

# NCP456R

## 2 A Single Load Switch for Low Voltage Rail

The NCP456R is a power load switch with very low Ron NMOSFET controlled by external logic pin, allowing optimization of battery life, and portable device autonomy.

Indeed, thanks to a best in class current consumption optimization with NMOS structure, leakage currents are drastically decreased. Offering optimized leakages isolation on the ICs connected on the battery.

Reverse voltage protection, from OUT to IN is offered in the NCP456R.

Proposed in wide input voltage range from 0.75 V to 5.5 V, and a very small CSP6 0.85 x 1.25 mm<sup>2</sup>.

### Features

- 0.75 V – 5.5 V Operating Range
- 24 mΩ N MOSFET
- Vbias Rail Input
- DC Current up to 2 A
- Reverse Blocking Option
- Active High EN Pin
- CSP6, 0.85 x 1.25 mm<sup>2</sup>, Pitch 0.4 mm
- These Devices are Pb-Free and are RoHS Compliant

### Typical Applications

- Notebooks
- Tablets
- Wireless
- Mobile Phones
- Digital Cameras



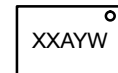
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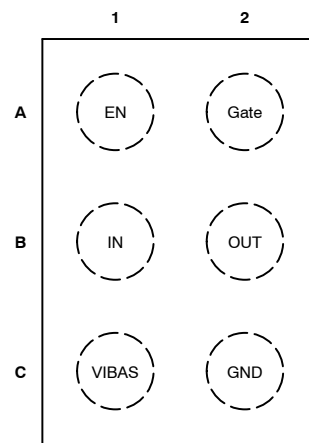
**WLCSP6, 1.25x0.85  
CASE 567GZ**

**MARKING  
DIAGRAM**



A = Assembly Location  
Y = Year  
W = Work Week

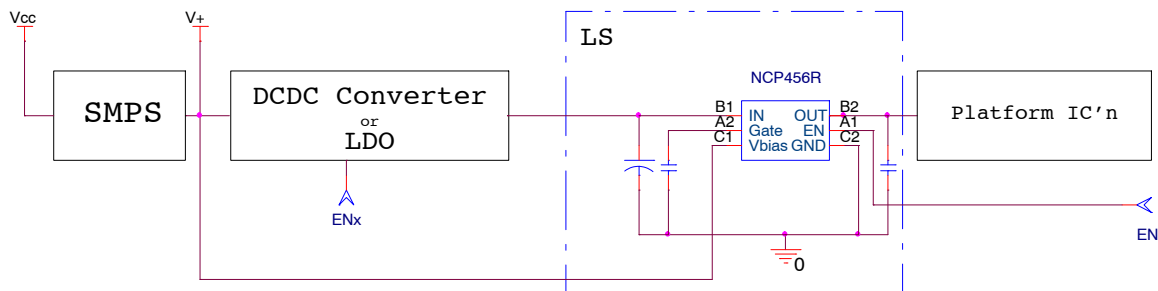
### PIN CONNECTIONS



Top View

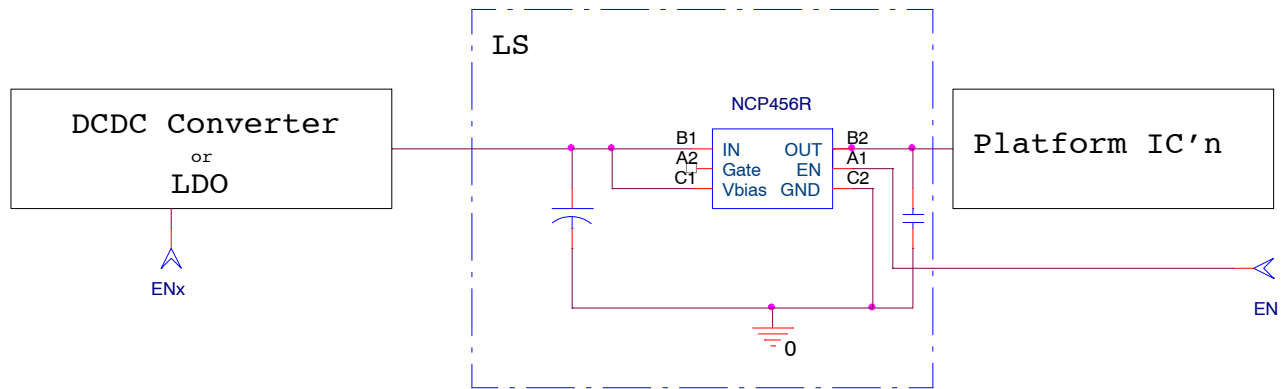
### ORDERING INFORMATION

See detailed ordering, marking and shipping information on page 11 of this data sheet.



