MP2340

24V, 2A, 1MHz Synchronous Step-Down LED Driver

The Future of Analog IC Technology®

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE

DESCRIPTION

The MP2340 is a 24V monolithic synchronous step-down white LED driver with a built-in power MOSFET and rectifier. It achieves up to 2A continue output current with excellent load and line regulation. Peak current mode operation provides fast transient response and eases loop stabilization.

The MP2340 incorporates both analog and PWM dimming onto a single control pin. The chip can implement deep analog dimming and PWM dimming.

Fault condition protection includes cycle-by-cycle peak current limiting, output short circuit protection, open LED protection and thermal shutdown.

The MP2340 requires a minimum number of readily available standard external components and is available in TSOT23-6 package.

FEATURES

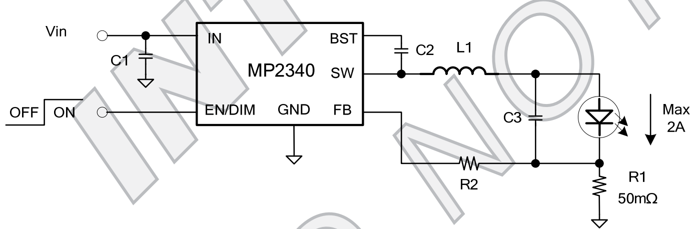
- 4.2V to 24V Wide Input Range
- Synchronous Step-Down Converter
- 100mΩ Internal High-side Power MOSFET
- 80mΩ Internal Low-side Synchronous Rectifier
- Peak Current Mode Control
- Up to 2A Continue Output Current
- 100mV Feedback Voltage
- Up to 97% Efficiency
- Fixed 1MHz Switching Frequency
- Analog & PWM Dimming
- Cycle-by-Cycle Current Limit
- Inherent LED Open Protection
- Output Short Circuit Protection
- Thermal Shutdown
- Auto-Restart Function
- Available in TSOT23-6 Package

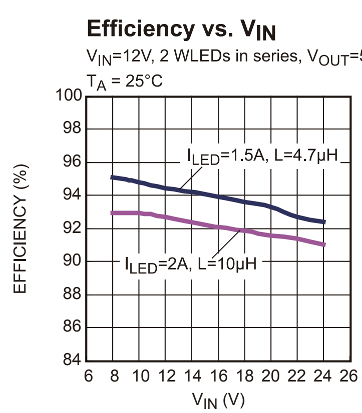
APPLICATIONS

- Infrared LED Driver
- General LED Driver
- Flashlight
- Handheld Computers Backlight

All MPS parts are lead-free, halogen free, and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance.

TYPICAL APPLICATION





ORDERING INFORMATION

Part Number	Package	Top Marking
MP2340GJ	TSOT23-6	*See Below*

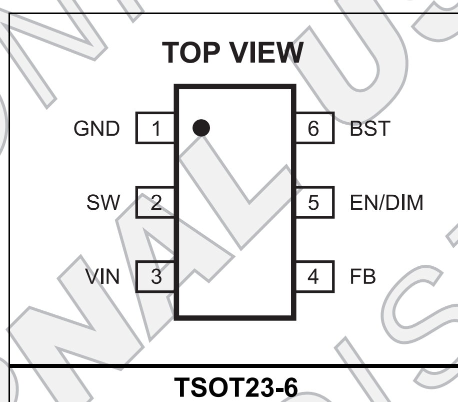
* For Tape & Reel, add suffix –Z (e.g. MP2340GJ–Z).

TOP MARKING

|AUBY

AUB: product code of MP2340GJ;
Y: year code;

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} 26V
V_{SW}..–0.3V to V_{IN} +0.3V
V_{BST} .... V_{SW} + 6V
All Other Pins................................–0.3V to +6V
Continuous Power Dissipation (T_A = 25°C) (2)
TSOT23-6 .... 1.25W
Junction Temperature ....150°C
Lead Temperature ....260°C
Storage Temperature.............. –65°C to +150°C
ESD Capability Human Body Mode.......... 2.0kV

Recommended Operating Conditions (3)

Supply Voltage V_{IN} ....4.2V to 24V
Operating Junction Temp. (T_J)…-40ºC to 125°C

Thermal Resistance (4) θ_{JA} θ_{JC}

TSOT23-6 ....100 ..... 55 ... °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 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.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

