

# IML204DG

## Four-Channel LED Backlight Controller IC to Partner with InnoMux2-BL for Computer Monitors

### Product Highlights

#### Highly Integrated, Compact Footprint

- Four channel LED backlight controller
- Low current source voltage drop for high system efficiency
- 3% matching accuracy over full current range
- Up to 150 V string voltage
- Up to 4x120 mA string current
- Extendable to 8 channels, with 3% matching accuracy
- PWM, analog, filtered PWM dimming options
- Wave-solderable SO-16 package

#### Advanced Protection / Safety Features

- String imbalance detection
- String open detection
- String short detection
- Over-temperature protection

#### Applications

- Four and eight channel LED backlight monitors
- Two channel LED backlight TVs
- For Energy Star 8, CEC, and 2023 EU labelling for monitors and TVs

#### Description

The IML204DG IC allows the InnoMux2-BL controller to drive up to 4 or 8 LED strings. It simplifies the design and manufacture of multi-LED string monitors and TVs with a highly integrated architecture allowing low BOM count and compact designs.

The IML204DG IC provides protection mechanisms for string-open, string-short and unbalanced strings.

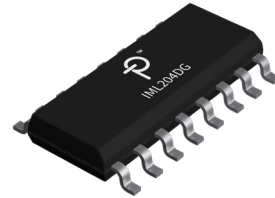


Figure 2. IML204DG in SO-16 Package.

#### IML204DG

Product	Output Configuration	Package
IML204DG	1 CV, 4 LED strings	SO-16

Table 1. IML204DG Part Numbers.

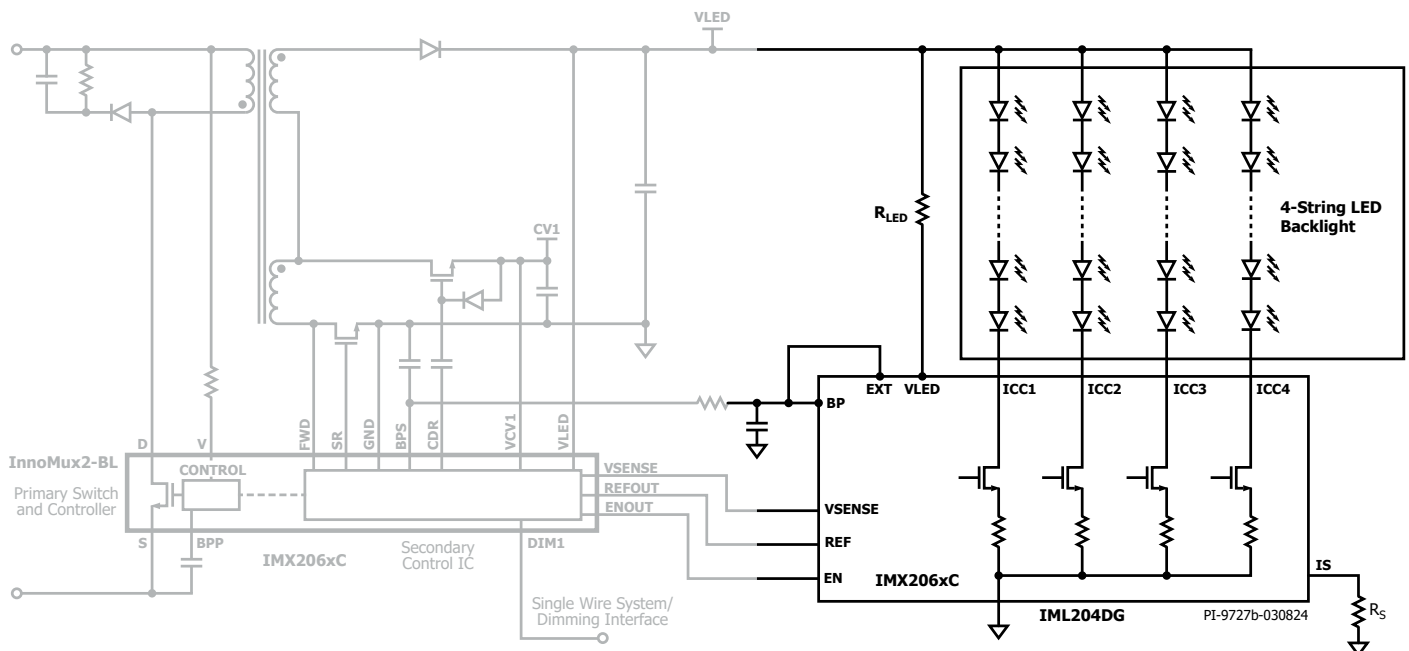


Figure 1. Typical Application Schematic.

