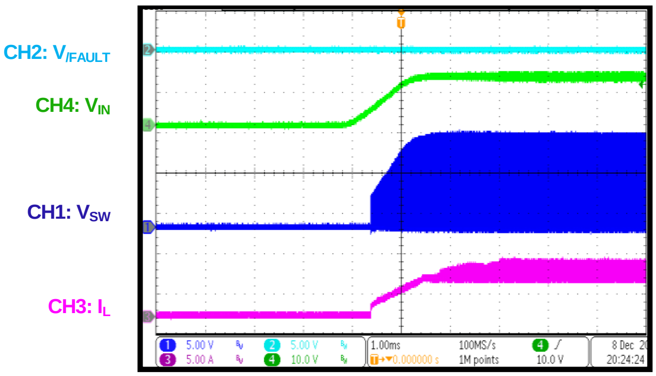
LED+ Short to GND Steady State



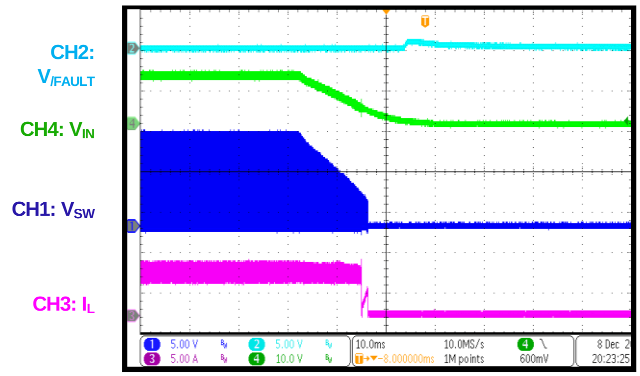
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

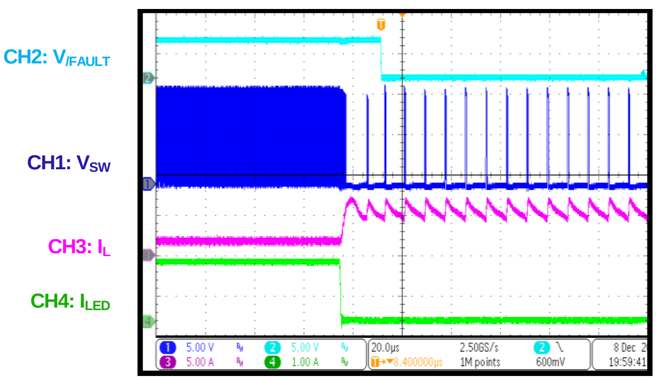
LED+ Short to GND Input Power-On



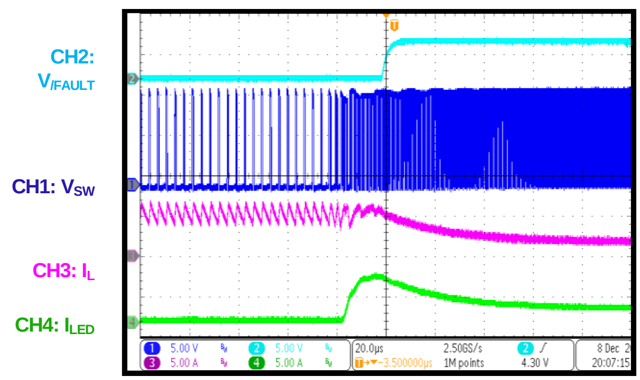
LED+ Short to GND Input Power-Off



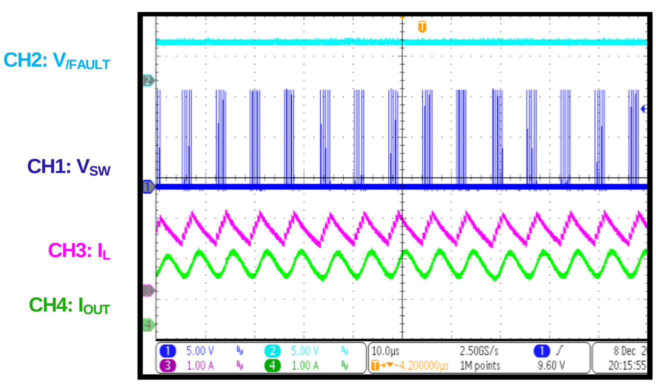
LED+ Short to GND Entry



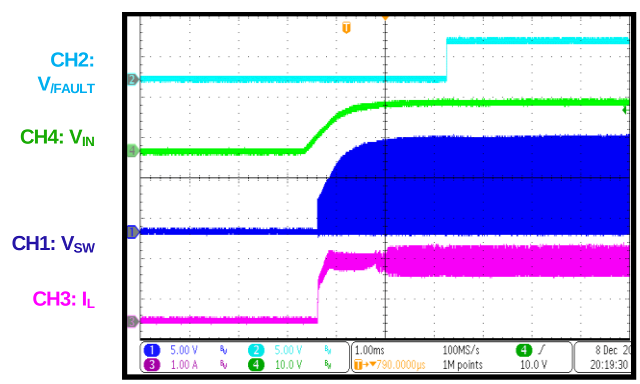
LED+ Short to GND Recovery



LED+ Short to LED- Steady State



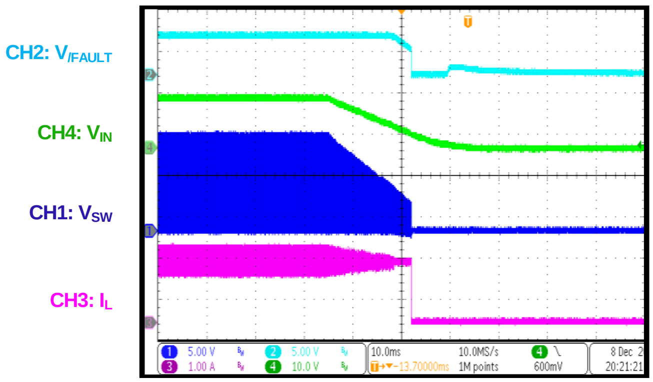
LED+ Short to LED- Input Power-On



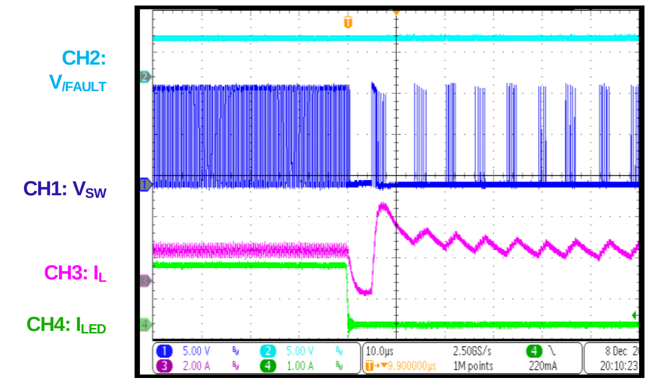
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