**Figure 1. Typical Application Schematic**

## NCP456R



**Figure 2. Application Schematic with Vbias Connected to IN and No Gate Delay**

### PIN FUNCTION DESCRIPTION

Pin Name	Pin Number	Type	Description
EN	A1	INPUT	Enable input, logic high turns on power switch .
IN	B1	POWER	Load-switch input pin.
VBIAS	C1	POWER	External supply voltage input.
GATE	A2	INPUT	OUT pin slew rate control ( $t_{rise}$ ).
OUT	B2	POWER	Load-switch output pin.
GND	C2	POWER	Ground connection.

# NCP456R

## BLOCK DIAGRAM

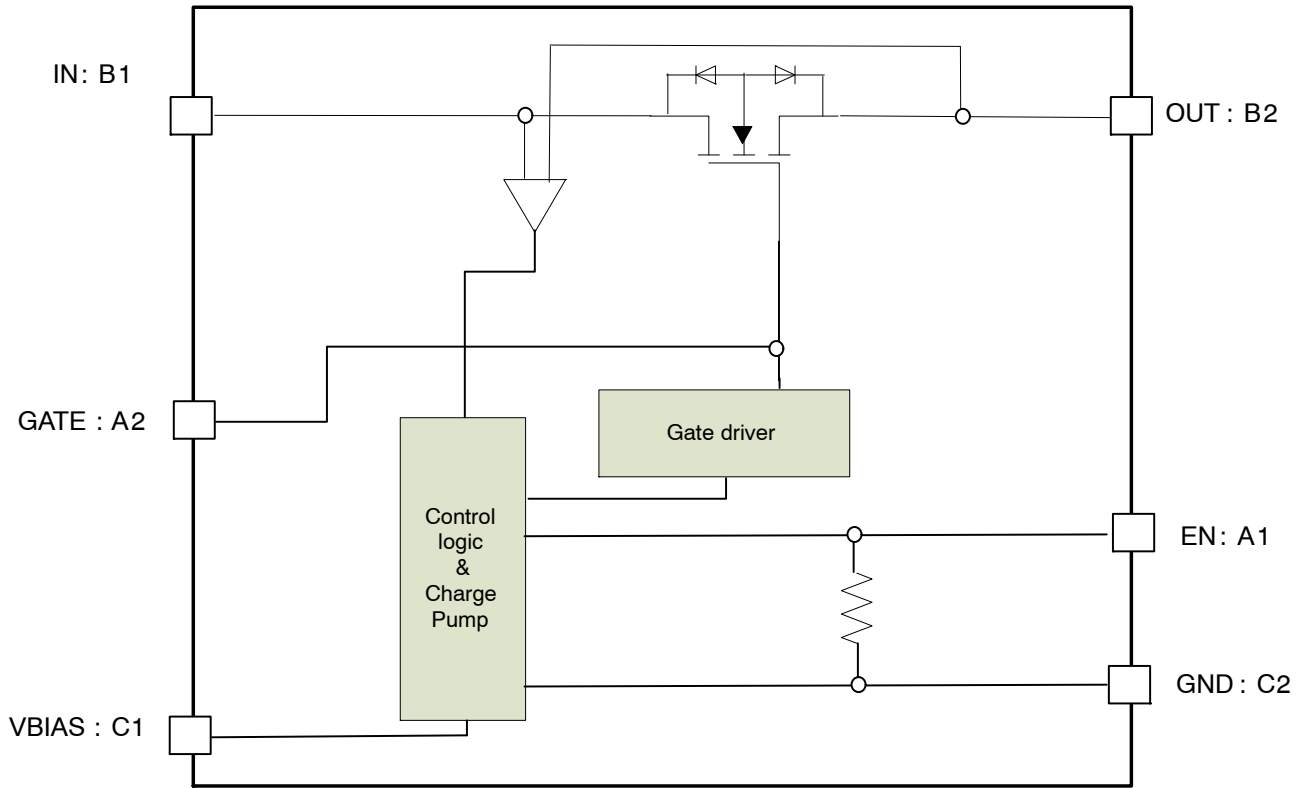


Figure 3. Block Diagram

# NCP456R

## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
IN, OUT, EN, VBIAS, GATE Pins: (Note 1)	$V_{EN}, V_{IN}, V_{OUT}, V_{BIAS}, V_{GATE}$	-0.3 to + 6.5	V
From IN to OUT Pins: Input/Output (Note 1)	$V_{IN}, V_{OUT}$	±6.5	V
Human Body Model (HBM) ESD Rating are (Note 2)	ESD HBM	2000	V
Machine Model (MM) ESD Rating are (Note 2)	ESD MM	200	V
Latch-up Protection (Note 3) Pins IN, OUT, EN, VBIAS and GATE	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) ±2.0 kV per JEDEC standard: JESD22-A114 for all pins.  
Machine Model (MM) ±250 V per JEDEC standard: JESD22-A115 for all pins.
3. Latch up Current Maximum Rating: ±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
$V_{BIAS}$	Bias voltage ( $V_{BIAS} \geq \text{best of } V_{IN}, V_{out}$ )		1.2		5.5	V
$T_A$	Ambient Temperature Range		-40	25	+85	°C
$C_{IN}$	Decoupling input capacitor		100			nF
$C_{OUT}$	Decoupling output capacitor		100			nF
$R_{\theta JA}$	Thermal Resistance Junction to Air	CSP6 (Note 5)		100		°C/W
