

# NCP5351

## 4 A Synchronous Buck Power MOSFET Driver

The NCP5351 is a dual MOSFET gate driver optimized to drive the gates of both high- and low-side Power MOSFETs in a Synchronous Buck converter. The NCP5351 is an excellent companion to multiphase controllers that do not have integrated gate drivers, such as ON Semiconductor's CS5323, CS5305 or CS5307. This architecture provides a power supply designer the flexibility to locate the gate drivers close to the MOSFETs.

4 Amp drive capability makes the NCP5351 ideal for minimizing switching losses in MOSFETs with large input capacitance. Optimized internal, adaptive nonoverlap circuitry further reduces switching losses by preventing simultaneous conduction of both MOSFETs.

The floating top driver design can accommodate MOSFET drain voltages as high as 25 V. Both gate outputs can be driven low, and supply current reduced to less than 25  $\mu$ A, by applying a low logic level to the Enable (EN) pin. An Undervoltage Lockout function ensures that both driver outputs are low when the supply voltage is low, and a Thermal Shutdown function provides the IC with overtemperature protection.

The NCP5351 is pin-to-pin compatible with the SC1205 and is available in a standard SO-8 package.

### Features

- 4 A Peak Drive Current
- Rise and Fall Times < 15 ns Typical into 6000 pF
- Propagation Delay from Inputs to Outputs < 20 ns
- Adaptive Nonoverlap Time Optimized for Large Power MOSFETs
- Floating Top Driver Accommodates Applications Up to 25 V
- Undervoltage Lockout to Prevent Switching when the Input Voltage is Low
- Thermal Shutdown Protection Against Overtemperature
- < 1 mA Quiescent Current – Enabled
- 25  $\mu$ A Quiescent Current – Disabled
- Internal TG to DRN Pulldown Resistor Prevents HV Supply-Induced Turn On of High-Side MOSFET



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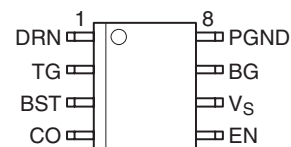
SO-8  
D SUFFIX  
CASE 751

### MARKING DIAGRAM



A = Assembly Location  
WL, L = Wafer Lot  
YY, Y = Year  
WW, W = Work Week

### PIN CONNECTIONS



### ORDERING INFORMATION

Device	Package	Shipping
NCP5351D	SO-8	98 Units/Rail
NCP5351DR2	SO-8	2500 Tape & Reel

