

# ON Semiconductor

## Is Now

# onsemi™

To learn more about onsemi™, please visit our website at  
[www.onsemi.com](http://www.onsemi.com)

---

**onsemi** and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

# NCP5338

## Integrated Driver and MOSFET

The NCP5338 integrates a MOSFET driver, high-side MOSFET and low-side MOSFET into a 6 mm x 6 mm 40-pin QFN package. The driver and MOSFETs have been optimized for high-current DC-DC buck power conversion applications. The NCP5338 integrated solution greatly reduces package parasitics and board space compared to a discrete component solution.

### Features

- Optimized for High Frequency, High Conversion Ratio Operation
- Capable of Switching Frequencies Up to 1.5 MHz
- Internal Bootstrap Diode
- Zero Current Detection
- Undervoltage Lockout
- Internal Thermal Warning / Thermal Shutdown
- 40 A Continuous Output Current Capability
- These are Pb-Free Devices

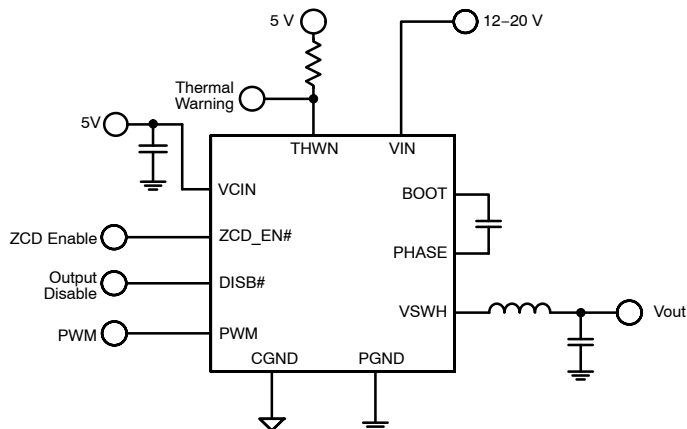
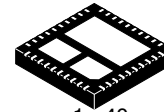


Figure 1. Application Schematic



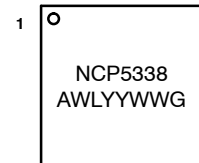
ON Semiconductor®

<http://onsemi.com>



QFN40  
MN SUFFIX  
CASE 485AZ

### MARKING DIAGRAM



A = Assembly Location  
WL = Wafer Lot  
YY = Year  
WW = Work Week  
G = Pb-Free Package

### ORDERING INFORMATION

Device	Package	Shipping†
NCP5338MNR2G	QFN40 (Pb-Free)	2500/Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

