# MPQ3359A

## 1-/2-/3-/4-Channel, Max 150mA/Ch, Boost WLED Driver with High Dimming Ratio, AEC-Q100 Qualified

## DESCRIPTION

The MPQ3359A is a step-up converter with 4 channel current sources. The device is designed to drive white LED arrays as backlighting for small- or medium-sized LCD panels.

The device uses peak current mode as its pulse-width modulation (PWM) control architecture to regulate the boost converter. Four channel current sources are applied to the LED cathode to adjust LED brightness. The MPQ3359A regulates the current in each LED string to the value set by an external current-setting resistor, with 2.5% current regulation accuracy between strings.

A low on resistance MOSFET and headroom voltage are provided to improve efficiency. The switching frequency ($f_{SW}$) can be configured via a resistor or external clock.

The MPQ3359A provides analog and PWM dimming with two separate input pins (EN/ADIM and PDIM). The device also has a fixed delay time between LED current channels to eliminate noise during PWM dimming.

Robust protections are included to guarantee safe operation of the device. Protection modes include over-current protection (OCP), over-voltage protection (OVP), over-temperature protection (OTP), LED string open/short protection, and LEDx pin short to GND protection.

The MPQ3359A is available in a QFN-20 (3mmx4mm) package. It is available in AEC-Q100 Grade 1.

## FEATURES

- 3.5V to 40V Input Voltage ($V_{IN}$) Range
- 4 Channels with Maximum of 150mA per Channel
- Internal 100mΩ, 50V MOSFET
- Configurable Switching Frequency ($f_{SW}$) Up to 2.2MHz
- External Sync SW Function
- Pulse-Width Modulation (PWM) Dimming
- Analog Dimming
- Deep Dimming Ratio
- Excellent EMI Performance and Frequency Spread Spectrum (FSS)
- Fixed 100μs Delay Time between LED Current Channels during PWM Dimming (Replaces Phase Shift)
- 2.5% Current Matching
- Cycle-by-Cycle Current Limiting
- Disconnect VOUT from VIN
- Input Over-Current Protection (OCP)
- LED String Open/Short Protection
- Over-Temperature Protection (OTP)
- Inductor Over-Current Protection (OCP)
- Inductor/Diode Short Protection
- LEDx Pin Short to GND Protection
- Be Able to Disable LED4 if LED4 is Unused
- Fault Indicator Signal Output
- Available in a QFN-20 (3mmx4mm) Package
- Available in AEC-Q100 Grade 1

## APPLICATIONS

- Automotive Displays
- Tablets and Notebooks

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## TYPICAL APPLICATION (1) (2) (3) (4)

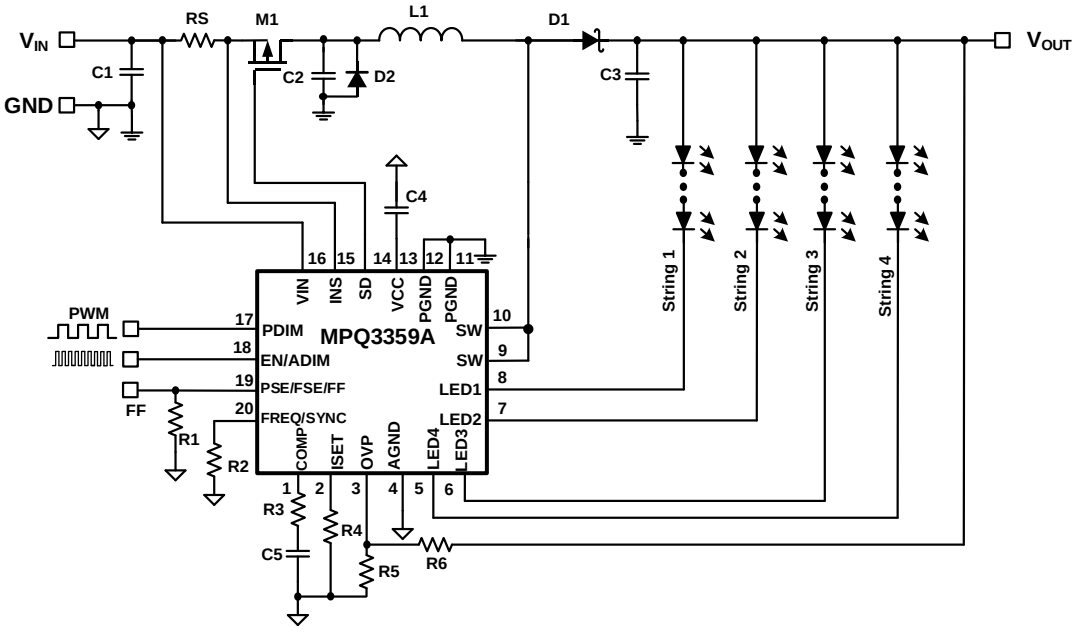


**Figure 1: Typical Application with 4 Strings**

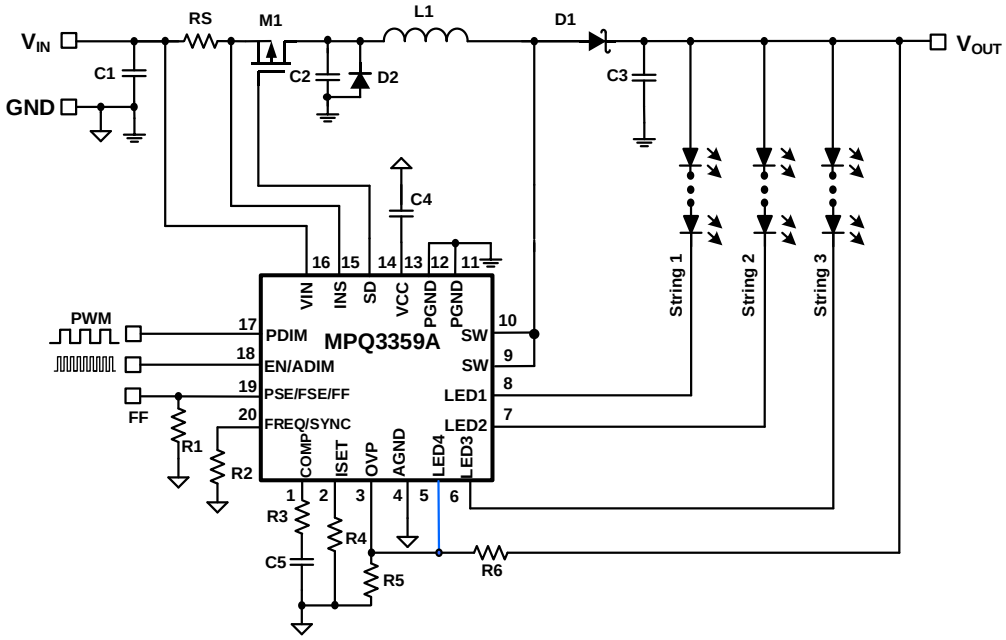


**Figure 2: Typical Application with 3 Strings (Connect LED4 to the OVP Pin)**

**Notes:**

1) For 1 channel, tie LED1~4 together.
2) For 2 channels, tie LED1~2 together, and tie LED3~4 together.
3) For 3 channels, connect the LED4 pin to the OVP pin.
4) M1 and D2 must be used together.


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## ORDERING INFORMATION

| Part Number* | Package | Top Marking | MSL Rating |
|---|---|---|---|
| MPQ3359AGLE-AEC1* | QFN-20 (3mmx4mm) WF | *See Below* | 1 |

* For Tape & Reel, add suffix -Z (e.g. MPQ3359AGLE-AEC1-Z).

