HV9967B

Integrated LED Driver with Average-Mode Current Control

Features

- 3% Accurate LED Current
- 60V, 0.8Ω Integrated MOSFET
- Low Sensitivity to External Component Variation
- Single-Resistor LED Current Setting
- Fixed Off-Time Control
- PWM Dimming Input
- Output Short-Circuit Protection with Skip Mode
- Overtemperature Protection

Applications

- DC/DC or AC/DC LED Drivers
- RGB Backlighting Drivers for Flat Panel Displays
- General Purpose Constant-Current Source
- Signage and Decorative LED Lighting
- Chargers

General Description

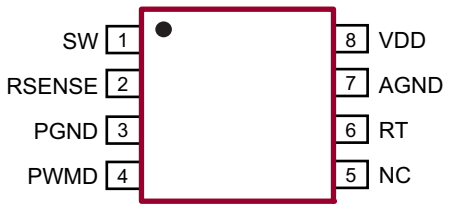
The HV9967B is an Average-mode current control LED driver IC operating in a Constant Off-time mode.

The IC features an integrated 60V, 0.8Ω MOSFET that can be used as a stand-alone buck converter switch or connected as a source driver for driving an external high-voltage Depletion-mode MOSFET. The HV9967B is powered through its switching output when the integrated switch is off. Therefore, the same external MOSFET can be used as a high-voltage linear regulator for powering the IC.

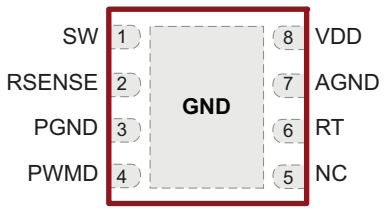
The LED current is programmed with one external resistor. The Average-mode current control method does not produce a peak-to-average error. This greatly improves the current accuracy as well as the line and load regulations of the LED current without any need for loop compensation or direct sensing of the LED current at a high-voltage potential. The auto-zero circuit cancels the effects of the input offset voltage and of the propagation delay of the current sense comparator.

Package Types

8-lead MSOP
(Top view)

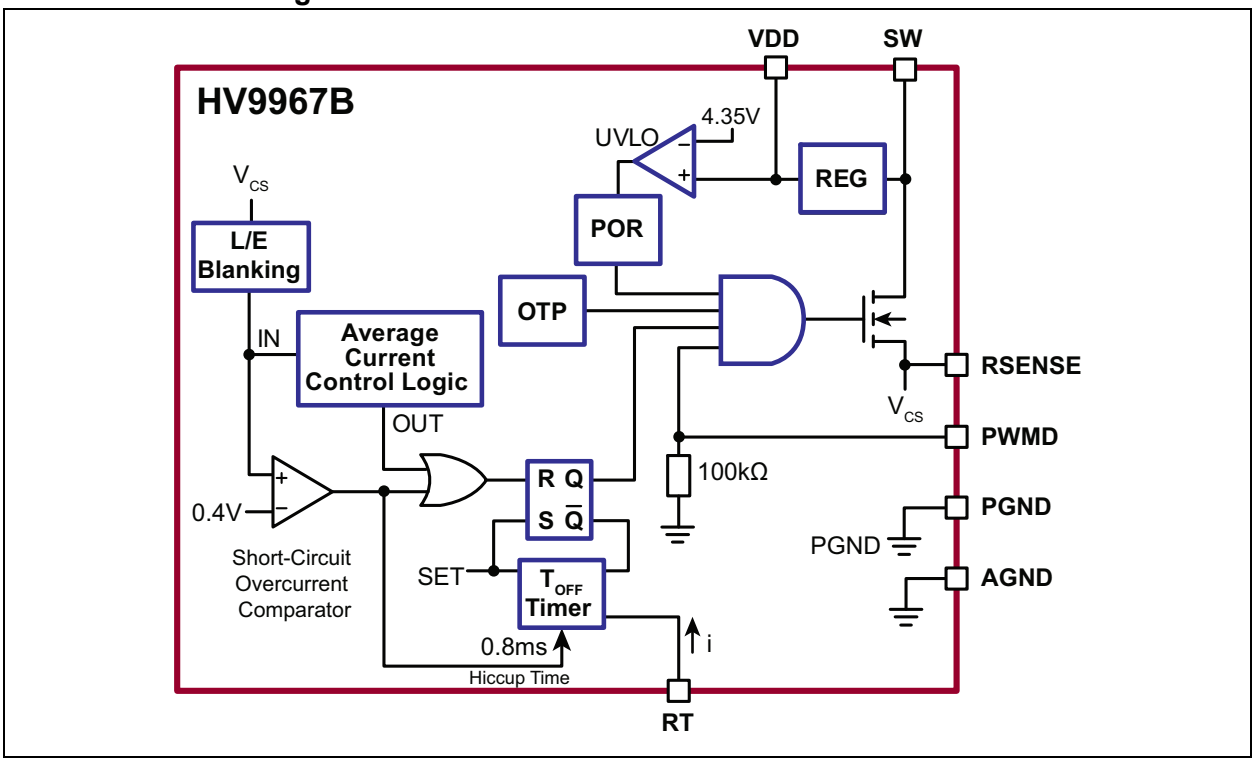


8-lead WDFN
(Top view)

