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# Wide Input Voltage Low Dropout, Ultra-Low Iq Regulator

## NCP716BC

The NCP716BC is 150 mA LDO Linear Voltage Regulator. It is a very stable and accurate device with ultra-low ground current consumption (4.7  $\mu$ A over the full output load range) and a wide input voltage range (up to 24 V). The regulator incorporates several protection features such as Thermal Shutdown and Current Limiting.

### Features

- Operating Input Voltage Range: 2.5 V to 24 V
- Fixed Voltage Options Available: 3.0 V, 3.3 V, 3.45 V and 5.0 V
- Ultra Low Quiescent Current: Max. 4.7  $\mu$ A over Temperature
- $\pm 2\%$  Accuracy over Full Temperature Range
- Noise: 115  $\mu$ V<sub>RMS</sub> from 200 Hz to 100 kHz
- Thermal Shutdown and Current Limit Protection
- Available in TSOP-5 Package
- This is a Pb-Free Device

### Typical Applications

- Portable Equipment
- Communication Systems
- Industrial Measurement Systems
- Home Automation Devices

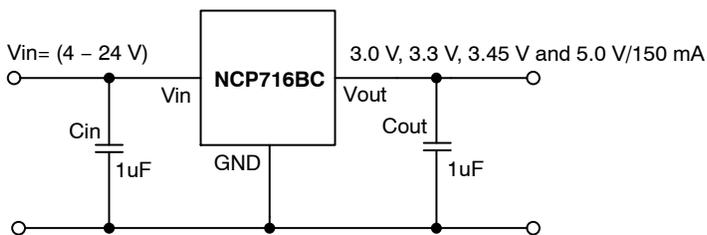
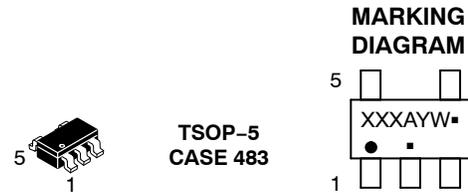


Figure 1. Typical Application Schematic



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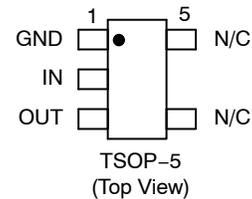
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XXX = Specific Device Code  
 A = Assembly Location  
 Y = Year  
 W = Work Week  
 ■ = Pb-Free Package

(Note: Microdot may be in either location)

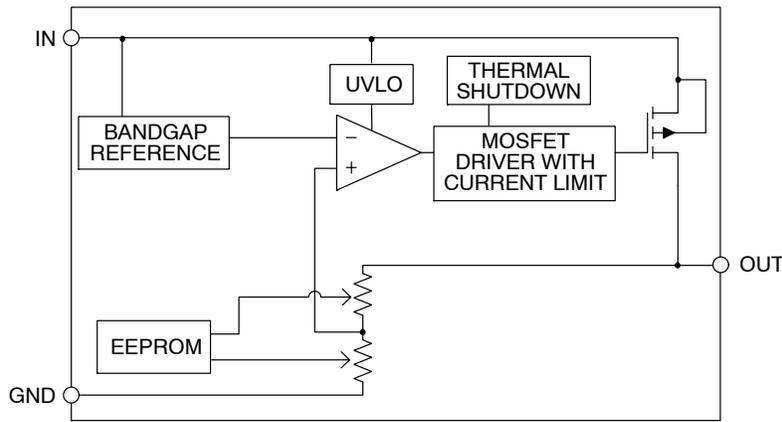
### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering, marking and shipping information in the package dimensions section on page 8 of this data sheet.

# NCP716BC



**Figure 2. Simplified Block Diagram**

**Table 1. PIN FUNCTION DESCRIPTION**

| Pin No. | Pin Name | Description  |
|---------|----------|--|
| 3       | OUT      | Regulated output voltage pin. A small 1.0 $\mu\text{F}$ ceramic capacitor is needed from this pin to ground to assure stability. |
| 1       | GND      | Power supply ground.   |
| 2       | IN       | Input pin. A small 1.0 $\mu\text{F}$ ceramic capacitor is needed from this pin to ground to assure stability.                    |
| 4       | N/C      | This pin can be tied to ground to improve thermal dissipation or left disconnected.  |
| 5       | N/C      | This pin can be tied to ground to improve thermal dissipation or left disconnected.  |

**Table 2. ABSOLUTE MAXIMUM RATINGS**

| Rating                                    | Symbol                    | Value      | Unit               |
|---|---------------------------|------------|--------------------|
| Input Voltage (Note 1)                    | $V_{\text{IN}}$           | -0.3 to 24 | V                  |
| Output Voltage                            | $V_{\text{OUT}}$          | -0.3 to 6  | V                  |
| Output Short Circuit Duration             | $t_{\text{SC}}$           | Indefinite | s                  |
| Maximum Junction Temperature              | $T_{\text{J(MAX)}}$       | 150        | $^{\circ}\text{C}$ |
| Storage Temperature                       | $T_{\text{STG}}$          | -55 to 150 | $^{\circ}\text{C}$ |
| ESD Capability, Human Body Model (Note 2) | $\text{ESD}_{\text{HBM}}$ | 2000       | V                  |
| ESD Capability, Machine Model (Note 2)    | $\text{ESD}_{\text{MM}}$  | 200        | V                  |

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. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
2. This device series incorporates ESD protection and is tested by the following methods:
  - ESD Human Body Model tested per EIA/JESD22-A114
  - ESD Machine Model tested per EIA/JESD22-A115
  - ESD Charged Device Model tested per EIA/JESD22-C101E
  - Latchup Current Maximum Rating tested per JEDEC standard: JESD78.

