

# High and Low Side Gate Driver, High Performance, 700 V, with 3.5 A Source and 3 A Sink Currents

## NCP51530

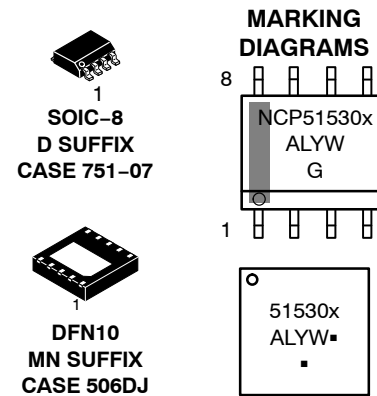
NCP51530 is a 700 V high side and low side driver with 3.5 A source & 3 A sink current drive capability for AC–DC power supplies and inverters. NCP51530 offers best in class propagation delay, low quiescent current and low switching current at high frequencies of operation. This device is tailored for highly efficient power supplies operating at high frequencies. NCP51530 is offered in two versions, NCP51530A/B. NCP51530A has a typical 60 ns propagation delay, while NCP51530B has a typical propagation delay of 25 ns. NCP51530 comes in SOIC8 and DFN10 packages.

### Features

- High voltage range: Up to 700 V
- NCP51530A: Typical 60 ns Propagation Delay
- NCP51530B: Typical 25 ns Propagation Delay
- Low Quiescent and Operating Currents
- 15 ns Max Rise and Fall Time
- 3.5 A Source / 3 A Sink Currents
- Under–voltage Lockout for Both Channels
- 3.3 V and 5 V Input Logic Compatible
- High dv/dt Immunity up to 50 V/ns
- Pin to Pin Compatible with Industry Standard Half–bridge ICs.
- Matched Propagation Delay (7 ns Max)
- High Negative Transient Immunity on Bridge Pin
- DFN10 Package Offers Both Improved Creepage and Exposed Pad

### Applications

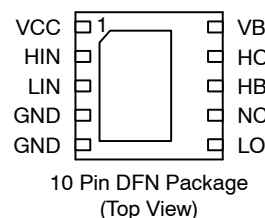
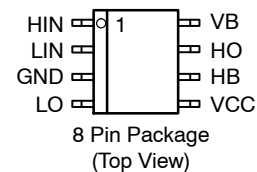
- High–density SMPS for Servers, Telecom and Industrial
- Half/Full–bridge & LLC Converters
- Active Clamp Flyback/Forward Converters
- Solar Inverters & Motor Controls
- Electric Power Steering



NCP51530 = Specific Device Code  
 x = A or B version  
 A = Assembly Location  
 WL = Wafer Lot  
 YY = Year  
 WW = Work Week  
 G = Pb–Free Package

(Note: Microdot may be in either location)

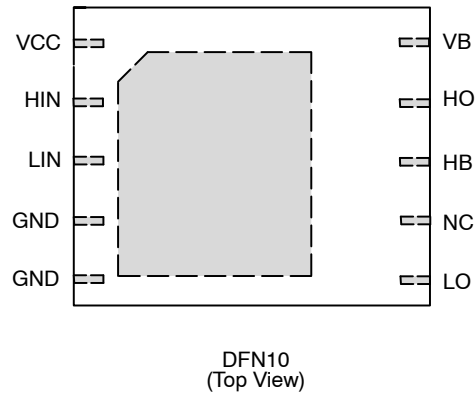
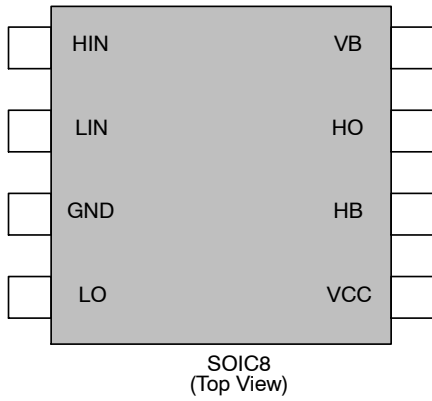
### PINOUT INFORMATION



### ORDERING INFORMATION

See detailed ordering and shipping information on page 26 of this data sheet.

# NCP51530



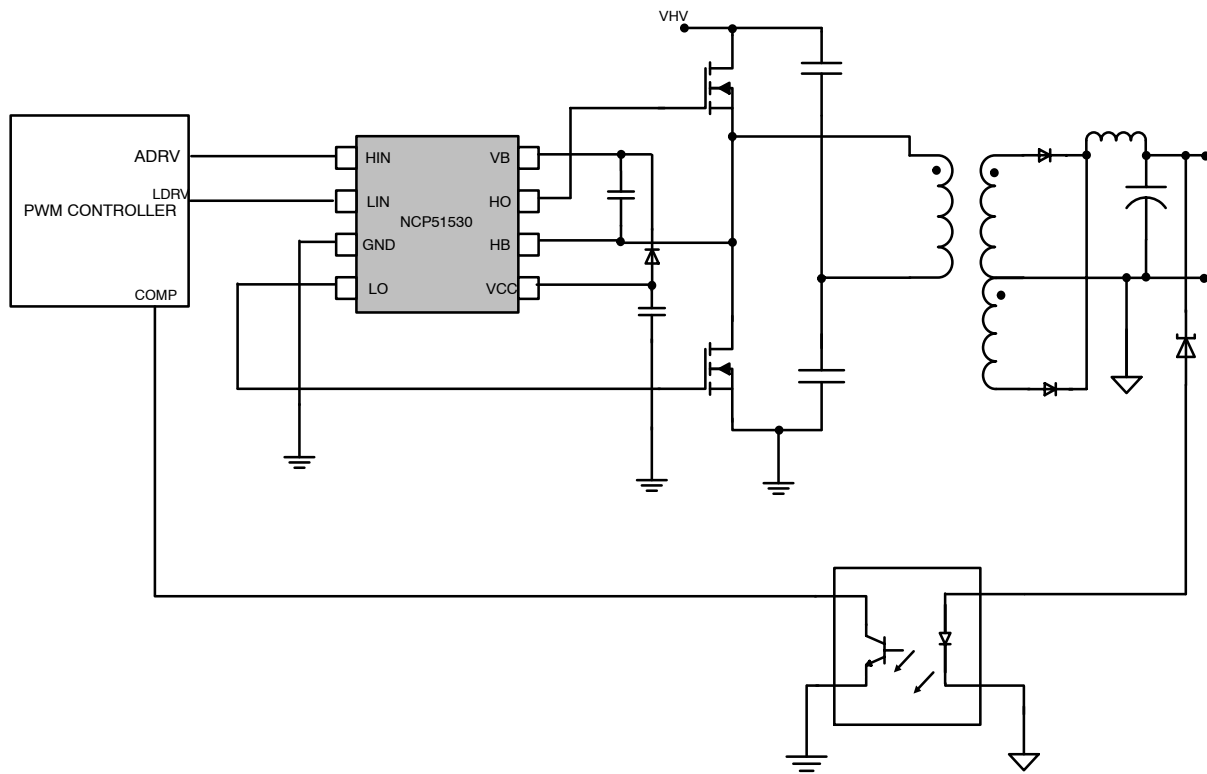
**Table 1. PIN DESCRIPTION SOIC 8 PACKAGE**

| Pin Out | Name | Function                  |
|---------|------|---------------------------|
| 1       | HIN  | High side input           |
| 2       | LIN  | Low side input            |
| 3       | GND  | Ground reference          |
| 4       | LO   | Low side output           |
| 5       | VCC  | Low side and logic supply |
| 6       | HB   | High side supply return   |
| 7       | HO   | High side output          |
| 8       | VB   | High side voltage supply  |

**Table 2. PIN DESCRIPTION DFN10 PACKAGE**

| Pin Out | Name | Function                                                                       |
|---------|------|--------------------------------------------------------------------------------|
| 1       | VCC  | Low side and logic supply                                                      |
| 2       | HIN  | High side input                                                                |
| 3       | LIN  | Low side input                                                                 |
| 4       | GND  | Ground Reference (Signal Ground should be connected to bulk ground externally) |
| 5       | GND  | Ground Reference (Driver ground should be connected to bulk ground externally) |
| 6       | LO   | Low side output                                                                |
| 7       | NC   | No Connect                                                                     |
| 8       | HB   | High side supply return                                                        |
| 9       | HO   | High side output                                                               |
| 10      | VB   | High side voltage supply                                                       |

# NCP51530



**Figure 1. Simplified Applications Schematic for a Half-Bridge Converter (SOIC8)**

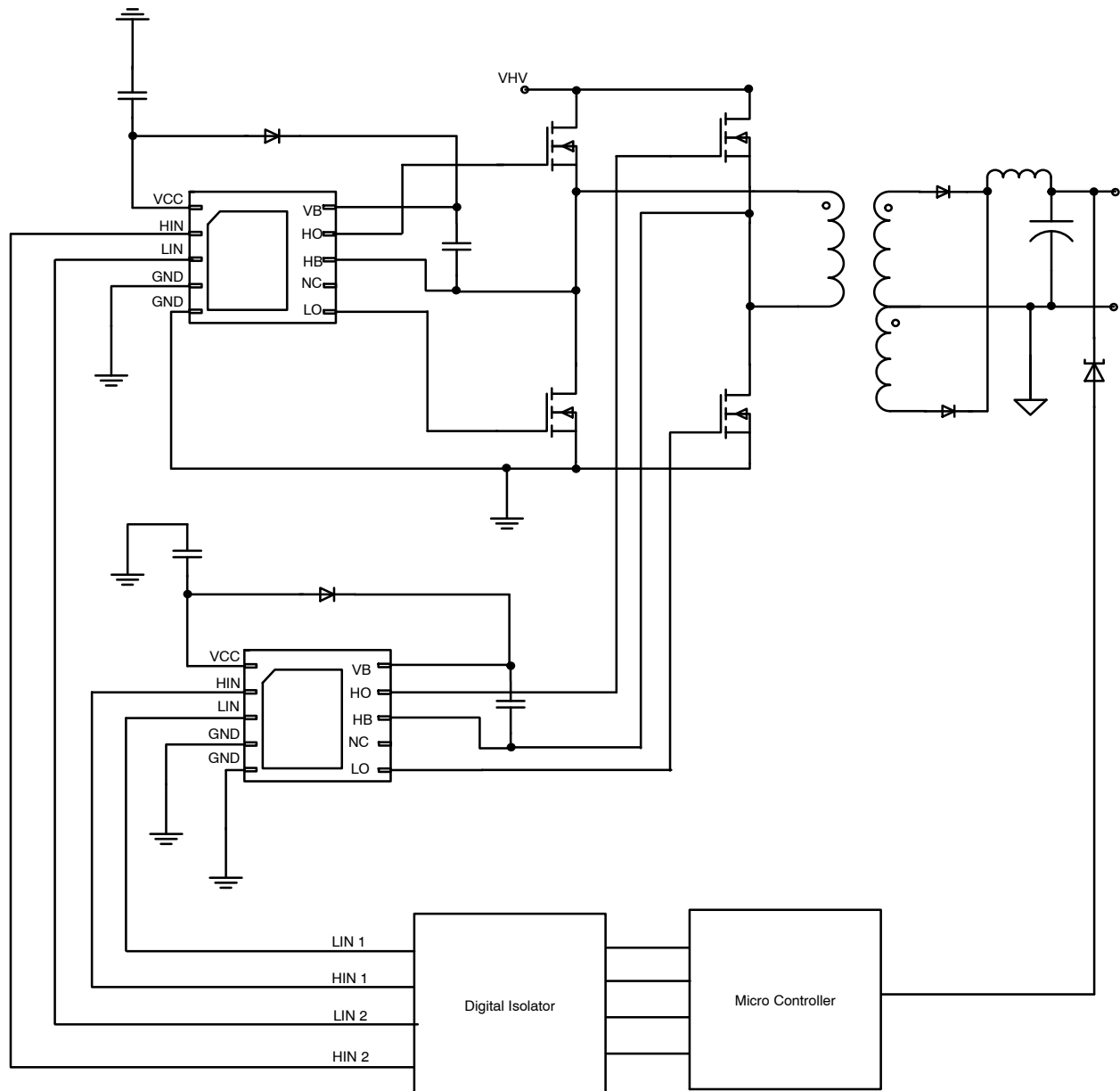
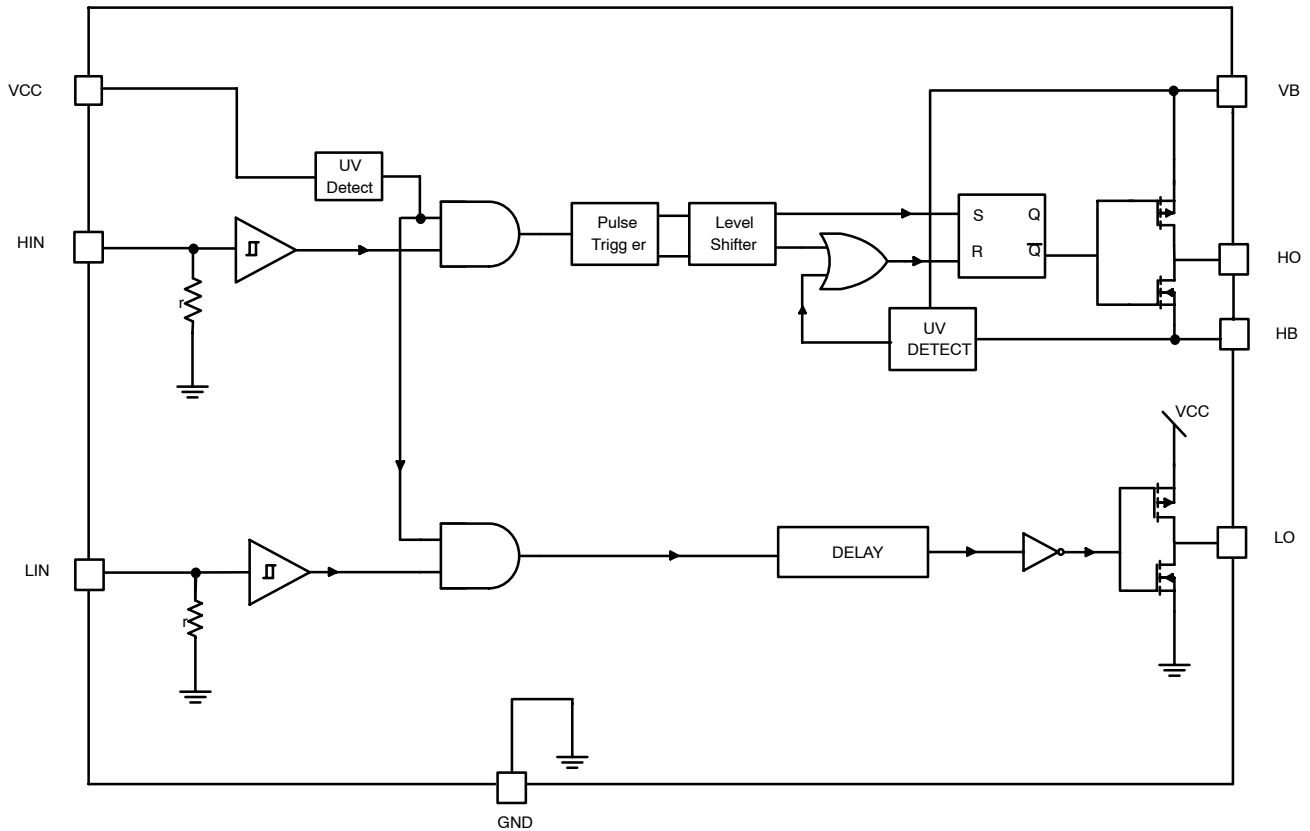


