

# NCP5369

## Integrated Driver and MOSFET

The NCP5369 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 NCP5369 integrated solution greatly reduces package parasitics and board space compared to a discrete component solution.

### Features

- Capable of Switching Frequencies Up to 1 MHz
- Capable of Output Currents Up to 35 A
- Internal Bootstrap Diode
- Zero Current Detection
- Undervoltage Lockout
- Internal Thermal Warning / Thermal Shutdown
- These are Pb-Free Devices

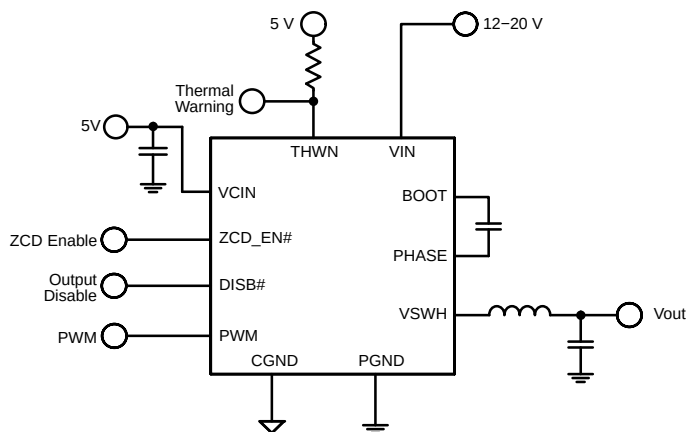
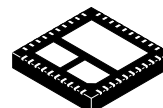


Figure 1. Application Schematic



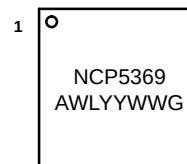
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**QFN40**  
**MN SUFFIX**  
**CASE 485AZ**

### MARKING DIAGRAM



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

### ORDERING INFORMATION

| Device       | Package         | Shipping†        |
|--------------|-----------------|------------------|
| NCP5369MNR2G | QFN40 (Pb-Free) | 2500/Tape & Reel |
| NCP5369MNTWG | 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.