# NCP5351

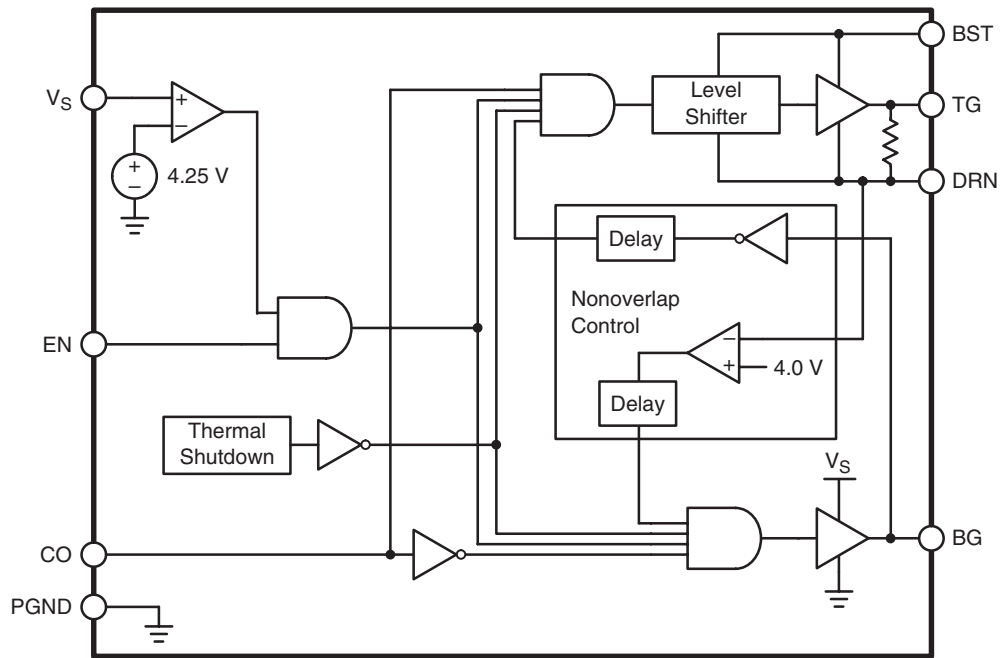


Figure 1. Block Diagram

Table 1. Input-Output Truth Table

EN	CO	DRN	TG	BG
L	X	X	L	L
H	L	< 3.0 V	L	H
H	H	< 3.0 V	H	L
H	L	> 5.0 V	L	L
H	H	> 5.0 V	H	L

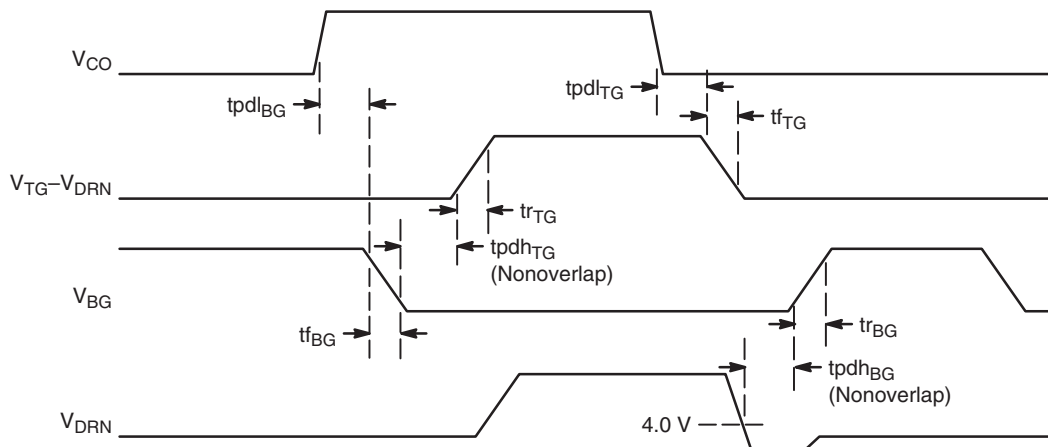


Figure 2. Timing Diagram

# NCP5351

## MAXIMUM RATINGS\*

Rating	Value	Unit
Operating Junction Temperature, $T_J$	Internally Limited	°C
Package Thermal Resistance: Junction to Case, $R_{\theta JC}$ Junction to Ambient, $R_{\theta JA}$	45 165	°C/W °C/W
Storage Temperature Range, $T_S$	-65 to 150	°C
Lead Temperature Soldering: Reflow: (SMD styles only) (Note 1)	230 peak	°C
MSL Rating	1	-

\*The maximum package power dissipation must be observed.

1. 60 seconds maximum above 183°C.

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

## MAXIMUM RATINGS

Pin Symbol	Pin Name	$V_{MAX}$	$V_{MIN}$	$I_{SOURCE}$	$I_{SINK}$
$V_S$	Main Supply Voltage Input	6.3 V	-0.3 V	NA	4.0 A Peak (< 100 $\mu$ s) 250 mA DC
BST	Bootstrap Supply Voltage Input	25 V wrt/PGND 6.3 V wrt/DRN	-0.3 V wrt/DRN	NA	4.0 A Peak (< 100 $\mu$ s) 250 mA DC
DRN	Switching Node (Bootstrap Supply Return)	25 V	-1.0 V DC -5.0 V for 100 ns -6.0 V for 20 ns	4.0 A Peak (< 100 $\mu$ s) 250 mA DC	NA
TG	High-Side Driver Output (Top Gate)	25 V wrt/PGND 6.3 V wrt/DRN	-0.3 V wrt/DRN	4.0 A Peak (< 100 $\mu$ s) 250 mA DC	4.0 A Peak (< 100 $\mu$ s) 250 mA DC
BG	Low-Side Driver Output (Bottom Gate)	6.3 V	-0.3 V	4.0 A Peak (< 100 $\mu$ s) 250 mA DC	4.0 A Peak (< 100 $\mu$ s) 250 mA DC
CO	TG & BG Control Input	6.3 V	-0.3 V	1.0 mA	1.0 mA
EN	Enable Input	6.3 V	-0.3 V	1.0 mA	1.0 mA
PGND	Ground	0 V	0 V	4.0 A Peak (< 100 $\mu$ s) 250 mA DC	NA

NOTE: All voltages are with respect to PGND except where noted.

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## ELECTRICAL CHARACTERISTICS (0°C < T<sub>J</sub> < 125°C; V<sub>S</sub> = 5.0 V; 4.0 V < V<sub>BST</sub> < 25 V; V<sub>EN</sub> = V<sub>S</sub>; unless otherwise noted.)

Parameter	Test Conditions	Min	Typ	Max	Unit
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### DC OPERATING SPECIFICATIONS

#### Power Supply

V <sub>S</sub> Quiescent Current, Operating	V <sub>CO</sub> = 0 V, 4.5 V; No output switching	–	1.0	–	mA
V <sub>BST</sub> Quiescent Current, Operating	V <sub>CO</sub> = 0 V, 4.5 V; No output switching	–	50	–	μA
Quiescent Current, Non-Operating	V <sub>EN</sub> = 0 V; V <sub>CO</sub> = 0 V, 4.5 V	–	–	25	μA

#### Undervoltage Lockout

Start Threshold	CO = 0 V	4.05	4.25	4.48	V
Hysteresis	CO = 0 V	–	275	–	mV

#### CO Input Characteristics

High Threshold	–	2.0	–	–	V
Low Threshold	–	–	–	0.8	V
Input Bias Current	0 < V <sub>CO</sub> < V <sub>S</sub>	–	0	1.0	μA

#### EN Input Characteristics

High Threshold	Both outputs respond to CO	2.0	–	–	V
Low Threshold	Both outputs are low, independent of CO	–	–	0.8	V
Input Bias Current	0 < V <sub>EN</sub> < V <sub>S</sub>	–	0	10	μA

