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MIC2291

1.2A PWM Boost Regulator
Photo Flash LED Driver

General Description

The MIC2291 is a 1.2MHz Pulse Width Modulation (PWM), boost-switching regulator that is optimized for high-current, white LED photo flash applications. With a guaranteed switch current of 1.2A, the MIC2291 easily drives a string of 3 white LEDs in series at 100mA, ensuring a high level of brightness and eliminating several ballast resistors.

The MIC2291 implements a constant frequency, 1.2MHz PWM control scheme. The high frequency PWM operation saves board space by reducing external component sizes. The added benefit of the constant frequency PWM scheme, in contrast to variable frequency topologies, is much lower noise and input ripple injected back to the battery source.

To optimize efficiency, the feedback voltage is set to only 95mV. This reduces the power dissipation in the current set resistor, and allows the lowest total output voltage, hence minimal current draw from the battery.

The MIC2291 is available with 2 levels of over-voltage protection, 15V, and 34V. This allows designers to choose the smallest possible external components with the appropriate voltage ratings for their applications.

The MIC2291 is available in low-profile, Thin SOT23 5-lead and 8-lead 2mm×2mm MLF™ package options. The MIC2291 has a junction temperature range of –40°C to +125°C.

All support documentation can be found on Micrel's web site at www.micrel.com.

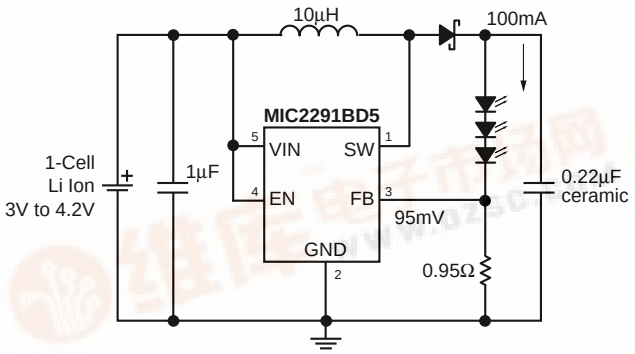
Features

- 2.5V to 10V input voltage
- Output voltage up to 34V
- 1.2A switch current
- 1.2MHz PWM operation
- 95mV feedback voltage
- Overvoltage protection (OVP)
  - Options for 15V and 34V
- Stable with ceramic capacitors
- <1% line and load regulation
- 1µA shutdown current
- Over temperature protection
- UVLO
- Low-profile Thin SOT23-5 package option
- 2mm × 2mm MLF™ package option
- –40°C to +125°C junction temperature range

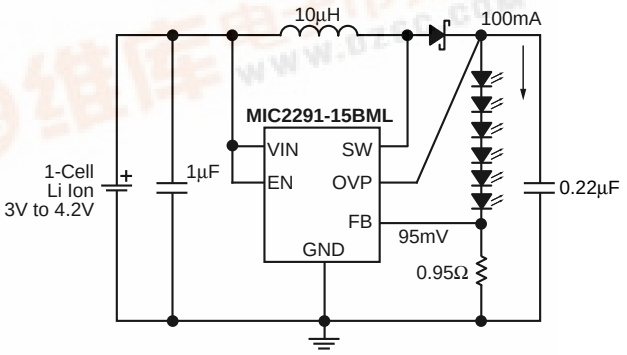
Applications

- Photo Flash LED driver
- Cell phones
- PDAs
- GPS systems
- Digital cameras
- IP phones
- LED flashlights

Typical Application



Thin SOT23 Flash LED Driver



2mm × 2mm Flash LED Driver with Output OVP

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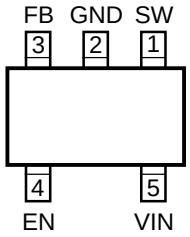
PowerPAK is a trademark of Siliconix, Inc.

