

# 3A Ultra-Small Low Ron and Controlled Load Switch with Auto-Discharge Path

## NCP451

The NCP451 is a very low Ron MOSFET controlled by external logic pin, allowing optimization of battery life, and portable device autonomy.

Indeed, due to a current consumption optimization with NMOS structure, leakage currents are eliminated by isolating connected IC on the battery when not used.

Output discharge path is also embedded to eliminate residual voltages on the output rail.

Proposed in a wide input voltage range from 0.75 V to 5.5 V, in a small 0.9 x 1.4 mm WLCSP6, pitch 0.5 mm.

### Features

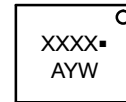
- 0.75 V – 5.5 V Operating Range
- 12 mΩ N MOSFET from 3.6 V to 5.5 V
- 13 mΩ N MOSFET from 1 V to 3.3 V
- DC Current Up to 3 A
- Output Auto-Discharge
- Active High EN Pin
- WLCSP6 0.9 x 1.4 mm
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

### Typical Applications

- Mobile Phones
- Tablets
- Digital Cameras
- GPS
- Portable Devices

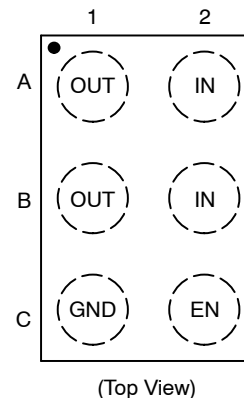


### MARKING DIAGRAM



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

### PINOUT DIAGRAM



### ORDERING INFORMATION

See detailed ordering, marking and shipping information on page 10 of this data sheet.

## NCP451

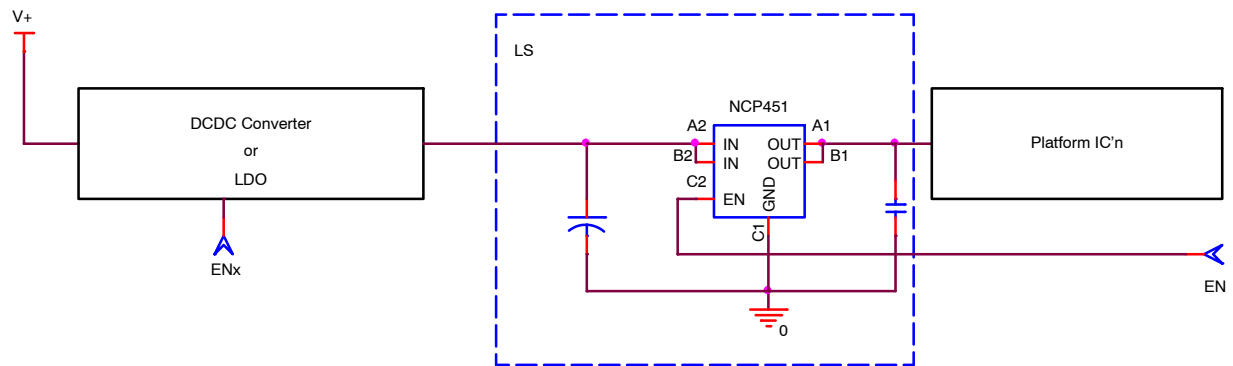


Figure 1. Typical Application Circuit

### PIN FUNCTION DESCRIPTION

Pin Name	Pin Number	Type	Description
IN	A2, B2	POWER	Load-switch input voltage; connect a 1 $\mu$ F or greater ceramic capacitor from IN to GND as close as possible to the IC.
GND	C1	POWER	Ground connection.
EN	C2	INPUT	Enable input, logic high turns on power switch.
OUT	A1, B1	OUTPUT	Load-switch output; connect a 1 $\mu$ F ceramic capacitor from OUT to GND as close as possible to the IC is recommended.

