



## MIC3289

### 1.2MHz PWM White LED Driver with Internal Schottky Diode and True 1-Wire Digital Control

#### PRELIMINARY INFORMATION

### General Description

The MIC3289 is a PWM boost-switching regulator that is optimized for constant-current white LED driver applications. The MIC3289 features an internal Schottky diode, allowing an efficient DC/DC solution that requires only 4 external components.

The MIC3289 allows for a single wire simple digital interface to control the dimming over 16 steps with a log scale to give better resolution at the lower currents to better match the sensitivity of the human eye

The feedback voltage of the MIC3289 is only 250mV, allowing high efficiency while retaining excellent accuracy for the white LED current.

The MIC3289 implements a constant frequency 1.2MHz PWM control scheme. The high frequency PWM operation saves board space by reducing external component sizes. The 1.2MHz PWM scheme also reduces switching noise and ripple to the input power source.

The 2.5V to 6.5V input voltage range of MIC3289 allows direct operation from single cell Li Ion as well as 3- to 4-cell NiCad/ NiMH/Alkaline batteries. Battery life is preserved with a low 1 $\mu$ A shutdown current.

The MIC3289 is available in a low profile Thin SOT23 6-lead package and a 2mm x 2mm MLF<sup>®</sup>-8L package and has a junction temperature range of -40°C to +125°C.

Data sheets and support documentation can be found on Micrel's web site at [www.micrel.com](http://www.micrel.com).

### Features

- 2.5V to 6.5V input voltage
- Output voltage up to 24V
- 16V & 24V OVP options
- Single wire combines 16 level logarithmic brightness & shutdown control
- Internal Schottky diode
- 1.2 MHz PWM operation
- Over 500mA switch current
- Programmable  $\pm 5\%$  current control
- <1% line and load regulation
- <1 $\mu$ A shutdown current
- Over temperature protection
- UVLO
- Thin SOT23-6L package option
- 2mm x 2mm leadless MLF<sup>®</sup>-8L package option
- -40°C to +125°C junction temperature range

### Applications

- White/Blue LED driver for backlighting
  - Cell phones
  - PDAs
  - GPS systems
  - Digital cameras
  - Multimedia / MP3 players
- LED flashlights
- Constant current power supplies

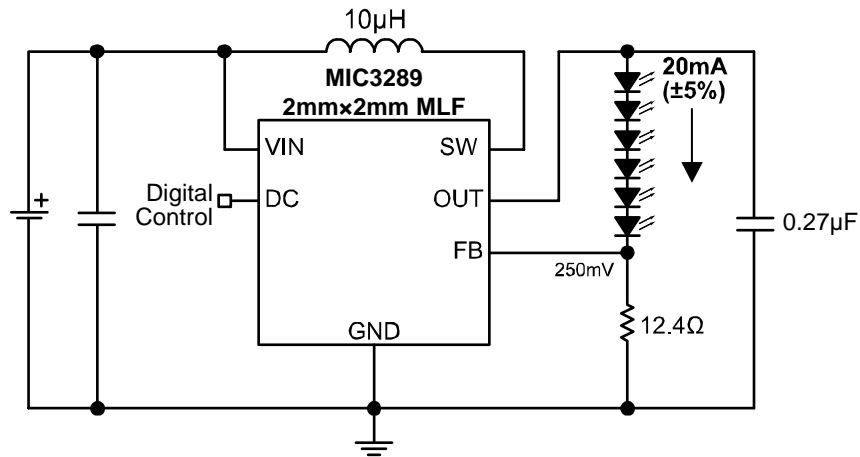
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(408) 944-0800

## Typical Application

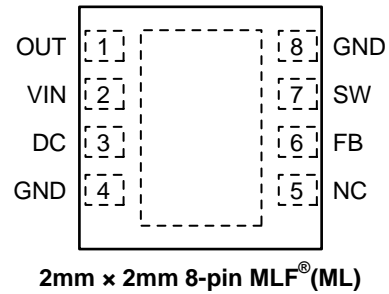
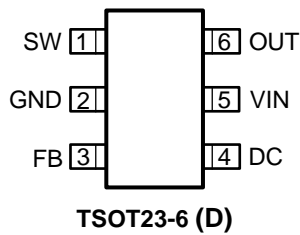


2mmx2mm 8-lead MLF<sup>®</sup> White LED Driver with OVP and Digital Control

## Ordering Information

Part Number	Marking Code	Output Voltage	Over Voltage Protection	Junction Temp. Range	Package
MIC3289-16YD6	WF16	Adjustable	16V	-40°C to 125°C	TSOT23-6
MIC3289-24YD6	WF24	Adjustable	24V	-40°C to 125°C	TSOT23-6
MIC3289-16YML	WFA	Adjustable	16V	-40°C to 125°C	2x2 MLF <sup>®</sup> -8L
MIC3289-24YML	WFB	Adjustable	24V	-40°C to 125°C	2x2 MLF <sup>®</sup> -8L