## IML204DG Controller

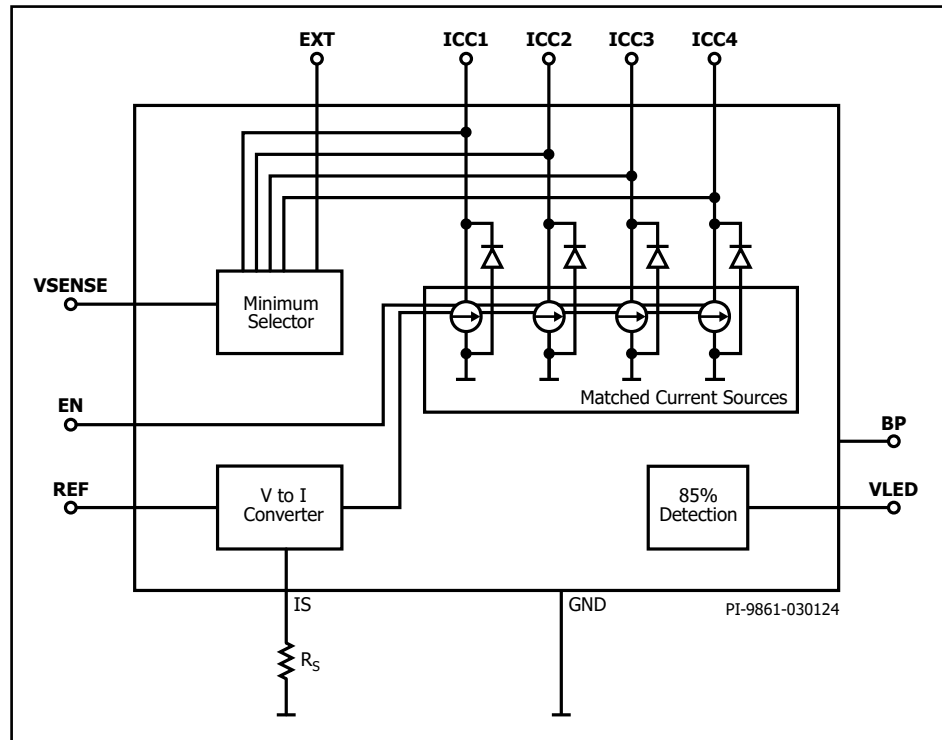


Figure 3. IML204DG Controller Functional Block Diagram.

## Pin Out

### Pin Functional Description

#### ICC2 Pin (Pin 1)

Cathode connection for LED channel 2.

#### ICC1 Pin (Pin 2)

Cathode connection for LED channel 1.

#### GROUND (GND) Pin (Pin 3)

Ground for the IML204DG controller.

#### Not Connected (NC) Pin (Pin 4)

This pin should be left floating.

#### Not Connected (NC) Pin (Pin 5)

This pin should be left floating.

#### ISET (IS) Pin (Pin 6)

This pin sets the full-scale (100% brightness) output current. The current is set with a resistor from the IS pin to Ground.

#### EXTENSION (EXT) Pin (Pin 7)

Should be connected to BPS in 4 channel operation. In 8 channel operation, the second controller should connect this pin to BPS, the first controller should connect this pin to the VSENSE pin of the IML204DG IC. For 8 string configuration, refer to Figure 6. IML204DG #2 VSENSE pin will output the lowest voltage on its ICC pins. This signal is connected to the EXT pin of IML204DG #1 whose VSENSE is connected to the InnoMux2-BL IC.

#### LED VOLTAGE SENSE (VLED) Pin (Pin 8)

Should be connected to the  $V_{LED}$  rail / LED anode connection through a high impedance resistor  $R_{LED}$ . The resistor current should be 20  $\mu$ A at 85% of  $V_{LED}$  maximum voltage when the VLED pin voltage is pulled low by the controller.

#### BYPASS (BP) Pin (Pin 9)

BP supply connection. Should be connected to the InnoMux2-BL BPS rail with 10  $\Omega$  resistor and must be decoupled with an external bypass capacitor.

