MIC2292/93

High-Frequency PWM White LED Drivers with Internal Schottky Diode and OVP

Features

- 2.5V to 10V Input Voltage Range
- Output Voltage up to 34V
- Internal Schottky Diode
- 1.6 MHz PWM Operation (MIC2292)
- 2.0 MHz PWM Operation (MIC2293)
- Stable with Ceramic Capacitors
- 15V, and 34V Output OVP Options
- 1.2 MHz PWM Operation
- 500 mA Switch Current Rating
- 95 mV Feedback Voltage
- <1% Line and Load Regulation
- <1 µA Shutdown Current
- Overtemperature Protection
- UVLO
- 2 mm x 2 mm DFN-8 Package
- –40°C to +125°C Junction Temperature Range

Applications

- White LED Driver for Backlighting:
  - Cell Phones
  - PDAs
  - GPS Systems
  - Digital Cameras
  - MP3 Players
  - IP Phones
- LED Flashlights
- Constant Current Power Supplies

General Description

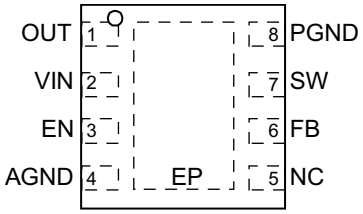
The MIC2292 and MIC2293 are high frequency, Pulse Width Modulator (PWM) boost regulators optimized for constant-current, white LED driver applications. Because of their constant PWM switching frequencies of 1.6 MHz and 2 MHz, respectively, the MIC2292/93 can use the smallest external components, allowing designers to avoid sensitive IF bands in their RF applications.

The products feature an internal Schottky diode and two levels of output overvoltage protection allowing a small size and efficient DC/DC solution that requires only four external components.

The 2.5V to 10V input voltage range of MIC2292/3 allows direct operation from 1- and 2-cell Li Ion as well as 3- to 4-cell NiCad/NiMH/Alkaline batteries. The MIC2292/3 products are available in a small size 2 mm x 2 mm 8-pin DFN package and have a junction temperature range of –40°C to +125°C.

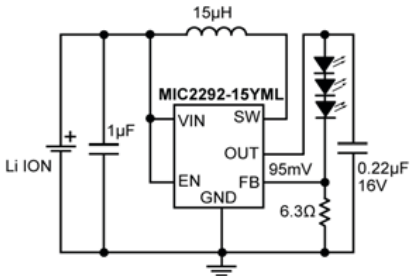
Package Type

MIC2292/93
DFN-8 (ML)
(Top View)
Fused Lead Frame

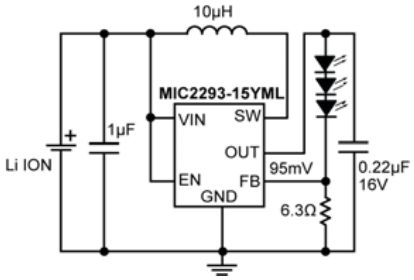


Typical Application Circuits

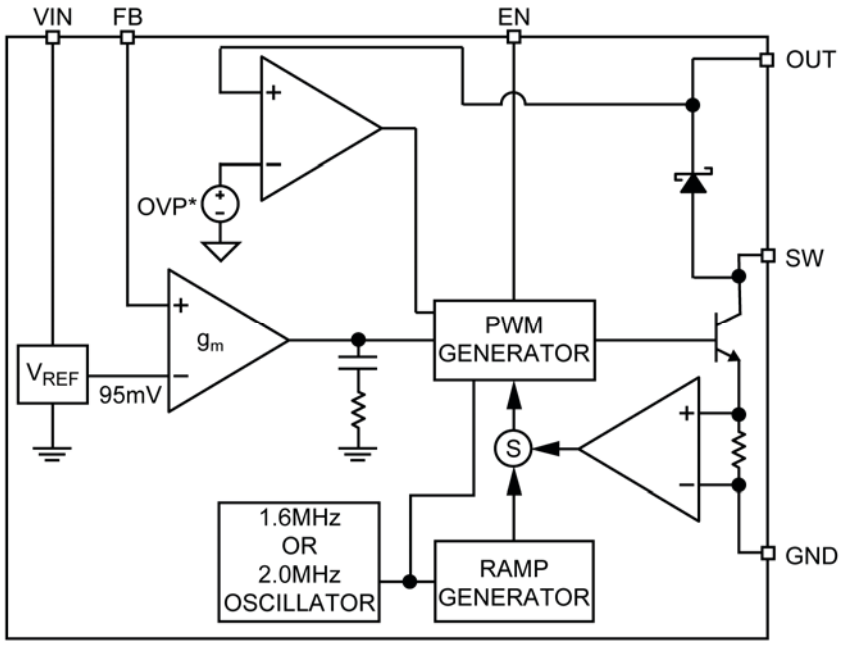
1.6 MHz PWM White LED Driver with 15V OVP



2 MHz PWM White LED Driver with 15V OVP



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) ..... +12V
Switch Voltage (V_{SW}) ..... –0.3V to +34V
Enable Pin Voltage (V_{EN}) ..... –0.3V to V_{IN}
FB Voltage (V_{FB}) ..... +6.0V
Switch Current (I_{SW}) 2A
Schottky Reverse Voltage (V_{DR}) 34V
Ambient Storage Temperature Range (T_S) ..... –65°C to +150°C
ESD Rating (Note 1) ..... 2 kV

Operating Ratings ††

Supply Voltage (V_{IN}) ..... +2.5V to +10V
Output Voltage (V_{OUT}) ..... V_{IN} to V_{OVP}

† Notice: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

†† Notice: The device is not guaranteed to function outside its operating ratings.