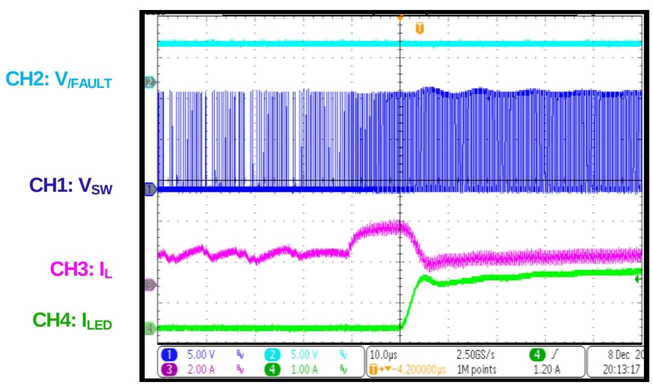
LED+ Short to LED- Input Power-Off



LED+ Short to LED- Entry

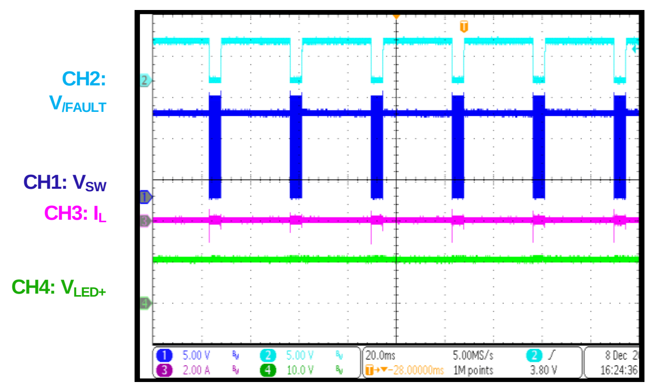


LED+ Short to LED- Recovery



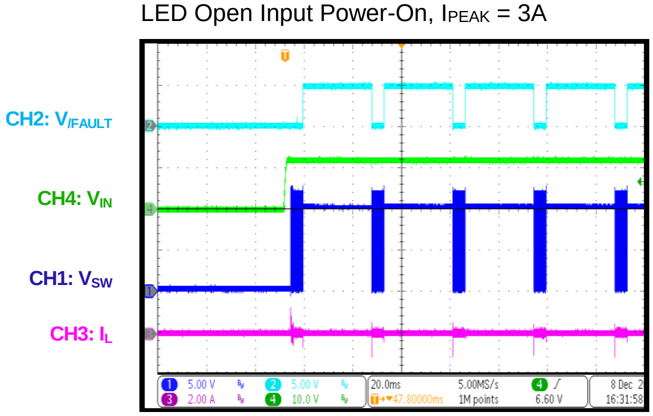
PWM Dimming

LED Open Steady State, I_{PEAK} = 3A



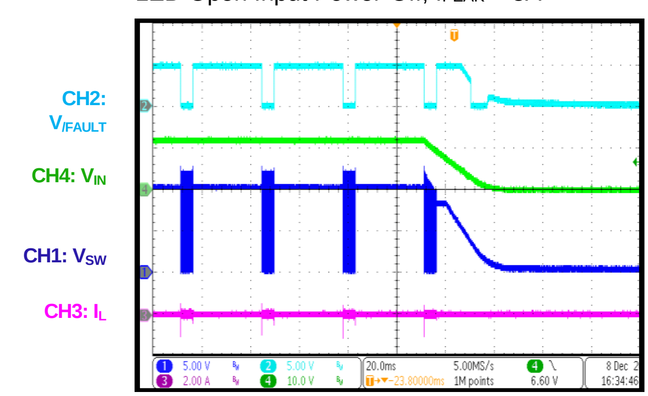
PWM Dimming

LED Open Input Power-On, I_{PEAK} = 3A



PWM Dimming

LED Open Input Power-Off, I_{PEAK} = 3A

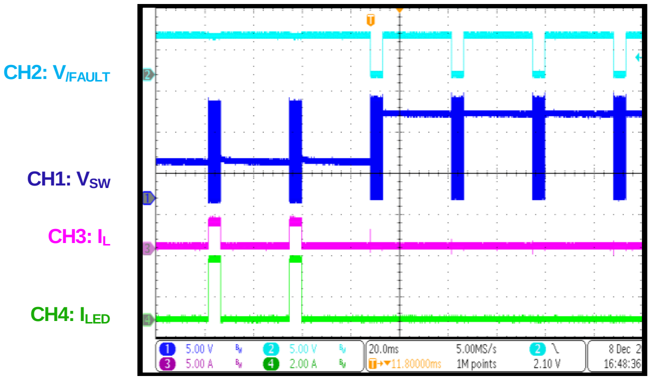


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

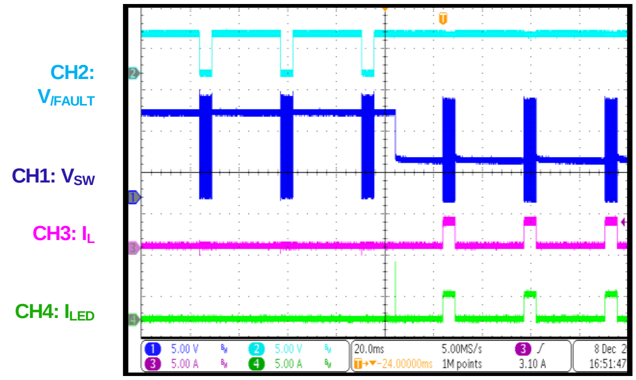
PWM Dimming

LED Open Entry, I_{PEAK} = 3A



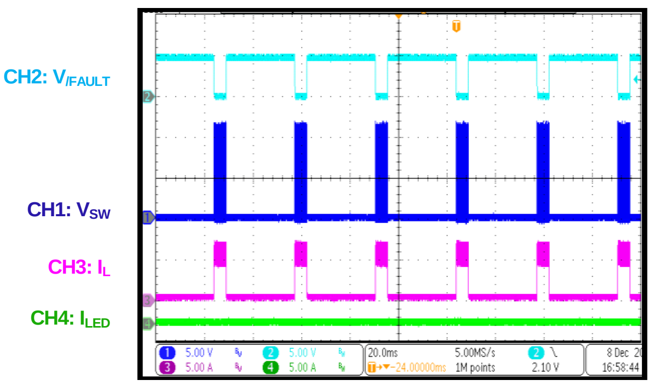