$I_{OUT}$	Maximum DC current				2	A
$P_D$	Power Dissipation Rating	(Note 6)		0.2		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:

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

# NCP456R

**ELECTRICAL CHARACTERISTICS** Min & Max Limits apply for  $T_A$  between  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for  $V_{IN}$  and  $V_{BIAS}$  between 0.75 V to 5.5 V (Unless otherwise noted). Typical values are referenced to  $T_A = +25^{\circ}\text{C}$ ,  $V_{IN} = 3.3\text{ V}$  and  $V_{BIAS} = 5\text{ V}$  (Unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit	
<b>POWER SWITCH</b>							
$R_{DS(on)}$	Static drain-source on-state resistance for each rail	$V_{IN} = V_{BIAS} = 5.5\text{ V}$	$T_A = 25^{\circ}\text{C}$		24	33	$\text{m}\Omega$
			$T_J = 125^{\circ}\text{C}$			39	
		$V_{IN} = V_{BIAS} = 3.3\text{ V}$	$T_A = 25^{\circ}\text{C}$		24	33	
			$T_J = 125^{\circ}\text{C}$			39	
		$V_{IN} = V_{BIAS} = 1.8\text{ V}$	$T_A = 25^{\circ}\text{C}$		25	34	
			$T_J = 125^{\circ}\text{C}$			40	
		$V_{IN} = V_{BIAS} = 1.5\text{ V}$	$T_A = 25^{\circ}\text{C}$		26	35	
			$T_J = 125^{\circ}\text{C}$			41	
		$V_{IN} = V_{BIAS} = 1.2\text{ V}$	$T_A = 25^{\circ}\text{C}$		28	40	
			$T_J = 125^{\circ}\text{C}$			42	
		$V_{IN} = 1.0\text{ V}$ , $V_{BIAS} = 1.2\text{ V}$	$T_A = 25^{\circ}\text{C}$		30	40	
			$T_J = 125^{\circ}\text{C}$			42	
		$V_{IN} = 0.8\text{ V}$ , $V_{BIAS} = 1.2\text{ V}$	$T_A = 25^{\circ}\text{C}$		35	45	
			$T_J = 125^{\circ}\text{C}$			50	