Typical values are V_{IN} = 12V, T_J = 25°C, unless otherwise noted.
Minimum and maximum values are at V_{IN} = 12V, T_J = -40°C to +125°C, unless otherwise noted, guaranteed by characterization.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply Voltage						
Operating Range	V_{IN}	After turn on	4.2		24	V
Turn On Threshold	V_{IN_ON}	V_{IN} rising edge	3.5	3.7	4	V
Hysteretic Voltage	V_{IN_HYS}		0.08	0.12	0.24	V
Supply Current						
Shutdown Current	I_{SD}	V_{EN} = 0V		10	50	μA
Quiescent Current	I_Q	V_{EN} = 2V, V_{FB} = 200mV		0.9	1.1	mA
Enable & Dimming						
EN/DIM OFF Threshold	V_{EN_OFF}	$V_{EN/DIM}$ falling edge	0.27	0.31	0.35	V
EN/DIM ON Threshold	V_{EN_ON}	$V_{EN/DIM}$ rising edge	0.55	0.59	0.63	V
Turn Off Delay Time	t_{OFF_DELAY}		16	22	28	ms
EN/DIM Pull-Up Current	$I_{EN/DIM}$	V_{EN} = 0V	2.8	3.8	5.3	μA
Max Analog Dimming Threshold	V_{ADIM_MAX}	Theoretically, V_{FB} = 100mV	1.31	1.44	1.57	V
Min Analog Dimming Threshold	V_{ADIM_MIN}	V_{FB} = 5mV	0.63	0.7	0.78	V
Feedback						
Feedback Voltage	V_{FB}	4.2V ≤ V_{IN} ≤ 24V	93	100	107	mV
Burst Mode Allowable Threshold	$V_{FB\_BURST\_AL}$			112	126	mV
Burst Mode Recovery Hysteresis (5)	$V_{FB\_BURST\_HYS}$			10		mV
Feedback Current	I_{FB}	V_{FB} = 150mV	-65		65	nA
Power Switch						
High-Side MOSFET On-Resistance	$R_{DS(ON)\_H}$	V_{IN} = 5.0V		100	170	mΩ
		V_{IN} = 4.2V		110	180	mΩ
Low-Side Sync-Rectifier Switch On-Resistance	$R_{DS(ON)\_L}$	V_{IN} = 5.0V		80	140	mΩ
		V_{IN} = 4.2V		90	150	mΩ
Switch Leakage	I_{SW_LKG}	V_{EN} = 0V, V_{SW} = 0V			1	μA
High-Side Current Limit	I_{LIMIT_H}	When high-side switch turn-on	3.5	5	6.6	A
Low-Side Current Limit	I_{LIMIT_L}	When low-side switch turn-on	-950	-600	-350	mA
OCP Current Threshold	I_{OCP}	Both for high-side & low-side	3.5	5.5	7	A
Oscillator Frequency	f_{SW}	V_{FB} = 80mV	0.8	1	1.2	MHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 80mV	90	94		%
Minimum On-Time	t_{ON_MIN}			70		ns
Restart Timer						
Hiccup Timer at Fault Condition	t_{START}			2.4		ms

ELECTRICAL CHARACTERISTICS *(continued)*

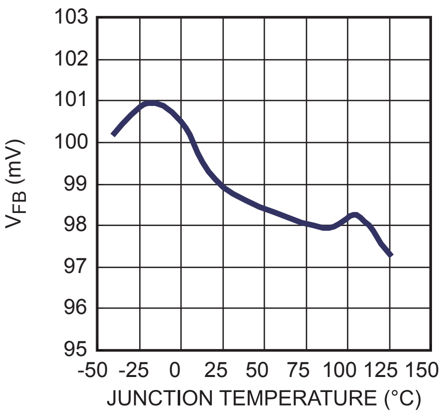
Typical values are V_{IN} = 12V, T_J = 25°C, unless otherwise noted.
Minimum and maximum values are at V_{IN} = 12V, T_J = -40°C to +125°C, unless otherwise noted, guaranteed by characterization.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Bootstrap						
Bias Voltage for High-Side Driver	V_{BST}-V_{SW}	5.5V≤V_{IN}≤24V	4.8	5.1	5.5	V
		V_{IN} =4.2V	3.6			V
Thermal Shutdown						
Thermal Shutdown Threshold (6)	T_{SD}			150		°C
Thermal Shutdown Hysteresis (6)	T_{HYS}			60		°C

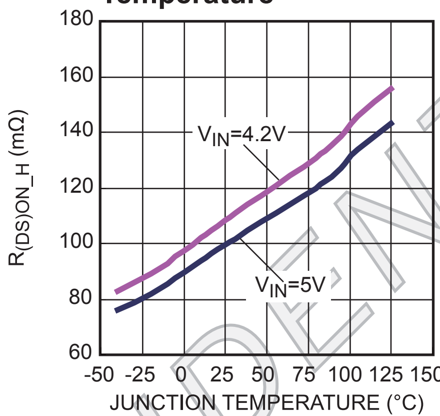
Notes:
5) Guaranteed by design.
6) Guaranteed by characterization.