# NCP5369

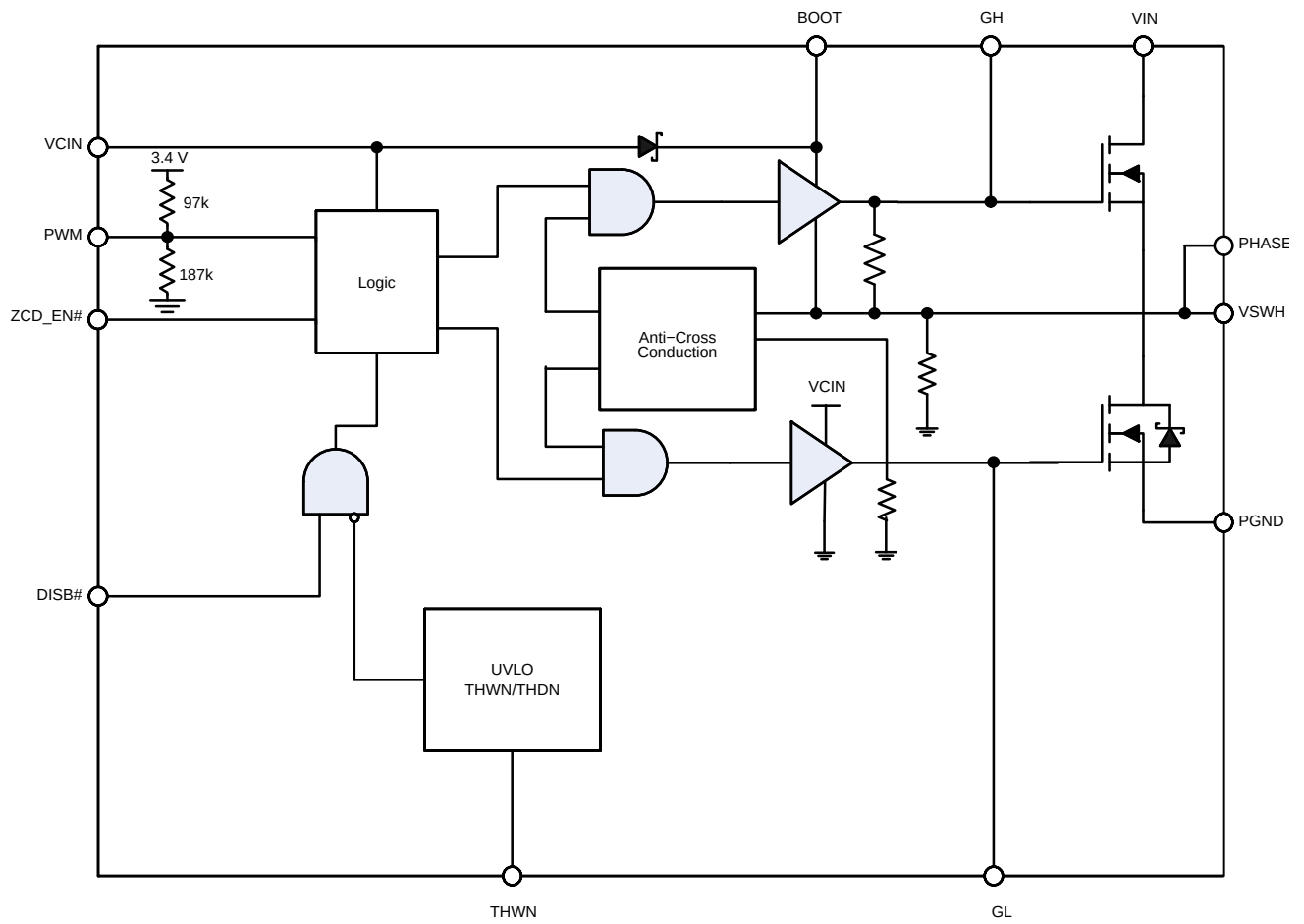
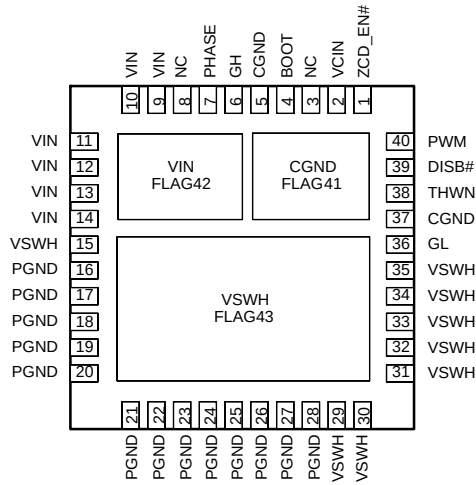


Figure 2. Simplified Block Diagram

# NCP5369



**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, 8               | 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. |
| 9–14, 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            | Pin Name / Rating                                                                                                       | Min                    | Max                                                    | Unit |
|-------------------|-------------------------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------------------------|------|
| VCIN              | Control Input Voltage                                                                                                   | -0.3                   | 7                                                      | V    |
| VIN               | Power Input Voltage                                                                                                     | -0.3                   | 30                                                     | V    |
| BOOT              | Bootstrap Voltage                                                                                                       | -0.3 V wrt/VSWH        | 35 V wrt/PGND<br>40 V < 50 ns wrt/PGND<br>7 V wrt/VSWH | V    |
| VSWH              | Switch Node Output                                                                                                      | -5 V<br>-10 V < 200 ns | 35 V<br>40 V < 50 ns                                   | V    |
| ZCD_EN#           | Zero Current Detection                                                                                                  | -0.3                   | 6.5                                                    | V    |
| PWM               | PWM Drive Logic                                                                                                         | -0.3                   | 6.5                                                    | V    |
| DISB#             | Output Disable                                                                                                          | -0.3                   | 6.5                                                    | V    |
| THWN              | Thermal Warning                                                                                                         | -0.3                   | 6.5                                                    | V    |
|                   | Continuous Output Current, $F_{SW} = 300$ kHz,<br>$V_{IN} = 12$ V, $V_{OUT} = 1.2$ V (Note 1)                           | -                      | 35                                                     | A    |
|                   | Peak Output Current, $F_{SW} = 300$ kHz, $V_{IN} = 12$ V, $V_{OUT} = 1.2$ V, Duration = 10 ms, Period = 1 sec. (Note 1) | -                      | 50                                                     | A    |
| $T_J$             | Junction Temperature                                                                                                    | -55 to 150             |                                                        | °C   |
| $T_S$             | Storage Temperature                                                                                                     | -55 to 150             |                                                        | °C   |
| $R_{\theta JPCB}$ | Thermal Resistance, High-Side FET                                                                                       | 13                     |                                                        | °C/W |
| $R_{\theta JPCB}$ | Thermal Resistance, Low-Side FET                                                                                        | 5                      |                                                        | °C/W |
| MSL               | Moisture Sensitivity Level                                                                                              | 3                      |                                                        |      |

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.  $I_{OUT}$  rating is based on using a 3 x 3 sq. in. PCB, 6-layer, 1 oz. Copper,  $T_A = 25^\circ\text{C}$ , natural convection.