## TIMINGS

$T_R$	Output rise time	$V_{IN} = 5\text{ V}$	No cap on GATE pin		0.11		$\text{ms}$	
			Gate capacitor = 1 nF		1.4			
			Gate capacitor = 10 nF		15.7			
$T_F$	Output fall time		$C_{LOAD} = 1\ \mu\text{F}$ , $R_{LOAD} = 25\ \Omega$ (Note 8)		50		$\mu\text{s}$	
$T_{en}$	Enable time		From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. 10 nF gate capacitor		3		$\text{ms}$	
			From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. 1 nF gate capacitor		300		$\mu\text{s}$	
			From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. Without gate capacitor		51		$\mu\text{s}$	
$T_R$	Output rise time		$V_{IN} = 3.3\text{ V}$	No cap on GATE pin		0.1	0.3	$\text{ms}$
				Gate capacitor = 1 nF		1		
				Gate capacitor = 10 nF		11		
$T_F$	Output fall time			$C_{LOAD} = 1\ \mu\text{F}$ , $R_{LOAD} = 25\ \Omega$ (Note 8)		60	120	$\mu\text{s}$
$T_{en}$	Enable time			From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. 10 nF Gate capacitor.		2.4		$\text{ms}$
				From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. 1 nF Gate capacitor.		230		$\mu\text{s}$
				From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. Without gate capacitor		50	120	$\mu\text{s}$

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

8. Guaranteed by design and characterization, not production tested.

# NCP456R

**ELECTRICAL CHARACTERISTICS** Min & Max Limits apply for  $T_A$  between  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for  $V_{IN}$  and  $V_{BIAS}$  between 0.75 V to 5.5 V (Unless otherwise noted). Typical values are referenced to  $T_A = +25^{\circ}\text{C}$ ,  $V_{IN} = 3.3\text{ V}$  and  $V_{BIAS} = 5\text{ V}$  (Unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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## TIMINGS

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$T_R$	Output rise time	No cap on GATE pin		0.06		ms
		Gate capacitor = 1 nF		0.6		
		Gate capacitor = 10 nF		6		
$T_F$	Output fall time	$C_{LOAD} = 1\ \mu\text{F}$ , $R_{LOAD} = 25\ \Omega$ (Note 8)		35		$\mu\text{s}$
$T_{en}$	Enable time	$V_{IN} = 1.8\text{ V}$ From EN low to high to $V_{out} = 10\%$ of fully on- 10 nF Gate capacitor		1.8		ms
		From EN low to high to $V_{out} = 10\%$ of fully on- 1 nF Gate capacitor		180		$\mu\text{s}$
		From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. Without gate capacitor		42		$\mu\text{s}$
$T_R$	Output rise time	No cap on GATE pin		0.04		ms
		Gate capacitor = 1 nF		0.35		
		Gate capacitor = 10 nF		3.5		
$T_F$	Output fall time	$C_{LOAD} = 1\ \mu\text{F}$ , $R_{LOAD} = 25\ \Omega$ (Note 8)		20		$\mu\text{s}$
$T_{en}$	Enable time	$V_{IN} = 1\text{ V}$ From EN low to high to $V_{out} = 10\%$ of fully on- 1 nF gate capacitor		140		$\mu\text{s}$
		From EN low to high to $V_{out} = 10\%$ of fully on- NCP456R. Without gate capacitor		40		$\mu\text{s}$

## LOGIC

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IH}$	High-level input voltage		0.9			V
$V_{IL}$	Low-level input voltage				0.4	V
$R_{EN}$	Pull down resistor		3		7	$\text{M}\Omega$

## REVERSE CURRENT BLOCKING

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{rev\_thr}$	Reverse threshold	$V_{out} - V_{in}$		32		mV
$V_{rev\_hyst}$	Reverse threshold hysteresis			50		mV
$T_{rev}$	Reverse comparator response time	$V_{out} - V_{in} > V_{rev\_thr}$		2.5		$\mu\text{s}$

## QUIESCENT CURRENT

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{VBIAS}$	Bias current for charge pump	$V_{BIAS} = 3.3\text{ V}$ , EN = high		1.5	6	$\mu\text{A}$
$I_{IN}$	IN Current consumption	EN = high		0.01	0.3	$\mu\text{A}$
$I_{STB}$	Standby current IN	EN = low, IN standby current, $V_{IN} = 3.3\text{ V}$		0.01	0.3	$\mu\text{A}$