TYPICAL CHARACTERISTICS

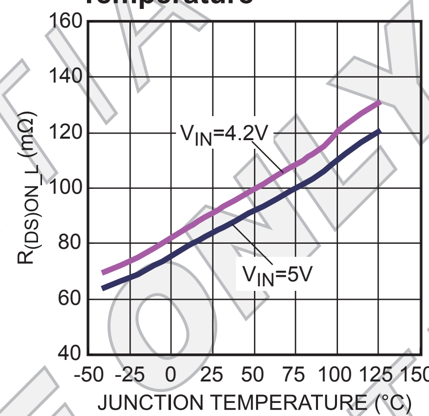
Feedback Voltage vs. Junction Temperature



High-Side MOSFET On-Resistance vs.Junction Temperature



Low-Side Rectifier On-Resistance vs. Junction Temperature



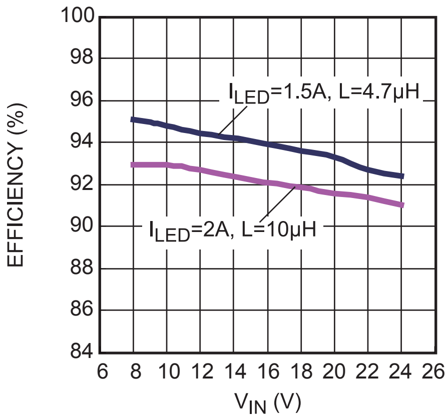
TYPICAL PERFORMACE CHARACTERISTICS

Performance waveforms are tested on the evaluation board.

V_{IN}=12V, 2 WLEDs in series, V_{OUT}=5.9V, I_{LED}=1.5A, L=4.7μH, T_A = 25°C, unless otherwise noted.