PWM Dimming

LED Open Recovery, I_{PEAK} = 3A



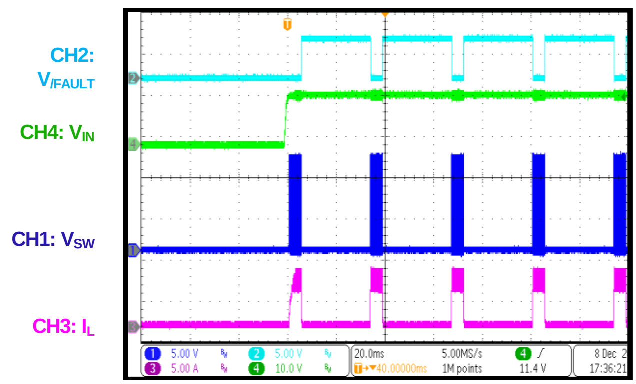
PWM Dimming

LED+ Short to GND Steady State, I_{PEAK} = 3A



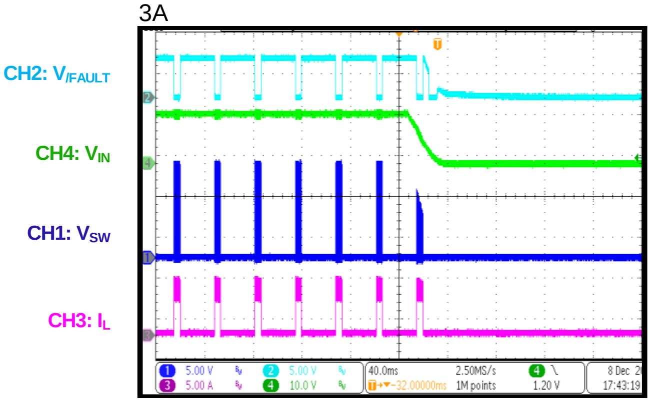
PWM Dimming

LED+ Short to GND Input Power-On, I_{PEAK} = 3A



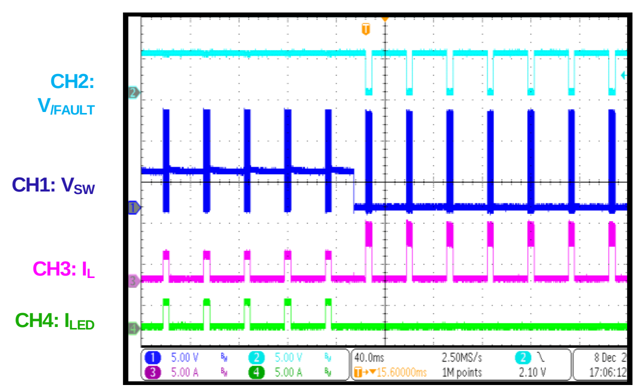
PWM Dimming

LED+ Short to GND Input Power-Off, I_{PEAK} = 3A



PWM Dimming

LED+ Short to GND Entry, I_{PEAK} = 3A

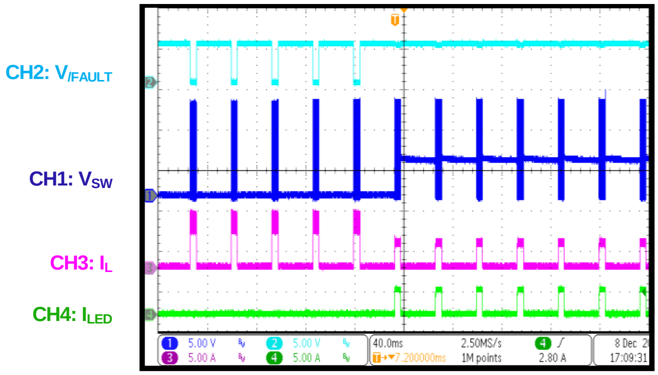


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{LED+} - V_{LED-} = 2 x 3.2V @ I_{LED} = 1.5A, L = 2.2µH, f_{SW} = 2.2MHz, T_A = 25°C, unless otherwise noted.