# NCP5338

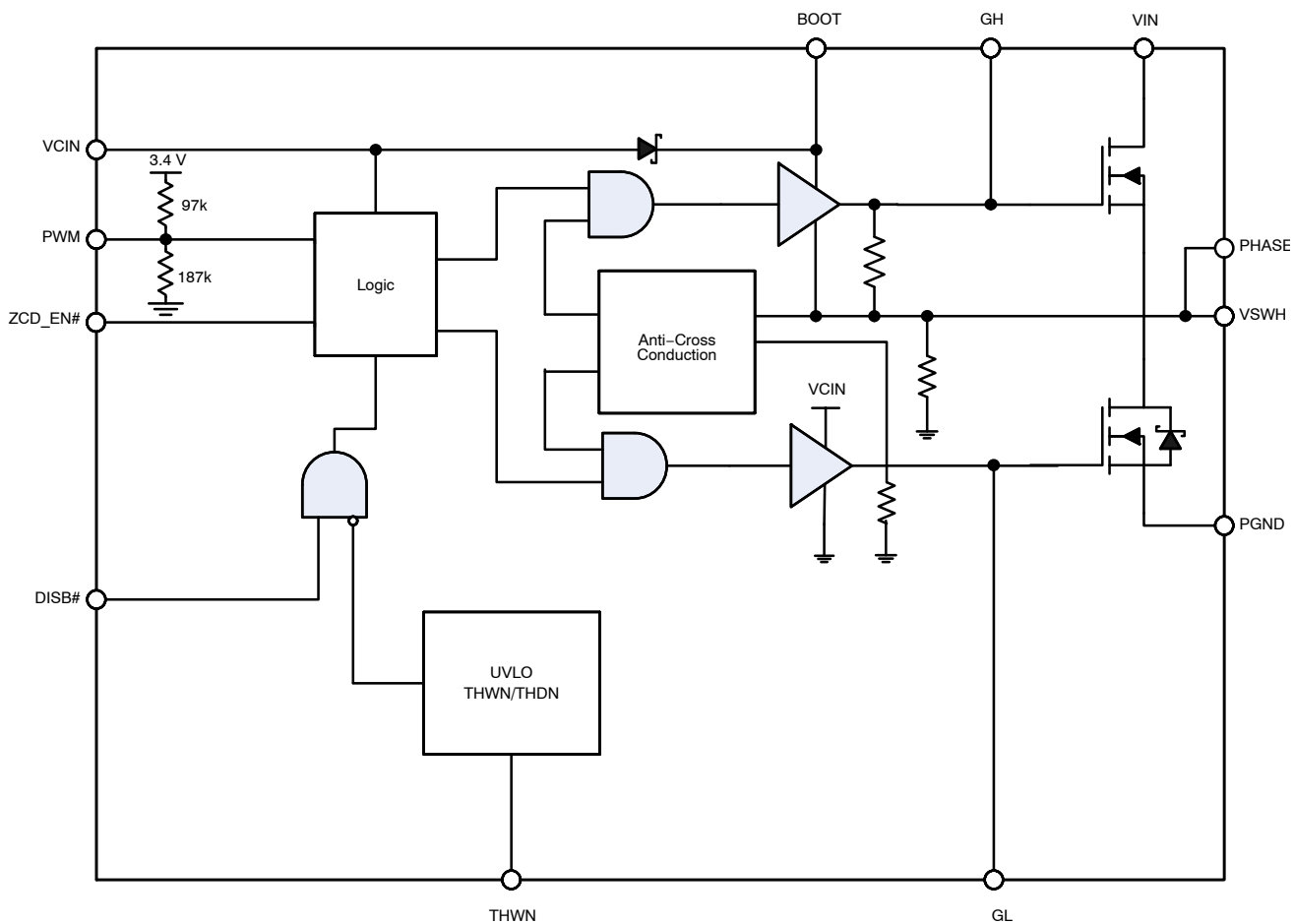


Figure 2. Simplified Block Diagram

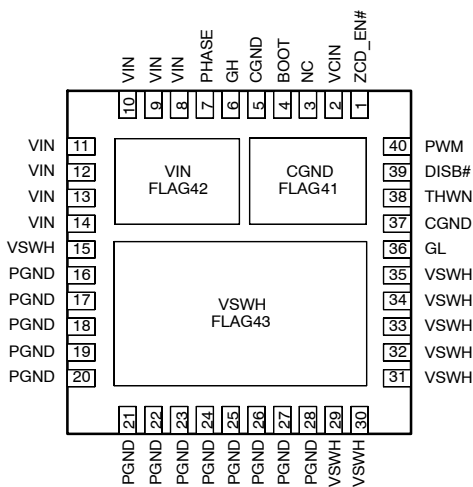


Figure 3. Pin Connections (Top View)

**Table 1. PIN FUNCTION DESCRIPTION**

Pin No.	Pin Name	Description
1	ZCD_EN#	Enable Zero Current Detection
2	VCIN	Control Input Voltage
3	NC	No Connect
4	BOOT	Bootstrap Voltage
5, 37, FLAG 41	CGND	Control Signal Ground
6	GH	High Side FET Gate Access
7	PHASE	Provides a return path for the high side driver of the internal IC. Place a high frequency ceramic capacitor of 0.1 uF to 1.0 uF from this pin to BOOT pin.
8–14, FLAG 42	VIN	Input Voltage
15, 29–35, FLAG 43	VSWH	Switch Node Output
16–28	PGND	Power Ground
36	GL	Low Side FET Gate Access
38	THWN	Thermal Warning
39	DISB#	Output Disable Pin
40	PWM	PWM Drive Logic