### BLOCK DIAGRAM

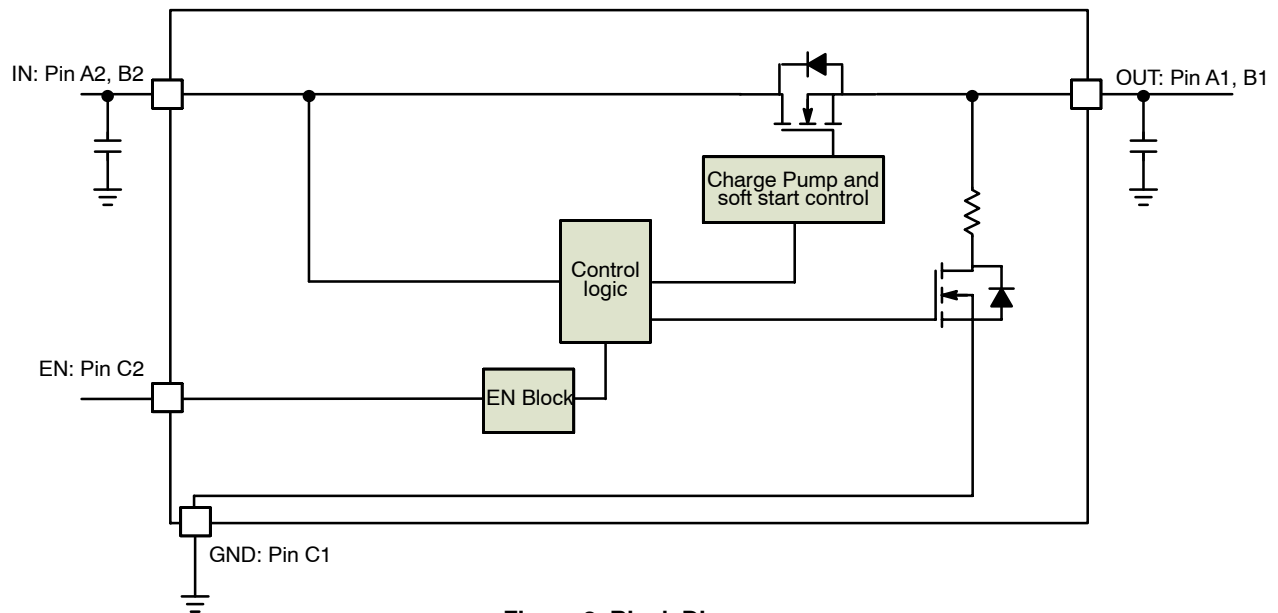


Figure 2. Block Diagram

# NCP451

## MAXIMUM RATINGS

Symbol	Rating	Value	Unit
IN, OUT, EN, Pins: (Note 1)	$V_{EN}, V_{IN}, V_{OUT}$	-0.3 to + 7.0	V
From IN to OUT Pins: Input/Output (Note 1)	$V_{IN}, V_{OUT}$	0 to + 7.0	V
Human Body Model (HBM) ESD Rating are (Notes 1 and 2)	ESD HBM	1.5	kV
Machine Model (MM) ESD Rating are (Notes 1 and 2)	ESD MM	250	V
Charge Device Model (CDM) ESD Rating are (Notes 1 and 2)	ESD CDM	2000	V
Latch-up protection (Note 3) -Pins IN, OUT, EN	LU	100	mA
Maximum Junction Temperature	$T_J$	-40 to + 125	°C
Storage Temperature Range	$T_{STG}$	-40 to + 150	°C
Moisture Sensitivity (Note 4)	MSL	Level 1	

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. According to JEDEC standard JESD22-A108.
2. This device series contains ESD protection and passes the following tests:  
Human Body Model (HBM)  $\pm 1.5$  kV per JEDEC standard: JESD22-A114 for all pins.  
Machine Model (MM)  $\pm 250$  V per JEDEC standard: JESD22-A115 for all pins.  
Charge Device Model (CDM)  $\pm 2.0$  kV per JEDEC standard: JESD22-C101 for all pins.
3. Latchup Current Maximum Rating:  $\pm 100$  mA per JEDEC standard: JESD78 class II.
4. Moisture Sensitivity Level (MSL): 1 per IPC/JEDEC standard: J-STD-020.

## OPERATING CONDITIONS

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IN}$	Operational Power Supply		0.75		5.5	V
$V_{EN}$	Enable Voltage		0		5.5	V
$T_A$	Ambient Temperature Range		-40	25	+85	°C
$T_J$	Junction Temperature Range		-40	25	+125	°C
$C_{IN}$	Decoupling input capacitor		1			$\mu F$
$C_{OUT}$	Decoupling output capacitor		0.1			$\mu F$
$R_{\theta JA}$	Thermal Resistance Junction to Air	(Note 5)		100		°C/W
$I_{OUT}$	Maximum DC current				3	A
$P_D$	Power Dissipation Rating (Note 6)	Over temperature		0.315		W

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.

5. The  $R_{\theta JA}$  is dependent of the PCB heat dissipation and thermal via.
6. The maximum power dissipation ( $P_D$ ) is given by the following formula:

$$P_D = \frac{T_{JMAX} - T_A}{R_{\theta JA}}$$

# NCP451

**ELECTRICAL CHARACTERISTICS** Min & Max Limits apply for  $T_A$  between  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for  $V_{IN}$  between 0.75 V to 5.0 V (Unless otherwise noted). Typical values are referenced to  $T_A = +25^{\circ}\text{C}$  and  $V_{IN} = 3.6\text{ V}$  (Unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>POWER SWITCH</b>						
$R_{DS(on)}$	Static drain-source on-state resistance	$V_{IN} = 5\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		12	20
			$T_J = 125^{\circ}\text{C}$			25
		$V_{IN} = 3.6\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		12	20
			$T_J = 125^{\circ}\text{C}$			25
		$V_{IN} = 3.3\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		13	24
			$T_J = 125^{\circ}\text{C}$			28
		$V_{IN} = 2.5\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		13	24
			$T_J = 125^{\circ}\text{C}$			28
		$V_{IN} = 1.8\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		13	24
			$T_J = 125^{\circ}\text{C}$			28
		$V_{IN} = 1.0\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		13	24
			$T_J = 125^{\circ}\text{C}$			28
		$V_{IN} = 0.75\text{ V}$	$I_{OUT} = 200\text{ mA}, T_A = 25^{\circ}\text{C}$		15	28
			$T_J = 125^{\circ}\text{C}$			35
$R_{dis}$	Output discharge path	EN = low	NCP451		1.2	1.7
			NCP451A		1.0	1.7
$V_{IH}$	High-level input voltage			0.8		V
$V_{IL}$	Low-level input voltage				0.4	
$I_{EN}$	EN pin leakage current	$V_{IN} = 3.6\text{ V}$			0.1	$\mu\text{A}$