#### Not Connected (NC) Pin (Pin 10)

This pin has no internal connection. It is allowed to connect this pin to the CDR1 pin of the InnoMux2-BL IC to facilitate PCB layout (but this is not essential).

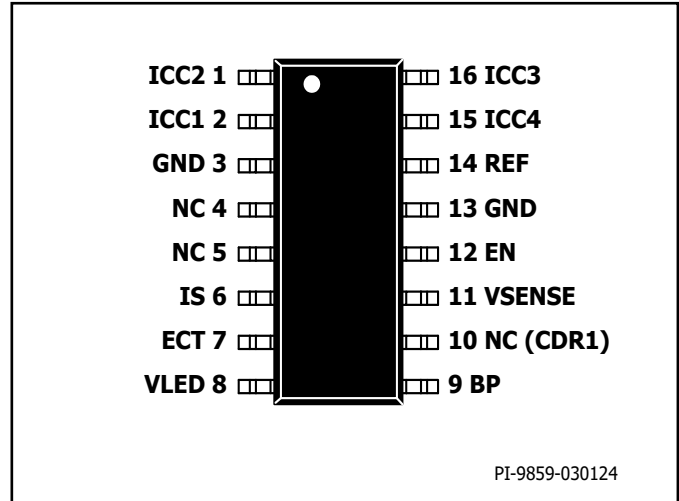


Figure 4. IML204DG LED Controller in SO-16 Package.

#### VOLTAGE SENSE (VSENSE) Pin (Pin 11)

This pin outputs the lowest of the 5 voltages on the ICC and EXT pins. Should be connected to InnoMux2-BL VSENSE pin for  $V_{LED}$  regulation.

#### ENABLE (EN) Pin (Pin 12)

This pin enables/disables the current in the four current sources. Should be connected to the InnoMux2-BL ENOUT pin. If EN pin is low for more than  $T_{STBY}$  the controller will enter standby mode.

#### GROUND (GND) Pin (Pin 13)

Ground for the IML204DG controller.

#### REFERENCE (REF) Pin (Pin 14)

This pin sets the analog brightness level (0-100%). Should be connected to the InnoMux2-BL REFOUT pin.

#### ICC4 Pin (Pin 15)

Cathode connection for LED channel 4.

#### ICC3 Pin (Pin 16)

Cathode connection for LED channel 3.

## IML204DG Functional Description

The IML204DG IC is a companion controller for the InnoMux2-BL IC, extending the number of controlled LED strings to four. It consists of four matched current sources allowing for up to 120 mA LED current per string. The combination of InnoMux2-BL IC and IML204DG IC therefore can accurately control the voltage on CV outputs as well as the current in 4 LED strings. There is no need for additional DCDC buck or boost converters.

### LED String Current Control

#### Operation

The IML204DG IC features a four channel matched LED driver (four current sources) for controlling the current through a four string LED backlight. Two and three channel operation is also supported. Channels can be ganged together to obtain a higher string current. Unused channels should be tied to GND.

The LED driver uses the  $R_S$  resistor to set the LED string current. The maximum LED string current is given by:

$$I_{LED(MAX)} = \frac{1.5 V}{R_S} \times 320$$

The resistor  $R_S$  will have a value between 4 k $\Omega$  (120 mA) to 24 k $\Omega$  (20 mA).

#### Output Voltage Regulation for VLED Output

The InnoMux2-BL IC and IML204DG IC keep the voltage drop over the current sources as low as possible to maintain optimum system efficiency. The output voltage for driving the LED string ( $V_{LED}$ ) is regulated to maintain the minimum required voltage drop over the current source for the LED string with the largest  $V_F$ . The low voltage drop over the current source is maintained for any LED current by changing the  $V_{LED}$  output voltage set point.

To ensure stability of the LED voltage regulation, a maximum  $V_{LED}$  output capacitance is recommended and depends on the maximum LED voltage and the maximum combined LED string current (all strings together).

Please refer to the InnoMux2-BL data sheet for more information on the  $V_{LED}$  voltage regulation and on the maximum  $V_{LED}$  rail capacitance.

#### LED Dimming

The current through the LED strings can be varied for changing (dimming) the LED brightness.

All InnoMux2-BL dimming modes are supported in 4-string operation: e.g. Analog dimming, PWM dimming and filtered dimming. PWM and filtered dimming are supported up to 27 kHz. In PWM mode, the four strings will operate synchronously and in phase. Please refer to the InnoMux2-BL data sheet for more information on the various dimming modes.

