



YOUSHANG SEMICONDUCTOR

**设计研发新型功率器件**

**各类小信号开关**

**中低压及高压大电流等场效应管**

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## Description

The NK-AP716 is a 600mA, adjustable output voltage, ultra-low dropout linear regulator. The device includes pass element, error amplifier, band-gap reference, current limit and thermal shutdown circuitry. The device is turned on when EN pin is set to logic high level. A Power-OK (POK) output is available for power sequence control.

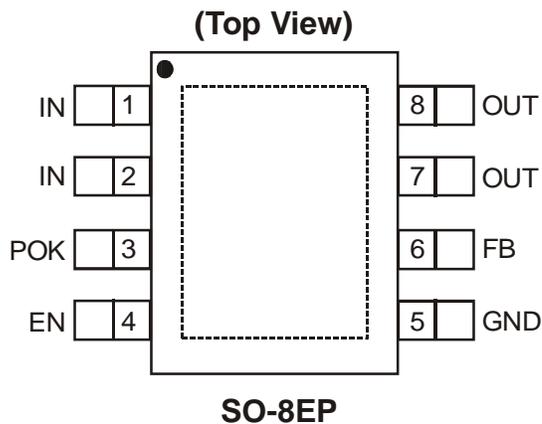
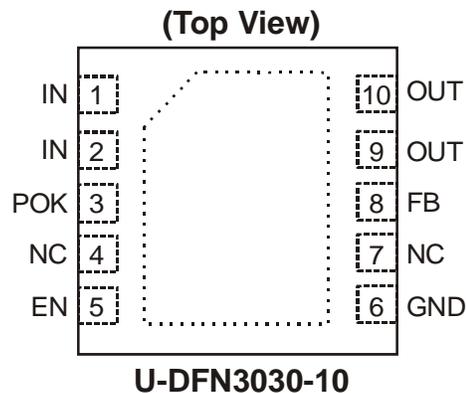
The characteristics of the low dropout voltage and low quiescent current make it suitable for low to medium power applications, for example, laptop computers, audio and video applications, and battery powered devices. The typical quiescent current is approximately 125 $\mu$ A.

Built-in current-limit and thermal-shutdown functions prevent IC from damage in fault conditions. The NK-AP716 are available in U-DFN3030-10 and SO-8EP packages.

## Features

- Wide input voltage range: 2.2V – 5.5V
- 300mV very low dropout at 500mA load
- Very low quiescent current ( $I_Q$ ): 125 $\mu$ A typical
- $\pm 2.5\%$  total accuracy over line, load and temperature
- Adjustable output voltage range: 0.8V to 5.0V
- Very fast transient response
- High PSRR
- Accurate voltage regulation
- Current limiting and short circuit protection
- Thermal shutdown protection
- Stable with any type output capacitor  $\geq 4.7\mu$ F
- Ambient temperature range -40 $^{\circ}$ C to +85 $^{\circ}$ C
- U-DFN3030-10 and SO-8EP: Available in “Green” Molding Compound (No Br, Sb)
- Lead Free Finish/RoHS Compliant (Note 1)

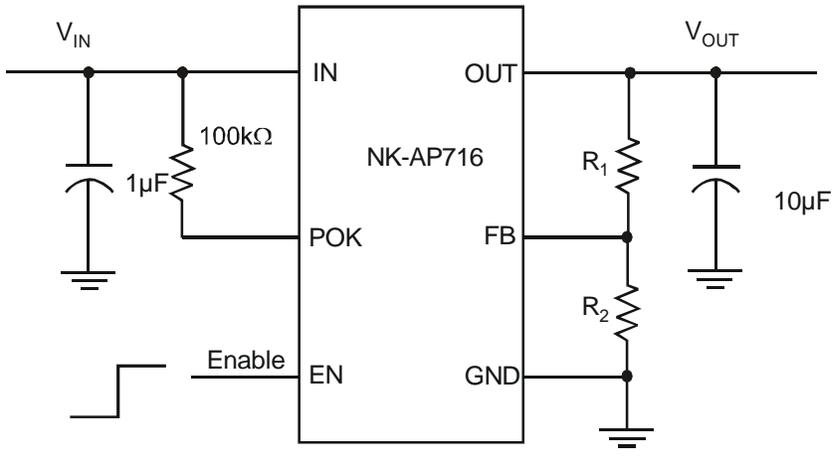
## Pin Assignments



## Applications

- Servers and laptops
- Smart phone and PDA
- MP3/MP4
- Bluetooth headset
- Low and medium power applications
- FPGA and DSP core or I/O power

### Typical Application Circuit

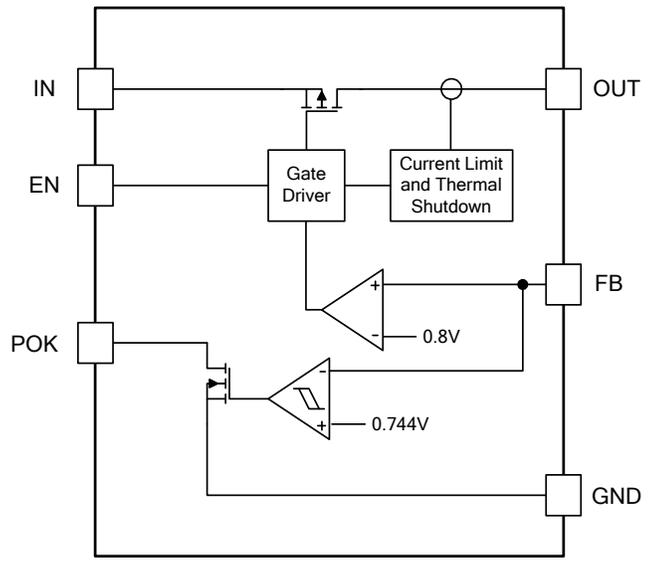


$$V_{OUT} = V_{REF} \left( 1 + \frac{R_1}{R_2} \right)$$

### Pin Descriptions

| Name | Pin #        |        | Description   |
|------|--------------|--------|---|
|      | U-DFN3030-10 | SO-8EP |   |
| IN   | 1, 2         | 1, 2   | Voltage input pins, to be tied together externally. Bypass to ground through at least 1µF capacitor.            |
| POK  | 3            | 3      | Power-OK output, active-high open-drain.  |
| EN   | 5            | 4      | Enable input, active high.  |
| GND  | 6            | 5      | Ground.   |
| FB   | 8            | 6      | Output feedback.  |
| OUT  | 9, 10        | 7, 8   | Voltage output pins, to be tied together externally. Bypass to ground through at least 4.7µF ceramic capacitor. |
| NC   | 4, 7         | NA     | No connection.  |