## QUIESCENT CURRENT

$I_{std}$	Standby current	$V_{IN} = 4.2\text{ V}$	EN = low, No load		0.9	2	$\mu\text{A}$
$I_q$	Quiescent current	$V_{IN} = 3.6\text{ V}$ $V_{IN} = 2.5\text{ V}$ $V_{IN} = 1.8\text{ V}$ $V_{IN} = 1.2\text{ V}$ $V_{IN} = 1.0\text{ V}$ $V_{IN} = 0.75\text{ V}$	EN = high, No load (Note 7)		8	15	$\mu\text{A}$

## TIMINGS

$T_{EN}$	Enable time	$V_{IN} = 3.6\text{ V}$ (Note 8)	$R_L = 25\ \Omega, C_{OUT} = 1\ \mu\text{F}$		600		$\mu\text{s}$
$T_R$	Output rise time		$R_L = 25\ \Omega, C_{OUT} = 1\ \mu\text{F}$		800		
$T_{ON}$	ON time ( $T_{EN} + T_R$ )		$R_L = 25\ \Omega, C_{OUT} = 1\ \mu\text{F}$		1400		
$T_F$	Output fall time		$R_L = 25\ \Omega, C_{OUT} = 1\ \mu\text{F}$		55		

## TIMINGS

$T_{EN}$	Enable time	$V_{IN} = 3.6\text{ V}$ (Note 8)	$R_L = 10\ \Omega, C_{OUT} = 0.1\ \mu\text{F}$		540		$\mu\text{s}$
$T_R$	Output rise time		$R_L = 10\ \Omega, C_{OUT} = 0.1\ \mu\text{F}$		670		
$T_{ON}$	ON time ( $T_{EN} + T_R$ )		$R_L = 10\ \Omega, C_{OUT} = 0.1\ \mu\text{F}$		1210		
$T_F$	Output fall time		$R_L = 10\ \Omega, C_{OUT} = 0.1\ \mu\text{F}$		2.5		

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.