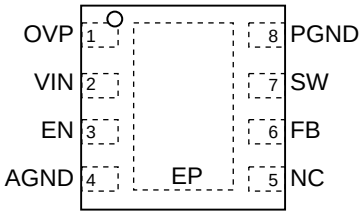
Ordering Information

Part Number	Marking Code	Overvoltage Protection	Junction Temp. Range	Package	Lead Finish
MIC2291BD5	SSAA	—	–40°C to 125°C	Thin SOT-23-5	Standard
MIC2291YD5	SSAA	—	–40°C to 125°C	Thin SOT-23-5	Pb-Free
MIC2291-15BML	STA	15V	–40°C to 125°C	2mm × 2mm MLF™	Standard
MIC2291-15YML	STA	15V	–40°C to 125°C	2mm × 2mm MLF™	Pb-Free
MIC2291-34BML	STC	34V	–40°C to 125°C	2mm × 2mm MLF™	Standard
MIC2291-34YML	STC	34V	–40°C to 125°C	2mm × 2mm MLF™	Pb-Free

Pin Configuration



TSOT-23-5 (BD5)



8-Pin MLF™ (BML)
(Top View)

Fused Lead Frame

Pin Description

Pin Number TSOT-23-5	Pin Number 2mm × 2mm MLF™	Pin Name	Pin Function
1	7	SW	Switch node (Output): Internal power BIPOLAR collector.
2		GND	Ground (Return): Ground.
3	6	FB	Feedback (Input): Output voltage sense node. Connect the cathode of the LED to this pin. Connect current set resistor from this pin to ground.
4	3	EN	Enable (Input): Logic high (≥1.5V) enables regulator. Logic low (≤0.4V) shuts down regulator.
5	2	VIN	Supply (Input): Input Voltage.
—	1	OVP	Overvoltage protection (Input): Connect to the output to clamp the maximum output voltage.
—	4	AGND	Analog ground. Internally connected to ground.
—	8	PGND	Power ground.
—	5	NC	No connect (no internal connection to die).
—	EP	GND	Ground (Return): Exposed backside pad.

Absolute Maximum Ratings[1]

Supply Voltage (V_{IN}) 12V
Switch Voltage (V_{SW}) ..... –0.3V to 34V
Enable Pin Voltage (V_{EN}) ..... –0.3 to V_{IN}
FB Voltage (V_{FB}) 6V
Switch Current (I_{SW}) 2A
Ambient Storage Temperature (T_S) ..... –65°C to +150°C
ESD Rating[3] 2kV

Operating Ratings[2]

Supply Voltage (V_{IN}) ..... 2.5V to 10V
Junction Temperature Range (T_J) ..... –40°C to +125°C
Package Thermal Impedance
8-lead 2mm × 2mm MLF™ (θ_{JA}) ..... 93°C/W
Thin SOT-23-5 (θ_{JA}) ..... 256°C/W

Electrical Characteristics[4]

T_A = 25°C, V_{IN} = V_{EN} = 3.6V, V_{OUT} = 10V, I_{OUT} = 40mA, unless otherwise noted. **Bold** values indicate –40°C ≤ T_J ≤125°C.

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{IN}	Supply Voltage Range		**2.5**		**10**	V
V_{UVLO}	Under Voltage Lockout		1.8	2.1	2.4	V
I_{VIN}	Quiescent Current	V_{FB} > 200mV, (not switching)		2.8	5	mA
I_{SD}	Shutdown Current	V_{EN} = 0V[5]		0.1	**1**	µA
V_{FB}	Feedback Voltage	(±5%)	90	95	100	mV
I_{FB}	Feedback Input Current	V_{FB} = 95mV		–450		nA
	Line Regulation	3V ≤ V_{IN} ≤ 5V		0.5	1	%
	Load Regulation	5mA ≤ I_{OUT} ≤ 40mA		0.5	2	%
D_{MAX}	Maximum Duty Cycle		**85**	90		%
I_{SW}	Switch Current Limit			1.2		A
V_{SW}	Switch Saturation Voltage	I_{SW} = 1.0A		550		mV
I_{SW}	Switch Leakage Current	V_{EN} = 0V, V_{SW} = 10V		0.01	**5**	µA
V_{EN}	Enable Threshold	TURN ON TURN OFF	**1.5**		 **0.4**	V V
I_{EN}	Enable Pin Current	V_{EN} = 10V[6]		20	40	µA
f_{SW}	Oscillator Frequency		1.05	1.2	1.35	MHz
V_{OVP}	Overvoltage Protection	MIC2291BML- 15 only MIC2291BML- 34 only	13 30	14 32	16 34	V V
T_J	Overtemperature Threshold Shutdown	 Hysteresis		150 10		°C °C