Note 1: Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: T_A = +25°C, V_{IN} = V_{EN} = 3.6V, V_{OUT} = 15V, I_{OUT} = 20 mA, unless otherwise noted. **Bold** values indicate –40°C ≤ T_J ≤ ±125°C. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Supply Voltage Range	V_{IN}	**2.5**	—	**10**	V	—
Undervoltage Lockout	V_{UVLO}	1.8	2.1	2.4	V	—
Quiescent Current	I_{VIN}	—	2.5	5	mA	V_{FB} > 200 mV, not switching
Shutdown Current	I_{SD}	—	0.1	**1**	µA	V_{EN} = 0V, Note 2
Feedback Voltage	V_{FB}	90	95	100	mV	±5%
Feedback Input Current	I_{FB}	—	–450	—	nA	V_{FB} = 95 mV
Line Regulation	—	—	0.5	1	%	3V ≤ V_{IN} ≤ 5V, Note 3
Load Regulation	—	—	0.5	2	%	5 mA ≤ I_{OUT} ≤ 20 mA, Note 3
Maximum Duty Cycle	D_{MAX}	**85**	90	—	%	—
Switch Current Limit	$I_{SW(LIM)}$	—	750	—	mA	—
Switch Saturation Voltage	$V_{SW(SAT)}$	—	450	—	mV	I_{SW} = 0.5A
Switch Leakage Current	$I_{SW(LK)}$	—	0.01	**5**	µA	V_{EN} = 0V, V_{SW} = 10V
Enable Threshold	V_{EN}	**1.5**	—	—	V	Turn on
		—	—	**0.4**		Turn off
Enable Pin Current	I_{EN}	—	20	40	µA	V_{EN} = 10V
Oscillator Frequency	f_{SW}	1.4	1.6	1.8	MHz	MIC2292
		1.75	2.0	2.25		MIC2293
Schottky Forward Drop	V_D	—	0.8	1	V	I_D = 150 mA
Schottky Leakage Current	I_{RD}	—	—	**4**	µA	V_R = 30
Overvoltage Protection	V_{OVP}	13	14	16	V	MIC2292/93-15
		30	32	34		MIC2292/93-34
Turn-On Time	t_{ON}	—	—	50	µs	V_{IN} = 2.5V, V_{EN} ramped 0V to V_{IN}
		—	—	50		V_{IN} = 5V, V_{EN} ramped 0V to V_{IN}
		—	—	50		V_{IN} = 5V, V_{EN} ramped 0V to V_{IN}
Overtemperature Shutdown	t_{SD}	—	150	—	°C	Threshold
		—	10	—		Hysteresis

Note 1: Specification for packaged product only.

2: I_{SD} = I_{VIN}.

3: Guaranteed by design.

TEMPERATURE SPECIFICATIONS

Parameters	Symbol	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Operating Temperature	T_J	–40	—	+125	°C	—
Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistance						
Thermal Resistance, 2x2 DFN 8-Lead	θ_{JA}	—	93	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°C can impact the device reliability.