**Table 3. THERMAL CHARACTERISTICS**

| Rating   | Symbol                | Value | Unit                        |
|--|-----------------------|-------|-----------------------------|
| Thermal Characteristics, TSOP-5<br>Thermal Resistance, Junction-to-Air | $R_{\theta\text{JA}}$ | 250   | $^{\circ}\text{C}/\text{W}$ |

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**Table 4. ELECTRICAL CHARACTERISTICS Voltage version 3.0 V**

$-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ;  $V_{IN} = 4.0\text{ V}$ ;  $I_{OUT} = 1\text{ mA}$ ,  $C_{IN} = C_{OUT} = 1.0\text{ }\mu\text{F}$ , unless otherwise noted. Typical values are at  $T_J = +25^{\circ}\text{C}$ . (Note 5)

| Parameter                             | Test Conditions   | Symbol                              | Min  | Typ    | Max   | Unit                |
|---------------------------------------|---|-------------------------------------|------|--------|-------|---------------------|
| Operating Input Voltage               |   | $V_{IN}$                            | 2.5  |        | 24    | V                   |
| Output Voltage Accuracy               | $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$   | $V_{OUT}$                           | 2.94 | 3.0    | 3.06  | V                   |
| Line Regulation                       | $V_{OUT} + 1\text{ V} \leq V_{IN} \leq 24\text{ V}$ , $I_{OUT} = 0.1\text{ mA}$                                     | $\text{Reg}_{LINE}$                 |      | 4      | 20    | mV                  |
| Load Regulation                       | $I_{OUT} = 0.1\text{ mA}$ to $150\text{ mA}$  | $\text{Reg}_{LOAD}$                 |      | 0.0013 | 0.008 | %/mA                |
| Dropout Voltage (Note 3)              | $V_{OUT} = 0.97 V_{OUT(NOM)}$ , $I_{OUT} = 150\text{ mA}$   | $V_{DO}$                            |      | 700    | 1100  | mV                  |
| Maximum Output Current                | (Note 6)  | $I_{OUT}$                           | 150  |        |       | mA                  |
| Ground Current                        | $I_{OUT} = 0\text{ mA}$ , $-40 < T_A < 125^{\circ}\text{C}$   | $I_{GND}$                           |      | 3.2    | 4.7   | $\mu\text{A}$       |
| Power Supply Rejection Ratio          | $V_{IN} = 4.0\text{ V} + 200\text{ mVpp}$ modulation<br>$I_{OUT} = 1\text{ mA}$ , $C_{OUT} = 10\text{ }\mu\text{F}$ | $f = 1\text{ kHz}$<br>$\text{PSRR}$ |      | 55     |       | dB                  |
| Output Noise Voltage                  | $V_{OUT} = 3.0\text{ V}$ , $I_{OUT} = 150\text{ mA}$<br>$f = 100\text{ Hz}$ to $100\text{ kHz}$                     | $V_{NOISE}$                         |      | 80     |       | $\mu\text{V}_{rms}$ |
| Thermal Shutdown Temperature (Note 4) | Temperature increasing from $T_J = +25^{\circ}\text{C}$   | $T_{SD}$                            |      | 180    |       | $^{\circ}\text{C}$  |
| Thermal Shutdown Hysteresis (Note 4)  | Temperature falling from $T_{SD}$   | $T_{SDH}$                           | -    | 10     | -     | $^{\circ}\text{C}$  |

3. Characterized when  $V_{OUT}$  falls 3% below the nominal  $V_{OUT} = 3.0\text{ V}$

4. Guaranteed by design and characterization.

5. Performance guaranteed over the indicated operating temperature range by design and/or characterization production tested at  $T_J = T_A = 25^{\circ}\text{C}$ . Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.

6. Please follow the Safe Operating Area.

**Table 5. ELECTRICAL CHARACTERISTICS Voltage version 3.3 V**

$-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ;  $V_{IN} = 4.3\text{ V}$ ;  $I_{OUT} = 1\text{ mA}$ ,  $C_{IN} = C_{OUT} = 1.0\text{ }\mu\text{F}$ , unless otherwise noted. Typical values are at  $T_J = +25^{\circ}\text{C}$ . (Note 9)