Efficiency vs. V_{IN}

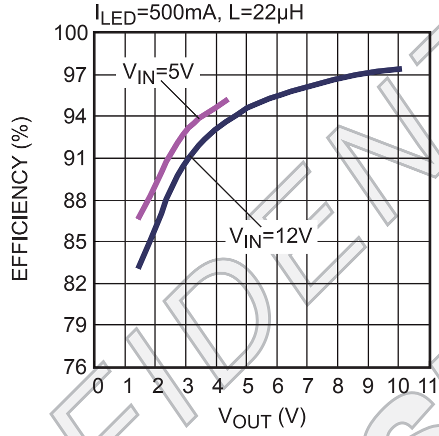
2 WLEDs in series



Efficiency vs. V_{OUT}

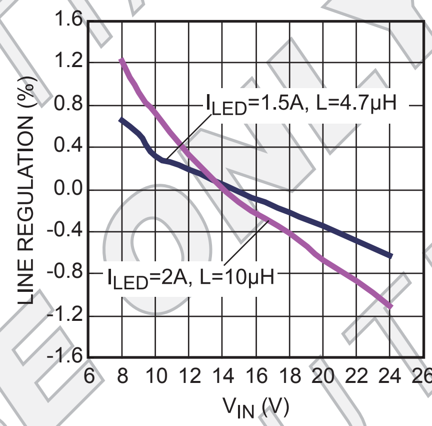
1 to 7 IR LEDs in series,

I_{LED}=500mA, L=22μH



Line Regulation

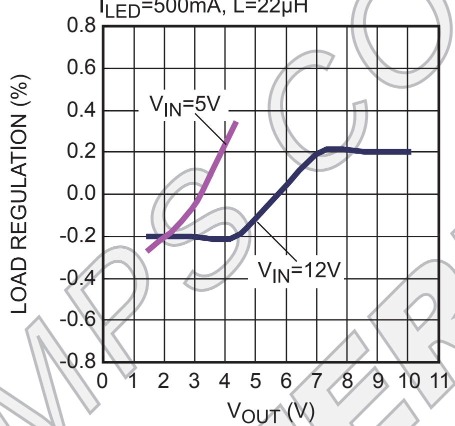
2 WLEDs in series



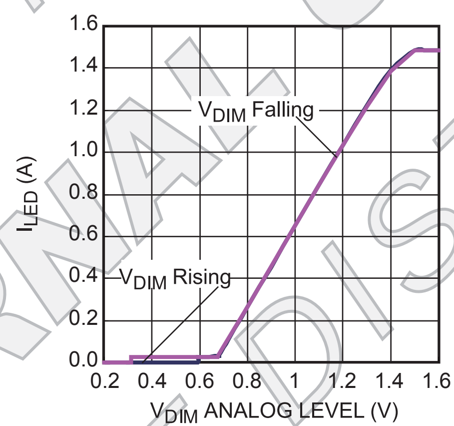
Load Regulation

1 to 7 IR LEDs in series,

I_{LED}=500mA, L=22μH



Analog Dimming Curve

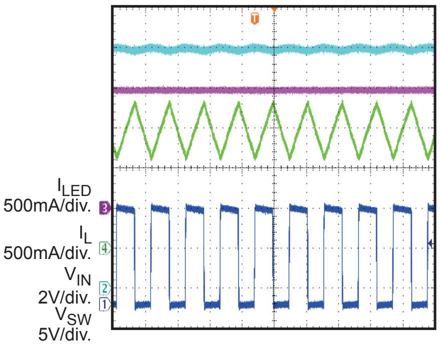


TYPICAL PERFORMACE CHARACTERISTICS *(continued)*

Performance waveforms are tested on the evaluation board.

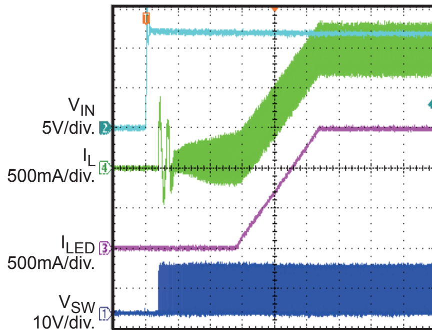
V_{IN}=12V, 2 WLEDs in series, V_{OUT}=5.9V, I_{LED}=1.5A, L=4.7μH, T_A = 25°C, unless otherwise noted.

Steady State



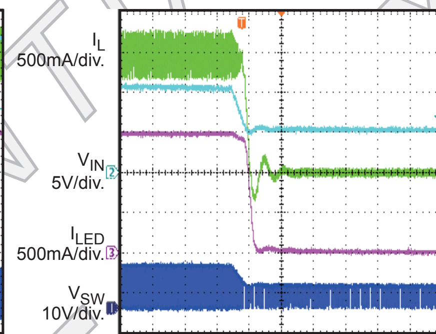
1μs/div.

V_{IN} Start-Up



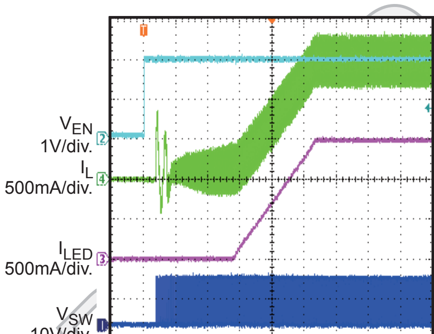
200μs/div.

V_{IN} Shutdown



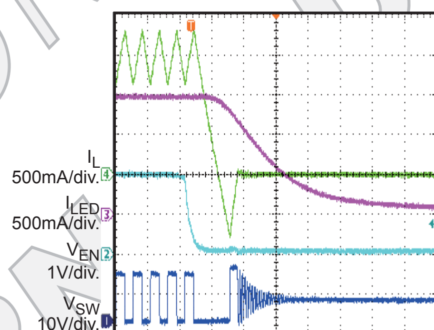
40μs/div.