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

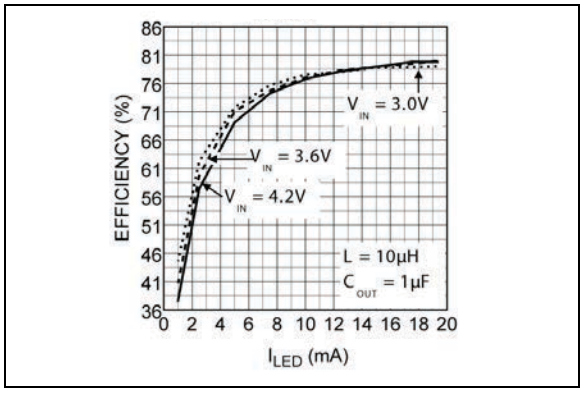


FIGURE 2-1: *MIC2292 3 Series LED Efficiency.*

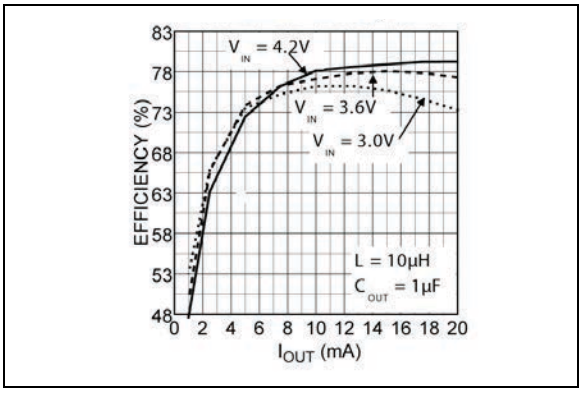


FIGURE 2-4: *MIC2293 6 Series LED Efficiency.*

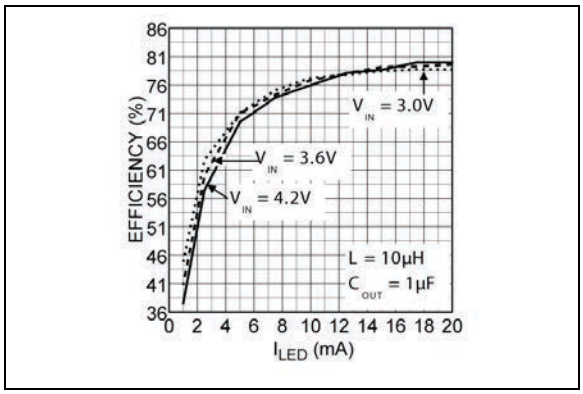


FIGURE 2-2: *MIC2293 3 Series LED Efficiency.*

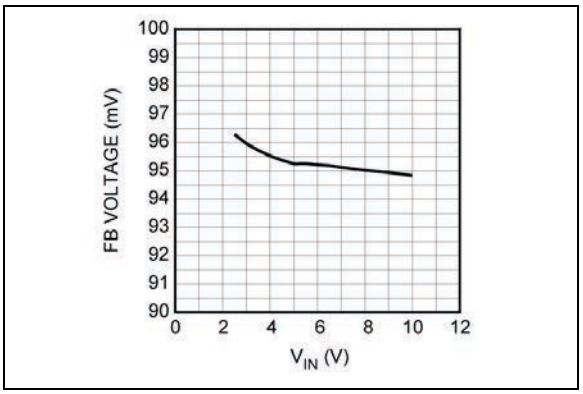


FIGURE 2-5: *Feedback Voltage vs. Input Voltage.*

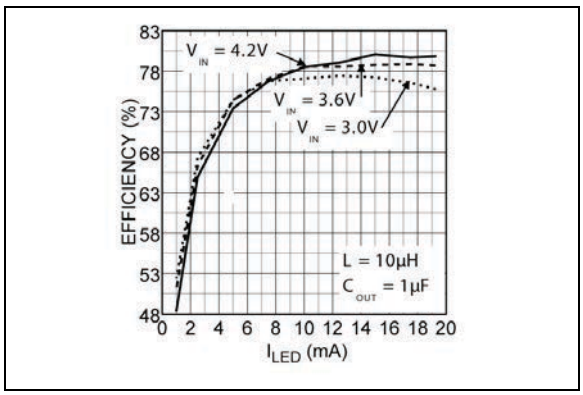


FIGURE 2-3: *MIC2292 6 Series LED Efficiency.*

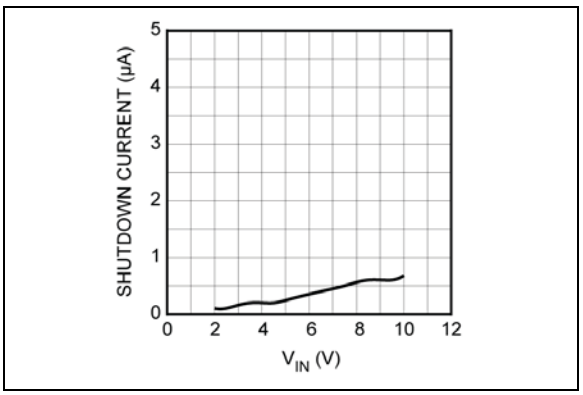


FIGURE 2-6: *Shutdown Current vs. Input Voltage.*

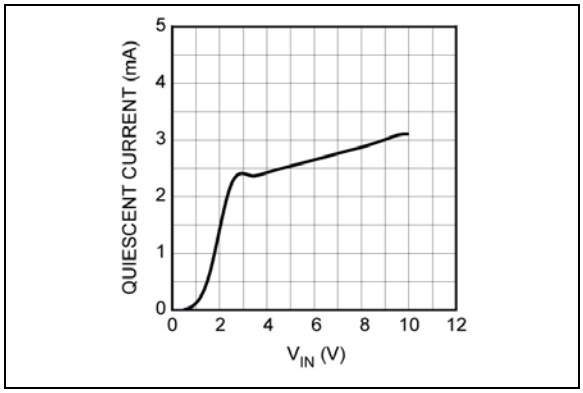


FIGURE 2-7: *Quiescent Current vs. Input Voltage.*

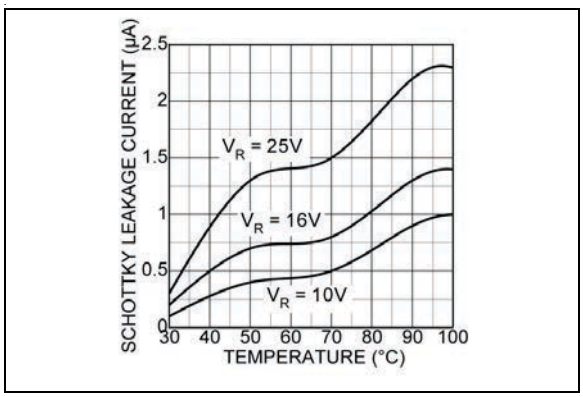


FIGURE 2-10: *Schottky Reverse Leakage Current.*

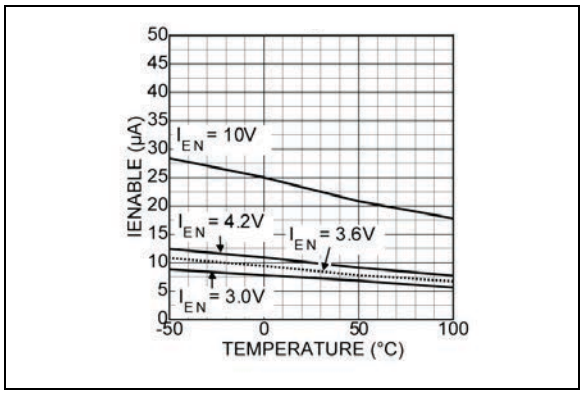


FIGURE 2-8: *EN Pin Bias Current vs. Temperature.*

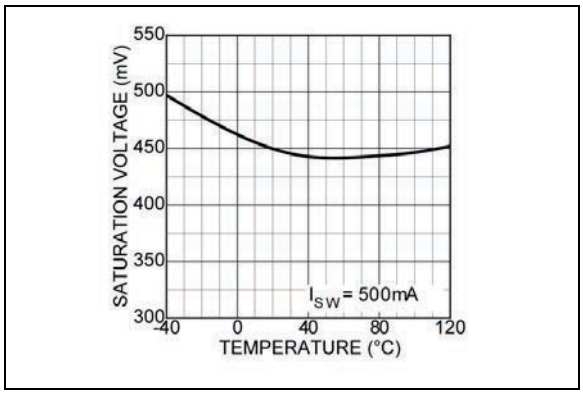


FIGURE 2-11: *Saturation Voltage vs. Temperature.*

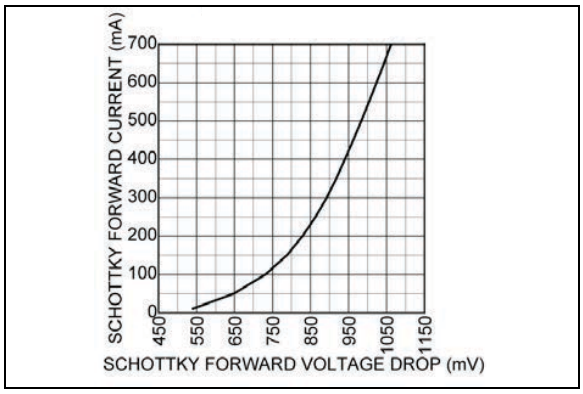


FIGURE 2-9: *Schottky Forward Voltage Drop.*

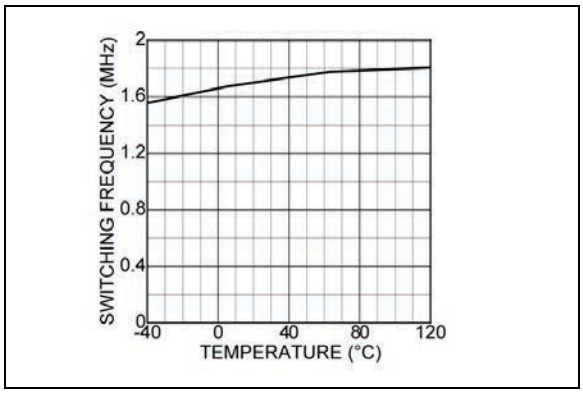


FIGURE 2-12: *MIC2292 Switch Frequency vs. Temperature.*

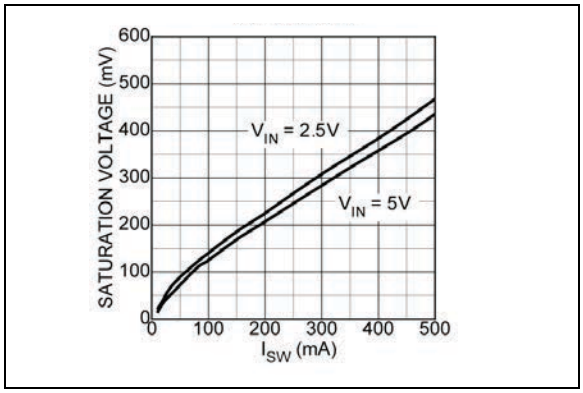


FIGURE 2-13: *Switch Saturation Voltage vs. Current.*

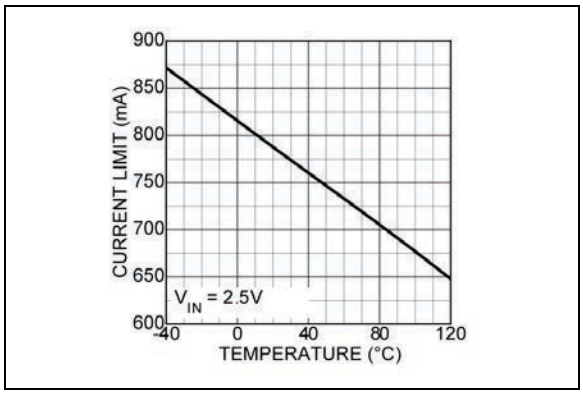