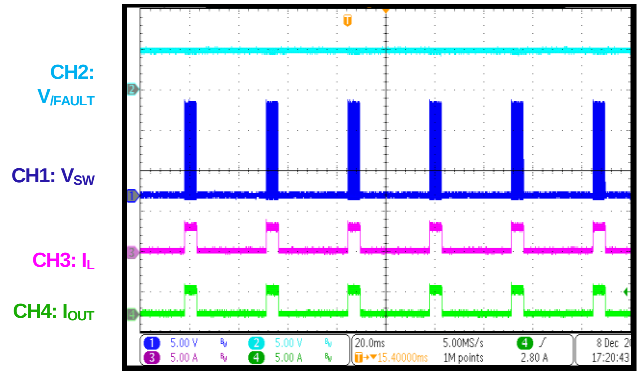
PWM Dimming

LED+ Short to GND Recovery, I_{PEAK} = 3A



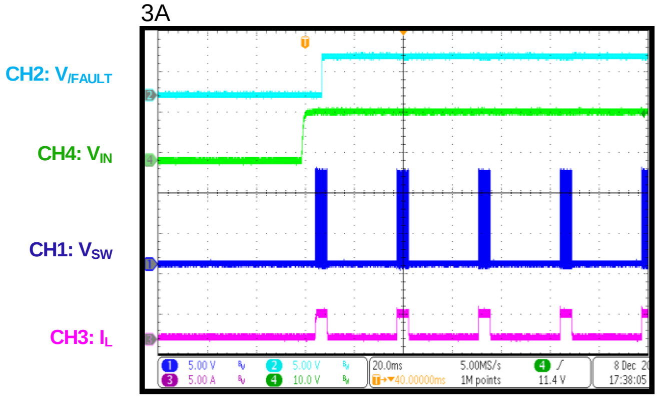
PWM Dimming

LED+ Short to LED- Steady State, I_{PEAK} = 3A



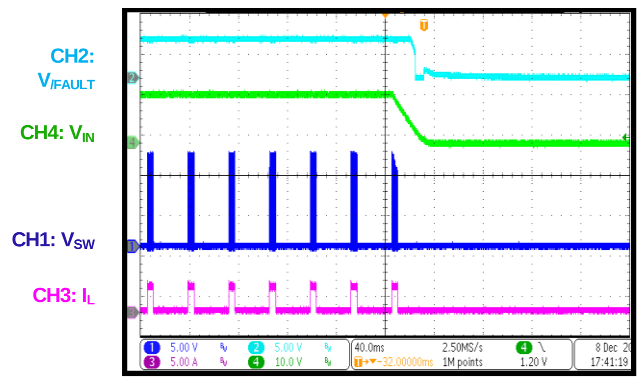
PWM Dimming

LED+ Short to LED- Input Power-On, I_{PEAK} = 3A



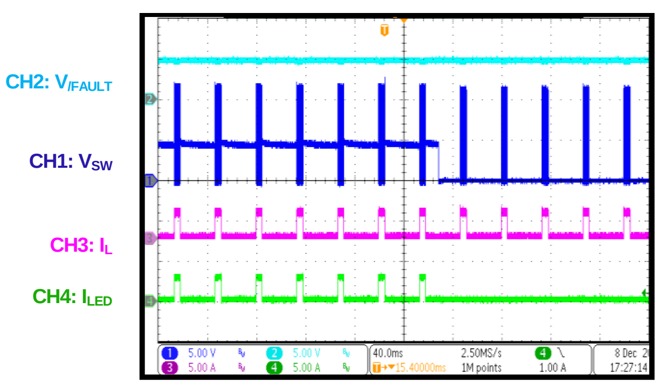
PWM Dimming

LED+ Short to LED- Input Power-Off, I_{PEAK} = 3A



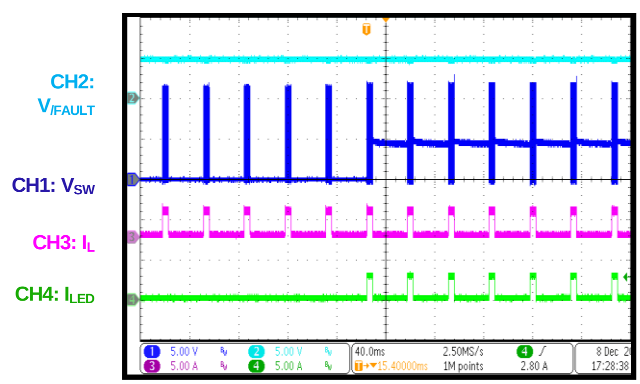
PWM Dimming

LED+ Short to LED- Entry, I_{PEAK} = 3A



PWM Dimming

LED+ Short to LED- Recovery, I_{PEAK} = 3A



FUNCTIONAL BLOCK DIAGRAM

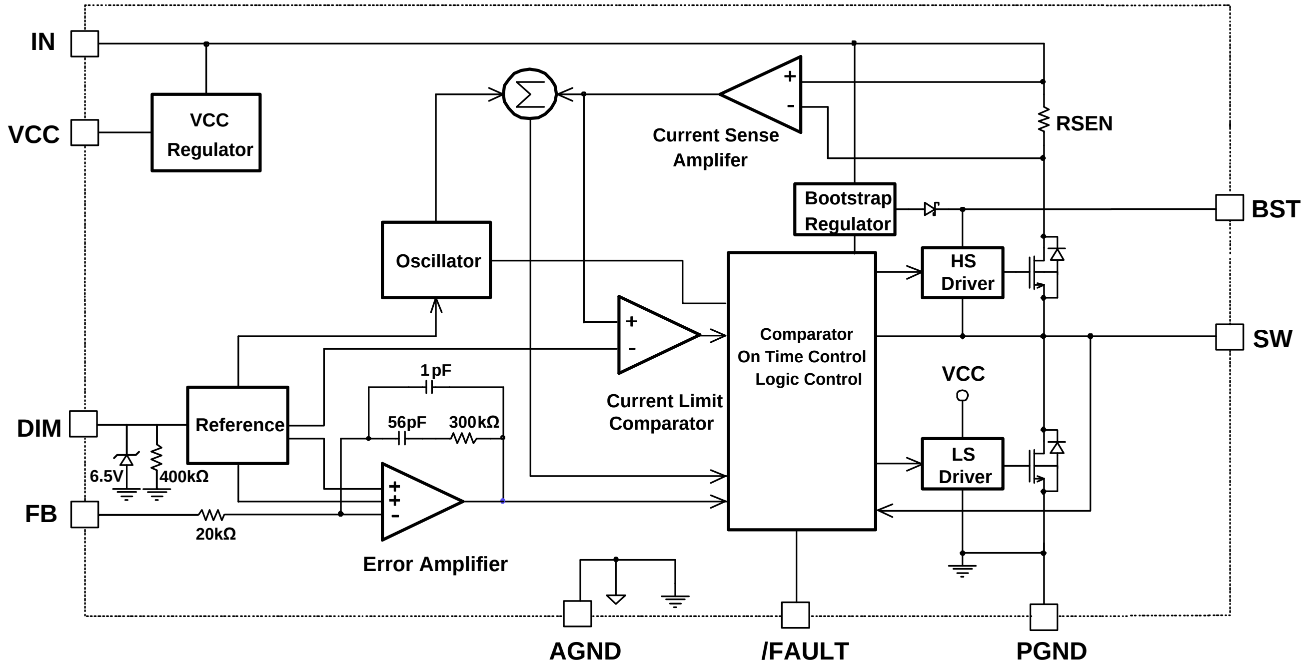


Figure 1: Functional Block Diagram

OPERATION

The MPQ7235 is a high-frequency, synchronous rectified, step-down, switch-mode LED driver with built-in power MOSFETs. It offers a very compact solution to achieve 1.5A continuous output current and 3A peak current with low PWM dimming frequency at small dimming duty cycle; it has excellent load and line regulation over a 4V to 36V input supply range.