7. Production tested at  $V_{IN} = 3.6\text{ V}$ .

8. Parameters are guaranteed for  $C_{LOAD}$  and  $R_{LOAD}$  connected to the OUT pin with respect to the ground

# NCP451

## TIMINGS

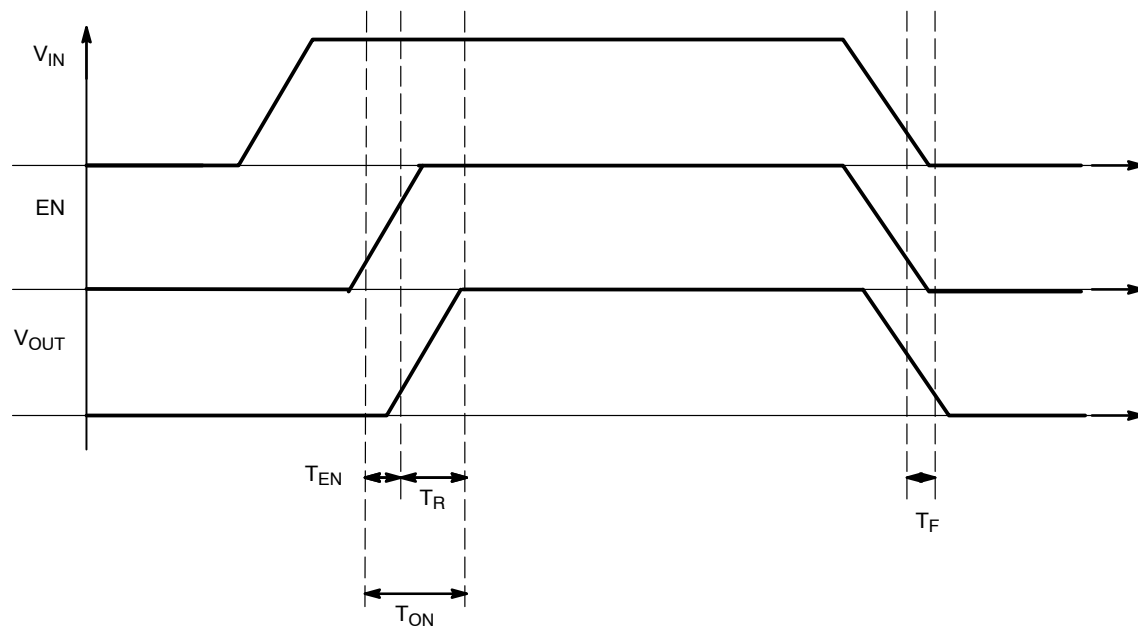


Figure 3. Enable, Rise and Fall Time

ELECTRICAL CURVES

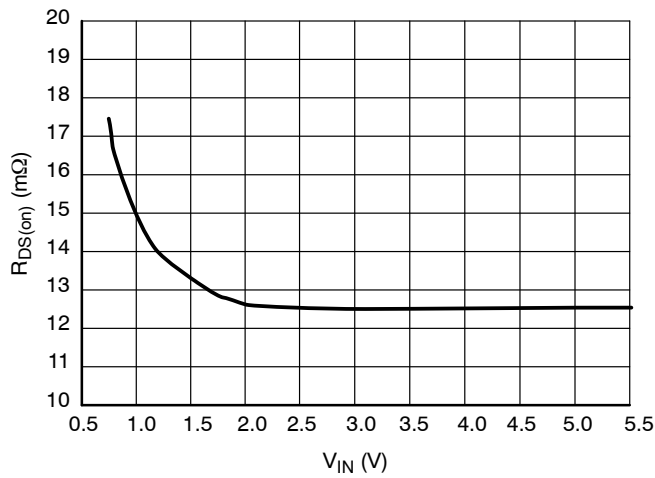


Figure 4.  $R_{DS(on)}$  vs.  $V_{IN}$ , Low Load

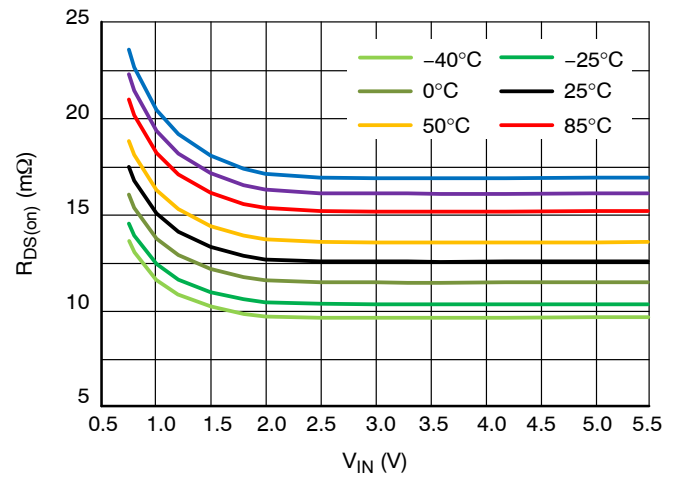


Figure 5.  $R_{DS(on)}$  vs.  $V_{IN}$ , Low Load, Multi Temperature

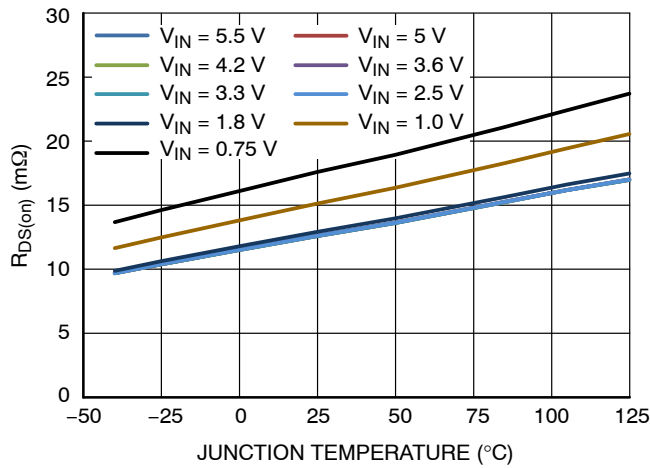


Figure 6.  $R_{DS(on)}$  vs. Temperature, Multi  $V_{IN}$  Voltage

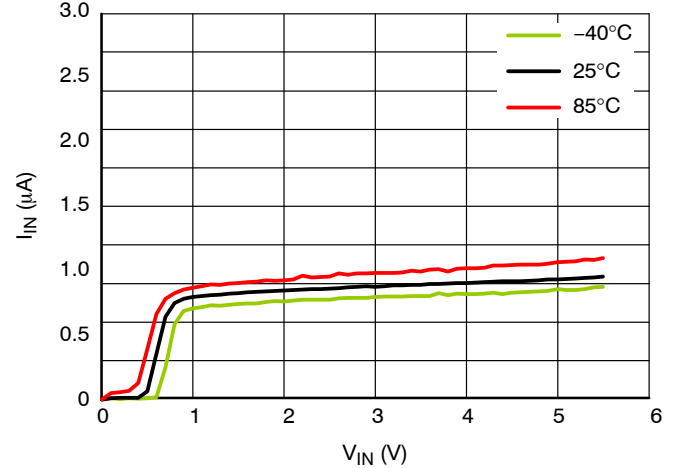


Figure 7. Standby Current ( $\mu A$ ) vs. Temperature

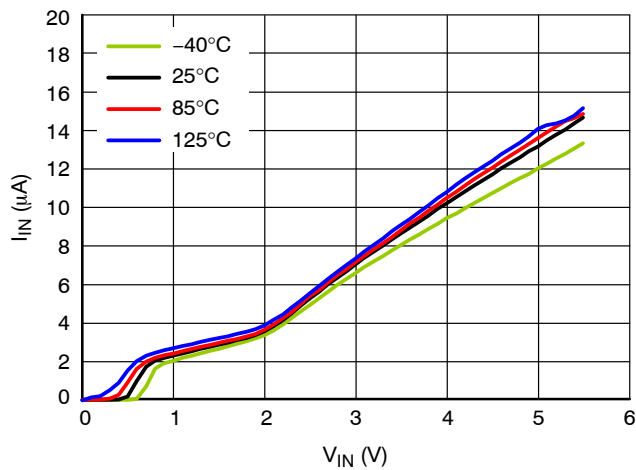


Figure 8. Quiescent Current ( $\mu A$ ) vs. Temperature

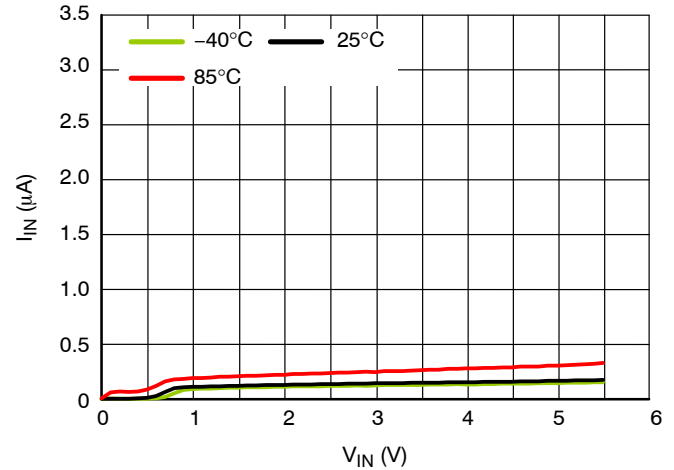
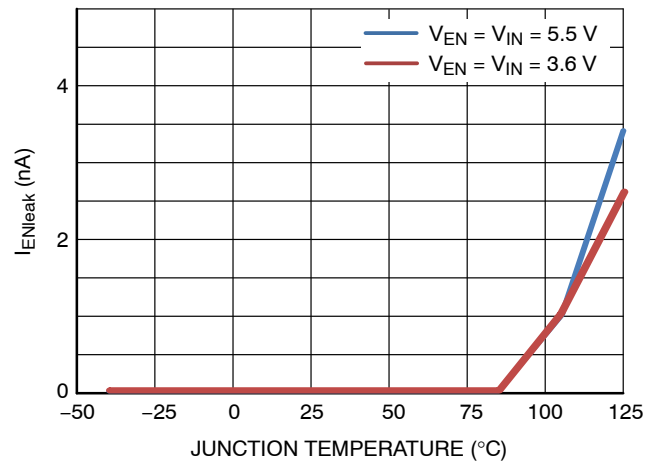


Figure 9. MOSFET Leakage Current ( $\mu A$ ) vs. Temperature

# NCP451

## ELECTRICAL CURVES



**Figure 10. EN Pin Leakage vs. Temperature**

## FUNCTIONAL DESCRIPTION

### Overview

The NCP451 is a high side N channel MOSFET power distribution switch designed to isolate ICs connected on the battery in order to save energy. The part can be turned on, with a wide range of battery from 0.75 V to 5.5 V.

### Enable Input

Enable pin is an active high. The path is opened when EN pin is tied low (disable), forcing N-MOSFET switch off.

The IN/OUT path is activated with a minimum of  $V_{IN}$  of 0.75 V and EN forced to high level.

### Auto Discharge

N-MOSFET is placed between the output pin and GND, in order to discharge the application capacitor connected on OUT pin.

The auto-discharge is activated when EN pin is set to low level (disable state).

The discharge path (Pull down NMOS) stays activated as long as EN pin is set at low level and  $V_{IN} > 0.75$  V.

In order to limit the current across the internal discharge N-MOSFET, the typical value is set at  $R_{DIS}$ .

### $C_{IN}$ and $C_{OUT}$ Capacitors

IN and OUT, 1  $\mu$ F, at least, capacitors must be placed as close as possible the part to for stability improvement.