EN Start-Up



200μs/div

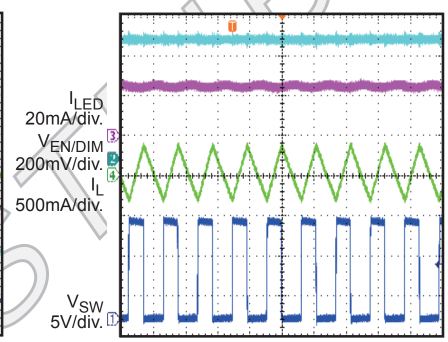
EN Shutdown



2μs/div

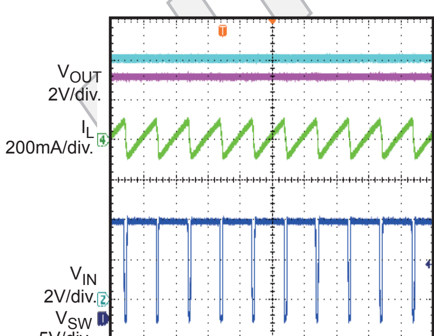
Minimum Analog Dimming

$V_{EN/DIM}$=0.6V



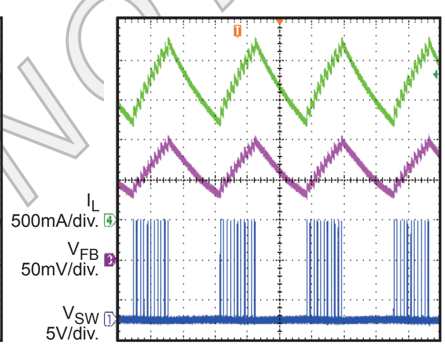
1μs/div

Open LED Protection



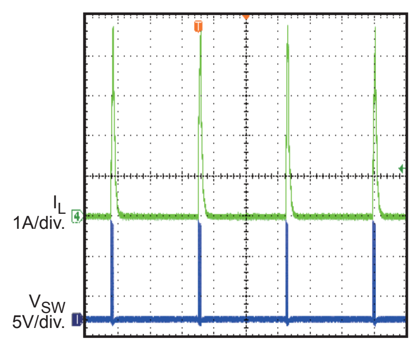
1μs/div

Short LED+ to LED- Protection



10μs/div

Short LED+ to GND Protection



1ms/div

PIN FUNCTIONS

Pin #	Name	Description
1	GND	**Ground.** This pin is the voltage reference for the regulated output voltage. For this reason care must be taken in its layout.
2	SW	**Switch Output.**
3	VIN	**Supply Voltage.** The MP2340 operates from a 4.2V to 24V unregulated input. Input capacitor is needed to prevent large voltage spikes from appearing at the input.
4	FB	**Current Sense Feedback Voltage.** Its internal reference voltage is 0.1V.
5	EN/DIM	**On/Off Control Input & Dimming Command Input.** Leave EN/DIM floating or a voltage higher than 0.59V on this pin turns on the chip. For analog dimming, when the EN/DIM voltage rises up from 0.7V to 1.44V, the output current changes from min value to the full-scale LED current. To apply PWM dimming, apply a 100Hz to 2kHz PWM signal with amplitude higher than 1.6V to this pin.
6	BST	**Bootstrap.** A capacitor is connected between SW and BST pins to form a floating supply across the power switch driver. This capacitor is needed to drive the power switch's gate above the supply voltage.

FUNCTION BLOCK DIAGRAM

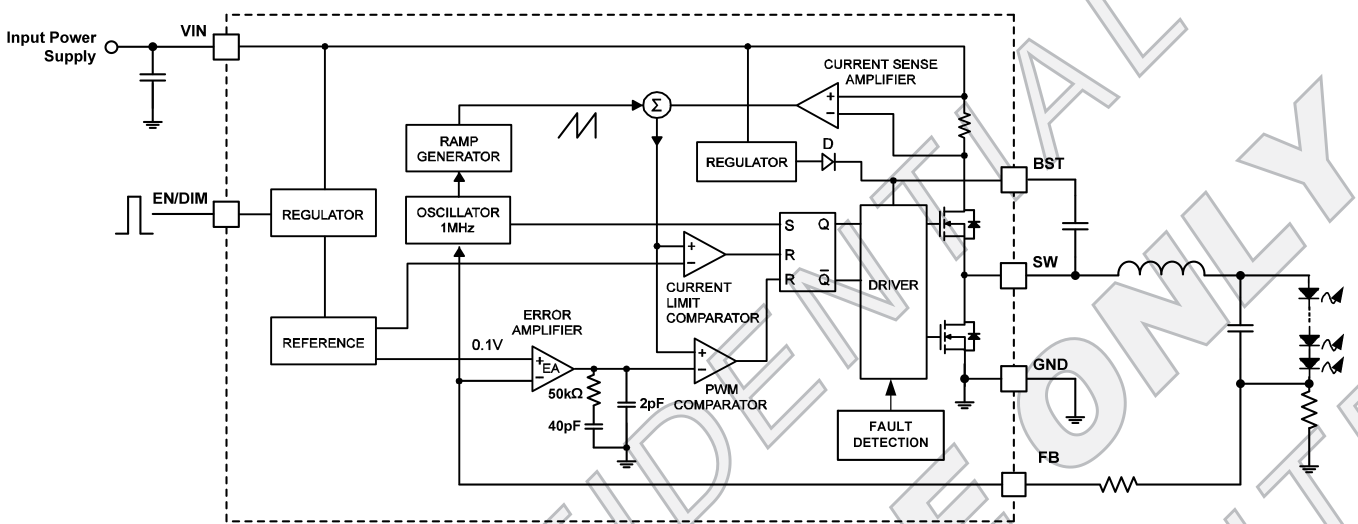


Figure 1: Functional Block Diagram

OPERATION

The MP2340 is a high frequency synchronous rectified step-down switching mode LED driver with built-in internal power MOSFET and synchronous rectifier switch. It offers a very high performance solution to achieve up to 2A continuous output LED current over a wide input supply range with excellent load and line regulation.