Notes:

1. Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its operating ratings. 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 power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.

2. This device is not guaranteed to operate beyond its specified operating ratings.

3. Devices are inherently ESD sensitive. Handling precautions required. Human body model.

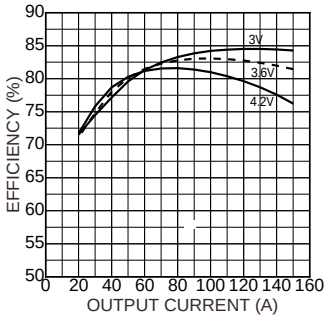
4. Specification for packaged product only.

5. I_{SD} = I_{VIN}.

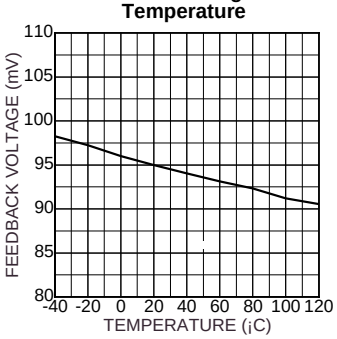
6. See “Typical Characteristics ”section for other V_{EN}.

Typical Characteristics

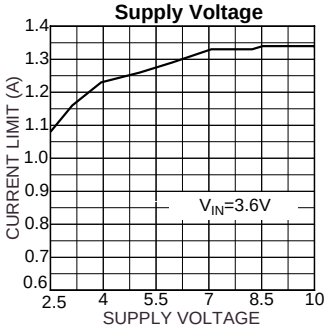
Efficiency 12V$_{OUT}$



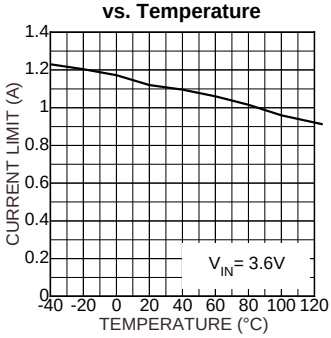
Feedback Voltage vs. Temperature



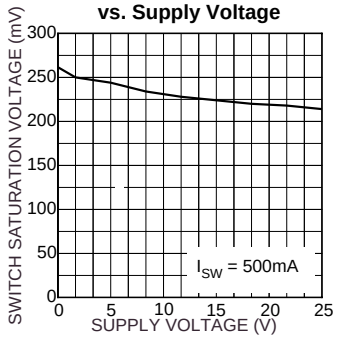
Current Limit vs. Supply Voltage



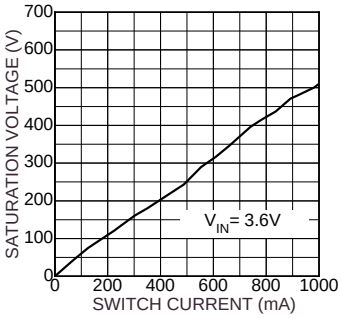
Current Limit vs. Temperature



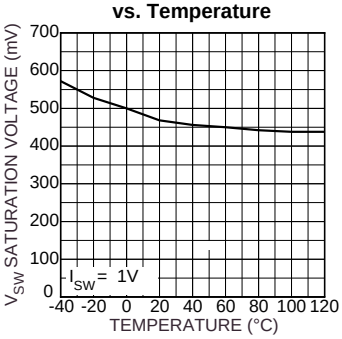
Switch Saturation vs. Supply Voltage



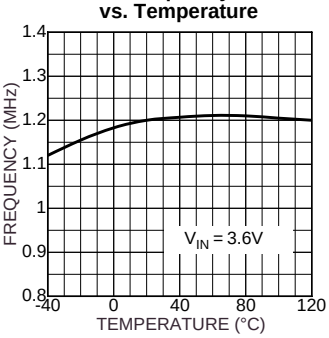
Saturation Voltage vs. Current



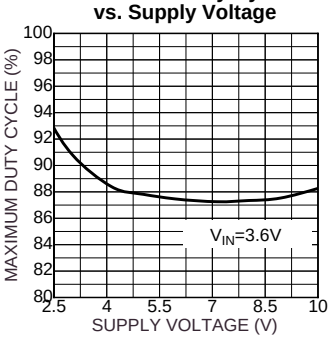
Switch Saturation vs. Temperature



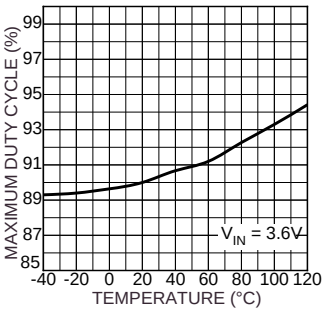
Frequency vs. Temperature



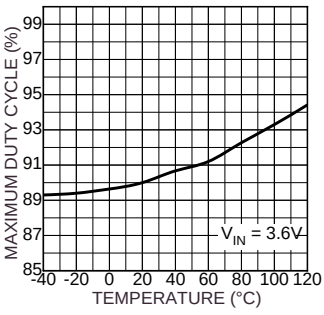
Maximum Duty Cycle vs. Supply Voltage



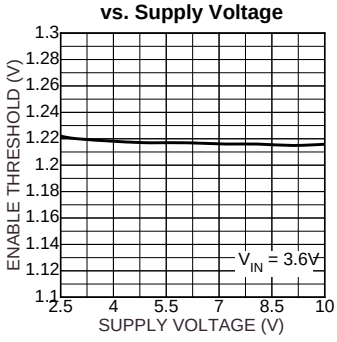
Maximum Duty Cycle vs. Temperature



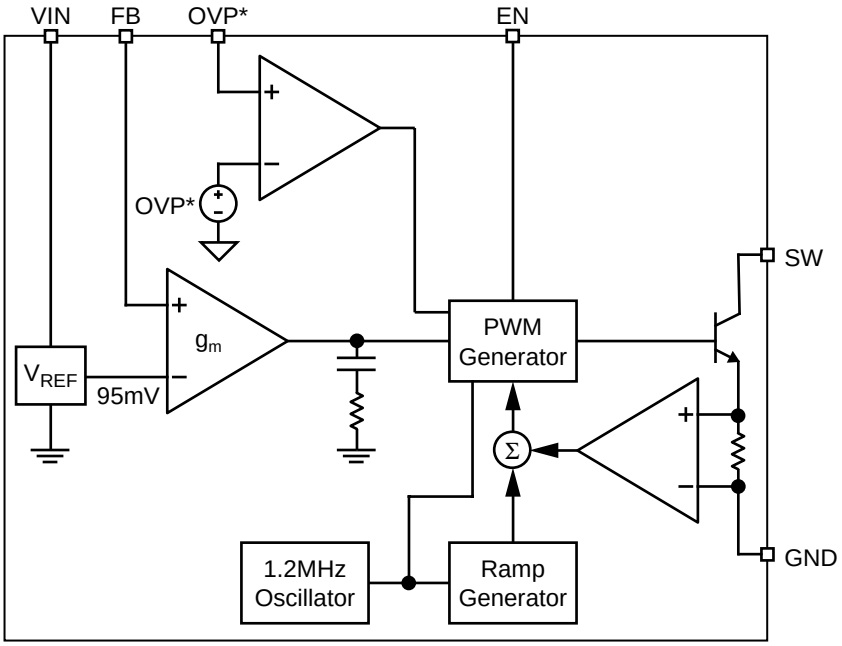
Maximum Duty Cycle vs. Temperature



Enable Threshold vs. Supply Voltage



Functional Diagram



*OVP available on MLF™ package option only

Figure 1. MIC2291 Block Diagram

Functional Description