**Table 2. ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Min	Max
VCIN	Control Input Voltage	-0.3 V	6.5 V
VIN	Power Input Voltage (Note 1)	-0.3 V	28 V
BOOT	Bootstrap Voltage	-0.3 V wrt/VSWH	35 V wrt/PGND, 40 V < 50 ns wrt/PGND, 6.5 V wrt/VSWH
VSWH	Switch Node Output (Note 1)	-0.3 V	30 V
ZCD_EN#	Zero Current Detection	-0.3 V	6.5 V
PWM	PWM Drive Logic	-0.3 V	6.5 V
DISB#	Output Disable	-0.3 V	6.5 V
THWN	Thermal Warning	-0.3 V	6.5 V
Continuous Output Current, I <sub>OUT</sub>	Output Current, F <sub>SW</sub> = 300 kHz, V <sub>IN</sub> = 12 V, V <sub>OUT</sub> = 1.2 V (Note 2)	-	40 A
Continuous Output Current, I <sub>OUT</sub>	Output Current, F <sub>SW</sub> = 300 kHz, V <sub>IN</sub> = 12 V, V <sub>OUT</sub> = 1.2 V, LFM = 300 (Note 2)	-	50 A
Peak Output Current, I <sub>out-Pk</sub> (Note 3)	Output Current, F <sub>SW</sub> = 300 kHz, V <sub>IN</sub> = 12 V, V <sub>OUT</sub> = 1.2 V (Note 2)	-	80 A

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. During switching of the MOSFETs, high transient voltages can appear on these pins. It is important to keep these transients within the Maximum Ratings range.
2. I<sub>OUT</sub> rating is based on using 3.0" x 3.0" PCB, 6 layer, 2 oz, T<sub>A</sub> = 25°C, board design, natural convection, unless otherwise noted.
3. Peak Output Current is applied for t<sub>p</sub> = 10 ms.

NOTE: This device is ESD sensitive. Use standard ESD precautions when handling.

**Table 3. OPERATING RANGES**

Rating	Symbol	Min	Typ	Max	Unit
Control Input Voltage	VCIN	4.5	5	5.5	V
Input Voltage	VIN	4.5	12	20	V

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

# NCP5338

**Table 4. THERMAL CHARACTERISTICS**

Rating	Symbol	Value	Unit
Thermal Resistance, High-Side FET (Note 4)	$R_{\theta JPCB}$	11.7	°C/W
Thermal Resistance, Low-Side FET (Note 4)	$R_{\theta JPCB}$	2.8	°C/W
Operating Junction Temperature	$T_J$	-40 to 150	°C
Storage Temperature	$T_S$	-55 to 150	°C
Moisture Sensitivity Level	MSL	3	

4. When mounted on 1 in<sup>2</sup> of Cu., 1 oz. Thickness.

**ELECTRICAL CHARACTERISTICS** (Note 5) ( $V_{CIN} = 5\text{ V}$ ,  $V_{IN} = 12\text{ V}$ ,  $T_A = -10^\circ\text{C}$  to  $+100^\circ\text{C}$ , unless otherwise noted)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
-----------	--------	-----------	-----	-----	-----	------

**SUPPLY CURRENT**

VCIN Current (normal mode)	-	DISB# = 5 V, PWM = OSC, FSW = 400 kHz		20	35	mA
VCIN Current (shutdown mode)	-	DISB# = GND		15	30	μA

**UNDERVOLTAGE LOCKOUT**

UVLO Startup	-		3.8	4.35	4.5	V
UVLO Hysteresis	-		150	200	250	mV

**BOOTSTRAP DIODE**

Forward Voltage	-	$V_{CIN} = 5\text{ V}$ , forward bias current = 2 mA	0.1	0.4	0.6	V
-----------------	---	--	-----	-----	-----	---

**PWM INPUT**

PWM Input Voltage High	$V_{PWM\_HI}$		3.7			V
PWM Input Voltage Mid-State	$V_{PWM\_MID}$		1.3		3.0	V
PWM Input Voltage Low	$V_{PWM\_LO}$				0.7	V
Tri-State Shutdown Holdoff Time	$t_{holdoff}$			250		ns
PWM Input Resistance				63		kΩ
PWM Input Bias Voltage				2.2		V

