

# NCP1729

## Switched Capacitor Voltage Inverter

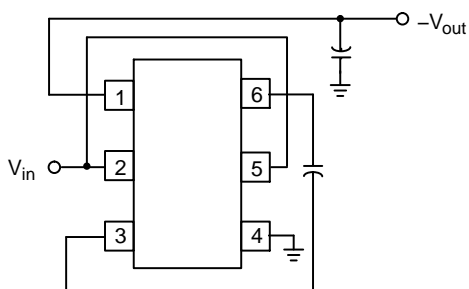
The NCP1729 is a CMOS charge pump voltage inverter that is designed for operation over an input voltage range of 1.5 V to 5.5 V with an output current capability in excess of 50 mA. The operating current consumption is only 122  $\mu$ A, and a power saving shutdown input is provided to further reduce the current to a mere 0.4  $\mu$ A. The device contains a 35 kHz oscillator that drives four low resistance MOSFET switches, yielding a low output resistance of 26  $\Omega$  and a voltage conversion efficiency of 99%. This device requires only two external 3.3  $\mu$ F capacitors for a complete inverter making it an ideal solution for numerous battery powered and board level applications. The NCP1729 is available in the space saving TSOP-6 package.

### Features

- Operating Voltage Range of 1.5 V to 5.5 V
- Output Current Capability in Excess of 50 mA
- Low Current Consumption of 122  $\mu$ A
- Power Saving Shutdown Input for a Reduced Current of 0.4  $\mu$ A
- Operation at 35 kHz
- Low Output Resistance of 26  $\Omega$
- Space Saving TSOP-6 Package
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable
- These Devices are Pb-Free and are RoHS Compliant

### Typical Applications

- LCD Panel Bias
- Cellular Telephones
- Pagers
- Personal Digital Assistants
- Electronic Games
- Digital Cameras
- Camcorders
- Hand Held Instruments



This device contains 77 active transistors.

**Figure 1. Typical Application**



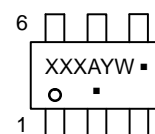
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**TSOP-6  
(SOT23-6)  
SN SUFFIX  
CASE 318G**

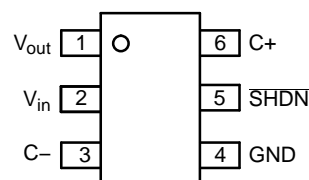
### MARKING DIAGRAM



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

(Note: Microdot may be in either location)

### PIN CONNECTIONS



(Top View)

### ORDERING INFORMATION

See detailed ordering, marking and shipping information in the package dimensions section on page 22 of this data sheet.

# NCP1729

## MAXIMUM RATINGS\*

Rating	Symbol	Value	Unit
Input Voltage Range ( $V_{in}$ to GND)	$V_{in}$	-0.3 to 6.0	V
Output Voltage Range ( $V_{out}$ to GND)	$V_{out}$	-6.0 to 0.3	V
Output Current	$I_{out}$	100	mA
Output Short Circuit Duration ( $V_{out}$ to GND)	$t_{SC}$	Indefinite	sec
Operating Junction Temperature	$T_J$	150	°C
Power Dissipation and Thermal Characteristics Thermal Resistance, Junction-to-Air Maximum Power Dissipation @ $T_A = 70^\circ\text{C}$	$R_{\theta JA}$ $P_D$	256 313	°C/W mW
Storage Temperature	$T_{stg}$	-55 to 150	°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.

### \*ESD Ratings

- ESD Machine Model Protection up to 200 V, Class B
- ESD Human Body Model Protection up to 2000 V, Class 2

## ELECTRICAL CHARACTERISTICS ( $V_{in} = 5.0\text{ V}$ , $C_1 = 3.3\ \mu\text{F}$ , $C_2 = 3.3\ \mu\text{F}$ , $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ , typical values shown are for $T_A = 25^\circ\text{C}$ unless otherwise noted. See Figure 14 for Test Setup.)

Characteristic	Symbol	Min	Typ	Max	Unit
Operating Supply Voltage Range ( $\overline{\text{SHDN}} = V_{in}$ , $R_L = 10\text{ k}$ )	$V_{in}$	1.5	-	5.5	V
Supply Current Device Operating ( $\overline{\text{SHDN}} = 5.0\text{ V}$ , $R_L = \infty$ ) $T_A = 25^\circ\text{C}$ $T_A = 85^\circ\text{C}$	$I_{in}$	-	122 128	200 200	$\mu\text{A}$
Supply Current Device Shutdown ( $\overline{\text{SHDN}} = 0\text{ V}$ ) $T_A = 25^\circ\text{C}$ $T_A = 85^\circ\text{C}$	$I_{\text{SHDN}}$	-	0.4 1.7	-	$\mu\text{A}$
Oscillator Frequency $T_A = 25^\circ\text{C}$ $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$	$f_{\text{OSC}}$	24.5 19	33.5 -	45.6 54	kHz
Output Resistance ( $I_{out} = 25\text{ mA}$ , Note 1)	$R_{out}$	-	26	50	$\Omega$
Voltage Conversion Efficiency ( $R_L = \infty$ )	$V_{EFF}$	99	99.9	-	%
Power Conversion Efficiency ( $R_L = 1.0\text{ k}$ )	$P_{EFF}$	-	96	-	%
Shutdown Input Threshold Voltage ( $V_{in} = 1.5\text{ V}$ to $5.5\text{ V}$ ) High State, Device Operating Low State, Device Shutdown	$V_{th(\overline{\text{SHDN}})}$	-	$0.6 V_{in}$ $0.5 V_{in}$	-	V
Shutdown Input Bias Current High State, Device Operating, $\overline{\text{SHDN}} = 5.0\text{ V}$ $T_A = 25^\circ\text{C}$ $T_A = 85^\circ\text{C}$ Low State, Device Shutdown, $\overline{\text{SHDN}} = 0\text{ V}$ $T_A = 25^\circ\text{C}$ $T_A = 85^\circ\text{C}$	$I_{IH}$  $I_{IL}$	-	5.0 100 5.0 100	-	pA
Wake-Up Time from Shutdown ( $R_L = 1.0\text{ k}$ )	$t_{WKUP}$	-	1.0	-	ms

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.