The MIC2291 is a constant frequency, PWM current mode boost regulator. The block diagram is shown above. The MIC2291 is composed of an oscillator, slope compensation ramp generator, current amplifier, g_m error amplifier, PWM generator, and a 500mA bipolar output transistor. The oscillator generates a 1.2MHz clock. The clock's 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 95mV 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 is set by the feedback resistor:

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

The Enable pin shuts down the output switching and disables control circuitry to reduce input current-to-leakage levels. Enable pin input current is zero at zero volts.

Applications Information

DC to DC PWM Boost Conversion

The MIC2291 is a constant frequency boost converter. It operates by taking a DC input voltage and regulating current through series LED's by monitoring voltage across the sense resistor (R2). LED current regulation is achieved by turning on an internal switch, which draws current through the inductor (L1). When the switch turns off, the inductor's magnetic field collapses, causing the current to be discharged into the output capacitor through an external schottkey diode (D1). Regulation is then achieved by pulse width modulation (PWM) to maintain a constant voltage on the FB pin. This in turn provides constant LED current.

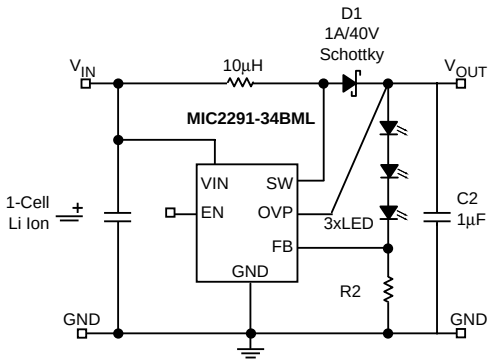


Figure 2. DC to DC PWM Boost Conversion

Duty Cycle Considerations

Duty cycle refers to the switch on-to-off time ratio and can be calculated as follows for a boost regulator;

$$D = 1 - \frac{V_{IN}}{V_{OUT}}$$