**Table 3. RECOMMENDED OPERATING RANGES**

| Rating                | Symbol | Min | Typ | Max | Unit |
|-----------------------|--------|-----|-----|-----|------|
| Control Input Voltage | VCIN   | 4.5 | 5   | 5.5 | V    |
| Input Voltage         | VIN    | 4.5 | 12  | 25  | 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.

# NCP5369

## ELECTRICAL CHARACTERISTICS (Note 2) (VCIN = 5 V, VIN = 12 V, TA = -10°C to +100°C, unless otherwise noted)

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

### SUPPLY CURRENT

|                              |   |                                          |  |    |    |    |
|------------------------------|---|------------------------------------------|--|----|----|----|
| VCIN Current (normal mode)   | – | DISB# = 5 V, PWM = OSC,<br>FSW = 400 kHz |  | 14 | 20 | 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 | – | VCIN = 5 V, forward bias current = 2 mA | 0.1 | 0.4 | 0.6 | V |
|-----------------|---|-----------------------------------------|-----|-----|-----|---|

### PWM INPUT

|                                 |                      |  |     |     |     |    |
|---------------------------------|----------------------|--|-----|-----|-----|----|
| PWM Input Voltage High          | V <sub>PWM_HI</sub>  |  | 3.6 | –   | –   | V  |
| PWM Input Voltage Mid-State     | V <sub>PWM_MID</sub> |  | 1.3 | –   | 3.0 | V  |
| PWM Input Voltage Low           | V <sub>PWM_LO</sub>  |  | –   | –   | 0.7 | V  |
| Tri-State Shutdown Holdoff Time | t <sub>holdoff</sub> |  |     | 250 |     | ns |
| PWM Input Resistance            |                      |  |     | 63  |     | kΩ |
| PWM Input Bias Voltage          |                      |  |     | 2.2 |     | V  |

### OUTPUT DISABLE

|                                   |                       |  |     |     |     |    |
|-----------------------------------|-----------------------|--|-----|-----|-----|----|
| Output Disable Input Voltage High | V <sub>DISB#_HI</sub> |  | 2.0 | –   | –   | V  |
| Output Disable Input Voltage Low  | V <sub>DISB#_LO</sub> |  | –   | –   | 0.8 | V  |
| Output Disable Hysteresis         | –                     |  | –   | 500 | –   | mV |
| Output Disable Propagation Delay  |                       |  | –   | 20  | 40  | ns |

### ZERO CROSS DETECT

|                             |                         |  |     |     |     |    |
|-----------------------------|-------------------------|--|-----|-----|-----|----|
| Zero Cross Detect High      | V <sub>ZCD_EN#_HI</sub> |  | 2.0 | –   | –   | V  |
| Zero Cross Detect Low       | V <sub>ZCD_EN#_LO</sub> |  | –   | –   | 0.8 | V  |
| Zero Cross Detect Threshold |                         |  |     | –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.

2. Performance guaranteed over the indicated operating temperature range by design and/or characterization tested at T<sub>J</sub> = T<sub>A</sub> = 25°C. Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.

## APPLICATIONS INFORMATION

**Theory of Operation**

The NCP5369 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 NCP5369 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 NCP5369 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 55  $\mu$ 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 NCP5369 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 ( $t_{pdlGL}$ ). The time it takes for the low-side MOSFET to turn off ( $t_{fGL}$ ) is dependent on the total charge on the low-side MOSFET gate. The NCP5369 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 ( $t_{pdhGH}$ ) 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 ( $t_{pdlGH}$ ). The time to turn off the high-side MOSFET ( $t_{fGH}$ ) 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 ( $t_{pdhGL}$ ) 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 NCP5369 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.