## Pin Configuration



## Pin Description

Pin Number SOT23-6	Pin Number 8-pin MLF <sup>®</sup>	Pin Name	Pin Name
6	1	OUT	Output and Over Voltage Protection (output)
5	2	VIN	Supply (Input): 2.5V to 6.5V for internal circuitry.
4	3	DC	See diagrams
	5	N/C	No connect (no internal connection to die)
3	6	FB	Feedback (Input): Output voltage sense node. Connect the cathode of the LED to this pin.
1	7	SW	Switch Node (Input): Internal power BIPOLAR collector.
2	4,8	GND	Ground (Return): Ground.
	Pad	GND	Ground (Return): Backside pad.

**Absolute Maximum Ratings<sup>(1)</sup>**

Supply voltage ( $V_{IN}$ )	7.5V
Switch voltage ( $V_{SW}$ )	-0.3V to 27V
Digital Control Voltage ( $V_{DC}$ )	-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, <b>Note 3</b>	2KV

**Operating Ratings<sup>(2)</sup>**

Supply Voltage ( $V_{IN}$ )	2.5V to 6.5V
Output Voltage ( $V_{OUT}$ )	$V_{IN}$ to ( $V_{SW(MAX)} - 4V$ ) or $V_{IN}$ to VOVP (for options with over voltage protection)
Junction Temperature Range ( $T_J$ )	-40°C to +125°C
Package Thermal Impedance	
$\theta_{JA}$ 2mm x 2mm MLF <sup>®</sup> -8L	93°C/W
$\theta_{JA}$ TSOT23-6	235°C/W

**Electrical Characteristics<sup>(4)</sup>**

$T_A=25^\circ\text{C}$ ,  $V_{IN} = 3.6\text{V}$ ,  $V_{OUT} = 10\text{V}$ ,  $I_{OUT} = 20\text{mA}$ , unless otherwise noted. Bold values indicate  $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ .

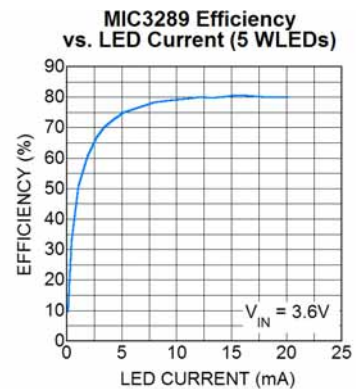
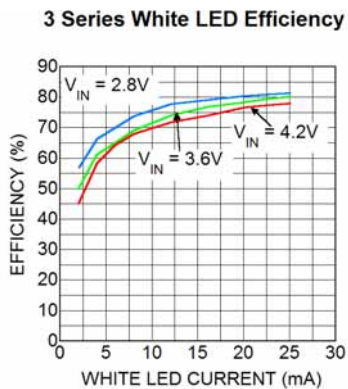
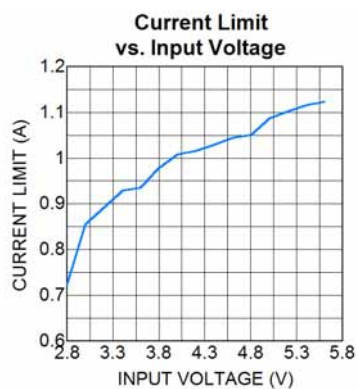
Symbol	Parameter	Condition	Min	Typ	Max	Units
$V_{IN}$	Supply Voltage Range		2.5		6.5	V
$V_{UVLO}$	Under-voltage Lockout		1.8	2.1	2.4	V
$I_{VIN}$	Quiescent Current	$V_{FB} > 500\text{mV}$		1.4	5	mA
$I_{SD}$	Shutdown Current (DC pin low)	$V_{DC} = 0\text{V}$ for > 2ms.		0.01	<b>1</b>	$\mu\text{A}$
$V_{FB}$	Feedback Voltage	(+/-5%)	<b>237</b>	250	<b>263</b>	mV
$I_{FB}$	Feedback Input Current	$V_{FB} = 250\text{mV}$		450		nA
	Line Regulation	$2.5\text{V} \leq V_{IN} \leq 4.5\text{V}$		0.5		%
	Load Regulation	$5\text{mA} \leq I_{OUT} \leq 20\text{mA}$		0.5		%
$D_{MAX}$	Maximum Duty Cycle		<b>85</b>	90		%
$I_{SW}$	Switch Current Limit	$V_{IN} = 3.6\text{V}$	<b>500</b>	750	<b>1200</b>	mA
$V_{DC}$	DC pin thresholds	High Low	<b>1.1</b>		<b>0.4</b>	V
	DC Pin Hysteresis			20		mV
$I_{DC}$	DC Pin Current	$V_{DC} = 3.6\text{V}$		5	10	$\mu\text{A}$
$t_{shutdown}$	Shutdown Pulse Width	$V_{IN} = 2.8\text{V}$ to 5.5V $V_{DC} = \text{Low}$	<b>1260</b>			$\mu\text{s}$
$t_{MODE\_UP}$	Count UP mode pulse width	$V_{IN} = 2.8\text{V}$ to 5.5V $V_{DC} = \text{Low}$	<b>100</b>		<b>160</b>	$\mu\text{s}$
$t_{MODE\_DO\_WN}$	Count Down mode pulse width	$V_{IN} = 2.8\text{V}$ to 5.5V $V_{DC} = \text{Low}$	<b>420</b>		<b>500</b>	$\mu\text{s}$
$t_{start\_up}$	Turn-on Delay Time	$V_{IN} = 2.8\text{V}$ to 5.5V	<b>140</b>			$\mu\text{s}$
$t_{prog\_low}$	Programming pulse width low	$V_{IN} = 2.8\text{V}$ to 5.5V	<b>1</b>		<b>32</b>	$\mu\text{s}$
$t_{prog\_high}$	Programming pulse width high	$V_{IN} = 2.8\text{V}$ to 5.5V	<b>1</b>		<b>32</b>	$\mu\text{s}$
$t_{delay}$	Minimum Delay for mode change	$V_{IN} = 2.8\text{V}$ to 5.5V $V_{DC} = \text{High}$	<b>140</b>			$\mu\text{s}$
$T_{prog\_setup}$	First Pulse Window for Preprogramming	$V_{IN} = 2.8\text{V}$ to 5.5V	<b>35</b>		<b>50</b>	$\mu\text{s}$
$f_{SW}$	Oscillator Frequency		1	1.2	1.35	MHz