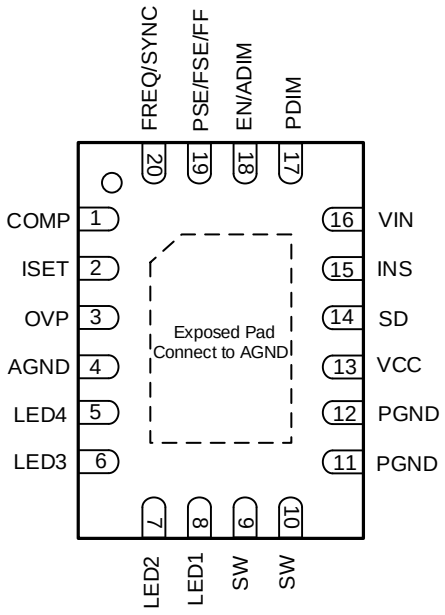
## TOP MARKING
## (MPQ3359AGLE-AEC1)

**MPYW**
**3359**
**ALLL**
**E**

MP: MPS prefix
Y: Year code
W: Week code
3359A: Part number
LLL: Lot number
E: Wettable flank

## PACKAGE REFERENCE

**TOP VIEW**




**QFN-20 (3mmx4mm)**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## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1 | COMP | **Compensation pin.** |
| 2 | ISET | **LED current setting.** Tie a current-setting resistor from ISET to GND to configure the current in each LED string. |
| 3 | OVP | **Over-voltage protection pin.** Connect a resistor divider from VOUT to OVP and OVP to GND to configure the over-voltage protection (OVP) threshold. |
| 4 | AGND | **Analog ground.** |
| 5 | LED4 | **LED string 4 current input.** Connect the LED string 4 cathode to this pin. If LED4 is not used, connect it to the OVP pin directly. |
| 6 | LED3 | **LED string 3 current input.** Connect the LED string 3 cathode to this pin. |
| 7 | LED2 | **LED string 2 current input.** Connect the LED string 2 cathode to this pin. |
| 8 | LED1 | **LED string 1 current input.** Connect the LED string 1 cathode to this pin. |
| 9, 10 | SW | **Drain for the internal low-side MOSFET switch.** Connect the power inductor to SW. |
| 11, 12 | PGND | **Step-up converter power ground.** |
| 13 | VCC | **5V LDO output pin.** The VCC pin provides power to the internal logic and gate driver. Place a ceramic capacitor as close to this pin as possible to reduce noise. |
| 14 | SD | **External disconnect P-channel MOSFET gate drive pin.** The SD pin turns off the external P-channel MOSFET if some special fault occurs. Float this pin if it is not used. |
| 15 | INS | **Input current sense pin.** When the voltage across a current-sense resister ($R_S$) exceeds the input over-current protection (OCP) threshold, the IC turns off the P-channel MOSFET. If this pin is not used, connect it to the VIN pin directly. |
| 16 | VIN | **Power supply input.** The VIN pin supplies power to the IC. |
| 17 | PDIM | **Pulse-width modulation (PWM) dimming signal input pin.** Apply a PWM signal on the PDIM pin for PWM dimming. PDIM is pulled low internally, and a 100Hz to 30kHz PWM signal is recommended. |
| 18 | EN/ADIM | **IC enable and analog dimming signal input pin.** Apply a PWM signal on the EN/ADIM pin for analog dimming. EN/ADIM is pulled low internally, and a >5kHz PWM signal is recommended. Pull this pin low for >30ms to shut down the IC. |
| 19 | PSE/ FSE/FF | **Delay function enable, frequency spread spectrum (FSS) enable, and fault flag pin.** The PSE/FSE/FF pin is a current-source output (32μA). Connect a resistor from this pin to GND to configure its voltage. After VIN and EN power on, the IC detects the PSE/FSE/FF pin's voltage to enable the corresponding functions:<br>• >2.85V: Enable the delay function and FSS function.<br>• 2V to 2.55V: Enable the delay function only.<br>• 1.27V to 1.8V: Enable the FSS function only.<br>• <1.13V: Disable the delay function and FSS function.<br>If the delay function is enabled, there is a fixed 100μs delay between the LED current channels to reduce system stress and eliminate noise during PWM dimming. The FSS function improves EMI performance. The fault flag function indicates the fault status when a fault occurs, and the fault flag function is always enabled. |
| 20 | FREQ/ SYNC | **Switching frequency ($f_{SW}$) setting and SYNC pin.** The FREQ/SYNC pin configures $f_{SW}$. Connect a resistor between FREQ/SYNC and GND to set the converter's $f_{SW}$, or connect an external clock to this pin to synchronize the boost $f_{SW}$. |
| Exposed pad | AGND | **Chip ground.** Connect the exposed pad to AGND. |


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## ABSOLUTE MAXIMUM RATINGS (5)

$V_{IN}$ .....-0.3V to +42V
$V_{SW}$, $V_{LED1}$ to $V_{LED4}$.....-0.5V to +50V
$V_{SW}$..... -1.0V for <100ns
$V_{SD}$, $V_{INS}$ .....$V_{IN}$ - 6V to $V_{IN}$
$V_{SD}$, $V_{INS}$ .....> -0.3V
All other pins .....-0.3V to +6V
Junction temperature ($T_J$) .....150°C
Lead temperature .....260°C
Storage temperature..... -65°C to +150°C
Continuous power dissipation ($T_A$ = 25°C) (6)
QFN-20 (3mmx4mm)..... 2.6W

### *ESD Ratings*

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

### *Recommended Operating Conditions* (7)

Supply voltage ($V_{IN}$) .....3.5V to 40V
Operating junction temp ($T_J$).... -40°C to +150°C

### *Thermal Resistance* (8) $\theta_{JA}$ $\theta_{JC}$

QFN-20 (3mmx4mm)……....48…….10.....°C/W

**Notes:**

5) Exceeding these ratings may damage the device.
6) The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J$ (MAX), the junction-to-ambient thermal resistance, $\theta_{JA}$, and the ambient temperature, $T_A$. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_D$ (MAX) = ($T_J$ (MAX) - $T_A$) / $\theta_{JA}$. Exceeding the maximum allowable power dissipation can cause excessive die temperature, and the regulator may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
7) The device is not guaranteed to function outside of its operating conditions.
8) Measured on a JESD51-7, 4-layer PCB.


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## ELECTRICAL CHARACTERISTICS

**$V_{IN}$ = 12V, $V_{EN}$ = 2V, $T_J$ = -40°C to +150°C, typical value is at $T_J$ = 25°C, unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Operating input voltage | $V_{IN}$ | | 3.5 | | 40 | V |
| Quiescent supply current | $I_Q$ | No switching | | 3 | | mA |
| Shutdown supply current | $I_{ST}$ | $V_{EN}$ = 0V, $V_{IN}$ = 12V | | | 1 | µA |
| Input under-voltage lockout (UVLO) threshold | $V_{IN_UVLO}$ | Rising edge | | 3.25 | 3.45 | V |
| Input UVLO hysteresis | | | | 250 | | mV |
| Low-dropout (LDO) regulator output voltage | $V_{CC}$ | $V_{EN}$ = 2V, 6V < $V_{IN}$ < 24V, 0mA < $I_{VCC}$ < 10mA | | 5 | | V |
| EN on threshold | $V_{EN_ON}$ | $V_{EN}$ rising | 1.4 | | | V |
| EN off threshold | $V_{EN_OFF}$ | $V_{EN}$ falling | | | 0.5 | V |
| EN/ADIM and PDIM pull-down resistance | $R_{EN/ADIM}$ | | | 1 | | MΩ |
| PSE/FSE/FF source current | $I_{PSE}$ | | 29.7 | 32 | 34.3 | µA |
| **Step-Up Converter** | | | | | | |
| Low-side MOSFET (LS-FET) on resistance | $R_{DS(ON)_LS}$ | $V_{IN}$ = 12V | | 100 | | mΩ |
| SW leakage current | $I_{SW_LK}$ | $V_{SW}$ = 45V | | | 4 | µA |
| Switching frequency | $f_{SW}$ | $R_{FREQ}$ = 10kΩ | 1.85 | 2.05 | 2.25 | MHz |
| | | $R_{FREQ}$ = 50kΩ | 400 | 440 | 480 | kHz |
| FREQ voltage | $V_{FREQ}$ | | -5% | 1.1 | +5% | V |
| Maximum duty cycle | $D_{MAX}$ | $f_{SW}$ = 440kHz | 92 | | | % |
| Cycle-by-cycle current limiting | $I_{SW_LIMIT}$ | | 5.5 | 7 | | A |
| Current-limit protection | $I_{CL}$ | To trigger latch-off protection | | 12 | | A |
| SYNC low threshold | $V_{SYNC_LO}$ | $V_{SYNC}$ falling | | | 0.5 | V |
| SYNC high threshold | $V_{SYNC_HI}$ | $V_{SYNC}$ rising | 1.4 | | | V |
| COMP transconductance | $G_{COMP}$ | $\Delta I_{COMP}$ ≤ 10µA | | 100 | | µA/V |
| COMP source current limit | $I_{COMP_SO}$ | | | 90 | | µA |
| COMP sink current limit | $I_{COMP_SI}$ | | | 90 | | µA |
| **Current Dimming** | | | | | | |
| PDIM and EN/ADIM input low threshold | $V_{DIM_LO}$ | $V_{DIM}$ falling | | | 0.5 | V |
| PDIM and EN/ADIM input high threshold | $V_{DIM_HI}$ | $V_{DIM}$ rising | 1.4 | | | V |