**OUTPUT DISABLE**

Output Disable Input Voltage High	$V_{DISB\#\_HI}$		2.0			V
Output Disable Input Voltage Low	$V_{DISB\#\_LO}$				0.8	V
Output Disable Hysteresis	-			500		mV
Output Disable Propagation Delay				20	40	ns

**ZERO CROSS DETECT**

Zero Cross Detect High	$V_{ZCD\_EN\#\_HI}$		2.0			V
Zero Cross Detect Low	$V_{ZCD\_EN\#\_LO}$				0.8	V
Zero Cross Detect Threshold (Note 6)				-6		mV
ZCD Blanking Timer				250		ns

**THERMAL WARNING/SHUTDOWN**

Thermal Warning Temperature				150		°C
Thermal Warning Hysteresis				15		°C
Thermal Shutdown Temperature				180		°C
Thermal Shutdown Hysteresis				25		°C

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

- Performance guaranteed over the indicated operating temperature range by design and/or characterization tested at  $T_J = T_A = 25^\circ\text{C}$ . Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.
- Guaranteed by design. Not production tested.

## APPLICATIONS INFORMATION

**Theory of Operation**

The NCP5338 is an integrated driver and MOSFET module designed for use in a synchronous buck converter topology. A single PWM input signal is all that is required to properly drive the high-side and low-side MOSFETs.

**Low-Side Driver**

The low-side driver is designed to drive a ground-referenced low  $R_{DS(on)}$  N-Channel MOSFET. The voltage rail for the low-side driver is internally connected to VCIN and PGND.

**High-Side Driver**

The high-side driver is designed to drive a floating low  $R_{DS(on)}$  N-channel MOSFET. The gate voltage for the high side driver is developed by a bootstrap circuit referenced to Switch Node (VSWH) pin.

The bootstrap circuit is comprised of the internal diode and an external bootstrap capacitor. When the NCP5338 is starting up, the VSWH pin is at ground, so the bootstrap capacitor will charge up to VCIN through the bootstrap diode. See Figure 1. When the PWM input goes high, the high-side driver will begin to turn on the high-side MOSFET using the stored charge of the bootstrap capacitor. As the high-side MOSFET turns on, the VSWH pin will rise. When the high-side MOSFET is fully on, the switch node will be at 12 V, and the BST pin will be at 5 V plus the charge of the bootstrap capacitor (approaching 17 V).

The bootstrap capacitor is recharged when the switch node goes low during the next cycle.

**Zero Current Detect**

When ZCD\_EN# is set high, the NCP5338 will operate in normal PWM mode.

When ZCD\_EN# is set low, zero current detect (ZCD) will be enabled. If PWM goes high, GH will go high after the non-overlap delay. If PWM goes low, GL will go high after the non-overlap delay, and stay high for the duration of the ZCD blanking timer. Once this timer has expired, VSWH will be monitored for zero current detection, and will pull GL low once detected. The threshold on VSWH to determine zero current undergoes an auto-calibration cycle every time DISB# is brought from low to high. This auto-calibration cycle typically takes 28  $\mu$ s to complete.

**Safety Timer and Overlap Protection Circuit**

It is very important that MOSFETs in a synchronous buck regulator do not both conduct at the same time. Excessive shoot-through or cross conduction can damage the MOSFETs, and even a small amount of cross conduction will cause a decrease in the power conversion efficiency.

The NCP5338 prevents cross conduction by monitoring the status of the MOSFETs and applying the appropriate amount of “dead-time” or the time between the turn off of one MOSFET and the turn on of the other MOSFET.

When the PWM input pin goes high, the gate of the low-side MOSFET (GL pin) will go low after a propagation delay (tpdLGL). The time it takes for the low-side MOSFET to turn off (tfGL) is dependent on the total charge on the low-side MOSFET gate. The NCP5338 monitors the gate voltage of both MOSFETs and the switchnode voltage to determine the conduction status of the MOSFETs. Once the low-side MOSFET is turned off an internal timer will delay (tpdhGH) the turn on of the high-side MOSFET.