Figure 2. Simplified Applications Schematic for a Full Bridge Converter (DFN 10)

# NCP51530



**Figure 3. Internal Block Diagram for NCP51530**

**Table 3. ABSOLUTE MAXIMUM RATINGS** All voltages are referenced to GND pin.

| Rating                                                                                                                               | Symbol             | Value                                  | Unit |
|--------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------------------------------------|------|
| Input voltage range                                                                                                                  | $V_{CC}$           | -0.3 to 20                             | V    |
| High side boot pin voltage                                                                                                           | $V_B$              | -0.3 to 720                            | V    |
| High side floating voltage                                                                                                           | $V_B - V_{HB}$     | -0.3 to 20                             | V    |
| High side drive output voltage                                                                                                       | $V_{HO}$           | $V_{HB} - 0.3$ to $V_B + 0.3$          | V    |
|                                                                                                                                      |                    | $V_{HB} - 2.0$ to $V_B + 0.3$ (Note 3) |      |
| Low side drive output voltage                                                                                                        | $V_{LO}$           | -0.3 to $V_{CC} + 0.3$                 | V    |
|                                                                                                                                      |                    | -2.0 to $V_{CC} + 0.3$ (Note 3)        |      |
| Allowable hb slew rate                                                                                                               | $dV_{HB}/dt$       | 50                                     | V/ns |
| Drive input voltage                                                                                                                  | $V_{LIN}, V_{HIN}$ | -5 to $V_{CC} + 0.3$                   | V    |
| Junction temperature                                                                                                                 | $T_{J(MAX)}$       | 150°                                   | C    |
| Storage temperature range                                                                                                            | $T_{STG}$          | -55° to 150°                           | C    |
| ESD Capability (Note 1)<br>Human Body Model per JEDEC Standard JESD22-A114E.<br>Charge Device Model per JEDEC Standard JESD22-C101E. |                    | 4000<br>1000                           | V    |
| Lead Temperature Soldering<br>Reflow (SMD Styles ONLY), Pb-Free Versions (Note 2)                                                    |                    | 260                                    | °C   |

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.

- This device series incorporates ESD protection and is tested by the following methods. ESD Human Body Model tested per AEC-Q100-002(EIA/JESD22-A114)  
ESD Charged Device Model tested per AEC-Q100-11(EIA/JESD22-C101E)  
Latchup Current Maximum Rating:  $\leq 150$  mA per JEDEC standard: JESD78
- For information, please refer to our Soldering and Mounting Techniques Reference Manual, SOLDERM/D
- Transient, less than 100 ns. Values verified by bench characterization.

**Table 4. THERMAL CHARACTERISTICS**

| Rating                                                                         | Symbol          | Value | Unit                        |
|--------------------------------------------------------------------------------|-----------------|-------|-----------------------------|
| Thermal Characteristics, SOIC8 (Note 4)<br>Thermal Resistance, Junction to Air | $R_{\theta JA}$ | 183   | $^{\circ}\text{C}/\text{W}$ |
| Thermal Characteristics, DFN10<br>Thermal Resistance, Junction to Air (Note 5) | $R_{\theta JA}$ | 162   | $^{\circ}\text{C}/\text{W}$ |

4. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.

5. Values based on copper area of 50 mm<sup>2</sup> of 1 oz thickness and FR4 PCB substrate.

**Table 5. RECOMMENDED OPERATING CONDITIONS**

| Rating                               | Symbol             | Min      | Max          | Unit               |
|--------------------------------------|--------------------|----------|--------------|--------------------|
| Input Voltage Range                  | $V_{CC}$           | 10       | 17           | V                  |
| High Side Floating Voltage           | $V_B - V_{HB}$     | 10       | 17           | V                  |
| High Side Bridge pin Voltage         | $V_{HB}$           | -1       | 700          | V                  |
| High Side Output Voltage             | $V_{HO}$           | $V_{HB}$ | $V_B$        | V                  |
| High Side Output Voltage             | $V_{LO}$           | GND      | $V_{CC}$     | V                  |
| Input Voltage on LIN and HIN pins    | $V_{LIN}, V_{HIN}$ | GND      | $V_{CC} - 2$ | V                  |
| Operating Junction Temperature Range | $T_J$              | -40      | 125          | $^{\circ}\text{C}$ |

**Table 6. ELECTRICAL CHARACTERISTICS**

(-40 $^{\circ}\text{C}$  <  $T_J$  < 125 $^{\circ}\text{C}$ ,  $V_{CC} = V_B = 12\text{V}$ ,  $V_{HB} = \text{GND}$ , outputs are not loaded, all voltages are referenced to GND; unless otherwise noted, Typical values are at  $T_J = 25^{\circ}\text{C}$ .)

| Parameters | Test Conditions | Symbol | Min | Typ | Max | Unit |
|------------|-----------------|--------|-----|-----|-----|------|
|------------|-----------------|--------|-----|-----|-----|------|

**SUPPLY SECTION**

|                                |                                       |           |  |      |      |               |
|--------------------------------|---------------------------------------|-----------|--|------|------|---------------|
| $V_{CC}$ quiescent current     | $V_{LIN} = V_{HIN} = 0$               | $I_{CCQ}$ |  | 0.15 | 0.25 | mA            |
| $V_{CC}$ operating current     | $f = 500\text{ kHz}$ , $C_{LOAD} = 0$ | $I_{CCO}$ |  | 0.7  | 1.0  | mA            |
| Boot voltage quiescent current | $V_{LIN} = V_{HIN} = 0\text{ V}$      | $I_{BQ}$  |  | 0.1  | 0.15 | mA            |
| Boot voltage operating current | $f = 500\text{ kHz}$ , $C_{LOAD} = 0$ | $I_{BO}$  |  | 0.7  | 1.0  | mA            |
| HB to GND quiescent current    | $V_{HS} = V_{HB} = 700\text{ V}$      | $I_{HBQ}$ |  | 6    | 11   | $\mu\text{A}$ |

**INPUT SECTION**

|                           |                        |            |     |     |     |            |
|---------------------------|------------------------|------------|-----|-----|-----|------------|
| Input rising threshold    |                        | $V_{HIT}$  | 2.3 | 2.7 | 3.1 | V          |
| Input falling threshold   |                        | $V_{LIT}$  | 1   | 1.4 | 1.8 | V          |
| Input voltage Hysteresis  |                        | $V_{IHYS}$ |     | 1.3 |     | V          |
| Input pulldown resistance | $V_{XIN} = 5\text{ V}$ | $R_{IN}$   | 100 | 175 | 250 | k $\Omega$ |

**UNDER VOLTAGE LOCKOUT (UVLO)**

|                        |                                                             |               |     |     |     |               |
|------------------------|-------------------------------------------------------------|---------------|-----|-----|-----|---------------|
| $V_{CC}$ ON            | $V_{CC}$ Rising                                             | $V_{CCON}$    | 8.6 | 9.1 | 9.6 | V             |
| $V_{CC}$ hysteresis    |                                                             | $V_{CCHYS}$   |     | 0.5 |     | V             |
| $V_B$ ON               | $V_B$ Rising                                                | $V_{BON}$     | 8   | 8.5 | 9   | V             |
| $V_B$ hysteresis       |                                                             | $V_{BHYS}$    |     | 0.5 |     | V             |
| High Side Startup Time | Time between $V_B > \text{UVLO}$ & 1 <sup>st</sup> HO Pulse | $T_{startup}$ |     |     | 10  | $\mu\text{s}$ |

**LO GATE DRIVER**

|                           |                                                             |                |  |       |  |   |
|---------------------------|-------------------------------------------------------------|----------------|--|-------|--|---|
| Low level output voltage  | $I_{LO} = 100\text{ mA}$                                    | $V_{LOL}$      |  | 0.125 |  | V |
| High level output voltage | $I_{LO} = -100\text{ mA}$ , $V_{LOH} = V_{CC}$<br>$-V_{LO}$ | $V_{LOH}$      |  | 0.150 |  | V |
| Peak source current       | $V_{LO} = 0\text{ V}$                                       | $I_{LOpullup}$ |  | 3.5   |  | A |

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**Table 6. ELECTRICAL CHARACTERISTICS**

( $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $V_{CC} = V_B = 12\text{V}$ ,  $V_{HB} = \text{GND}$ , outputs are not loaded, all voltages are referenced to GND; unless otherwise noted, Typical values are at  $T_J = 25^{\circ}\text{C}$ .)

| Parameters | Test Conditions | Symbol | Min | Typ | Max | Unit |
|------------|-----------------|--------|-----|-----|-----|------|
|------------|-----------------|--------|-----|-----|-----|------|

## LO GATE DRIVER

|                   |                        |                         |  |     |  |   |
|-------------------|------------------------|-------------------------|--|-----|--|---|
| Peak sink current | $V_{LO} = 12\text{ V}$ | $I_{LO\text{pulldown}}$ |  | 3.0 |  | A |
|-------------------|------------------------|-------------------------|--|-----|--|---|

## HO GATE DRIVER

|                           |                                                         |                         |  |       |  |   |
|---------------------------|---------------------------------------------------------|-------------------------|--|-------|--|---|
| Low level output voltage  | $I_{HO} = 100\text{ mA}$                                | $V_{HOL}$               |  | 0.125 |  | V |
| High level output voltage | $I_{HO} = -100\text{ mA}$ , $V_{HOH} = V_{HB} - V_{HO}$ | $V_{HOH}$               |  | 0.150 |  | V |
| Peak source current       | $V_{HO} = 0\text{ V}$                                   | $I_{HO\text{pullup}}$   |  | 3.5   |  | A |
| Peak sink current         | $V_{HO} = 12\text{ V}$                                  | $I_{HO\text{pulldown}}$ |  | 3.0   |  | A |

## OUTPUT RISE AND FALL TIME

|                  |                             |       |  |   |    |    |
|------------------|-----------------------------|-------|--|---|----|----|
| Rise Time LO, HO | $C_{load} = 1000\text{ pF}$ | $T_R$ |  | 8 | 15 | ns |
| Fall Time LO, HO | $C_{load} = 1000\text{ pF}$ | $T_F$ |  | 8 | 15 | ns |

## DELAY MATCHING

|               |                                      |            |  |  |   |    |
|---------------|--------------------------------------|------------|--|--|---|----|
| LI ON, HI OFF | Pulse width = $1\text{ }\mu\text{s}$ | $T_{MON}$  |  |  | 7 | ns |
| LI OFF, HI ON | Pulse width = $1\text{ }\mu\text{s}$ | $T_{MOFF}$ |  |  | 7 | ns |

## TIMING

|                                  |                                                                              |          |    |    |  |    |
|----------------------------------|------------------------------------------------------------------------------|----------|----|----|--|----|
| Minimum Input Filter (NCP51530A) | $V_{XIN} = 5\text{ V}$ , Input pulse width above which output change occurs. | $T_{FT}$ | 30 | 40 |  | ns |
|----------------------------------|------------------------------------------------------------------------------|----------|----|----|--|----|

## PROPAGATION DELAY NCP51530A

|                                      |                                                                            |            |  |    |     |    |
|--------------------------------------|----------------------------------------------------------------------------|------------|--|----|-----|----|
| $V_{LI}$ falling to $V_{LO}$ falling | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DLFF}$ |  | 60 | 100 | ns |
| $V_{HI}$ falling to $V_{HO}$ falling | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DHFF}$ |  | 60 | 100 | ns |
| $V_{LI}$ rising to $V_{LO}$ rising   | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DLRR}$ |  | 60 | 100 | ns |
| $V_{HI}$ rising to $V_{HO}$ rising   | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DHRR}$ |  | 60 | 100 | ns |

## PROPAGATION DELAY NCP51530B

|                                      |                                                                            |            |  |    |    |    |
|--------------------------------------|----------------------------------------------------------------------------|------------|--|----|----|----|
| $V_{LI}$ falling to $V_{LO}$ falling | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DLFF}$ |  | 25 | 40 | ns |
| $V_{HI}$ falling to $V_{HO}$ falling | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DHFF}$ |  | 25 | 40 | ns |
| $V_{LI}$ rising to $V_{LO}$ rising   | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DLRR}$ |  | 25 | 40 | ns |
| $V_{HI}$ rising to $V_{HO}$ rising   | $C_{load} = 0$ , Minimum On/Off-time to register as a valid change = 50 ns | $T_{DHRR}$ |  | 25 | 40 | ns |