1. Capacitors  $C_1$  and  $C_2$  contribution is approximately 20% of the total output resistance.

TYPICAL CHARACTERISTICS

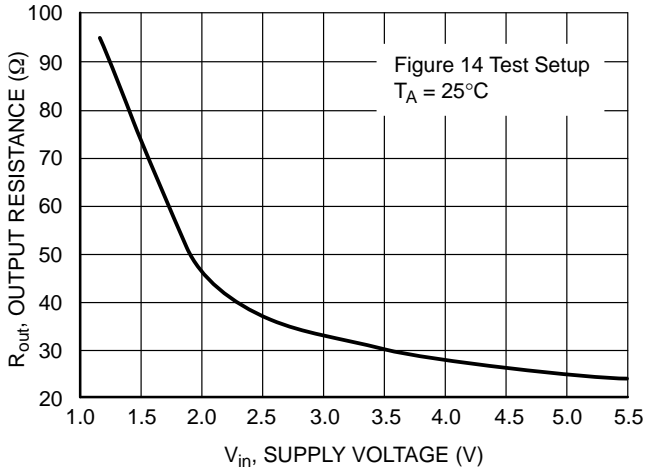


Figure 2. Output Resistance vs. Supply Voltage

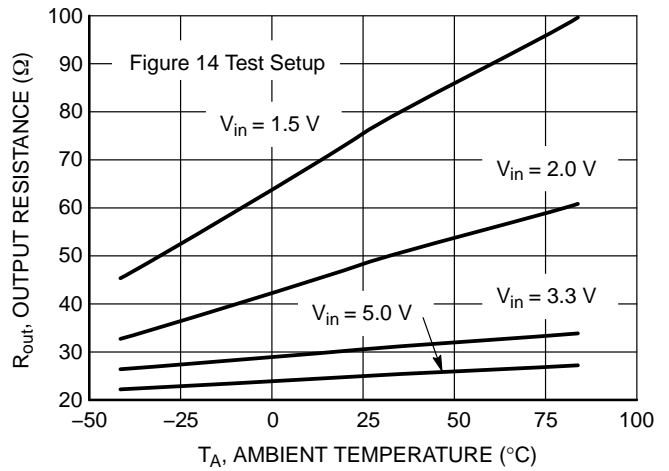


Figure 3. Output Resistance vs. Ambient Temperature

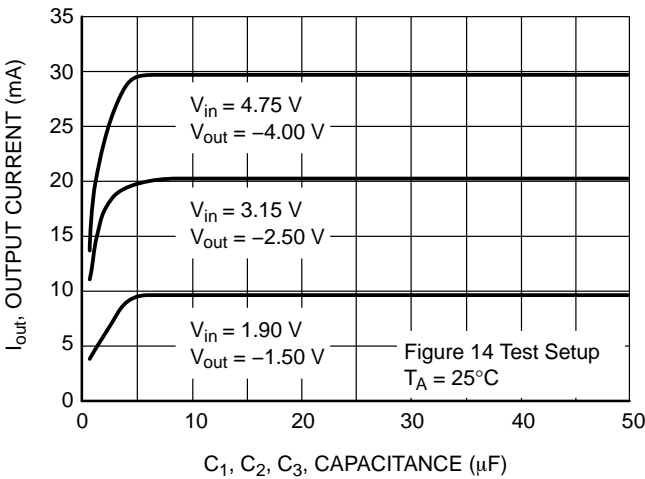


Figure 4. Output Current vs. Capacitance

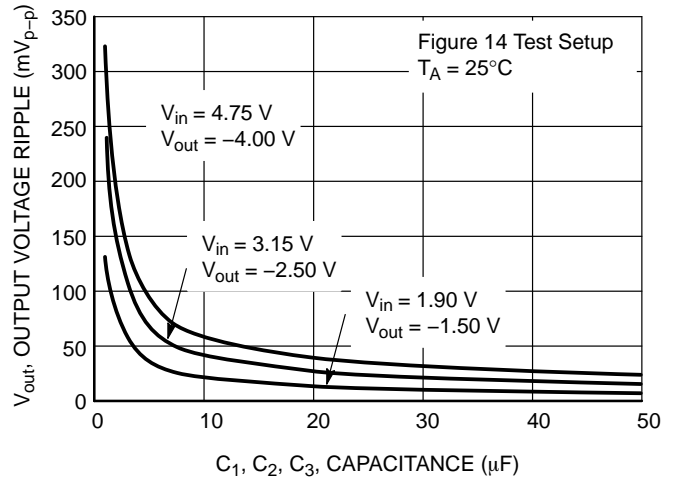


Figure 5. Output Voltage Ripple vs. Capacitance

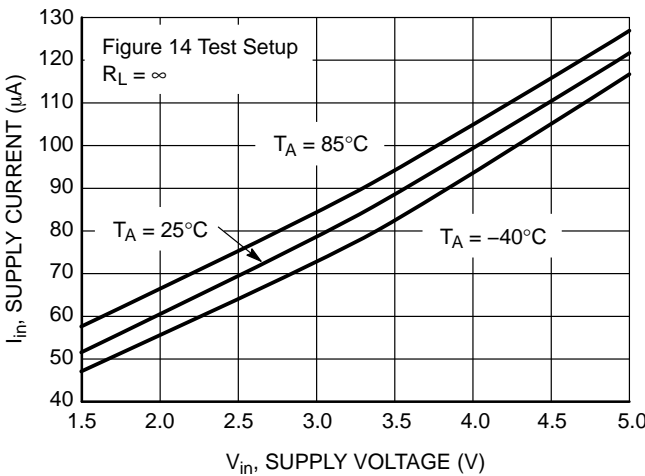


Figure 6. Supply Current vs. Supply Voltage

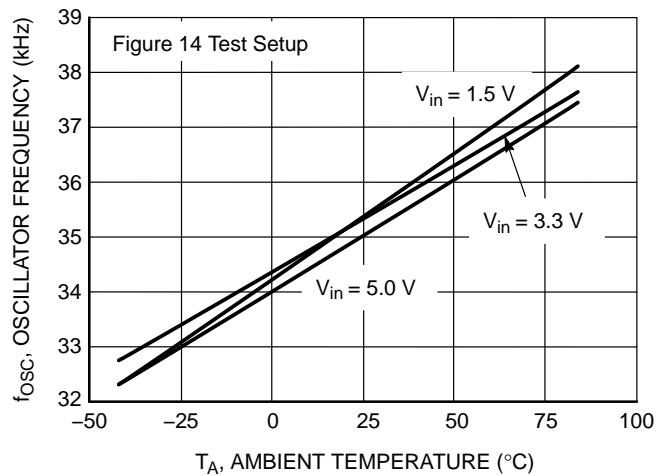


Figure 7. Oscillator Frequency vs. Ambient Temperature

TYPICAL CHARACTERISTICS

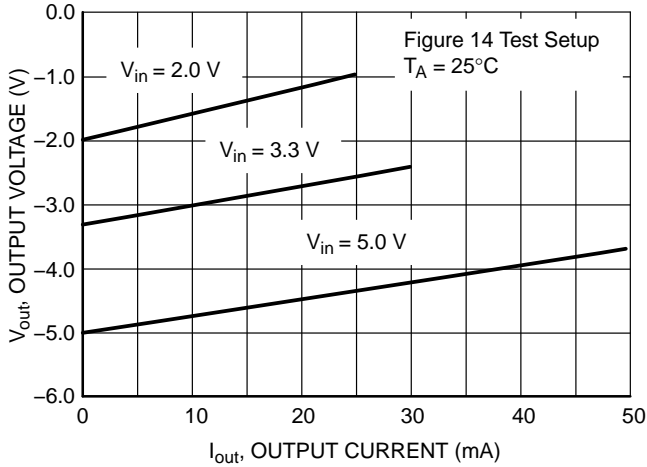


Figure 8. Output Voltage vs. Output Current

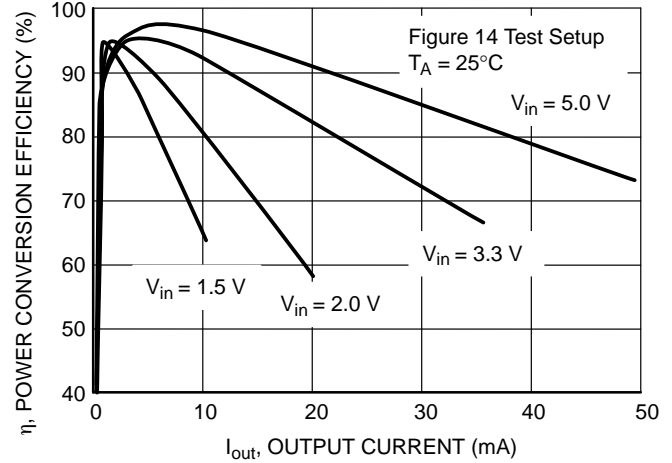


Figure 9. Power Conversion Efficiency vs. Output Current

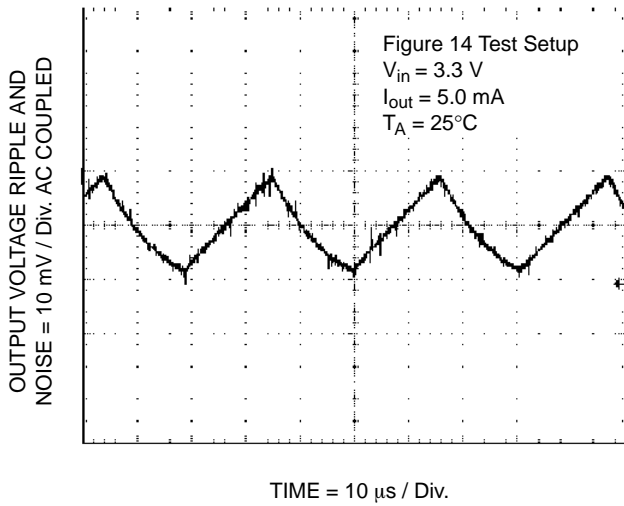


Figure 10. Output Voltage Ripple and Noise

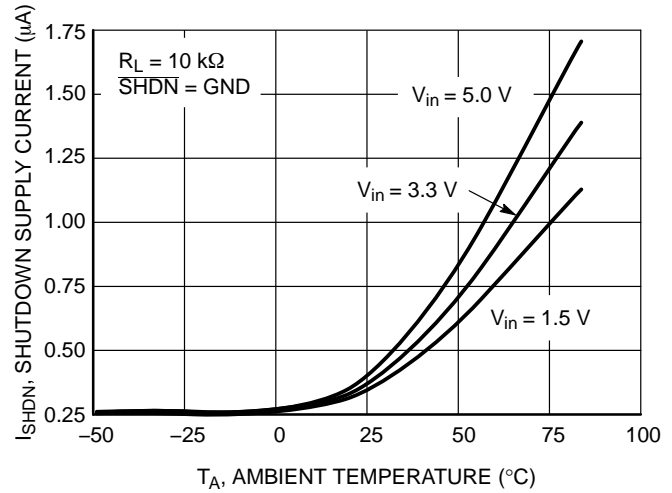


Figure 11. Shutdown Supply Current vs. Ambient Temperature

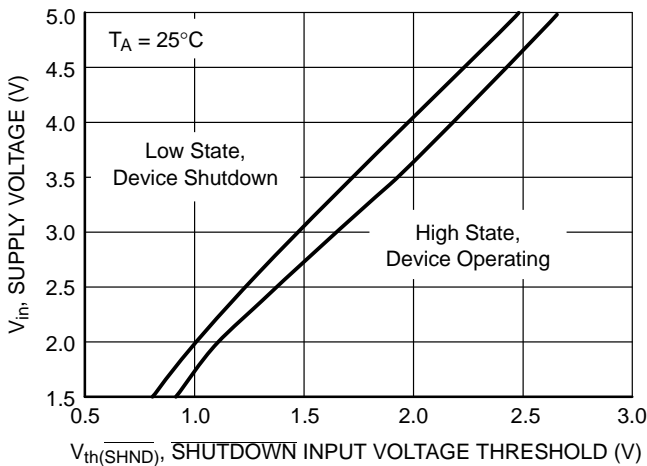


Figure 12. Supply Voltage vs. Shutdown Input Voltage Threshold

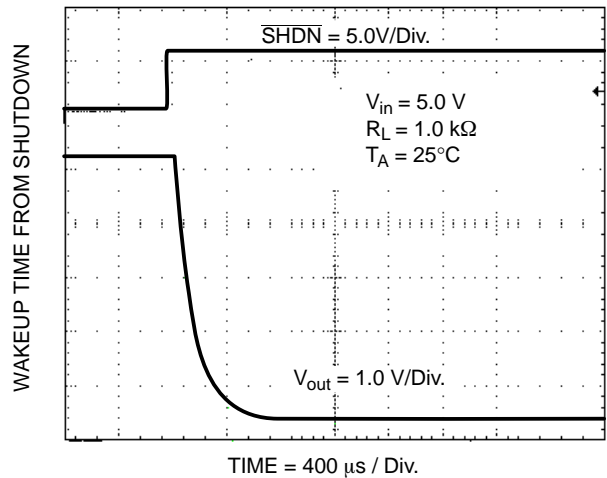


Figure 13. Wakeup Time From Shutdown

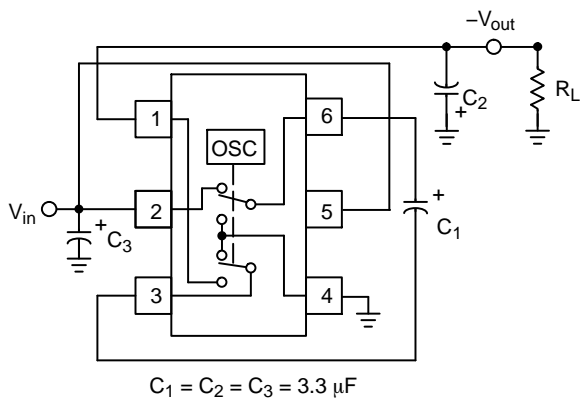


Figure 14. Test Setup/Voltage Inverter

**DETAILED OPERATING DESCRIPTION**

The NCP1729 charge pump converter inverts the voltage applied to the  $V_{in}$  pin. Conversion consists of a two-phase operation (Figure 15). During the first phase, switches  $S_2$  and  $S_4$  are open and  $S_1$  and  $S_3$  are closed. During this time,  $C_1$  charges to the voltage on  $V_{in}$  and load current is supplied from  $C_2$ . During the second phase,  $S_2$  and  $S_4$  are closed, and  $S_1$  and  $S_3$  are open. This action connects  $C_1$  across  $C_2$ , restoring charge to  $C_2$ .

