



# MIC4126/27/28

## Dual 1.5A-Peak Low-Side MOSFET Drivers in Advanced Packaging

### Features

- Dual 1.5A-Peak Drivers
- 4.5V to 20V Operating Range
- Exposed Backside Pad Packaging Reduces Heat
  - ePAD SOIC-8L ( $\theta_{JA} = 58^{\circ}\text{C/W}$ )
  - ePAD MSOP-8L ( $\theta_{JA} = 60^{\circ}\text{C/W}$ )
  - VDFN ML™-8L ( $\theta_{JA} = 60^{\circ}\text{C/W}$ )
- Bipolar/CMOS/DMOS Construction
  - 25mV maximum output offset from supply or ground
- Latch-Up Protection to >200mA Reverse Current
- Switches 1000pF in 25ns
- Logic-Input Threshold Independent of Supply Voltage
- Logic-Input Protection to -5V
- 6pF Typical Equivalent Input Capacitance
- Dual Inverting, Dual Noninverting, and Complementary Configurations
  - $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  operating junction temperature range

### Applications

- DC/DC Converters
- Motor Drivers
  - Clock Line Driver

### General Description

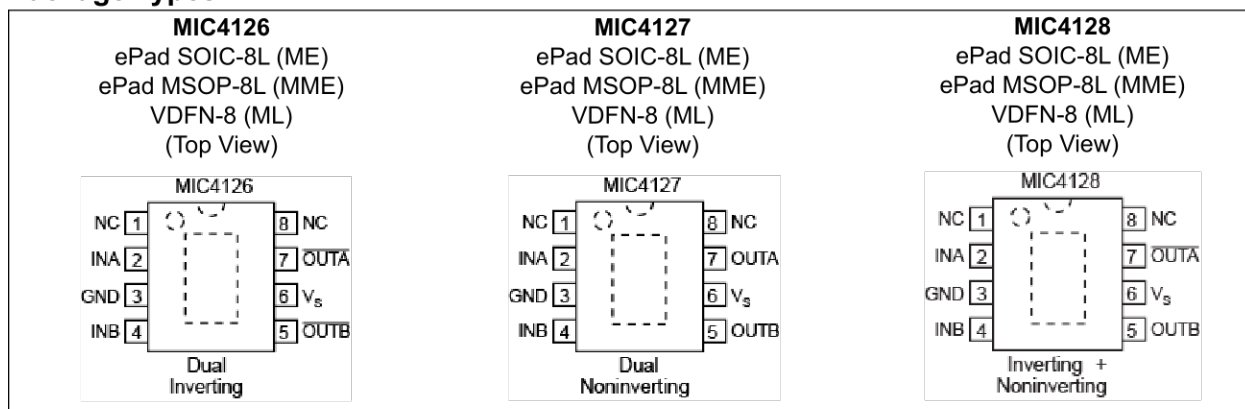
The MIC4126, MIC4127, and MIC4128 family are highly-reliable dual 1.5A low-side MOSFET drivers fabricated on Microchip's BiCMOS/DMOS process. The devices feature low power consumption and high efficiency. The MIC4126/27/28 translate TTL or CMOS input logic levels to output voltage levels that swing within 25mV of the positive supply or ground whereas comparable bipolar devices are capable of swinging only to within 1V of the supply. The MIC4126/7/8 is available in three configurations: dual inverting, dual noninverting, and complimentary output.

The MIC4126/27/28 offer pin-compatible as well as smaller footprint replacements for the MIC4426/27/28 with improved packaging and electrical performance. The MIC4126/27/28 are available in exposed pad, EPAD, SOIC-8L and MSOP-8L options as well as a small-size VDFN ML™-8L option. The devices have an input operating range of 4.5V to 20V.

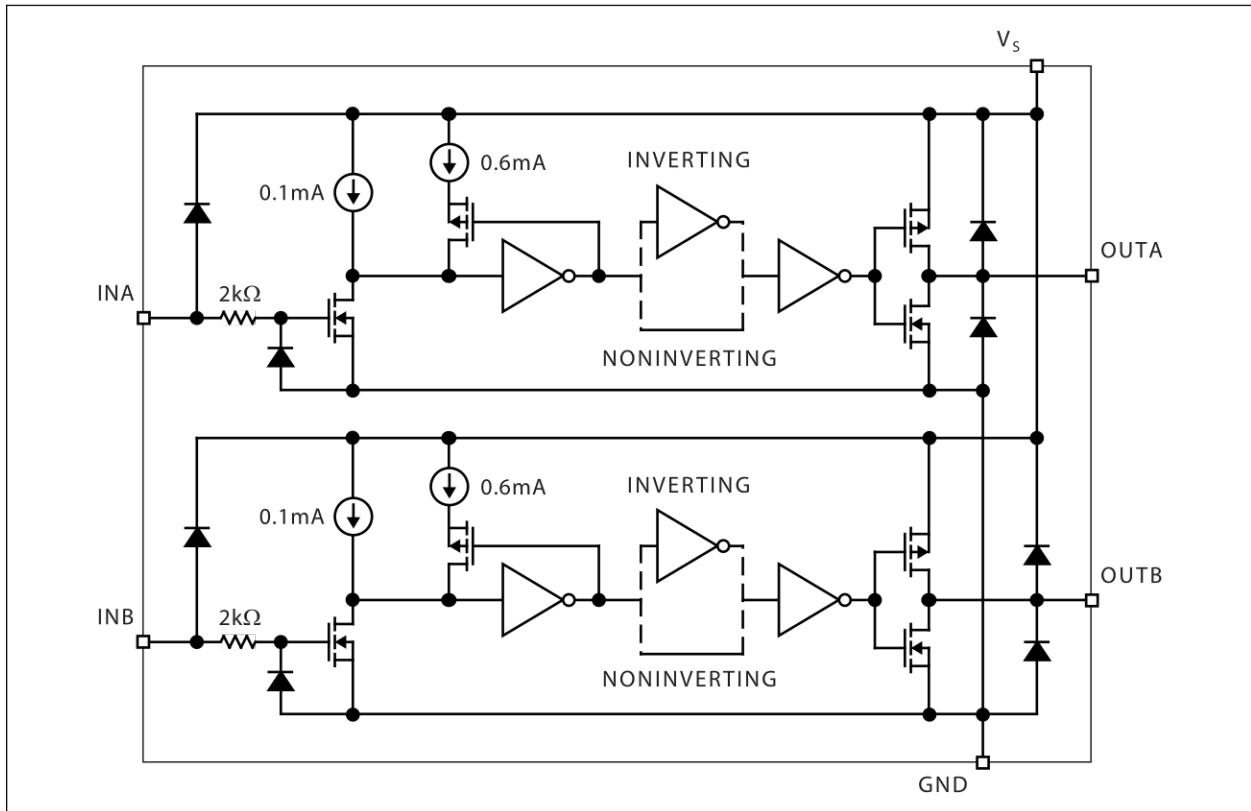
Primarily intended for driving power MOSFETs, MIC4426/7/8 drivers are suitable for driving other loads (capacitive, resistive, or inductive) which require low-impedance, high peak current, and fast switching time. The devices can withstand up to 500mA of reverse current (either polarity) without latching and up to 5V noise spikes (either polarity) on ground pins.

Data sheets and support documentation can be found on Microchip's website at [www.microchip.com](http://www.microchip.com).

### Package Types



## Functional Block Diagram



The function block diagram contains only four resistors, four capacitors, and 52 transistors. Be sure to ground any unused inputs.

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Supply Voltage .....	+24V
Input Voltage .....	$V_S + 0.3V$ to GND – 5V
ESD Susceptibility .....	(Note 1)

### Operating Ratings ††

Supply Voltage ( $V_S$ ) .....	+4.5V to +20V
--------------------------------	---------------

† **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 k $\Omega$  in series with 100 pF.