The MPQ7235 operates in a fixed-frequency, peak-current–control mode to regulate the output current. An internal clock initiates a PWM cycle. The integrated high-side power MOSFET turns on and remains on until its current reaches the value set by the COMP voltage (V_{COMP}). When the power switch is off, it remains off until the next clock cycle starts. If the current in the power MOSFET does not reach the current value set by V_{COMP} within 87% of one PWM period, the power MOSFET is forced off.

Internal Regulator

The 4.9V internal regulator power most of the internal circuitries. This regulator takes the V_{IN} input and operates in the full V_{IN} range: When V_{IN} exceeds 4.9V, the output of the regulator is in full regulation; When V_{IN} falls below 4.9V, the output decreases following V_{IN}. A 0.1uF decoupling ceramic capacitor is needed at the pin.

The 4.9V internal regulator also can be used for biasing other circuitries up to 10mA load.

FCCM Operation

The MPQ7235 uses forced continuous conduction modulation (FCCM) mode to ensure that the part works with fixed frequency from a no-load to a full-load range. The advantage of FCCM is the controllable frequency and lower output ripple at light load.

Frequency Foldback

The MPQ7235 enters frequency foldback when the input voltage is higher than about 21V. The frequency decreases to half the nominal value and changes to 1.1MHz.

Frequency foldback also occurs during soft start and short-circuit protection.

Error Amplifier (EA)

The error amplifier compares the FB pin voltage to the internal 0.2V reference (V_{REF}) and outputs a current proportional to the difference between the two. This output current then charges or discharges the internal compensation network to form V_{COMP}, which controls the power MOSFET current. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

PWM Dimming

Apply an external 10Hz to 2kHz PWM waveform to the DIM pin for PWM dimming. The average LED current is proportional to PWM duty. The minimum amplitude of the PWM signal is 1.35V. If dimming signal is applied before the part starts up, the on time of the first dimming signal that the part does see must be longer than 5ms to make sure the soft start is finished, so output current can be built; then the dimming on time can be shorter after the first pulse, detail see figure 2. If dimming signal is applied after soft start is finished, the above 5ms limit is not required.

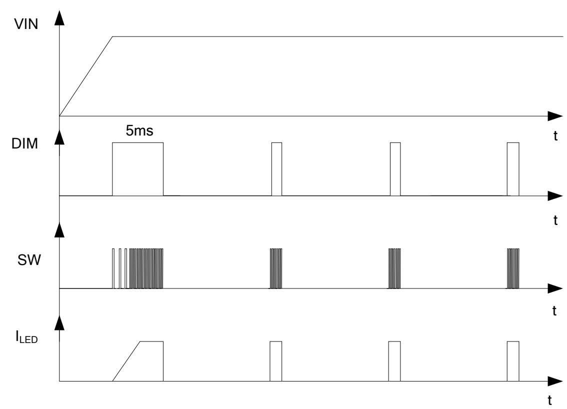


Figure 2: Timing with PWM Dimming Active

DIM is clamped internally using a 6.5V series Zener diode (see Figure 3). Connecting the DIM input through a pull-up resistor to the voltage on V_{IN} limits the DIM input current below 100uA. For example, with 36V connected to V_{IN}, $R_{PULL-UP} \geqslant (36V - 6.5V) \div 100\mu A = 295k\Omega$.

Connecting DIM to a voltage source directly without a pull-up resistor requires limiting the amplitude of the voltage source to ≤6V to prevent damage to the Zener diode.

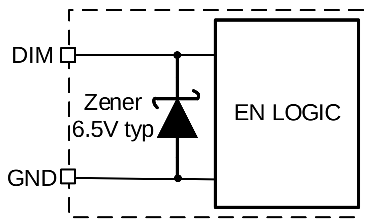


Figure 3: 6.5V Zener Diode Connection

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. The UVLO comparator monitors the output voltage of the internal regulator (VCC).

Internal Soft Start (SS)

The soft start (SS) prevents the converter output voltage from overshooting during start-up. When soft start block starts work, the internal circuitry generates a soft start voltage (V_{SS}). When V_{SS} is lower than the internal reference (V_{REF}), V_{SS} overrides V_{REF}, so the error amplifier uses V_{SS} as the reference. When V_{SS} exceeds V_{REF}, the error amplifier uses V_{REF} as the reference.

During soft start, the part has no fault detection, which means the /FAULT pin is pulled low when soft start.

Fault Indicator

The MPQ7235 has fault indication. The /FAULT pin is the open drain of a MOSFET. It should be connected to VCC or some other voltage source through a resistor (e.g. 100kΩ). /FAULT pin is pulled low when the part is disabled or thermal shutdown.

When DIM pin is always high (no dimming), /FAULT pin is pulled high at normal operation, and /FAULT is pulled low when LED short/open, to indicate a fault status.

When with PWM dimming single input (PWM dimming), /FAULT pin is pulled high at normal operation and no matter DIM is high or low; /FAULT is pulled low when LED short/open at DIM high, and pulled high at DIM low.

Over-Current Protection (OCP)

The MPQ7235 has cycle-by-cycle peak current-limit protection with valley-current detection. The inductor current is monitored during the high-side MOSFET (HS-FET) on-state. If the inductor current exceeds the peak current limit value (the typical value is 6A) set by the COMP high-clamp voltage, the HS-FET turns off immediately. Then the low-side MOSFET (LS-FET) turns on to discharge the energy, and the inductor current decreases. The HS-FET remains off unless the inductor valley current is lower than a certain current threshold (the valley current limit, the typical value is about 3.5A), even though the internal clock pulses high. If the inductor current does not drop below the valley current limit when the internal clock pulses high, the HS-FET misses the clock, and the switching frequency decreases to half the nominal value. Both the peak and valley current limits assist in keeping the inductor current from running away during an overload or short-circuit condition.

Reverse Current Protection

The MPQ7235 has a 1.2A reverse current limit. Once the inductor current reaches the reverse current limit, the LS-FET immediately turns off and the HS-FET turns on. The current limit prevents the negative current from dropping too low and damaging the components.

Thermal Shutdown (TSD)

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the die temperature exceeds 170°C, the entire chip shuts down. When the temperature drops below its lower threshold (typically 140°C), the chip is enabled again.