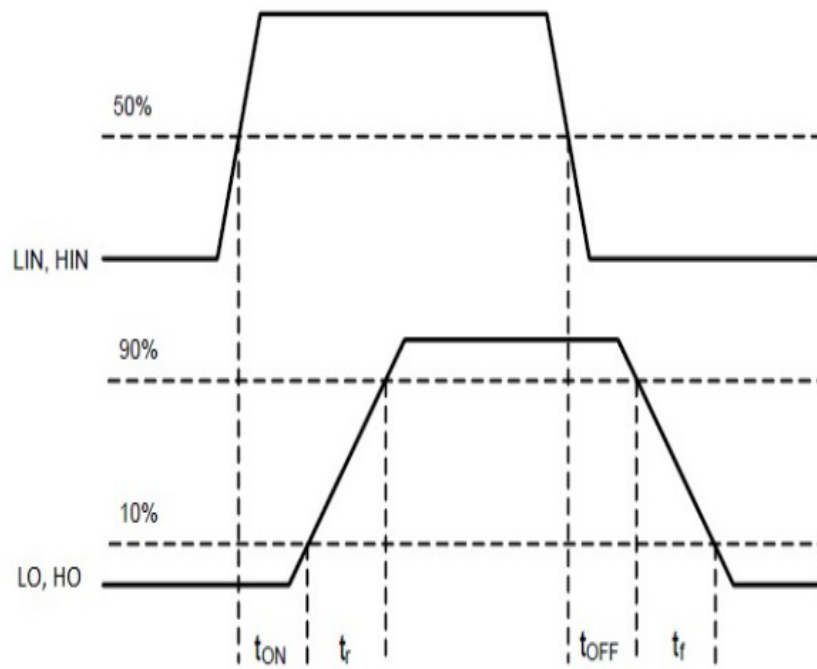


Figure 4. Propagation Delay, Rise and Fall Times

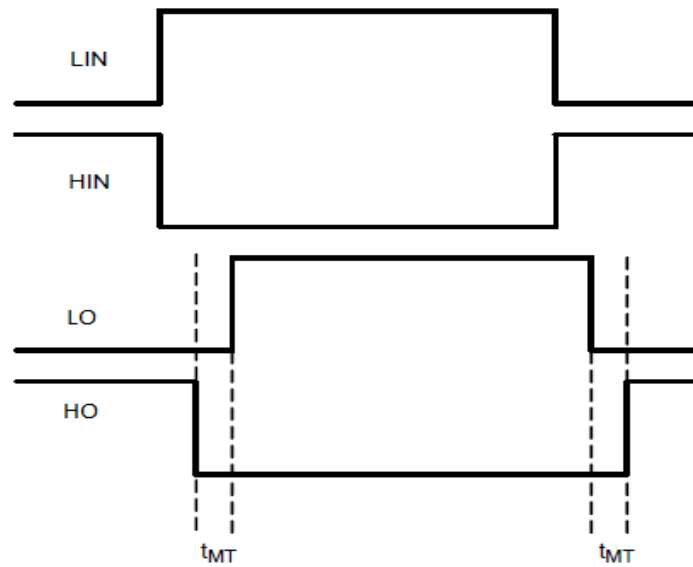


Figure 5. Delay Matching

## NCP51530

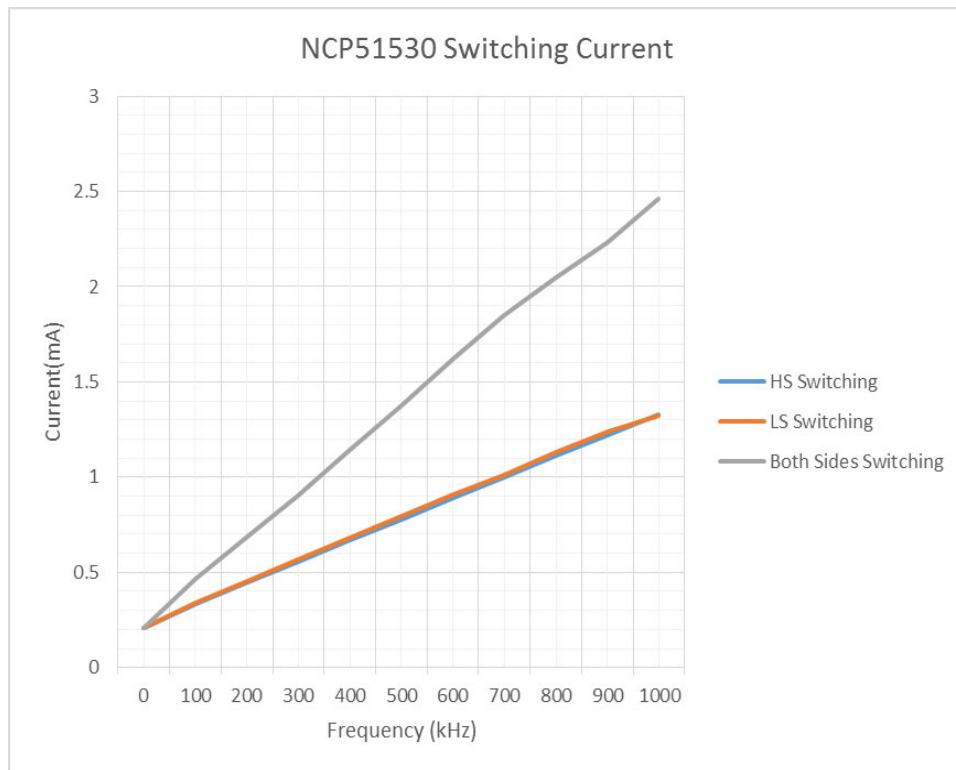


Figure 6. NCP51530 Operating Currents (No Load,  $V_{CC} = 12V$ )

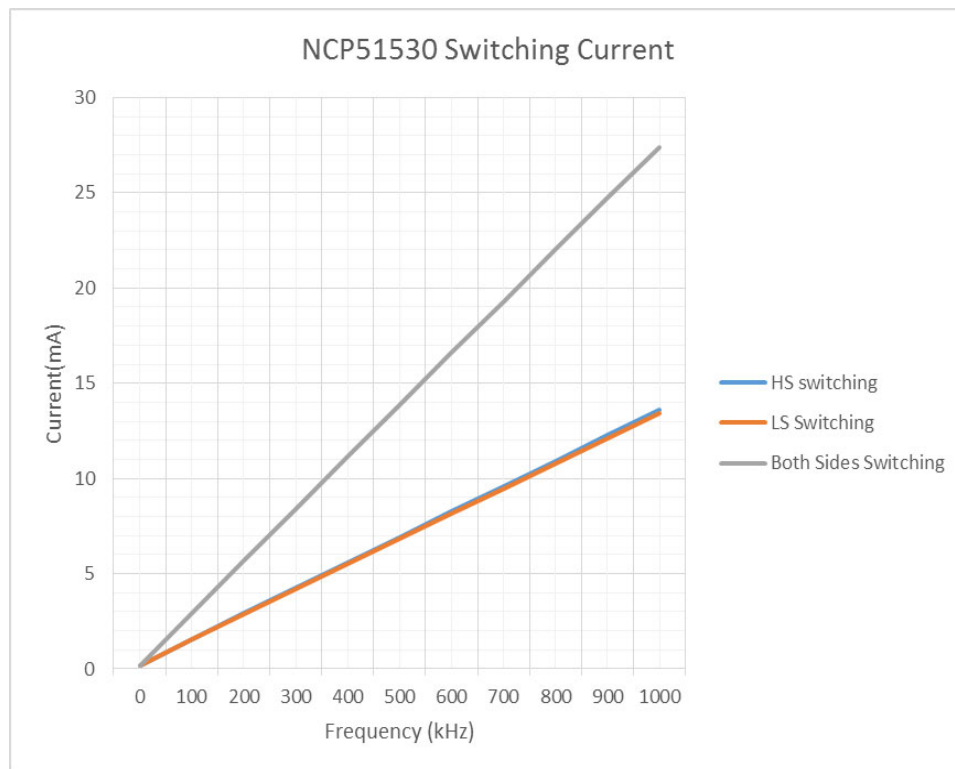


Figure 7. NCP51530 Operating Currents (1nF load,  $V_{CC} = 12V$ )

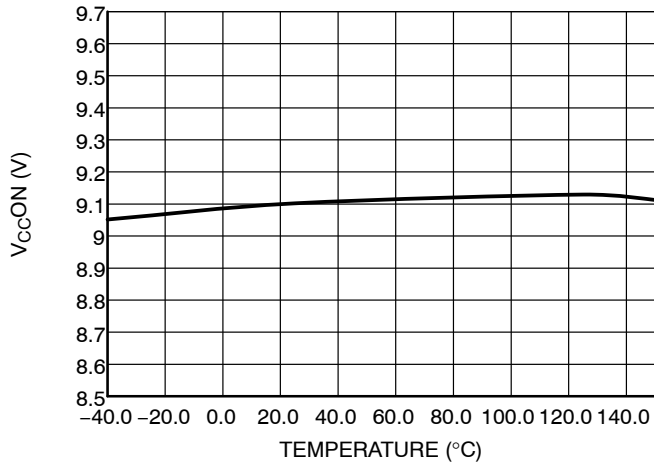


Figure 8. V<sub>CCON</sub> vs Temperature

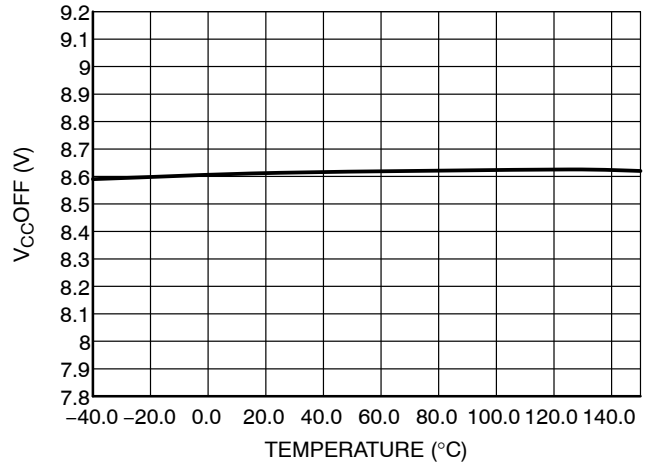


Figure 9. V<sub>CCOFF</sub> vs Temperature

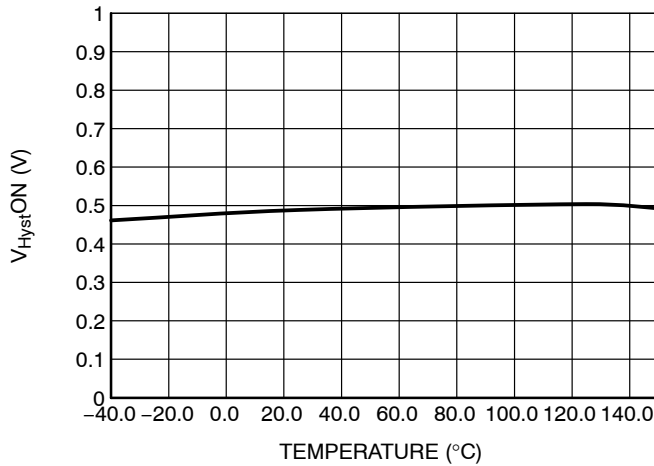


Figure 10. V<sub>CCHyst</sub> vs Temperature

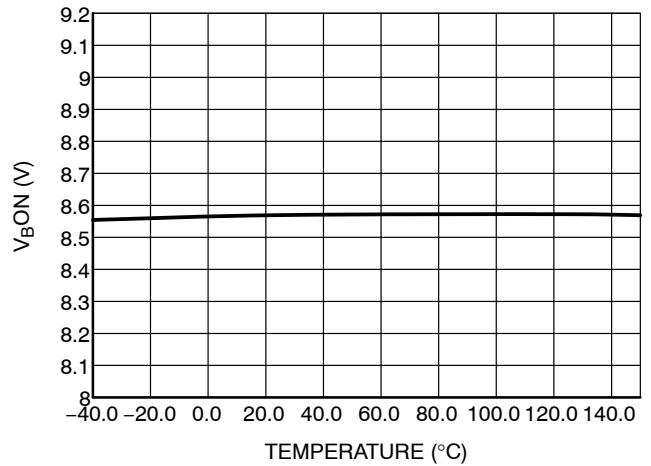


Figure 11. V<sub>BON</sub> vs Temperature

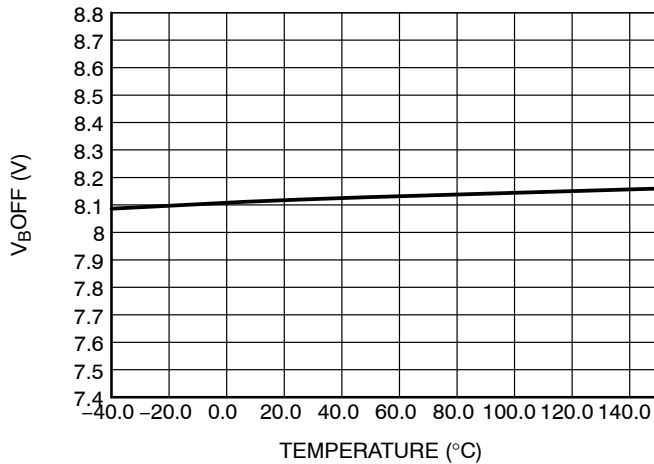


Figure 12. V<sub>BOff</sub> vs Temperature

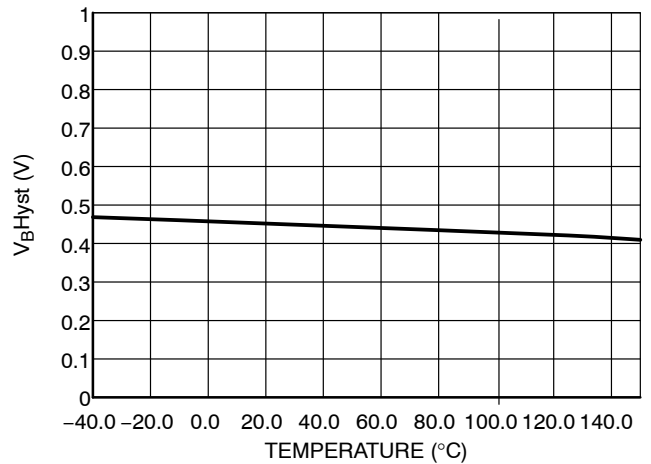
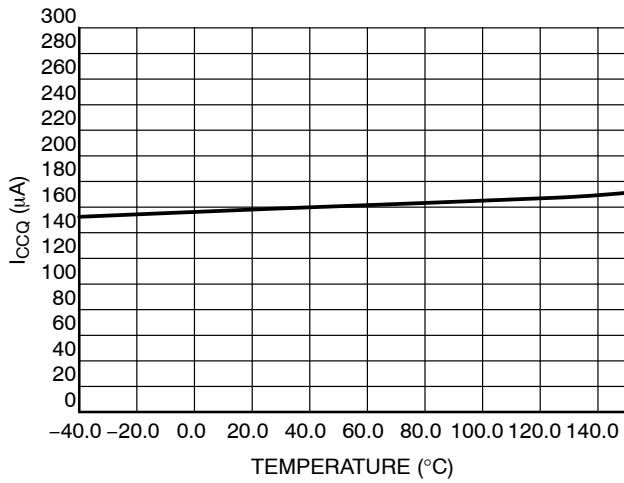
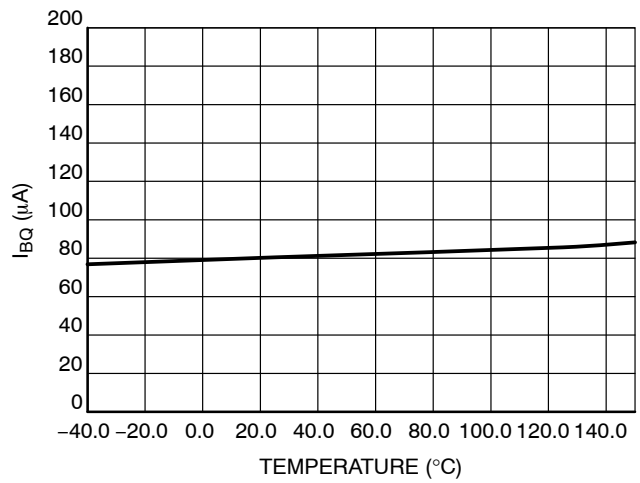