Symbol	Parameter	Condition	Min	Typ	Max	Units
$V_D$	Schottky Forward Drop	$I_D = 150\text{mA}$		0.8	1	V
$I_{RD}$	Schottky Leakage Current	$V_R = 30\text{V}$			4	$\mu\text{A}$
$V_{OVP}$	Over Voltage Protection	3289- 16 only (nominal voltage)	13	14	16	V
		3289- 24 only (nominal voltage)	21	22.5	24	V
$T_J$	Over-Temperature Threshold Shutdown			150		$^{\circ}\text{C}$

**Notes:**

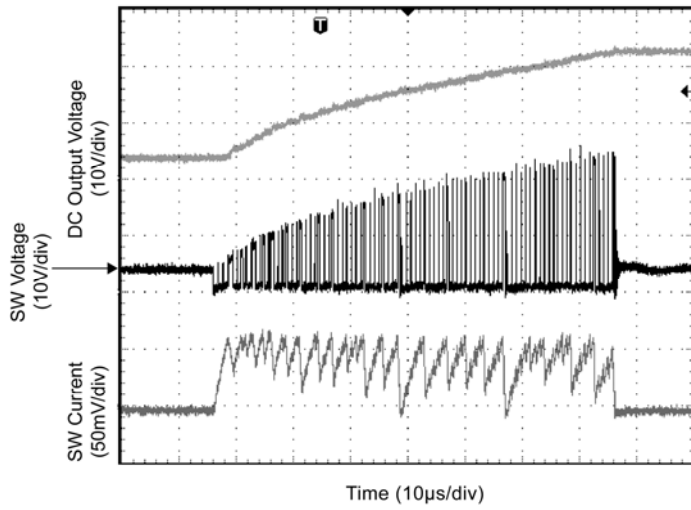
1. Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its operating ratings. The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_{J(\text{Max})}$ , the junction-to-ambient thermal resistance,  $\theta_{JA}$ , 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 rating.
3. IC devices are inherently ESD sensitive. Handling precautions required.
4. Specification for packaged product only.