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## ELECTRICAL CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{EN}$ = 2V, $T_J$ = -40°C to +150°C, typical value is at $T_J$ = 25°C, unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **LED Current Regulator** | | | | | | |
| LEDx regulation voltage | $V_{HD}$ | $I_{LED}$ = 20mA | | 350 | | mV |
| | | $I_{LED}$ = 100mA | | 650 | | mV |
| Current matching (9) | | $I_{LED}$ = 20mA | -2.5 | | +2.5 | % |
| | | $I_{LED}$ = 100mA | -2.5 | | +2.5 | % |
| ISET voltage | $V_{ISET}$ | | | 1.2 | | V |
| LED current | $I_{LED}$ | $R_{ISET}$ = 12kΩ, $T_J$ = 25°C | 97 | 100 | 103 | mA |
| | | $R_{ISET}$ = 24kΩ, ADIM duty = 2%, $I_{LED}$ = 1/50 x 50mA = 1mA | 0.7 | 0.9 | 1.1 | mA |
| Delay time | $t_{DELAY}$ | Between LED current channels | | 100 | | µs |
| **Protection** | | | | | | |
| Over-voltage protection (OVP) threshold | $V_{OVP}$ | | 1.9 | 2 | 2.1 | V |
| OVP hysteresis | | | | 200 | | mV |
| OVP UVLO threshold | $V_{OVP_UV}$ | Step-up converter fails | | 100 | | mV |
| Input over-current protection (OCP) threshold | $V_{INOCP}$ | Input current sense | 80 | 100 | 120 | mV |
| INS sink current | | | 16 | 20 | 24 | µA |
| LEDx OV threshold | $V_{LEDX_OV}$ | | | 5 | | V |
| LEDx OV fault timer | | | | 7.7 | | ms |
| LEDx UVLO threshold | $V_{LEDX_UV}$ | | | 100 | | mV |
| Thermal shutdown threshold (10) | $T_{ST}$ | Rising edge | | 170 | | °C |
| | | Hysteresis | | 20 | | °C |
| SD pull-down current | $I_{SD}$ | | | 60 | | µA |
| SD voltage (respective to $V_{IN}$) | $V_{SD-IN}$ | $V_{IN}$ = 12V, $V_{IN}$ - $V_{SD}$ | | 5.3 | | V |

**Notes:**

9) Matching is defined as the difference between the maximum current and minimum current, divided by 2 times the average current.
10) Guaranteed by design.


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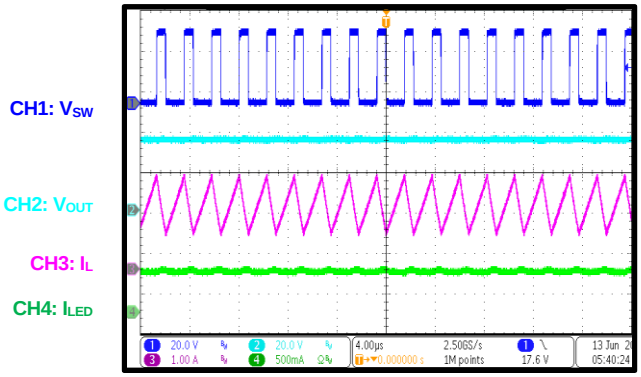
## TYPICAL PERFORMANCE CHARACTERISTICS

**$V_{IN}$ = 12V, 4 strings, 12 LEDs in series, 120mA/string, L = 15µH, $f_{SW}$ = 440kHz, $T_A$ = 25°C, unless otherwise noted.**

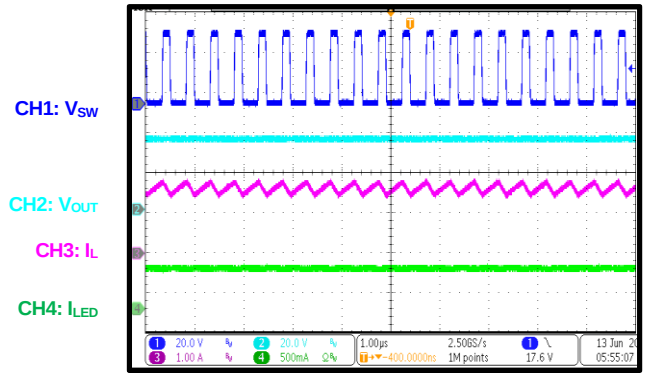
### Steady State

$f_{SW}$ = 440kHz

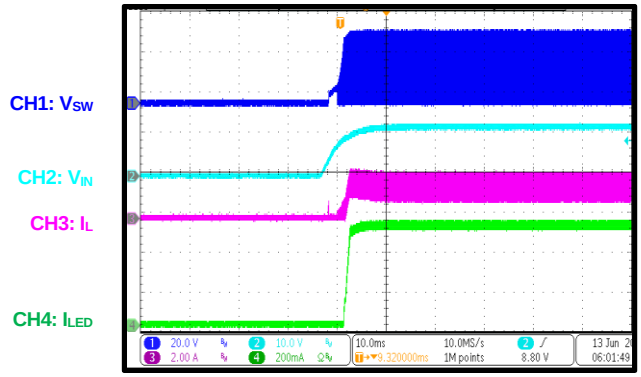



### Steady State

$f_{SW}$ = 2.2MHz

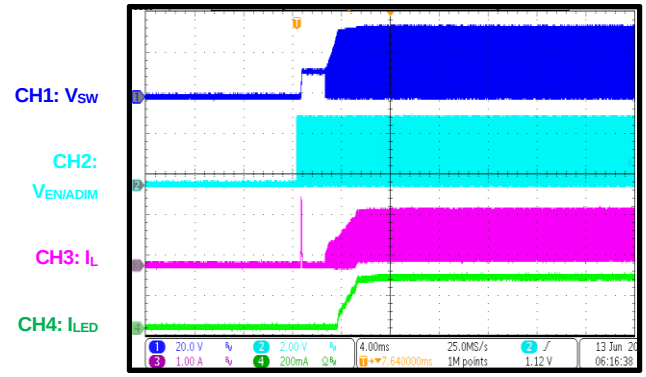



### Start-Up through VIN



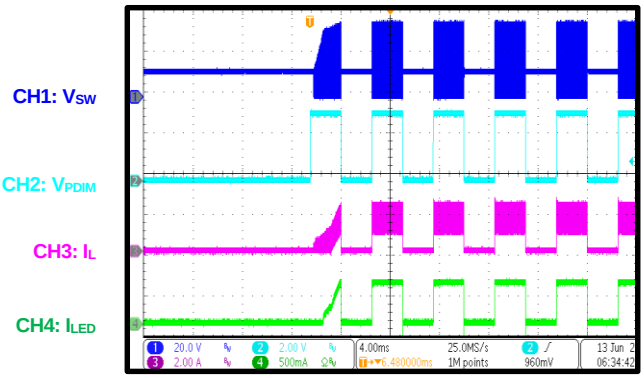

### Start-Up through EN/ADIM

$f_{EN/ADIM}$ = 10kHz, $D_{EN/ADIM}$ = 50%



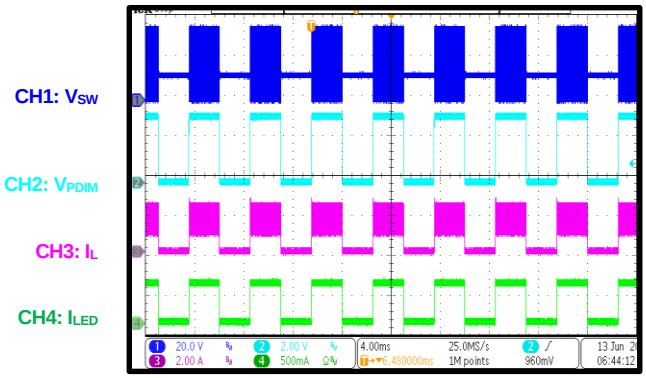

### Start-Up through PDIM

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 50%




### PWM Dimming

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 50%





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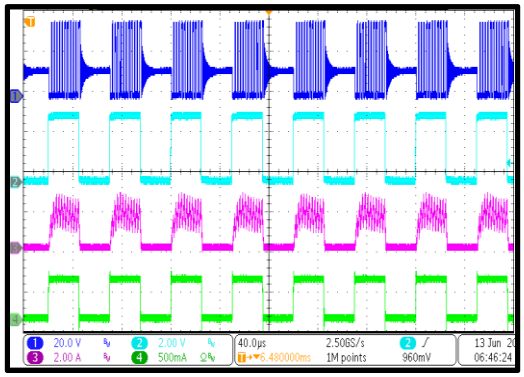
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, 4 strings, 12 LEDs in series, 120mA/string, L = 15µH, $f_{SW}$ = 440kHz, $T_A$ = 25°C, unless otherwise noted.**