| Parameter                             | Test Conditions   | Symbol                              | Min   | Typ    | Max   | Unit                |
|---------------------------------------|---|-------------------------------------|-------|--------|-------|---------------------|
| Operating Input Voltage               |   | $V_{IN}$                            | 2.5   |        | 24    | V                   |
| Output Voltage Accuracy               | $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$   | $V_{OUT}$                           | 3.234 | 3.30   | 3.366 | V                   |
| Line Regulation                       | $V_{OUT} + 1\text{ V} \leq V_{IN} \leq 24\text{ V}$ , $I_{OUT} = 0.1\text{ mA}$                                     | $\text{Reg}_{LINE}$                 |       | 4      | 20    | mV                  |
| Load Regulation                       | $I_{OUT} = 0.1\text{ mA}$ to $150\text{ mA}$  | $\text{Reg}_{LOAD}$                 |       | 0.0013 | 0.008 | %/mA                |
| Dropout Voltage (Note 7)              | $V_{OUT} = 0.97 V_{OUT(NOM)}$ , $I_{OUT} = 150\text{ mA}$   | $V_{DO}$                            |       | 685    | 1080  | mV                  |
| Maximum Output Current                | (Note 10)   | $I_{OUT}$                           | 150   |        |       | mA                  |
| Ground Current                        | $I_{OUT} = 0\text{ mA}$ , $-40 < T_A < 125^{\circ}\text{C}$   | $I_{GND}$                           |       | 3.2    | 4.7   | $\mu\text{A}$       |
| Power Supply Rejection Ratio          | $V_{IN} = 4.3\text{ V} + 200\text{ mVpp}$ modulation<br>$I_{OUT} = 1\text{ mA}$ , $C_{OUT} = 10\text{ }\mu\text{F}$ | $f = 1\text{ kHz}$<br>$\text{PSRR}$ |       | 54     |       | dB                  |
| Output Noise Voltage                  | $V_{OUT} = 3.3\text{ V}$ , $I_{OUT} = 150\text{ mA}$<br>$f = 100\text{ Hz}$ to $100\text{ kHz}$                     | $V_{NOISE}$                         |       | 86     |       | $\mu\text{V}_{rms}$ |
| Thermal Shutdown Temperature (Note 8) | Temperature increasing from $T_J = +25^{\circ}\text{C}$   | $T_{SD}$                            |       | 180    |       | $^{\circ}\text{C}$  |
| Thermal Shutdown Hysteresis (Note 8)  | Temperature falling from $T_{SD}$   | $T_{SDH}$                           | -     | 10     | -     | $^{\circ}\text{C}$  |

7. Characterized when  $V_{OUT}$  falls 3% below the nominal  $V_{OUT} = 3.3\text{ V}$

8. Guaranteed by design and characterization.

9. Performance guaranteed over the indicated operating temperature range by design and/or characterization production tested at  $T_J = T_A = 25^{\circ}\text{C}$ . Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.

10. Please follow the Safe Operating Area.

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**Table 6. ELECTRICAL CHARACTERISTICS Voltage version 3.45 V**

$-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ;  $V_{IN} = 4.45\text{ V}$ ;  $I_{OUT} = 1\text{ mA}$ ,  $C_{IN} = C_{OUT} = 1.0\text{ }\mu\text{F}$ , unless otherwise noted. Typical values are at  $T_J = +25^{\circ}\text{C}$ . (Note 13)

| Parameter                              | Test Conditions  | Symbol                              | Min   | Typ    | Max   | Unit                |
|--|--|-------------------------------------|-------|--------|-------|---------------------|
| Operating Input Voltage                |  | $V_{IN}$                            | 2.5   |        | 24    | V                   |
| Output Voltage Accuracy                | $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$  | $V_{OUT}$                           | 3.381 | 3.45   | 3.519 | V                   |
| Line Regulation                        | $V_{OUT} + 1\text{ V} \leq V_{IN} \leq 24\text{ V}$ , $I_{OUT} = 0.1\text{ mA}$                                      | $\text{Reg}_{LINE}$                 |       | 4      | 20    | mV                  |
| Load Regulation                        | $I_{OUT} = 0.1\text{ mA}$ to 150 mA  | $\text{Reg}_{LOAD}$                 |       | 0.0013 | 0.008 | %/mA                |
| Dropout Voltage (Note 11)              | $V_{OUT} = 0.97 V_{OUT(NOM)}$ , $I_{OUT} = 150\text{ mA}$  | $V_{DO}$                            |       | 680    | 1070  | mV                  |
| Maximum Output Current                 | (Note 14)  | $I_{OUT}$                           | 150   |        |       | mA                  |
| Ground Current                         | $I_{OUT} = 0\text{ mA}$ , $-40 < T_A < 125^{\circ}\text{C}$  | $I_{GND}$                           |       | 3.2    | 4.7   | $\mu\text{A}$       |
| Power Supply Rejection Ratio           | $V_{IN} = 4.45\text{ V} + 200\text{ mVpp}$ modulation<br>$I_{OUT} = 1\text{ mA}$ , $C_{OUT} = 10\text{ }\mu\text{F}$ | $f = 1\text{ kHz}$<br>$\text{PSRR}$ |       | 54     |       | dB                  |
| Output Noise Voltage                   | $V_{OUT} = 4.45\text{ V}$ , $I_{OUT} = 150\text{ mA}$<br>$f = 100\text{ Hz}$ to 100 kHz                              | $V_{NOISE}$                         |       | 88     |       | $\mu\text{V}_{rms}$ |
| Thermal Shutdown Temperature (Note 12) | Temperature increasing from $T_J = +25^{\circ}\text{C}$  | $T_{SD}$                            |       | 180    |       | $^{\circ}\text{C}$  |
| Thermal Shutdown Hysteresis (Note 12)  | Temperature falling from $T_{SD}$  | $T_{SDH}$                           | -     | 10     | -     | $^{\circ}\text{C}$  |

11. Characterized when  $V_{OUT}$  falls 3% below the nominal  $V_{OUT} = 3.45\text{ V}$

12. Guaranteed by design and characterization.

13. Performance guaranteed over the indicated operating temperature range by design and/or characterization production tested at  $T_J = T_A = 25^{\circ}\text{C}$ . Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.