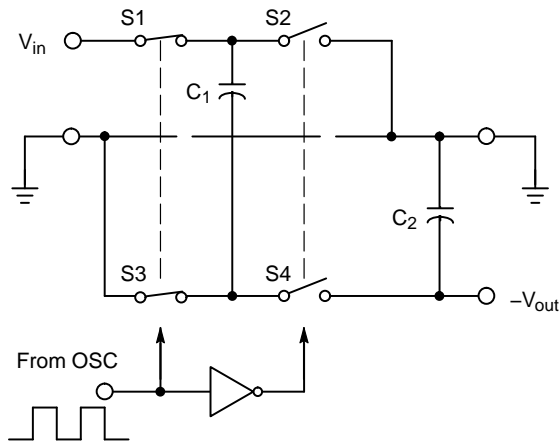


Figure 15. Ideal Switched Capacitor Charge Pump

**APPLICATIONS INFORMATION**

**Output Voltage Considerations**

The NCP1729 performs voltage conversion but does not provide regulation. The output voltage will drop in a linear manner with respect to load current. The value of this equivalent output resistance is approximately 26  $\Omega$  nominal at 25°C with  $V_{in} = 5.0$  V.  $V_{out}$  is approximately -5.0 V at light loads, and drops according to the equation below:

$$V_{DROP} = I_{out} \times R_{out}$$

$$V_{out} = - (V_{in} - V_{DROP})$$

**Charge Pump Efficiency**

The overall power conversion efficiency of the charge pump is affected by four factors:

1. Losses from power consumed by the internal oscillator, switch drive, etc. (which vary with input voltage, temperature and oscillator frequency).
2.  $I^2R$  losses due to the on-resistance of the MOSFET switches on-board the charge pump.
3. Charge pump capacitor losses due to Equivalent Series Resistance (ESR).
4. Losses that occur during charge transfer from the commutation capacitor to the output capacitor when a voltage difference between the two capacitors exists.

Most of the conversion losses are due to factors 2, 3 and 4. These losses are given by Equation 1.

$$P_{LOSS(2,3,4)} = I_{out}^2 \times R_{out} \cong I_{out}^2 \times \left[ \frac{1}{(f_{OSC})C_1} + 8R_{SWITCH} + 4ESR_{C_1} + ESR_{C_2} \right]$$

(eq. 1)

The  $1/(f_{OSC})(C_1)$  term in Equation 1 is the effective output resistance of an ideal switched capacitor circuit (Figures 16 and 17).

The losses due to charge transfer above are also shown in Equation 2. The output voltage ripple is given by Equation 3.

$$P_{LOSS} = [0.5C_1 (V_{in}^2 - V_{out}^2) + 0.5C_2 (V_{RIPPLE}^2 - 2V_{out}V_{RIPPLE})] \times f_{OSC}$$

(eq. 2)

$$V_{RIPPLE} = \frac{I_{out}}{(f_{OSC})(C_2)} + 2(I_{out})(ESR_{C_2})$$

(eq. 3)

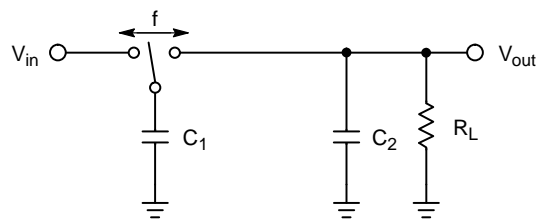


Figure 16. Ideal Switched Capacitor Model

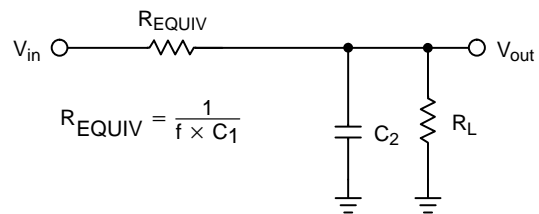


Figure 17. Equivalent Output Resistance

### Capacitor Selection

In order to maintain the lowest output resistance and output ripple voltage, it is recommended that low ESR capacitors be used. Additionally, larger values of  $C_1$  will lower the output resistance and larger values of  $C_2$  will reduce output voltage ripple. (See Equation 3).

Table 1 shows various values of  $C_1$ ,  $C_2$  and  $C_3$  with the corresponding output resistance values at 25°C. Table 2 shows the output voltage ripple for various values of  $C_1$ ,  $C_2$  and  $C_3$ . The data in Tables 1 and 2 was measured not calculated.

**Table 1. Output Resistance vs. Capacitance**  
( $C_1 = C_2 = C_3$ ),  $V_{in} = 4.75\text{ V}$  and  $V_{out} = -4.0\text{ V}$

$C_1 = C_2 = C_3$ ( $\mu\text{F}$ )	$R_{out}$ ( $\Omega$ )
0.68	55.4
1.3	36.9
3.3	26.0
7.3	25.8
10	25.5
24	25.0
50	24.0

**Table 2. Output Voltage Ripple vs. Capacitance**  
( $C_1 = C_2 = C_3$ ),  $V_{in} = 4.75\text{ V}$  and  $V_{out} = -4.0\text{ V}$

$C_1 = C_2 = C_3$ ( $\mu\text{F}$ )	Output Voltage Ripple (mV)
0.68	322
1.3	205
3.3	120
7.3	69
10	56
24	32
50	20

### Input Supply Bypassing

The input voltage,  $V_{in}$  should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the switching internals in the device. If the device is loaded from

$V_{out}$  to GND, it is recommended that a large value capacitor (at least equal to  $C_1$ ) be connected from  $V_{in}$  to GND. If the device is loaded from  $V_{in}$  to  $V_{out}$ , a small (0.7  $\mu\text{F}$ ) capacitor between the pins is sufficient.

### Voltage Inverter

The most common application for a charge pump is the voltage inverter (Figure 14). This application uses two or three external capacitors. The  $C_1$  (pump capacitor) and  $C_2$  (output capacitor) are required. The input bypass capacitor  $C_3$ , may be necessary depending on the application. The output is equal to  $-V_{in}$  plus any voltage drops due to loading. Refer to Tables 1 and 2 for capacitor selection. The test setup used for the majority of the characterization is shown in Figure 14.

### Layout Considerations

As with any switching power supply circuit, good layout practice is recommended. Mount components as close together as possible to minimize stray inductance and capacitance. Also use a large ground plane to minimize noise leakage into other circuitry.

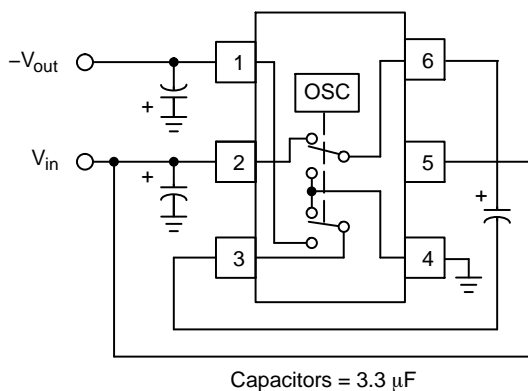
### Capacitor Resources

Selecting the proper type of capacitor can reduce switching loss. Low ESR capacitors are recommended. The NCP1729 was characterized using the capacitors listed in Table 3. This list identifies low ESR capacitors for the voltage inverter application.

**Table 3. Capacitor Types**

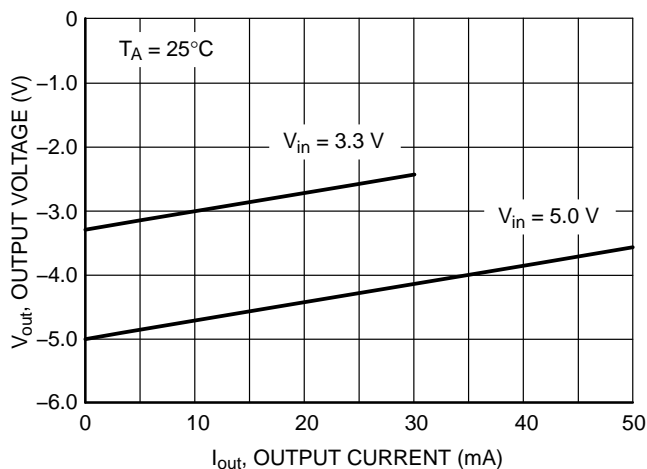
Manufacturer/Contact	Part Types/Series
<b>AVX</b> 843-448-9411 www.avxcorp.com	TPS
<b>Cornell Dubilier</b> 508-996-8561 www.cornell-dubilier.com	ESRD
<b>Sanyo/Os-con</b> 619-661-6835 www.sanyovideo.com/oscon.htm	SN SVP
<b>Vishay</b> 603-224-1961 www.vishay.com	593D 594

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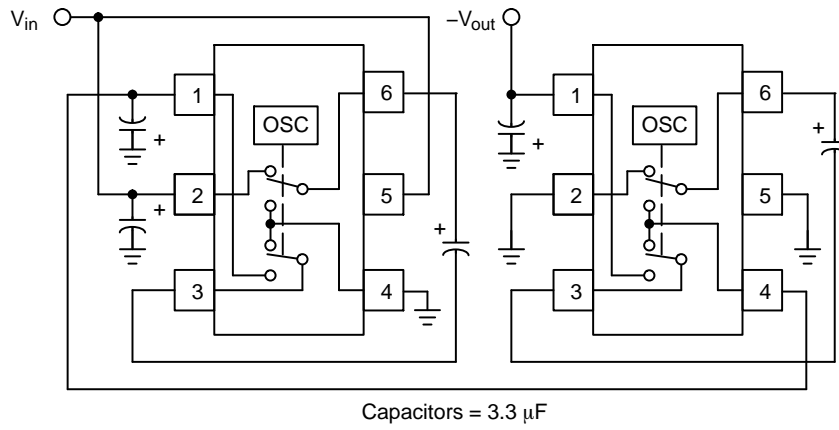
**Figure 18. Voltage Inverter**

The NCP1729 primary function is a voltage inverter. The device will convert 5.0 V into -5.0 V with light loads. Two capacitors are required for the inverter to function. A third capacitor, the input bypass capacitor, may be required depending on the power source for the inverter. The performance for this device is illustrated below.