## Typical Characteristics

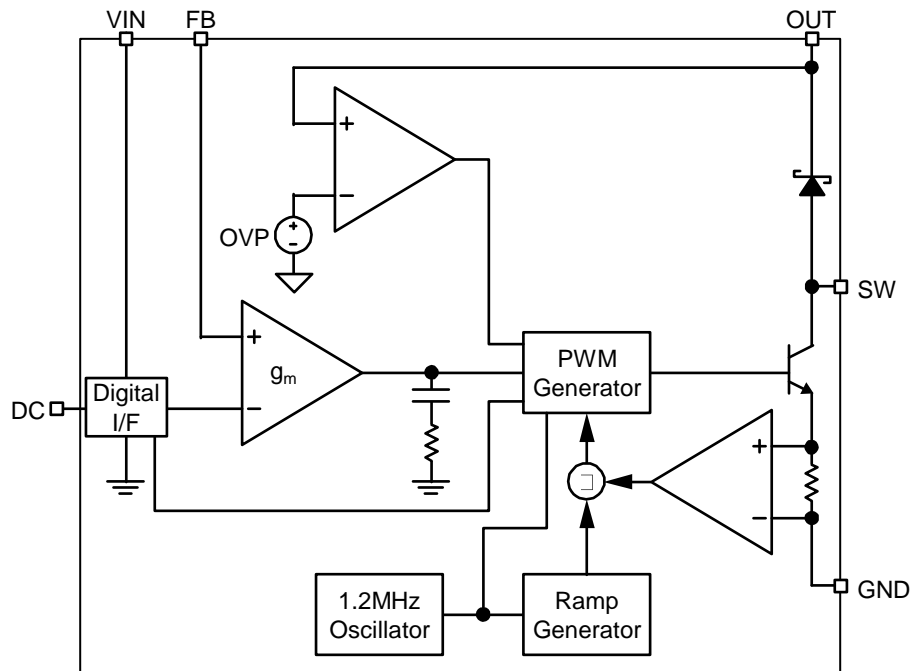


## Functional Characteristics

### OVP Response MIC3289-24



## Functional Diagram



MIC3289 Block Diagram

## Functional Description

The MIC3289 is a constant frequency, PWM current mode boost regulator. The MIC3289 is composed of an oscillator, slope compensation ramp generator, current amplifier, gm error amplifier, PWM generator, bipolar output transistor, digital interface with D/A converter and Schottky rectifier diode. It features true one-wire digital control that may be used to vary the brightness of the output LEDs and place the device into shutdown mode. The oscillator generates a 1.2MHz clock which triggers the PWM generator that turns on the output transistor and resets 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.

### MIC3289 Block Diagram

The gm error amplifier measures the LED current through the external sense resistor and amplifies the error between the detected signal and the reference voltage indicated by the digital interface. The output of the gm 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 level at maximum brightness is set by the feedback resistor:

$$I_{LED} = \frac{250mV}{R_{LED}}$$

## MIC3289 Digital Interface

The MIC3289 incorporates an easy to use single-wire, serial programming interface allowing users to set LED brightness to one of 16 levels spaced in a logarithmic manner. In contrast to other solutions requiring a PWM drive signal to maintain LED brightness, the MIC3289 is “set and forget”, relieving the controlling processor of the constant burden of supplying a drive signal. Additionally, brightness levels can be preset so that LEDs can be turned on at a particular brightness level.

## State Diagram

The MIC3289 logic state flow is depicted in Figure 1 below. State changes are asynchronous and are edge triggered, with the exception of Start Up and Shutdown, which are level triggered.



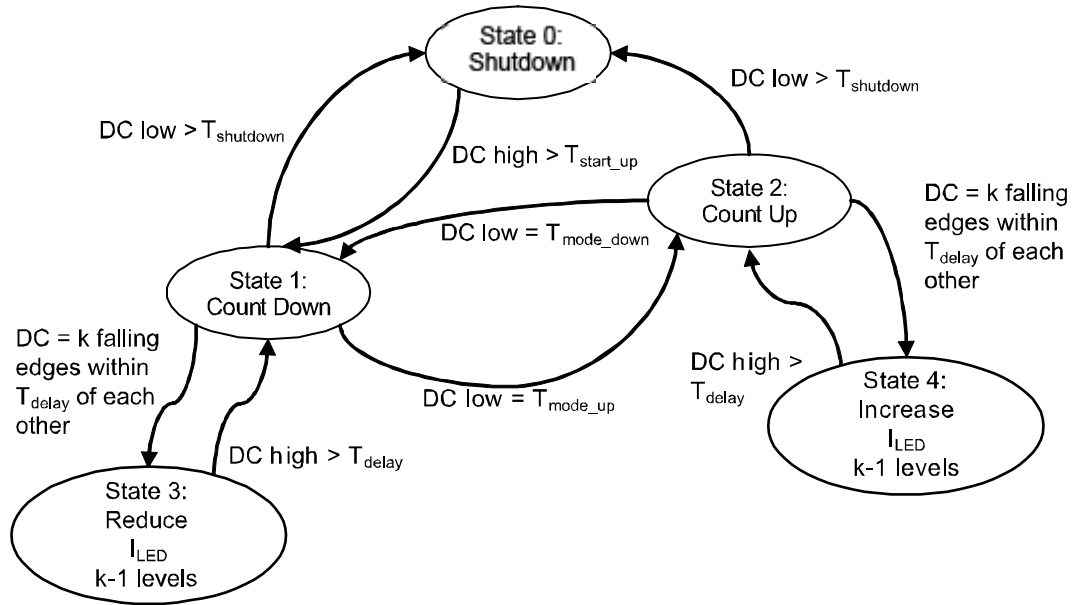


Figure 1. MIC3289 Logic State Diagram

With an input supply voltage between 2.5V and 6.5V and a logic-level LOW applied to the DC pin, the MIC3289 will enter State 0, Shutdown, and remain there consuming less than 1µA until a logic level high is applied to the DC pin.