FIGURE 2-14: *Current Limit vs. Temperature.*

FUNCTIONAL CHARACTERISTICS

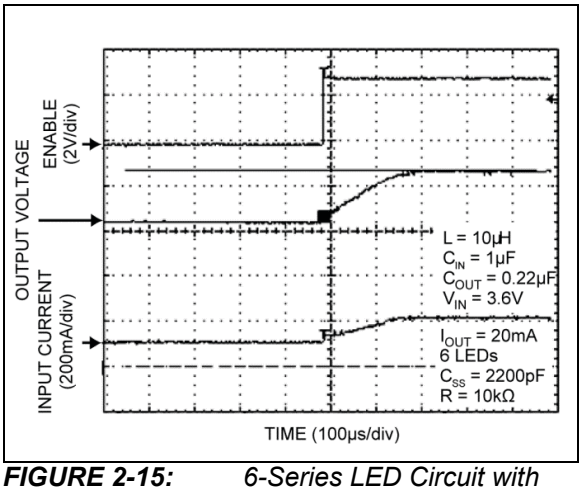


FIGURE 2-15: *6-Series LED Circuit with External Soft-Start.*

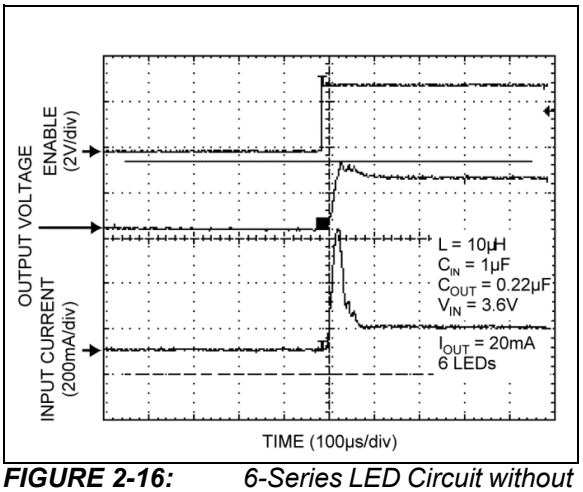


FIGURE 2-16: *6-Series LED Circuit without External Soft-Start.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number DFN-8	Pin Name	Description
1	OUT	Output Pin and Overvoltage Protection (Output). Connect to the output capacitor and LEDs.
2	VIN	Supply (Input). Input voltage.
3	EN	Enable (Input). Logic HIGH enables regulator and logic LOW shuts down regulator.
5	NC	No Connect. No internal connection to die.
6	FB	Feedback (Input). Output voltage sense node. Connect the cathode of the LED to this pin. A resistor from this pin to Ground (GND) sets the LED current.
7	SW	Switch Node (Input). Internal power transistor collector.
4, 8	GND	Ground (Return). Ground.
EP	GND	Ground (Return). Exposed backside pad (ePad).

4.0 FUNCTIONAL DESCRIPTION

The MIC2292/93 are constant frequency, PWM current-mode boost regulators. The Functional Block Diagram is on page two. The MIC2292/93 are composed of an oscillator, slope compensation ramp generator, current amplifier, gm error amplifier, PWM generator, 500 mA bipolar output transistor, and Schottky rectifier diode. The oscillator generates a 1.6 MHz clock for the MIC2292 and a 2.0 MHz clock for the MIC2293. The clocks' two functions are to trigger the PWM generator that turns on the output transistor and to reset the slope compensation ramp generator. The current amplifier is used to measure the switch current by amplifying the voltage signal from the internal sense resistor. The output of the current amplifier is summed with the output of the slope compensation ramp generator. This summed current-loop signal is fed to one of the inputs of the PWM generator.

The g_m error amplifier measures the LED current through the external sense resistor and amplifies the error between the detected signal and the 95 mV reference voltage. The output of the g_m error amplifier provides the voltage loop signal that is fed to the other input of the PWM generator. When the current-loop signal exceeds the voltage loop signal, the PWM generator turns off the bipolar output transistor. The next clock period initiates the next switching cycle, maintaining the constant frequency current mode PWM control. The LED current is set by the feedback resistor:

EQUATION 4-1:

$$I_{LED} = \frac{95mV}{R_{FB}}$$

The Enable pin shuts down the output switching and disables control circuitry to reduce VIN pin input current to leakage current level. Enable pin input current is zero at zero volt.