Figure 13. V<sub>BHyst</sub> vs Temperature

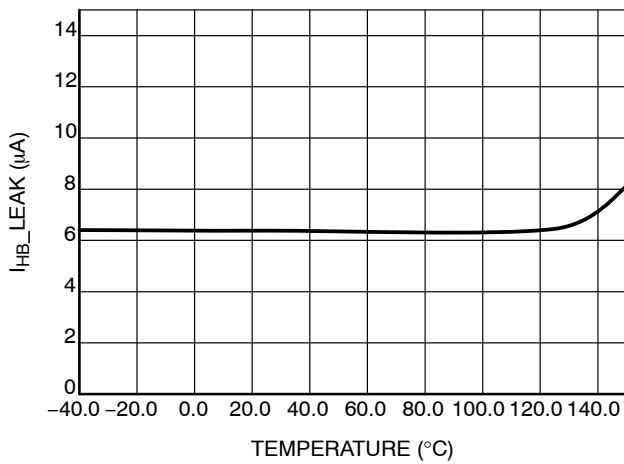
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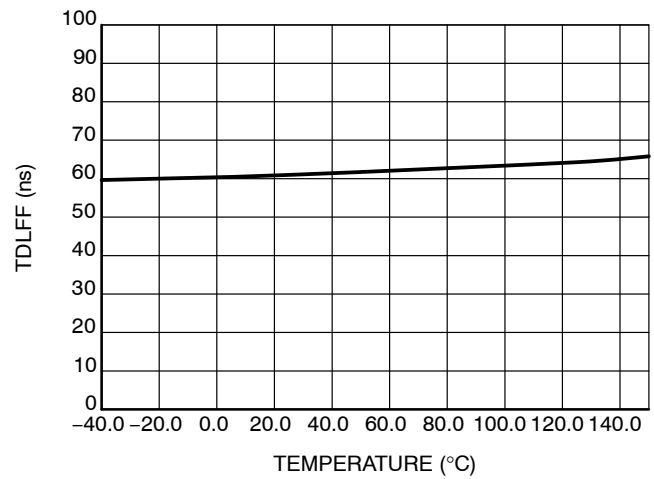
**Figure 14. I<sub>CCQ</sub> vs Temperature**



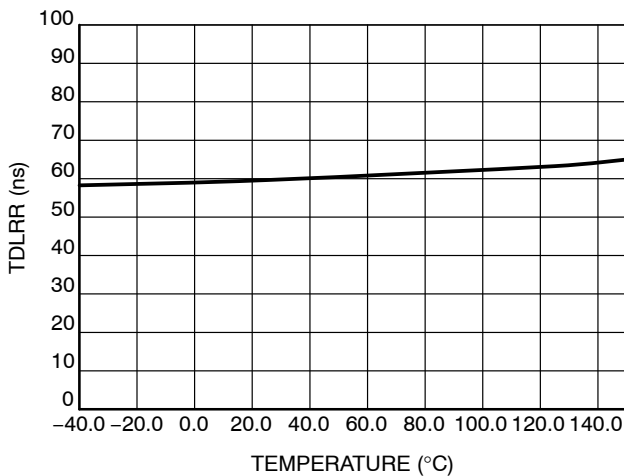
**Figure 15. I<sub>BQ</sub> vs Temperature**



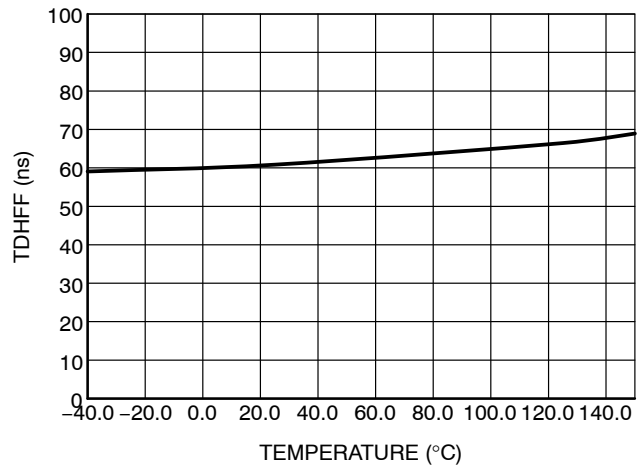
**Figure 16. I<sub>HB\_Leakage</sub> vs Temperature**



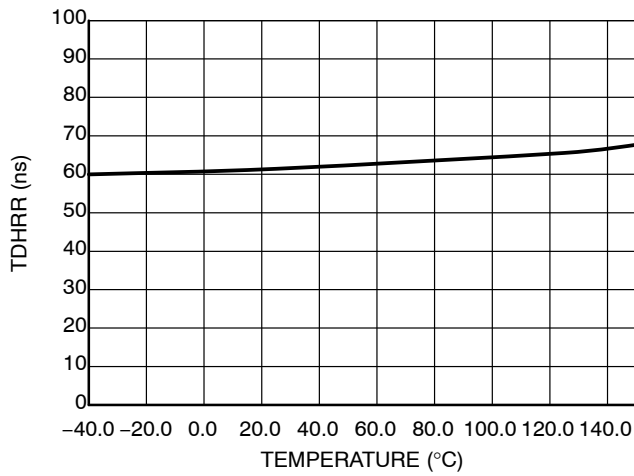
**Figure 17. Low Side Turn on Propagation Delay vs Temperature**



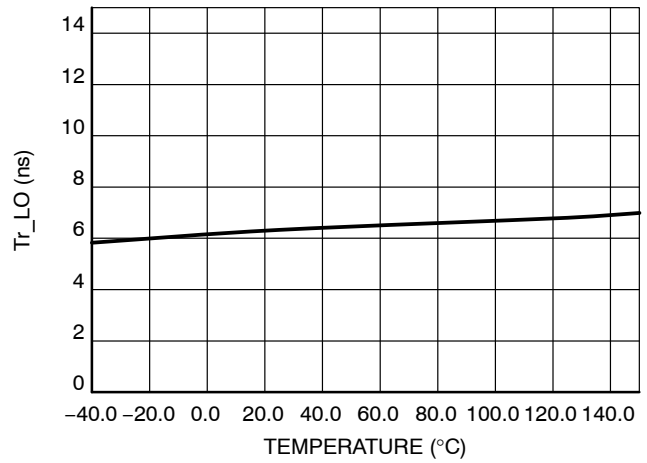
**Figure 18. Low Side Turn on Propagation Delay vs Temperature**



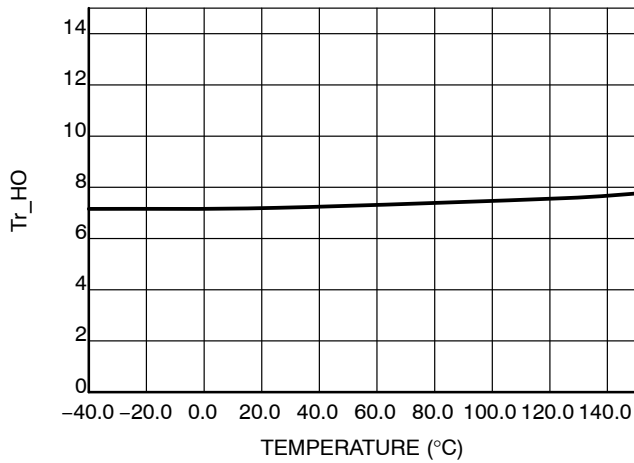
**Figure 19. High Side Turn off Propagation Delay vs Temperature**



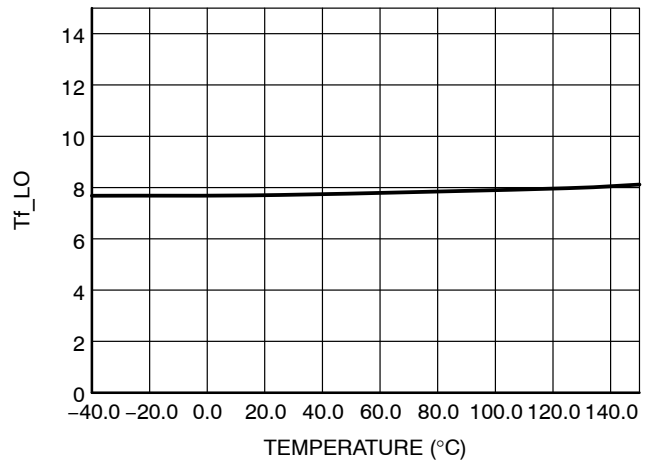
**Figure 20. High Side Turn off Propagation Delay vs Temperature**



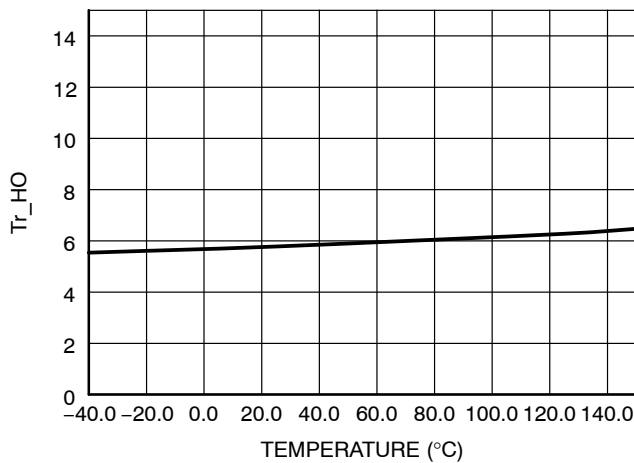
**Figure 21. Low Side Rise Time vs Temperature**



**Figure 22. High Side Rise Time vs Temperature**



**Figure 23. Low Side Fall Time vs Temperature**



**Figure 24. High Side Fall Time vs Temperature**

## GENERAL DESCRIPTION

For popular topologies like LLC, half bridge converters, full bridge converters, two switch forward converter etc. low-side high-side drivers are needed which perform the function of both buffer and level shifter. These devices can drive the gate of the topside MOSFETs whose source node is a dynamically changing node. The bias for the high side driver in these devices is usually provided through a bootstrap circuit.

In a bid to make modern power supplies more compact and efficient, power supply designers are increasingly opting for high frequency operations. High frequency operation causes higher losses in the drivers, hence reducing the efficiency of the power supply.

NCP51530 is a 700 V high side-low side driver for AC-DC power supplies and inverters. NCP51530 offers best in class propagation delay, low quiescent current and low switching current at high frequencies of operation. This device thus enables highly efficient power supplies operating at high frequencies.

NCP51530 is offered in two versions, NCP51530A/B. NCP51530A has a typical 60 ns propagation delay, while NCP51530B has propagation delay of 25 ns.

NCP51530 comes in SOIC8 and DFN10 packages. SOIC8 package of the device is pin to pin compatible with industry standard solutions.

NCP51530 has two independent input pins HIN and LIN allowing it to be used in a variety of applications. This device also includes features wherein, in case of floating input, the logic is still defined. Driver inputs are compatible with both CMOS and TTL logic hence it provides easy interface with analog and digital controllers. NCP51530 has under voltage lock out feature for both high and low side drivers which

ensures operation at correct  $V_{CC}$  and  $V_B$  voltage levels. The output stage of NCP51530 has 3.5 A/3 A current source/sink capability which can effectively charge and discharge a 1 nF load in 15 ns.

## FEATURES

### INPUT STAGES

NCP51530 has two independent input pins HIN and LIN allowing it to be used in a variety of applications. The input stages of NCP51530 are TTL and CMOS compatible. This ensures that the inputs of NCP51530 can be driven with 3.3 V or 5 V logic signals from analog or digital PWM controllers or logic gates.

The input pins have Schmitt triggers to avoid noise induced logic errors. The hysteresis on the input pins is typically 1.3 V. This high value ensures good noise immunity.

NCP51530 comes with an important feature wherein outputs (HO, LO) stays low in case any of the input pin is floating. At both the input pins there is an internal pull down resistor to define its logic value in case the pin is left open or NCP51530 is driven by open drain signal. The input logic is explained in the Table 7 below.

NCP51530 input pins are also tolerant to negative voltage below the GND pin level as long as it is within the ratings defined in the datasheet. This tolerance allows the use of transformer as an isolation barrier for input pulses.

NCP51530A features a noise rejection function to ensure that any pulse glitch shorter than 30 ns will not produce any output. These features are well illustrated in the Figure 25 below.

NCP51530B has no such filters in the input stages. The timing diagram NCP51530B is Figure 26 below.

**Table 7. INPUT TABLE**

| S.No | LIN | HIN | LO | HO |
|------|-----|-----|----|----|
| 1    | 0   | 0   | 0  | 0  |
| 2    | 0   | 1   | 0  | 1  |
| 3    | 1   | 0   | 1  | 0  |
| 4    | 1   | 1   | 1  | 1  |
| 5    | X   | 0   | 0  | 0  |
| 6    | X   | 1   | 0  | 1  |
| 7    | X   | X   | 0  | 0  |
| 8    | 0   | X   | 0  | 0  |
| 9    | 1   | X   | 1  | 0  |

# NCP51530

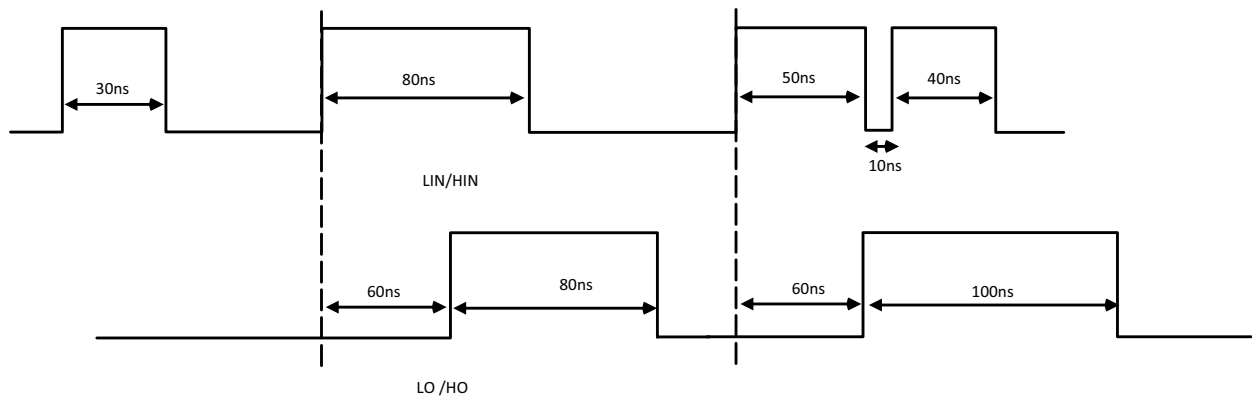


Figure 25. Input Filter (NCP51530A)