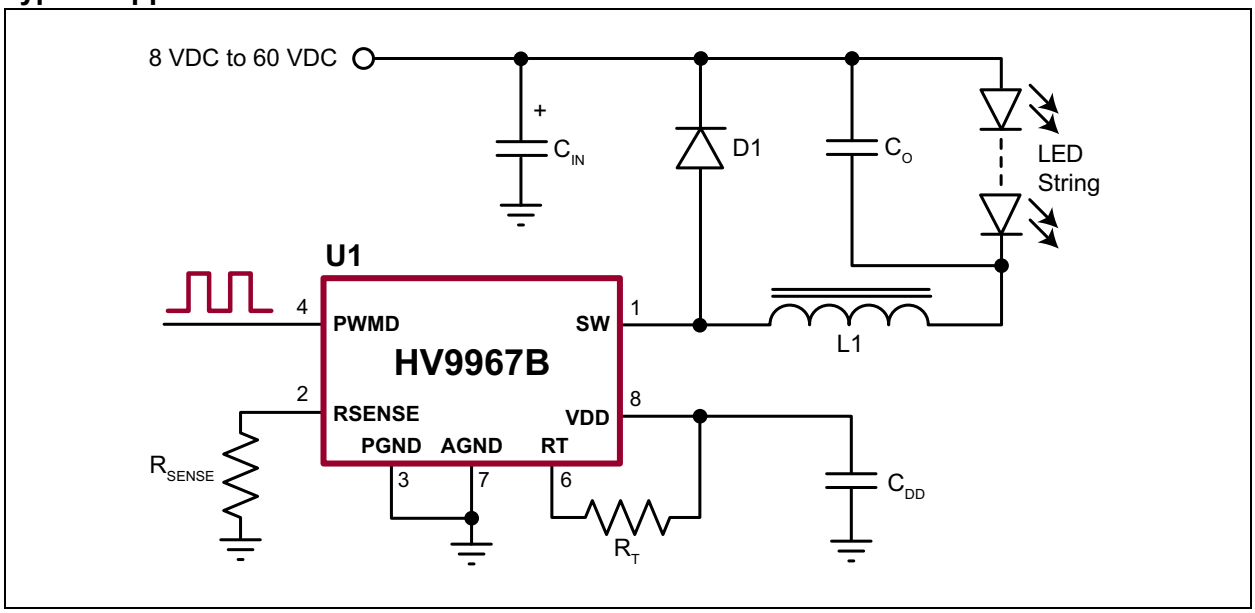


See Table 2-1 for pin information.

Functional Block Diagram



Typical Application Circuit



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings(†)

SW to GND .....–0.5V to +65V
V_{DD} to GND.....–0.3V to 6V
Other I/O to GND .....–0.3V to (V_{DD} + 0.3V)
I_{RT}..... 2 mA
Junction Temperature Range, T_J ..... –40°C to +150°C
Storage Temperature Range, T_S..... –65°C to +150°C
Continuous Power Dissipation (T_A = +25°C):
8-lead MSOP ..... 350 mW
8-lead WDFN..... 1.6W

† **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.

ELECTRICAL CHARACTERISTICS

Electrical Specifications: T_A = 25°C, V_{SW} = 10V/10 mA, V_{DD} = 5V unless otherwise specified.