### Functional Block Diagram



### Absolute Maximum Ratings

| Symbol     | Parameter                       | Ratings                  | Unit |   |
|------------|---------------------------------|--------------------------|------|---|
| ESD HBM    | Human Body Model ESD Protection | 4                        | KV   |   |
| ESD MM     | Machine Model ESD Protection    | 300                      | V    |   |
| $V_{IN}$   | Input Voltage                   | 7                        | V    |   |
|            | OUT, FB, POK, EN Voltage        | $V_{IN} + 0.3$           | V    |   |
|            | Continuous Load Current         | Internal Limited         |      |   |
| $T_{Jmax}$ | Maximum Junction Temperature    | 150                      | °C   |   |
| $T_{ST}$   | Storage Temperature Range       | -65 ~ +150               | °C   |   |
| $P_D$      | Power Dissipation               | U-DFN3030-10 (Note 2, 4) | 3.1  | W |
|            |                                 | SO-8EP (Note 2, 5)       | 4.0  | W |

Notes: 2. Ratings apply to ambient temperature at 25°C

### Recommended Operating Conditions

| Symbol    | Parameter                     | Min | Max | Unit |
|-----------|-------------------------------|-----|-----|------|
| $V_{IN}$  | Input voltage                 | 2.2 | 5.5 | V    |
| $I_{OUT}$ | Output Current                | 0   | 600 | mA   |
| $T_A$     | Operating Ambient Temperature | -40 | +85 | °C   |

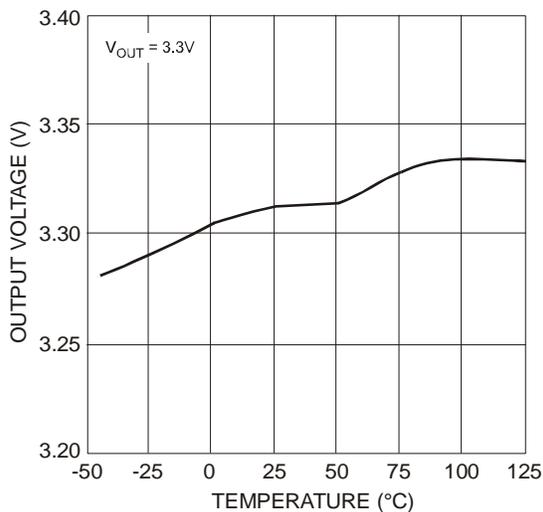
## Electrical Characteristics

( $T_A = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT} + 1\text{V}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 10\mu\text{F}$ ,  $V_{EN} = V_{IN}$ , unless otherwise stated)

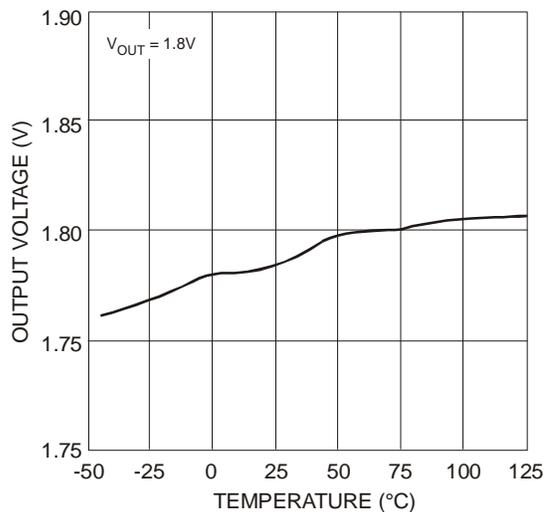
| Symbol   | Parameter                               | Test Conditions  | Min  | Typ.  | Max  | Unit               |
|--|---|--|------|-------|------|--------------------|
| $I_Q$  | Input Quiescent Current                 | $I_{OUT} = 0$  | —    | 125   | 170  | $\mu\text{A}$      |
| $I_{SHDN}$                                       | Input Shutdown Current                  | $V_{EN} = 0\text{V}$ , $I_{OUT} = 0$ (Note 3)                                      | -1   | 0.01  | +1   | $\mu\text{A}$      |
| $V_{ROPOUT}$                                     | Dropout Voltage                         | $V_{OUT} \geq 1.5\text{V}$ , $I_{OUT} = 500\text{mA}$                              |      | 300   | 400  | mV                 |
| $V_{REF}$  | FB reference voltage                    |  |      | 0.8   |      | V                  |
| $I_{FB}$   | FB leakage                              |  | —    | 0.01  | 1    | $\mu\text{A}$      |
| $V_{OUT}$  | Output Voltage Total Accuracy           | Over line, load and temperature  | -2.5 |       | +2.5 | %                  |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}} / V_{OUT}$ | Line Regulation                         | $V_{IN} = V_{OUT} + 1\text{V}$ to 5.5V,<br>$I_{OUT} = 1\text{mA}$                  |      | 0.015 |      | %/V                |
| $\Delta V_{OUT} / V_{OUT}$                       | Load Regulation                         | $I_{OUT}$ from 1mA to 500mA  | -1.0 |       | +1.0 | %                  |
| $t_{ST}$   | Start-up Time, from EN high to POK high | $V_{EN} = 0\text{V}$ to 2.0V,<br>$I_{OUT} = 100\text{mA}$ , $V_{IN} = 3.3\text{V}$ |      | 170   |      | $\mu\text{s}$      |
| PSRR   | Power Supply Rejection Ratio            | 1kHz, $V_{IN} = 3.3\text{V}$ ,<br>$V_{OUT} = 1.2\text{V}$ , $I_{OUT} = 0\text{mA}$ |      | 60    |      | dB                 |
| $I_{LIMIT}$                                      | Current limit                           | $V_{OUT} = 1.8\text{V}$ , $R_{OUT} = 0.5\Omega$                                    | 600  | 950   |      | mA                 |
| $I_{SHORT}$                                      | Short-circuit Current                   | $V_{IN} = 3.3\text{V}$ , $V_{OUT} < 0.2\text{V}$                                   |      | 380   |      | mA                 |
| $V_{IL}$   | EN Input Logic Low Voltage              |  |      |       | 0.4  | V                  |
| $V_{IH}$   | EN Input Logic High Voltage             |  | 1.4  |       |      | V                  |
| $I_{EN}$   | EN Input leakage                        | $V_{EN} = 0\text{V}$ or 5.5V   | —    | 0.01  | 1    | $\mu\text{A}$      |
| $V_{OL}$   | POK output low voltage                  | Force 2mA  |      | 100   | 200  | mV                 |
| $V_{POK\_TH\_UP}$                                | Output voltage (rising) POK threshold   | FB (or OUT for fixed version) rising   | 87%  | 92%   | 97%  | $V_{ref}$          |
| $V_{POK\_Hys}$                                   | Output voltage POK hysteresis           |  |      | 4%    |      | $V_{ref}$          |
| POK deglitch                                     |   | $V_{IN} = 3.3\text{V}$ , $V_{OUT} = 1.2\text{V}$                                   |      | 150   |      | $\mu\text{s}$      |
| $I_{POK\_LK}$                                    | POK leakage current                     | $V_{POK} = 5.5\text{V}$  | —    | 0.01  | 1    | $\mu\text{A}$      |
| $T_{SHDN}$                                       | Thermal shutdown threshold              |  |      | 150   |      | $^\circ\text{C}$   |
| $T_{HYS}$  | Thermal shutdown hysteresis             |  |      | 25    |      | $^\circ\text{C}$   |
| $\theta_{JA}$                                    | Thermal Resistance Junction-to-Ambient  | U-DFN3030-10 (Note 4)  |      | 40    |      | $^\circ\text{C/W}$ |
|  |   | SO-8EP (Note 5)  |      | 27    |      | $^\circ\text{C/W}$ |
| $\theta_{JC}$                                    | Thermal Resistance Junction-to- Case    | U-DFN3030-10 (Note 4)  |      | 9     |      | $^\circ\text{C/W}$ |
|  |   | SO-8EP (Note 5)  |      | 4     |      | $^\circ\text{C/W}$ |