The duty cycle required for voltage conversion should be less than the maximum duty cycle of 85%. Also, in light load conditions where the input voltage is close to the output voltage, the minimum duty cycle can cause pulse skipping. This is due to the energy stored in the inductor causing the output to overshoot slightly over the regulated output voltage. During the next cycle, the error amplifier detects the output as being high and skips the following pulse. This effect can be reduced by increasing the minimum load or by increasing the inductor value. Increasing the inductor value reduces peak current, which in turn reduces energy transfer in each cycle.

Over Voltage Protection

For MLF package of MIC2291, there is an over voltage protection function. If the feedback resistors are disconnected from the circuit or the feedback pin is shorted to ground, the feedback pin will fall to ground potential. This will cause the MIC2291 to switch at full duty-cycle in an attempt to maintain the feedback voltage. As a result the output voltage will climb out of control. This may cause the switch node voltage to exceed its maximum voltage rating, possibly damaging the IC and the external components. To ensure the highest level of protection, the MIC2291 OVP pin will shut the switch off when an over-voltage condition is detected saving itself and other sensitive circuitry downstream.

Component Selection

Inductor

Inductor selection is a balance between efficiency, stability, cost, size and rated current. For most applications a 10uH is the recommended inductor value. It is usually a good balance between these considerations.