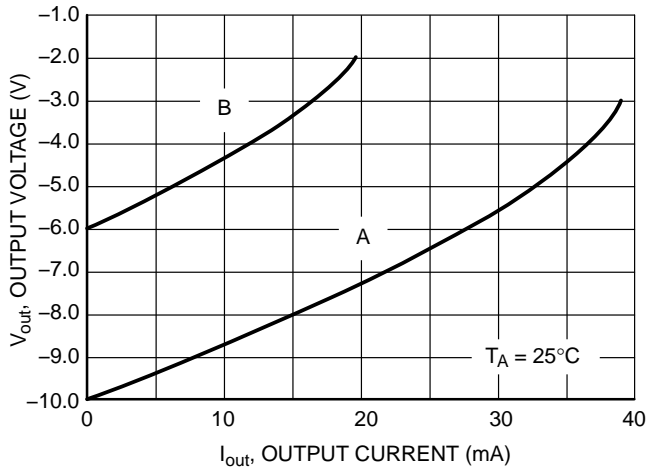
**Figure 19. Voltage Inverter Load Regulation, Output Voltage vs. Output Current**

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**Figure 20. Cascaded Devices for Increased Negative Output Voltage**

Two or more devices can be cascaded for increased output voltage. Under light load conditions, the output voltage is approximately equal to  $-V_{in}$  times the number of stages. The converter output resistance increases dramatically with each additional stage. This is due to a reduction of input voltage to each successive stage as the converter output is loaded. Note that the ground connection for each successive stage must connect to the negative output of the previous stage. The performance characteristics for a converter consisting of two cascaded devices are shown below.

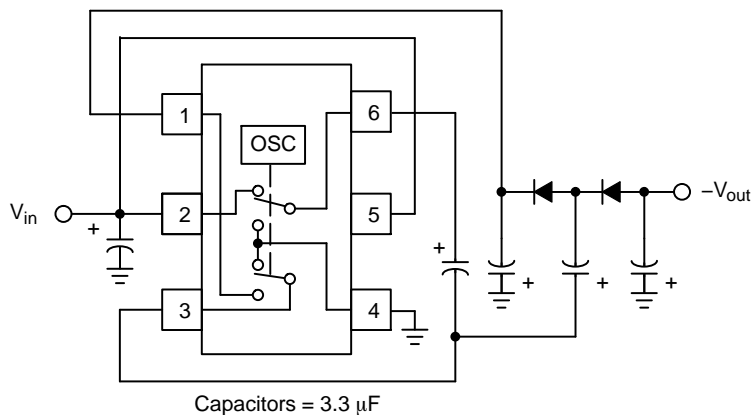


Curve	$V_{in}$ (V)	$R_{out}$ ( $\Omega$ )
A	5.0	145
B	3.0	180

**Figure 21. Cascade Load Regulation, Output Voltage vs. Output Current**

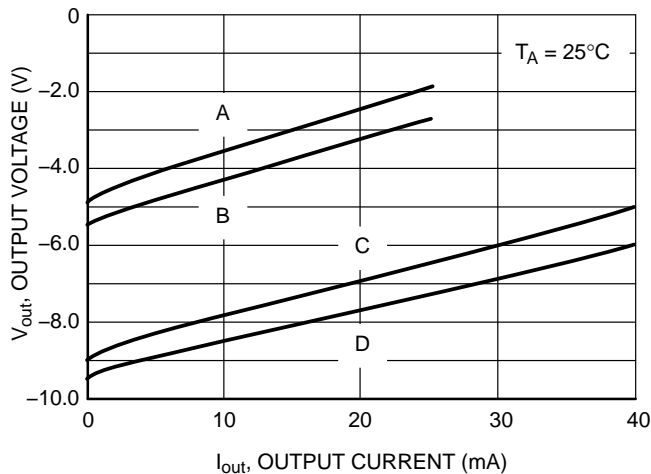


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**Figure 22. Negative Output Voltage Doubler**

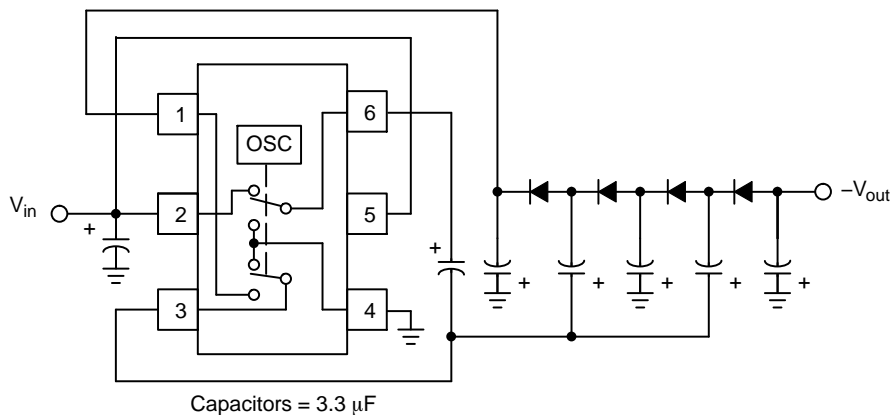
A single device can be used to construct a negative voltage doubler. The output voltage is approximately equal to  $-2.0 V_{in}$  minus the forward voltage drop of each external diode. The performance characteristics for the above converter are shown below. Note that curves A and C show the circuit performance with economical 1N4148 diodes, while curves B and D are with lower loss MBRA120E Schottky diodes.



Curve	$V_{in}$ (V)	All Diodes	$R_{out}$ ( $\Omega$ )
A	3.0	1N4148	118
B	3.0	MBRA120E	107
C	5.0	1N4148	91
D	5.0	MBRA120E	85

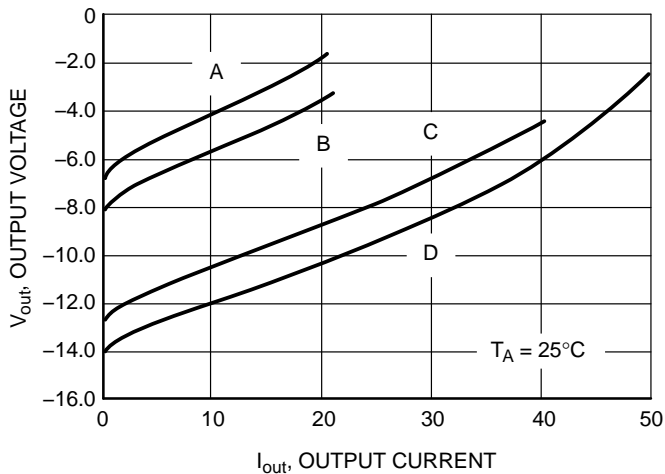
**Figure 23. Doubler Load Regulation, Output Voltage vs. Output Current**

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**Figure 24. Negative Output Voltage Tripler**

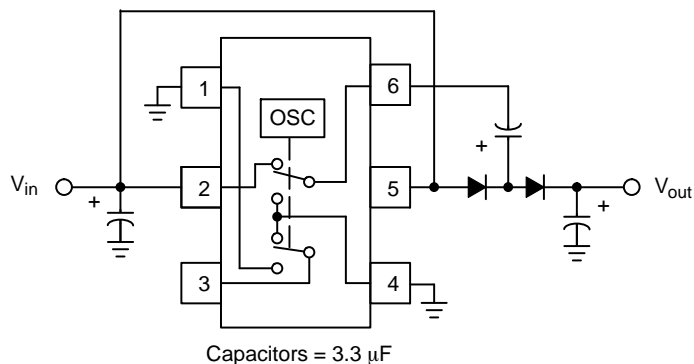
A single device can be used to construct a negative voltage tripler. The output voltage is approximately equal to  $-3.0 V_{in}$  minus the forward voltage drop of each external diode. The performance characteristics for the above converter are shown below. Note that curves A and C show the circuit performance with economical 1N4148 diodes, while curves B and D are with lower loss MBRA120E Schottky diodes.



Curve	$V_{in}$ (V)	All Diodes	$R_{out}$ ( $\Omega$ )
A	3.0	1N4148	247
B	3.0	MBRA120E	228
C	5.0	1N4148	198
D	5.0	MBRA120E	188

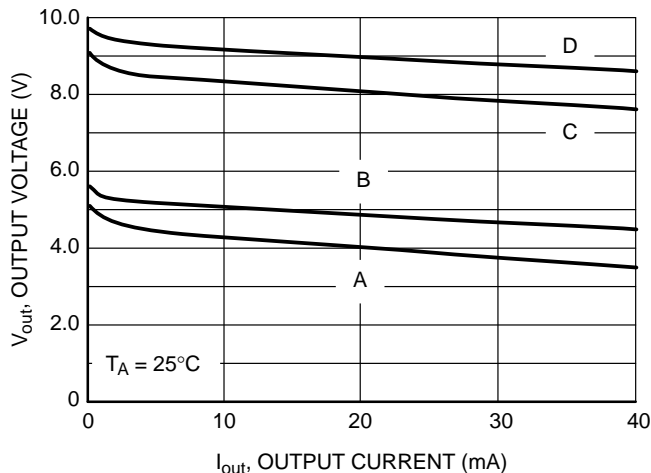
**Figure 25. Tripler Load Regulation, Output Voltage vs. Output Current**

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**Figure 26. Positive Output Voltage Doubler**

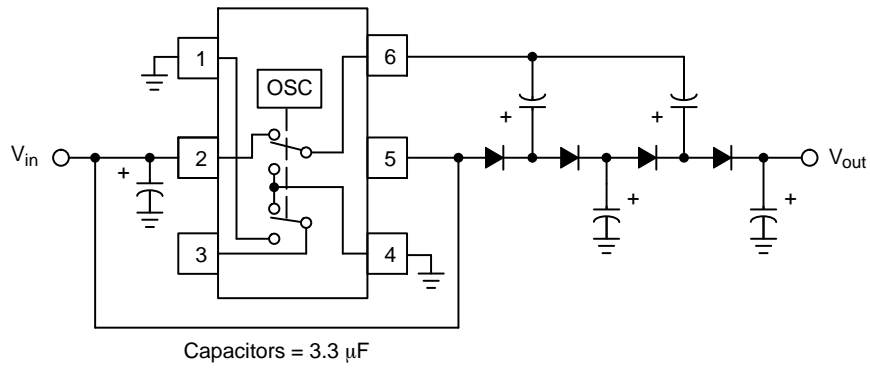
A single device can be used to construct a positive voltage doubler. The output voltage is approximately equal to  $2.0 V_{in}$  minus the forward voltage drop of each external diode. The performance characteristics for the above converter are shown below. Note that curves A and C show the circuit performance with economical 1N4148 diodes, while curves B and D are with lower loss MBRA120E Schottky diodes.