- Notes:
- POK pin must be disconnected from IN pin.
  - Test condition for U-DFN3030-10: Device mounted on FR-4 2-layer board, 2oz copper, with minimum recommended pad on top layer and 6 vias to bottom layer 1.0"x1.5" ground plane.
  - Test condition for SO-8EP: Device mounted on 2" x 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

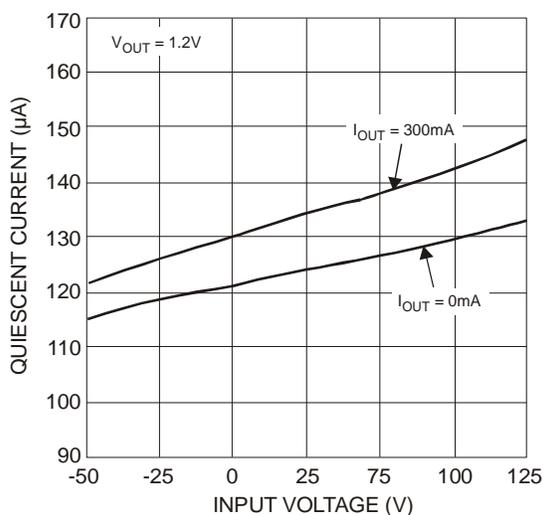
**Typical Performance Characteristics**



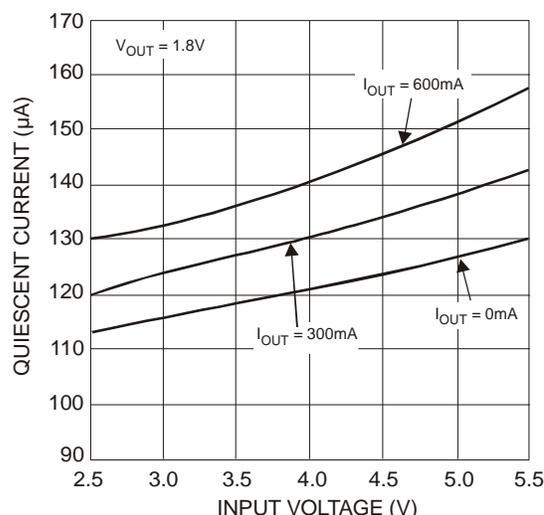