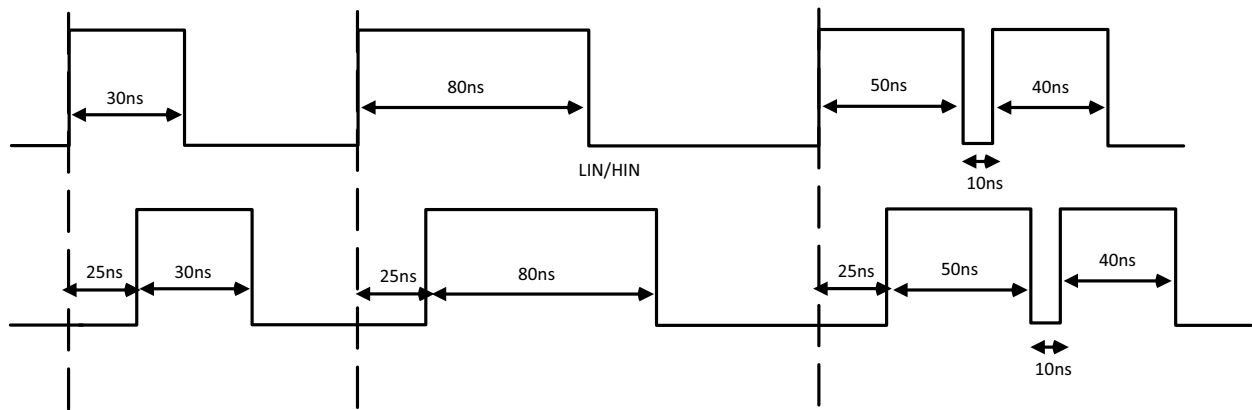


Figure 26. No Input Filter (NCP51530B)

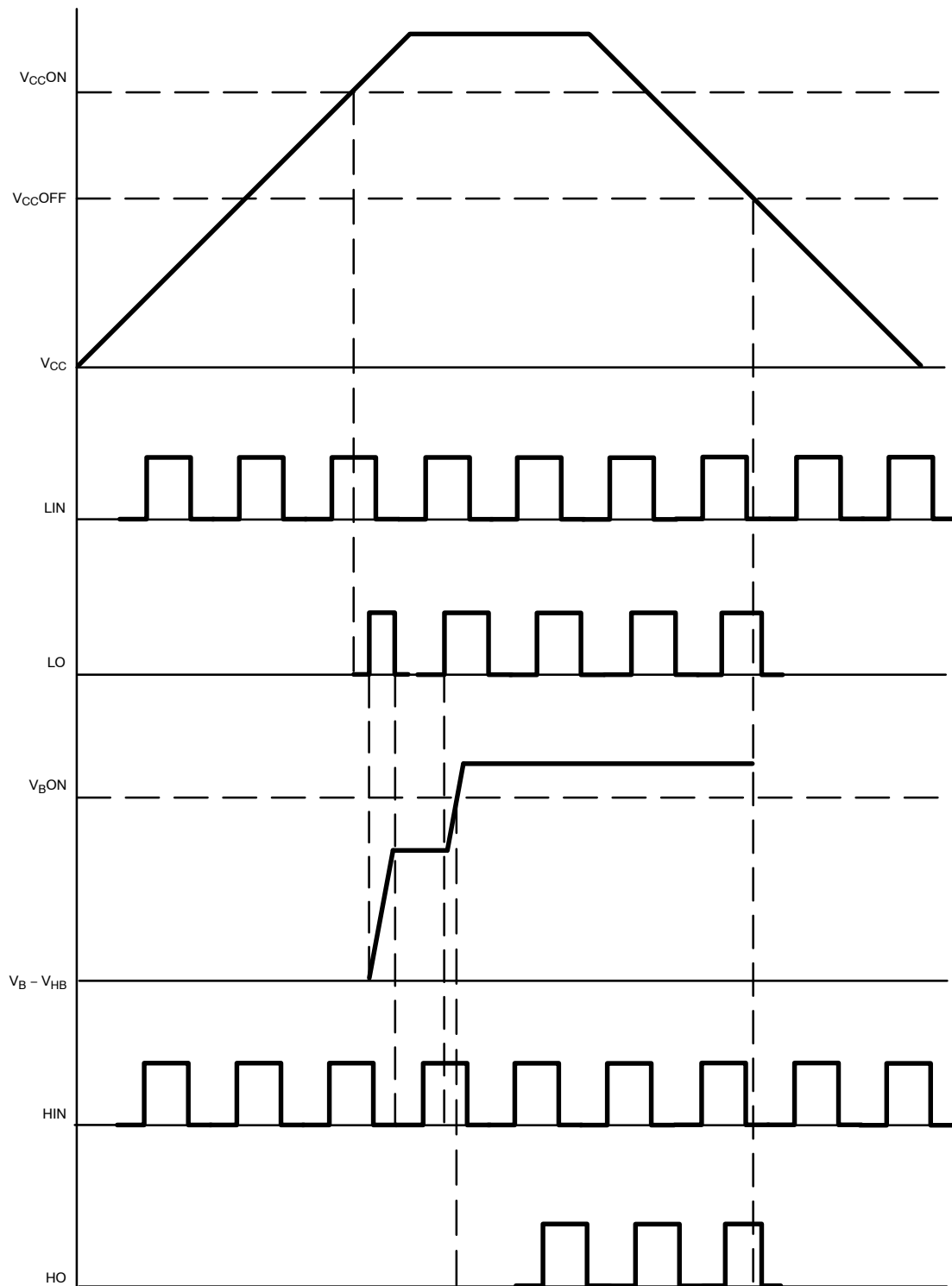


Figure 27. UVLO Timing Diagram

#### UNDER VOLTAGE LOCK-OUT

NCP51530 has under voltage lockout protection on both the high side and the low side driver. The function of the UVLO circuits is to ensure that there is enough supply voltages ( $V_{CC}$  and  $V_B$ ) to correctly bias high side and low side circuits. This also ensures that the gate of external MOSFETs are driven at an optimum voltage.

If the  $V_{CC}$  is below the  $V_{CC}$  UVLO voltage, the low side driver output (LO) and high side driver output (HO) both remain low.

If  $V_B$  is below  $V_B$  UVLO voltage the high side driver output (HO) remains low. However if the  $V_{CC}$  is above  $V_{CC}$  UVLO voltage level, the low side driver output (LO) can still turn on and off based on the low side driver input (LI)

and is not affected by the  $V_B$  status. This ensures proper charging of the bootstrap capacitor to bring the high side bias supply  $V_B$  above UVLO voltage.

Both the  $V_{CC}$  and  $V_B$  UVLO circuits are provided with hysteresis feature. This hysteresis feature avoids errors due to ground noise in the power supply. The hysteresis also

ensures continuous operation in case of a small drop in the bias voltage. This drop in the bias can happen when device starts switching MOSFET and the operating current of the device increases. The UVLO feature of the device is explained in the Figure 27.

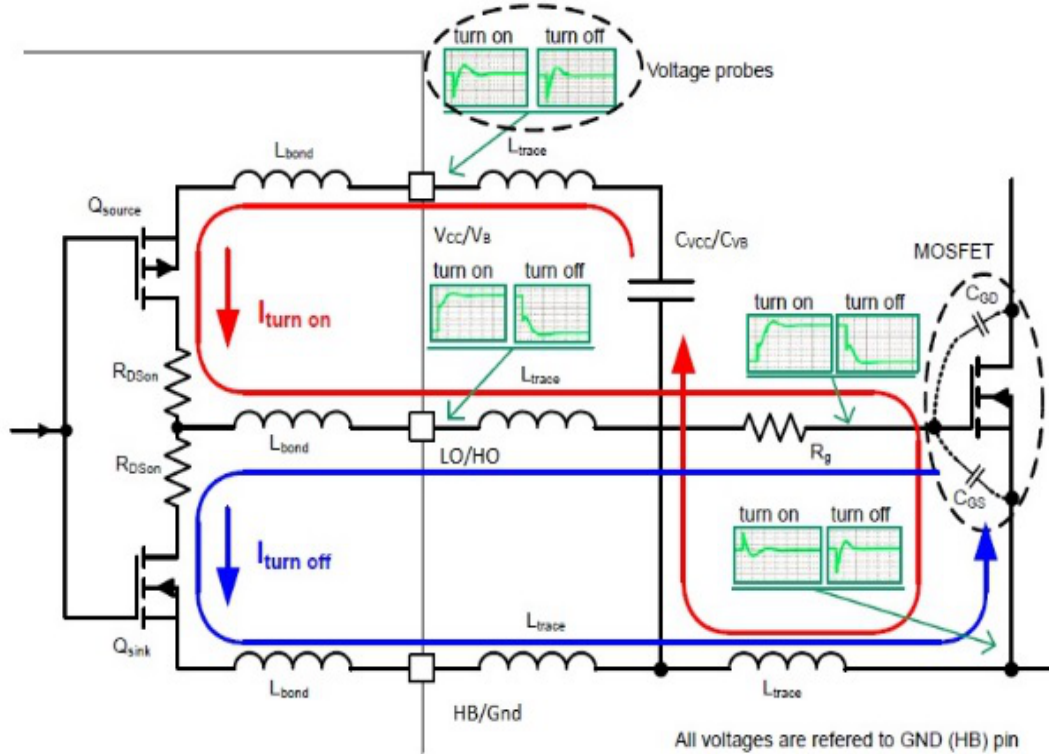


Figure 28. NCP51530 Turn ON-OFF Paths

## OUTPUT STAGES

The NCP51530 is equipped with two independent drivers. The output stage of NCP51530 has 3.5 A/3 A current source/sink capability which can effectively charge and discharge a 1 nF load in 15 ns.

The outputs of NCP51530 can be turned on at the same time and there is no internal dead-time built between them. This allows NCP51530 to be used in topologies like two switch forward converter.

The figure below show the output stage structure and the charging and discharging path of the external power MOSFET. The bias supply  $V_{CC}$  or  $V_B$  supply the energy to charge the gate capacitance  $C_{gs}$  of the low side or the top

side external MOSFETs respectively. When a logic high is received from input stage, Qsource turns on and  $V_{CC}/V_B$  starts charging  $C_{gs}$  through  $R_g$ . Once the  $C_{gs}$  is charged to the drive voltage level the external power MOSFET turns on the external MOSFET to discharge to GND/HB level.

When a logic low signal is received from the input stage, Qsource turns off and Qsink turns on providing a path for gate terminal of

As seen in the figure, there are parasitic inductances in charging and discharging path of the  $C_{gs}$ . This can result in a little dip in the bias voltages  $V_{CC}/V_B$ . If the  $V_{CC}/V_B$  drops below UVLO the power supply can shut down the device.

## NCP51530



**Figure 29. Low Side Turn-ON Propagation Delay (NCP51530A)**

### FAST PROPAGATION DELAY

NCP51530 boasts of industry best propagation delay between input and output. NCP51530A has a typical of 60 ns propagation delay. The best in class propagation delay in NCP51530 makes it suitable for high frequency operation.

Since NCP51530B doesn't have the input filter included, the propagation delay are even faster. NCP51530B offers 25 ns propagation delay between input and output.

# NCP51530



Figure 30. Low Side Turn-Off Propagation Delay (NCP51530A)

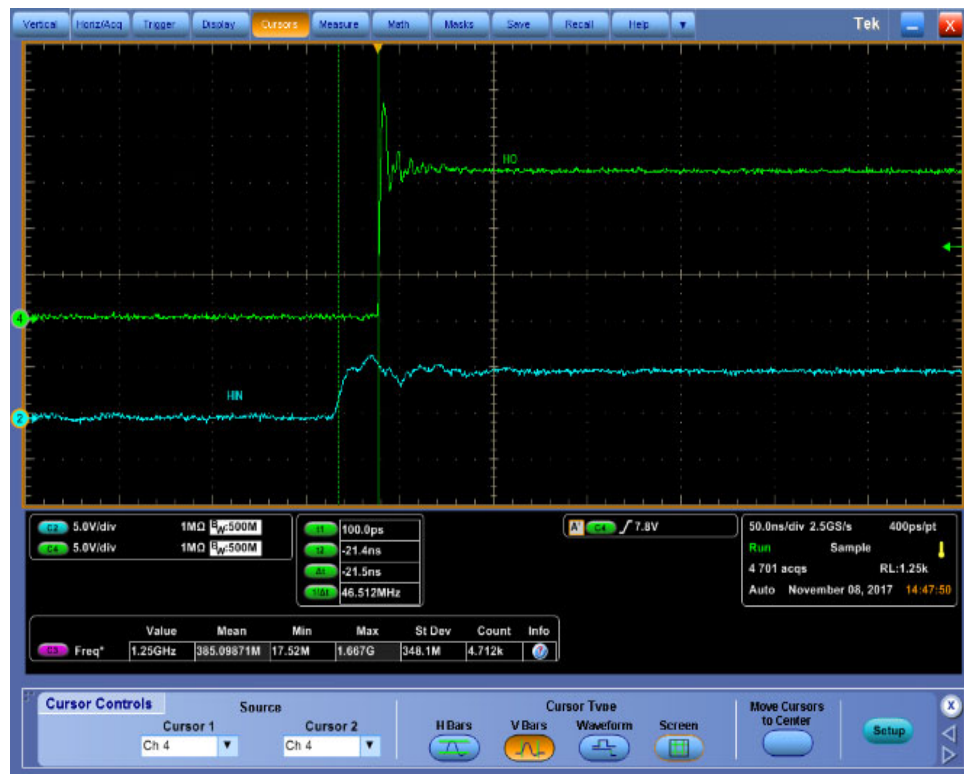


Figure 31. High Side Turn-Off Propagation Delay (NCP51530B)

# NCP51530



Figure 32. High Side Turn-Off Propagation Delay (NCP51530B)

## Negative Transient Immunity (NTI) Operating Conditions

In any HB switching applications the HB node is often pulled under the ground during the switching operation because of parasitic inductances and inductive load. These

negative spikes may lead to malfunction or damage of the circuit.

Below schematics depicts parasitic and current circulation during switching operations that could create the negative deep of the HB node.

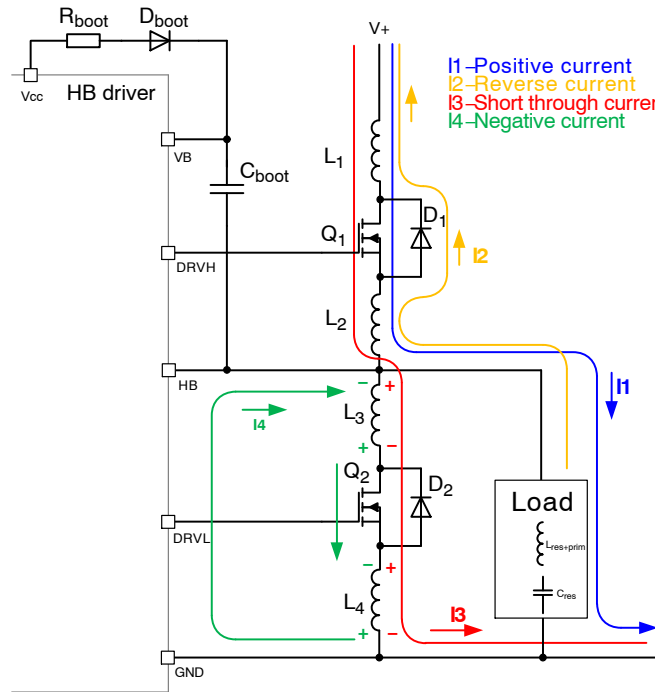


Figure 33. HB Negative Voltage in an LLC Configuration

## NTI Robustness Measurement

The capability of NCP51530 to operate under negative voltage conditions is reported in NTI graph using below test set up.