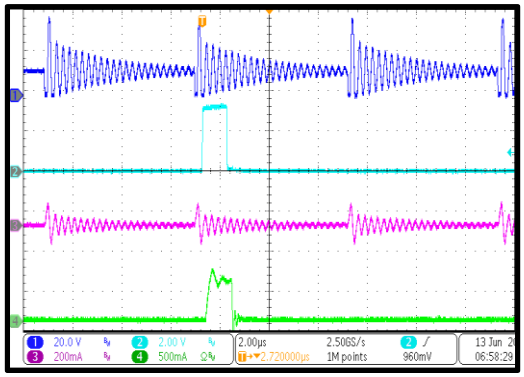
### PWM Dimming

$f_{PDIM}$ = 20kHz, $D_{PDIM}$ = 50%



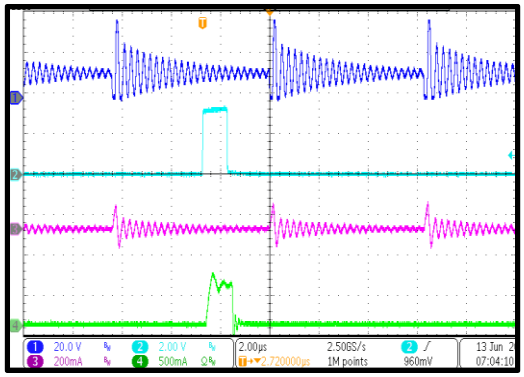

### PWM Dimming

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 0.02%



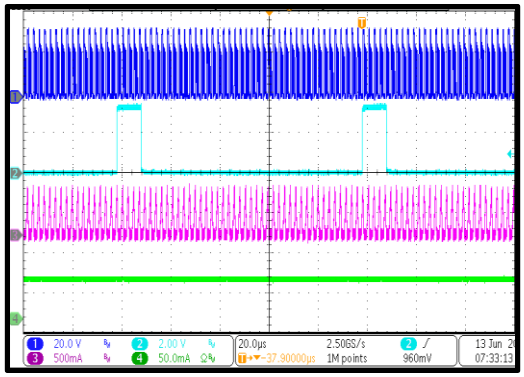

### PWM Dimming

$f_{PDIM}$ = 100Hz, $D_{PDIM}$ = 0.01%



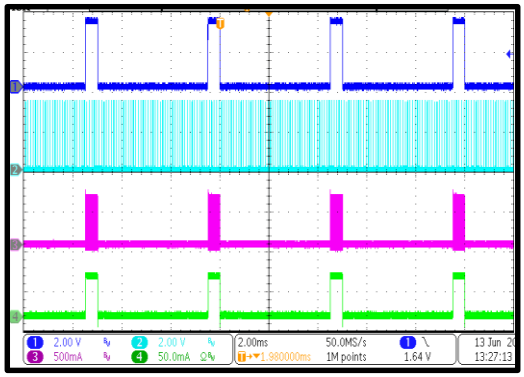

### Analog Dimming

$f_{EN/ADIM}$ = 10kHz, $D_{EN/ADIM}$ = 10%



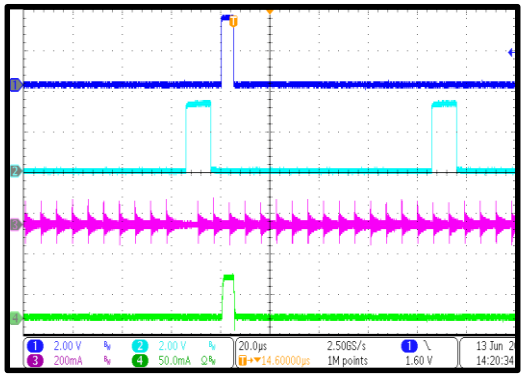

### Both PWM Dimming and Analog Dimming

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 10%, $f_{EN/ADIM}$ = 10kHz, $D_{EN/ADIM}$ = 10%




### Both PWM Dimming and Analog Dimming

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 0.1%, $f_{EN/ADIM}$ = 10kHz, $D_{EN/ADIM}$ = 10%





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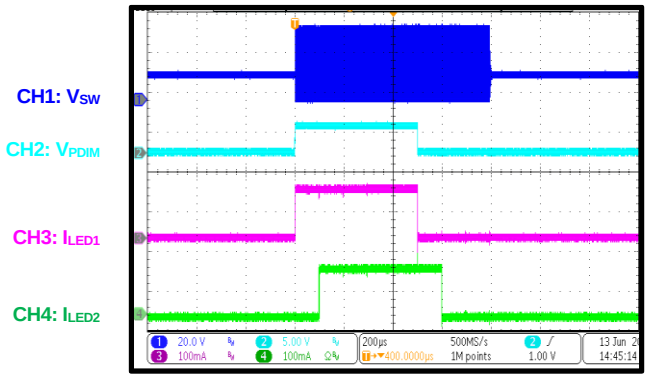
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

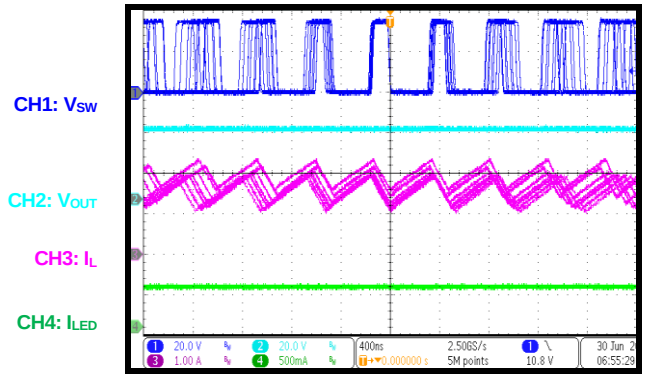
**$V_{IN}$ = 12V, 4 strings, 12 LEDs in series, 120mA/string, L = 15µH, $f_{SW}$ = 440kHz, $T_A$ = 25°C, unless otherwise noted.**