## ELECTRICAL CHARACTERISTICS

**Electrical Characteristics:**  $4.5V \leq V_S \leq 20V$ ;  $T_A = +25^\circ C$ , **bold** values indicate full specified temperature range; unless noted. Input voltage slew rate  $>1V/\mu s$ ;  $C_{OUT} = 1000pF$ . [Note 1](#)

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Input</b>						
Logic 1 Input Voltage	$V_{IH}$	2.4	1.4	—	V	—
		<b>2.4</b>	<b>1.6</b>	—	V	—
Logic 0 Input Voltage	$V_{IL}$	—	1.1	0.8	V	—
		—	<b>1.3</b>	<b>0.8</b>	V	—
Input Current	$I_{IN}$	<b>-1</b>	—	<b>1</b>	$\mu A$	$0V \leq V_{IN} \leq V_S$
<b>Output</b>						
High Output Voltage	$V_{OH}$	<b><math>V_S - 0.025</math></b>	—	—	V	—
Low Output Voltage	$V_{OL}$	—	—	<b>0.025</b>	V	—
Output Resistance	$R_O$	—	6	10	$\Omega$	$I_{OUT} = 10\text{ mA}$ , $V_S = 20V$
		—	<b>8</b>	<b>12</b>		
Peak Output Current	$I_{PK}$	—	<b>1.5</b>	—	A	—
Latch-Up Protection	I	<b>&gt;200</b>	—	—	mA	Withstand Reverse Current
<b>Switching Time</b>						
Rise Time	$t_R$	—	13	30	ns	Test <a href="#">Figure 1-1</a>
		—	<b>20</b>	<b>40</b>		
Fall Time	$t_F$	—	15	25	ns	Test <a href="#">Figure 1-1</a>
		—	<b>18</b>	<b>40</b>		
Delay Time	$t_{D1}$	—	37	50	ns	Test <a href="#">Figure 1-1</a>
		—	<b>43</b>	<b>60</b>		
Delay Time	$t_{D2}$	—	40	60	ns	Test <a href="#">Figure 1-1</a>
		—	<b>45</b>	<b>70</b>		

**Note 1:** Specification for packaged product only.

## ELECTRICAL CHARACTERISTICS (CONTINUED)

**Electrical Characteristics:**  $4.5V \leq V_S \leq 20V$ ;  $T_A = +25^\circ C$ , **bold** values indicate full specified temperature range; unless noted. Input voltage slew rate  $>1V/\mu s$ ;  $C_{OUT} = 1000pF$ . [Note 1](#)

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Power Supply</b>						
Power Supply Current	$I_S$	—	1.4	4.5	mA	$V_{INA} = V_{INB} 3.0V$
		—	<b>1.5</b>	<b>8</b>		
Power Supply Current	$I_S$	—	0.18	0.4	mA	$V_{INA} = V_{INb} 0.0V$
		—	<b>0.19</b>	<b>0.6</b>		

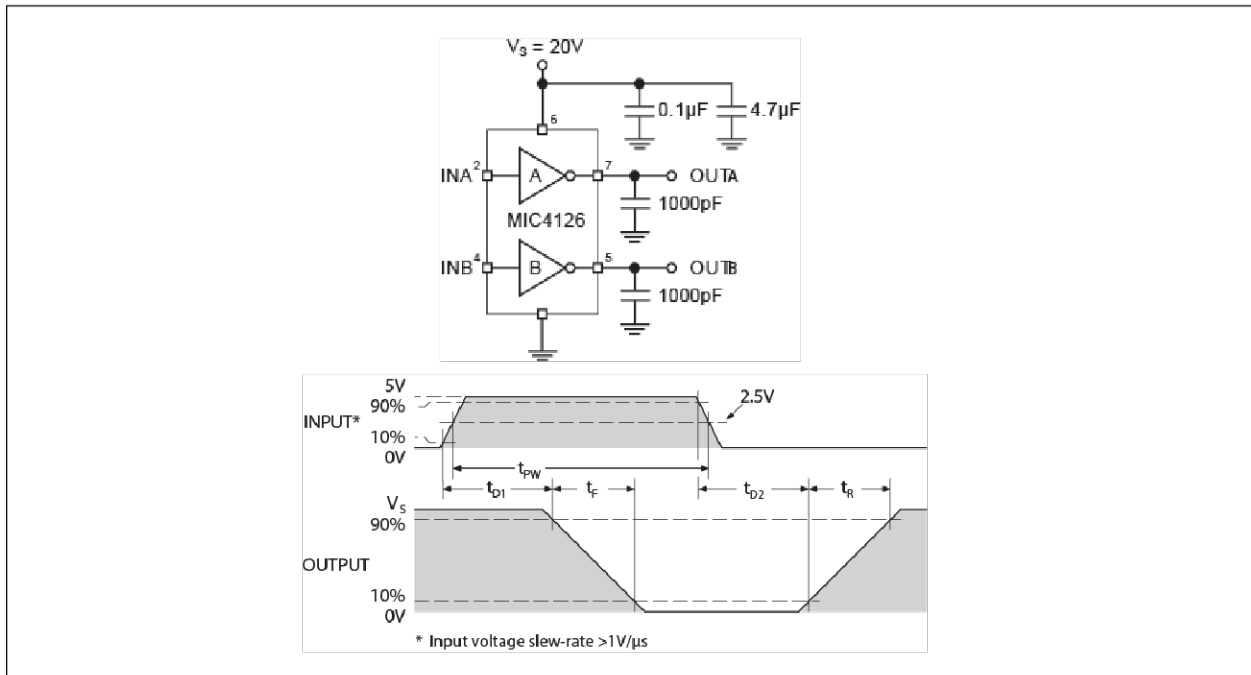
**Note 1:** Specification for packaged product only.

## TEMPERATURE SPECIFICATIONS

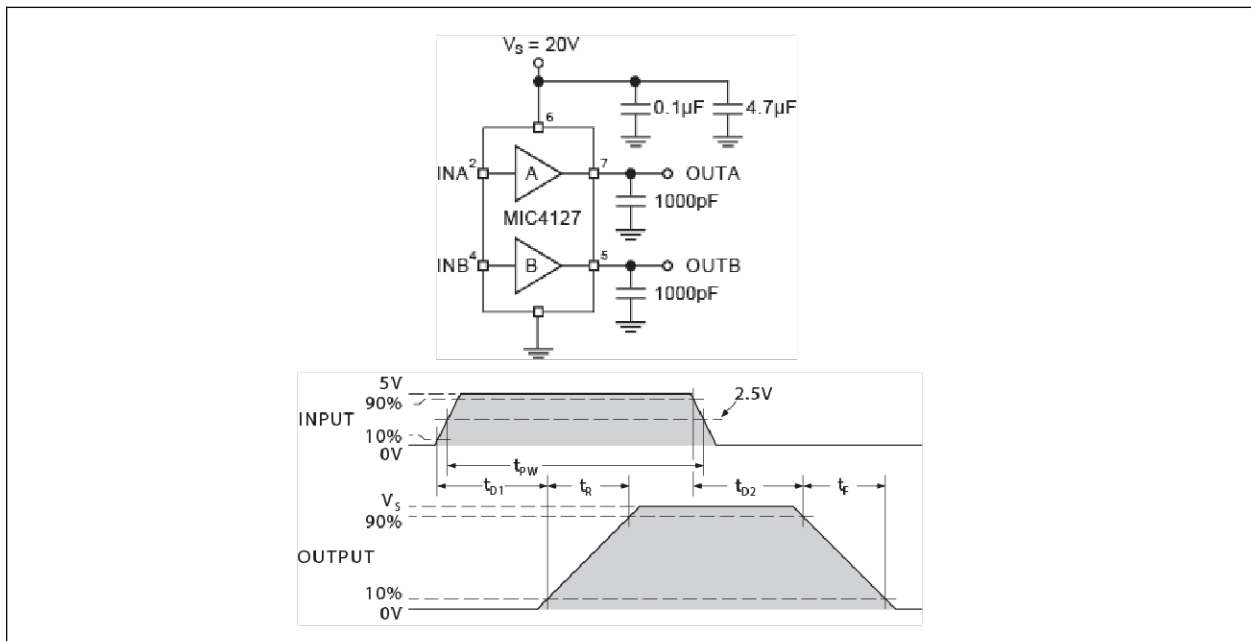
Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Temperature Ranges</b>						
Maximum Junction Temperature	$T_J$	—	—	+150	°C	—
Storage Temperature Range	$T_S$	-65	—	+150	°C	—
Lead Temperature	—	—	—	+300	°C	10 sec.
Junction Operating Temperature Range	$T_J$	-40	—	+125	°C	—
<b>Package Thermal Resistances</b>						
Thermal Resistance, 3x3 VDFN 8-Ld	$\theta_{JA}$	—	60	—	°C/W	—
Thermal Resistance, EP MSOP 8-Ld	$\theta_{JA}$	—	60	—	°C/W	—
Thermal Resistance, EP SOIC 8-Ld	$\theta_{JA}$	—	58	—	°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.,  $T_A$ ,  $T_J$ ,  $\theta_{JA}$ ). 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.