#### Thermal Shutdown

Overtemperature Trip Point	–	–	170	–	°C
Hysteresis	–	–	30	–	°C

#### High-Side Driver

Peak Output Current	–	–	4.0	–	A
Output Resistance (Sourcing)	Duty Cycle < 2.0%, Pulse Width < 100 μs, T <sub>J</sub> = 125°C, V <sub>BST</sub> – V <sub>DNRN</sub> = 4.5 V, V <sub>TG</sub> = 4.0 V + V <sub>DNRN</sub>	–	0.5	–	Ω
Output Resistance (Sinking)	Duty Cycle < 2.0%, Pulse Width < 100 μs, T <sub>J</sub> = 125°C, V <sub>BST</sub> – V <sub>DNRN</sub> = 4.5 V, V <sub>TG</sub> = 0.5 V + V <sub>DNRN</sub>	–	0.42	–	Ω

#### Low-Side Driver

Peak Output Current	–	–	4.0	–	A
Output Resistance (Sourcing)	Duty Cycle < 2.0%, Pulse Width < 100 μs, T <sub>J</sub> = 125°C, V <sub>S</sub> = 4.5 V, V <sub>BG</sub> = 4.0 V	–	0.6	–	Ω
Output Resistance (Sinking)	Duty Cycle < 2.0%, Pulse Width < 100 μs, T <sub>J</sub> = 125°C, V <sub>S</sub> = 4.5 V, V <sub>BG</sub> = 0.5 V	–	0.42	–	Ω

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**ELECTRICAL CHARACTERISTICS (continued)** ( $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ;  $V_S = 5.0\text{ V}$ ;  $4.0\text{ V} < V_{\text{BST}} < 25\text{ V}$ ;  $V_{\text{EN}} = V_S$ ,  $C_{\text{LOAD}} = 5.7\text{ nF}$ ; unless otherwise noted.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
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## AC OPERATING SPECIFICATIONS

### High-Side Driver

Rise Time	$t_{\text{rTG}}$	$V_{\text{BST}} - V_{\text{DRN}} = 5.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	–	8.0	16	ns
Fall Time	$t_{\text{fTG}}$	$V_{\text{BST}} - V_{\text{DRN}} = 5.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	–	14	21	ns
Propagation Delay Time, TG Going High (Nonoverlap Time)	$t_{\text{pdhTG}}$	$V_{\text{BST}} - V_{\text{DRN}} = 5.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	30	45	60	ns
Propagation Delay Time, TG Going Low	$t_{\text{pdlTG}}$	$V_{\text{BST}} - V_{\text{DRN}} = 5.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	–	18	37	ns

### Low-Side Driver

Rise Time	$t_{\text{rBG}}$	$T_J = 125^{\circ}\text{C}$	–	10	15	ns
Fall Time	$t_{\text{fBG}}$	$T_J = 125^{\circ}\text{C}$	–	12	20	ns
Propagation Delay Time, BG Going High (Non-Overlap Time)	$t_{\text{pdhBG}}$	$T_J = 125^{\circ}\text{C}$	25	55	80	ns
Propagation Delay Time, BG Going Low	$t_{\text{pdlBG}}$	$T_J = 125^{\circ}\text{C}$	–	10	18	ns

### Undervoltage Lockout

$V_S$ Rising	$t_{\text{pdhUVLO}}$	$V_{\text{EN}} = V_S$ , $\text{CO} = 0\text{ V}$ , $dV_S/dt > 1.0\text{ V}/\mu\text{s}$ , from $4.0\text{ V}$ to $4.5\text{ V}$ , time to BG $> 1.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	–	30	–	$\mu\text{s}$
$V_S$ Falling	$t_{\text{pdlUVLO}}$	$V_{\text{EN}} = V_S$ , $\text{CO} = 0\text{ V}$ , $dV_S/dt < -1.0\text{ V}/\mu\text{s}$ , from $4.5\text{ V}$ to $4.0\text{ V}$ , time to BG $< 1.0\text{ V}$ , $T_J = 125^{\circ}\text{C}$	–	500	–	$\mu\text{s}$

## PACKAGE PIN DESCRIPTION

Pin Number	Pin Symbol	Description
1	DRN	The switching node common to the high and low-side FETs. The high-side (TG) driver and supply (BST) are referenced to this pin.
2	TG	Driver output to the high-side MOSFET gate.
3	BST	Bootstrap supply voltage input. In conjunction with a Schottky diode to $V_S$ , a $0.1\text{ }\mu\text{F}$ to $1.0\text{ }\mu\text{F}$ ceramic capacitor connected between BST and DRN develops supply voltage for the high-side driver (TG).
4	CO	Logic level control input produces complementary output states – no inversion at TG; inversion at BG.
5	EN	Logic level enable input forces TG and BG low, and supply current to $10\text{ }\mu\text{A}$ when EN is low.
6	$V_S$	Power supply input. A $0.1\text{ }\mu\text{F}$ to $1.0\text{ }\mu\text{F}$ ceramic capacitor should be connected from this pin to PGND.
7	BG	Driver output to the low-side (synchronous rectifier) MOSFET gate.
8	PGND	Ground.