### PWM Dimming with 100µs Delay Time Function

$f_{PDIM}$ = 200Hz, $D_{PDIM}$ = 10%

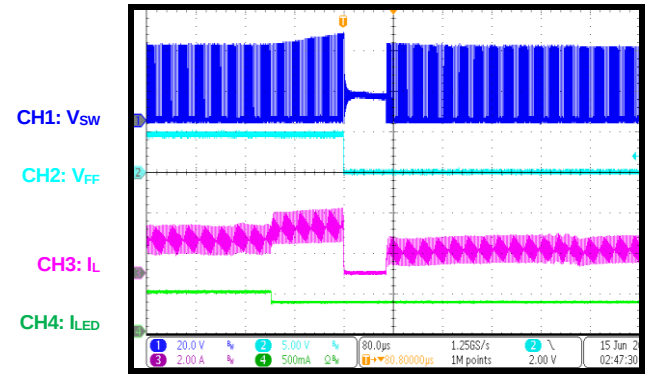



### Frequency Spread Spectrum



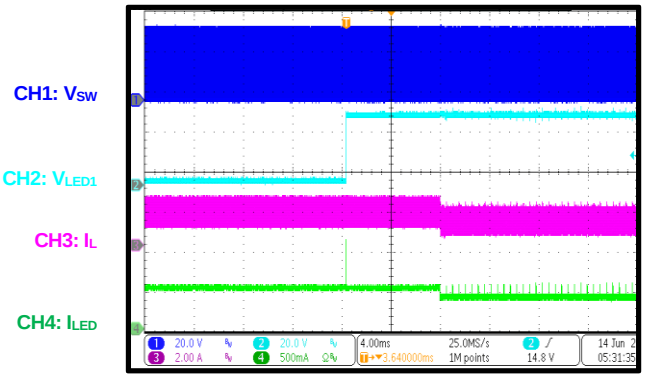

### LED Open Protection

Open LED1 under normal operation



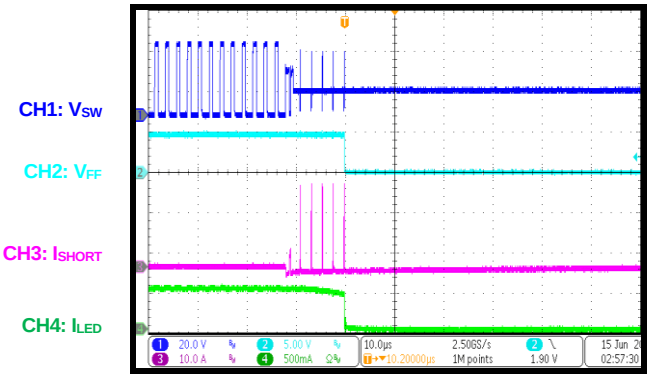

### LED Short Protection

Short LED1 under normal operation



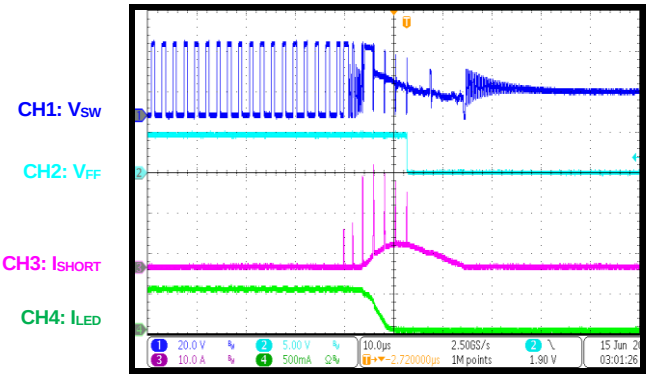

### Short Inductor Protection

Short inductor under normal operation




### Short Diode Protection

Short diode under normal operation





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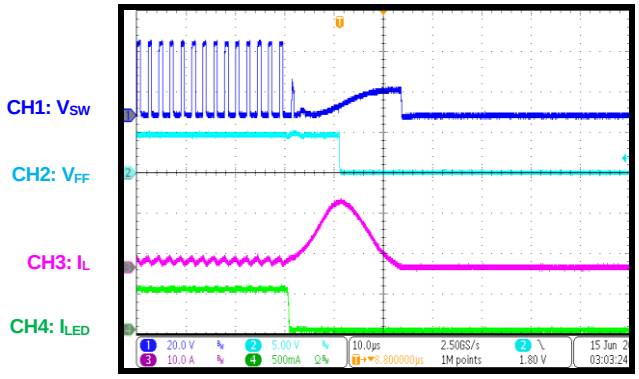
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, 4 strings, 12 LEDs in series, 120mA/string, L = 15µH, $f_{SW}$ = 440kHz, $T_A$ = 25°C, unless otherwise noted.**

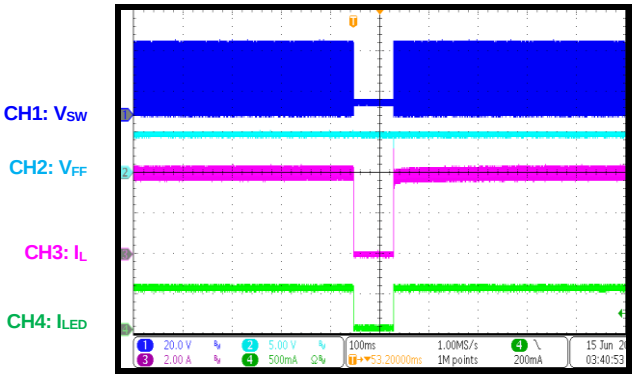
### Short VOUT to GND Protection

Set the input OCP threshold = 10A




### Over-Temperature Protection

$V_{IN}$ = 6V





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# FUNCTIONAL BLOCK DIAGRAM

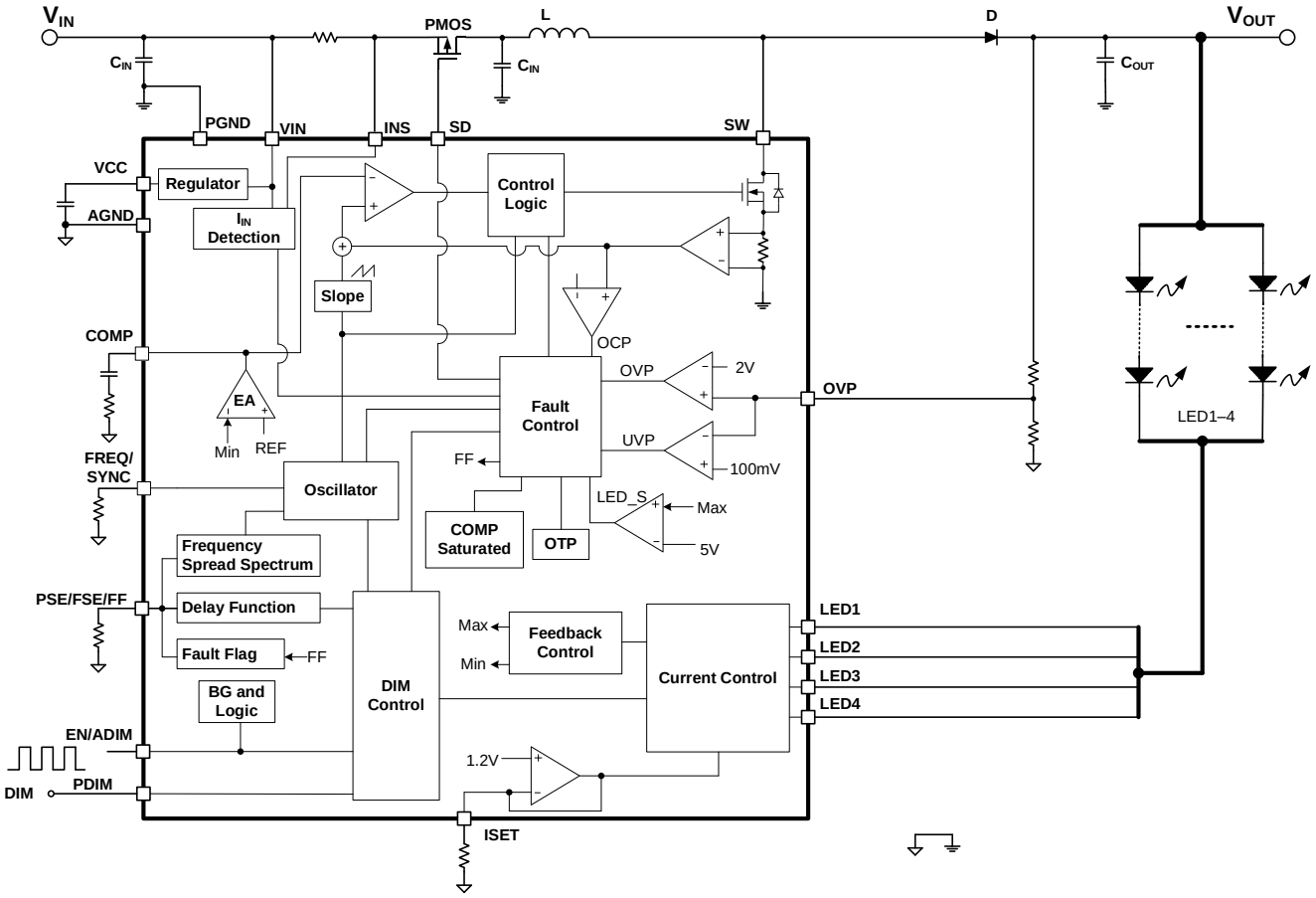


**Figure 3: Functional Block Diagram**


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# OPERATION

The MPQ3359A is a configurable, fixed-frequency, peak current mode boost converter with up to four channels of regulated current sources to drive an array of white LEDs (WLEDs).

### Internal 5V Regulator

The MPQ3359A includes an internal linear regulator (VCC). When the input voltage ($V_{IN}$) exceeds 6V, this regulator provides a 5V power supply to the internal MOSFET switch gate driver and the internal control circuitry. The VCC voltage ($V_{CC}$) drops to 0V when the device shuts down. The device remains disabled until $V_{CC}$ exceeds the under-voltage lockout (UVLO) threshold.

### System Start-Up

When enabled, the MPQ3359A checks the topology connection. The IC draws current from the SD pin to turn on the P-channel MOSFET if it is used. After a 500µs delay, the IC monitors the OVP pin to see if the output is shorted to GND. If the OVP voltage is below 100mV, the IC latches off. The MPQ3359A then continues to check other safety limits (e.g. over-voltage protection (OVP)). If all protection tests pass, the IC starts boosting the step-up converter.