## Test Circuits



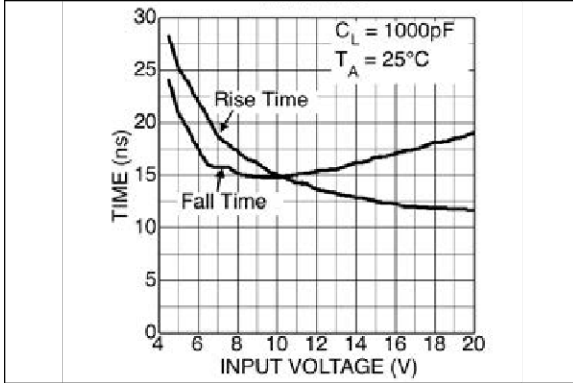
**FIGURE 1-1:** Inverting Driver Switching Time.



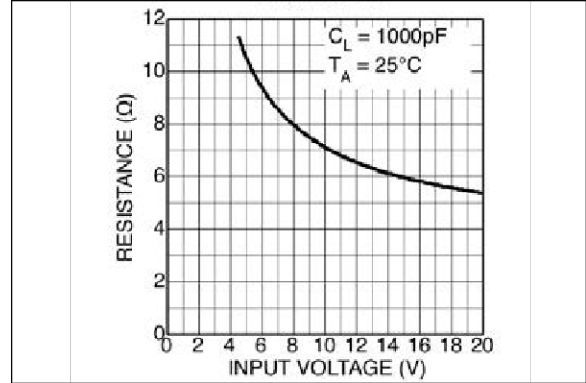
**FIGURE 1-2:** Noninverting Driver Switching Time.

## 2.0 TYPICAL PERFORMANCE CURVES

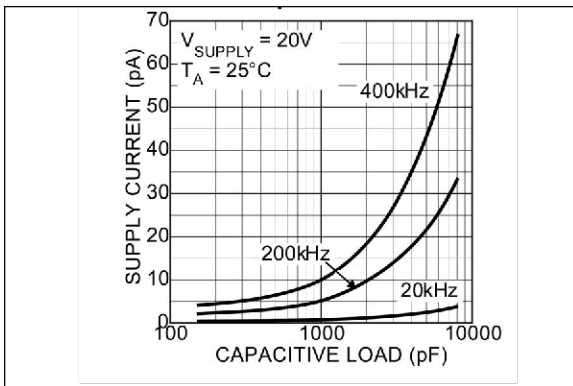
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be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



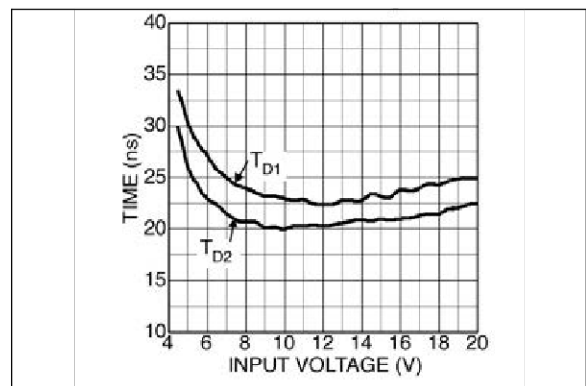
**FIGURE 2-1:** Rise and Fall Time.



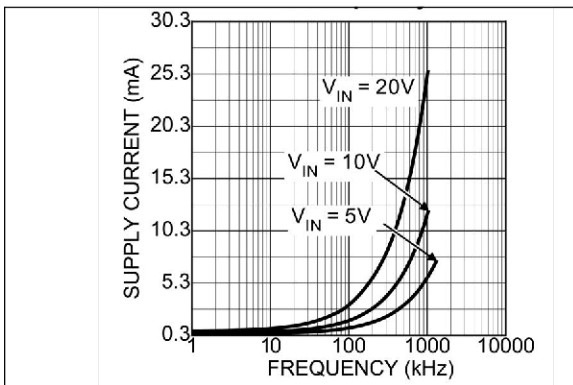
**FIGURE 2-4:** MIC4126 Output Resistance.



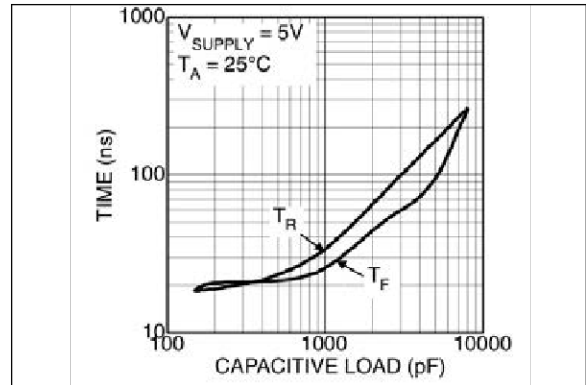
**FIGURE 2-2:** MIC4127 Supply Current vs. Capacitive Load.



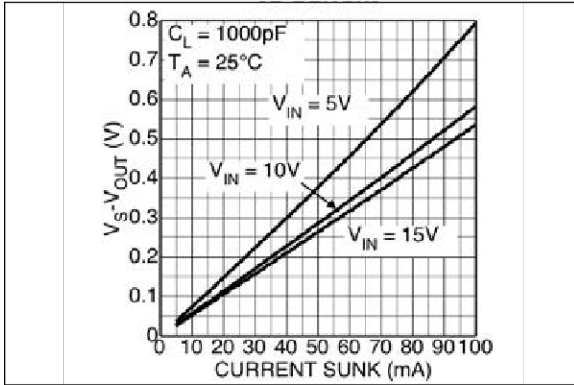
**FIGURE 2-5:** Turn On and Turn Off Delay.



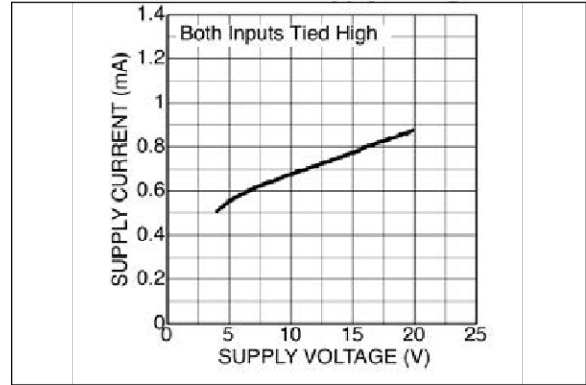
**FIGURE 2-3:** Supply Current vs. Frequency.