### Start-Up and LED Detection

At start-up, the IML204DG IC detects which channels have an LED connected. The InnoMux2-BL IC will increase the  $V_{LED}$  until the voltage on all four ICC pins starts to rise above the LED detection threshold or the  $V_{LED}$  rail crosses the 85% threshold. A rising voltage on an ICC pin indicates that an LED string is present. During this time IML204DG controller will keep the VSENSE pin to be 0 V. As soon as  $V_{LED}$  crosses the 85% threshold, any ICC pin that is below the detection threshold will be permanently disabled.

The  $V_{LED}$  is sensed by the IML204DG IC by pulling the VLED pin low and measuring the current into the VLED pin. A current of 20  $\mu$ A is assumed to represent 85% of the maximum LED rail voltage.

The  $R_{LED}$  resistor value is given by,

$$R_{LED} = \frac{0.85 \times V_{LED MAX}}{20 \mu A}$$

A short-circuit string (LED cathode short to  $V_{LED}$  voltage) will be detected during start-up. This will permanently enable all ICC pins with the current set to 10% of the maximum current as set by the  $I_S R_S$  resistor until the short is removed. During this time, the VSENSE pin output will be pulled high so InnoMux2-BL IC will reduce  $V_{LED}$ .

### LED Fault Detection During RUN

During operation, the controller will continuously monitor the voltages on the ICC pins. If a large asymmetry between the LED strings ( $>V_{ICCOV}$ ) is detected, the shorter string(s) will be disabled to prevent excessive power dissipation in the controller. Any strings that go open-circuit or short-circuit during RUN will be disabled.

LED cathode short to ground will be detected as string open by the IML204DG controller. The InnoMux2-BL IC will then detect an over-power condition and perform an auto-restart.

### Standby Mode

In case the EN pin is low for more than  $T_{STBY}$  the IML204DG IC controller will enter standby mode. In standby mode the IML204DG will stop communicating the minimum ICC voltage and instead set the VSENSE pin to be high.

### Interface with InnoMux2-BL IC

There are 3 interface wires connected between IML204DG IC and InnoMux2-BL IC:

- REFERENCE – analog signal set by InnoMux2-BL IC to set the LED string current level between 0 and full range (as set by  $R_S$ ).
- ENABLE – digital signal set by InnoMux2-BL IC. A high level will enable the LED driver in the companion controller.
- VSENSE – analog signal set by IML204DG IC, reflecting the lowest ICC voltage out of the four strings.

## Over-Temperature

Built-in thermal protection circuitry continuously measures the controller temperature. The threshold is set at  $T_{PROT}$ . When the temperature rises above  $T_{PROT}$ , the IML204DG IC will disable all LEDs and set  $V_{SENSE}$  to be high with hysteretic over-temperature protection; the LEDs will remain disabled until the temperature drops below  $T_{PROT} - T_{HYST}$ .

## Other Faults

In case the REFERENCE pin is out of range, the IML204DG IC will disable all LEDs and set  $V_{SENSE}$  to be high until the fault is cleared.

In case the IS pin shorted to ground (minimum value is  $4\text{ k}\Omega$ ), the IML204DG IC will disable all LEDs and set  $V_{SENSE}$  to be high until the fault is cleared.

## Cascading Multiple IML204DG

It is possible to cascade IML204DG IC for 8 channel LED backlight operation. LED output accuracy and channel-to-channel matching specifications will be maintained when using more than one IML204DG controller.

The connections between InnoMux2-BL IC, IML204DG IC #1 and IML204DG IC #2 are shown in Figure 5.