Efficiency is affected by inductance value in that larger inductance values reduce the peak to peak ripple current. This has an effect of reducing both the DC losses and the transition losses. There is also a secondary effect of an inductors DC resistance (DCR). The DCR of an inductor will be higher for more inductance in the same package size. This is due to the longer windings required for an increase in inductance. Since the majority of input current (minus the MIC2291 operating current) is passed through the inductor, higher DCR inductors will reduce efficiency.

Also, to maintain stability, increasing inductor size will have to be met with an increase in output capacitance. This is due to the unavoidable "right half plane zero" effect for the continuous current boost converter topology. The frequency at which the right half plane zero occurs can be calculated as follows;

$$frhpz = \frac{V_{IN}^2}{V_{OUT} \times L \times I_{OUT} \times 2\pi}$$

The right half plane zero has the undesirable effect of increasing gain, while decreasing phase. This requires that the loop gain is rolled off before this has significant effect on the total loop response. This can be accomplished by either reducing inductance (increasing RHPZ frequency) or increasing the output capacitor value (decreasing loop gain).

Output Capacitor

A 1µF or greater output capacitor is sufficient for most designs. An X5R or X7R dielectric ceramic capacitors are recommended for designs with the MIC2291. Y5V values may be used, but to offset their tolerance over temperature, more capacitance is required.

Diode Selection

The MIC2291 requires an external diode for operation. A schottkey diode is recommended for most applications due to their lower forward voltage drop and reverse recovery time. Ensure the diode selected can deliver the peak inductor current, the maximum output current and the maximum reverse voltage is rated greater than the output voltage.

Input Capacitor

A minimum 1µF ceramic capacitor is recommended for designing with the MIC2291. Increasing input capacitance will improve performance and greater noise immunity on the source. The input capacitor should be as close as possible to

the inductor and the MIC2291, with short traces for good noise performance.

Feedback Resistors

The MIC2291 utilizes a feedback pin to compare the output to an internal reference. The LED current is adjusted by selecting the appropriate feedback resistor value. The desired current can be calculated as follows;

$$R2 = \frac{V_{REF}}{I_{LED}}$$

Where V_{REF} is equal to 95mV.

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 1. The MIC2291 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 PWM frequency should be between 100Hz and 10kHz.

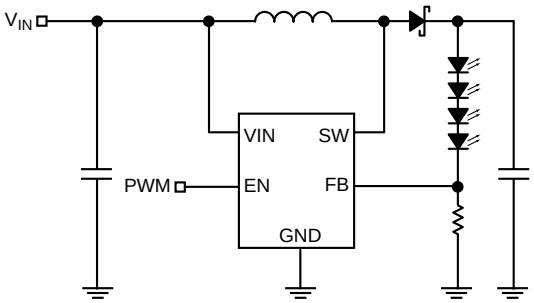


Figure 3. PWM Dimming Method

2. Continuous dimming control is implemented by applying a DC control voltage to the FB pin of the MIC2291 through a series resistor as shown in Figure 2. 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 (>10kHz) can be used to control LED intensity.