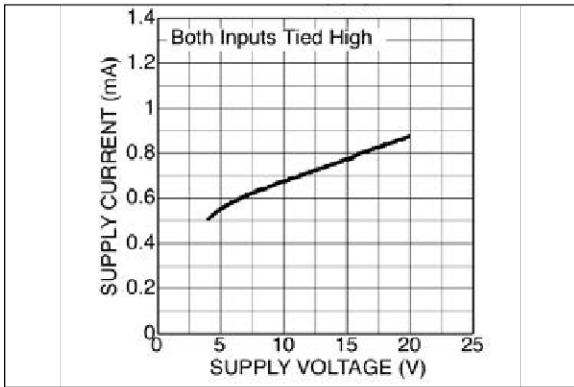
**FIGURE 2-6:** Rise and Fall Time vs. Capacitive Load.



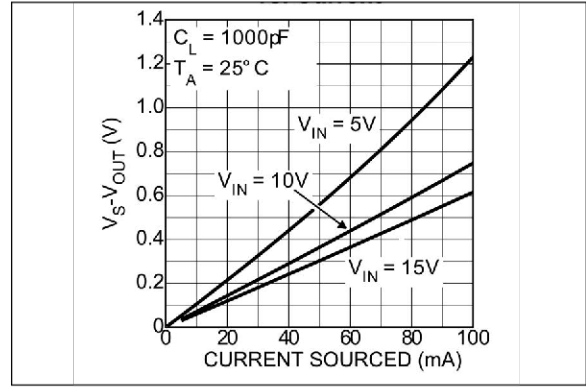
**FIGURE 2-7:** Low Output vs. Current.



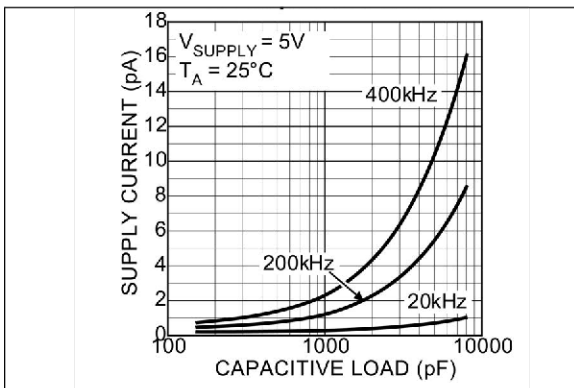
**FIGURE 2-10:** Rise and Fall Time vs. Capacitive Load.



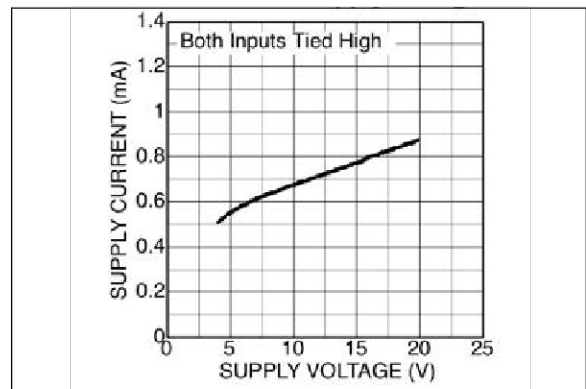
**FIGURE 2-8:** Quiescent Power Supply Current vs. Supply Voltage.



**FIGURE 2-11:** High Output vs. Current.



**FIGURE 2-9:** MIC4127 Supply Current vs. Capacitive Load.



**FIGURE 2-12:** Quiescent Power Supply Current vs. Supply Voltage.



## 3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#).

**TABLE 3-1: PIN FUNCTION TABLE**

Pin Number	Pin Name	Description
1, 8	NC	Not internally connected
2	INA	Control Input A: TTL/CMOS compatible logic input
3	GND	Ground
4	INB	Control Input B: TTL/CMOS compatible logic input
5	OUTB	Output B: CMOS totem-pole output
6	V <sub>S</sub>	Supply Input: +4.5V to +20V
7	OUTA	Output A: CMOS totem-pole output
EP	GND	Ground, backside pad

## 4.0 APPLICATION INFORMATION

### Supply Bypassing

Large currents are required to charge and discharge large capacitive loads quickly. For example, changing a 1000pF load by 16V in 25ns requires 0.8A from the supply input.

To ensure low supply impedance over a wide frequency range, parallel capacitors are recommended for power supply bypassing. Low-inductance ceramic MLC capacitors with short lead lengths (< 0.5") should be used. A 1.0μF film capacitor in parallel with one or two 0.1μF ceramic MLC capacitors normally provides adequate bypassing.

### Grounding

When using the inverting drivers in the MIC4126 or MIC4128, individual ground returns for the input and output circuits or a ground plane are recommended for optimum switching speed. The voltage drop that occurs between the driver's ground and the input signal ground, during normal high-current switching, will behave as negative feedback and degrade switching speed.

The E-pad and ML packages have an exposed pad under the package. It is important for good thermal performance that this pad is connected to a ground plane.

### Control Input

Unused driver inputs must be connected to logic high (which can be VS) or ground. For the lowest quiescent current (< 500μA), connect unused inputs-to-ground. A logic-high signal will cause the driver to draw up to 9mA.

The control input voltage threshold is approximately 1.5V. The control input recognizes 1.5V up to VS as a logic high and draws less than 1μA within this range.

### Power Dissipation

Power dissipation should be calculated to make sure that the driver is not operated beyond its thermal ratings. Quiescent power dissipation is negligible. A practical value for total power dissipation is the sum of the dissipation caused by the load and the transition power dissipation (PL + PT).

#### Load Dissipation

Power dissipation caused by continuous load current (when driving a resistive load) through the driver's output resistance is:

$$P_L = I_L^2 R_O$$

For capacitive loads, the dissipation in the driver is:

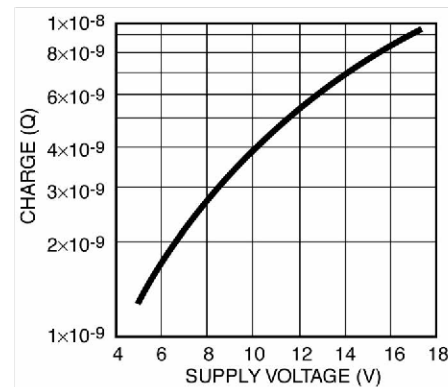
$$P_L = f C_L V_S^2$$

#### Transition Dissipation

In applications switching at a high frequency, transition power dissipation can be significant. This occurs during switching transitions when the P-channel and N-channel output FETs are both conducting for the brief moment when one is turning on and the other is turning off.