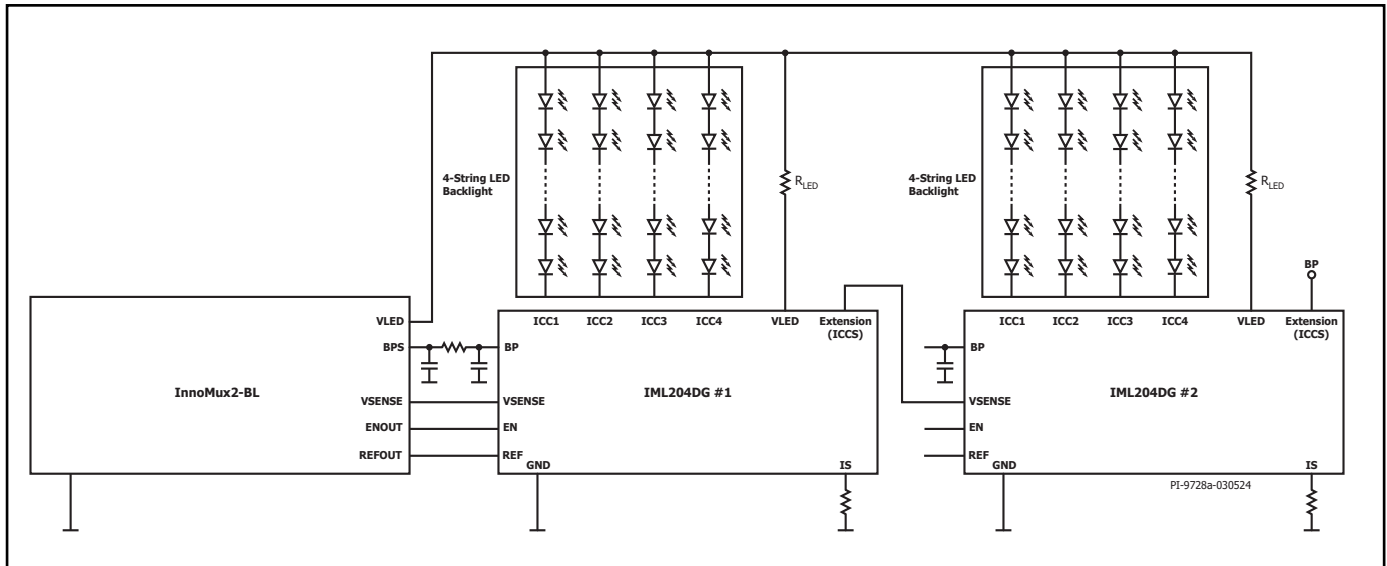


Figure 5. Cascading Two IML204DG Controllers.

## Absolute Maximum Ratings<sup>1,2</sup>

ICC Pin Voltage .....	-0.5 V to $V_{ICCLAMP}$ V	<b>Notes:</b> 1. All voltages referenced to GROUND, $T_A = 25\text{ }^\circ\text{C}$ . 2. Maximum ratings specified may be applied one at a time without causing permanent damage to the product. Exposure to Absolute Maximum Ratings conditions for extended periods of time may affect product reliability. 3. Normally limited by internal circuitry. 4. 1/16" from case for 5 seconds.
VLED Pin Voltage .....	-0.5 to 175 V	
BP Pin Voltage .....	-0.3 to 6 V	
All Other Pins Voltage .....	-0.3 to 6 V	
Storage Temperature .....	-65 to 150 $^\circ\text{C}$	
Operating Junction Temperature <sup>3</sup> .....	-40 to 150 $^\circ\text{C}$	
Lead Temperature <sup>4</sup> .....	260 $^\circ\text{C}$	

## Thermal Resistance

Thermal Resistance: IML204DG		<b>Notes:</b>
$(\theta_{JA})$ .....	49 $^\circ\text{C}/\text{W}^1$ 84 $^\circ\text{C}/\text{W}^2$	1. Tested using EIA/JEDEC standard test method JESD51-2A with device mounted on "High Effective Thermal Conductivity Test Board" as described in EIA/JEDEC standard JESD51-7. 2. Tested using EIA/JEDEC standard test method JESD51-2A with device mounted on "Low Effective Thermal Conductivity Test Board" as described in EIA/JEDEC standard JESD51-3. 3. Tested using MIL-STD-883, Method 1012.1, case temperature measured at top of package body.
$(\theta_{JC})$ .....	25 $^\circ\text{C}/\text{W}^3$	