Output Voltage vs. Temperature



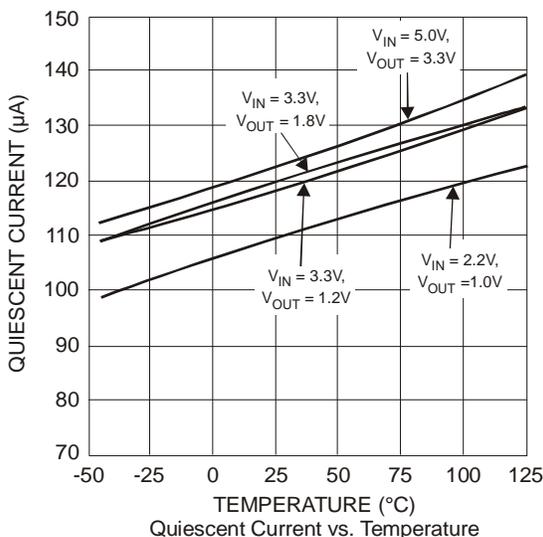
Output Voltage vs. Temperature



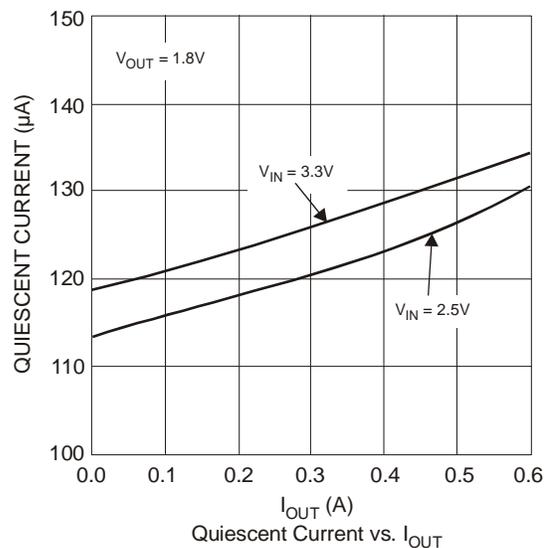
Quiescent Current vs. Input Voltage



Quiescent Current vs. Input Voltage

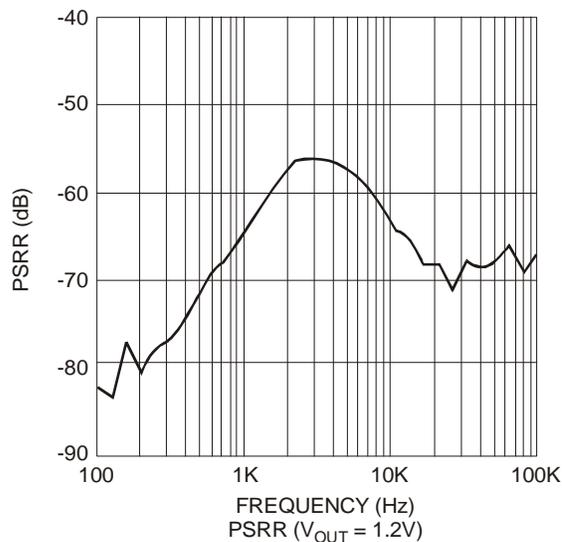
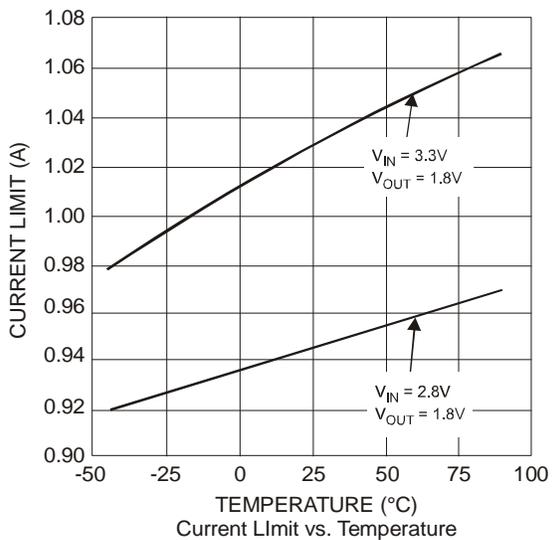
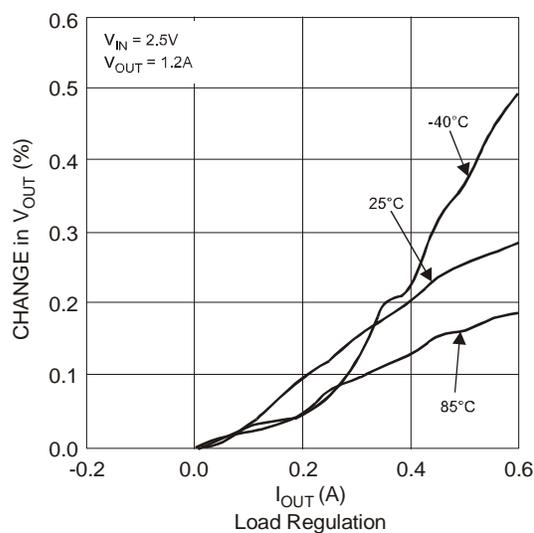
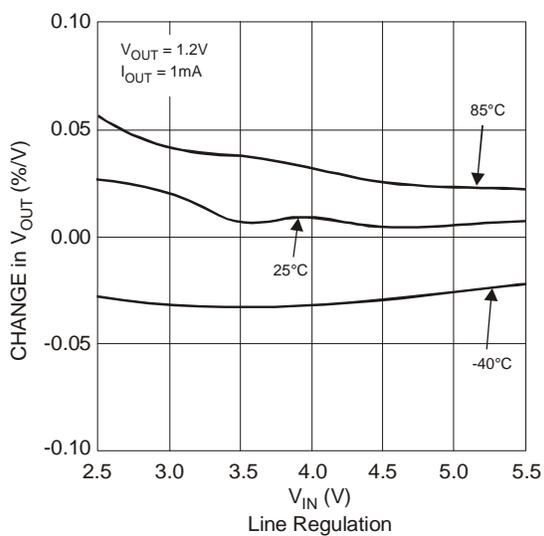
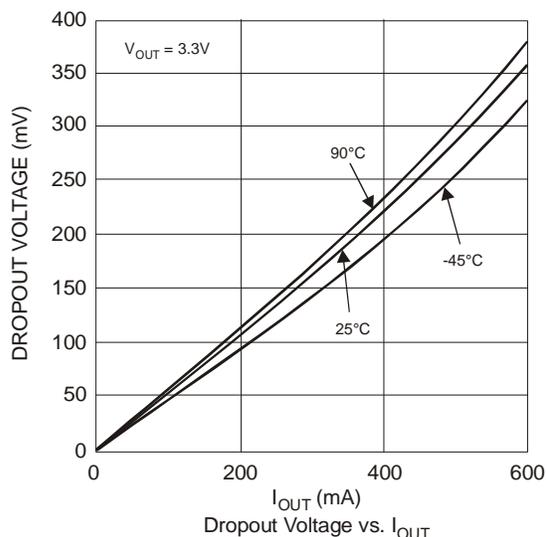
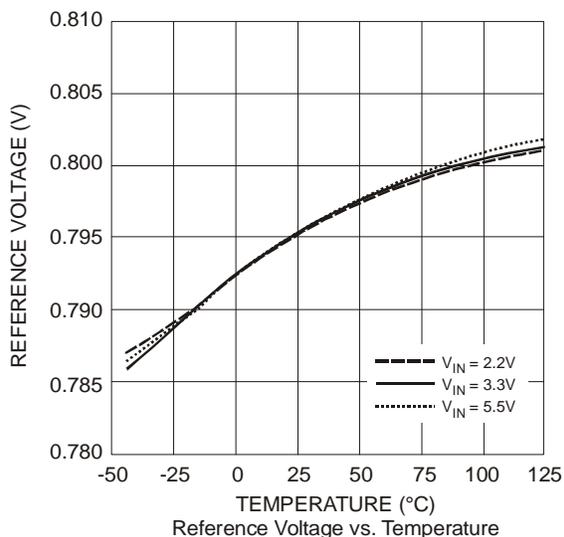