Floating Driver and Bootstrap Charging

An external bootstrap capacitor powers the floating power MOSFET driver. This floating driver has its own UVLO protection, with a rising threshold of 2.2V and hysteresis of 150mV. The bootstrap capacitor voltage is regulated internally by V_{IN} through D1, M1, C3, L1 and C4 (see Figure 4). If (V_{IN} - V_{SW}) exceeds 5V, U1 regulates M1 to maintain a 5V BST voltage across C4. As long as V_{IN} is sufficiently higher than SW, the bootstrap capacitor can be charged. When the HS-FET is on, $V_{IN} \approx V_{SW}$, so the bootstrap capacitor cannot be charged. When the LS-FET is on, V_{IN} - V_{SW} reaches its maximum for fast charging. When there is no inductor current, V_{SW} = V_{OUT}, so the difference between V_{IN} and V_{OUT} can charge the bootstrap capacitor. A 20Ω resistor placed between SW and BST cap is strongly recommended to reduce SW spike voltage.

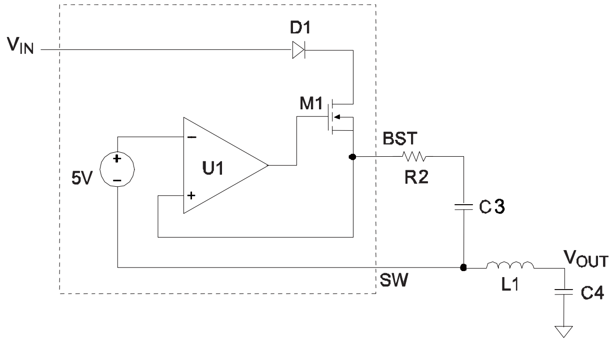


Figure 4: Internal Bootstrap Charging Circuit

Start-up and Shutdown

If V_{IN} exceed its appropriate threshold, the chip starts up, and then the internal regulator VCC is enable, which provides a stable supply for the internal circuitries. Once the first DIM pulse is high, the reference block starts first, then the start soft block start works. Please note, after IC soft start finished, DIM low can't shut down the part, include the VCC regulator, and then there will be a ~380µA current flow into the part.

Two events can shut down the chip: V_{IN} low, and thermal shutdown. During the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. V_{COMP} and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

APPLICATION INFORMATION

Setting the Output Current

The output current is set by the external resistor R_{FB} (see Figure 5). Feedback reference voltage is 0.2V, I_{LED} is then given by Equation (1):

$$I_{LED} = \frac{0.2V}{R_{FB}} \quad (1)$$

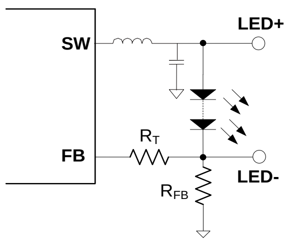


Figure 5: Feedback Network

R_T is used to set the loop bandwidth. Basically, lower R_T, higher bandwidth. But high bandwidth may cause insufficient phase margin, resulting in loop unstable. So a proper value of R_T is needed to make a trade-off between bandwidth and phase margin. Table 1 lists the recommended feedback resistor and R_T values for common output with 1 or 2 series LED.

Table 1: Resistor Selection for Common Output

I_{LED} (A)	R_{FB} (mΩ)	R_T (kΩ)
0.5	400(1%)	200
1	200(1%)	150
1.5	133(1%)	100
3	66.5(1%)	100

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, therefore it requires a capacitor to supply the 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 application, use a 4.7µF to 10µF capacitor. And it is strongly recommended to use another lower value capacitor (e.g. 0.1µF) with small package size (0603) to absorb high frequency switching noise. Make sure place the small size capacitor as close to IN and GND pins as possible.

Since C_{IN} absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (2):

$$I_{CIN} = I_{LED} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})} \quad (2)$$

The worst case condition occurs at $V_{IN} = 2V_{OUT}$, shown in Equation (3):

$$I_{CIN} = \frac{I_{LED}}{2} \quad (3)$$

For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, add a small, high-quality ceramic capacitor (e.g. 0.1µF) as close to the IC as possible. When using ceramic capacitors, ensure that they have enough capacitance to provide a sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated with Equation (4):

$$\Delta V_{IN} = \frac{I_{LED}}{f_{SW} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (4)$$

Selecting the Output Capacitor

The output capacitor maintains the DC output voltage. Use ceramic, tantalum, or low-ESR electrolytic capacitors. For best results, use low ESR capacitors to keep the output voltage ripple low. The output voltage ripple can be estimated with Equation (5):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \cdot (1 - \frac{V_{OUT}}{V_{IN}}) \cdot (R_{ESR} + \frac{1}{8 f_{SW} \times C_{OUT}}) \quad (5)$$

Where L is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

For ceramic capacitors, the capacitance dominates the impedance at the switching frequency, and the capacitance causes the majority of the output voltage ripple. For simplification, the output voltage ripple can be estimated with Equation (6):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^{2} \times L \times C_{OUT}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (6)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated with Equation (7):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \times R_{ESR} \quad (7)$$

The characteristics of the output capacitor also affect the stability of the regulation system. The MPQ7235 can be optimized for a wide range of capacitance and ESR values.

Selecting the Inductor

A 1µH to 10µH inductor with a DC current rating at least 25% higher than the maximum load current is recommended for most applications. For higher efficiency, choose an inductor with lower DC resistance. A larger value inductor results in less ripple current and a lower output ripple voltage. However, the larger value inductor also has a larger physical size, higher series resistance, and lower saturation current. A good rule for determining the inductor value is to allow the inductor ripple current to be approximately 30% of the maximum load current. The inductance value can be then be calculated with Equation (8):

$$L = \frac{V_{OUT}}{f_{SW} \times \Delta I_L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (8)$$

Where ΔI_L is the peak-to-peak inductor ripple current.

Choose the inductor ripple current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (9):

$$I_{LP} = I_{LED} + \frac{V_{OUT}}{2f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (9)$$

For the typical application circuit design (see Figure 9), 2.2uH inductor is sufficient, and VCHA042A-2R2MS6-89 is recommended here.

BST Resistor and External BST Diode

A 20ohm resistor in series with BST capacitor is recommended to reduce the SW spike voltage. Higher resistance is better for SW spike reduction, but will compromise the efficiency on the other hand.