The MP2340 operates in a fixed 1MHz frequency, peak current control mode to regulate the output current. A new switching cycle is initiated by the internal clock at the beginning of every switching cycle. The integrated high-side power MOSFET is turned on and the inductor current rises linearly to provide the energy to the load. The high-side power MOSFET remains on until its current hits the value of the COMP level which is the output of the internal error amplifier. The output voltage of error amplifier depends on the difference of output feedback and the internal high precision reference and it decides how much energy should be transferred to the load. The high-side power switch remains off until the next clock cycle starts. After the high-side switch is off, the low-side sync-switch is on and the inductor current flows through the low-side switch. In order to avoid shoot-through issue, the dead time is inserted to avoid the high-side and low-side FETs to turn on at the same time. By maximum duty cycle limit, when the duty cycle of one switching period reaches 94%, the current in the high-side power MOSFET does not reach the COMP set current value, the high-side power MOSFET is forced to turn off.

Under-Voltage Lockout (UVLO) & IC Startup/Shutdown Procedure

Under-voltage lockout (UVLO) is implemented to avoid the chip from operating at insufficient supply voltage. The MP2340 UVLO comparator monitors the output voltage of the internal regulator, which is supplied from V_{IN}.

If both V_{IN} and EN/DIM are higher than their appropriate thresholds, the chip starts. The reference block starts first to generate stable reference voltages and currents, then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries.

Three events can shut down the chip: EN/DIM keeps low for more than t_{OFF_DELAY}, V_{IN} drops below UVLO and thermal shutdown. In shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The COMP voltage and the internal supply rail are then pulled down.

Error Amplifier

The internal low offset error amplifier compares the FB voltage with the internal 100mV reference and outputs COMP voltage, which is inside of the chip and used to control the high-side MOSFET peak current and then to regulate the output current.

Internal Soft-Start

The soft start is implemented to prevent the converter output current from overshooting during start up. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V. The soft-start period lasts until the voltage on the soft-start capacitor exceeds the 0.1V reference voltage. At this point the reference voltage takes over.

Floating Driver and Bootstrap Charging

The high-side floating power MOSFET driver is powered by an external bootstrap capacitor. The bootstrap capacitor voltage is regulated internally. At normal operation, a 5.1V bootstrap voltage is maintained between BST and SW.

Enable Control

EN/DIM is a control pin that turns the regulator on/off and dims the output LED current. Leave this pin floating or drive it high to turn on the MP2340. After the pin is pulled down to low for t_{OFF_DELAY} (typical 22ms), the MP2340 is turned off. Figure 2 shows the control logic of the EN/DIM pin.

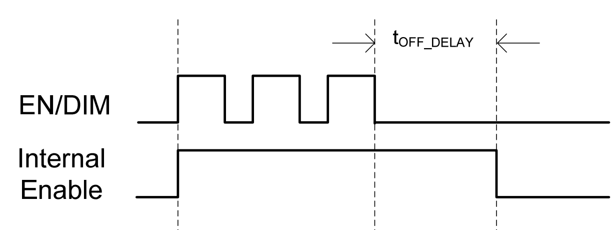


Figure 2: EN/DIM Time Sequence

Analog Dimming

Apply DC signal on EN/DIM can dim the MP2340 on the analog dimming mode. When the voltage on EN/DIM is lower than V_{ADIM_MIN}, the LED current is regulated to the minimal scale. When the voltage on EN/DIM is between V_{ADIM_MIN} and V_{ADIM_MAX}, the LED current changes from the minimal scale to the full scale of LED current. If the voltage on EN/DIM pin is higher than V_{ADIM_MAX}, the maximum LED current is regulated.

Figure 3 shows the Analog Dimming Curve. Due to the hysteretic of EN/DIM ON/OFF Threshold, at $V_{EN/DIM}$ falling edge, the chip maintains at minimal LED current longer until $V_{EN/DIM}$ is lower than V_{EN_OFF}. The dimming curve is absolutely same in linear dimming range.