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
INPUT						
Input DC Supply Voltage Range	V_{SWDC}	8	—	60	V	DC input voltage (**Note 1**)
Shutdown Mode Supply Current	I_{INSD}	—	0.5	1	mA	Pin PWMD connected to GND
INTERNAL REGULATOR						
Internally Regulated Voltage	V_{DD}	4.7	5	5.2	V	V_{PWMD} = V_{DD}, R_T = 100 kΩ
V_{DD} Undervoltage Lockout Upper Threshold	V_{UVLOR}	4.1	4.35	4.7	V	V_{DD} rising, as needed to ensure $I_{C(MIN)}$ (**Note 1**)
V_{DD} Undervoltage Lockout Hysteresis	ΔV_{UVLO}	—	150	—	mV	V_{DD} falling
PMW DIMMING						
PWMD Input Low Voltage	$V_{EN(LO)}$	—	—	0.8	V	**Note 1**
PWMD Input High Voltage	$V_{EN(HI)}$	2.2	—	—	V	**Note 1**
PWMD Pull-Down Resistance	R_{EN}	50	100	150	kΩ	V_{PWMD} = 5V
CURRENT CONTROL						
RSENSE Current Threshold Voltage	$V_{CS(TH)}$	243	250	257	mV	
Threshold Voltage Temperature Coefficient	dV_{CS}/dT	—	0.1	—	mV/°C	
Current Sense Blanking Interval	T_{BLANK}	140	—	290	ns	**Note 1**
Minimum On-Time	$T_{ON(MIN)}$	—	—	950	ns	V_{RSENSE} = $V_{CS(TH)}$ + 50 mV (**Note 1**)
Maximum Steady-State Duty Cycle	D_{MAX}	80	—	—	%	Reduction in output LED current may occur beyond this duty cycle. (**Note 1**)
SHORT-CIRCUIT PROTECTION						
Hiccup Threshold Voltage at RSENSE	$V_{CS(SHORT)}$	355	400	440	mV	**Note 1**
Current Limit Delay RSENSE to SW-OFF	T_{DELAY}	—	—	150	ns	V_{RSENSE} = $V_{CS(SHORT)}$ + 50 mV

Note 1: Denotes specifications which apply over the full operating ambient temperature range of –40°C < T_A < +125°C

2: For design guidance only

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Specifications: T_A = 25°C, V_{SW} = 10V/10 mA, V_{DD} = 5V unless otherwise specified.

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
Short-Circuit Hiccup Time	T_{HICCUP}	—	800	—	µs	
Minimum On-Time (Short-Circuit)	$T_{ON(MIN),SC}$	—	—	400	ns	V_{RSENSE} = $V_{CS(SHORT)}$ + 50 mV
T_{OFF} TIMER						
Off Time	T_{OFF}	28	40	48	µs	R_T = 100 kΩ (**Note 1**)
		7	10	12		R_T = 100 kΩ (**Note 1**)
		0.7	1	1.2		R_T = 10 kΩ (**Note 1**)
SW OUTPUT						
On Resistance	R_{ON}	—	0.8	—	Ω	V_{DD} = 5V
Continuous Current	I_C	0.75	—	—	A	V_{DD} = 4.75V, V_{RSENSE} = 370 mV, V_{SW} = 10V (**Note 1**)
OVERTEMPERATURE PROTECTION						
Thermal Shutdown Temperature	T_{SD}	125	145	—	°C	**Note 2**
Thermal Shutdown Hysteresis	ΔT_{SD}	—	20	—	°C	**Note 2**

Note 1: Denotes specifications which apply over the full operating ambient temperature range of –40°C < T_A < +125°C

2: For design guidance only

TEMPERATURE SPECIFICATIONS

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
TEMPERATURE RANGE						
Operating Ambient Temperature	T_A	–40	—	+125	°C	
Maximum Junction Temperature	$T_{J(ABSMAX)}$	—	—	+150	°C	
Storage Temperature	Ts	–65	—	+150	°C	
PACKAGE THERMAL RESISTANCE						
8-lead MSOP	θ_{JA}	—	216	—	°C/W	
8-lead WDFN	θ_{JA}	—	60	—	°C/W	

2.0 PIN DESCRIPTION

Table 2-1 shows the pin description details of HV9967B. Refer to **Package Types** for the location of pins.

TABLE 2-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	SW	Drain of 60V 0.8Ω NDMOS switch and input of H/V regulator
2	RSENSE	Source of NDMOS switch and current sense input. Connect a resistor between RSENSE and GND to program the output current and short-circuit protection tripping current.
3	PGND	Power ground. Must be wired to AGND on PCB.
4	PWMD	PWM dimming input. This TTL input enables switching of SW when in High state.
5	NC	No connection
6	RT	Resistor connected between RT and VDD. This programs the off time of SW.
7	AGND	Analog ground (0V)
8	VDD	Power supply for all internal circuits. Bypass with a low-ESR capacitor to PGND (>0.5 µF). Connect gate of external Depletion-mode NFET for high-voltage operation.

3.0 APPLICATION INFORMATION

3.1 General Description

The HV9967B employs a control scheme that achieves fast and extremely accurate control of the average current in the buck inductor by sensing only the switch current. No compensation of the current control loop is required. The LED current response to PWMD input is similar to that of the peak-current control ICs, such as the HV9910B. The inductor current ripple amplitude does not affect this control scheme significantly. Therefore, the LED current is independent of the variation in inductance, switching frequency, and output voltage. Constant off-time control of the buck converter is used for stability and to reduce input voltage regulation of the LED current.