An external BST diode can enhance the efficiency of the regulator when the duty cycle is high (>65%). A power supply between 2.5V and 5V can be used to power the external bootstrap diode and VCC or V_{OUT} is the good choice of this power supply in the circuit (see Figure 6).

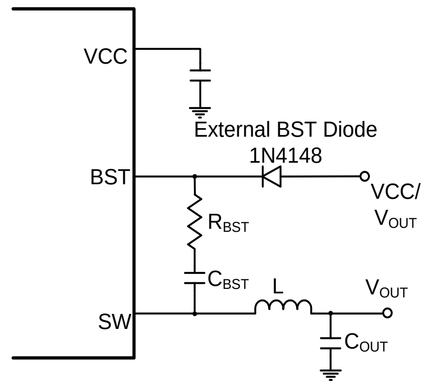


Figure 6: Optional External Bootstrap Diode to Enhance Efficiency

The recommended external BST diode is 1N4148, and the BST capacitor value is 0.1µF to 1µF.

Low Dimming Frequency Application

For application with low PWM dimming frequency at small dimming duty cycle, the V_{COMP} (the error amplifier output voltage) voltage maybe discharged by the leakage if dimming off time is too long. It is suggested the minim dimming frequency is not lower than 10Hz.

PCB Layout Guidelines

Efficient PCB layout is critical for stable operation, especially for input capacitor placement. And the small board size is suitable for IR application, MPQ7235 could achieve small size with 30mm×20mm. For best results, refer to Figure 7 follow the guidelines below: [11]

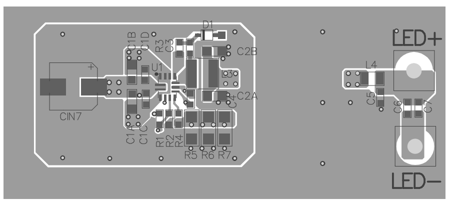
1. Use a large ground plane to connect directly to PGND. If the bottom layer is a ground plane, add vias near PGND.
2. Ensure that the high-current paths at PGND and IN have short, direct, and wide traces.
3. Place the ceramic input capacitor, especially the small package (0603) input bypass capacitor as close to IN and PGND pins as possible to minimize high frequency noise.

Keep the connection of the input capacitor and IN as short and wide as possible.

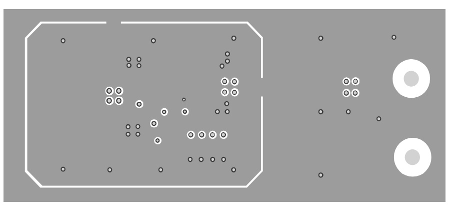
4. Place the VCC capacitor to VCC pin and GND pin as close as possible.
5. Route SW, BST away from sensitive analog areas such as FB.
6. Place the feedback resistors close to chip to ensure the trace which connects to FB pin as short as possible.
7. A four-layer layout is strongly recommended to achieve better thermal performance. Use multiple vias to connect the power planes to internal layers.

Note:

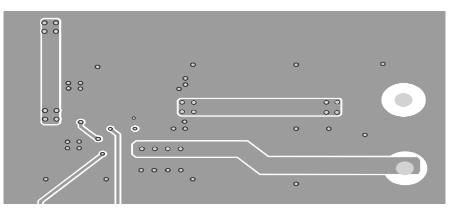
11) The recommended PCB layout is based on the Typical Application Circuit (see Figure 8).



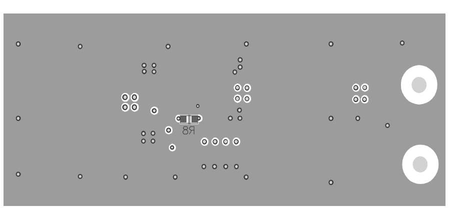
Top Layer



Inner1 Layer



Inner2 Layer



Bottom Layer

Figure 7: Recommended PCB Layout (11)