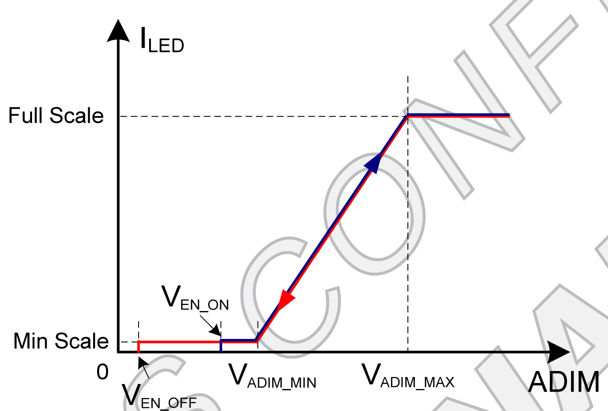


Figure 3: Analog Dimming Curve

PWM Dimming

Apply PWM signal on EN/DIM to implement PWM dimming mode. The dimming frequency is recommended in the range of 100Hz to 2kHz to achieve a good dimming linearity. The digital signal's amplitude must be higher than 1.6V.

Open LED

If LED is open without feedback signal, the MP2340 works at the maximum duty cycle and the output voltage rises up very close to the input voltage. Every power component operates at a safe state.

LED Short Circuit Protection

The MP2340 integrates the LED Short Circuit Protection circuitry. There are several features preventing the MP2340 from damage when the LED short circuit occurs.

The MP2340 features a cycle-by-cycle current limit to restrict the maximum current of the inductor. And a protection mechanism monitors FB level though an internal RC filter. Once it rises up to hit $V_{FB\_BURST\_AL}$, the chip stops switching until FB level drops to a lower value, and the system works in burst mode.

In the worst case, LED Short Circuit to GND, if the cycle-by-cycle current limit function can not clamp the current overshoot sufficiently, the current (thru both the high-side and low-side FETs) is also monitored by over-current detector inside the chip. If it is higher than the short circuit threshold (I_{OCP}), the MP2340 treats it as a short circuit condition.

When Over Current Condition or Short Circuit Condition is detected, the MP2340 turns off the high-side and low-side MOSFETs both for 2.4ms, then restart again. During this period, the COMP voltage is pulled down to ground, so the restart from the fault condition is also with soft-start.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceeding high temperature. When the silicon die temperature is higher than 150°C, the OTP shuts down the whole chip. When the temperature is lower than its lower threshold, typically 90°C, the chip restarts again.

APPLICATION INFORMATION

Setting LED Current

The current sense resistor is inserted between the anode of LED and GND. The current sense resistor value is calculated as:

$$R_S = \frac{0.1V}{I_{LED}}$$

For 2A LED current output, choose R_S = 50mΩ.

Selecting the Inductor

A <100µH inductor with a nominal DC current rating of at least 25% higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor's DC resistance should be less than 100mΩ. For most designs, the required inductance value can be derived from the following equation.

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

Where ΔI_L is the inductor ripple current.

Choose the inductor ripple current to be 30% of the maximum load current. The maximum inductor peak current is calculated from:

$$I_{L(MAX)} = I_{LED} + \frac{\Delta I_L}{2}$$

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 output source impedance of the input source to prevent high frequency switching current from passing through the input. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 10µF capacitor is sufficient.

Selecting the Output Capacitor

The output capacitor keeps the output current ripple small and ensures feedback loop stability. The output capacitor impedance should be low at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended for their low ESR characteristics. For most applications, a 10µF ceramic capacitor is sufficient.

PC Board Layout

The high current paths (GND, VIN and SW) should be placed very close to the device with short, direct and wide traces. The input capacitor needs to be as close as possible to the VIN and GND pins. The external feedback resistors should be placed next to the FB pin. Keep the switch node traces short and away from the feedback network. Refer to EVB datasheet for more information.