## APPLICATION INFORMATION

### Power Dissipation

Main contributor in term of junction temperature is the power dissipation of the power MOSFET. Assuming this, the power dissipation and the junction temperature in normal mode can be calculated with the following equations:

$$P_D = R_{DS(on)} \times (I_{OUT})^2$$

$P_D$  = Power dissipation (W)

$R_{DS(on)}$  = Power MOSFET on resistance ( $\Omega$ )

$I_{OUT}$  = Output current (A)

$$T_J = P_D \times R_{\theta JA} + T_A$$

$T_J$  = Junction temperature ( $^{\circ}$ C)

$R_{\theta JA}$  = Package thermal resistance ( $^{\circ}$ C/W)

$T_A$  = Ambient temperature ( $^{\circ}$ C)

### PCB Recommendations

The NCP451 integrates an up to 3 A rated NMOS FET, and the PCB design rules must be respected to properly evacuate the heat out of the silicon. By increasing PCB area, especially around IN and OUT pins, the  $R_{\theta JA}$  of the package can be decreased, allowing higher power dissipation.

Routing example: 2 oz, 4 layers with vias across 2 internal inners.

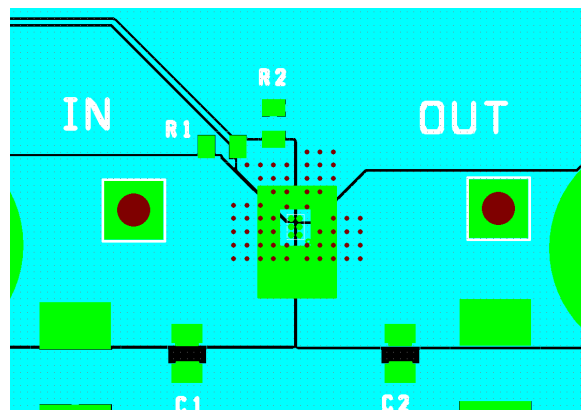


Figure 11.

Example of application definition.

$$T_J - T_A = R_{\theta JA} \times R_{DS(on)} \times I^2$$

$T_J$ : junction temperature.

$T_A$ : ambient temperature.

$R_{\theta JA}$ : Thermal resistance between IC and air, through PCB.

$R_{DS(on)}$ : intrinsic resistance of the IC MOSFET.

$I$ : load DC current.



## NCP451

Taking into account of  $R_{\theta JA}$  obtain with:

1 oz, 2 layers:  $100^{\circ}\text{C/W}$ .

At 3 A,  $25^{\circ}\text{C}$  ambient temperature,  $R_{DS(on)}$   $20\text{ m}\Omega$  @  $V_{IN}$  5 V, the junction temperature will be:

$$T_J - T_A = R_{\theta JA} \times P_D = 25 + (0.02 \times 3^2) \times 100 = 43^{\circ}\text{C}$$

Taking into account of  $R_{\theta JA}$  obtain with:

2 oz, 4 layers:  $60^{\circ}\text{C/W}$ .

At 3 A,  $65^{\circ}\text{C}$  ambient temperature,  $R_{DS(on)}$   $24\text{ m}\Omega$  @  $V_{IN}$  5 V, the junction temperature will be:

$$T_J = T_A + R_{\theta JA} \times P_D = 65 + (0.024 \times 3^2) \times 60 = 78^{\circ}\text{C}$$