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

8. Guaranteed by design and characterization, not production tested.

# NCP456R

**ELECTRICAL CHARACTERISTICS** Min & Max Limits apply for  $T_A$  between  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for  $V_{\text{IN}}$  and  $V_{\text{BIAS}}$  between 0.75 V to 5.5 V (Unless otherwise noted). Typical values are referenced to  $T_A = +25^{\circ}\text{C}$ ,  $V_{\text{IN}} = 3.3\text{ V}$  and  $V_{\text{BIAS}} = 5\text{ V}$  (Unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>QUIESCENT CURRENT</b>						
$I_{\text{STDVbias}}$	Standby current $V_{\text{BIAS}}$	$V_{\text{BIAS}} = 3.3\text{ V}$ EN = low		0.4	2	$\mu\text{A}$
$I_{\text{out\_leak}}$	Output leakage current	IN connected to GND, $V_{\text{OUT}} = 5\text{ V}$		0.01	0.5	$\mu\text{A}$

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

8. Guaranteed by design and characterization, not production tested.

## TIMINGS

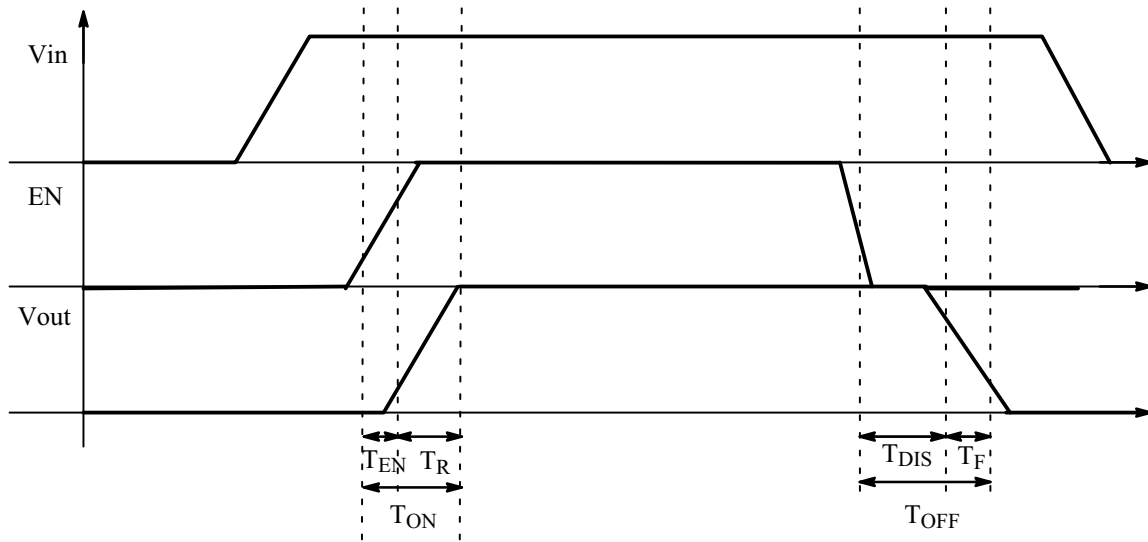


Figure 4. Enable, Rise and Fall Time

# NCP456R

## TYPICAL CHARACTERISTICS

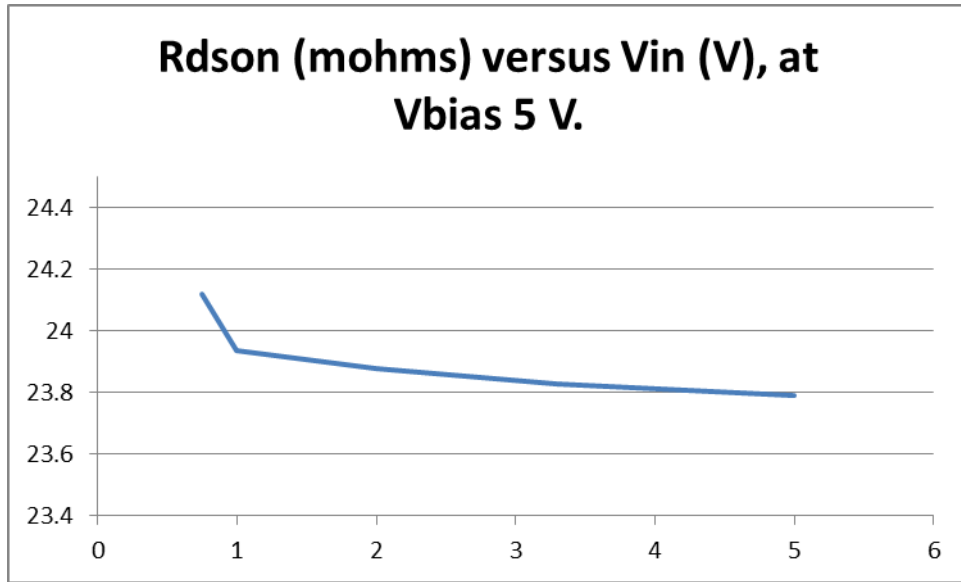


Figure 5.  $R_{DS(on)}$  versus  $V_{in}$ , Room Temperature, Vbias 5 V

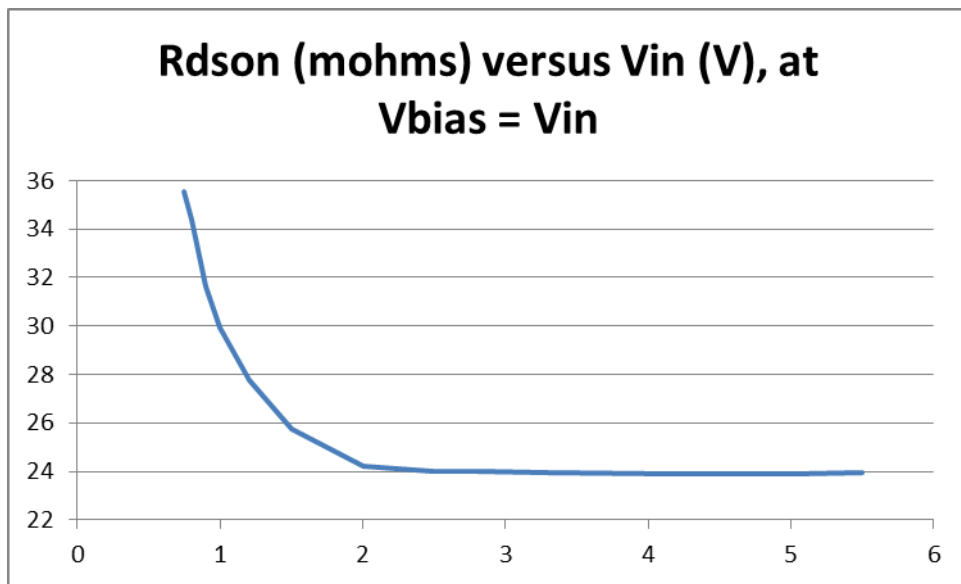


Figure 6.  $R_{DS(on)}$  versus  $V_{in}$ , Room Temperature, Vbias Connected to  $V_{in}$



FUNCTIONAL DESCRIPTION

**Overview**

The NCP456R is a high side N Channel MOSFET power distribution switch designed to isolate ICs connected on the battery or DCDC supplies in order to save energy. The part can be used with a wide range of supply 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 NMOS switch off.