**Start Up**

Applying a logic-level HIGH to the DC pin initiates the start-up sequence. After the  $t_{START\_UP}$  period the MIC3289 will transition to State 1, the boost drive will turn on and begin regulating LED drive current at maximum brightness level 15, and DC pin programming pulses will cause the brightness level to decrease.

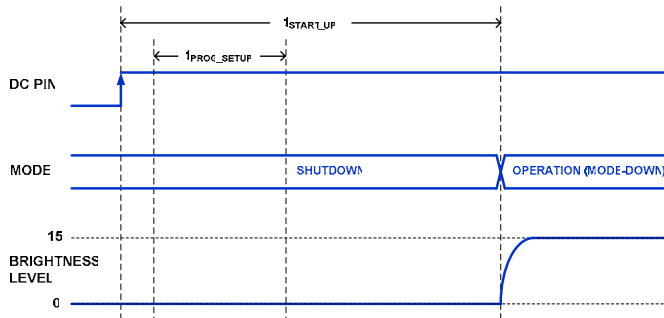


Figure 2. Start-Up Timing

**Shutdown**

Whenever a logic-level LOW is applied to the DC input pin for a period greater than or equal to  $t_{SHUTDOWN}$ , the MIC3289 will return to State 0 entering its power saving

shutdown mode.

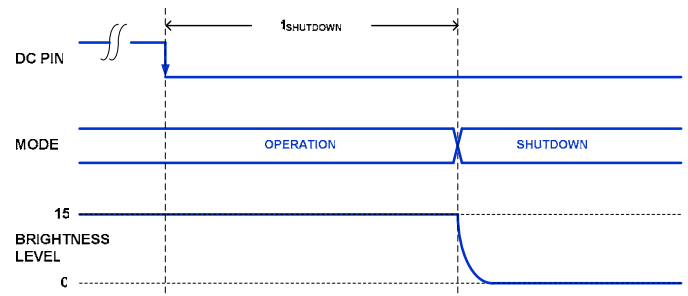


Figure 3. Shutdown Timing

Once the device is shutdown, the boost supply is disabled, and the LEDs are turned off. Brightness level information stored in the MIC3289 prior to shutdown will be lost.

**Programming Pulse Counter Modes**

Referring once again to the state diagram in Figure 1, notice that there are two programming pulse counting modes. At power up the MIC3289 defaults to State 1, the count-down mode. The counting mode can be changed to State 2, the count-up mode, by pulling the DC pin low for a period equal to  $t_{MODE\_UP}$ . Subsequent programming pulses will then increase the LED brightness one level for each pair of programming pulses. Figure 4 shows the timing for the mode change.

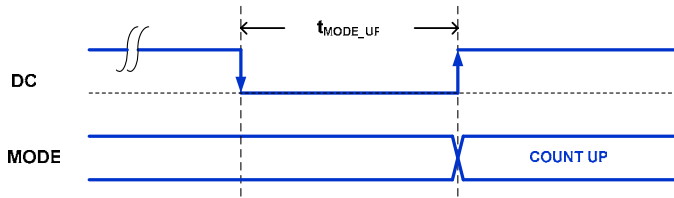


Figure 4. Mode Change to Count Up

To return the programming pulse counter to the Count-Down Mode, apply a negative going pulse to the DC pin with a period equal to  $t_{MODE\_DOWN}$ . Now each pair of programming pulses will cause the LED brightness to decrease one level.

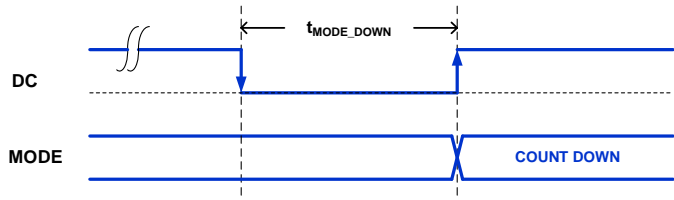


Figure 5. Mode Change to Count Down

**Programming the Brightness Level**

When it is powered up and the DC pin is at a logic level high for greater than  $t_{START\_UP}$ , the MIC3289 will begin regulating LED drive current at the maximum brightness level (Level 15). The internal control logic is set to decrease the LED brightness upon receiving programming pulses (falling edges of the DC input pin). Applying a pair of clock signals as shown in Figure 6 below, decreases the brightness one level. Notice that the first clock pulse is ignored. This is done so that Mode Change pulses do not produce brightness changes. The user may also elect to send a Mode Change as shown in Figure 4 to set the MIC3289 to increment the brightness level with subsequent programming pulses.