3.2 Off Timer

The timing resistor connected to RT pin determines the off time of the gate driver and SW. The timing resistor must be wired across RT pin and VDD pin. Refer to Equation 3-1 for the computation of the SW off time.

EQUATION 3-1:

$$T_{OFF} = R_T \times 100pF$$

Within the range of 10 kΩ ≤ R_T ≤ 400 kΩ

3.3 Average Current Control Feedback and Output Short-Circuit Protection

The constant-current control feedback derives the average-current signal from the source current of the switching MOSFET. This current is detected with a sense resistor at the RSENSE pin. The feedback operates in a fast Open-loop mode. No compensation is required. Output current is programmed as seen in Equation 3-2:

EQUATION 3-2:

$$I_{LED} = \frac{0.25V}{R_{CS}}$$

The above equation is only valid for continuous conduction of the output inductor. It is a good practice to design the inductor such that the peak-to-peak switching inductor ripple current in it is 30% to 40% of its average full DC current load. Hence, the recommended inductance can be computed as specified in Equation 3-3:

EQUATION 3-3:

$$L_O = \frac{V_{O(MAX)} \times T_{OFF}}{0.4 \times I_O}$$

The duty cycle range of the current control feedback is limited to D ≤ 0.8. A reduction in the LED current may occur when the LED string voltage V_O is greater than 80% of the input voltage V_{IN} of the HV9967B LED driver.

Reducing the output LED voltage V_O below $V_{O(MIN)} = V_{IN} \times D_{MIN}$, where $D_{MIN} = 0.8\ \mu s/(T_{OFF} + 8\ \mu s)$, may also result in loss of LED current regulation. This condition, however, causes an increase in the LED current and can potentially trip the short-circuit protection comparator threshold.

The short-circuit protection comparator trips when the voltage at RSENSE exceeds 0.4V. When this occurs, the SW off time T_{HICCUP} = 800 µs is generated to prevent the staircasing of the inductor current and, potentially, its saturation due to insufficient output voltage. The typical short-circuit inductor current is shown in the waveform in Figure 3-1.

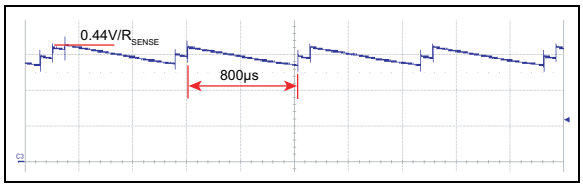


FIGURE 3-1: *Short-Circuit Inductor Current.*

A leading-edge blanking delay is provided at RSENSE pin to prevent false triggering of the short-circuit hiccup threshold voltage and the short-circuit protection.

3.4 SW Input and Linear Regulator

The HV9967B includes an integrated 60V, 0.8Ω switching MOSFET at the SW input. The power for the IC is supplied from a built-in linear 5V regulator that is also derived from the SW input.

3.5 PWM Dimming

The HV9967B features a TTL-compatible dimming input PWMD. Applying a square-wave voltage to PWMD will modulate the duty ratio of the LED current accordingly. The rising and falling edges are limited by the current slew rate in the inductor. The first switching cycle is terminated upon reaching the 250 mV level at RSENSE pin. The circuit will reach the Steady state within three to four switching cycles regardless of the switching frequency.

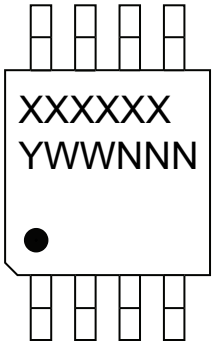
3.6 Overtemperature Protection

The HV9967B includes overtemperature protection. Typically, when the junction temperature exceeds 145°C, switching of the SW input is disabled. The switching resumes when the temperature falls by approximately 20°C from the trip point.