14. Please follow the Safe Operating Area.

**Table 7. ELECTRICAL CHARACTERISTICS Voltage version 5.0 V**

$-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ;  $V_{IN} = 6.0\text{ V}$ ;  $I_{OUT} = 1\text{ mA}$ ,  $C_{IN} = C_{OUT} = 1.0\text{ }\mu\text{F}$ , unless otherwise noted. Typical values are at  $T_J = +25^{\circ}\text{C}$ . (Note 17)

| Parameter                              | Test Conditions   | Symbol                              | Min  | Typ    | Max   | Unit                |
|--|---|-------------------------------------|------|--------|-------|---------------------|
| Operating Input Voltage                |   | $V_{IN}$                            | 2.5  |        | 24    | V                   |
| Output Voltage Accuracy                | $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$   | $V_{OUT}$                           | 4.90 | 5.0    | 5.10  | V                   |
| Line Regulation                        | $V_{OUT} + 1\text{ V} \leq V_{IN} \leq 24\text{ V}$ , $I_{OUT} = 0.1\text{ mA}$                                     | $\text{Reg}_{LINE}$                 |      | 4      | 20    | mV                  |
| Load Regulation                        | $I_{OUT} = 0.1\text{ mA}$ to 150 mA   | $\text{Reg}_{LOAD}$                 |      | 0.0013 | 0.008 | %/mA                |
| Dropout Voltage (Note 15)              | $V_{OUT} = 0.97 V_{OUT(NOM)}$ , $I_{OUT} = 150\text{ mA}$   | $V_{DO}$                            |      | 600    | 955   | mV                  |
| Maximum Output Current                 | (Note 18)   | $I_{OUT}$                           | 150  |        |       | mA                  |
| Ground Current                         | $I_{OUT} = 0\text{ mA}$ , $-40 < T_A < 125^{\circ}\text{C}$   | $I_{GND}$                           |      | 3.2    | 4.7   | $\mu\text{A}$       |
| Power Supply Rejection Ratio           | $V_{IN} = 6.0\text{ V} + 200\text{ mVpp}$ modulation<br>$I_{OUT} = 1\text{ mA}$ , $C_{OUT} = 10\text{ }\mu\text{F}$ | $f = 1\text{ kHz}$<br>$\text{PSRR}$ |      | 53     |       | dB                  |
| Output Noise Voltage                   | $V_{OUT} = 5.0\text{ V}$ , $I_{OUT} = 150\text{ mA}$<br>$f = 100\text{ Hz}$ to 100 kHz                              | $V_{NOISE}$                         |      | 115    |       | $\mu\text{V}_{rms}$ |
| Thermal Shutdown Temperature (Note 16) | Temperature increasing from $T_J = +25^{\circ}\text{C}$   | $T_{SD}$                            |      | 180    |       | $^{\circ}\text{C}$  |
| Thermal Shutdown Hysteresis (Note 16)  | Temperature falling from $T_{SD}$   | $T_{SDH}$                           | -    | 10     | -     | $^{\circ}\text{C}$  |

15. Characterized when  $V_{OUT}$  falls 3% below the nominal  $V_{OUT} = 5.0\text{ V}$

16. Guaranteed by design and characterization.

17. Performance guaranteed over the indicated operating temperature range by design and/or characterization production tested at  $T_J = T_A = 25^{\circ}\text{C}$ . Low duty cycle pulse techniques are used during testing to maintain the junction temperature as close to ambient as possible.