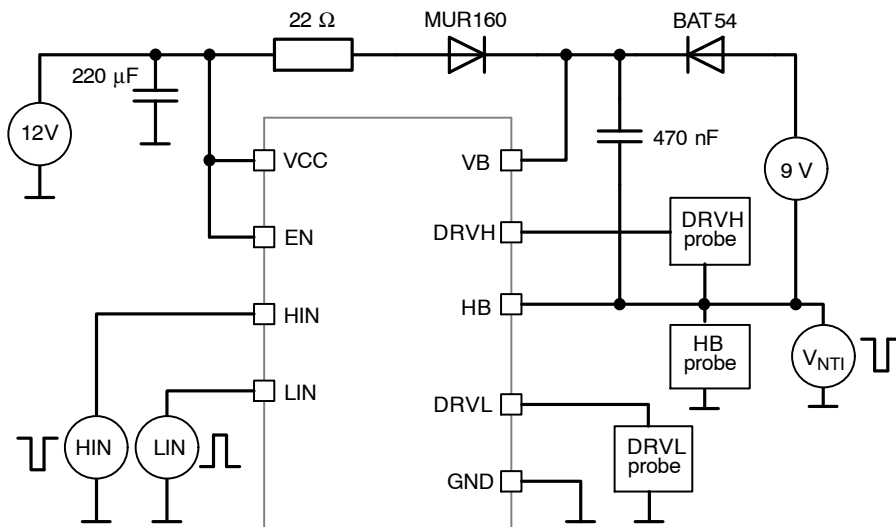
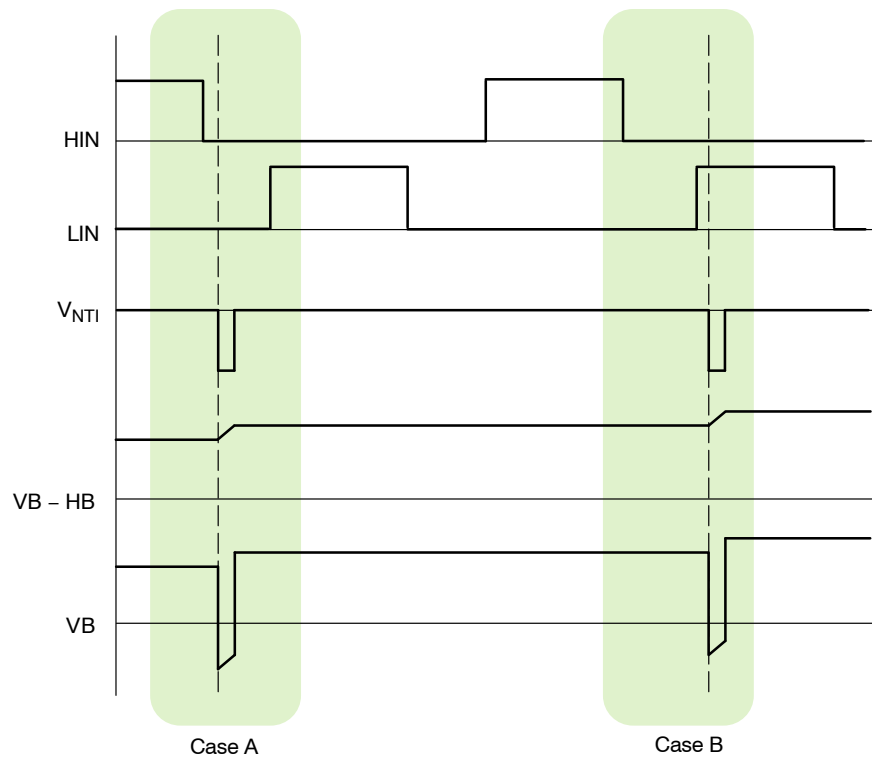


Figure 34. NTI Test Set Up

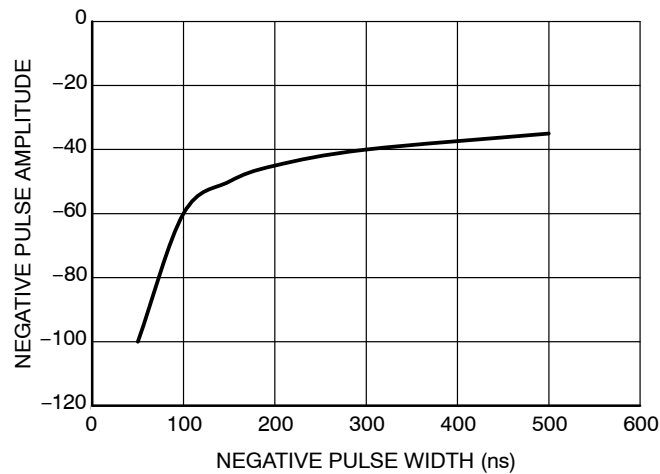
## NCP51530



**Figure 35. Timing Diagram**

NCP51530 robustness against negative spikes is shown in Figure 36. The result is a curve which shows negative

voltage level for specific pulse width under which driver could still operate properly.



**Figure 36. Typical Safe Operating Area with Negative Transient Voltage on HB Pin**

### **Important note:**

Even though above figure shows that NCP51530 is able to handle negative transient voltage conditions, it is highly recommended that the application circuit design is such that

it removes or at least always limit the negative transient voltage on VB pin as much as possible via careful PCB layout and proper component selection.

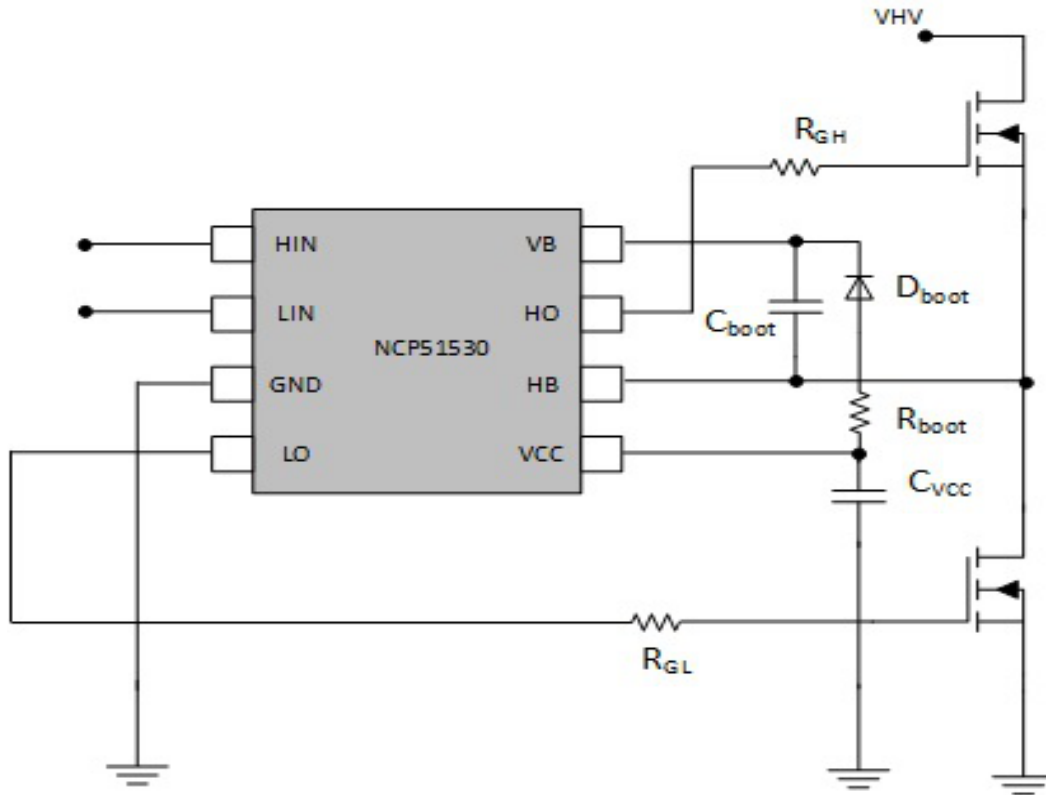


Figure 37. Bootstrap Circuit

## COMPONENT SELECTION

### C<sub>BOOT</sub> CAPACITOR VALUE CALCULATION

NCP51530 has two independent drivers for driving high side and low side external MOSFETs. The bias for the high side driver is usually provided through a bootstrap circuit. A typical bootstrap circuit is shown in Figure 37.

The high side driver is biased by the C<sub>boot</sub> (bootstrap capacitor). As can be seen in the circuit, C<sub>boot</sub> will charge only when HB goes to GND level. Low value of C<sub>boot</sub> can result in a little dip in the bias voltages V<sub>B</sub>. If the V<sub>B</sub> drops below UVLO the power supply can shut down the high side driver. Therefore choosing the right value of C<sub>boot</sub> is very important for a robust design.

An example design for C<sub>boot</sub> is given below.

$$Q_g = 30 \text{ nC}, V_{CC} = 15 \text{ V} \quad (\text{eq. 1})$$

$$Q_b = I_{BQ} * t_{\text{discharge}} = 81 \mu\text{C} * 5 \mu\text{s} = 405 \text{ pC} \quad (\text{eq. 2})$$

$$Q_{\text{tot}} = Q_g + Q_b = 30 \text{ nC} + 405 \text{ pC} = 30.4 \text{ pC} \quad (\text{eq. 3})$$

$$C_{\text{boot}} = \frac{Q_{\text{tot}}}{V_{\text{ripple}}} = \frac{30.4 \text{ nC}}{150 \text{ mV}} = 203 \text{ nF} \quad (\text{eq. 4})$$

Q<sub>g</sub> is equivalent gate charge of the FET

I<sub>BQ</sub> is the boot quiescent current

t<sub>discharge</sub> is the discharge time for bootstrap capacitor

V<sub>ripple</sub> is the allowed ripple voltage in the bootstrap capacitor

It is recommended to use a larger value so as to cover any variations in the gate charge and voltage with temperature.

### R<sub>boot</sub> RESISTOR VALUE CALCULATION

R<sub>boot</sub> resistor value is very important to ensure proper function of the device. A high value of R<sub>boot</sub> would slow down the charging of the C<sub>boot</sub> while too low a value would push very high charging currents for C<sub>boot</sub>. For NCP51530 a value between 2 Ω and 10 Ω is recommended for R<sub>boot</sub>.

For example R<sub>boot</sub> = 5 Ω

$$I_{\text{boot(pk)}} = \frac{V_{CC} - V_D}{R_{\text{boot}}} = \frac{15 \text{ V} - 1 \text{ V}}{5 \Omega} = 2.8 \text{ A} \quad (\text{eq. 5})$$

Where V<sub>D</sub> is the bootstrap diode forward drop.

Thus, R<sub>boot</sub> value of 5 Ω keeps the peak current below 2.8 A.

### HIN AND LIN INPUT FILTER

For PWM connection on the LIN and HIN pin of the NCP51530, a RC is recommended to filter high frequency input noise.

This filter is particularly important in case of NCP51530B where no internal filter is included.

The recommended value for R<sub>LIN</sub>/R<sub>HIN</sub> and C<sub>HIN</sub>/C<sub>LIN</sub> are as below.

$$R_{\text{LIN}}/R_{\text{HIN}} = 100 \Omega$$

$$C_{\text{HIN}}/C_{\text{LIN}} = 120 \text{ pF}$$

### V<sub>CC</sub> CAPACITOR SELECTION

V<sub>CC</sub> capacitor value should be selected at least ten times the value of C<sub>boot</sub>. In this case thus C<sub>VCC</sub> > 2 μF.

### R<sub>gate</sub> SELECTION

R<sub>gate</sub> are selected to limit the peak gate current during charging and discharging of the gate capacitance. This resistance also helps to damp the ringing due to the parasitic inductances.

For example for a R<sub>gate</sub> value of 5 Ω, the peak source and sink currents would be limited to the following values.

$$R_{gate} = 5\Omega \quad (\text{eq. 6})$$

$$I_{LO\_Source} = \frac{V_{CC}}{R_{Lgate} + R_{LOH}} = \frac{15\text{ V}}{6.7\ \Omega} = 2.23\text{ A} \quad (\text{eq. 7})$$

$$I_{LO\_Sink} = \frac{V_{CC}}{R_{Lgate} + R_{LOL}} = \frac{15\text{ V}}{6.8\ \Omega} = 2.20\text{ A} \quad (\text{eq. 8})$$

$$I_{HO\_Source} = \frac{V_{CC} - V_{Dboot}}{R_{Lgate} + R_{HOH}} = \frac{14\text{ V}}{6.7\ \Omega} = 2.09\text{ A} \quad (\text{eq. 9})$$

$$I_{HO\_Sink} = \frac{V_{CC} - V_{Dboot}}{R_{Lgate} + R_{HOL}} = \frac{15\text{ V} - 1\text{ V}}{6.8\ \Omega} = 2.06\text{ A} \quad (\text{eq. 10})$$

### TOTAL POWER DISSIPATION

Total power dissipation of NCP51530 can be calculated as follows.

1. Static power loss of device (excluding drivers) while switching at an appropriate frequency.

$$P_{operating} = V_{boot} * I_{BO} + V_{CC} * I_{CCO} \quad (\text{eq. 11})$$

$$= 14\text{ V} * 0.4\text{ mA} + 15\text{ V} * 0.4\text{ mA} = 11.6\text{ mW}$$

I<sub>BO</sub> is the operating current for the high side driver

I<sub>CCO</sub> is the operating current for the low side driver

2. Power loss of driving external FET (Hard Switching)

$$P_{drivers} = ((Q_g * V_{boot}) + (Q_g * V_{CC}))f \quad (\text{eq. 12})$$

$$= ((30\text{ nC} * 14\text{ V}) + (30\text{ nC} * 15\text{ V})) * 100\text{ kHz} = 87\text{ mW}$$

Q<sub>g</sub> is total gate charge of the MOSFET

3. Power loss of driving external FET (Soft Switching)

$$P_{drivers} = ((Q_{gs} * V_{boot}) + (Q_{gs} * V_{CC})) * f \quad (\text{eq. 13})$$

$$= ((4\text{ nC} * 14\text{ V}) + (4\text{ nC} * 15\text{ V})) * 100\text{ kHz} = 11\text{ mW}$$

4. Level shifting losses

$$P_{levelshifting} = (V_r + V_b) * Q * f \quad (\text{eq. 14})$$

$$= 415\text{ V} * 0.5\text{ nC} * 100\text{ kHz} = 20.75\text{ mW}$$

V<sub>r</sub> is the rail voltage

Q is the substrate charge on the level shifter

5. Total Power Loss (Hard Switching)

$$P_{total} = P_{driver} + P_{operating} + P_{levelshifting} \quad (\text{eq. 15})$$

$$= 11.6\text{ mW} + 87\text{ mW} + 20.75\text{ mW} = 119.35\text{ mW}$$

6. Junction temperature increase

$$t_J = R_{\theta JA} * P_{total} = 183 * 0.14 = 25^\circ\text{C} \quad (\text{eq. 16})$$

## LAYOUT RECOMMENDATIONS

NCP51530 is a high speed and high current high side and low side driver. To avoid any device malfunction during device operation, it is very important that there is very low parasitic inductance in the current switching path. It is very important that the best layout practices are followed for the PCB layout of the NCP51530. An example layout is shown in the figure below. Some of the layout rules to be followed are listed below.