TYPICAL APPLICATION CIRCUIT

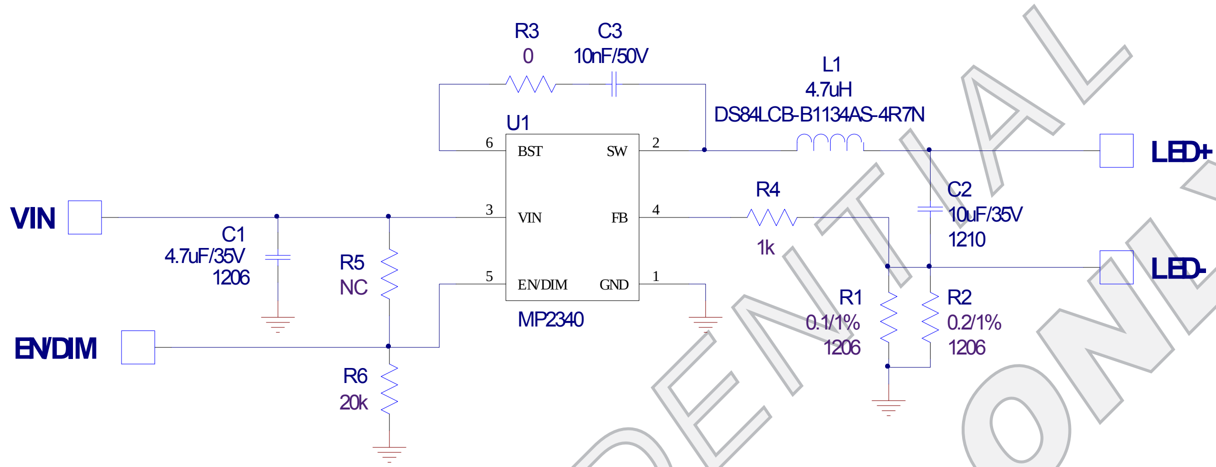
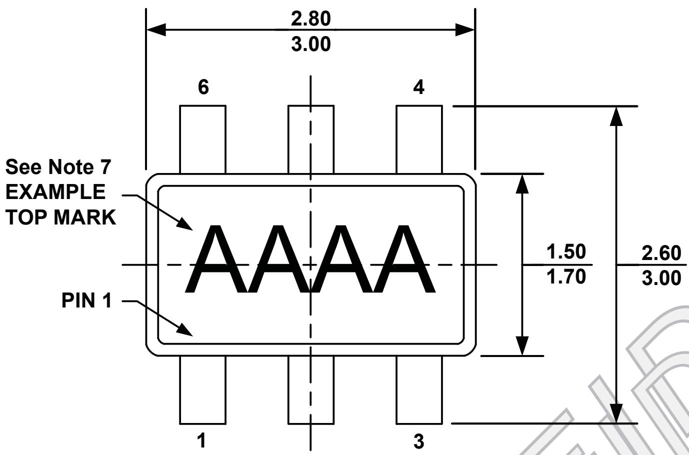


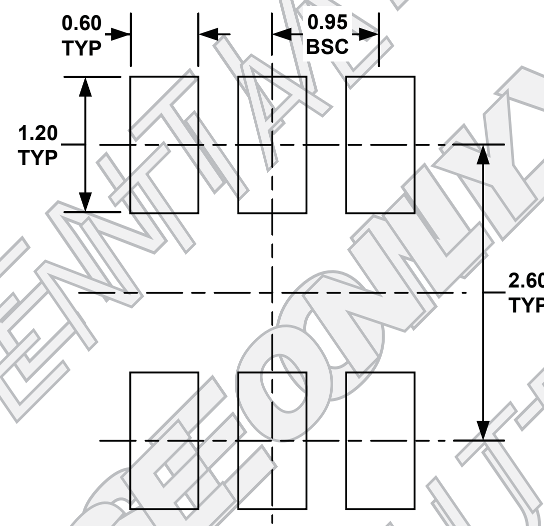
Figure 4: Typical Buck Converter Application, V_{IN} =8V to 24V, V_O=5.9V, I_{LED}=1.5A

PACKAGE INFORMATION

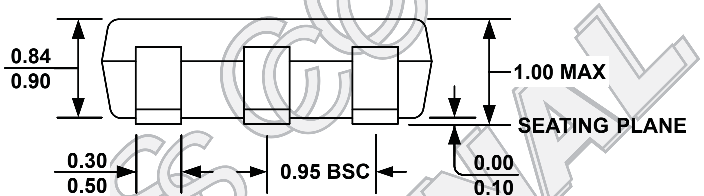
TSOT23-6



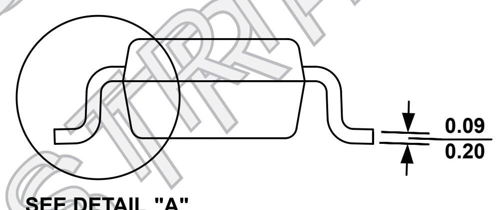
TOP VIEW



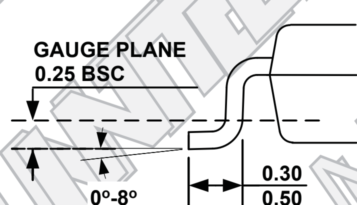
RECOMMENDED LAND PATTERN



FRONT VIEW



SIDE VIEW



DETAIL “A”

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-193, VARIATION AB.
6) DRAWING IS NOT TO SCALE.
7) PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT, (SEE EXAMPLE TOP MARK)