$$P_T = 2 f V_S Q$$

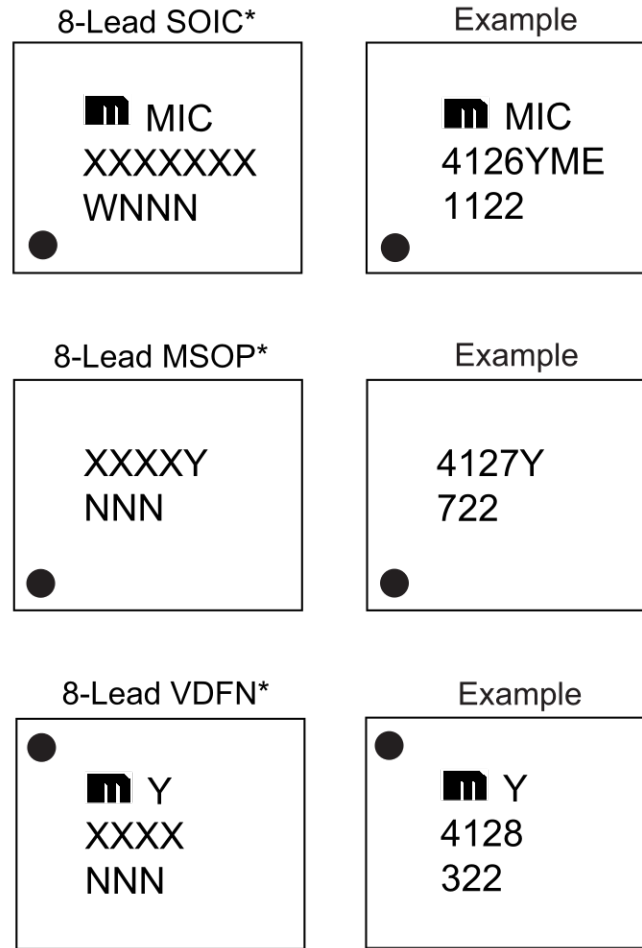
Charge (Q) is read from the following graph:



### Crossover Energy Loss per Transition

## 5.0 PACKAGING INFORMATION

### 5.1 Package Marking Information

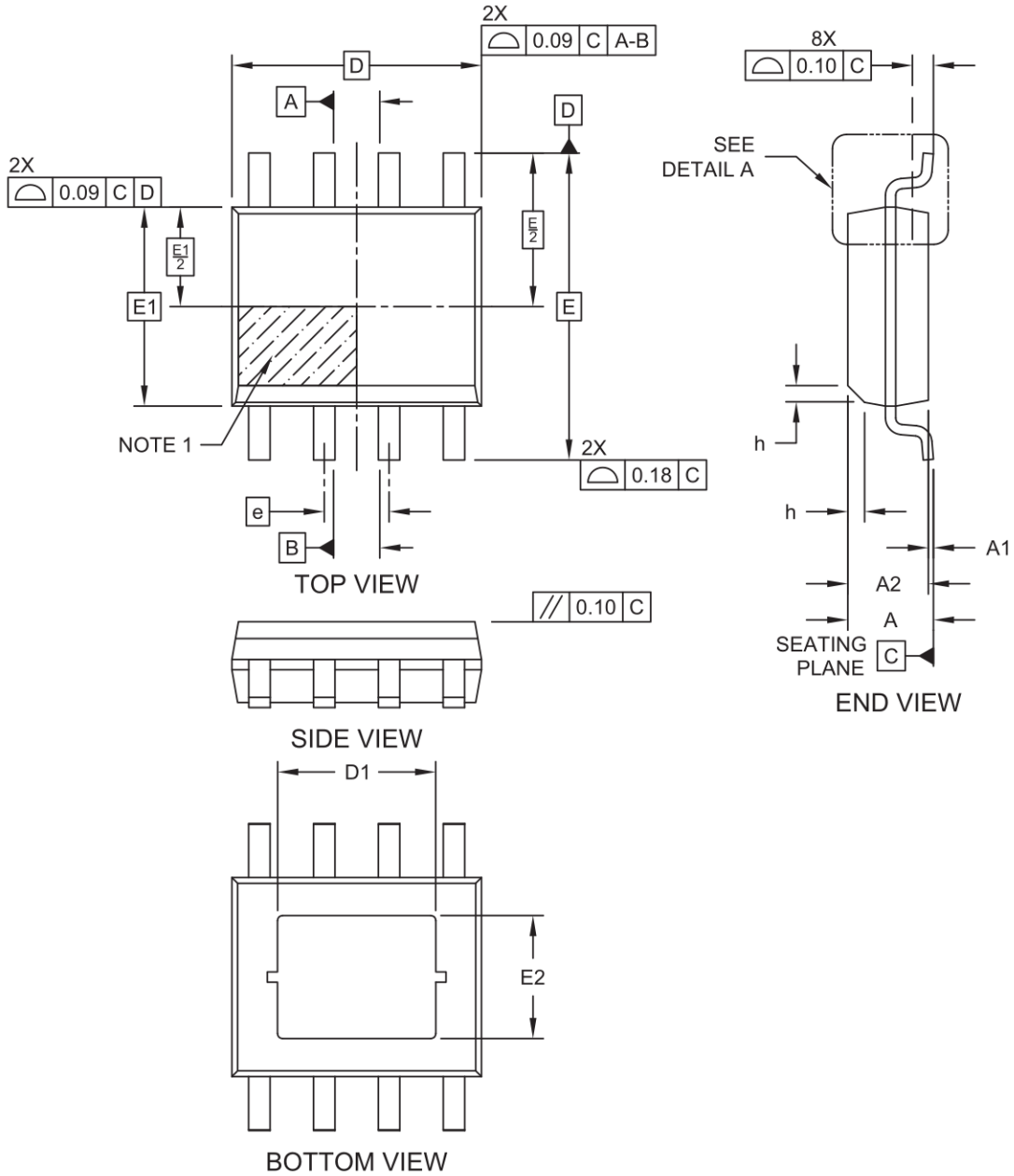


<p><b>Legend:</b></p> <p>XX...X Product code or customer-specific information</p> <p>Y Year code (last digit of calendar year)</p> <p>YY Year code (last 2 digits of calendar year)</p> <p>WW Week code (week of January 1 is week '01')</p> <p>NNN Alphanumeric traceability code</p> <p>(e3) Pb-free JEDEC® designator for Matte Tin (Sn)</p> <p>* This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.</p> <p>•, ▲, ▼ Pin one index is identified by a dot, delta up, or delta down (triangle mark).</p>
<p><b>Note:</b> 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.</p> <p>Underbar ( ) and/or Overbar ( ) symbol may not be to scale.</p>

## 8-Lead SOICN ePad Package Outline and Recommended Land Pattern

### 8-Lead Small Outline Integrated Circuit Package (EQA) - 3.90 mm (1.50 In) Body [SOIC] With 3.10x2.41 mm Exposed Pad

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

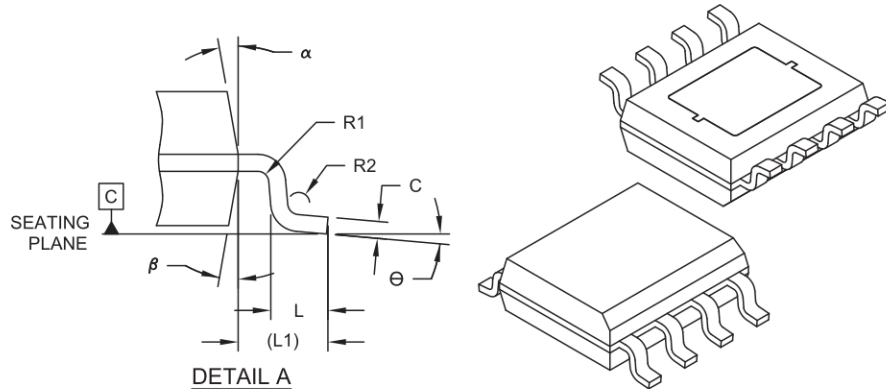


Microchip Technology Drawing C04-1136 Rev A Sheet 1 of 2



## 8-Lead Small Outline Integrated Circuit Package (EQA) - 3.90 mm (1.50 In) Body [SOIC] With 3.10x2.41 mm Exposed Pad

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



Dimension	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Terminals	N	8		
Pitch	e	1.27 BSC		
Overall Height	A	1.43	1.55	1.68
Standoff	A1	0.00	0.05	0.10
Molded Package Thickness	A2	1.25	-	-
Overall Length	D	4.89 BSC		
Exposed Pad Length	D1	-	3.10	-
Overall Width	E	6.02 BSC		
Molded Package Width	E1	3.90 BSC		
Exposed Pad Width	E2	-	2.41	-
Terminal Width	b	0.35	0.41	0.49
Lead Thickness	c	0.19	0.20	0.25
Terminal Length	L	0.41	0.64	0.89
Terminal-to-Exposed-Pad	L1	1.04 REF		
Foot Angle	θ	0°	5°	8°
Lead Bend Radius	R1	0.07	-	-
Terminal Length	R2	0.07	-	-
Mold Draft Angle	α	5°	-	15°
Mold Draft Angle	β	5°	-	15°