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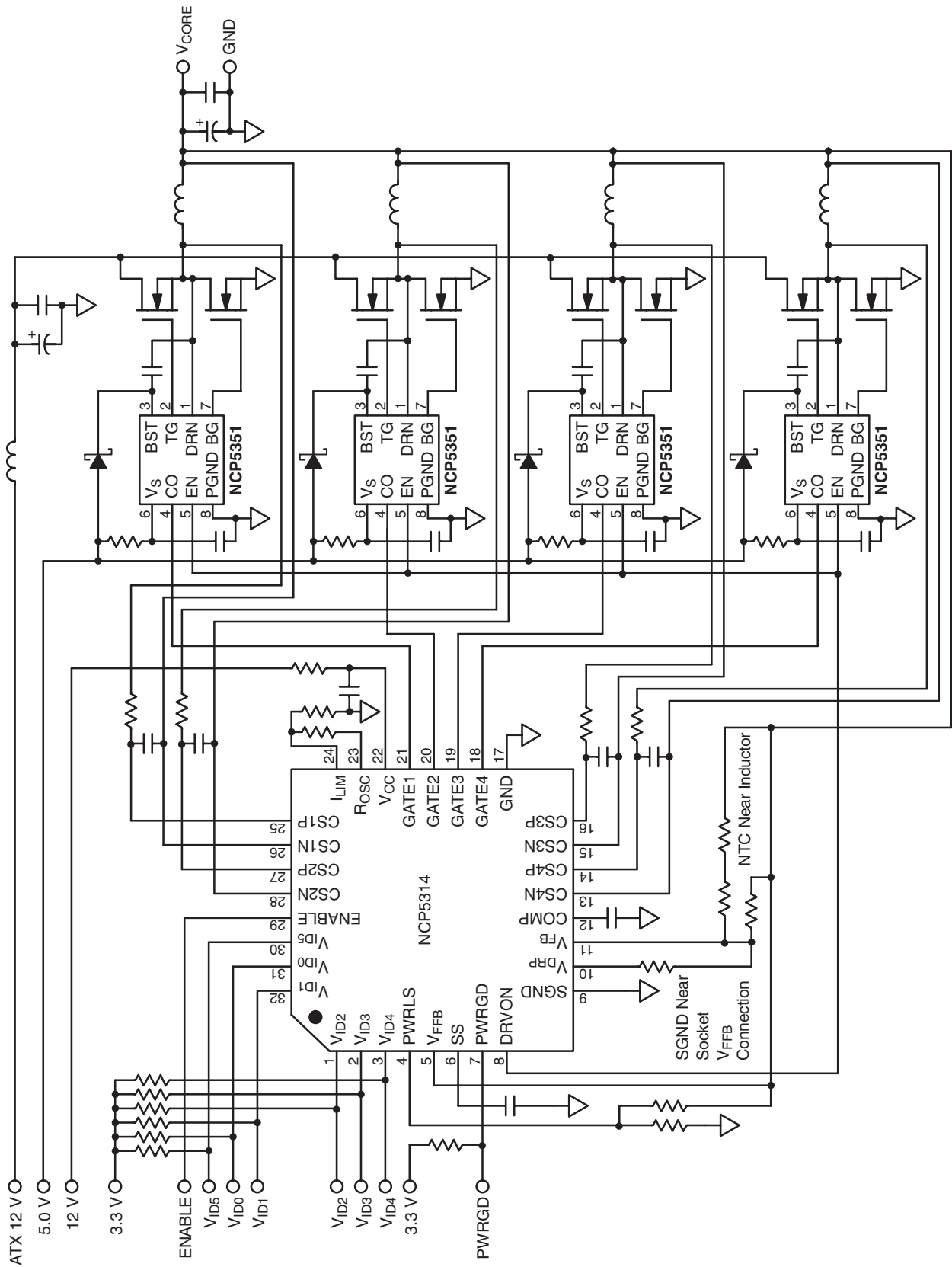


Figure 3. Application Diagram

APPLICATIONS INFORMATION

Theory Of Operation

Enable Pin

The Enable pin is controlled by a logic level input. With a logic level high on the EN pin, the output states of the drivers are controlled by applying a logic level voltage to the CO pin. With a logic level low both gates are forced low. By bringing both gates low when disabling, the output voltage is prevented from ringing below ground, which could potentially cause damage to the microprocessor or the device being powered.

Undervoltage Lockout

The TG and BG are held low until  $V_S$  reaches 4.25 V during startup. The CO pin takes control of the gates' states when the  $V_S$  threshold is exceeded. If  $V_S$  decreases 300 mV below threshold, the output gate will be forced low and remain low until  $V_S$  rises above startup threshold.

Adaptive Nonoverlap

The Adaptive Nonoverlap prevents a condition where the top and bottom MOSFETs conduct at the same time and short the input supply. When the top MOSFET is turning off,

the drain (switch node) is sampled and the BG is disabled for a fixed delay time ( $tpdh_{BG}$ ) after the drain drops below 4 V, thus eliminating the possibility of shoot-through. When the bottom MOSFET is turning off, TG is disabled for a fixed delay ( $tpdh_{TG}$ ) after BG drops below 2 V. (See Figure 2 for complete timing information).

Layout Guidelines

When designing any switching regulator, the layout is very important for proper operation. The designer should follow some simple layout guidelines when incorporating gate drivers in their designs. Gate drives experience high di/dt during switching and the inductance of gate drive traces should be minimized. Gate drive traces should be kept as short and wide as practical and should have a return path directly below the gate trace. The use of a ground plane is a desirable way to return ground signals. Also, component location will make a difference. The boost and the  $V_S$  capacitor are the most critical and should be placed as close as possible to the driver IC pins, as shown in Figure 4(a), C21 and C17.