18. Please follow the Safe Operating Area.

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## TYPICAL CHARACTERISTICS

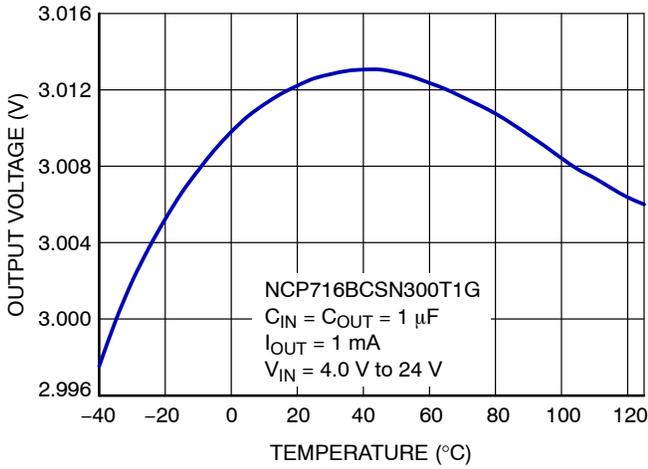


Figure 3. Output Voltage vs. Temperature

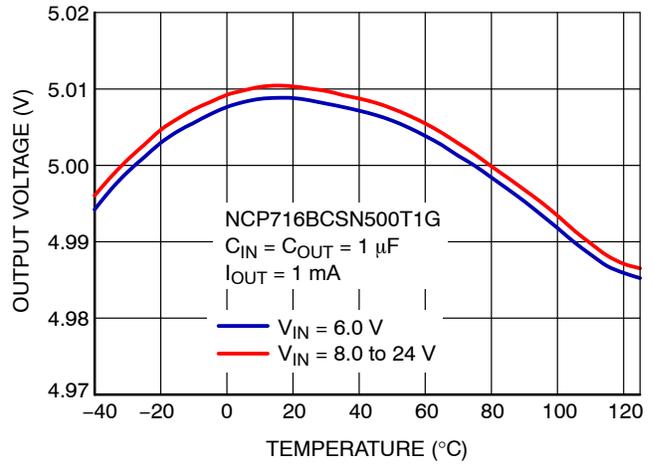


Figure 4. Output Voltage vs. Temperature

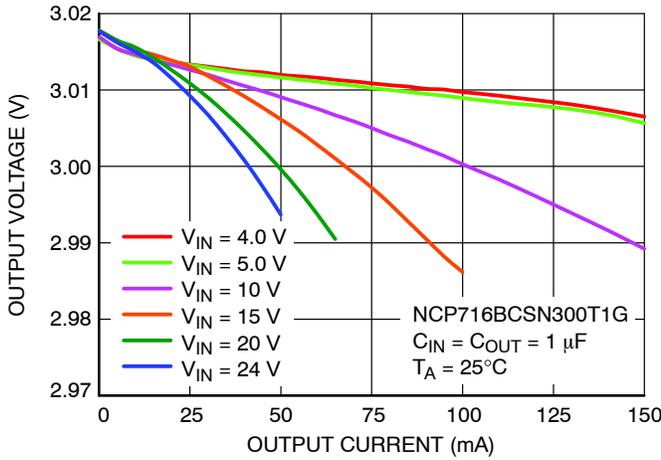


Figure 5. Output Voltage vs. Output Current

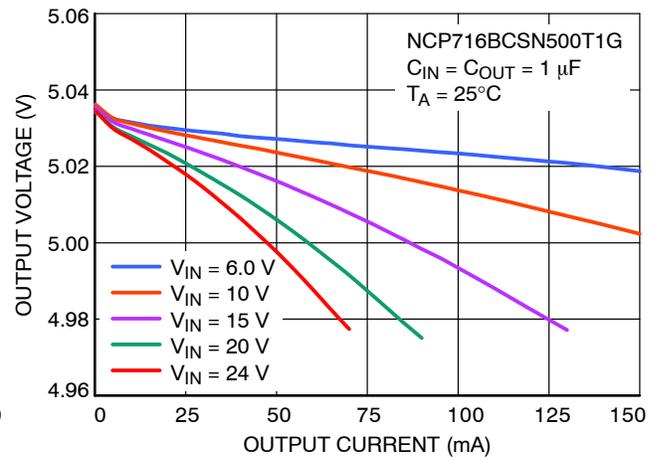


Figure 6. Output Voltage vs. Output Current

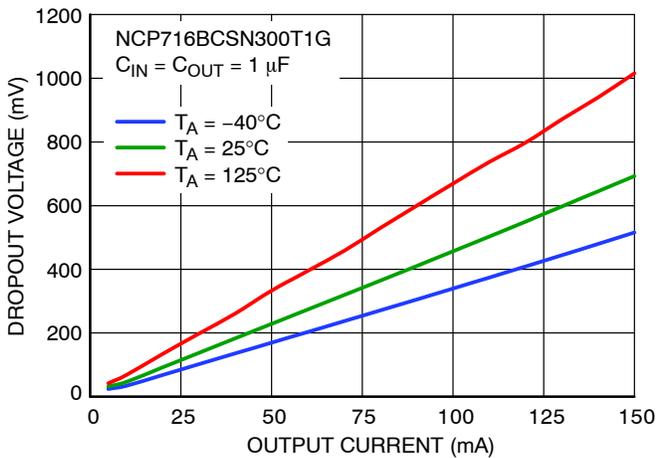


Figure 7. Dropout Voltage vs. Output Current

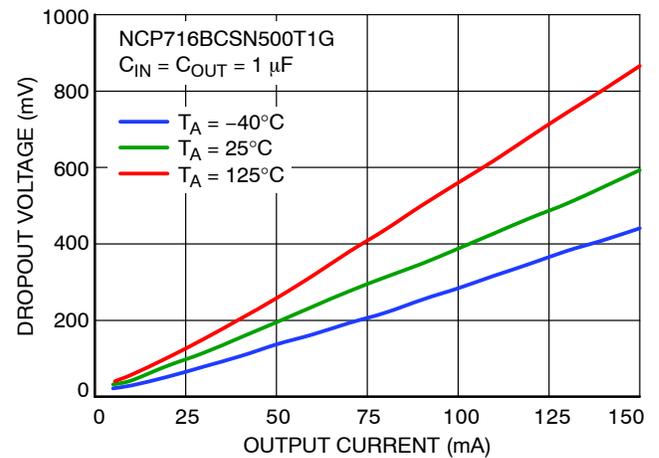


Figure 8. Dropout Voltage vs. Output Current

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## TYPICAL CHARACTERISTICS

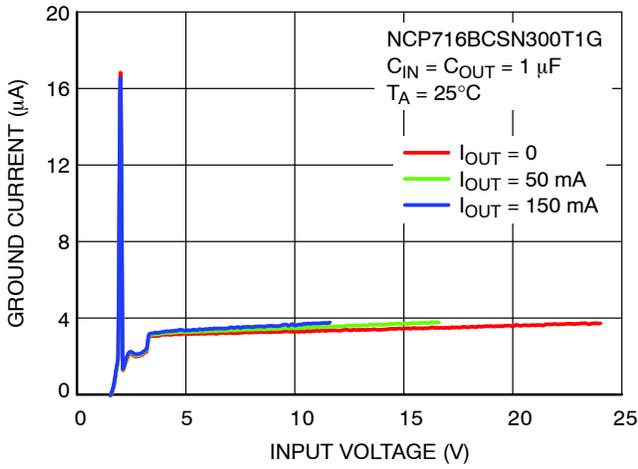


Figure 9. Ground Current vs. Input Voltage