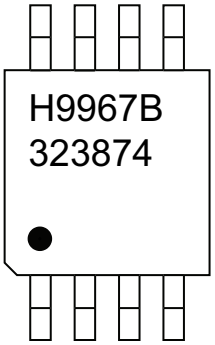
4.0 PACKAGING INFORMATION

4.1 Package Marking Information

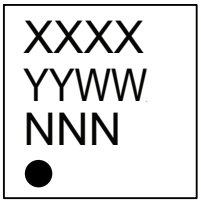
8-lead MSOP



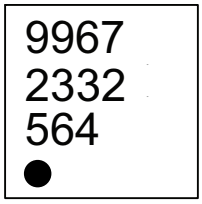
Example



8-lead WDFN



Example

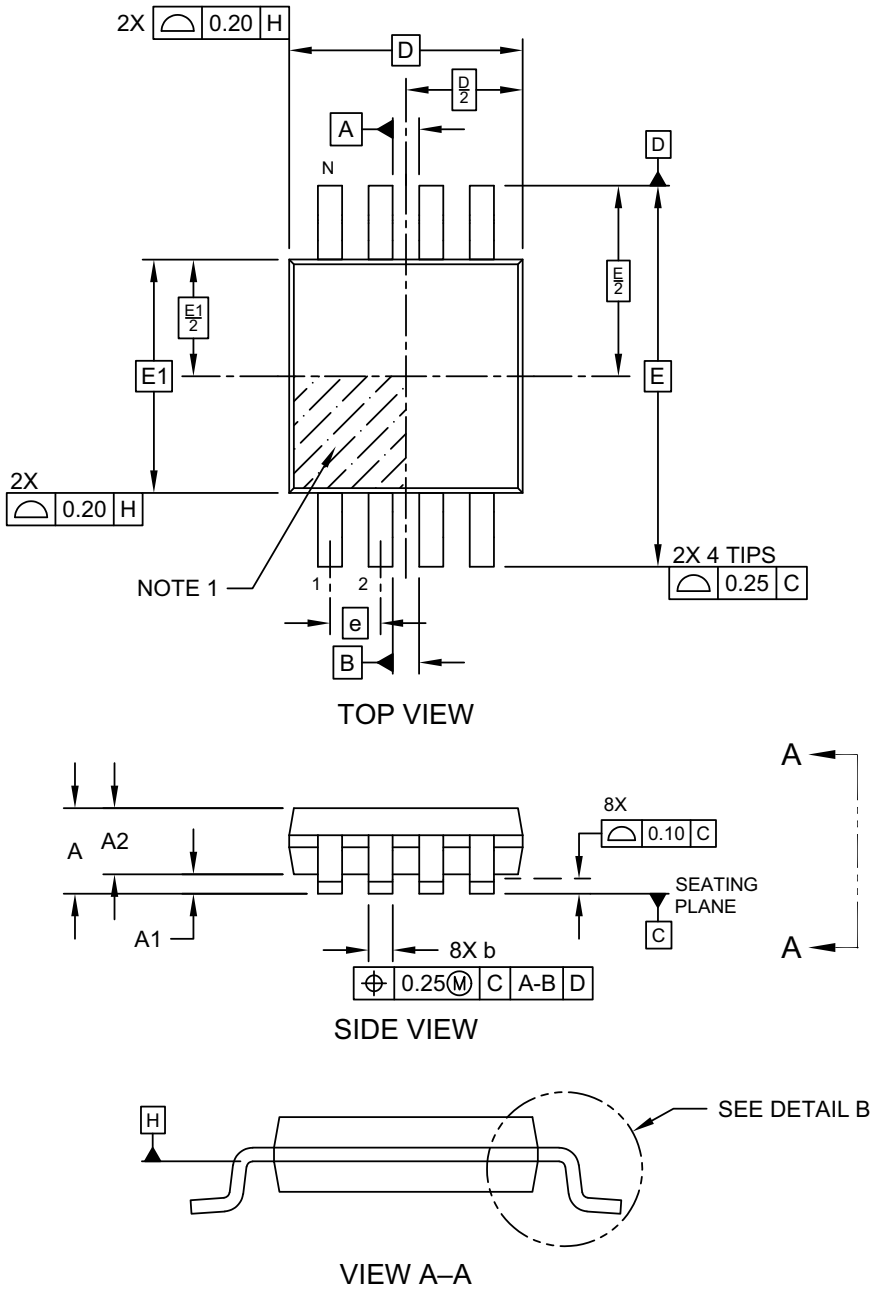


Legend:	XX...X	Product Code or Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

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 product code or customer-specific information. Package may or not include the corporate logo.

8-Lead Plastic Micro Small Outline Package (MS) - 3x3 mm Body [MSOP]

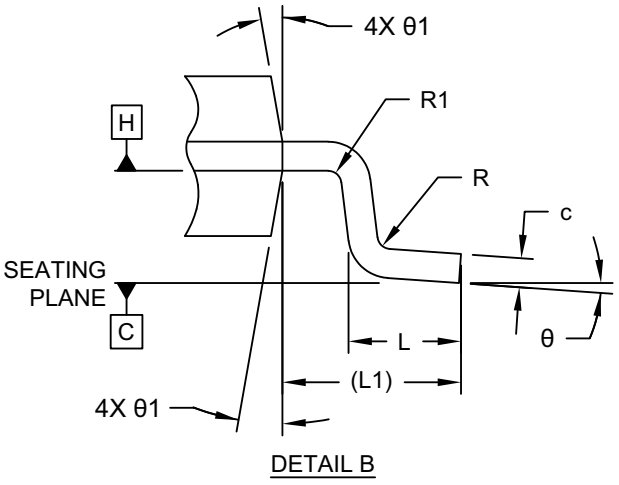
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