Curve	$V_{in}$ (V)	All Diodes	$R_{out}$ ( $\Omega$ )
A	3.0	1N4148	32
B	3.0	MBRA120E	25
C	5.0	1N4148	24
D	5.0	MBRA120E	19.3

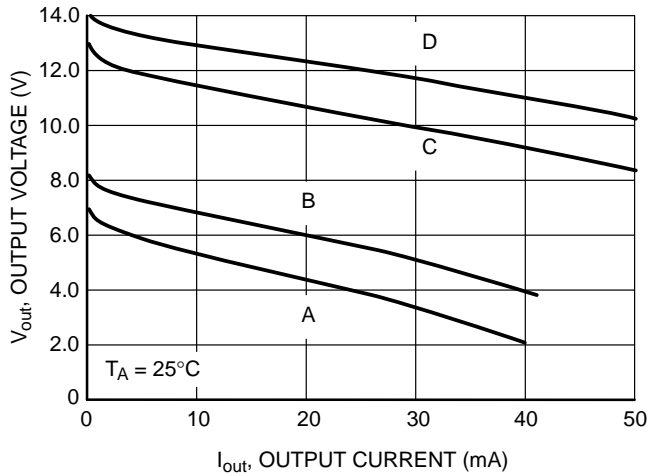
**Figure 27. Doubler Load Regulation, Output Voltage vs. Output Current**

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**Figure 28. Positive Output Voltage Tripler**

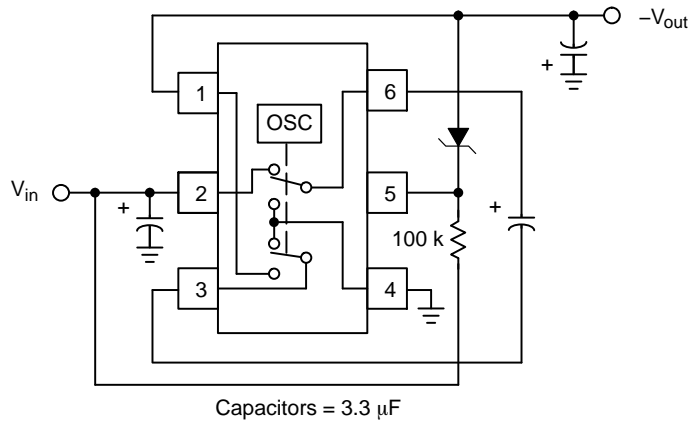
A single device can be used to construct a positive voltage tripler. The output voltage is approximately equal to  $3.0 V_{in}$  minus the forward voltage drop of each external diode. The performance characteristics for the above converter are shown below. Note that curves A and C show the circuit performance with economical 1N4148 diodes, while curves B and D are with lower loss MBRA120E Schottky diodes.



Curve	$V_{in}$ (V)	All Diodes	$R_{out}$ ( $\Omega$ )
A	3.0	1N4148	110
B	3.0	MBRA120E	95
C	5.0	1N4148	88
D	5.0	MBRA120E	78

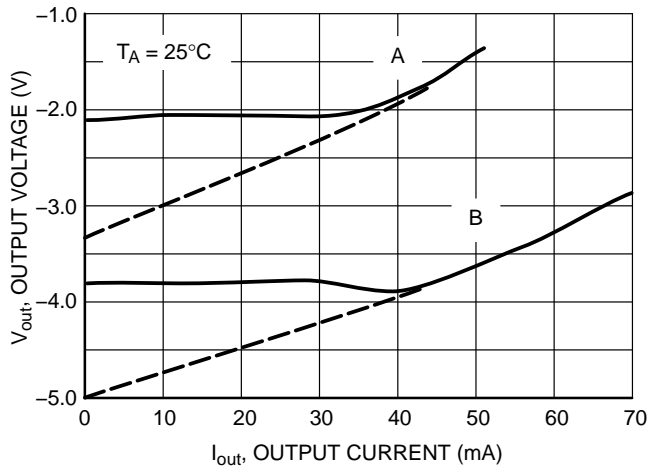
**Figure 29. Tripler Load Regulation, Output Voltage vs. Output Current**

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**Figure 30. Load Regulated Negative Output Voltage**

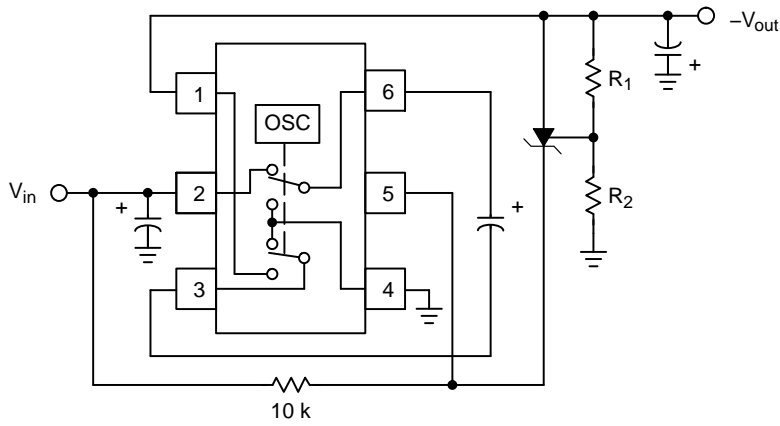
A zener diode can be used with the shutdown input to provide closed loop regulation performance. This significantly reduces the converter's output resistance and dramatically enhances the load regulation. For closed loop operation, the desired regulated output voltage must be lower in magnitude than  $-V_{in}$ . The output will regulate at a level of  $-V_Z + V_{th(SHDN)}$ . Note that the shutdown input voltage threshold is typically  $0.5 V_{in}$  and therefore, the regulated output voltage will change proportional to the converter's input. This characteristic will not present a problem when used in applications with constant input voltage. In this case the zener breakdown was measured at  $25 \mu A$ . The performance characteristics for the above converter are shown below. Note that the dashed curve sections represent the converter's open loop performance.



**Figure 31. Load Regulation, Output Voltage vs. Output Current**

Curve	$V_{in}$ (V)	$V_Z$ (V)	$V_{out}$ (V)
A	3.3	3.9	-2.1
B	5.0	6.5	-3.8

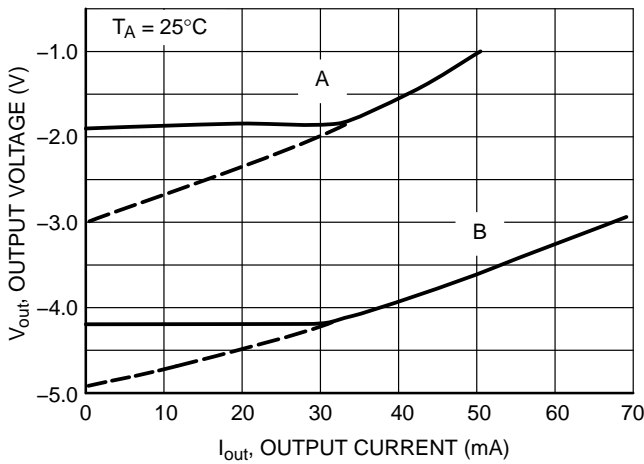
# NCP1729



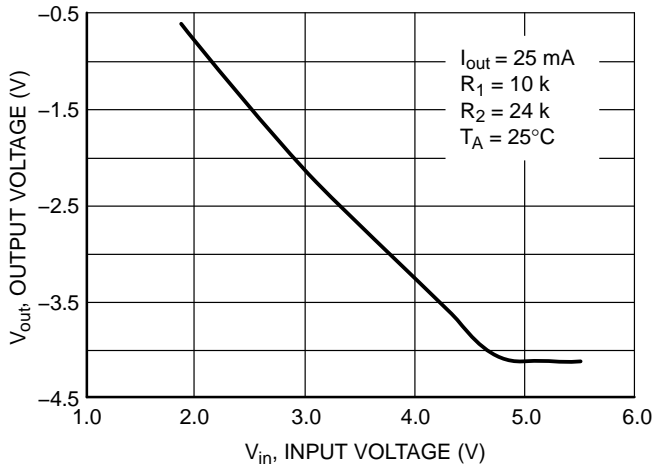
Capacitors = 3.3  $\mu$ F

**Figure 32. Line and Load Regulated Negative Output Voltage**

An adjustable shunt regulator can be used with the shutdown input to give excellent closed loop regulation performance. The shunt regulator acts as a comparator with a precise input offset voltage which significantly reduces the converter's output resistance and dramatically enhances the line and load regulation. For closed loop operation, the desired regulated output voltage must be lower in magnitude than  $-V_{in}$ . The output will regulate at a level of  $-V_{ref} (R_2/R_1 + 1)$ . The adjustable shunt regulator can be from either the TLV431 or TL431 families. The comparator offset or reference voltage is 1.25 V or 2.5 V respectively. The performance characteristics for the converter are shown below. Note that the dashed curve sections represent the converter's open loop performance.