# NCP5369

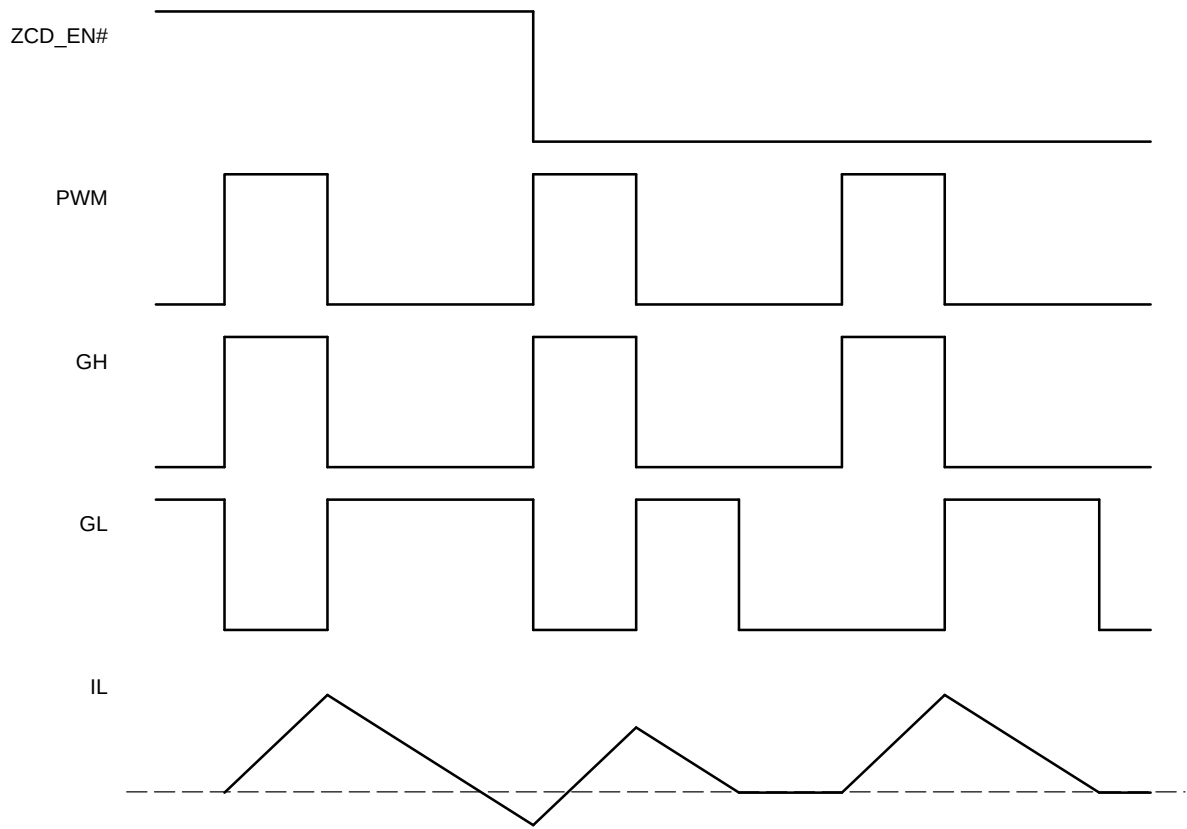


Figure 4. Zero Current Detection

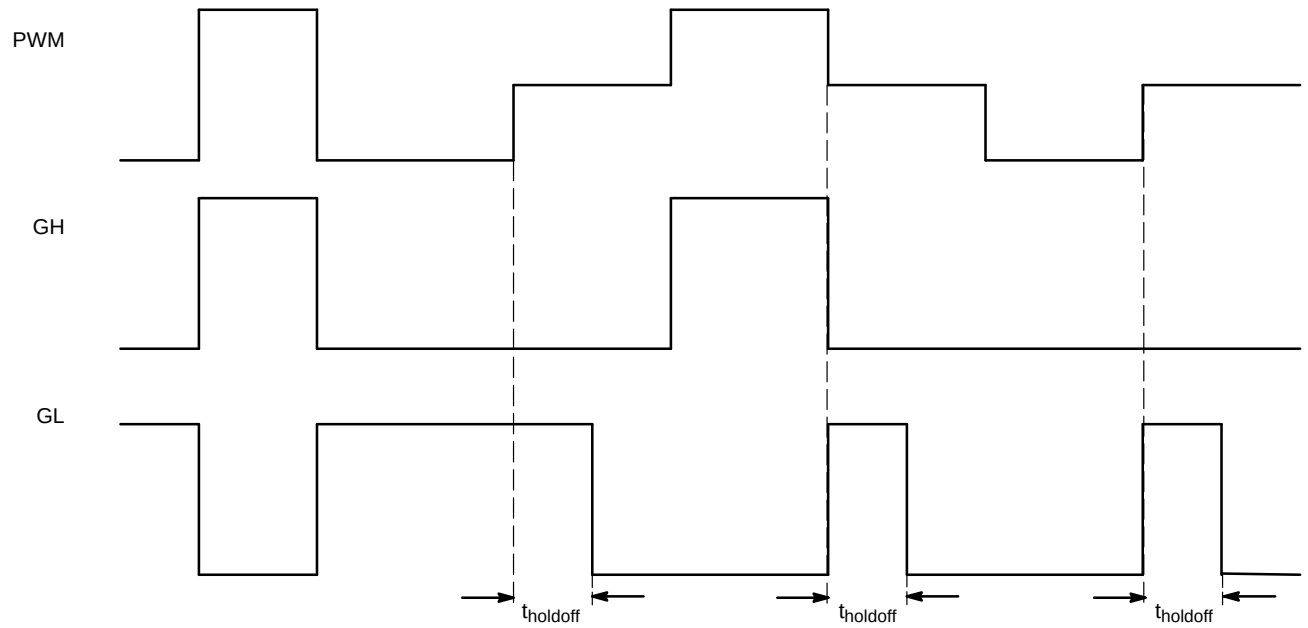
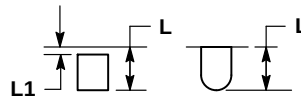
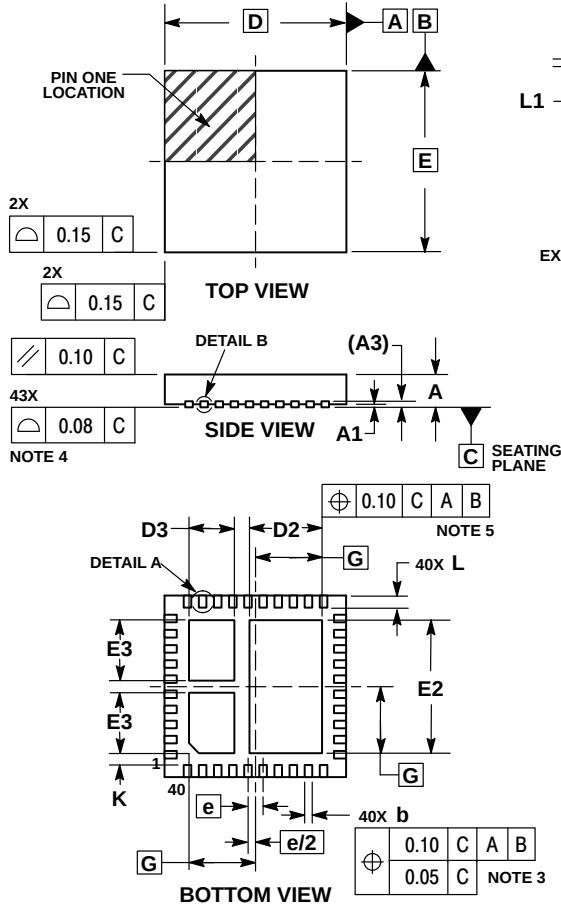


Figure 5. Tri-State Operation

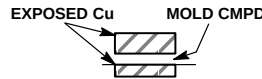
# NCP5369

## PACKAGE DIMENSIONS

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



**DETAIL A**  
ALTERNATE CONSTRUCTIONS

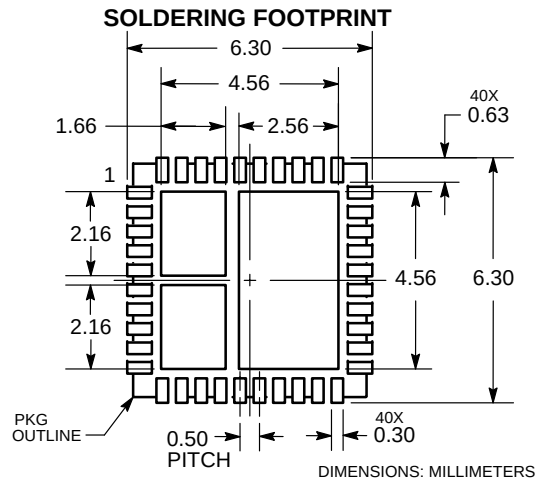


**DETAIL B**  
ALTERNATE CONSTRUCTION

### 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 |



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