TYPICAL APPLICATION CIRCUIT

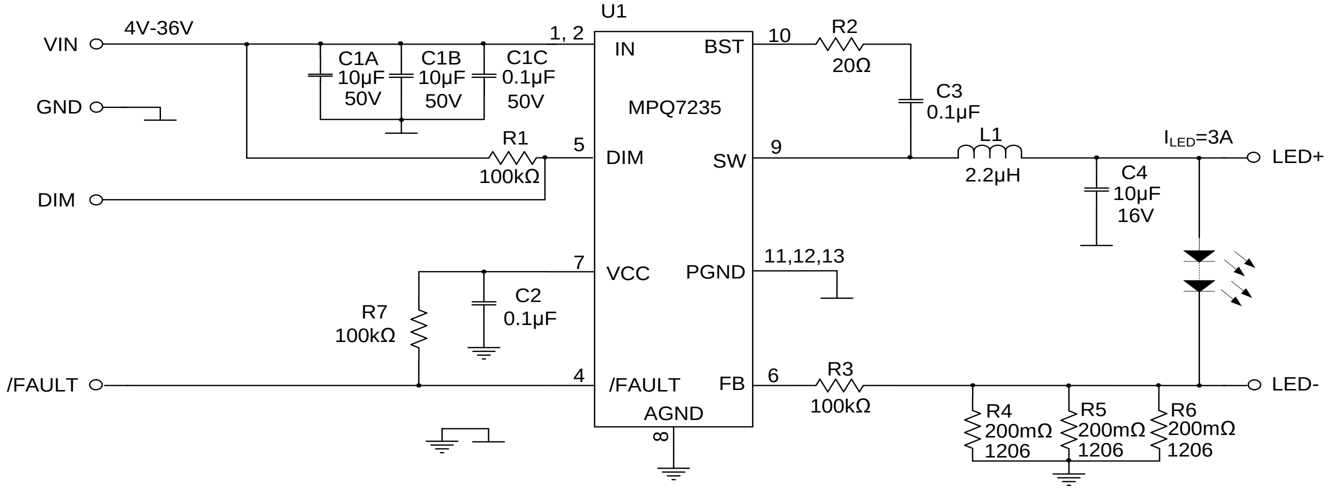


Figure 8: I_{LED}=3A Application Circuit

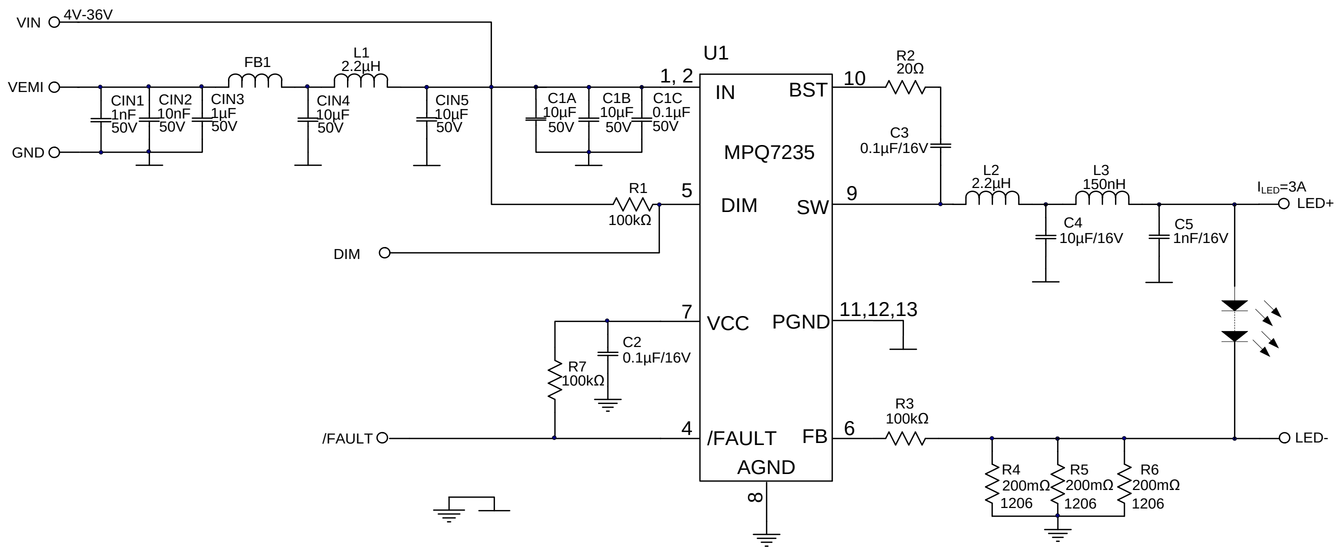
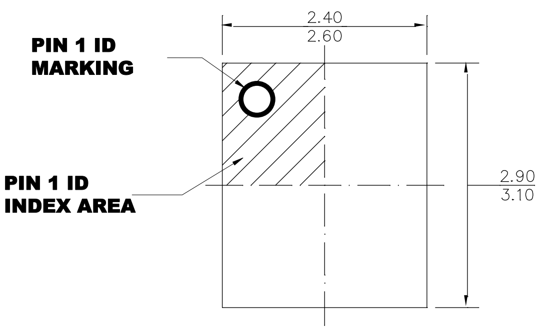


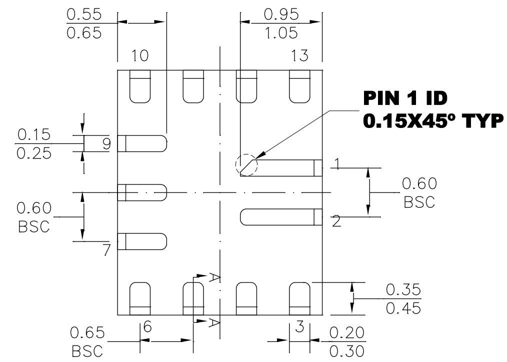
Figure 9: I_{LED}=3A Application Circuit with EMI Filters

PACKAGE INFORMATION

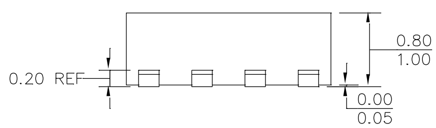
QFN-13 (2.5mmx3mm)
Wettable Flank



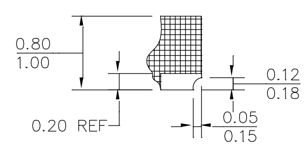
TOP VIEW



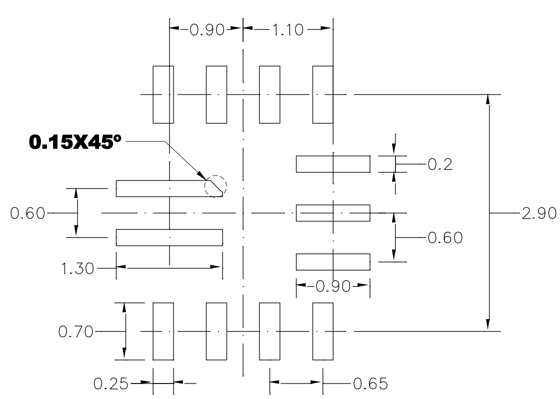
BOTTOM VIEW



SIDE VIEW



SECTION A-A

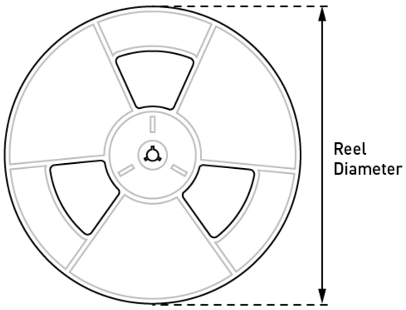


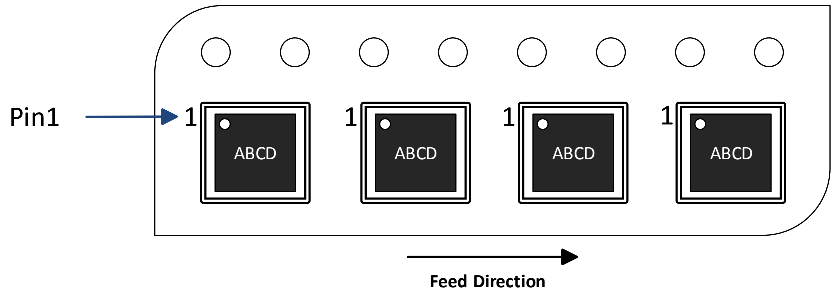
RECOMMENDED LAND PATTERN

NOTE:

1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
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	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MPQ7235GQBE-AEC1-Z	QFN-13 (2.5mmx3mm)	5000	NA	13 in.	12 mm	8 mm

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