- Keep the low side drive path LO–Q1–GND as small as possible. This reduces the parasitic inductance in the path and hence eliminates ringing on the gate terminal of the low side MOSFET Q1.
- Keep the high side drive loop HO–Q2–HB as small as possible. This reduces the parasitic inductance in the

path and hence eliminates ringing on the gate terminal of the low side MOSFET Q1.

- Keep  $C_{VCC}$  as near to the  $V_{CC}$  pin as possible and the  $V_{CC}$ – $C_{VCC}$ –GND loop as small as possible.
- Keep  $C_{VB}$  as near to VB pin as possible and  $V_B$ – $C_{VB}$ –HB loop as small as possible.
- Keep the HB–GND–Q1 loop as small as possible. This loop has the potential to produce a negative voltage spike on the HB pin. This negative voltage spike can cause damage to the driver. This negative spike can increase the boot capacitor voltage above the maximum rating and hence cause damage to the driver.

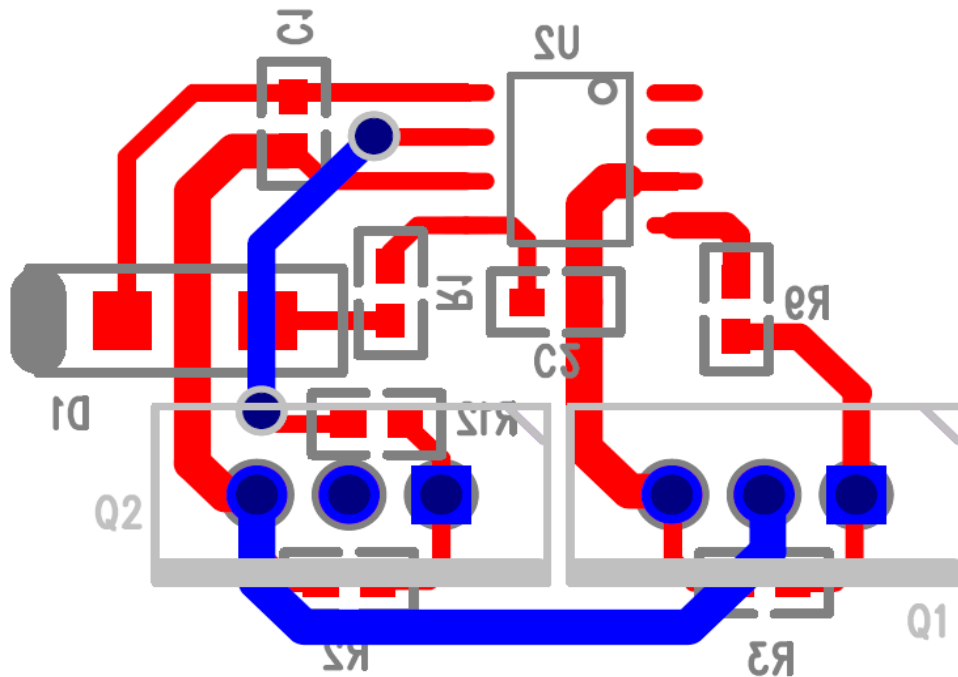


Figure 38. Example Layout

## IMPACT IONIZATION CURRENT

NCP51530 tends to exhibit an Impact Ionization current that flows from the boot pin (VB) to ground (GND) under certain conditions. This happens when voltage on the bridge pin (HB) is less than 40 V for a time greater than 100  $\mu$ s and that is immediately followed by switching event that pulls-up the HB pin above 150 V. This current can potentially last multiple switching cycle before it diminishes. Furthermore, Impact Ionization current is not seen in systems where the bulk voltage is always below 150 V i.e., HB node is never pulled above 150 V, for instance, a 48 V to 12 V full-bridge power converter.

Figure 39 below shows an example of Impact Ionization current. This example shows a half-bridge converter running at 100 kHz frequency with 3  $\mu$ s on-time. It shows

Impact Ionization current flowing in first three pulses during startup and subsiding thereafter.

Depending on the duration and magnitude of the Impact Ionization current it can lead to thermal stress on the device which can potentially, in corner cases, cause a thermal failure of NCP51530.

Following are the safe conditions under which the Impact Ionization current doesn't occur:

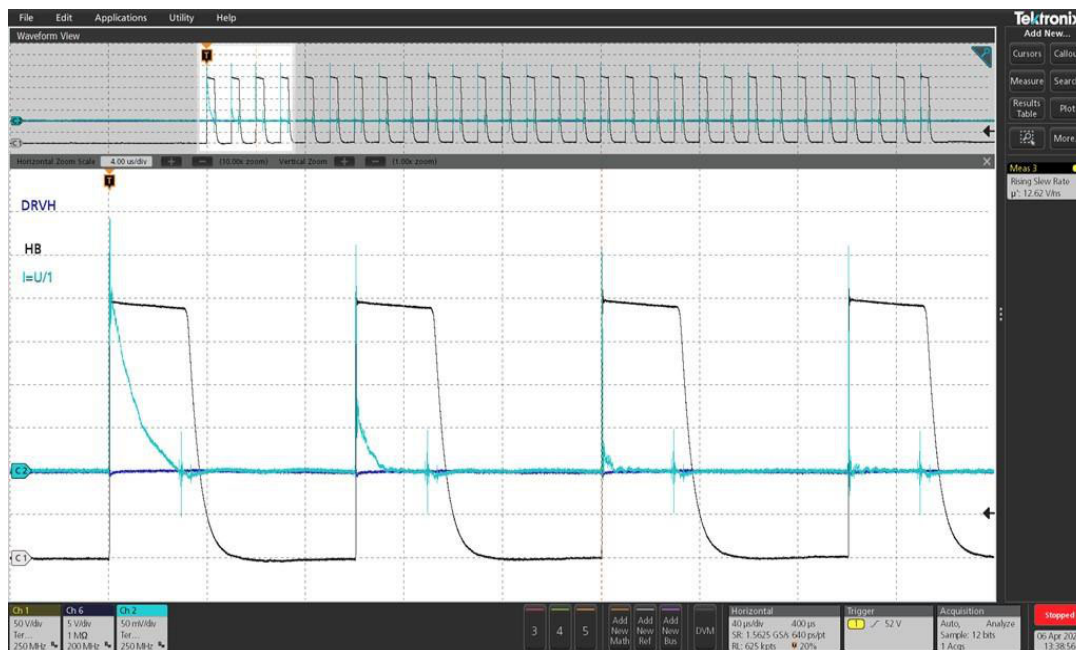
1. Systems where  $V_{HB} < 150$  V and  $V_{BOOT} < 170$  V.  
OR
2. Systems where  $V_{HB} > 40$  V before the start of switching  
OR

- Further, if the  $dv/dt$  of the VHB is kept under 0.1 V/ns, then the Impact Ionization current substantially reduces.

## Mitigating Impact Ionization Current in Various Topologies

- Flyback Converters and derivatives: Any topologies based on flyback or derivatives (DCM/CCM Flyback,

Active Clamp Flyback, and AHB Flyback) do not show any Impact Ionization current. This is because that transformer in the flyback topology is connected to input directly hence the VHB at  $t = 0$  is at input voltage ( $> 40$  V) satisfying the second condition mentioned above.



**Figure 39. Impact Ionization Current in NCP51530. C1 is HB node at 50 V/div and C2 is Impact Ionization Current at 50 mA/div**

- Synchronous Boost Converter: Similar to flyback the VHB at  $t = 0$  is at input voltage ( $> 40$  V) so no Impact Ionization current flows.
- Phase Shifted Full-bridge: The HB pin can be potentially at less than 40 V when switching starts. This can cause Impact Ionization current to flow during startup and in burst mode. This can be mitigated by adding parallel resistors ( $>1$  Meg) across the FETs. This ensures that the voltage on HB pin at  $t = 0$  is greater than 40 V. This is shown in figure 2 below. R1, R2, R3 and R4 ensure that the switch node voltage is at a voltage greater than 40 V before the switching starts.
- High Voltage Synchronous Buck Converter: Synchronous buck presents the worst case for the

Impact Ionization current. The HB is at a voltage equal to output voltage always at  $t = 0$ . Hence at the startup or in the cases of burst mode we see Impact Ionization current when the  $V_{out} < 40$  V. One potential solution can be pre-charging the output with VCC through a diode and running the system in soft-switching from first pulse itself. However if the regulated  $V_{out}$  is less than 40 V then there is a chance of Impact Ionization current every burst cycle. But as explained earlier this occurs only in case of HV systems. When the bulk voltage is less than 150 V no Impact Ionization current is seen.

## NCP51530

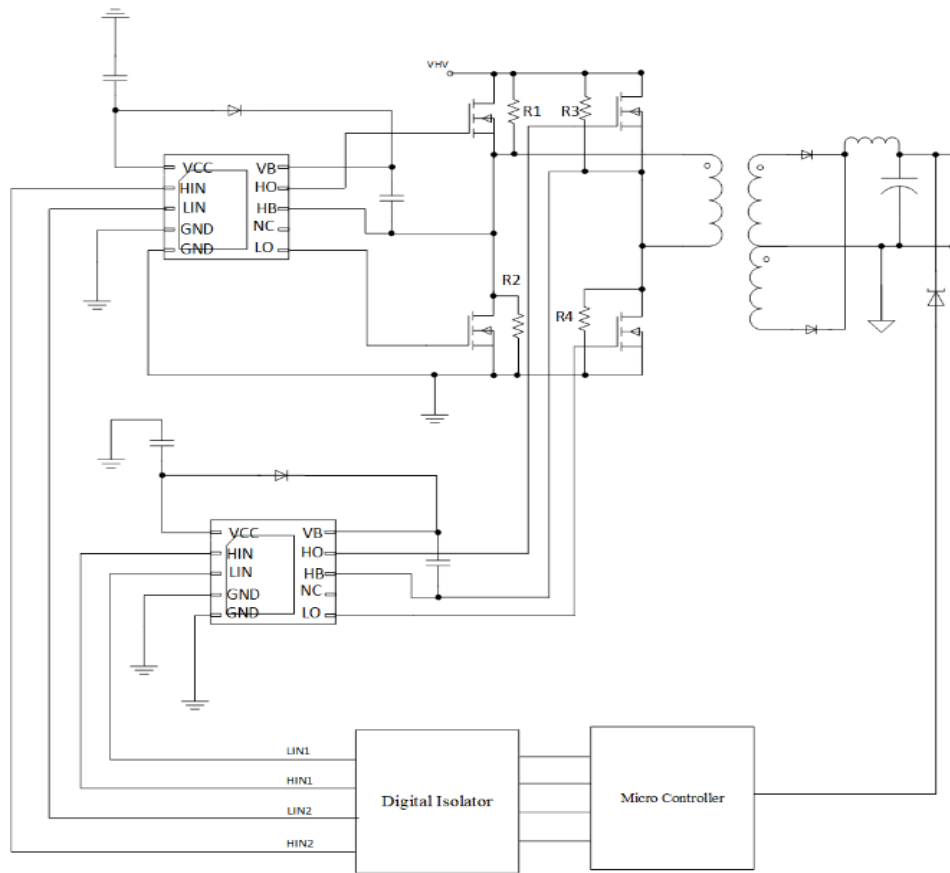


Figure 40. Phase Shifted Full Bridge Using NCP51530

### ORDERING INFORMATION

| Device         | Propagation Delay (ns) | Input filter | Package             | Shipping <sup>†</sup> |
|----------------|------------------------|--------------|---------------------|-----------------------|
| NCP51530ADR2G  | 60                     | Yes          | SOIC-8 (Pb-Free)    | 2500 / Tape & Reel    |
| NCP51530BDR2G  | 25                     | No           | SOIC-8 (Pb-Free)    | 2500 / Tape & Reel    |
| NCP51530AMNTWG | 60                     | Yes          | DFN10 4x4 (Pb-Free) | 4000 / Tape & Reel    |
| NCP51530BMNTWG | 25                     | No           | DFN10 4x4 (Pb-Free) | 4000 / Tape & Reel    |

<sup>†</sup>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.

# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS

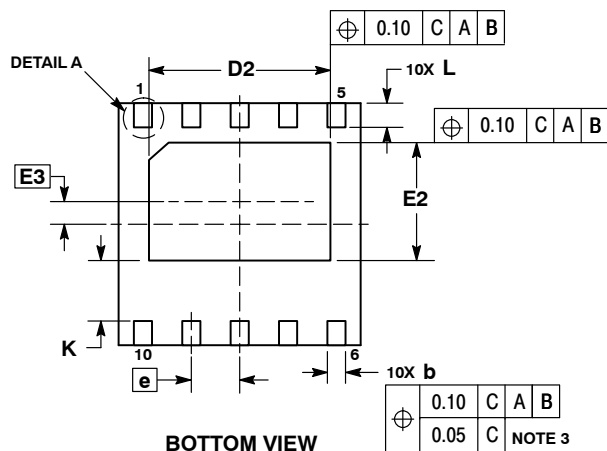
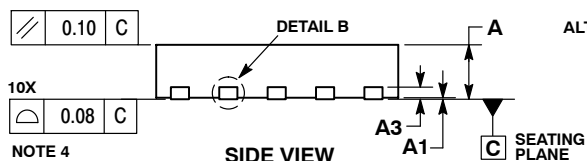
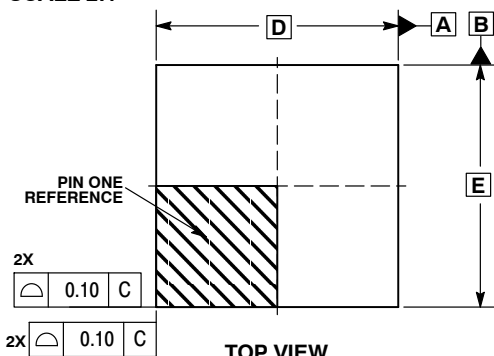
ON Semiconductor®



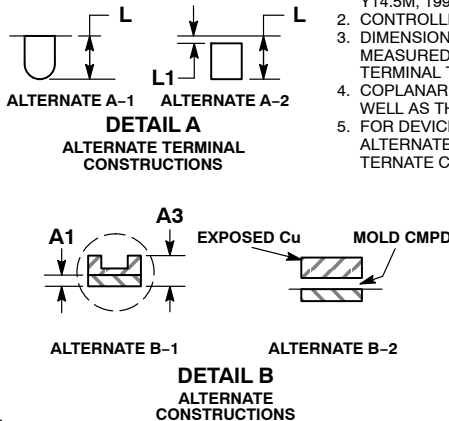
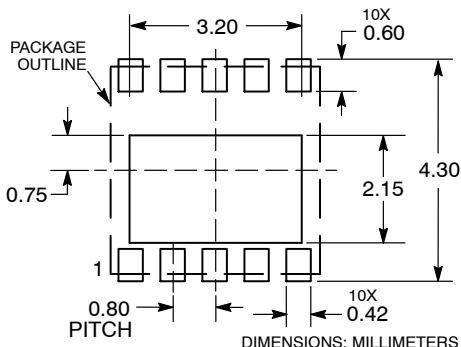
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CASE 506DJ  
ISSUE O

DATE 20 MAY 2016



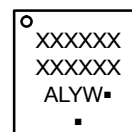
## RECOMMENDED MOUNTING FOOTPRINT



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  2. CONTROLLING DIMENSION: MILLIMETERS.
  3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM FROM THE TERMINAL TIP.
  4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.
  5. FOR DEVICE OPN CONTAINING W OPTION, DETAIL A ALTERNATE CONSTRUCTION A-2 AND DETAIL B ALTERNATE CONSTRUCTION B-2 ARE NOT APPLICABLE.

| DIM | MILLIMETERS |      |
|-----|-------------|------|
|     | MIN         | MAX  |
| A   | 0.80        | 1.00 |
| A1  | 0.00        | 0.05 |
| A3  | 0.20 REF    |      |
| b   | 0.25        | 0.35 |
| D   | 4.00 BSC    |      |
| D2  | 2.90        | 3.10 |
| E   | 4.00 BSC    |      |
| E2  | 1.85        | 2.05 |
| E3  | 0.375 BSC   |      |
| e   | 0.80 BSC    |      |
| K   | 0.90        |      |
| L   | 0.35        | 0.45 |
| L1  | 0.00        | 0.15 |

## GENERIC MARKING DIAGRAM\*



XXXXX = Specific Device Code  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

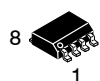
(Note: Microdot may be in either location)

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G", may or not be present.

|                  |                 |                                                                                                                                                                                     |
|------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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| DESCRIPTION:     | DFN10 4X4, 0.8P | PAGE 1 OF 1                                                                                                                                                                         |

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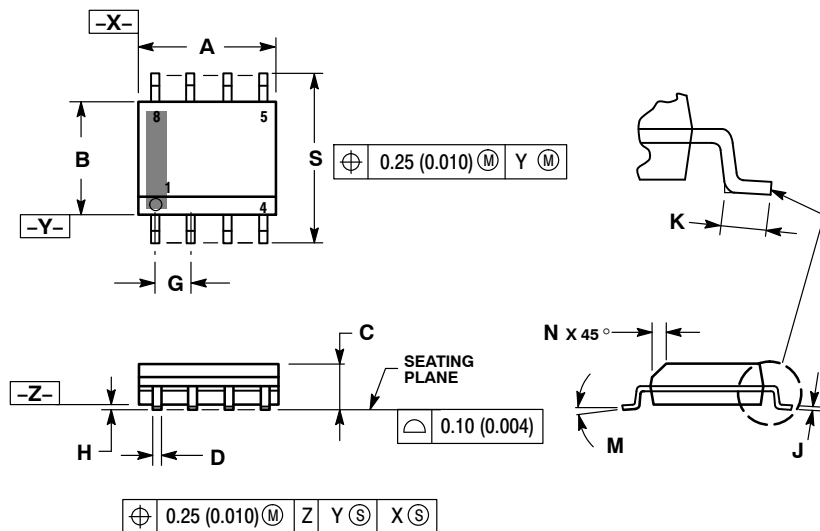
# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS



SCALE 1:1

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CASE 751-07  
ISSUE AK

DATE 16 FEB 2011

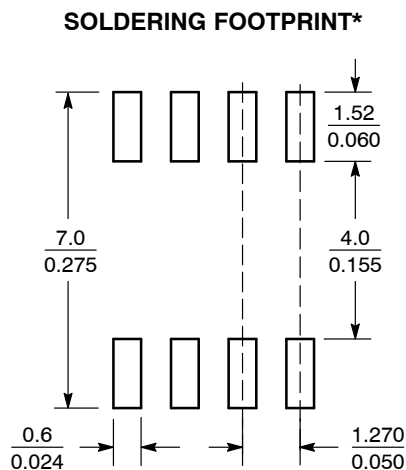


## NOTES:

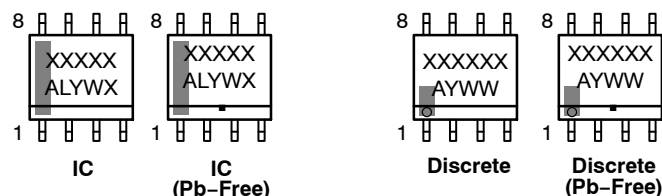
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 4.80        | 5.00 | 0.189     | 0.197 |
| B   | 3.80        | 4.00 | 0.150     | 0.157 |
| C   | 1.35        | 1.75 | 0.053     | 0.069 |
| D   | 0.33        | 0.51 | 0.013     | 0.020 |
| G   | 1.27 BSC    |      | 0.050 BSC |       |
| H   | 0.10        | 0.25 | 0.004     | 0.010 |
| J   | 0.19        | 0.25 | 0.007     | 0.010 |
| K   | 0.40        | 1.27 | 0.016     | 0.050 |
| M   | 0°          | 8°   | 0°        | 8°    |
| N   | 0.25        | 0.50 | 0.010     | 0.020 |
| S   | 5.80        | 6.20 | 0.228     | 0.244 |

## GENERIC MARKING DIAGRAM\*



SCALE 6:1 (mm/inches)



XXXXXX = Specific Device Code  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

XXXXXX = Specific Device Code  
A = Assembly Location  
Y = Year  
WW = Work Week  
▪ = Pb-Free Package

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present. Some products may not follow the Generic Marking.

\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

STYLES ON PAGE 2

|                  |             |                                                                                                                                                                                  |
|------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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**SOIC-8 NB**  
**CASE 751-07**  
**ISSUE AK**

DATE 16 FEB 2011

|                                                                                                                                                                                                   |                                                                                                                                                                                          |                                                                                                                                                                                    |                                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>STYLE 1:</b><br>PIN 1. EMITTER<br>2. COLLECTOR<br>3. COLLECTOR<br>4. EMITTER<br>5. EMITTER<br>6. BASE<br>7. BASE<br>8. EMITTER                                                                 | <b>STYLE 2:</b><br>PIN 1. COLLECTOR, DIE, #1<br>2. COLLECTOR, #1<br>3. COLLECTOR, #2<br>4. COLLECTOR, #2<br>5. BASE, #2<br>6. EMITTER, #2<br>7. BASE, #1<br>8. EMITTER, #1               | <b>STYLE 3:</b><br>PIN 1. DRAIN, DIE #1<br>2. DRAIN, #1<br>3. DRAIN, #2<br>4. DRAIN, #2<br>5. GATE, #2<br>6. SOURCE, #2<br>7. GATE, #1<br>8. SOURCE, #1                            | <b>STYLE 4:</b><br>PIN 1. ANODE<br>2. ANODE<br>3. ANODE<br>4. ANODE<br>5. ANODE<br>6. ANODE<br>7. ANODE<br>8. COMMON CATHODE                                                                           |
| <b>STYLE 5:</b><br>PIN 1. DRAIN<br>2. DRAIN<br>3. DRAIN<br>4. DRAIN<br>5. GATE<br>6. GATE<br>7. SOURCE<br>8. SOURCE                                                                               | <b>STYLE 6:</b><br>PIN 1. SOURCE<br>2. DRAIN<br>3. DRAIN<br>4. SOURCE<br>5. SOURCE<br>6. GATE<br>7. GATE<br>8. SOURCE                                                                    | <b>STYLE 7:</b><br>PIN 1. INPUT<br>2. EXTERNAL BYPASS<br>3. THIRD STAGE SOURCE<br>4. GROUND<br>5. DRAIN<br>6. GATE 3<br>7. SECOND STAGE Vd<br>8. FIRST STAGE Vd                    | <b>STYLE 8:</b><br>PIN 1. COLLECTOR, DIE #1<br>2. BASE, #1<br>3. BASE, #2<br>4. COLLECTOR, #2<br>5. COLLECTOR, #2<br>6. EMITTER, #2<br>7. EMITTER, #1<br>8. COLLECTOR, #1                              |
| <b>STYLE 9:</b><br>PIN 1. EMITTER, COMMON<br>2. COLLECTOR, DIE #1<br>3. COLLECTOR, DIE #2<br>4. EMITTER, COMMON<br>5. EMITTER, COMMON<br>6. BASE, DIE #2<br>7. BASE, DIE #1<br>8. EMITTER, COMMON | <b>STYLE 10:</b><br>PIN 1. GROUND<br>2. BIAS 1<br>3. OUTPUT<br>4. GROUND<br>5. GROUND<br>6. BIAS 2<br>7. INPUT<br>8. GROUND                                                              | <b>STYLE 11:</b><br>PIN 1. SOURCE 1<br>2. GATE 1<br>3. SOURCE 2<br>4. GATE 2<br>5. DRAIN 2<br>6. DRAIN 2<br>7. DRAIN 1<br>8. DRAIN 1                                               | <b>STYLE 12:</b><br>PIN 1. SOURCE<br>2. SOURCE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                                 |
| <b>STYLE 13:</b><br>PIN 1. N.C.<br>2. SOURCE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                              | <b>STYLE 14:</b><br>PIN 1. N-SOURCE<br>2. N-GATE<br>3. P-SOURCE<br>4. P-GATE<br>5. P-DRAIN<br>6. P-DRAIN<br>7. N-DRAIN<br>8. N-DRAIN                                                     | <b>STYLE 15:</b><br>PIN 1. ANODE 1<br>2. ANODE 1<br>3. ANODE 1<br>4. ANODE 1<br>5. CATHODE, COMMON<br>6. CATHODE, COMMON<br>7. CATHODE, COMMON<br>8. CATHODE, COMMON               | <b>STYLE 16:</b><br>PIN 1. EMITTER, DIE #1<br>2. BASE, DIE #1<br>3. EMITTER, DIE #2<br>4. BASE, DIE #2<br>5. COLLECTOR, DIE #2<br>6. COLLECTOR, DIE #2<br>7. COLLECTOR, DIE #1<br>8. COLLECTOR, DIE #1 |
| <b>STYLE 17:</b><br>PIN 1. VCC<br>2. V2OUT<br>3. V1OUT<br>4. TXE<br>5. RXE<br>6. VEE<br>7. GND<br>8. ACC                                                                                          | <b>STYLE 18:</b><br>PIN 1. ANODE<br>2. ANODE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. CATHODE<br>8. CATHODE                                                                 | <b>STYLE 19:</b><br>PIN 1. SOURCE 1<br>2. GATE 1<br>3. SOURCE 2<br>4. GATE 2<br>5. DRAIN 2<br>6. MIRROR 2<br>7. DRAIN 1<br>8. MIRROR 1                                             | <b>STYLE 20:</b><br>PIN 1. SOURCE (N)<br>2. GATE (N)<br>3. SOURCE (P)<br>4. GATE (P)<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                   |
| <b>STYLE 21:</b><br>PIN 1. CATHODE 1<br>2. CATHODE 2<br>3. CATHODE 3<br>4. CATHODE 4<br>5. CATHODE 5<br>6. COMMON ANODE<br>7. COMMON ANODE<br>8. CATHODE 6                                        | <b>STYLE 22:</b><br>PIN 1. I/O LINE 1<br>2. COMMON CATHODE/VCC<br>3. COMMON CATHODE/VCC<br>4. I/O LINE 3<br>5. COMMON ANODE/GND<br>6. I/O LINE 4<br>7. I/O LINE 5<br>8. COMMON ANODE/GND | <b>STYLE 23:</b><br>PIN 1. LINE 1 IN<br>2. COMMON ANODE/GND<br>3. COMMON ANODE/GND<br>4. LINE 2 IN<br>5. LINE 2 OUT<br>6. COMMON ANODE/GND<br>7. COMMON ANODE/GND<br>8. LINE 1 OUT | <b>STYLE 24:</b><br>PIN 1. BASE<br>2. EMITTER<br>3. COLLECTOR/ANODE<br>4. COLLECTOR/ANODE<br>5. CATHODE<br>6. CATHODE<br>7. COLLECTOR/ANODE<br>8. COLLECTOR/ANODE                                      |
| <b>STYLE 25:</b><br>PIN 1. VIN<br>2. N/C<br>3. REXT<br>4. GND<br>5. IOUT<br>6. IOUT<br>7. IOUT<br>8. IOUT                                                                                         | <b>STYLE 26:</b><br>PIN 1. GND<br>2. dv/dt<br>3. ENABLE<br>4. ILIMIT<br>5. SOURCE<br>6. SOURCE<br>7. SOURCE<br>8. VCC                                                                    | <b>STYLE 27:</b><br>PIN 1. ILIMIT<br>2. OVLO<br>3. UVLO<br>4. INPUT+<br>5. SOURCE<br>6. SOURCE<br>7. SOURCE<br>8. DRAIN                                                            | <b>STYLE 28:</b><br>PIN 1. SW_TO_GND<br>2. DASIC_OFF<br>3. DASIC_SW_DET<br>4. GND<br>5. V_MON<br>6. VBULK<br>7. VBULK<br>8. VIN                                                                        |
| <b>STYLE 29:</b><br>PIN 1. BASE, DIE #1<br>2. EMITTER, #1<br>3. BASE, #2<br>4. EMITTER, #2<br>5. COLLECTOR, #2<br>6. COLLECTOR, #2<br>7. COLLECTOR, #1<br>8. COLLECTOR, #1                        | <b>STYLE 30:</b><br>PIN 1. DRAIN 1<br>2. DRAIN 1<br>3. GATE 2<br>4. SOURCE 2<br>5. SOURCE 1/DRAIN 2<br>6. SOURCE 1/DRAIN 2<br>7. SOURCE 1/DRAIN 2<br>8. GATE 1                           |                                                                                                                                                                                    |                                                                                                                                                                                                        |

|                         |                    |                                                                                                                                                                                     |
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