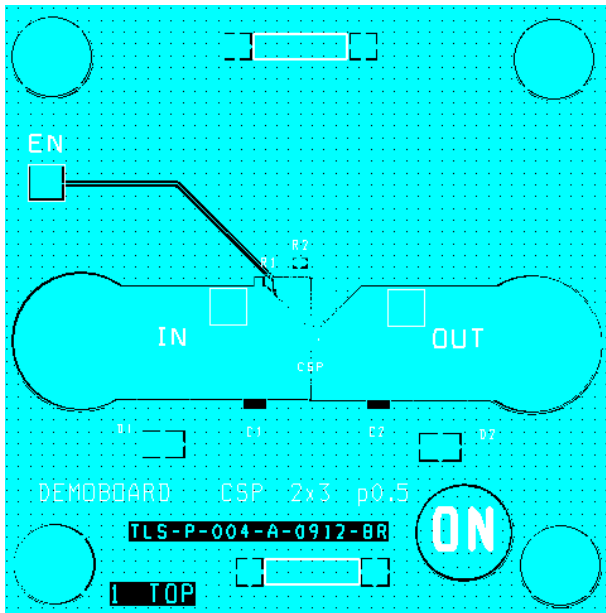


Figure 12. Demoboard PCB Top View

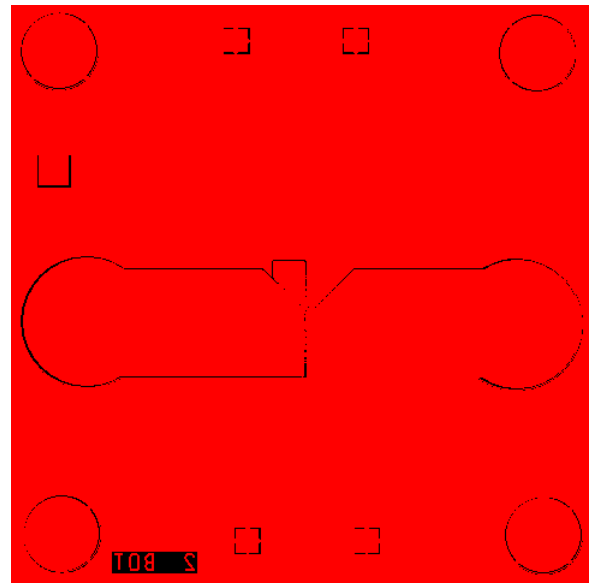


Figure 13. Demoboard PCB Top View

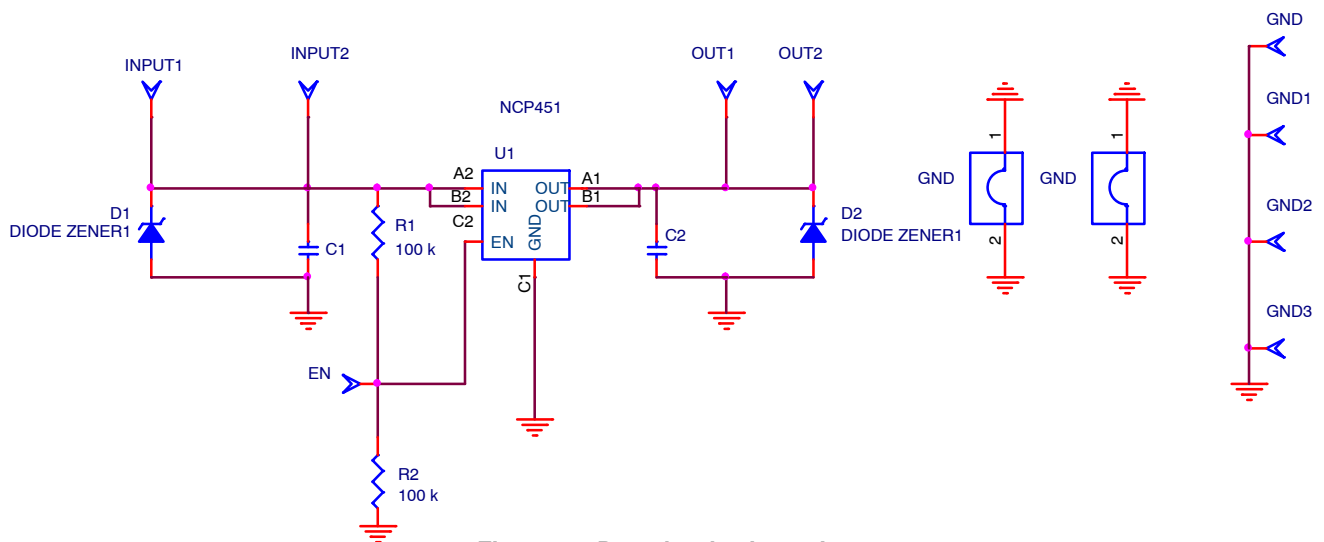


Figure 14. Demobard schematic

# NCP451

## BILL OF MATERIAL

Quantity	Reference Scheme	Part Description	Part Number	Manufacturer
2	IN, OUT	Socket, 4mm, metal, PK5	B010	HIRSCHMANN
3	IN_2, OUT_2, , EN	HEADER200	2.54 mm, 77313-101-06LF	FC
3	C1, C2	1uF	GRM155R70J105KA12#	Murata
1	D1, D2	TVS (not mounted)	ESD9x	onsemi
2	GND2,GND	GND JUMPER	D3082F05	Harvin
2	R2, R3	Resistor 100k 0603	MC 0.063 0603 1% 100K	MULTICOMP
1	U1	Load switch	NCP451	onsemi

## ORDERING INFORMATION

Device	Marking	Option	Package*	Shipping†
NCP451FCT2G	451	Auto Discharge 1.2 MΩ	Case 499BR (Pb-Free)	3000 / Tape & Reel
NCP451AFCT2G	51A	Auto Discharge 1.0 kΩ	Case 567KB* (Pb-Free)	3000 / Tape & Reel
NCP451AFCT2GA	51A	Auto Discharge 1.0 kΩ	Case 567KB* (Pb-Free)	3000 / Tape & Reel