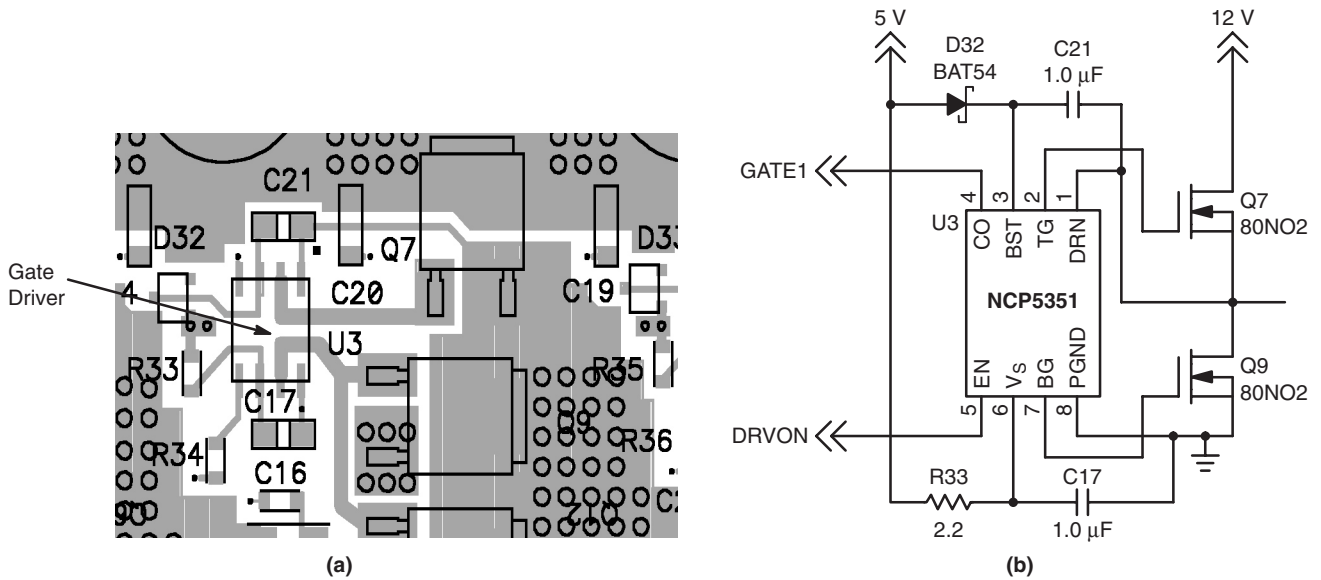
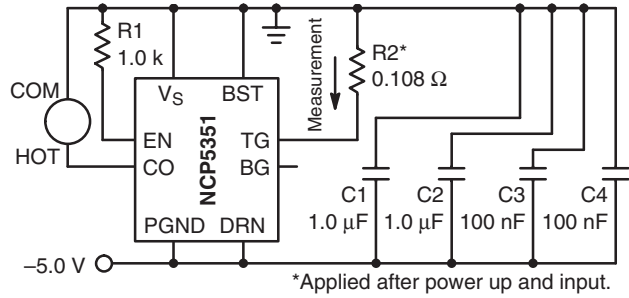
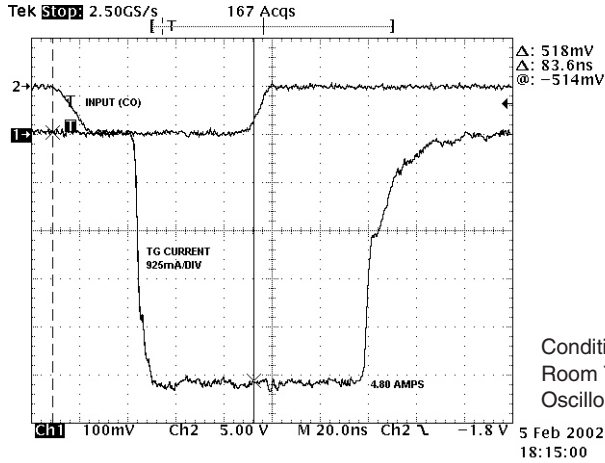


Figure 4. Proper Layout (a), Component Selection (b)

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## TYPICAL PERFORMANCE CHARACTERISTICS



Conditions: BST – DRN = 5.0 V;  
Room Temperature;  
Oscilloscope referenced to  $V_S$  (5.0 V).