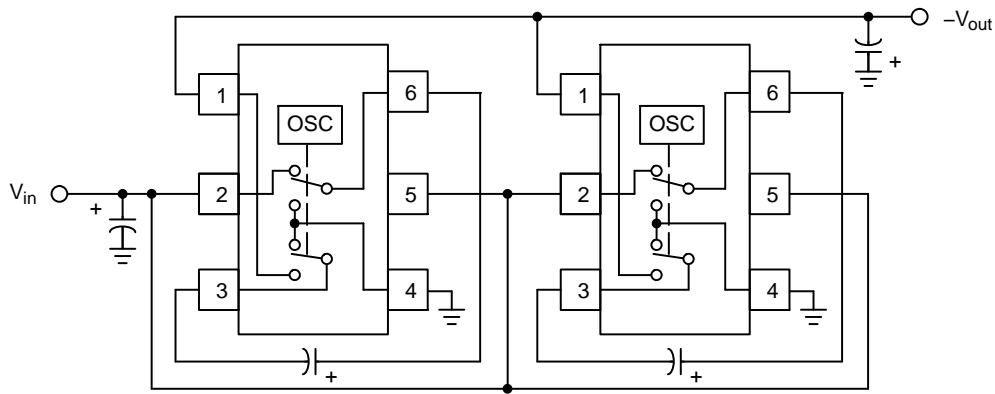
**Figure 33. Load Regulation, Output Voltage vs. Output Current**



**Figure 34. Line Regulation, Output Voltage vs. Input Current**

Curve	$V_{in}$ (V)	$R_1$ ( $\Omega$ )	$R_2$ ( $\Omega$ )	$V_{out}$ (V)
A	3.0	10 k	5.0 k	-1.8
B	5.0	10 k	24 k	-4.2

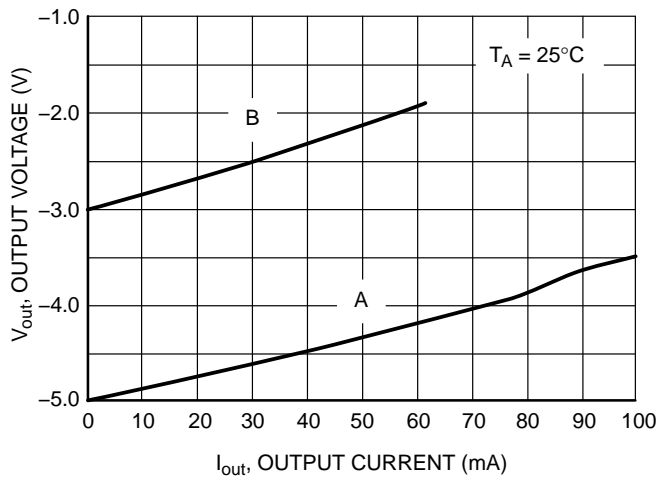
# NCP1729



Capacitors = 3.3  $\mu$ F

**Figure 35. Paralleling Devices for Increased Negative Output Current**

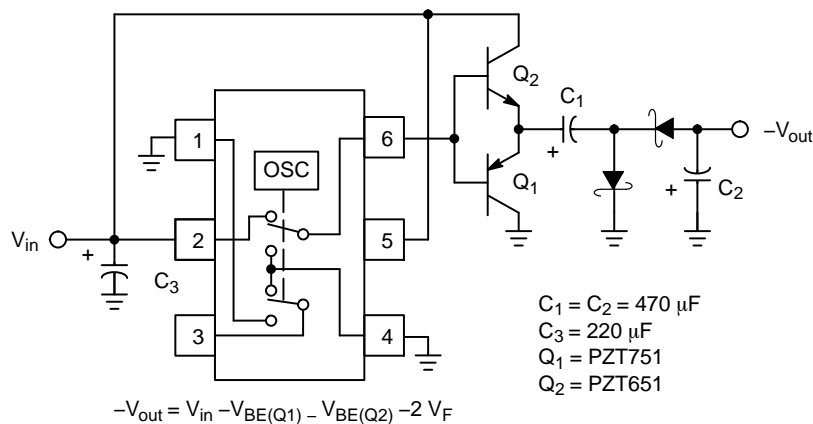
An increase in converter output current capability with a reduction in output resistance can be obtained by paralleling two or more devices. The output current capability is approximately equal to the number of devices paralleled. A single shared output capacitor is sufficient for proper operation but each device does require its own pump capacitor. Note that the output ripple frequency will be complex since the oscillators are not synchronized. The output resistance is approximately equal to the output resistance of one device divided by the total number of devices paralleled. The performance characteristics for a converter consisting of two paralleled devices is shown below.



Curve	$V_{in}$ (V)	$R_{out}$ ( $\Omega$ )
A	5.0	14
B	3.0	17

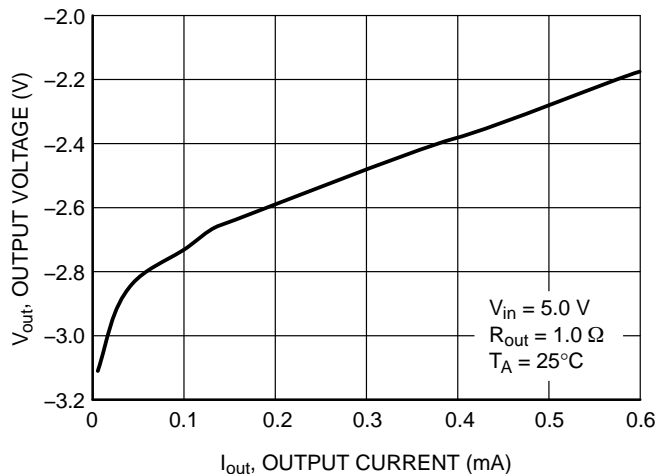
**Figure 36. Parallel Load Regulation, Output Voltage vs. Output Current**

## NCP1729



**Figure 37. External Switch for Increased Negative Output Current**

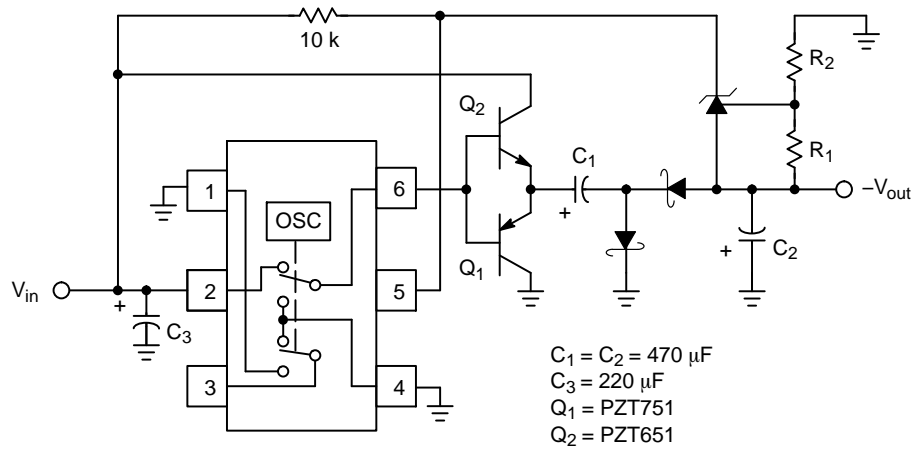
The output current capability of the NCP1729 can be extended beyond 600 mA with the addition of two external switch transistors and two Schottky diodes. The output voltage is approximately equal to  $-V_{in}$  minus the sum of the base emitter drops of both transistors and the forward voltage of both diodes. The performance characteristics for the converter are shown below. Note that the output resistance is reduced to 1.0  $\Omega$ .



**Figure 38. Current Boosted Load Regulation, Output Voltage vs. Output Current**

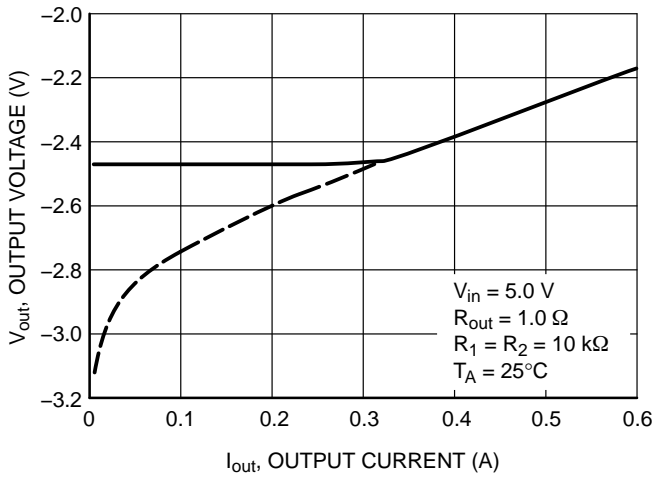


# NCP1729

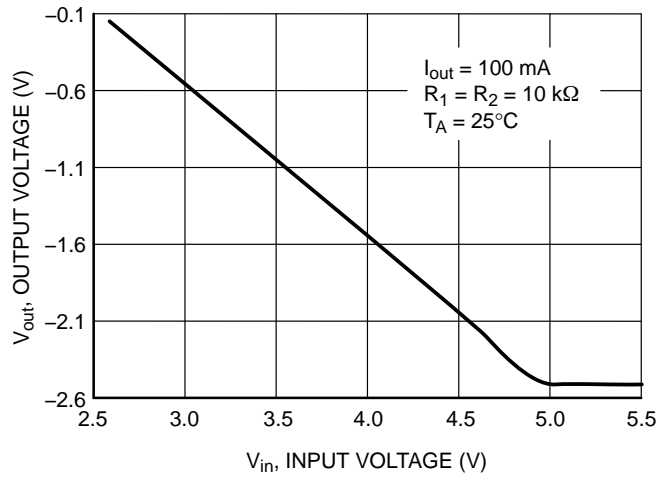


**Figure 39. Line and Load Regulated Negative Output Voltage with High Current Capability**

This converter is a combination of Figures 37 and 32. It provides a line and load regulated output of  $-2.47 \text{ V}$  at up to  $300 \text{ mA}$  with an input voltage of  $5.0 \text{ V}$ . The output will regulate at a level of  $-V_{\text{ref}} (R_2/R_1 + 1)$ . The performance characteristics are shown below. Note that the dashed line is the open loop and the solid line is the closed loop configuration for the load regulation.