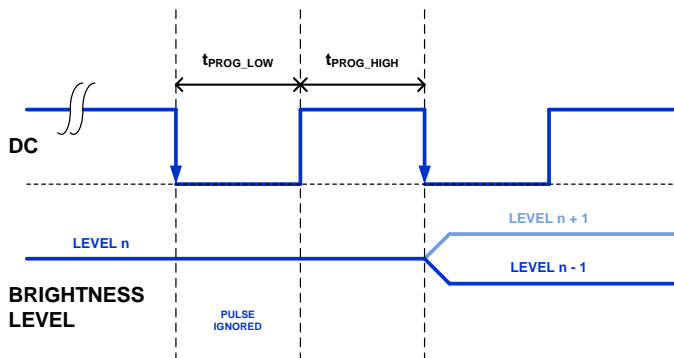


Figure 6. Brightness Programming Pulses

Brightness programming pulses are not restricted to just one pair at a time. Multiple level changes can be set as shown in Figure 7 below. Just remember that the first falling edge of the DC input clock will be ignored so long

as  $t_{PROG\_LOW}$  and  $t_{PROG\_HIGH}$  are not exceeded.

To maintain operation at the current brightness level simply maintain a logic level high signal at the DC pin.

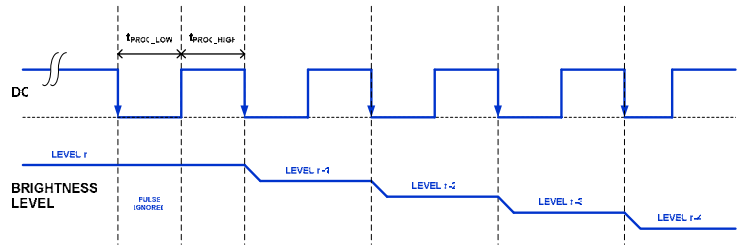


Figure 7. Decreasing Brightness Several Levels

As mentioned, the MIC3289 can be programmed to set LED drive current to produce one of 16 distinct brightness levels. The MIC3289s internal logic keeps track of the brightness level with an Up/Down counter circuit. The following section explains how the MIC3289s brightness counter functions with continued programming pulses.

**Counter Roll-Over**

The MIC3289 internal up/down counter counts from 0 to 15. When counting DOWN, and brightness level 0 is reached, the counter will roll-over to level 15. This is illustrated in Figure 8 below.

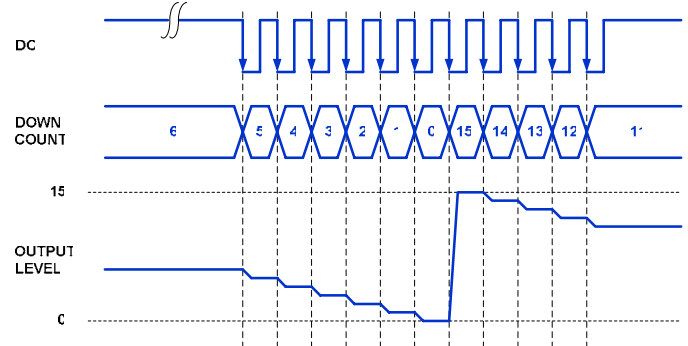


Figure 8. Down Counter Roll-over

When the counter Mode is set to count Up and brightness level 15 is reached, the counter will roll-over to level 0. Figure 9 shows that continuing to send programming pulses will cause the brightness level to start over at level zero.

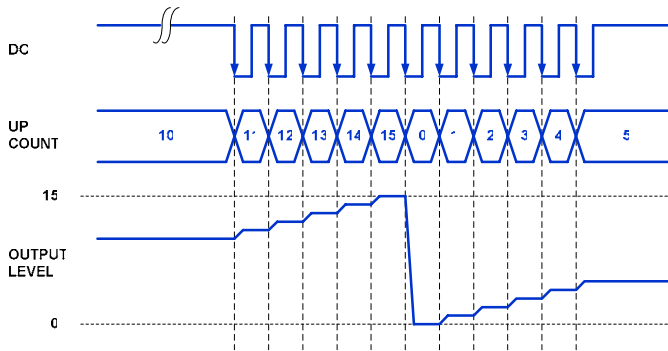


Figure 9. Up Counter Roll-over

**One-Step Brightness Changes**

For applications where a keypad button press is to be translated into a brightness level change, the following method of decreasing the brightness level may be useful. This “One-Step” brightness change procedure relieves the user from keeping track of the MIC3289’s up/down counter state. It combines a counter mode change with a programming pulse, therefore a one-step decrease in brightness is assured no matter what the previous up/down counter mode was.