Likewise, when the PWM input pin goes low, the gate of the high-side MOSFET (GH pin) will go low after the propagation delay (tpdIGH). The time to turn off the high-side MOSFET (tfGH) is dependent on the total gate charge of the high-side MOSFET. A timer will be triggered once the high-side MOSFET has stopped conducting, to delay (tpdhGL) the turn on of the low-side MOSFET.

**Thermal Warning / Thermal Shutdown**

When the temperature of the driver reaches 150°C, the THWN pin will be pulled low indicating a thermal warning. At this point, the part continues to function normally. When the temperature drops below 135°C, the THWN will go high.

If the driver temperature exceeds 180°C, the part will enter thermal shutdown and turn off both MOSFETs. Once the temperature falls below 155°C, the part will resume normal operation. The THWN pin has a maximum current capability of 30 mA.

**Power Supply Decoupling**

The NCP5338 can source and sink relatively large current to the gate pins of the MOSFETs. In order to maintain a constant and stable supply voltage (VCIN) a low ESR capacitor should be placed near the power and ground pins. A 1  $\mu$ F to 4.7  $\mu$ F multi layer ceramic capacitor (MLCC) is usually sufficient.

**Bootstrap Circuit**

The bootstrap circuit uses a charge storage capacitor ( $C_{BST}$ ) and the internal diode. The bootstrap capacitor must have a voltage rating that is able to withstand twice the maximum supply voltage. A minimum 50 V rating is recommended. A bootstrap capacitance greater than 100 nF and a minimum 50 V rating is recommended. A good quality ceramic capacitor should be used.