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

\*UBM = 190 μm

# MECHANICAL CASE OUTLINE

## PACKAGE DIMENSIONS

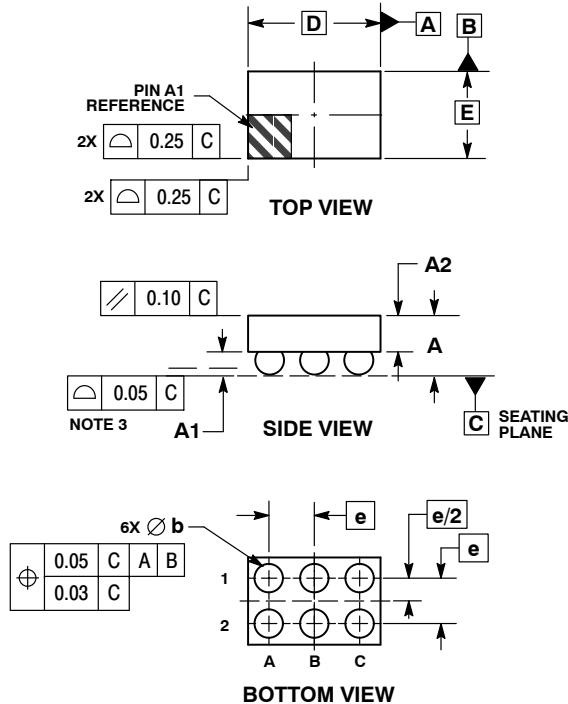
ON Semiconductor®



SCALE 4:1

WLCSP6, 1.40x0.90  
CASE 499BR  
ISSUE A

DATE 05 DEC 2012

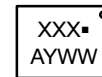


### NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. COPLANARITY APPLIES TO SPHERICAL CROWNS OF SOLDER BALLS.

DIM	MILLIMETERS	
	MIN	MAX
A	---	0.50
A1	0.17	0.23
A2	0.25	REF
b	0.21	0.25
D	1.40	BSC
E	0.90	BSC
e	0.50	BSC

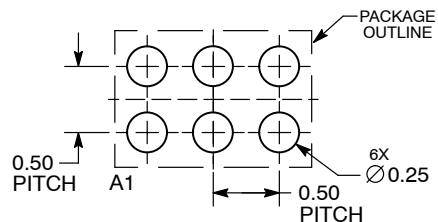
### GENERIC MARKING DIAGRAM\*



- 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.

### RECOMMENDED SOLDERING FOOTPRINT\*



DIMENSIONS: MILLIMETERS

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

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DESCRIPTION:	WLCSP6, 1.40X0.90	PAGE 1 OF 1

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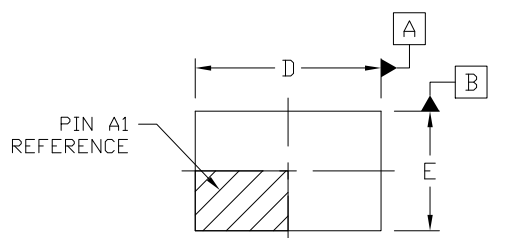
# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS



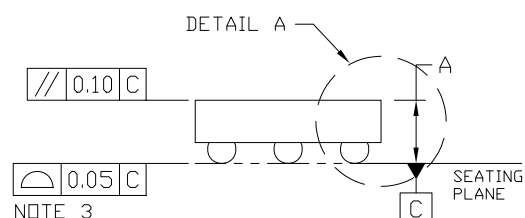
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WLCSP6, 1.40x0.90  
CASE 567KB  
ISSUE B

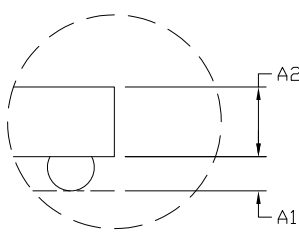
DATE 08 MAR 2022



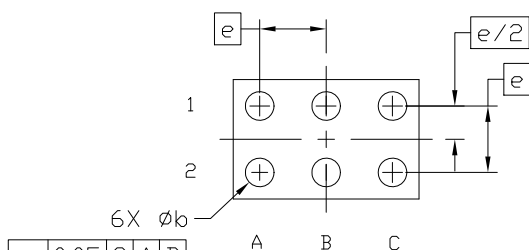
TOP VIEW



SIDE VIEW



DETAIL A  
SCALE 1:2

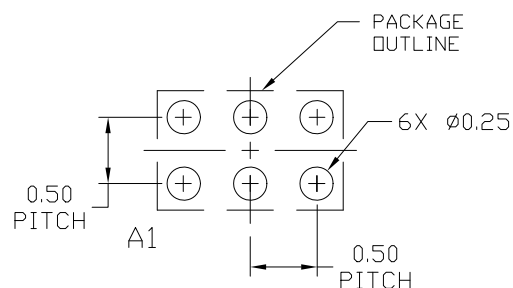


BOTTOM VIEW

## NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS
3. COPLANARITY APPLIES TO THE SPHERICAL CROWNS OF THE SOLDER BALLS.

DIM	MILLIMETERS		
	MIN.	NOM.	MAX.
A	---	---	0.510
A1	0.142	---	0.172
A2	---	0.320	0.338
b	0.195	---	0.235
D	1.360	1.400	1.440
E	0.860	0.900	0.940
e	0.50 BSC		



RECOMMENDED  
MOUNTING FOOTPRINT\*

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

## GENERIC MARKING DIAGRAM\*



XXXX = 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.

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DESCRIPTION:	WLCSP6, 1.40x0.90	PAGE 1 OF 1

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