**Notes:**

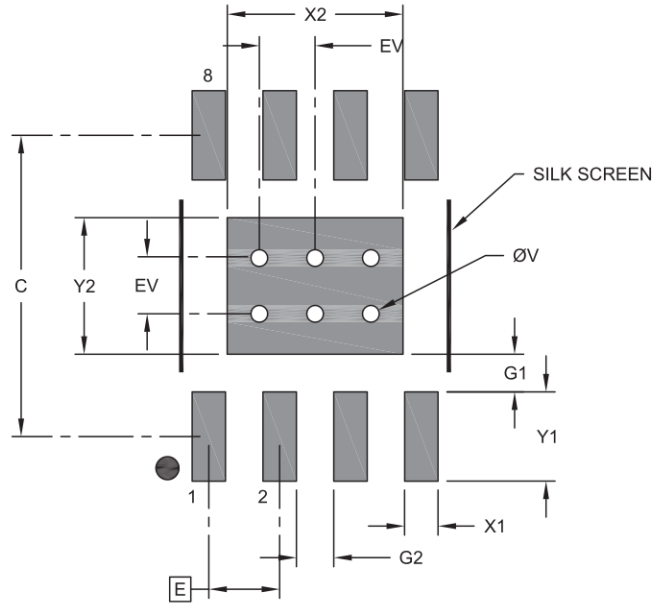
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated
- Dimensioning and tolerancing per ASME Y14.5M  
BSC: Basic Dimension. Theoretically exact value shown without tolerances.  
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-1136 Rev A Sheet 2 of 2



## 8-Lead Small Outline Integrated Circuit Package (EQA) - 3.90 mm (1.50 In) Body [SOIC] With 3.10x2.41 mm Exposed Pad

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



RECOMMENDED LAND PATTERN

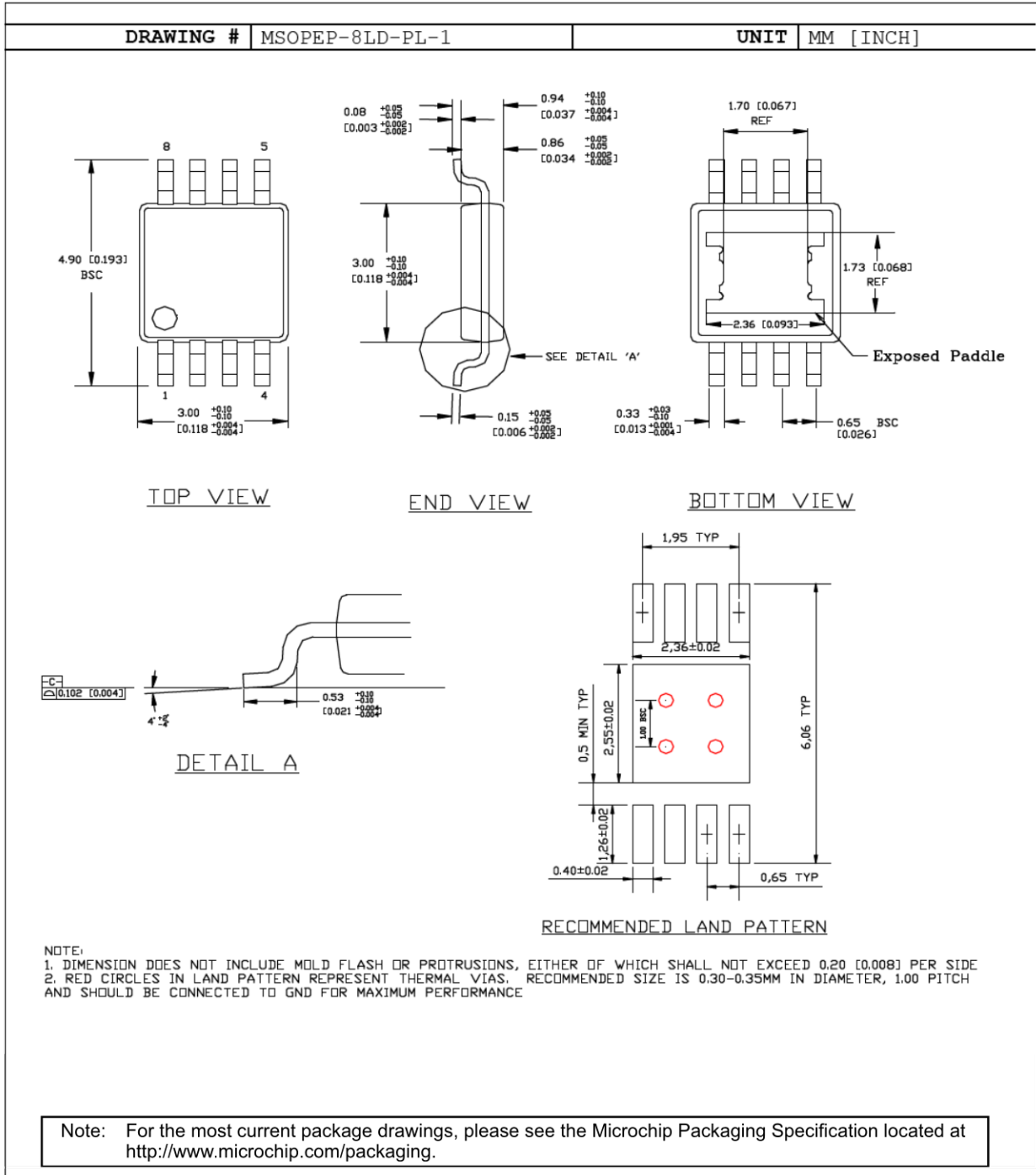
Dimension	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Optional Center Pad Width	X2			3.15
Optional Center Pad Length	Y2			2.45
Contact Pad Spacing	C		5.40	
Contact Pad Width (X8)	X1			0.60
Contact Pad Length (X8)	Y1			1.60
Contact Pad to Center Pad (X8)	G1	0.68		
Contact Pad to Contact Pad (X6)	G2	0.67		
Thermal Via Diameter	V		0.30	
Thermal Via Pitch	EV		1.00	