Figure 5. Top Gate Sinking Current from 0.108  $\Omega$

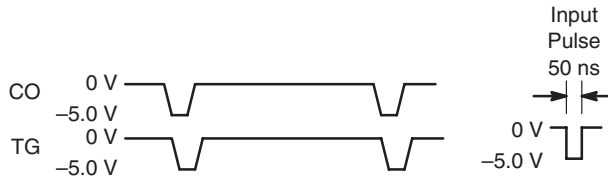
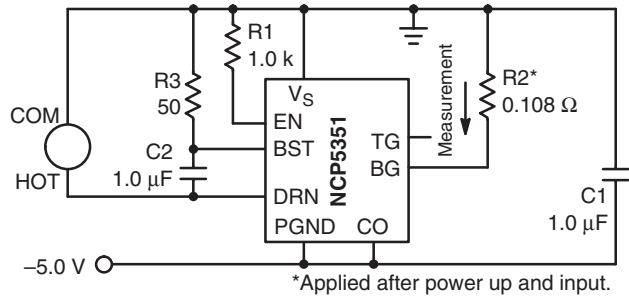
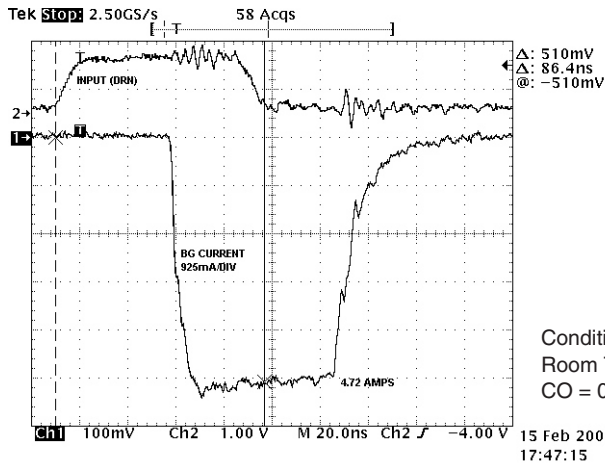


Figure 6. Top Gate Sinking



Conditions:  $V_S$  = 5.0 V;  
Room Temperature;  
CO = 0 V.

Figure 7. Bottom Gate Sinking Current from 0.108  $\Omega$

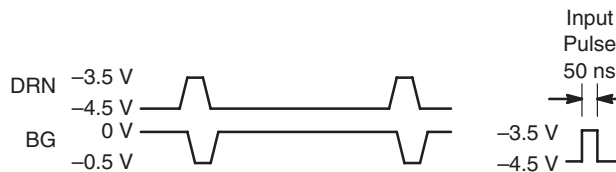


Figure 8. Bottom Gate Sinking



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## TYPICAL PERFORMANCE CHARACTERISTICS

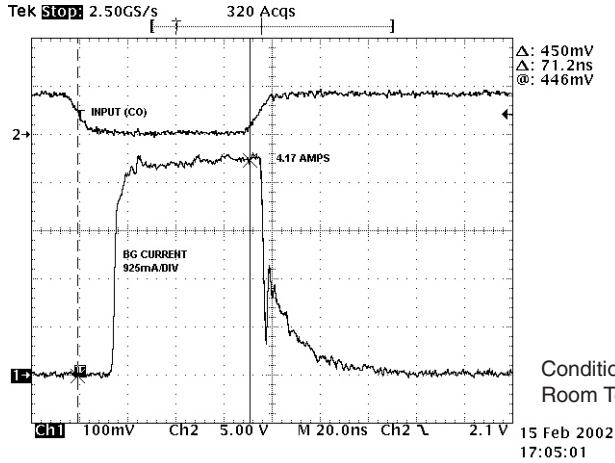


Figure 9. Bottom Gate Sourcing Current into  $0.108\ \Omega$

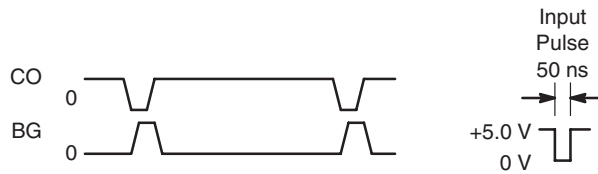
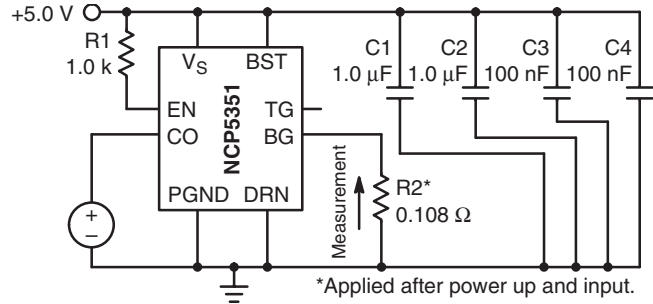


Figure 10. Bottom Gate Sourcing

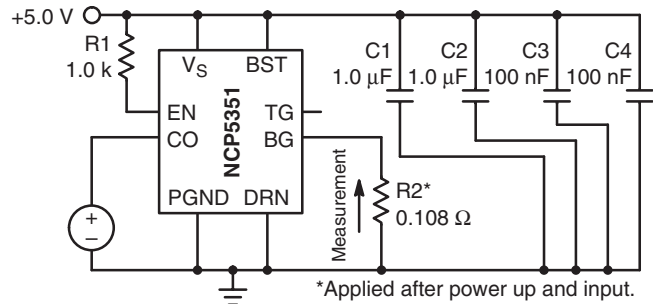
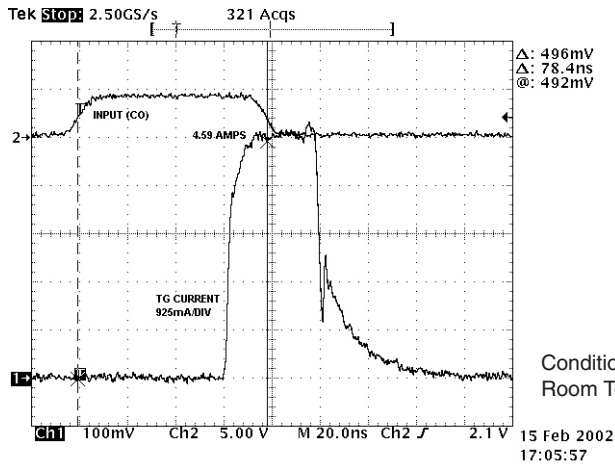