# NCP5338

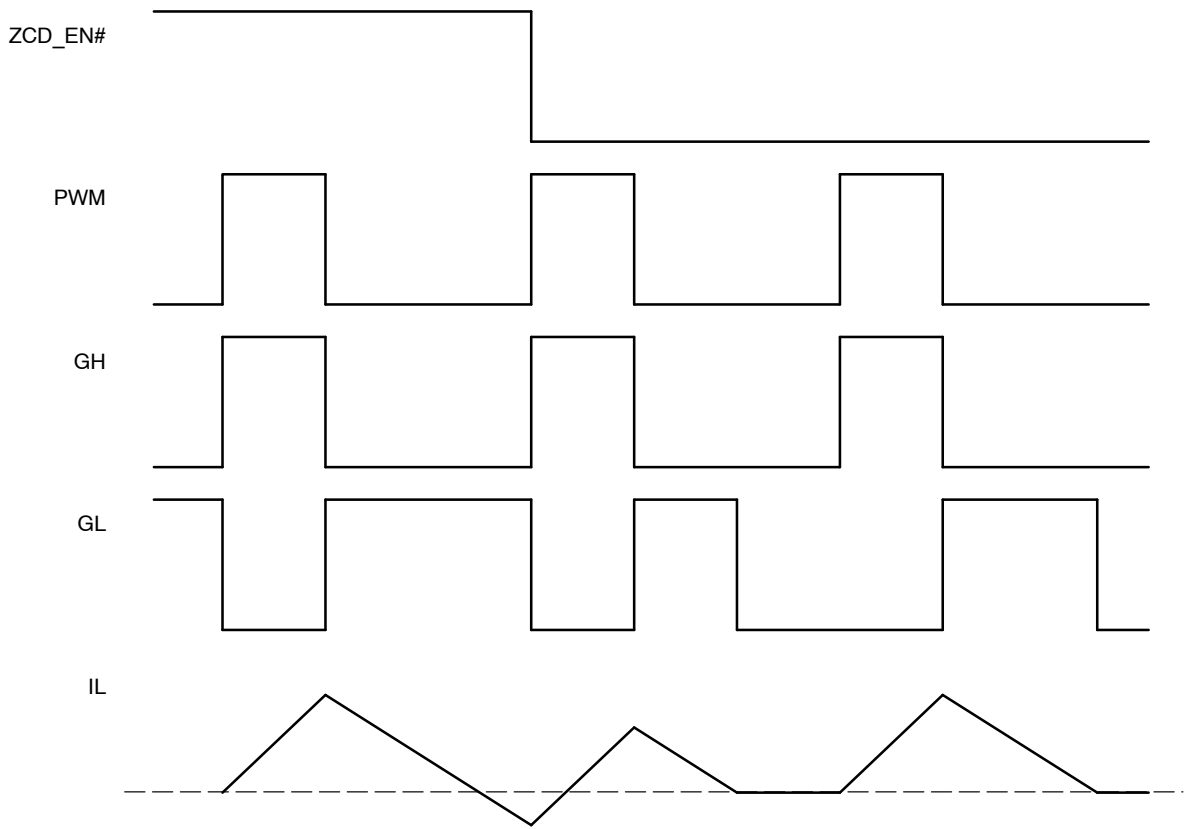


Figure 4. Zero Current Detection

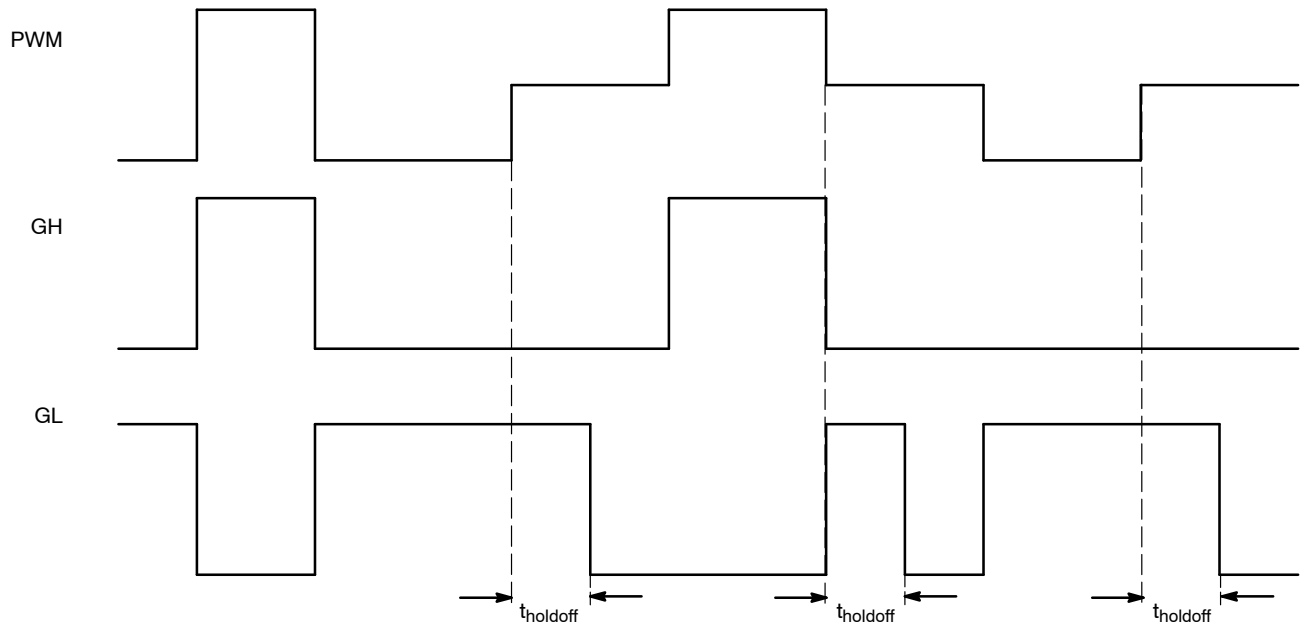
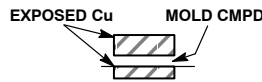
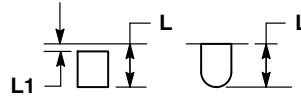
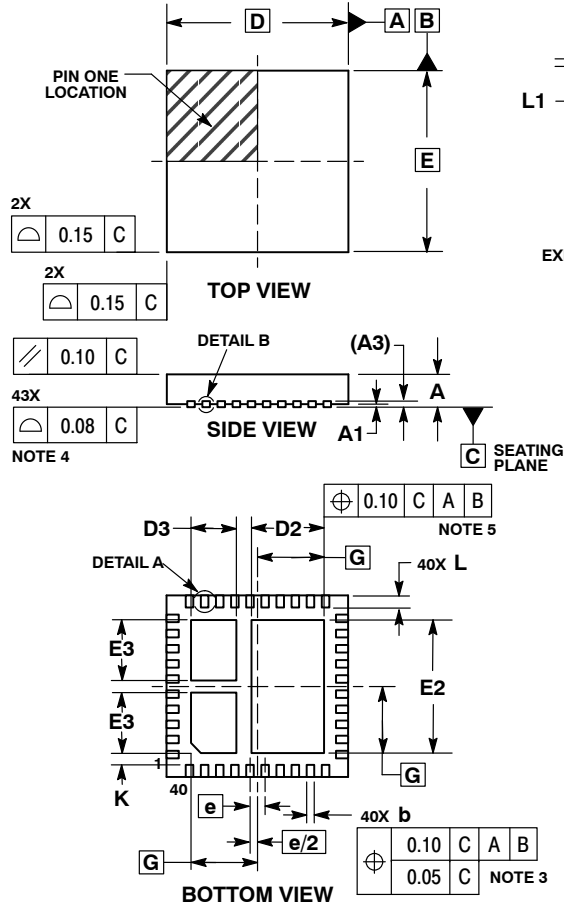