**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 C04-1136 Rev A

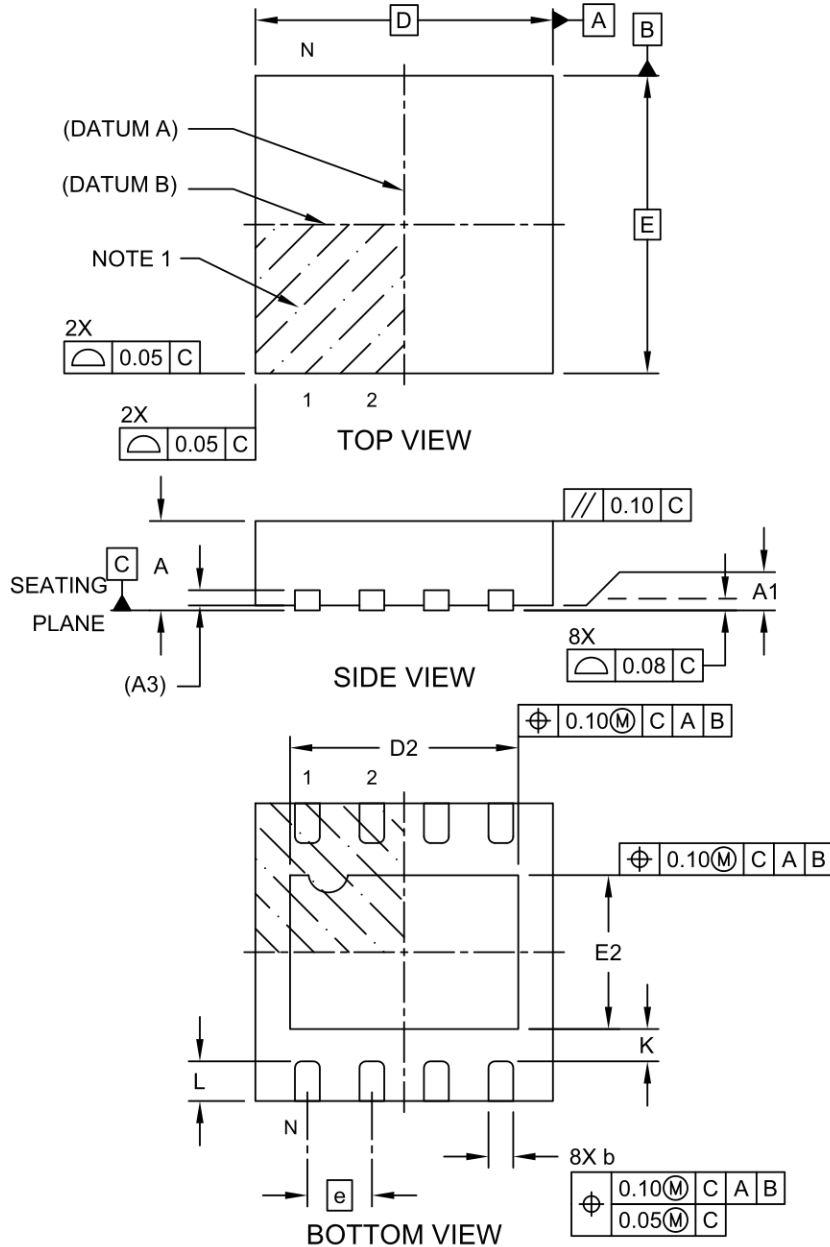
## 8-Lead MSOP ePad Package Outline and Recommended Land Pattern



## 8-Lead VDFN Package Outline and Recommended Land Pattern

### 8-Lead Very Thin Plastic Dual Flat, No Lead Package (JMA) - 3x3x0.9 mm Body [VDFN] Micrel Legacy Package DFN33-8LD-PL-1

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

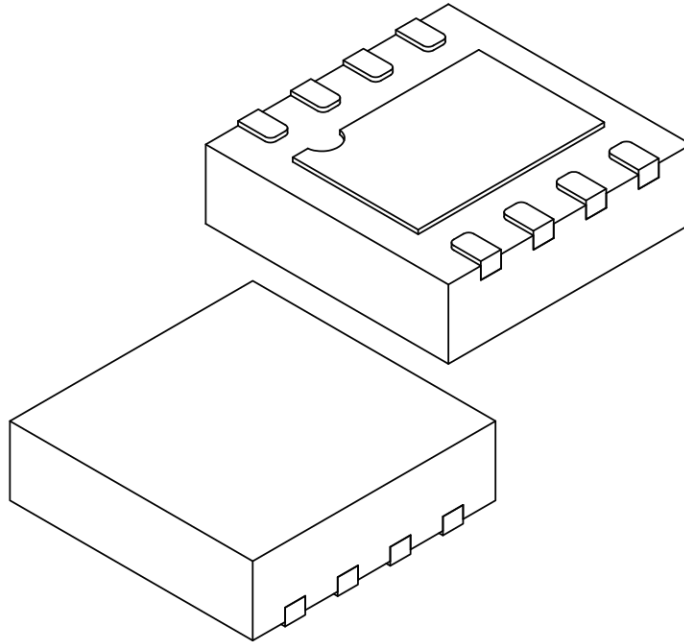


Microchip Technology Drawing C04-1021 A Sheet 1 of 2



## 8-Lead Very Thin Plastic Dual Flat, No Lead Package (JMA) - 3x3x0.9 mm Body [VDFN] Micrel Legacy Package DFN33-8LD-PL-1

**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	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3	0.203 REF		
Overall Length	D	3.00 BSC		
Exposed Pad Length	D2	2.25	2.30	2.35
Overall Width	E	3.00 BSC		
Exposed Pad Width	E2	1.50	1.55	1.60
Terminal Width	b	0.20	0.25	0.30
Terminal Length	L	0.35	0.40	0.45
Terminal-to-Exposed-Pad	K	0.20	-	-

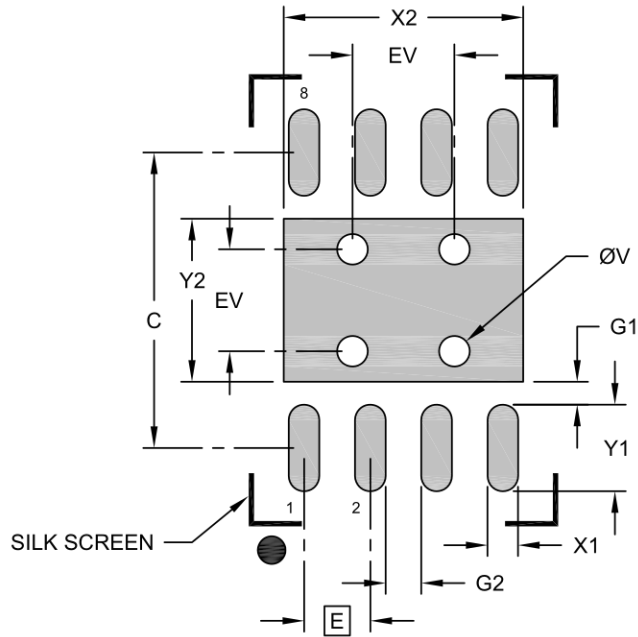
**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated
- 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 C04-1021 A Sheet 1 of 2

## 8-Lead Very Thin Plastic Dual Flat, No Lead Package (JMA) - 3x3x0.9 mm Body [VDFN] Micrel Legacy Package DFN33-8LD-PL-1

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



### RECOMMENDED LAND PATTERN

Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Optional Center Pad Width	X2			2.35
Optional Center Pad Length	Y2			1.60
Contact Pad Spacing	C		2.90	
Contact Pad Width (X8)	X1			0.30
Contact Pad Length (X8)	Y1			0.85
Contact Pad to Center Pad (X8)	G1	0.23		
Contact Pad to Contact Pad (X6)	G2	0.35		
Thermal Via Diameter	V		0.30	
Thermal Via Pitch	EV		1.00	

**Notes:**

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

Microchip Technology Drawing C04-3021 Rev A

## APPENDIX A: REVISION HISTORY

### Revision A (June 2019)

- Converted Micrel document MIC4126/27/28 (M9999-072605) to Microchip data sheet template DS20006084A.
- Minor grammatical text changes throughout.
- Updated [Packaging Information](#) to MCHP standard versions.

### Revision B (May 2022)

- Updated package marking drawing in **Section 5.1 “Package Marking Information”**.