Figure 11. Top Gate Sourcing Current into  $0.108\ \Omega$

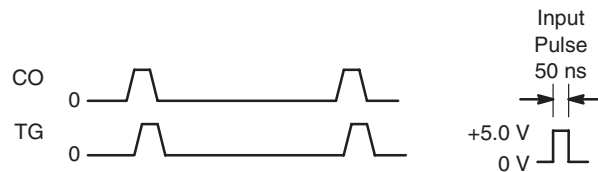


Figure 12. Top Gate Sourcing

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## TYPICAL PERFORMANCE CHARACTERISTICS

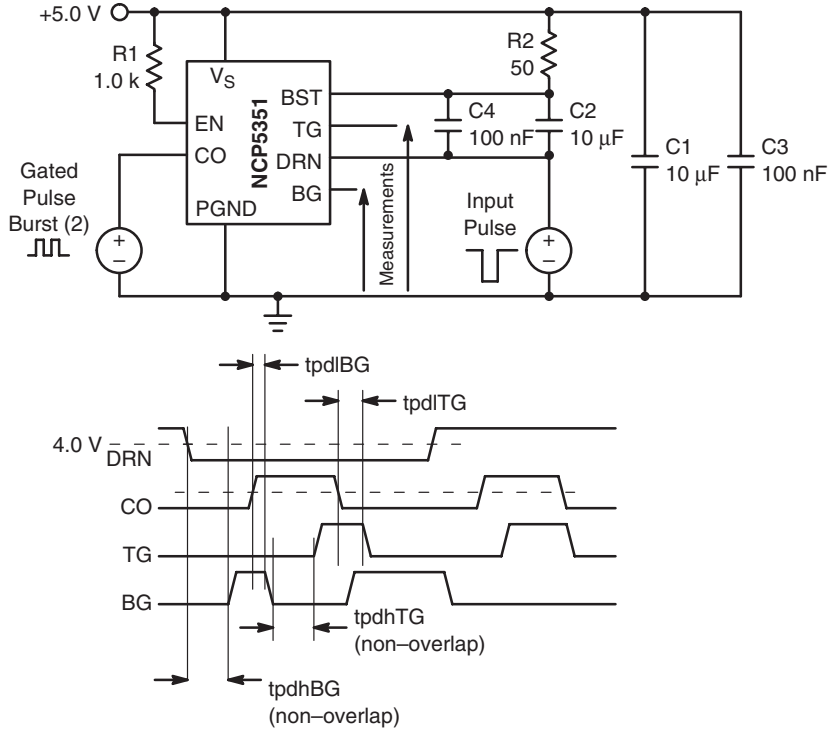
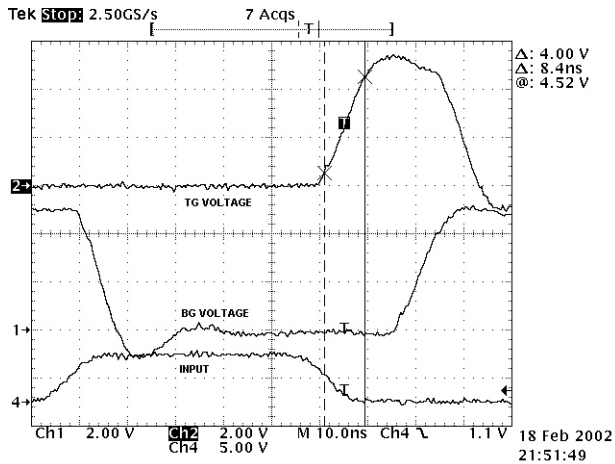
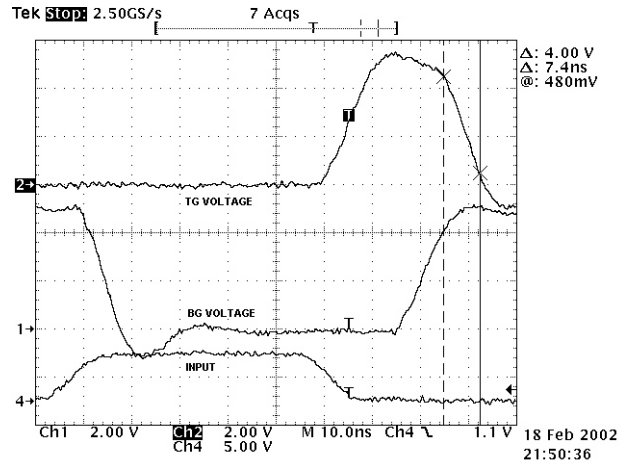


Figure 13. Nonoverlap Test Configuration



Conditions:  $V_S = 5.0\text{ V}$ ;  $BST - DRN = 5.0\text{ V}$ ;  $C_{LOAD} = 5.7\text{ nF}$ ; Room Temperature.