Quiescent Current vs. Temperature



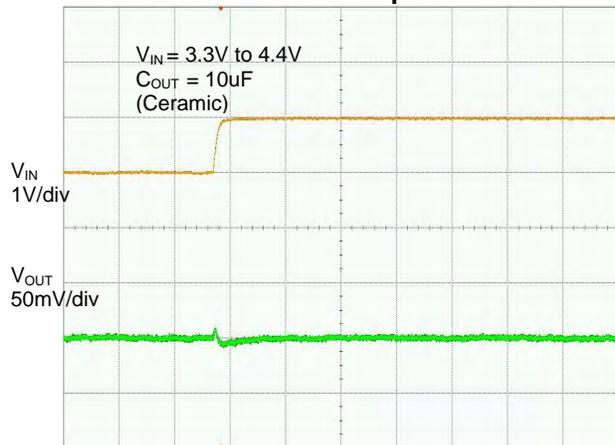
Quiescent Current vs. I<sub>OUT</sub>

**Typical Performance Characteristics (cont.)**



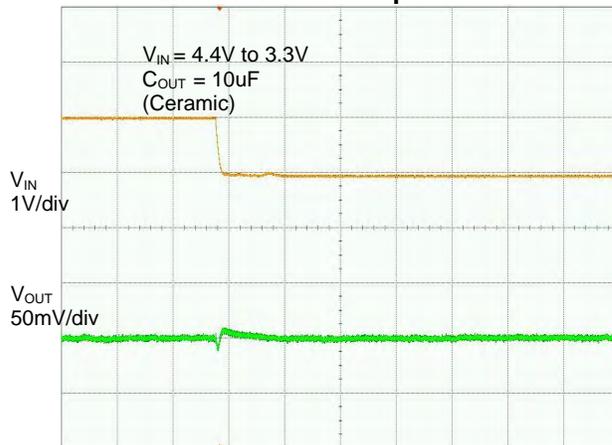
**Typical Performance Characteristics (cont.)**

**Line Transient Response**



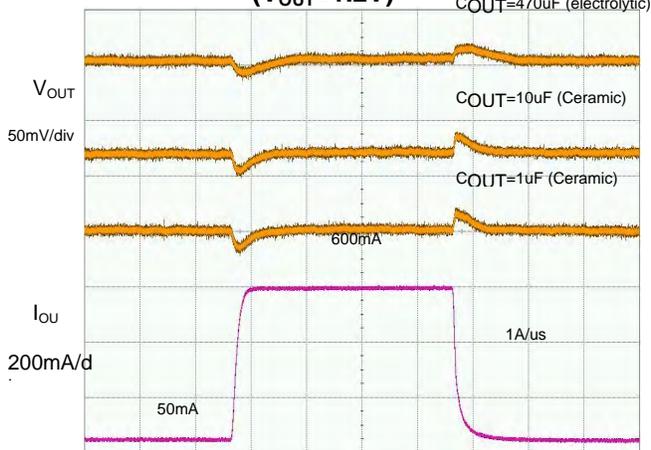
Time (50 $\mu$ s/div)

**Line Transient Response**



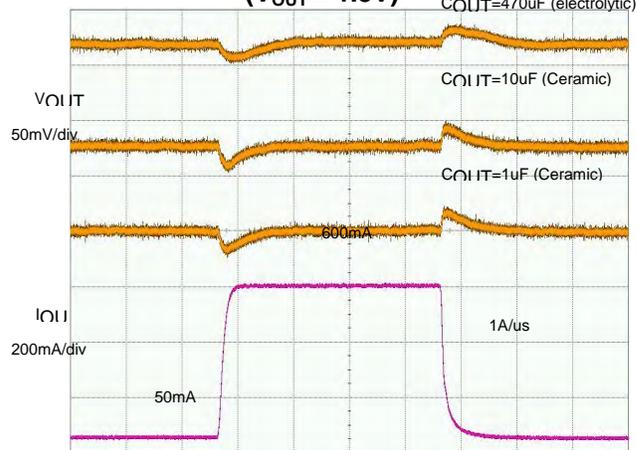
Time (50 $\mu$ s/div)

**Output Load Transient Response  
( $V_{OUT}=1.2V$ )**



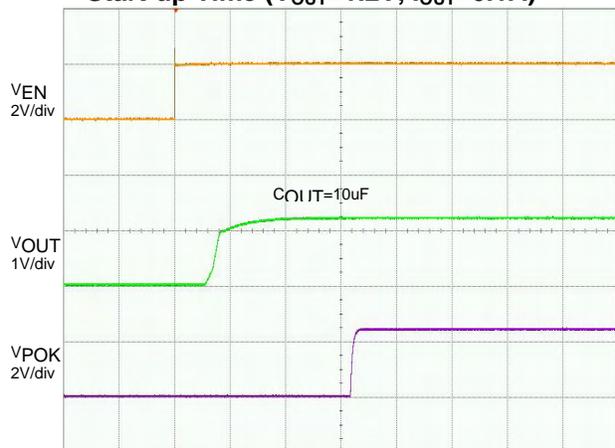
Time (100 $\mu$ s/div)