4.1 Dimming Control

There are two techniques for dimming control. One is PWM dimming, and the other is continuous dimming.

1. PWM dimming control is implemented by applying a PWM signal on EN pin as shown in Figure 4-1. The MIC2292/93 is turned on and off by the PWM signal. With this method, the LEDs operate with either zero or full current. The average LED current is increased proportionally to the duty-cycle of the PWM signal. This technique has high efficiency because the IC and the LEDs consume no current during the off-cycle of the PWM signal. Typical frequency should be between 100 Hz and 10 kHz.
2. Continuous dimming control is implemented by applying a DC control voltage to the FB pin of the MIC2289 through a series resistor as shown in Figure 4-2. The LED current is decreased proportionally with the amplitude of the control voltage. The LED intensity (current) can be dynamically varied applying a DC voltage to the FB pin. The DC voltage can come from a DAC signal, or a filtered PWM signal. The advantage of this approach is that a high frequency PWM signal (>10 kHz) can be used to control LED intensity.

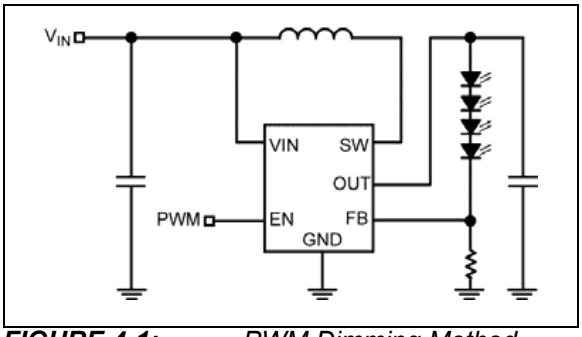


FIGURE 4-1: *PWM Dimming Method.*

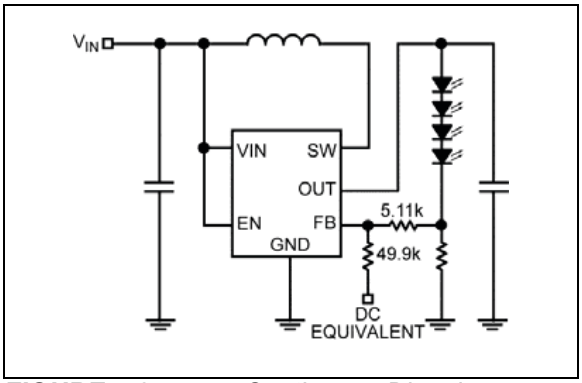


FIGURE 4-2: *Continuous Dimming.*

4.2 Open Circuit Protection

If the LEDs are disconnected from the circuit, or in case an LED fails open, the sense resistor will pull the FB pin to ground. This will cause the MIC2292/93 to switch with a high duty cycle, resulting in output overvoltage. This may cause the SW pin voltage to exceed its maximum voltage rating, possibly damaging the IC and the external components. To ensure the highest level of protection, the MIC2292/93 has two product options in the 2 mm × 2 mm DFN-8 with overvoltage protection, OVP. The extra pins of the 8-pin DFN package allow the use of a dedicated OVP monitor with options for 15V or 34V (see Figure 4-3). The reason for the two OVP levels is to let users choose the suitable level of OVP for their application. For example, a 4-LED application would typically see an output voltage of no more than 12V, so a 15V OVP option would offer a suitable level of protection. This allows the user to select the output diode and capacitor with the lowest voltage ratings, therefore smallest size and lowest cost. The OVP will clamp the output voltage to within the specified limits.

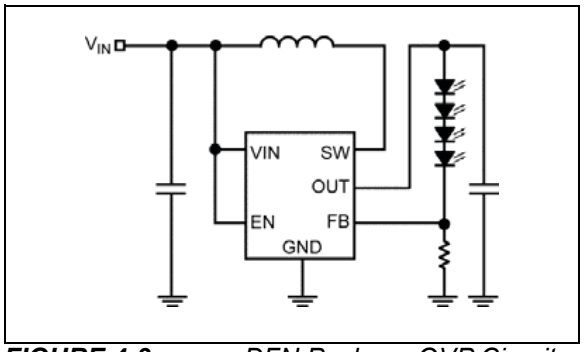


FIGURE 4-3: *DFN Package OVP Circuit.*

4.3 Start-Up and Inrush Current

During start-up, inrush current of approximately double the nominal current flows to set up the inductor current and the voltage on the output capacitor. If the inrush current needs to be limited, a soft-start circuit similar to Figure 4-4 could be implemented. The soft-start capacitor, C_{SS}, provides over drive voltage to the FB pin at start-up, resulting in gradual increase of switch duty cycle and limited inrush current.