Figure 14. Top Gate Rise Time

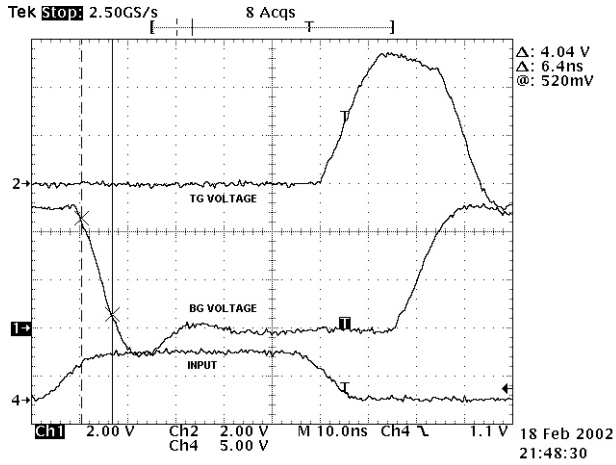


Conditions:  $V_S = 5.0\text{ V}$ ;  $BST - DRN = 5.0\text{ V}$ ;  $C_{LOAD} = 5.7\text{ nF}$ ; Room Temperature.

Figure 15. Top Gate Fall Time

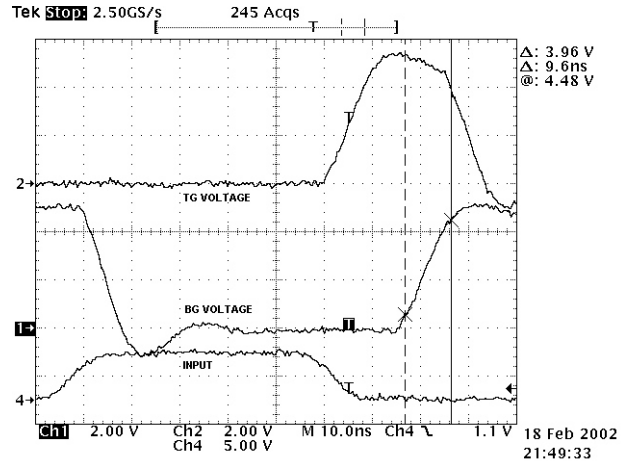
# NCP5351

## TYPICAL PERFORMANCE CHARACTERISTICS



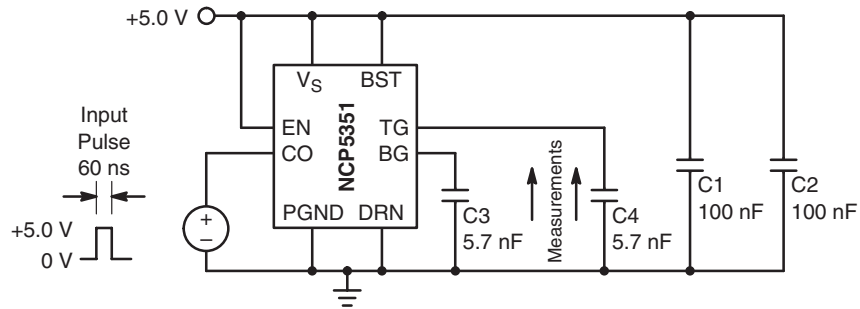
Conditions:  $V_S = 5.0\text{ V}$ ;  $BST - DRN = 5.0\text{ V}$ ;  $C_{LOAD} = 5.7\text{ nF}$ ; Room Temperature.

**Figure 16. Bottom Gate Fall Time**



Conditions:  $V_S = 5.0\text{ V}$ ;  $BST - DRN = 5.0\text{ V}$ ;  $C_{LOAD} = 5.7\text{ nF}$ ; Room Temperature.

**Figure 17. Bottom Gate Rise Time**

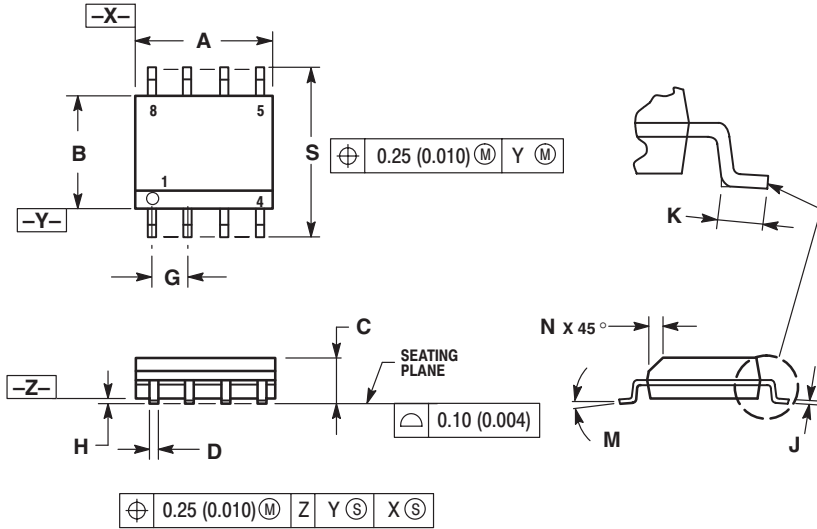


**Figure 18. Bottom Gate and Top Gate Rise/Fall Time Test**

# NCP5351

## PACKAGE DIMENSIONS


SO-8  
D SUFFIX  
CASE 751-07  
ISSUE AA



### 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

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