Parameter	Symbol	Conditions $T_J = -40\text{ }^\circ\text{C}$ to $125\text{ }^\circ\text{C}$ (Unless Otherwise Specified)	Min	Typ	Max	Units
<b>Control Functions</b>						
<b>Current Consumption</b>	$I_{S1}$	EN Low > $T_{STBY}$		0.1	0.2	mA
	$I_{S2}$	EN High $V_{REF} = 1.5\text{ V}$ , $R_S = 24\text{ k}\Omega$		3.6		mA
<b>BPS Power-Up Reset Threshold Voltage</b>	$V_{BPS(RESET)}$		3.4	3.8	4.2	V
<b>LED Current Control</b>						
<b>REF (Input)</b>	$V_{REF}$	$T_J = 25\text{ }^\circ\text{C}$ 3% brightness: 45 mV, 100% brightness: 1.5 V	0		1.5	V
<b>ICC Voltage Protection Limit</b>	$V_{ICC(OV)}$	$V_{ICC}$ rising	8.5	9	9.5	V
<b>Minimum Full-Scale ICC Current</b>	$I_{CC(MIN)}$			20		mA
<b>Maximum Full-Scale ICC Current</b>	$I_{CC(MAX)}$			120		mA
<b>ICC Channel Matching (See Note A)</b>	$\Delta 100\text{ mA}$	100 mA current per string, measured in analog dimming. Equal voltage on all ICC pins (0.3 V). $T_J = 25\text{ }^\circ\text{C}$			3	%
	$\Delta 5\text{ mA}$	5 mA current per string, measured in analog dimming. Equal voltage on all ICC pins (0.3 V). $T_J = 25\text{ }^\circ\text{C}$			3	

Parameter	Symbol	Conditions			Min	Typ	Max	Units
		T <sub>J</sub> = -40 °C to 125 °C (Unless Otherwise Specified)						
<b>LED Current Control (cont.)</b>								
<b>Minimum Current Source Compliance Voltage</b>	V <sub>ICC(MIN)</sub>	120 mA current per string, measured in analog dimming					300	mV
<b>LED Detection Threshold</b>	V <sub>LED(DET)</sub>					0.1		V
<b>ICC Clamp Voltage</b>	V <sub>ICC(CLAMP)</sub>					50		V
<b>Maximum ICC Clamp Current</b>	I <sub>CCHV(CLAMP)</sub>				4			μA
<b>ICC Leakage</b>	I <sub>ICCLEAK(STANDBY)</sub>	T <sub>J</sub> ≤ 85 °C, V <sub>ICC</sub> < 40 V					1	μA
	I <sub>ICCLEAK(STOP)</sub>	Full scale I <sub>CC</sub> current ≤ 50 mA, V <sub>ICC</sub> = 3 V					100	μA
<b>LED Current Accuracy</b>	I <sub>ICCEERROR(ABS)</sub>	I <sub>CC</sub> current > 20 mA T <sub>J</sub> = 25 °C					3	%
		5 mA ≤ I <sub>CC</sub> current ≤ 20 mA T <sub>J</sub> = 25 °C					10	
<b>Part-to-Part Matching for Average ICC Current</b>	I <sub>ICCAVG(REL)</sub>	I <sub>CC</sub> current > 5 mA I <sub>ICCAVG</sub> = (I <sub>CC1</sub> + I <sub>CC2</sub> + I <sub>CC3</sub> + I <sub>CC4</sub> )/4 T <sub>J</sub> = 25 °C					2.5	%
<b>IS Pin Current Gain</b>	I <sub>S(RATIO)</sub>	I <sub>LED</sub> = 100 mA				320		
<b>LED PWM Control</b>								
<b>EN Frequency</b>	PWM <sub>F(RANGE)</sub>	See Note C			100		27,000	Hz
<b>EN Duty Cycle Range</b>	PWM <sub>D(RANGE)</sub>	Minimum on-time is 4.8 μs See Note C			2		100	%
<b>Other Parameters</b>								
<b>OTL Shutdown</b>	T <sub>PROT</sub>	See Note B			125			°C
<b>OTL Hysteresis</b>	T <sub>HYST</sub>	See Note B			50			°C
<b>LED 85% Detection</b>	I <sub>LED(85%)</sub>					20		μA
<b>Standby Mode Delay</b>	T <sub>STBY</sub>				15	25	60	ms