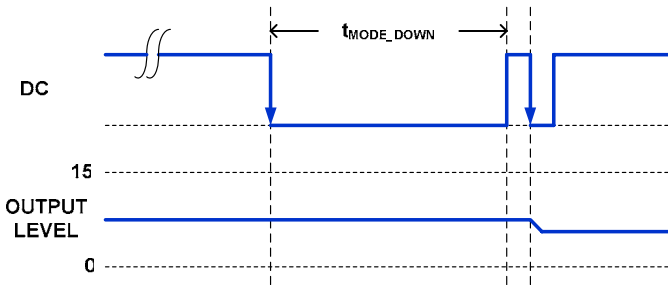


Figure 10. One-Step Brightness Decrease

This method is quite simple and the only requirement is that the first DC down clock period be equal to the  $t_{MODE\_DOWN}$  period. Similarly a one-step increase can be assured by generating a first DC down pulse whose period is equal to the  $t_{MODE\_UP}$  period followed by one DC falling edge.

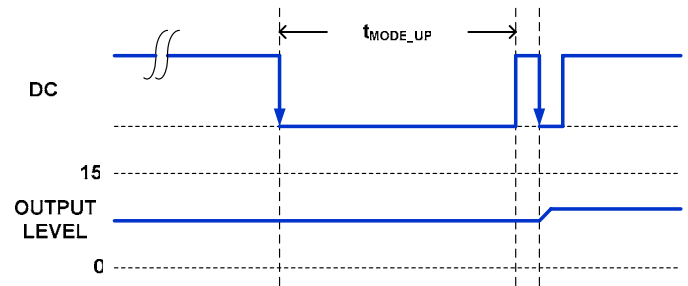


Figure 11. One-Step Brightness Increase

**Presetting Brightness**

The brightness level can be preset by sending a series of programming pulses via the DC pin within the  $t_{PROG\_SETUP}$  period. This pre-programming window starts at  $35\mu s$  after the DC pin is driven high and ends  $15\mu s$  later. Although the MIC3289s does not drive current into the load until DC pin is kept high for  $t_{start\_up}$ , pre-programming must begin somewhere with the  $15\mu s$  window or the MIC3289 may continue to start at the full (default) brightness level.

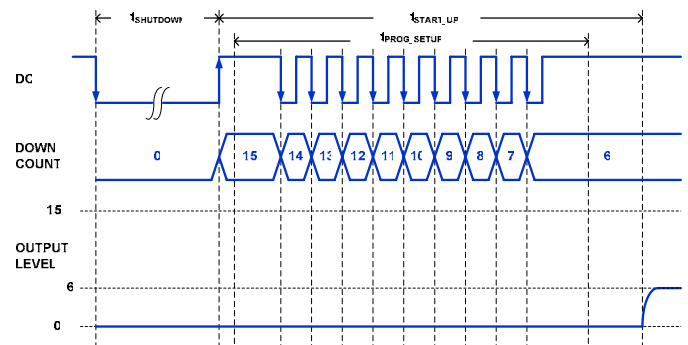
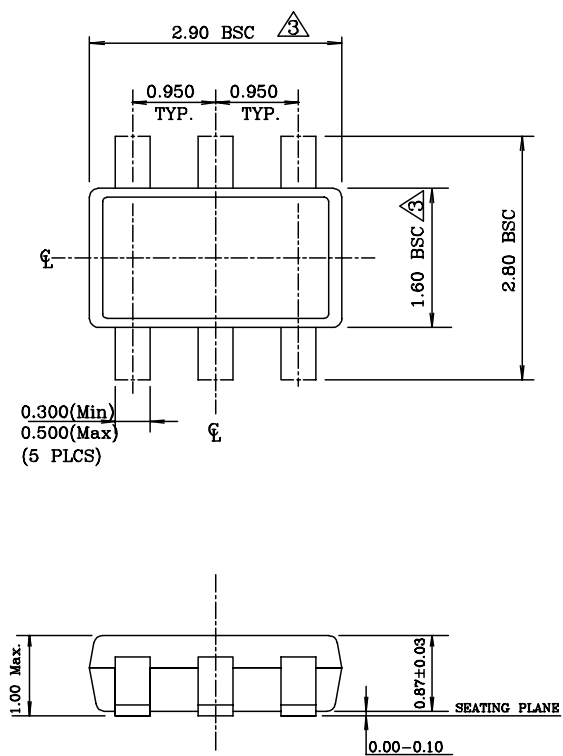