Figure 5. Tri-State Operation

# NCP5338

## PACKAGE DIMENSIONS

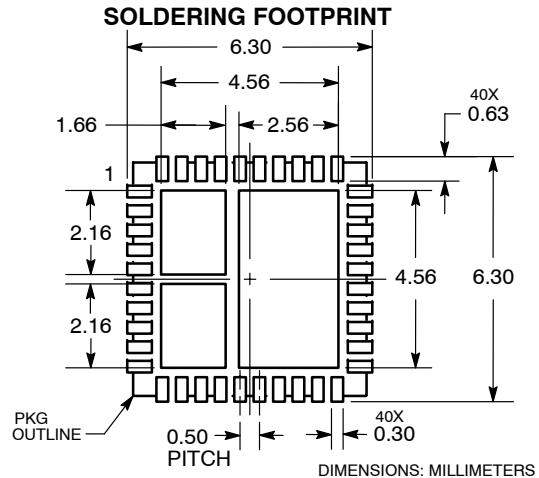
QFN40 6x6, 0.5P  
MN SUFFIX  
CASE 485AZ  
ISSUE O



**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSIONS: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.
5. POSITIONAL TOLERANCE APPLIES TO ALL THREE EXPOSED PADS.

DIM	MILLIMETERS	
	MIN	MAX
A	0.80	1.00
A1	---	0.05
A3	0.20	REF
b	0.18	0.30
D	6.00	BSC
D2	2.30	2.50
D3	1.40	1.60
E	6.00	BSC
E2	4.30	4.50
E3	1.90	2.10
e	0.50	BSC
G	2.20	BSC
K	0.20	---
L	0.30	0.50
L1	---	0.15



**ON Semiconductor** and are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of SCILLC's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

### PUBLICATION ORDERING INFORMATION

**LITERATURE FULFILLMENT:**  
 Literature Distribution Center for ON Semiconductor  
 P.O. Box 5163, Denver, Colorado 80217 USA  
**Phone:** 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
**Fax:** 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
**Email:** [orderlit@onsemi.com](mailto:orderlit@onsemi.com)

**N. American Technical Support:** 800-282-9855 Toll Free  
 USA/Canada  
**Europe, Middle East and Africa Technical Support:**  
 Phone: 421 33 790 2910  
**Japan Customer Focus Center**  
 Phone: 81-3-5817-1050

**ON Semiconductor Website:** [www.onsemi.com](http://www.onsemi.com)  
**Order Literature:** <http://www.onsemi.com/orderlit>  
 For additional information, please contact your local Sales Representative