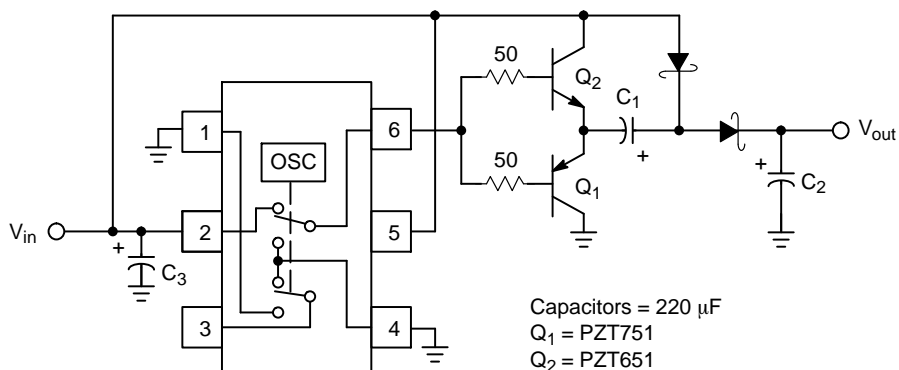


**Figure 40. Current Boosted Load Regulation, Output Voltage vs. Output Current**



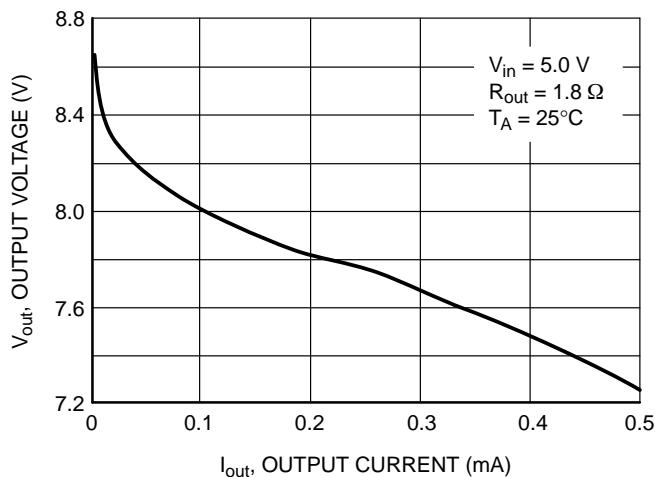
**Figure 41. Current Boosted Line Regulation, Output Voltage vs. Output Current**

## NCP1729

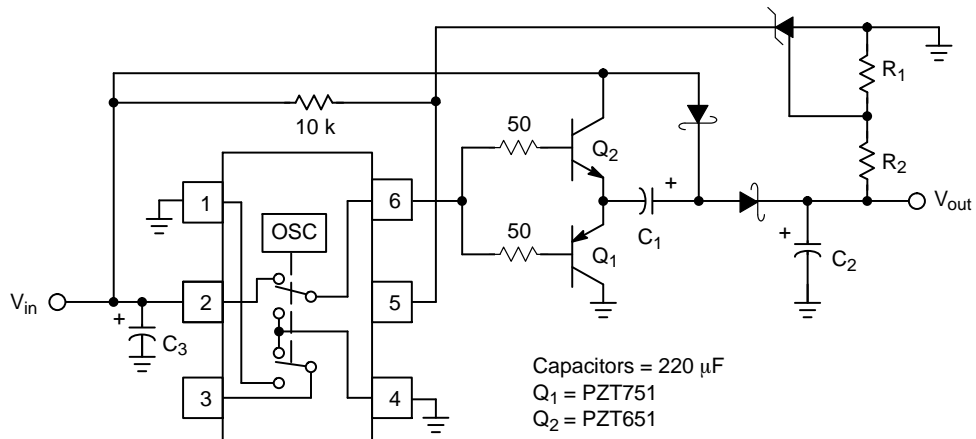


**Figure 42. Positive Output Voltage Doubler with High Current Capability**

The NCP1729 can be configured to produce a positive output voltage doubler with current capability of 500 mA. This is accomplished with the addition of two external switch transistors and two Schottky diodes. The output voltage is approximately equal to  $2.0 V_{in}$  minus the sum of the base emitter drops of both transistors and the forward voltage of both diodes. The performance characteristics for the converter is shown below. Note that the output resistance is reduced to  $1.8 \Omega$ .

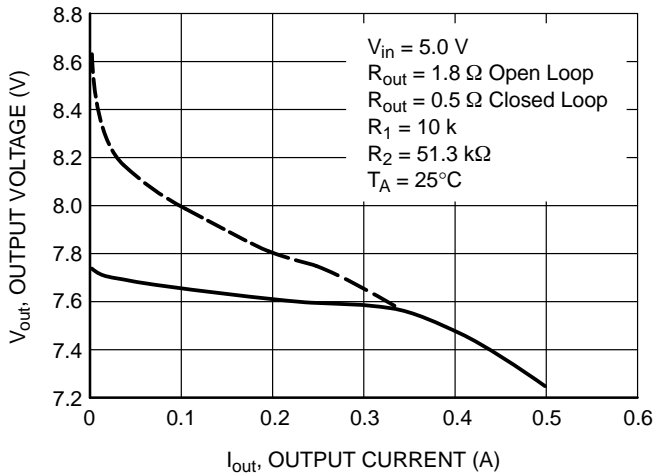


**Figure 43. Positive Doubler with Current Boosted Load Regulation, Output Voltage vs. Output Current**

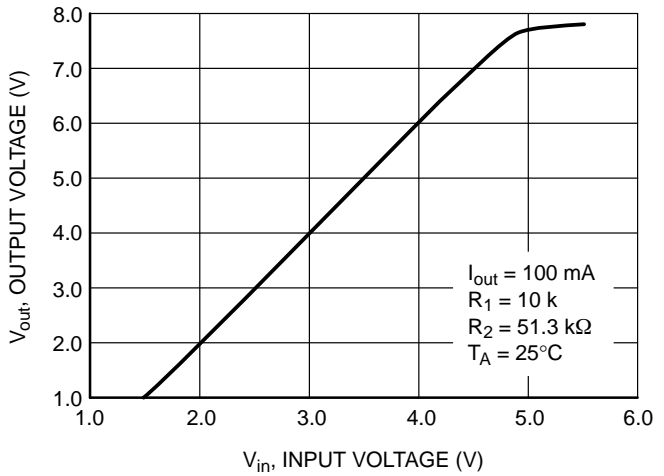


**Figure 44. Line and Load Regulated Positive Output Voltage Doubler with High Current Capability**

This converter is a combination of Figures 42 and the shunt regulator to close the loop. In this case the anode of the regulator is connected to ground. It provides a line and load regulated output of 7.6 V at up to 300 mA with a input voltage of 5.0 V. The output will regulate at a level of  $V_{ref} (R_2/R_1 + 1)$ . The open loop configuration is the dashed line and the closed loop is the solid line. The performance characteristics are shown below.

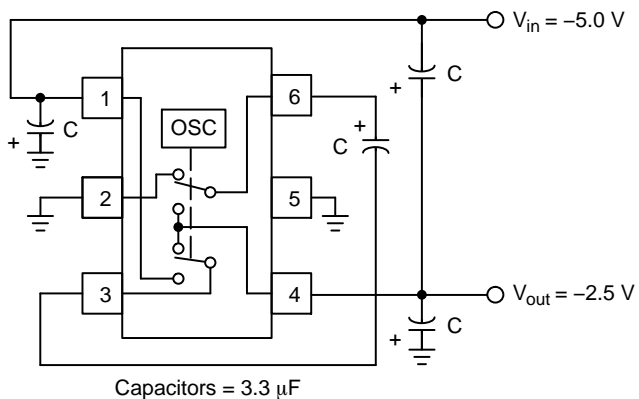


**Figure 45. Current Boosted Close Loop Load Regulation, Output Voltage vs. Output Current**



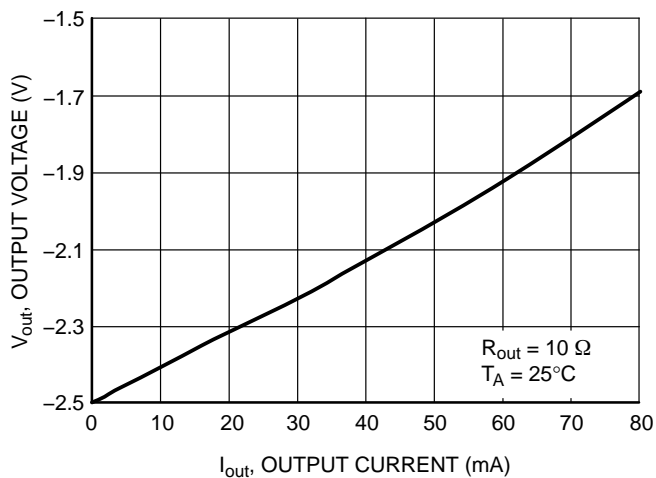
**Figure 46. Current Boosted Close Loop Line Regulation, Output Voltage vs. Input Voltage**

# NCP1729



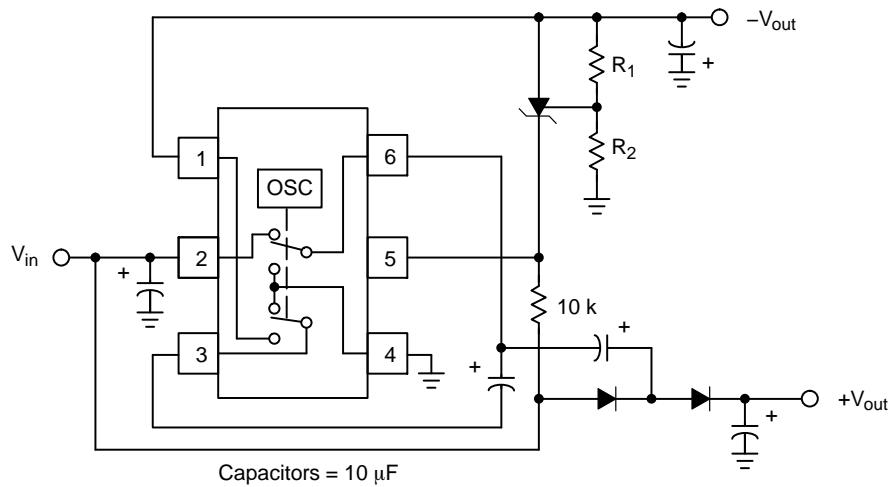
**Figure 47. Negative Input Voltage Splitter**

A single device can be used to split a negative input voltage. The output voltage is approximately equal to  $-V_{in} / 2.0$ . The performance characteristics are shown below. Note that the converter has an output resistance of  $10 \Omega$ .