The IN/OUT path is activated with a minimum of  $V_{BIAS} \geq \max(V_{IN}, V_{OUT}) = 0.75\text{ V}$  and EN forced to high level.

**V<sub>BIAS</sub> Rail**

The core of the IC is supplied due to  $V_{BIAS}$  supply rail (common +5 V, 3.3 V, 1.8 V, 1.2 V ...etc). Indeed, no current consumption is used on IN pin, allowing to improve power saving of the rail that must be isolated by the power switch.

If Vbias rail is not available or used, Vbias pin and Vin pin can be connected together as close as possible the DUT.

**Output Rise Time – Gate Control**

The NMOS is control with internal charge pump and driver. A minimum gate slew rate is internally set to avoid

huge inrush current when EN is set from low to high. The default gate slew rate depends on Vin level. The higher Vin level, the longer rise time.

In addition, an external capacitor can be connected between Gate pin and GND in order to slow down the gate rising. See electrical table for more details.

**C<sub>in</sub> and C<sub>out</sub> Capacitors**

100 nF external capacitors must be connected as close as possible the DUT for noise immunity and better stability. In case of input hot plug (input voltage connected with fast slew rate – few  $\mu\text{s}$  – it's strongly recommended to avoid big capacitor connected on the input. That allows to avoid input over voltage transients.