The recommended start-up sequence is listed below:

1. $V_{IN}$
2. EN/ADIM
3. PWM dimming signal

### Step-Up Converter

The MPQ3359A employs peak current mode control to regulate the output power. At the beginning of each switching cycle, the internal clock turns on the internal N-channel MOSFET. During normal operation, the minimum turn-on time is about 100ns. A stabilizing ramp is added to the output of the current-sense amplifier to prevent sub-harmonic oscillations for duty cycles exceeding 50%. This result is fed into the pulse-width modulation (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 ($V_{REF}$) and the feedback voltage ($V_{FB}$). The converter automatically chooses the lowest active LEDx pin voltage as the $V_{FB}$ to provide a sufficient output voltage to power all the LED arrays.

If $V_{FB}$ drops below $V_{REF}$, the output of the error amplifier increases. Then more current flows through the MOSFET, which increases the power delivered to the output. This forms a closed loop that regulates $V_{OUT}$.

During light-load operation (e.g. when $V_{OUT}$ is almost equal to $V_{IN}$), the converter runs in pulse-skip mode. In this mode, the MOSFET turns on for a minimum on time, then the converter discharges the power to the output for the remaining period. The external MOSFET remains off until the output voltage requires another boost.

### Be Able to Disable LED4 if LED4 is Unused

If LED4 is unused, connect it to the OVP pin directly. The IC can disable the block of LED4 and remove it from the boost loop. Then the PSE/FSE/FF pin can provide optimal performance for a 3-string application.

### Dimming Control

The MPQ3359A provides analog and PWM dimming with two separated EN/ADIM and PDIM input pins.

#### *Pulse-Width Modulation (PWM) Dimming Mode*

When a PWM signal is applied to PDIM pin, the amplitude of the LED current remains at the full-scale LED current, and the LED current duty cycle is the same as the input PWM signal duty cycle. The LED current duty cycle follows the PWM input duty cycle, and the LED current frequency is the same as the PWM input.

#### *Analog Dimming Mode*

The PWM input signal is connected to the EN/ADIM pin. The amplitude of the LED current is equal to $I_{SET}$ x $D_{DIM}$, where $I_{SET}$ is the full-scale LED current, and $D_{DIM}$ is the duty cycle of the input PWM signal.

To improve analog dimming performance, a PWM signal >5kHz is recommended.


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To ensure excellent performance with a small dimming ratio, the minimum LEDx voltage rises up to 1.2V when the dimming duty cycle is below 10%. Analog dimming supports a 200:1 dimming ratio.

### Deep Dimming Ratio for PWM Dimming

When the PWM pin on time is shorter than 5µs, the output voltage is regulated to be 93% of the OVP voltage (see Figure 4).

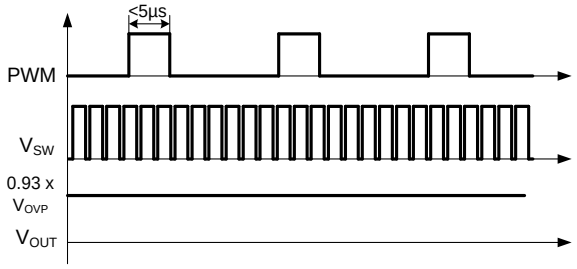


**Figure 4: Deep Dimming Ratio for PWM Dimming**

### PSE/FSE/FF Pin

When $V_{CC}$ exceeds its UVLO threshold, the PSE/FSE/FF pin sources a current (typically 32µA) to charge the resistor between the PSE/FSE/FF pin and GND. The IC detects the voltage of this pin to enable certain functions (see Table 1).

**Table 1: PSE/FSE/FF Pin Function**

| Voltage of the PSE/FSE/FF Pin | Frequency Spread Spectrum | Delay Function |
|---|---|---|
| <1.13V | Disabled | Disabled |
| 1.27V~1.8V | Enabled | Disabled |
| 2V~2.55V | Disabled | Enabled |
| >2.85V | Enabled | Enabled |

The PSE/FSE/FF pin must have a suitable voltage to match the logic level of the microcontroller (MCU). After $V_{CC}$ exceeds its UVLO threshold for a delay (typically 310µs), the IC raises the voltage on the PSE/FSE/FF pin to be between 4.35V and 5.22V when $V_{IN}$ exceeds 6V (see Figure 5).

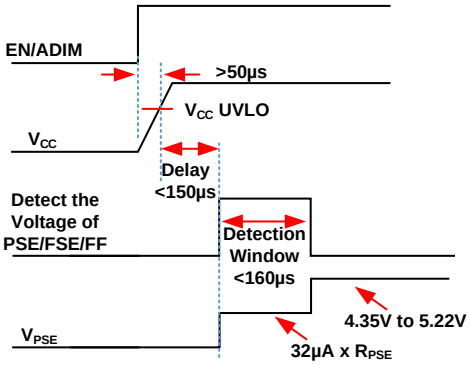


**Figure 5: PSE/FSE/FF Pin Timing**

### Delay Time Function

To reduce inrush current and audible noise during PWM dimming, the MPQ3359A employs a delay time function. There is a 100µs delay time between the LED channels (see Figure 6).

When operating in phase shift mode, the recommended $I_{LED}$ pulse on time is ≥10µs.

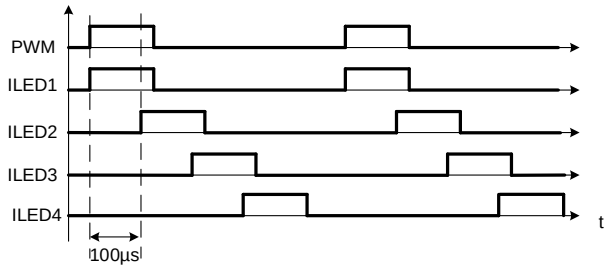


**Figure 6: 100µs Delay Time with 4 Channels**

### Frequency Spread Spectrum (FSS)

The MPQ3359A uses switching frequency jitter to spread the switching frequency spectrum. This reduces the spectrum spike around $f_{SW}$ and its harmonic frequencies.

The jitter frequency is ±10% of $f_{SW}$.

The modulation frequency is fixed at 6kHz.

### Protections

The MPQ3359A provides input over-current protection, LED open protection, LED short protection, LEDx-to-GND short protection, over-current protection (OCP), VOUT-to-GND short protection, and thermal protection. If a protection is triggered, the PSE/FSE/FF pin pulls to GND. If a recoverable fault is removed, PSE/FSE/FF is released to high again.

These protections are described in greater detail below.


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### *LED Open Protection*

LED open protection is achieved by detecting the voltage on the OVP pin and LEDx pins. If one string is open during normal operation, the respective LEDx voltage drops low to ground, and the IC keeps charging $V_{OUT}$ until it reaches the OVP threshold.

If OVP has been triggered, the chip stops switching and marks off the fault string, which has an LEDx pin voltage below 100mV. The remaining LED strings force $V_{OUT}$ back to normal regulation. The string with the largest voltage drop determines the output regulation value.

Every 500µs, the LEDx pin that was marked off turns on for 4µs to check whether the open fault has been removed.

If all used strings are open, the IC latches off and cannot recover until VIN is reset or EN/ADIM is pulled low for >30ms and the device is turned on again.

### *Short String Protection*

The MPQ3359A monitors the LEDx voltages to determine whether a short string fault has occurred. If one or more strings are shorted, the shorted LEDx pins tolerate the high voltage stress. If an LEDx voltage exceeds the short protection threshold, an internal counter starts counting.

If the fault condition lasts for 7.7ms ($D_{PWM}$ = 100%), the fault string is marked off. Once a string is marked off, it disconnects from the $V_{OUT}$ loop until the short fault is removed.

Every 500µs, the LEDx pin that was marked off turns on for 4µs to check whether the short fault has been removed.

If all the active LEDx pins' voltages exceed the threshold for 480ms ($D_{PWM}$ = 100%), all strings are marked off and the IC latches off.

Note: short LED protection is disable when open LED condition occurs, which helps avoid mis-triggering the short LED protection.

### *LEDx-to-GND Short Protection*

If an LEDx pin is shorted to GND, the COMP voltage increases and saturates. If COMP is saturated for 40ms, a protection is triggered. FF pulls low, and SD pulls high to turn off the external P-channel MOSFET. Then the IC latches off.

### *VOUT-to-GND Short Protection*

If VOUT is shorted to GND, $V_{OUT}$ decreases. If the voltage on the OVP pin reaches the under-voltage lockout (UVLO) threshold and lasts for 10µs, the protection is triggered. SD pulls high to turn off the external P-channel MOSFET. VOUT disconnects from VIN, and the IC latches off.