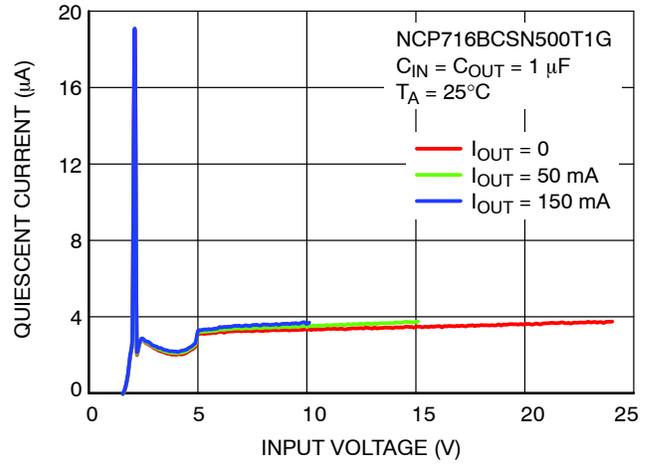


Figure 10. Ground Current vs. Input Voltage

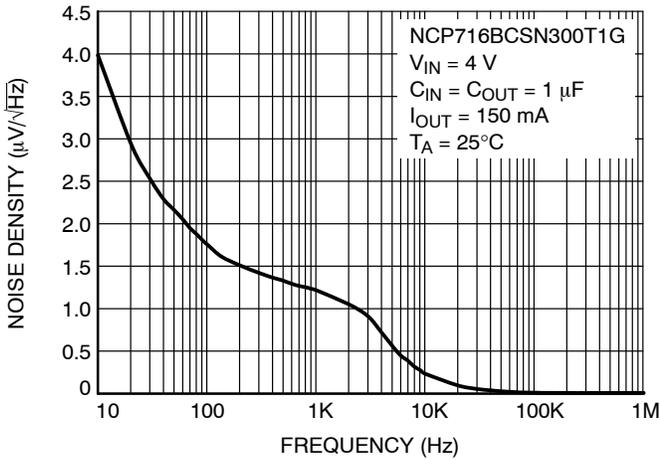


Figure 11. Spectral Noise Density vs. Frequency

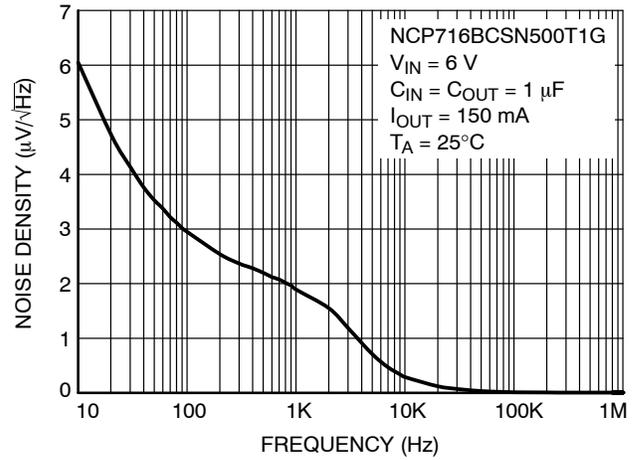


Figure 12. Spectral Noise Density vs. Frequency

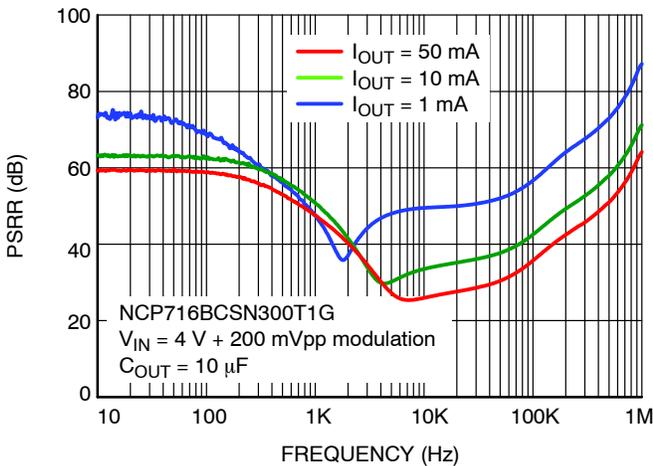


Figure 13. PSRR vs. Frequency

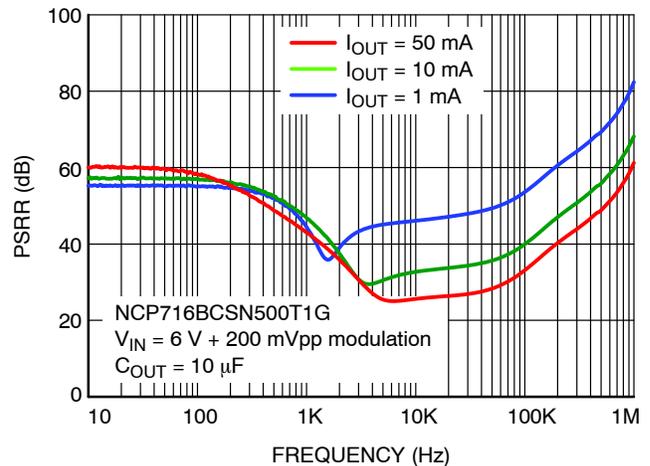


Figure 14. PSRR vs. Frequency

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## TYPICAL CHARACTERISTICS

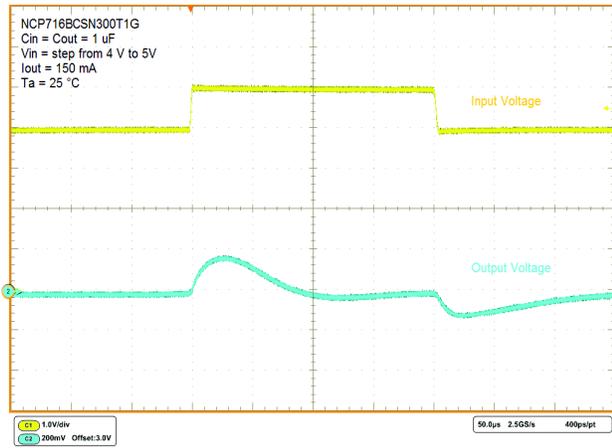


Figure 15. Line Transient Response

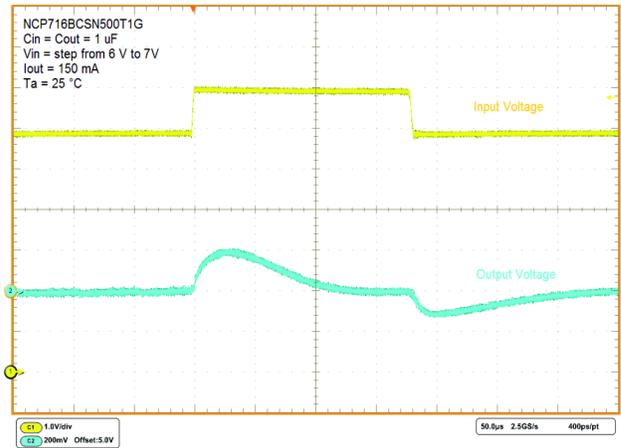


Figure 16. Line Transient Response

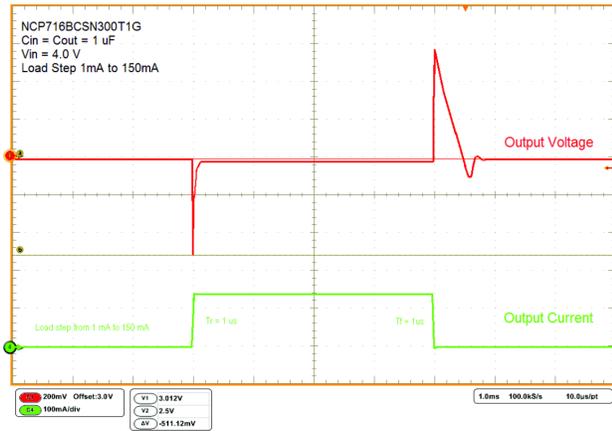


Figure 17. Load Transient Response

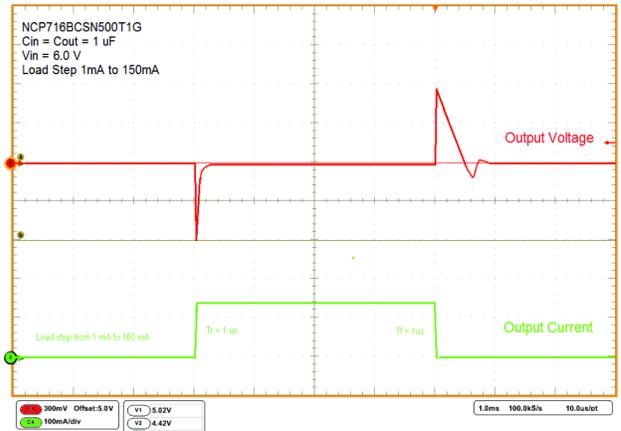


Figure 18. Load Transient Response