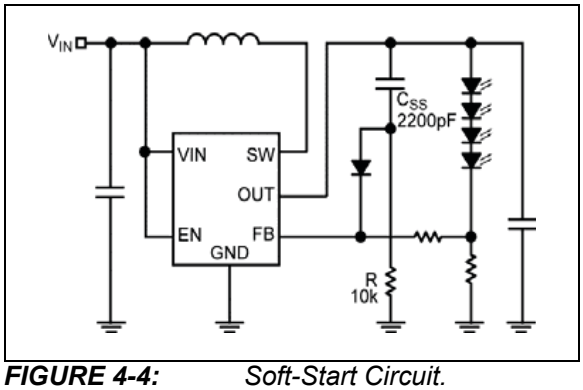


FIGURE 4-4: *Soft-Start Circuit.*

5.0 EXTERNAL COMPONENT SELECTION

The MIC2292/93 can be used across a wide rage of applications. The table below shows recommended inductor and output capacitor values for various series-LED applications.

TABLE 5-1: RECOMMENDED INDUCTOR AND OUTPUT CAPACITOR VALUES

Series LEDs	L	Part #	Manufacturer	Min. C_{OUT}	Part #	Manufacturer
2	22 µH	LQH32CN220K21	Murata	2.2 µF	0805ZD225KAT	AVX
		NLC453232T-220K	TDK		GRM40X5R225K10	Murata
	15 µH	LQH32CN150K21	Murata	1 µF	0805ZD105KAT	AVX
		NLC453232T-150K	TDK		GRM40X5R105K10	Murata
	10 µH	LQH32CN100K21	Murata	0.22 µF	0805ZD224KAT	AVX
		NLC453232T-100K	TDK		GRM40X5R224K10	Murata
	6.8 µH	LQH32CN6R8K21	Murata	0.22 µF	0805ZD224KAT	AVX
		NLC453232T-6R8K	TDK		GRM40X5R224K10	Murata
	4.7 µH	LQH32CN4R7K21	Murata	0.22 µF	0805ZD224KAT	AVX
		NLC453232T-4R7K	TDK		GRM40X5R224K10	Murata
3	22 µH	LQH43MN220K21	Murata	2.2 µF	0805YD225KAT	AVX
		NLC453232T-220K	TDK		GRM40X5R225K16	Murata
	15 µH	LQH43MN150K21	Murata	1 µF	0805YD105KAT	AVX
		NLC453232T-150K	TDK		GRM40X5R105K16	Murata
	10 µH	LQH43MN100K21	Murata	0.22 µF	0805YC224KAT	AVX
		NLC453232T-100K	TDK		GRM40X5R224K16	Murata
	6.8 µH	LQH43MN6R8K21	Murata	0.22 µF	0805YC224KAT	AVX
		NLC453232T-6R8K	TDK		GRM40X5R224K16	Murata
	4.7 µH	LQH43MN4R7K21	Murata	0.27 µF	0805YC274KAT	AVX
		NLC453232T-4R7K	TDK		GRM40X5R274K16	Kemet
4	22 µH	LQH43MN220K21	Murata	1 µF, 25V	08053D105KAT	AVX
		NLC453232T-220K	TDK		GRM40X5R105K25	Kemet
	15 µH	LQH43MN150K21	Murata	1 µF, 25V	08053D105KAT	AVX
		NLC453232T-150K	TDK		GRM40X5R105K25	Kemet
	10 µH	LQH43MN100K21	Murata	0.27 µF	08053C274KAT2A	AVX
		NLC453232T-100K	TDK		GRM40X5R274K25	Kemet
	6.8 µH	LQH43MN6R8K21	Murata	0.27 µF	08053C274KAT	AVX
		NLC453232T-6R8K	TDK		GRM40X5R274K25	Kemet
	4.7 µH	LQH43MN4R7K21	Murata	0.27 µF	08053C274KAT	AVX
		NLC453232T-4R7K	TDK		GRM40X5R274K25	Kemet

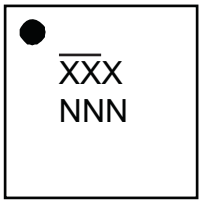
TABLE 5-1: RECOMMENDED INDUCTOR AND OUTPUT CAPACITOR VALUES (CONTINUED)

Series LEDs	L	Part #	Manufacturer	Min. C_{OUT}	Part #	Manufacturer
5, 6	22 µH	LQH43MN220K21	Murata	0.22 µF	08053C224KAT	AVX
		NLC453232T-220K	TDK		GRM40X5R224K25	Murata
	15 µH	LQH43MN150K21	Murata	0.22 µF	08053C224KAT	AVX
		NLC453232T-150K	TDK		GRM40X5R224K25	Murata
	10 µH	LQH43MN100K21	Murata	0.27 µF	08053C274KAT	AVX
		NLC453232T-100K	TDK		GRM40X5R274K25	Kemet
	6.8 µH	LQH43MN6R8K21	Murata	0.27 µF	08053C274KAT	AVX
		NLC453232T-6R8K	TDK		GRM40X5R274K25	Kemet
	4.7 µH	LQH43MN4R7K21	Murata	0.27 µF	08053C274KAT	AVX
		NLC453232T-4R7K	TDK		GRM40X5R274K25	Kemet
7, 8	22 µH	LQH43MN220K21	Murata	0.22 µF	0805DD224KAT	AVX
		NLC453232T-220K	TDK		GRM40X5R224K25	Murata
	15 µH	LQH43MN150K21	Murata	0.22 µF	0805DD224KAT	AVX
		NLC453232T-150K	TDK		GRM40X5R224K25	Murata
	10 µH	LQH43MN100K21	Murata	0.27 µF	08055C274KAT	AVX
		NLC453232T-100K	TDK		GRM40X5R274K25	Kemet
	6.8 µH	LQH43MN6R8K21	Murata	0.27 µF	08055C274KAT	AVX
		NLC453232T-6R8K	TDK		GRM40X5R274K25	Kemet
	4.7 µH	LQH43MN4R7K21	Murata	0.27 µF	08055C274KAT	AVX
		NLC453232T-4R7K	TDK		GRM40X5R274K25	Kemet