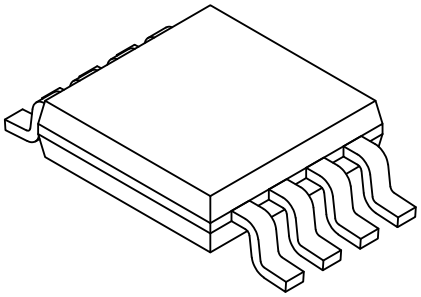


Microchip Technology Drawing C04-111-MS Rev F Sheet 1 of 2

8-Lead Plastic Micro Small Outline Package (MS) - 3x3 mm Body [MSOP]

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





Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		8	
Pitch	e		0.65 BSC	
Overall Height	A	–	–	1.10
Standoff	A1	0.00	–	0.15
Molded Package Thickness	A2	0.75	0.85	0.95
Overall Length	D		3.00 BSC	
Overall Width	E		4.90 BSC	
Molded Package Width	E1		3.00 BSC	
Terminal Width	b	0.22	–	0.40
Terminal Thickness	c	0.08	–	0.23
Terminal Length	L	0.40	0.60	0.80
Footprint	L1		0.95 REF	
Lead Bend Radius	R	0.07	–	–
Lead Bend Radius	R1	0.07	–	–
Foot Angle	θ	0°	–	8°
Mold Draft Angle	θ1	5°	–	15°

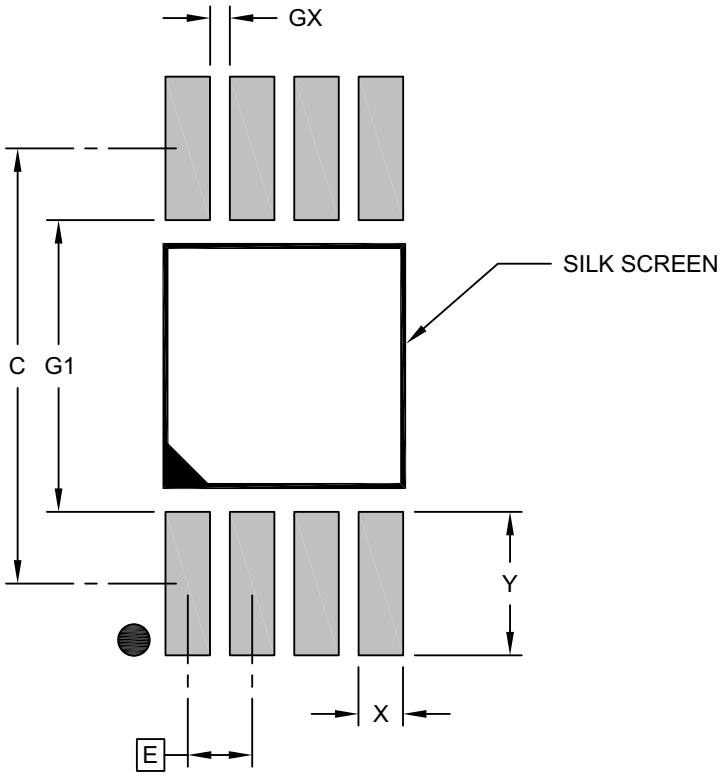
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111-MS Rev F Sheet 2 of 2

8-Lead Plastic Micro Small Outline Package (MS) - 3x3 mm Body [MSOP]

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Contact Pad Spacing	C		4.40	
Contact Pad Width (X8)	X			0.45
Contact Pad Length (X8)	Y			1.45
Contact Pad to Contact Pad (X4)	G1	2.95		
Contact Pad to Contact Pad (X6)	GX	0.20		

Notes:

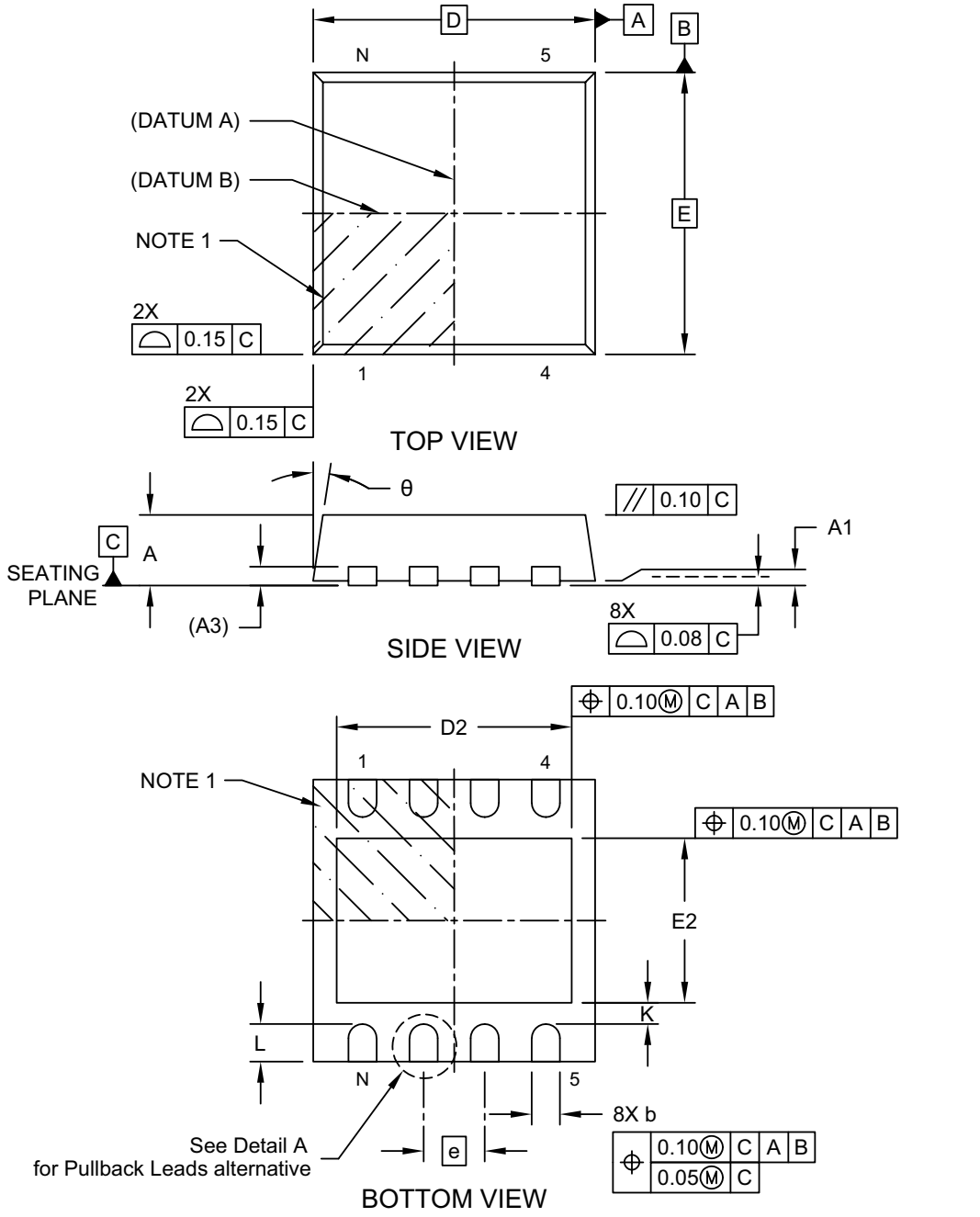
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-2111-MS Rev F

8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package (UQ) - 3x3 mm Body [WDFN]; Supertex Legacy Package

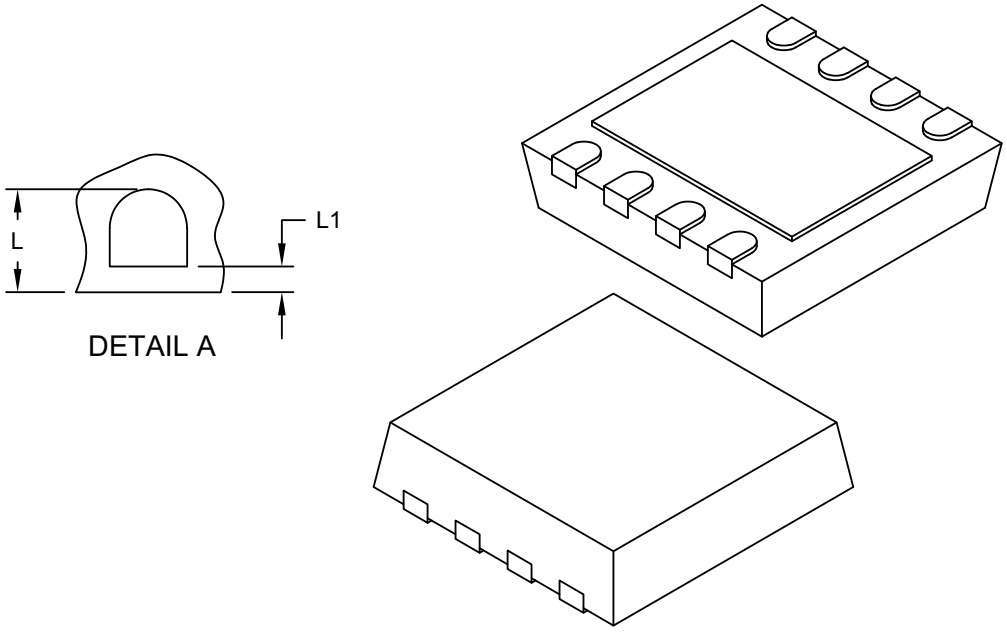
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-291 Rev A Sheet 1 of 2