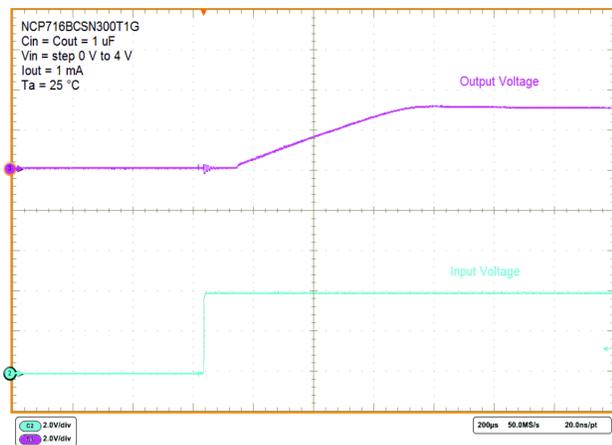


Figure 19. Turn-On Response

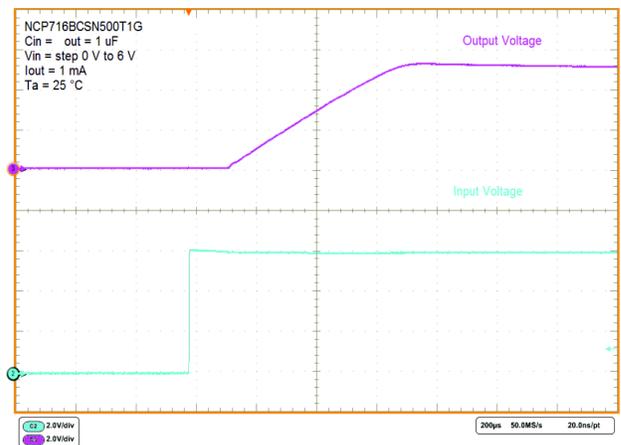


Figure 20. Turn-On Response

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## APPLICATIONS INFORMATION

The NCP716BC is the member of new family of Wide Input Voltage Range Low Dropout Regulators which delivers Ultra Low Ground Current consumption, Good Noise and Power Supply Rejection Ratio Performance.

### Input Decoupling ( $C_{IN}$ )

It is recommended to connect at least 1.0  $\mu$ F Ceramic X5R or X7R capacitor between IN and GND pin of the device. This capacitor will provide a low impedance path for any unwanted AC signals or Noise superimposed onto constant Input Voltage. The good input capacitor will limit the influence of input trace inductances and source resistance during sudden load current changes.