### *Cycle-by-Cycle Current Limit*

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

### *Current-Limit Protection with Latch-Off Mode*

The device can be damaged by extreme conditions, such as when an inductor or diode short fault occurs. To prevent damage, the MPQ3359A provides current-limit protection with latch-off mode. If the current flowing through the internal MOSFET reaches 12A and lasts for 5 switching cycles, current-limit protection is triggered. The external P-channel MOSFET turns off, and the MPQ3359A latches off.

### *Input Over-Current Protection (OCP)*

To prevent the input current ($I_{IN}$) from exceeding the current stress rating, the INS pin detects the voltage across the input sense resistor ($R_S$) (see Figure 7 on page 16). When the voltage between VIN and INS ($V_{IN}$ - $V_{INS}$) reaches the protection threshold for 3µs, the P-channel MOSFET turns off, and the MPQ3359A latches off.

For flexibility when selecting $R_S$, the INS pin has a 20µA sink current ability. It is possible to add a resistor ($R_{REG}$); then the voltage between VIN and INS is equal to the sum voltage of ($R_S$ + $R_{REG}$).


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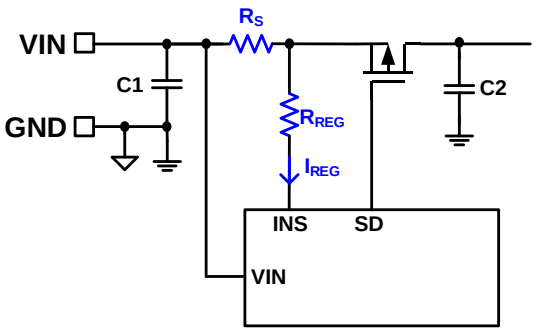


**Figure 7: Typical VIN Current Detection Circuit**

### *Thermal Shutdown*

If the die's junction temperature ($T_J$) exceeds the upper threshold ($T_{ST}$), the IC shuts down. When the temperature drops below the lower threshold, the IC recovers. The hysteresis value is about 20°C.


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# APPLICATION INFORMATION

### LED Current Setting

The LED current ($I_{LED}$) amplitude is set by an external resistor connected from ISET to GND. $I_{LED}$ can be calculated with Equation (1):

$$ILED(mA) = \frac{1200}{R_{ISET}(k\Omega)} \quad (1)$$

If $R_{ISET}$ = 10kΩ, then $I_{LED}$ is 120mA.

### Setting the Switching Frequency

The switching frequency can be configured by a resistor or external clock.

When using an external resistor on FREQ/SYNC to configure $f_{SW}$, then $f_{SW}$ can be estimated with Equation (2):

$$f_{SW}(kHz) = \frac{22000}{R_{FREQ}(k\Omega)} \quad (2)$$

If $R_{FREQ}$ = 44.2kΩ, then $f_{SW}$ is set to 500kHz.

There may be some deviation between the actual $f_{SW}$ and the calculated value from Equation (2). $R_{FREQ}$ = 50kΩ is recommended for a typical $f_{SW}$ of 440kHz, and $R_{FREQ}$ = 9.1kΩ is recommended for a typical $f_{SW}$ of 2.2MHz.

Synchronize $f_{SW}$ with an external clock to improve EMI, efficiency, and thermal performance.

A ≥250kHz external clock frequency is recommended for the external SYNC SW function.

If using the external clock on the FREQ/SYNC pin, do not stop the clock during operation, or the MPQ3359A may not operate normally.

### 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 below 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 due to their low ESR and small temperature coefficients. For most applications, a 10μF ceramic capacitor is sufficient.

### Selecting the Inductor

The MPQ3359A 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 N-channel MOSFET. However, a larger-value inductor has a larger physical size, higher series resistance, and lower saturation current.

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

Calculate the required inductance with Equation (3):

$$L \geq \frac{\eta \times V_{OUT} \times D \times (1-D)^2}{2 \times f_{SW} \times I_{LOAD}} \quad (3)$$

Where $V_{IN}$ and $V_{OUT}$ are the input and output voltages, $f_{SW}$ is the switching frequency, $I_{LOAD}$ is the LED load current, and η is the efficiency. D can be estimated with Equation (4):

$$D = 1 - \frac{V_{IN}}{V_{OUT}} \quad (4)$$

With the given inductance, the inductor DC current rating should be 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 the highest 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.


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## PCB Layout Guidelines

Efficient PCB layout is critical to reduce EMI noise and achieve stable operation. For the best results, refer to Figure 8 and follow the guidelines below:

1. The high-frequency switching current flows through the loop between the SW pin, output diode (D1), output capacitor (C1 and C2), and PGND. Keep this loop as short as possible to reduce noise and EMI.
2. Internally connect the IC's exposed pad to the AGND pin, and refer all logic signals to AGND.
3. Externally connect PGND to AGND, routing PGND away from the logic signals.
4. Place the ceramic capacitors for the VIN pin and VCC pin as close to the IC as possible.

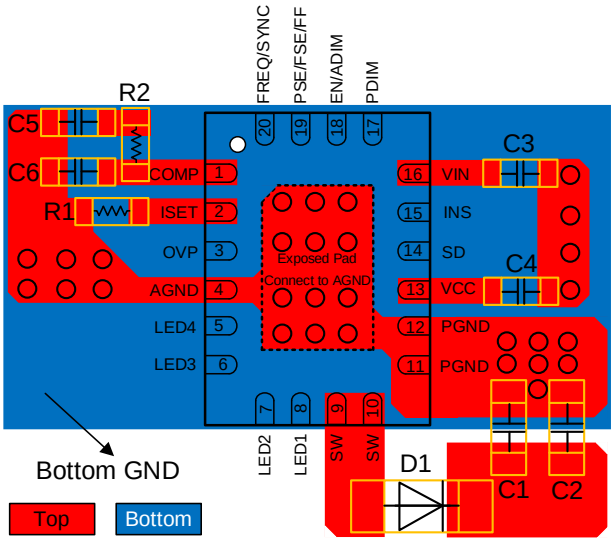


**Figure 8: Recommended PCB Layout**


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# TYPICAL APPLICATION CIRCUITS