Figure 12. Pre-programming Timing

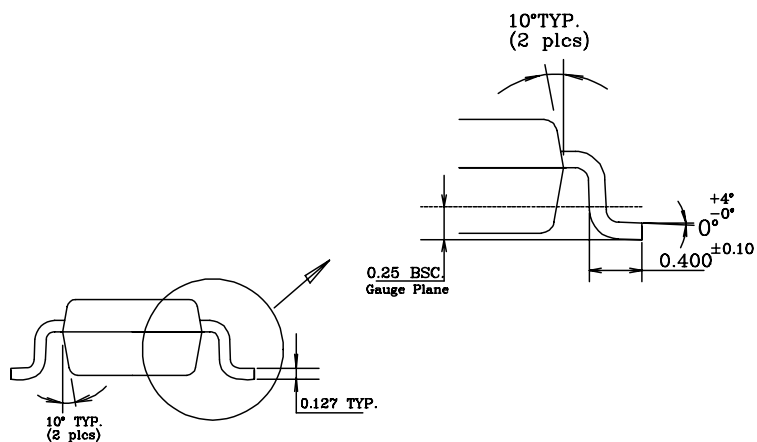
Figure 12 shows the correct pre-programming sequence to set the MIC3289 brightness to level 6 prior to start up. The sequence is initiated by driving the DC pin low for a period exceeding  $t_{SHUTDOWN}$ , to insure that the part has enter the power saving shutdown state, then the DC pin is driven high and a number of programming pulses are sent. Notice that when using the pre-programming feature the first programming pulse is not ignored. This is because the counter’s default mode is count down. The MIC3289 does not drive current into the load until the DC pin has remained high for time period  $t_{start\_up}$  from the last programming activity. Note that the same limits on programming timing in normal operation also apply in pre-programming.

# Package Information

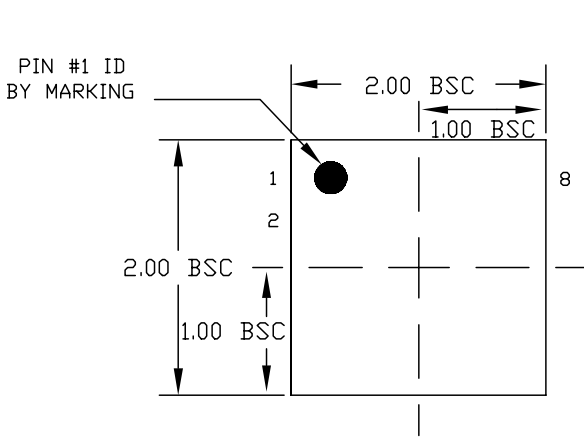


**NOTE:**

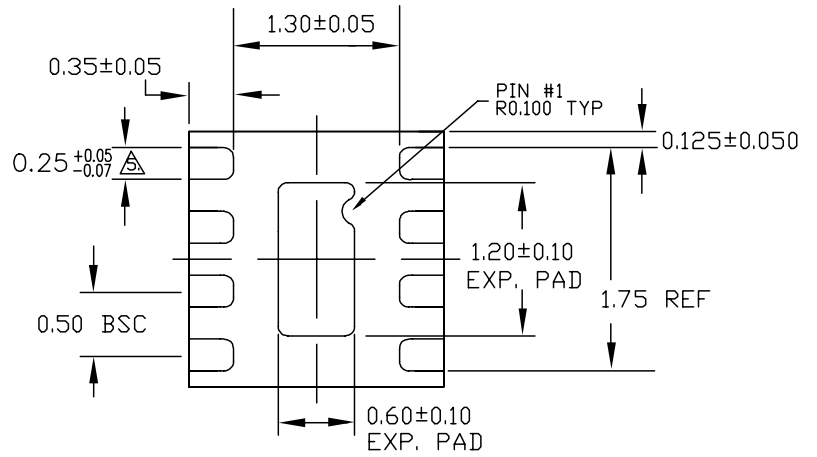
1. Dimensions and tolerances are as per ANSI Y14.5M, 1994.
2. Die is facing up for mold. Die is facing down for trim/form, ie. reverse trim/form.
- ⚠ Dimensions are exclusive of mold flash and gate burr.
4. The footlength measuring is based on the gauge plane method.
5. All specification comply to Jedec Spec M0193 Issue C.
6. All dimensions are in millimeters.



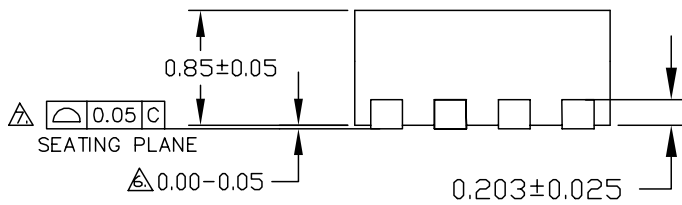
**6-Pin TSOT23 (D)**



TOP VIEW






BOTTOM VIEW



SIDE VIEW

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
  2. MAX. PACKAGE WARPAGE IS 0.05 mm.
  3. MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.
  4. PIN #1 ID ON TOP WILL BE LASER/INK MARKED.
-  DIMENSION APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25 mm FROM TERMINAL TIP.  
 APPLIED ONLY FOR TERMINALS.  
 APPLIED FOR EXPOSED PAD AND TERMINALS.

8-Pin MLF™ (ML)

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