Higher capacitance and lower ESR Capacitors will improve the overall line transient response.

### Output Decoupling ( $C_{OUT}$ )

The NCP716BC does not require a minimum Equivalent Series Resistance (ESR) for the output capacitor. The device is designed to be stable with standard ceramics capacitors with values of 1.0  $\mu$ F or greater up to 10  $\mu$ F. The X5R and X7R types have the lowest capacitance variations over temperature thus they are recommended.

### Power Dissipation and Heat sinking

The maximum power dissipation supported by the device is dependent upon board design and layout. Mounting pad configuration on the PCB, the board material, and the ambient temperature affect the rate of junction temperature rise for the part. The maximum power dissipation the NCP716BC can handle is given by:

$$P_{D(MAX)} = \frac{[T_{J(MAX)} - T_A]}{R_{\theta JA}} \quad (\text{eq. 1})$$

The power dissipated by the NCP716BC for given application conditions can be calculated from the following equations:

$$P_D \approx V_{IN}(I_{GND}(I_{OUT})) + I_{OUT}(V_{IN} - V_{OUT}) \quad (\text{eq. 2})$$

or

$$V_{IN(MAX)} \approx \frac{P_{D(MAX)} + (V_{OUT} \times I_{OUT})}{I_{OUT} + I_{GND}} \quad (\text{eq. 3})$$

For reliable operation, junction temperature should be limited to +125°C maximum.

### Hints

$V_{IN}$  and GND printed circuit board traces should be as wide as possible. When the impedance of these traces is high, there is a chance to pick up noise or cause the regulator to malfunction. Place external components, especially the output capacitor, as close as possible to the NCP716BC, and make traces as short as possible.

## ORDERING INFORMATION

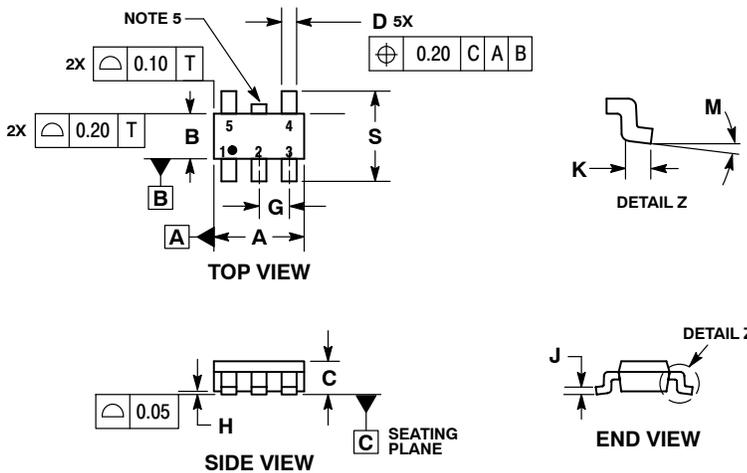
| Device           | Voltage Option | Marking | Package             | Shipping <sup>†</sup> |
|------------------|----------------|---------|---------------------|-----------------------|
| NCP716BCSN300T1G | 3.0 V          | 7AA     | TSOP-5<br>(Pb-Free) | 3000 / Tape & Reel    |
| NCP716BCSN330T1G | 3.3 V          | 7AC     | TSOP-5<br>(Pb-Free) | 3000 / Tape & Reel    |
| NCP716BCSN345T1G | 3.45 V         | 7AM     | TSOP-5<br>(Pb-Free) | 3000 / Tape & Reel    |
| NCP716BCSN500T1G | 5.0 V          | 7AV     | TSOP-5<br>(Pb-Free) | 3000 / Tape & Reel    |

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

# NCP716BC

## PACKAGE DIMENSIONS

TSOP-5  
CASE 483  
ISSUE N

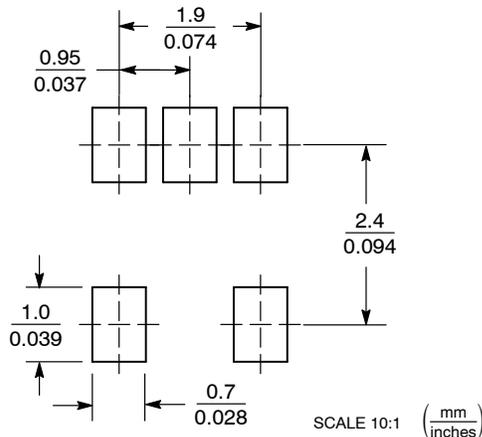


### NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH THICKNESS. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.
4. DIMENSIONS A AND B DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS. MOLD FLASH, PROTRUSIONS, OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE. DIMENSION A.
5. OPTIONAL CONSTRUCTION: AN ADDITIONAL TRIMMED LEAD IS ALLOWED IN THIS LOCATION. TRIMMED LEAD NOT TO EXTEND MORE THAN 0.2 FROM BODY.

| DIM | MILLIMETERS |      |
|-----|-------------|------|
|     | MIN         | MAX  |
| A   | 2.85        | 3.15 |
| B   | 1.35        | 1.65 |
| C   | 0.90        | 1.10 |
| D   | 0.25        | 0.50 |
| G   | 0.95 BSC    |      |
| H   | 0.01        | 0.10 |
| J   | 0.10        | 0.26 |
| K   | 0.20        | 0.60 |
| M   | 0°          | 10°  |
| S   | 2.50        | 3.00 |

### SOLDERING 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.

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