**Output Load Transient Response  
( $V_{OUT} = 1.8V$ )**



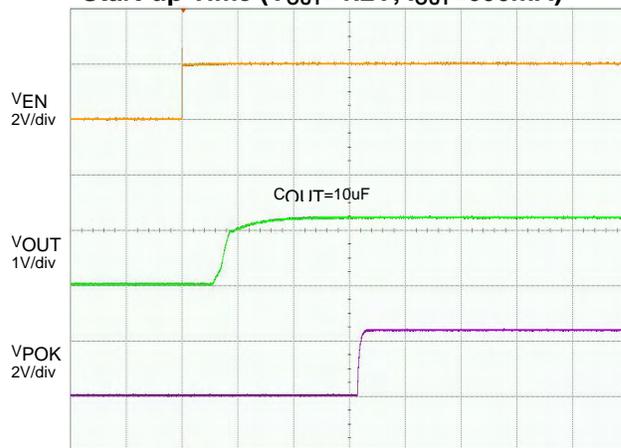
Time (100 $\mu$ s/div)

**Start-up Time ( $V_{OUT}=1.2V, I_{OUT}=0.1A$ )**



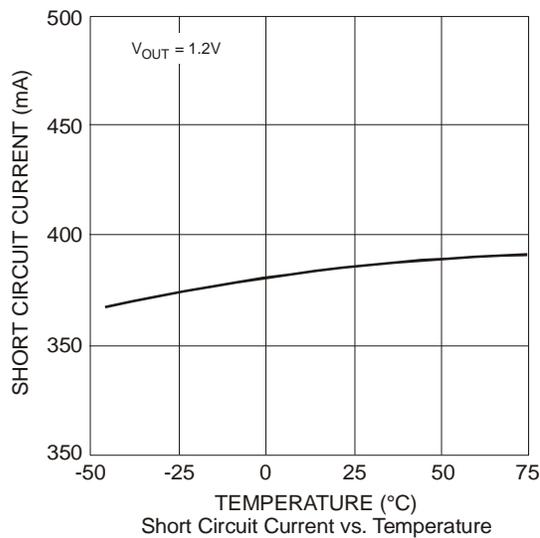
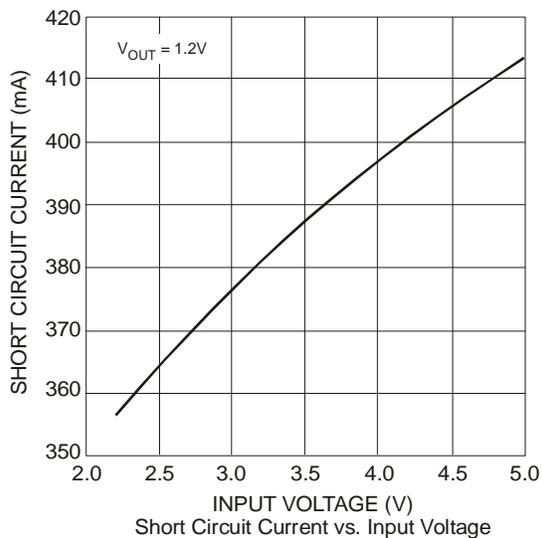
Time (50 $\mu$ s/div)

**Start-up Time ( $V_{OUT}=1.2V, I_{OUT}=600mA$ )**

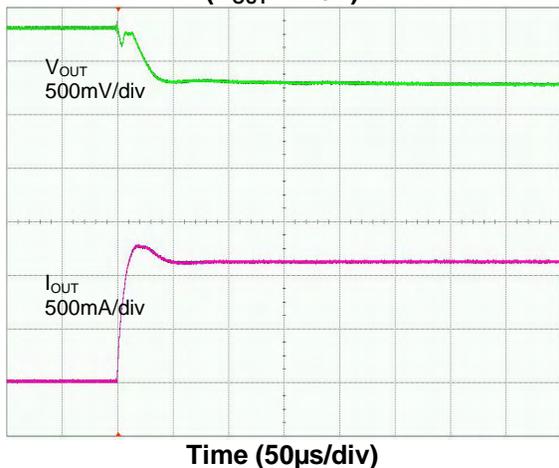


Time (50 $\mu$ s/div)

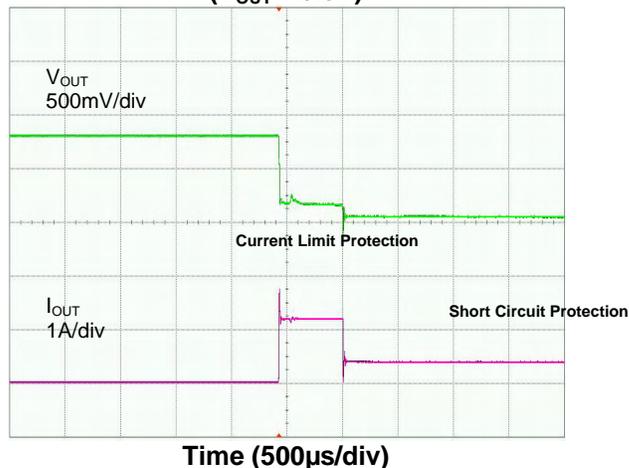
**Typical Performance Characteristics (cont.)**



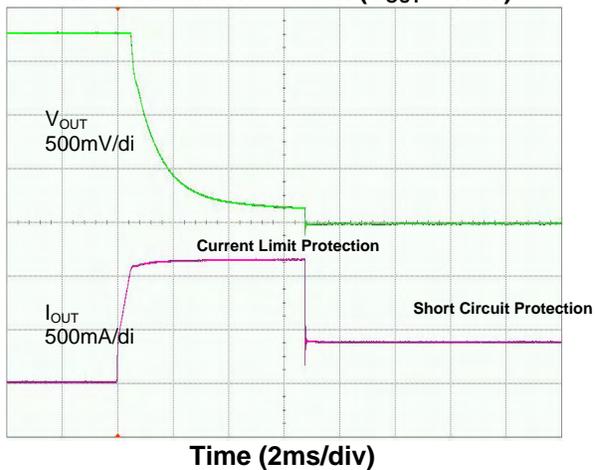
**Current Limit Protection**  
( $V_{OUT} = 1.8V$ )