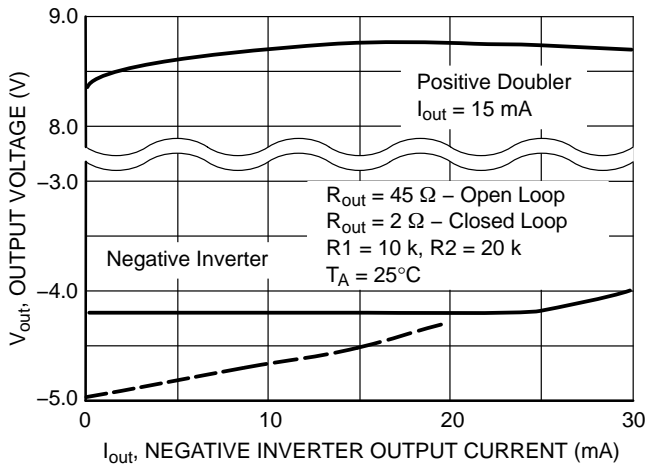
**Figure 48. Negative Voltage Splitter Load Regulation, Output Voltage vs. Output Current**

# NCP1729

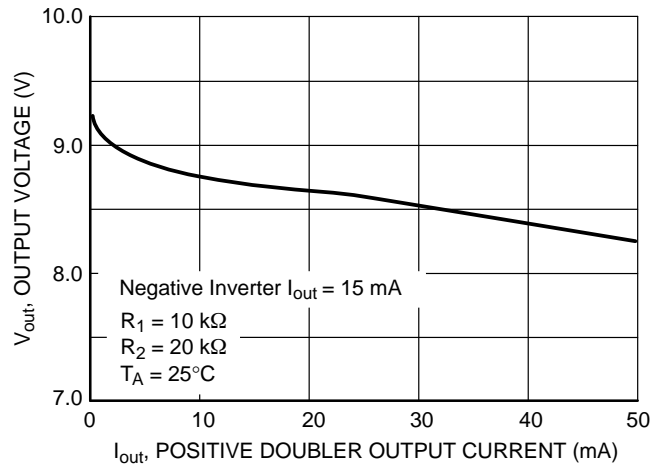


**Figure 49. Combination of a Closed Loop Negative Inverter with a Positive Output Voltage Doubler**

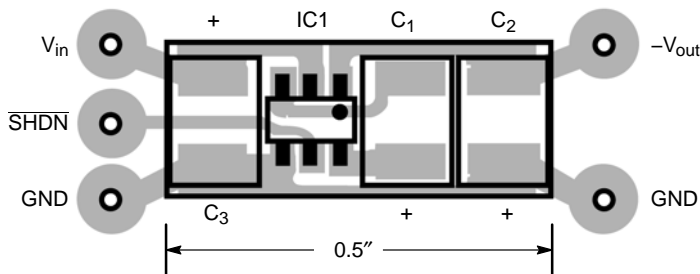
All of the previously shown converter circuits have only single outputs. Applications requiring multiple outputs can be constructed by incorporating combinations of the former circuits. The converter shown above combines Figures 26 and 32 to form a regulated negative output inverter with a non-regulated positive output doubler. The magnitude of  $-V_{out}$  is controlled by the resistor values and follows the relationship  $-V_{ref} (R_2/R_1 + 1)$ . Since the positive output is not within the feedback loop, its output voltage will increase as the negative output load increases. This cross regulation characteristic is shown in the upper portion of Figure 50. The dashed line is the open loop and the solid line is the closed loop configuration for the load regulation. The load regulation for the positive doubler with a constant load on the  $-V_{out}$  is shown in Figure 51.



**Figure 50. Load Regulation, Output Voltage vs. Output Current**



**Figure 51. Load Regulation, Output Voltage vs. Output Current**



Inverter Size = 0.5 in x 0.2 in  
Area = 0.10 in<sup>2</sup>, 64.5 mm<sup>2</sup>

**Figure 52. Inverter Circuit Board Layout, Top View Copper Side**

# NCP1729

## ORDERING INFORMATION

Device	Marking	Package	Shipping†
NCP1729SN35T1G	EAD	TSOP-6 (Pb-Free)	3000 / Tape & Reel
NCV1729SN35T1G*	NCV		

†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.

\*NCV:  $T_{low} = -40^{\circ}\text{C}$ ,  $T_{high} = +85^{\circ}\text{C}$ . Guaranteed by design. NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable.

# MECHANICAL CASE OUTLINE

## PACKAGE DIMENSIONS

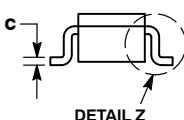
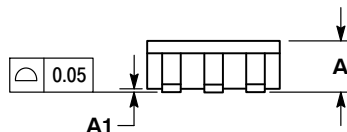
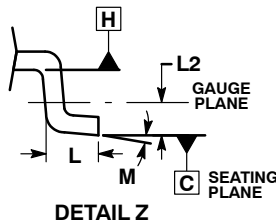
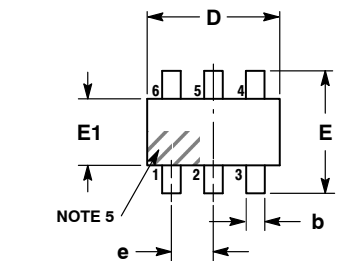
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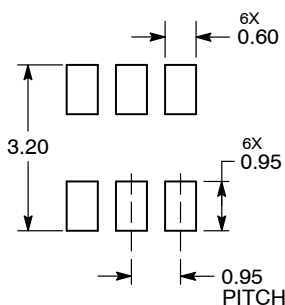


- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  2. CONTROLLING DIMENSION: MILLIMETERS.
  3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.
  4. DIMENSIONS D AND E1 DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS. MOLD FLASH, PROTRUSIONS, OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE. DIMENSIONS D AND E1 ARE DETERMINED AT DATUM H.
  5. PIN ONE INDICATOR MUST BE LOCATED IN THE INDICATED ZONE.

DIM	MILLIMETERS		
	MIN	NOM	MAX
A	0.90	1.00	1.10
A1	0.01	0.06	0.10
b	0.25	0.38	0.50
c	0.10	0.18	0.26
D	2.90	3.00	3.10
E	2.50	2.75	3.00
E1	1.30	1.50	1.70
e	0.85	0.95	1.05
L	0.20	0.40	0.60
L2	0.25 BSC		
M	0°	-	10°

- |  |  |   |   |   |  |
|--|--|---|---|---|--|
| <p>STYLE 1:<br/>PIN 1. DRAIN<br/>2. DRAIN<br/>3. GATE<br/>4. SOURCE<br/>5. DRAIN<br/>6. DRAIN</p>              | <p>STYLE 2:<br/>PIN 1. EMITTER 2<br/>2. BASE 1<br/>3. COLLECTOR 1<br/>4. EMITTER 1<br/>5. BASE 2<br/>6. COLLECTOR 2</p>    | <p>STYLE 3:<br/>PIN 1. ENABLE<br/>2. N/C<br/>3. R BOOST<br/>4. Vz<br/>5. V in<br/>6. V out</p>                            | <p>STYLE 4:<br/>PIN 1. N/C<br/>2. V in<br/>3. NOT USED<br/>4. GROUND<br/>5. ENABLE<br/>6. LOAD</p>                | <p>STYLE 5:<br/>PIN 1. EMITTER 2<br/>2. BASE 2<br/>3. COLLECTOR 1<br/>4. EMITTER 1<br/>5. BASE 1<br/>6. COLLECTOR 2</p> | <p>STYLE 6:<br/>PIN 1. COLLECTOR<br/>2. COLLECTOR<br/>3. BASE<br/>4. EMITTER<br/>5. COLLECTOR<br/>6. COLLECTOR</p> |
| <p>STYLE 7:<br/>PIN 1. COLLECTOR<br/>2. COLLECTOR<br/>3. BASE<br/>4. N/C<br/>5. COLLECTOR<br/>6. EMITTER</p>   | <p>STYLE 8:<br/>PIN 1. Vbus<br/>2. D(in)<br/>3. D(in)+<br/>4. D(out)+<br/>5. D(out)<br/>6. GND</p>                         | <p>STYLE 9:<br/>PIN 1. LOW VOLTAGE GATE<br/>2. DRAIN<br/>3. SOURCE<br/>4. DRAIN<br/>5. DRAIN<br/>6. HIGH VOLTAGE GATE</p> | <p>STYLE 10:<br/>PIN 1. D(OUT)+<br/>2. GND<br/>3. D(OUT)-<br/>4. D(IN)-<br/>5. VBUS<br/>6. D(IN)+</p>             | <p>STYLE 11:<br/>PIN 1. SOURCE 1<br/>2. DRAIN 2<br/>3. DRAIN 2<br/>4. SOURCE 2<br/>5. GATE 1<br/>6. DRAIN 1/GATE 2</p>  | <p>STYLE 12:<br/>PIN 1. I/O<br/>2. GROUND<br/>3. I/O<br/>4. I/O<br/>5. VCC<br/>6. I/O</p>                          |
| <p>STYLE 13:<br/>PIN 1. GATE 1<br/>2. SOURCE 2<br/>3. GATE 2<br/>4. DRAIN 2<br/>5. SOURCE 1<br/>6. DRAIN 1</p> | <p>STYLE 14:<br/>PIN 1. ANODE<br/>2. SOURCE<br/>3. GATE<br/>4. CATHODE/DRAIN<br/>5. CATHODE/DRAIN<br/>6. CATHODE/DRAIN</p> | <p>STYLE 15:<br/>PIN 1. ANODE<br/>2. SOURCE<br/>3. GATE<br/>4. DRAIN<br/>5. N/C<br/>6. CATHODE</p>                        | <p>STYLE 16:<br/>PIN 1. ANODE/CATHODE<br/>2. BASE<br/>3. EMITTER<br/>4. COLLECTOR<br/>5. ANODE<br/>6. CATHODE</p> | <p>STYLE 17:<br/>PIN 1. EMITTER<br/>2. BASE<br/>3. ANODE/CATHODE<br/>4. ANODE<br/>5. CATHODE<br/>6. COLLECTOR</p>       |  |

### RECOMMENDED SOLDERING FOOTPRINT\*



DIMENSIONS: MILLIMETERS

### GENERIC MARKING DIAGRAM\*



- |  |   |
|--|---|
| <p>XXX = Specific Device Code<br/>A = Assembly Location<br/>Y = Year<br/>W = Work Week<br/>▪ = Pb-Free Package</p> | <p>XXX = Specific Device Code<br/>M = Date Code<br/>▪ = Pb-Free Package</p> |
|--|---|

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

\*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.

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