**NOTES:**

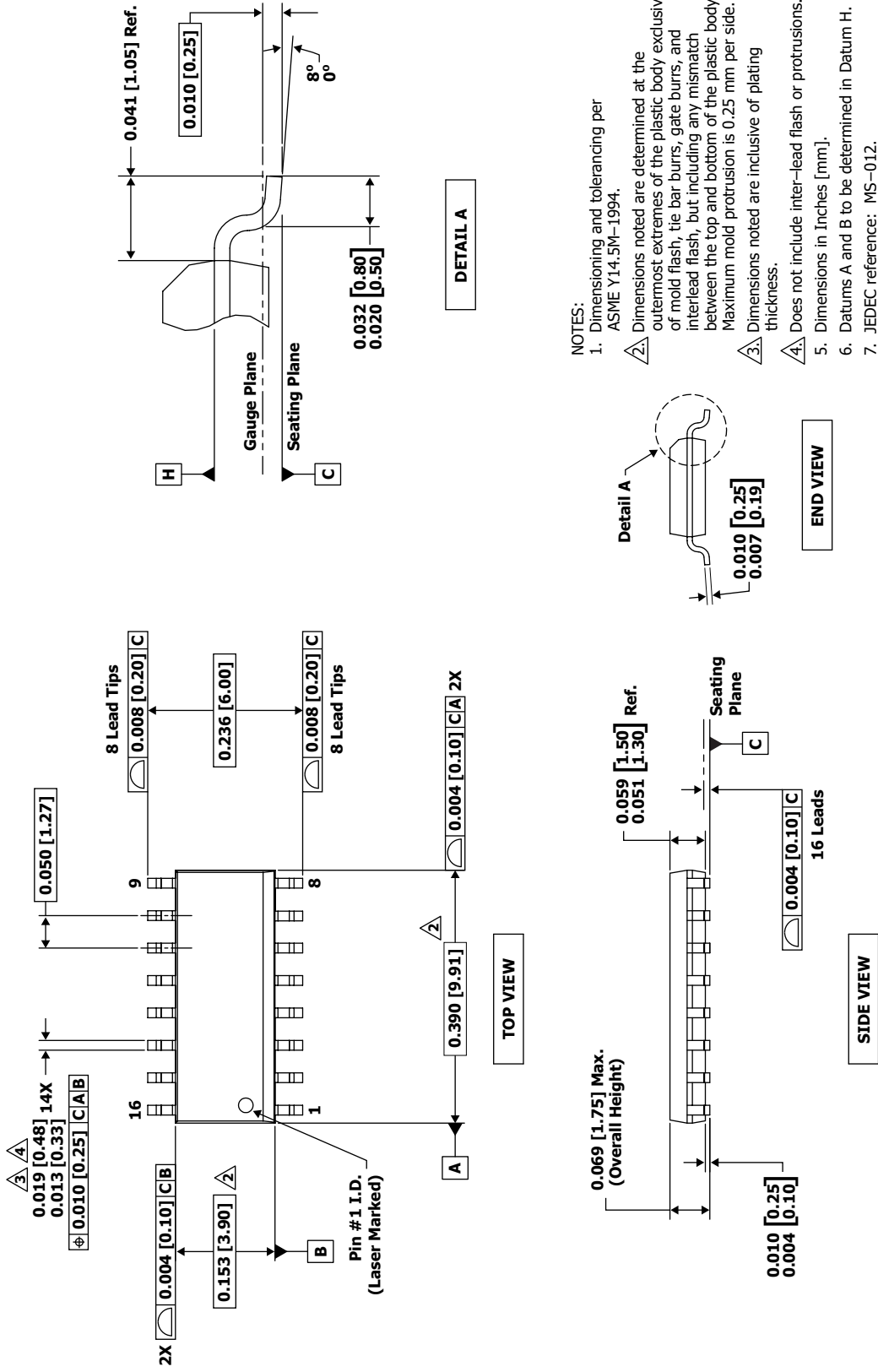
A. The mismatch is calculated using the following formula:

$$\Delta = \frac{(I_{MAX} - I_{MIN})}{2 \times I_{AVG}} \times 100\%$$

B. This parameter is derived from characterization.

C. This parameter is guaranteed by design.

SO-16



NOTES:

1. Dimensioning and tolerancing per ASME Y14.5M-1994.

**ΔA**: Dimensions noted are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs, and interlead flash, but including any mismatch between the top and bottom of the plastic body. Maximum mold protrusion is 0.25 mm per side.

**Δ3**: Dimensions noted are inclusive of plating thickness.

**Δ4**: Does not include inter-lead flash or protrusions.

5. Dimensions in Inches [mm].

6. Datums A and B to be determined in Datum H.

7. JEDEC reference: MS-012.

PI-9816-113023  
POD-SO-16 Rev A

POD-SO-16 Rev A\_112923



Revision	Notes	Date
B	Production release.	12/23
C	Updated schematics and text.	04/24

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