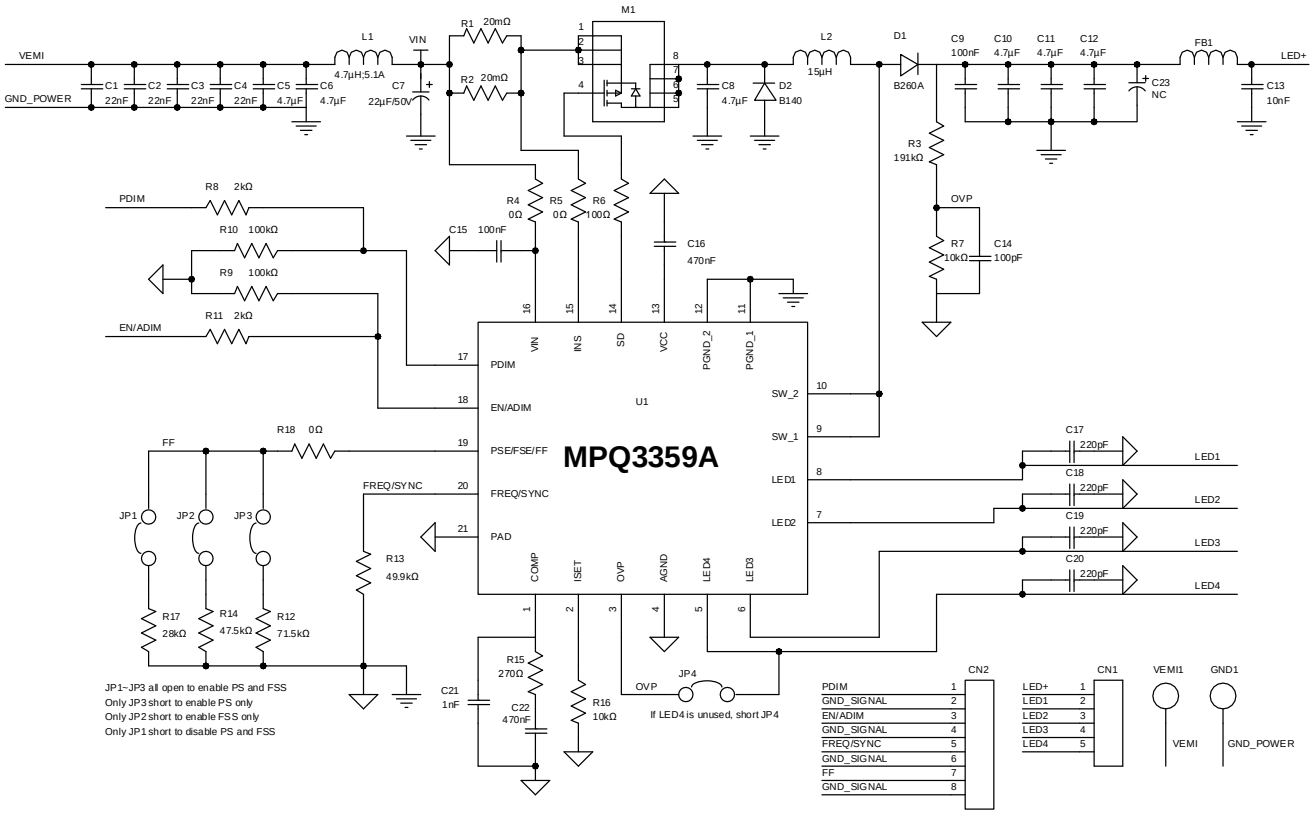


**Figure 9: Typical Application Circuit (Boost)**

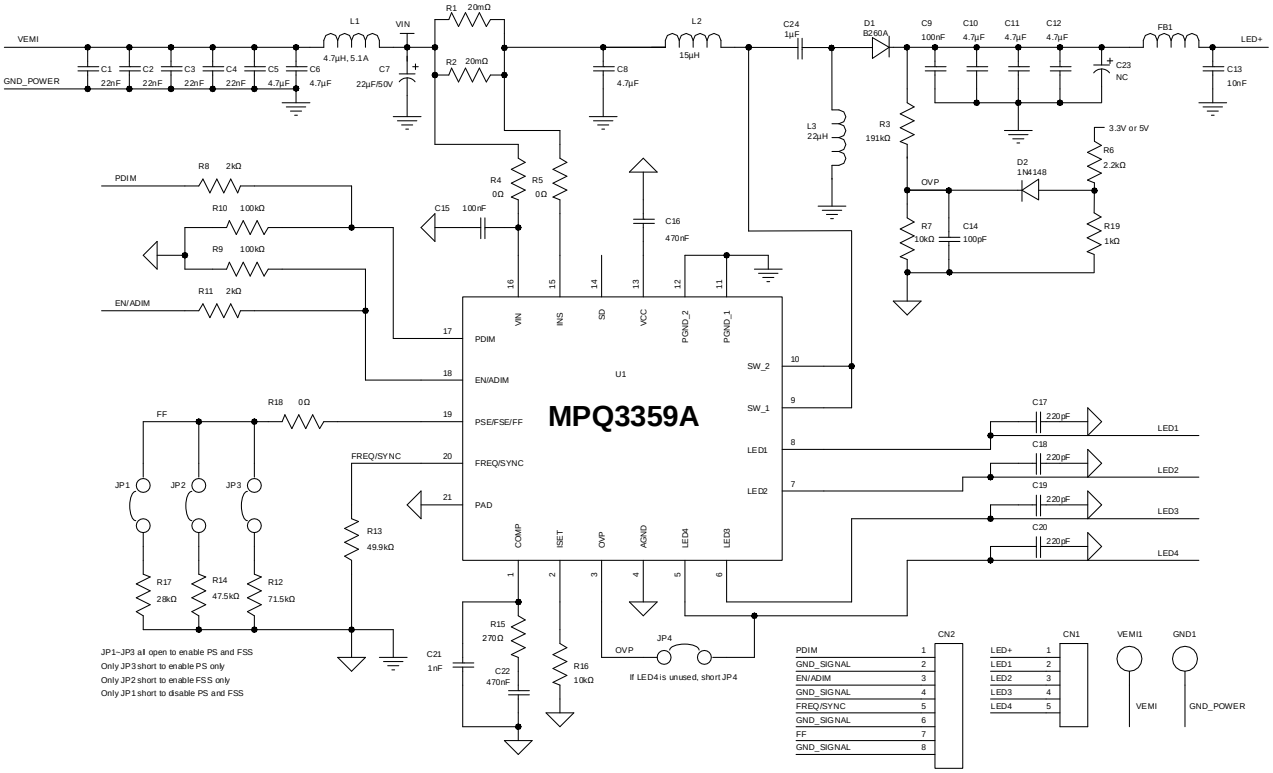


**Figure 10: Typical Application Circuit (SEPIC)**


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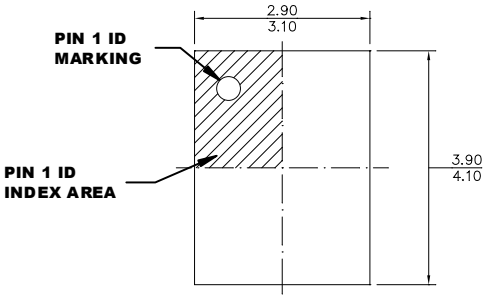
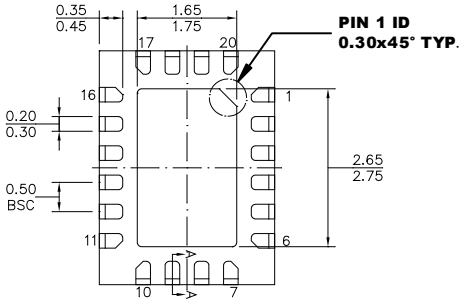
# PACKAGE INFORMATION

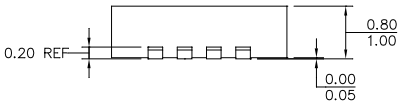
## QFN-20 (3mmx4mm)
## Wettable Flank



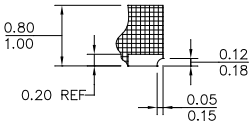

**TOP VIEW**



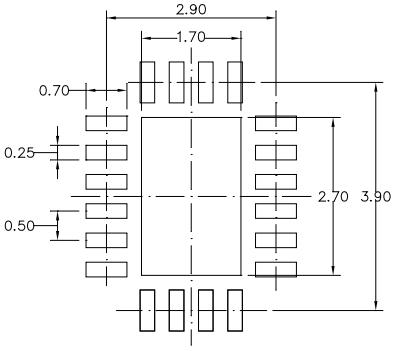

**BOTTOM VIEW**




**SIDE VIEW**




**SECTION A-A**




**RECOMMENDED LAND PATTERN**

**NOTE:**

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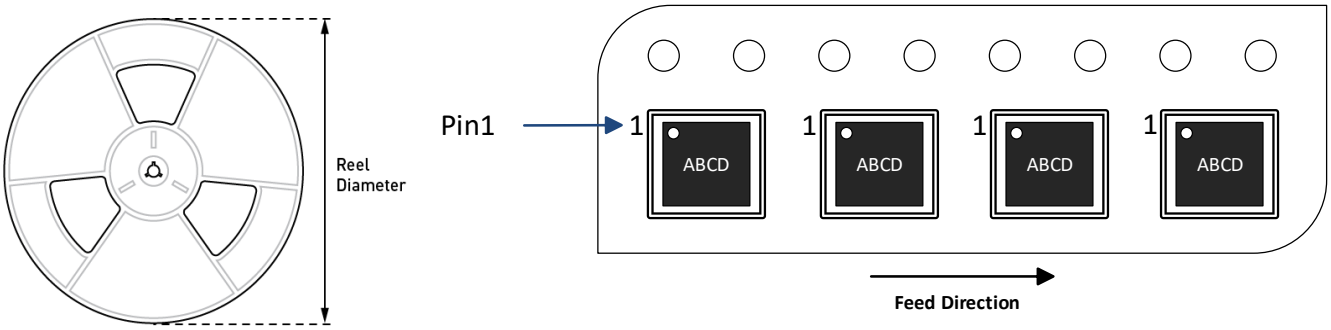
## CARRIER INFORMATION




| Part Number | Package Description | Quantity/ Reel | Quantity/ Tube | Quantity/ Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|---|---|---|---|---|---|---|---|
| MPQ3359AGLE-AEC1-Z | QFN-20 (3mmx4mm) WF | 5000 | N/A | N/A | 13in | 12mm | 8mm |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## REVISION HISTORY

| Revision # | Revision Date | Description | Pages Updated |
|---|---|---|---|
| 1.0 | 8/9/2024 | Initial Release | - |

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