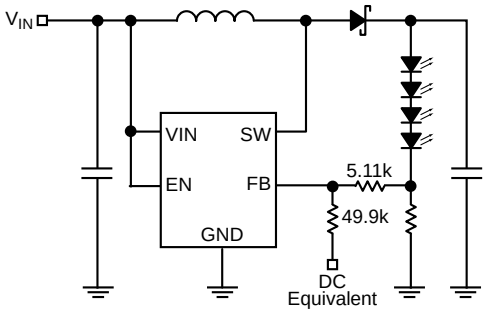
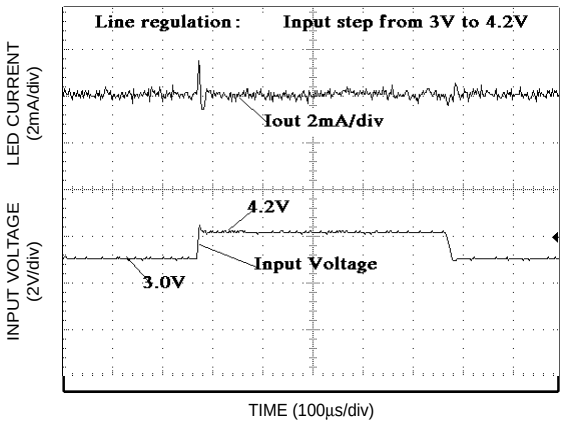
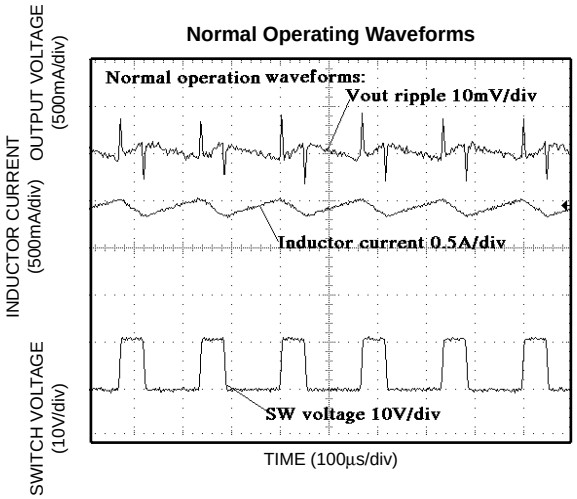