**Reverse Blocking Control**

A reverse blocking control circuitry is embedded to eliminate leakages from OUT to IN in case of  $V_{out} > V_{in}$ .

A comparator measures the dropout voltage on the switch between OUT and IN and turn off the NMOS if this voltage exceeds specified reverse voltage. This comparator is available whatever the EN pin level.

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:

$$P_D = R_{DS(on)} \times (I_{out})^2 \quad (\text{eq. 1})$$

- $P_D$  = Power dissipation (W)
- $R_{DS(on)}$  = Power MOSFET on resistance ( $\Omega$ )
- $I_{out}$  = Output current (A)

$$T_J = R_D \times R_{\theta JA} + T_A \quad (\text{eq. 2})$$

- $T_J$  = Junction temperature ( $^{\circ}\text{C}$ )
- $R_{\theta JA}$  = Package thermal resistance ( $^{\circ}\text{C}/\text{W}$ )
- $T_A$  = Ambient temperature ( $^{\circ}\text{C}$ )

**Demoboard**

The NCP456R integrates a 2 A rated NMOS FET, and the PCB rules must be respected to properly evacuate the heat out of the silicon.

The package is a CSP and due to the low thermal resistance of the silicon, all the balls can be used to improved power dissipation. Indeed, even if the power crosses the IN / OUT pins only, all the balls around this power area should be connected to the larger PCB area.

In the below PCB example (application demonstration board), all the PCB areas connected to 6 balls are enlarged. In addition vias are connected to bottom side with exactly same form factor of the other PCB side.

Additional improvements can be done also by using more copper thickness and the thinner epoxy as possible.