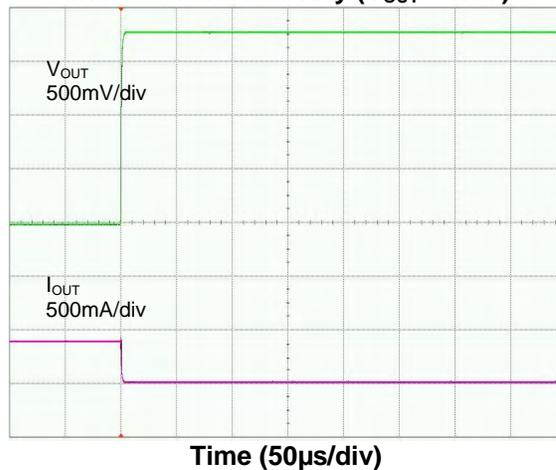
**Current Limit & Short Circuit Protection**  
( $V_{OUT} = 0.8V$ )



**Short Circuit Protection** ( $V_{OUT} = 1.8V$ )



**Short Circuit Recovery** ( $V_{OUT} = 1.8V$ )



## Application Notes

### Input Capacitor

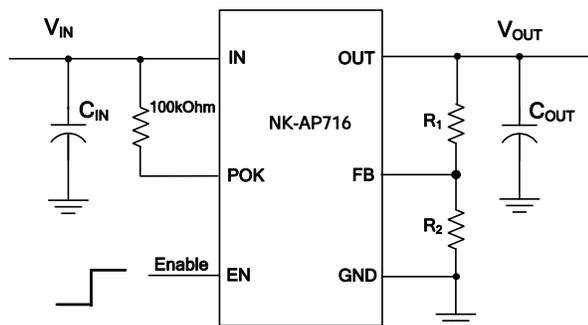
A 1 $\mu$ F ceramic capacitor is recommended to connect between IN and GND pins to decouple input power supply glitch and noise. The amount of the capacitance may be increased without limit. A lower ESR (Equivalent Series Resistance) capacitor allows the use of less capacitance, while higher ESR type requires more capacitance. This input capacitor should be located as close as possible to the device to assure input stability and less noise. For PCB layout, a wide copper trace is required for both IN and GND.

### Output Capacitor

The output capacitor is required to stabilize and help the transient response of the LDO. The NK-AP716 is designed to have excellent transient response for most applications with a small amount of output capacitance. The NK-AP716 is stable for all available types and values of output capacitors  $\geq 4.7\mu$ F. The device is also stable with multiple capacitors in parallel, which can be of any type of value. Additional capacitance helps to reduce undershoot and overshoot during transient. This capacitor should be placed as close as possible to OUT and GND pins for optimum performance.

### Adjustable Operation

The NK-AP716 provides output voltage from 0.8V to 5.0V through external resistor divider as shown below.



The output voltage is calculated by:

$$V_{OUT} = V_{REF} \left( 1 + \frac{R_1}{R_2} \right)$$

Where  $V_{REF} = 0.8V$  (the internal reference voltage).

Rearranging the equation will give the following equation to find the approximate resistor divider values:

$$R_1 = R_2 \left( \frac{V_{OUT}}{V_{REF}} - 1 \right)$$

To maintain the stability of the internal reference voltage,  $R_2$  needs to be kept smaller than 250k $\Omega$ .

### No Load Stability

Other than external resistor divider, no minimum load is required to keep the device stable. The device will remain stable and regulated in no load condition.

### ENABLE/SHUTDOWN Operation

The NK-AP716 is turned on by setting the EN pin high, and is turned off by pulling it low. If this feature is not used, the EN pin should be tied to IN pin to keep the regulator output on at all time. To ensure proper operation, the signal source used to drive the EN pin must be able to swing above and below the specified turn-on/off voltage thresholds listed in the Electrical Characteristics section under  $V_{IL}$  and  $V_{IH}$ .

### POWER-OK

The Power-Ok (POK) pin is an active high open-drain output. It can be connected to any 5.5V or lower rail through an external pull-up resistor. The recommended sink current of POK pin is up to 4mA, so the pull-up resistor for POK should be in the range of 10k $\Omega$  to 1M $\Omega$ . If output voltage monitoring is not needed, the POK pin can be left floating.

### Current Limit Protection

When output current at OUT pin is higher than current limit threshold, the current limit protection will be triggered and clamp the output current to approximately 950mA (600mA min) to prevent over-current and to protect the regulator from damage due to overheating.

### Short Circuit Protection

When OUT pin is short-circuited to GND or OUT pin voltage is less than 200mV, short circuit protection will be triggered and clamp the output current to approximately 380mA. This feature protects the regulator from over-current and damage due to overheating.

## Application Notes (cont.)

### Low Quiescent Current

The NK-AP716, consuming only around 125 $\mu$ A for all input range and output loading, provides great power saving in portable and low power applications.

### Wide Output Range

The NK-AP716, with a wide output range of 0.8V to 5.0V, provides a versatile solution for many portable and low power applications.

### Thermal Shutdown Protection

Thermal protection disables the output when the junction temperature rises to approximately +150 $^{\circ}$ C, allowing the device to cool down. When the junction temperature reduces to approximately +125 $^{\circ}$ C the output circuitry is enabled again. Depending on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit may cycle on and off. This cycling limits the heat dissipation of the regulator, protecting it from damage due to overheating.

### Power Dissipation

The device power dissipation and proper sizing of the thermal plane that is connected to the thermal pad is critical to avoid thermal shutdown and ensuring reliable operation. Power dissipation of the device depends on input voltage and load conditions and can be calculated by:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT}$$

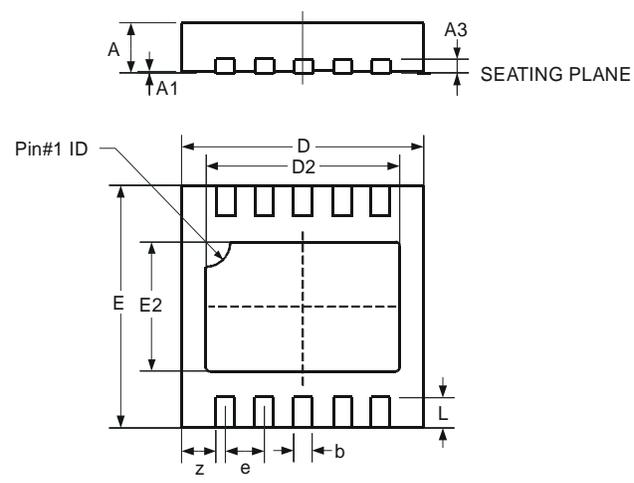
The NK-AP716 is available in the U-DFN3030-10 and SO-8EP packages, both with exposed pad, which is the primary conduction path for heat to the printed circuit board (PCB). The pad can be connected to ground or be left floating; however, to ensure the device will not overheat, it should be attached to an appropriate amount of copper PCB area.