8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package (UQ) - 3x3 mm Body [WDFN]; Supertex Legacy Package

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



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		8	
Pitch	e		0.65 BSC	
Overall Height	A	0.70	0.75	0.80
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.20 REF	
Overall Length	D		3.00 BSC	
Exposed Pad Length	D2	1.60	-	2.50
Overall Width	E		3.00 BSC	
Exposed Pad Width	E2	1.35	-	1.75
Terminal Width	b	0.25	0.30	0.35
Terminal Length	L	0.30	0.40	0.50
Pullback	L1	-	-	0.15
Mold Angle	θ	0°	7°	14°
Terminal-to-Exposed-Pad	K	0.20	-	-

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

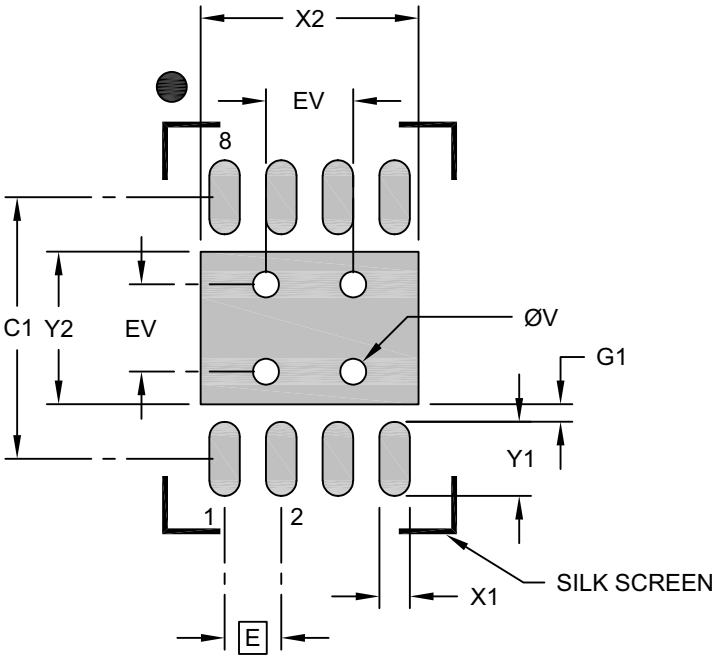
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-291A Sheet 2 of 2

8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package (UQ) - 3x3 mm Body [WDFN]; Supertex Legacy Package

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Optional Center Pad Width	X2			2.50
Optional Center Pad Length	Y2			1.75
Contact Pad Spacing	C1		3.00	
Contact Pad Width (X8)	X1			0.35
Contact Pad Length (X8)	Y1			0.85
Contact Pad to Center Pad (X8)	G1	0.20		
Thermal Via Diameter	V		0.33	
Thermal Via Pitch	EV		1.20	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2291 Rev A

APPENDIX A: REVISION HISTORY

Revision B (June 2023)

- Changed PWMD Input High Voltage from 2V to 2.2V
- Changed the package type “8-lead DFN K7” to “8-lead WDFN K7”
- Updated the 8-lead WDFN K7 package outline drawings
- Made minor text changes throughout the document

Revision A (February 2020)

- Converted Supertex Doc# DSFP-HV9967B to Microchip DS20005734A
- Updated the package marking format
- Updated the packaging quantity of the 8-lead DFN K7 package from 3000/Reel to 3300/Reel to align it with the actual BQM
- Made minor text changes throughout the document

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	-	X
Device	Package Options		Environmental		Media Type

Device:	HV9967B	=	Integrated LED Driver with Average-Mode Current Control
Packages:	MG	=	8-lead MSOP
	K7	=	8-lead WDFN
Environmental:	G	=	Lead (Pb)-free/RoHS-compliant Package
Media Type:	(blank)	=	2500/Reel for an MG Package, 3300/Reel for a K7 Package

Examples:

a) HV9967BMG-G: Integrated LED Driver with Average-Mode Current Control, 8-lead MSOP, 2500/Reel

b) HV9967BK7-G: Integrated LED Driver with Average-Mode Current Control, 8-lead WDFN, 3300/Reel

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ISBN: 978-1-6683-2706-7

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