# NCP456R

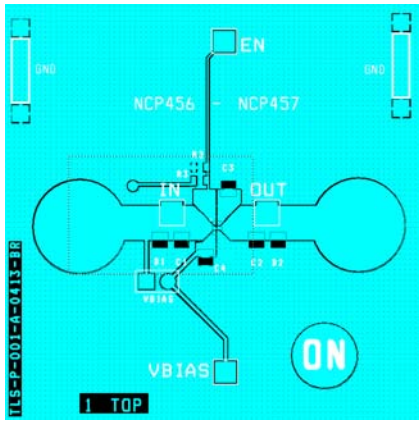


Figure 7. PCB Top View

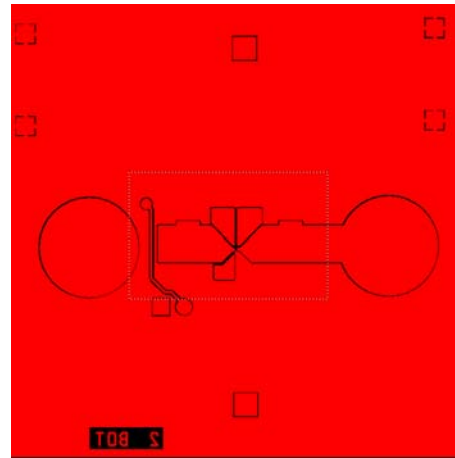


Figure 8. PCB Bottom View

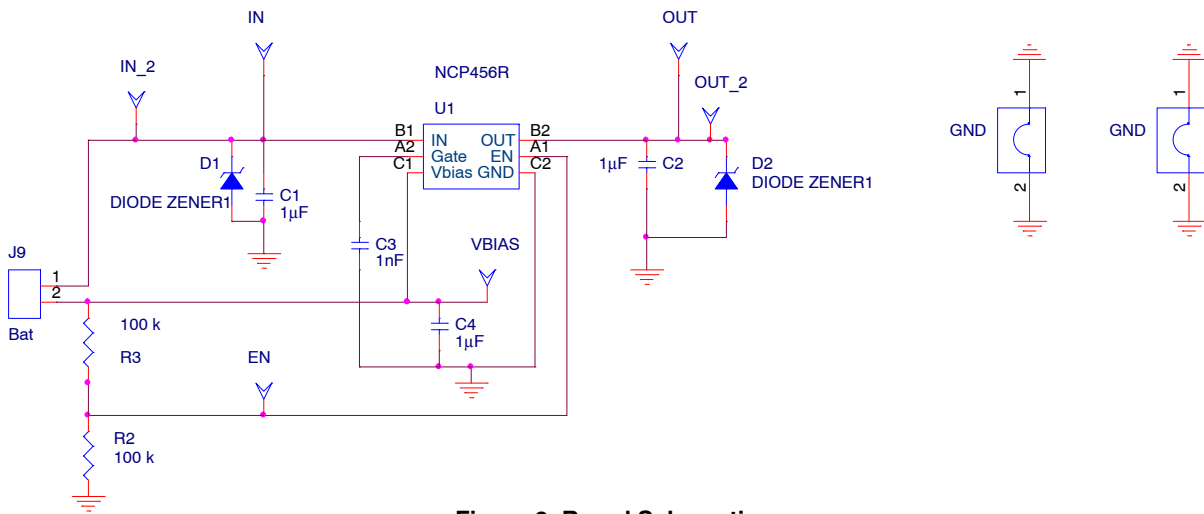


Figure 9. Board Schematic

## NCP456R

### BILL OF MATERIAL

Quantity	Reference schem	Part description	Part number	Manufacturer
2	IN, OUT	Socket, 4mm, metal, PK5	B010	HIRSCHMANN
4	IN_2, OUT_2, VBIAS, EN	HEADER200	2.54 mm, 77313-101-06LF	FC
1	J9 (Bat)	HEADER200-2	2.54 mm, 77313-101-06LF	FC
3	C1, C2, C4	1uF	GRM155R70J105KA12#	Murata
1	C3	1nF, Not mounted	GRM188R60J102ME47#	Murata
1	D1, D2	TVS	ESD9x	ON semiconductor
2	GND2,GND	GND JUMPER	D3082F05	Harvin
2	R2, R3	Resistor 100k 0603	MC 0.063 0603 1% 100K	MULTICOMP
1	U1	Load switch	NCP456 - 457	ON semiconductor

### ORDERING INFORMATION

Device	Options	Marking	Package	Shipping
NCP456RFCCT2G	Reverse Voltage Protection	56dYW	WLCSP 1.25 x 0.85 mm (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.

# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS

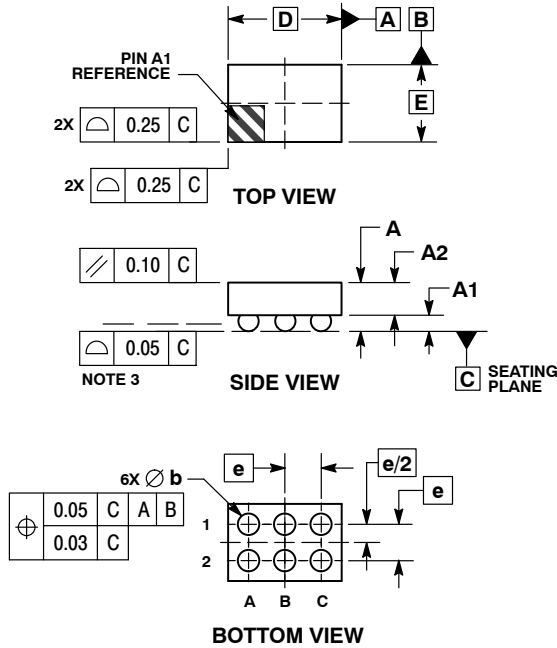
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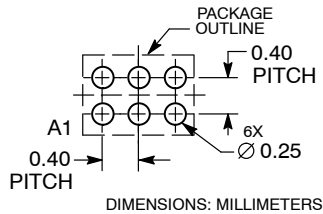
SCALE 4:1

WLCSP6, 1.25x0.85  
CASE 567GZ  
ISSUE B

DATE 02 DEC 2014



### RECOMMENDED SOLDERING FOOTPRINT\*

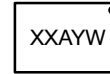


NOTES:

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	MAX
A	---	0.62
A1	0.17	0.23
A2	0.36 REF	
b	0.24	0.29
D	1.25 BSC	
E	0.85 BSC	
e	0.40 BSC	

### GENERIC MARKING DIAGRAM\*



- A = Assembly Location
- Y = Year
- W = Work Week

\*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.

\*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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<b>DESCRIPTION:</b>	<b>WLCSP6, 1.25X0.85</b>	<b>PAGE 1 OF 1</b>

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