However, the maximum power dissipation that can be handled by the device depends on the maximum junction to ambient thermal resistance, maximum ambient temperature, and maximum device junction temperature, which can be approximated by the equation below:

$$P_D(\text{max}@T_A) = \frac{(+145^{\circ}\text{C} - T_A)}{R_{\theta JA}}$$

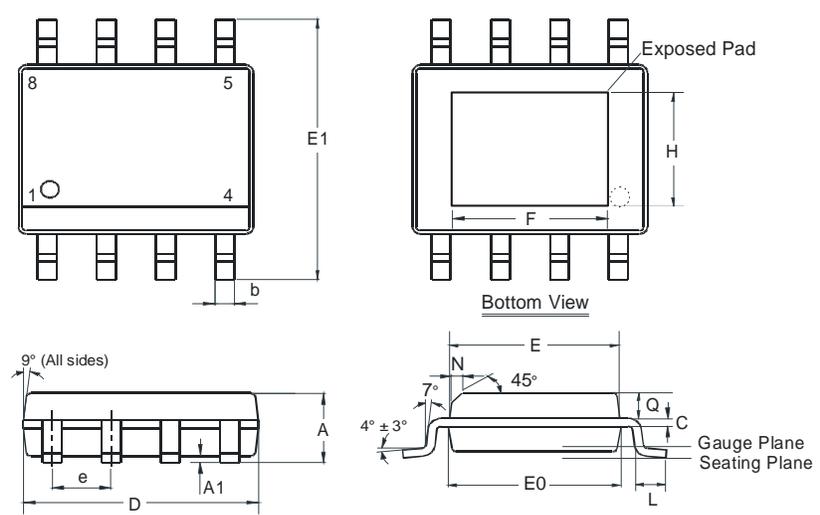
### Package Outline Dimensions

#### (1) Package Type: U-DFN3030-10



| U-DFN3030-10         |      |      |       |
|----------------------|------|------|-------|
| Dim                  | Min  | Max  | Typ   |
| A                    | 0.57 | 0.63 | 0.60  |
| A1                   | 0    | 0.05 | 0.02  |
| A3                   | —    | —    | 0.15  |
| b                    | 0.20 | 0.30 | 0.25  |
| D                    | 2.90 | 3.10 | 3.00  |
| D2                   | 2.30 | 2.50 | 2.40  |
| e                    | —    | —    | 0.50  |
| E                    | 2.90 | 3.10 | 3.00  |
| E2                   | 1.50 | 1.70 | 1.60  |
| L                    | 0.25 | 0.55 | 0.40  |
| z                    | —    | —    | 0.375 |
| All Dimensions in mm |      |      |       |

#### (2) Package Type: SO-8EP

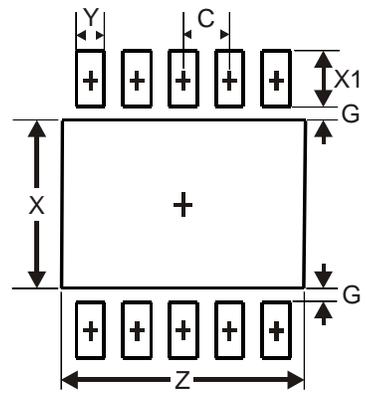


| SO-8EP (SOP-8L-EP)   |      |      |      |
|----------------------|------|------|------|
| Dim                  | Min  | Max  | Typ  |
| A                    | 1.40 | 1.50 | 1.45 |
| A1                   | 0.00 | 0.13 | -    |
| b                    | 0.30 | 0.50 | 0.40 |
| C                    | 0.15 | 0.25 | 0.20 |
| D                    | 4.85 | 4.95 | 4.90 |
| E                    | 3.80 | 3.90 | 3.85 |
| E0                   | 3.85 | 3.95 | 3.90 |
| E1                   | 5.90 | 6.10 | 6.00 |
| e                    | -    | -    | 1.27 |
| F                    | 2.75 | 3.35 | 3.05 |
| H                    | 2.11 | 2.71 | 2.41 |
| L                    | 0.62 | 0.82 | 0.72 |
| N                    | -    | -    | 0.35 |
| Q                    | 0.60 | 0.70 | 0.65 |
| All Dimensions in mm |      |      |      |

Notes: 7. All dimensions are in millimeters. Angles are in degrees.  
 8. Coplanarity applies to the exposed heat sink slug as well as the terminals.

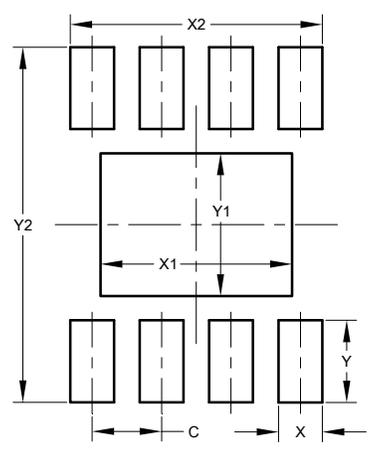
### Suggested Pad Layout

**(1) Package Type: U-DFN3030-10**



| Dimensions | Value (in mm) |
|------------|---------------|
| Z          | 2.60          |
| G          | 0.15          |
| X          | 1.80          |
| X1         | 0.60          |
| Y          | 0.30          |
| C          | 0.50          |

**(2) Package Type: SO-8EP**



| Dimensions | Value (in mm) |
|------------|---------------|
| C          | 1.270         |
| X          | 0.802         |
| X1         | 3.502         |
| X2         | 4.612         |
| Y          | 1.505         |
| Y1         | 2.613         |
| Y2         | 6.500         |

**Taping Orientation (Note 9)**

For U-DFN3030-10