## PRODUCT IDENTIFICATION SYSTEM

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

Device	X	XX	-XX
Part No.	Junction Temp. Range	Package	Media Type
Dual 1.5A-Peak Low-Side MOSFET Driver in Advance Packaging Bipolar/CMOS/DMOS Process			
<b>Device:</b>		MIC4126: Dual Inverting MIC4127: Dual Noninverting MIC4128: Inverting and Noninverting	
<b>Junction Temperature Range:</b>	Y =	-40°C to +125°C, RoHS Compliant	
<b>Package:</b>		ME = 8-Lead ePad SOIC MME = 8-Lead ePad MSOP ML = 8-Lead VDFN	
<b>Media Type:</b>		<blank>= 95/Tube (ME, ePad SOIC) <blank>= 100/Tube (MME, ePad MSOP) TR = 2,500/Reel (ME & MME, ePad SOIC) TR = 5,000/Reel (ML, VDFN)	
<b>Examples:</b>			
a) MIC4126:1.5A-Peak, Dual Inverting, Low-Side MOSFET Driver in Advanced Packaging, Extended Temperature Range, -40°C to +125°C, RoHS Compliant.			
		MIC4126YME 8-Lead ePad SOIC Package	95/Tube
		MIC4126YME-TR 8-Lead ePad SOIC Package	2500/Reeling
		MIC4126YMME 8-Lead ePad MSOP Package	100/Tube
		MIC4126YMME-TR 8-Lead ePad MSOP Package	2500/Reel
		MIC4126YML-TR 8-Lead VDFN Package	5000/Reel
b) MIC4127:1.5A-Peak, Dual Noninverting, Low-Side MOSFET Driver in Advanced Packaging, Extended Temperature Range, -40°C to +125°C, RoHS Compliant.			
		MIC4127YME 8-Lead ePad SOIC Package	95/Tube
		MIC4127YME-TR 8-Lead ePad SOIC Package	2500/Reeling
		MIC4127YMME 8-Lead ePad MSOP Package	100/Tube
		MIC4127YMME-TR 8-Lead ePad MSOP Package	2500/Reel
		MIC4127YML-TR 8-Lead VDFN Package	5000/Reel
c) MIC4128:1.5A-Peak, Inverting and Noninverting, Low-Side MOSFET Driver in Advanced Packaging, Extended Temperature Range, -40°C to +125°C, RoHS Compliant.			
		MIC4128YME 8-Lead ePad SOIC Package	95/Tube
		MIC4128YME-TR 8-Lead ePad SOIC Package	2500/Reeling
		MIC4128YMME 8-Lead ePad MSOP Package	100/Tube
		MIC4128YMME-TR 8-Lead ePad MSOP Package	2500/Reel
		MIC4128YML-TR 8-Lead VDFN Package	5000/Reel
<b>Note 1:</b> 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.			

---

---

**Note the following details of the code protection feature on Microchip products:**

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
- Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is “unbreakable”. Code protection is constantly evolving. Microchip is committed to continuously improving the code protection features of our products.

---

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. Contact your local Microchip sales office for additional support or, obtain additional support at <https://www.microchip.com/en-us/support/design-help/client-support-services>.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL, OR CONSEQUENTIAL LOSS, DAMAGE, COST, OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION.

Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

For information regarding Microchip's Quality Management Systems, please visit [www.microchip.com/quality](http://www.microchip.com/quality).

**Trademarks**

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, CryptoMemory, CryptoRF, dsPIC, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, Flashtec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, QuietWire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, TrueTime, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, GridTime, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, Inter-Chip Connectivity, JitterBlocker, Knob-on-Display, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, NVM Express, NVMe, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICTail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SmartHLS, SMART-I.S., storClad, SQL, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, Symmcom, and Trusted Time are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2019 - 2022, Microchip Technology Incorporated and its subsidiaries.

All Rights Reserved.

ISBN: 978-1-6683-0526-3



## Worldwide Sales and Service

### AMERICAS

**Corporate Office**  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200  
Fax: 480-792-7277  
Technical Support:  
[http://www.microchip.com/  
support](http://www.microchip.com/support)  
Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

**Austin, TX**  
Tel: 512-257-3370

**Boston**  
Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

**Chicago**  
Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

**Dallas**  
Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

**Detroit**  
Novi, MI  
Tel: 248-848-4000

**Houston, TX**  
Tel: 281-894-5983

**Indianapolis**  
Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453  
Tel: 317-536-2380

**Los Angeles**  
Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608  
Tel: 951-273-7800

**Raleigh, NC**  
Tel: 919-844-7510

**New York, NY**  
Tel: 631-435-6000

**San Jose, CA**  
Tel: 408-735-9110  
Tel: 408-436-4270

**Canada - Toronto**  
Tel: 905-695-1980  
Fax: 905-695-2078

### ASIA/PACIFIC

**Australia - Sydney**  
Tel: 61-2-9868-6733

**China - Beijing**  
Tel: 86-10-8569-7000

**China - Chengdu**  
Tel: 86-28-8665-5511

**China - Chongqing**  
Tel: 86-23-8980-9588

**China - Dongguan**  
Tel: 86-769-8702-9880

**China - Guangzhou**  
Tel: 86-20-8755-8029

**China - Hangzhou**  
Tel: 86-571-8792-8115

**China - Hong Kong SAR**  
Tel: 852-2943-5100

**China - Nanjing**  
Tel: 86-25-8473-2460

**China - Qingdao**  
Tel: 86-532-8502-7355

**China - Shanghai**  
Tel: 86-21-3326-8000

**China - Shenyang**  
Tel: 86-24-2334-2829

**China - Shenzhen**  
Tel: 86-755-8864-2200

**China - Suzhou**  
Tel: 86-186-6233-1526

**China - Wuhan**  
Tel: 86-27-5980-5300

**China - Xian**  
Tel: 86-29-8833-7252

**China - Xiamen**  
Tel: 86-592-2388138

**China - Zhuhai**  
Tel: 86-756-3210040

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444

**India - New Delhi**  
Tel: 91-11-4160-8631

**India - Pune**  
Tel: 91-20-4121-0141

**Japan - Osaka**  
Tel: 81-6-6152-7160

**Japan - Tokyo**  
Tel: 81-3-6880-3770

**Korea - Daegu**  
Tel: 82-53-744-4301

**Korea - Seoul**  
Tel: 82-2-554-7200

**Malaysia - Kuala Lumpur**  
Tel: 60-3-7651-7906

**Malaysia - Penang**  
Tel: 60-4-227-8870

**Philippines - Manila**  
Tel: 63-2-634-9065

**Singapore**  
Tel: 65-6334-8870

**Taiwan - Hsin Chu**  
Tel: 886-3-577-8366

**Taiwan - Kaohsiung**  
Tel: 886-7-213-7830

**Taiwan - Taipei**  
Tel: 886-2-2508-8600

**Thailand - Bangkok**  
Tel: 66-2-694-1351

**Vietnam - Ho Chi Minh**  
Tel: 84-28-5448-2100

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4485-5910  
Fax: 45-4485-2829

**Finland - Espoo**  
Tel: 358-9-4520-820

**France - Paris**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Garching**  
Tel: 49-8931-9700

**Germany - Haan**  
Tel: 49-2129-3766400

**Germany - Heilbronn**  
Tel: 49-7131-72400

**Germany - Karlsruhe**  
Tel: 49-721-625370

**Germany - Munich**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Germany - Rosenheim**  
Tel: 49-8031-354-560

**Israel - Ra'anana**  
Tel: 972-9-744-7705

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Italy - Padova**  
Tel: 39-049-7625286

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**Norway - Trondheim**  
Tel: 47-7288-4388

**Poland - Warsaw**  
Tel: 48-22-3325737

**Romania - Bucharest**  
Tel: 40-21-407-87-50

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**Sweden - Gothenberg**  
Tel: 46-31-704-60-40

**Sweden - Stockholm**  
Tel: 46-8-5090-4654

**UK - Wokingham**  
Tel: 44-118-921-5800  
Fax: 44-118-921-5820