Figure 4. Continuous Dimming

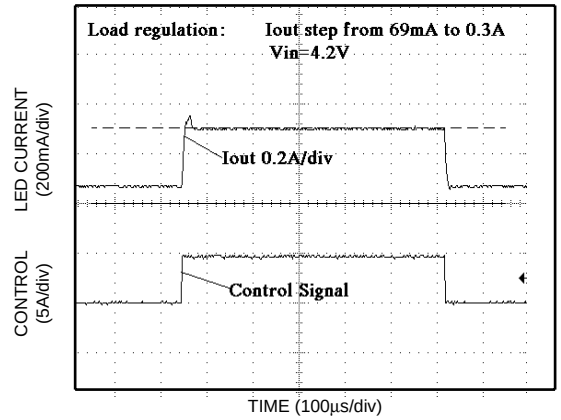
Line Transient



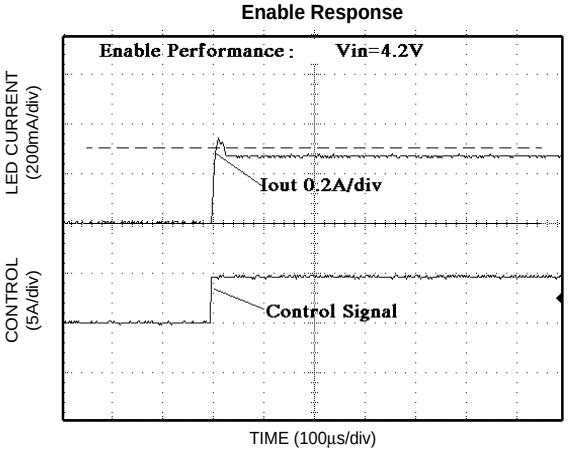
Normal Operating Waveforms



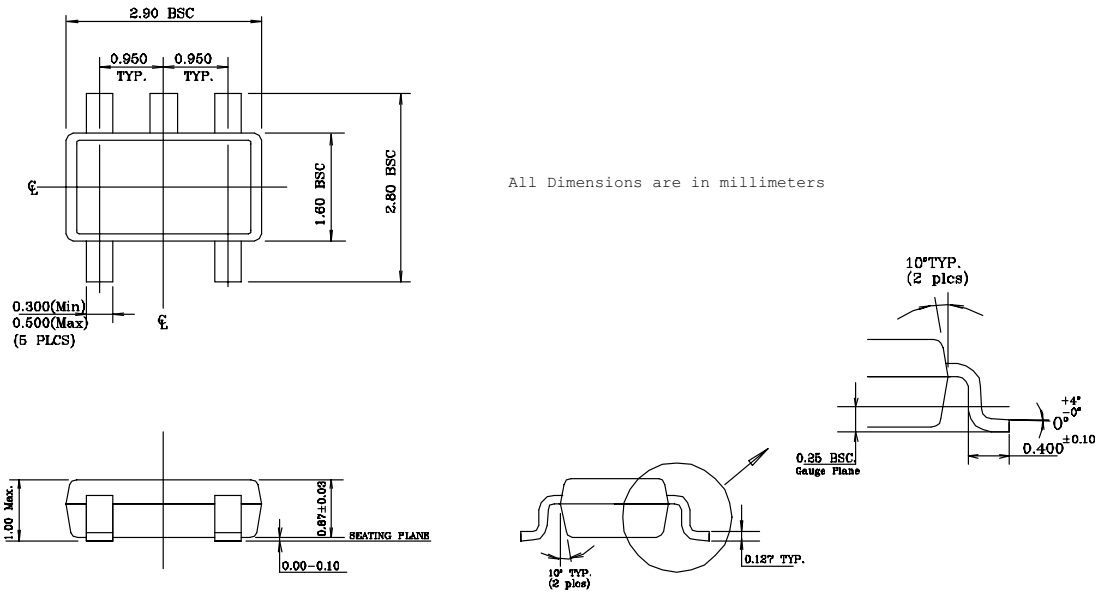
Load Step Response



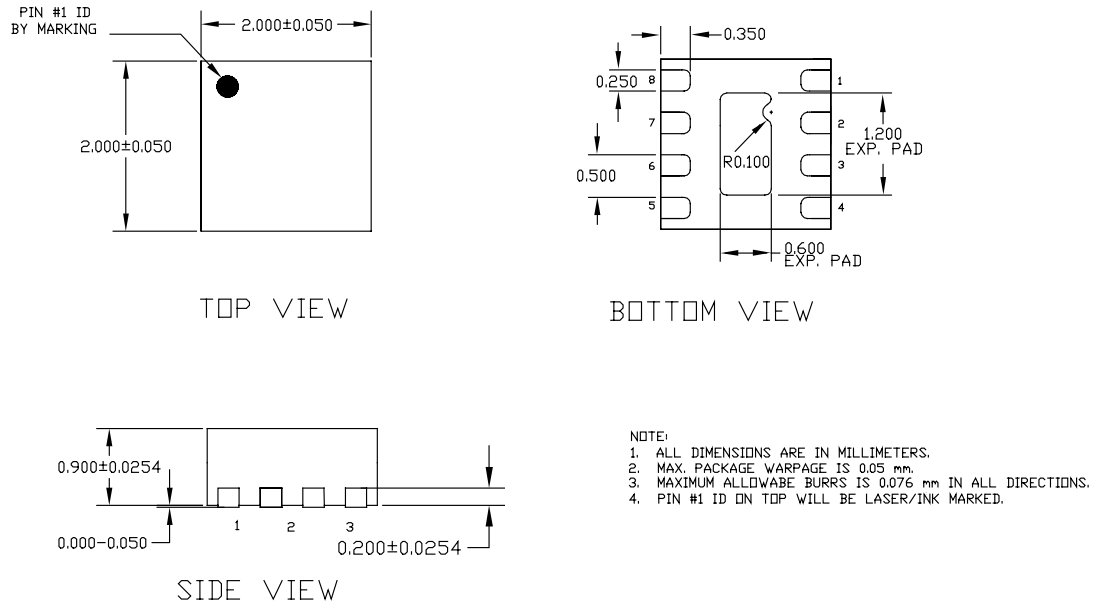
Enable Response



Package Information



5-Pin TSOT (BD5)



8-Pin MLF™ (BML)

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