6.0 PACKAGING INFORMATION

6.1 Package Marking Information

8-Lead VDFN*



Example

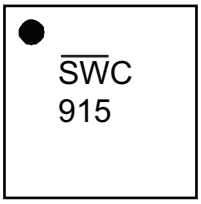


TABLE 6-1: MIC2292/93 PACKAGE MARKING CODES

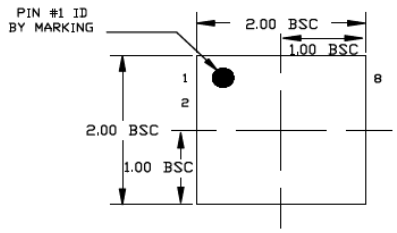
Part Number	Package	OVP	Product Code
MIC2292-15YML	DFN-8	15V	SWA
MIC2292-34YML	DFN-8	34V	SWC
MIC2293-15YML	DFN-8	15V	SZA
MIC2293-34YML	DFN-8	34V	SZC

Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).
Note:	In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.	
	Underbar (_) and/or Overbar (¯) symbol may not be to scale.	

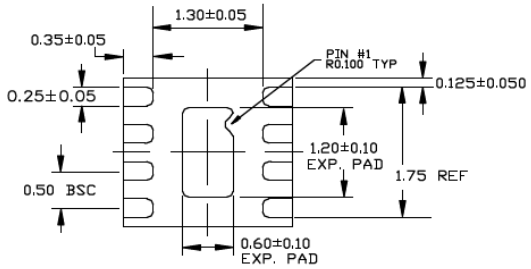
8-Lead 2 mm x 2 mm DFN Package Outline and Recommended Land Pattern

TITLE
8 LEAD DFN 2x2mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

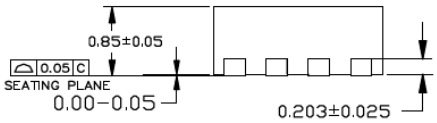
DRAWING #	DFN22-8LD-PL-1	UNIT	MM



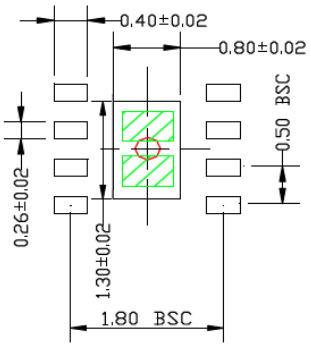
TOP VIEW
NOTE: 1, 2, 3



BOTTOM VIEW
NOTE: 1, 2, 3



END VIEW
NOTE: 1, 2, 3



RECOMMENDED LAND PATTERN
NOTE: 4, 5

NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. RED CIRCLE IN LAND PATTERN INDICATE THERMAL VIA. SIZE SHOULD BE 0.30-0.35MM IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE
5. GREEN RECTANGLES (SHADED AREA) INDICATE SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 0.60x0.40 MM IN SIZE, 0.20 MM SPACING.

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging.

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (October 2021)

- Converted Micrel document MIC2292/93 to Microchip data sheet template DS20006598A.
- Minor grammatical corrections throughout.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART NO.	-XX	X	XX	–XX
Device	Feature	Junction Temperature Range	Package	Media Type

Device:	MIC2292: High-Frequency PWM White LED Driver with Internal Schottky Diode and OVP MIC2293: High-Frequency PWM White LED Driver with Internal Schottky Diode and OVP		
Feature:	15	=	15V
	34	=	34V
Junction Temperature Range:	Y	=	–40°C to +125°C, RoHS Compliant
Package:	ML	=	8-Lead 2 mm x 2 mm x 0.9 mm DFN
Media Type:	TR	=	5,000/Reel

Examples:

a) MIC2292-15YML-TR: High-Frequency PWM White LED Driver with Internal Schottky Diode and OVP, 15V, –40°C to +125°C Junction Temperature Range, RoHS compliant, 8-Lead DFN 2 mm x 2 mm x 0.9 mm Package, 5,000/Reel

b) MIC2293-34YML-TR: High-Frequency PWM White LED Driver with Internal Schottky Diode and OVP, 15V, –40°C to +125°C Junction Temperature Range, RoHS compliant, 8-Lead DFN 2 mm x 2 mm x 0.9 mm Package, 5,000/Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

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