



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**

0755-83047638

ysbdt@szyoushang.cn

www.szyoushang.cn



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## Description

The NK-AP7173 is a 1.5A low-dropout (LDO) linear regulator that features a user-programmable soft-start, an enable input and a power-good output.

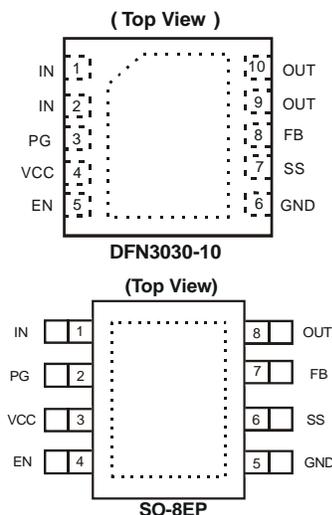
The soft-start reduces inrush current of the load capacitors and minimizes stress on the input power source during start-up. The enable input and power-good output allow users to configure power management solutions that can meet the sequencing requirements of FPGAs, DSPs, and other applications with different start-up and power-down requirements.

The NK-AP7173 is stable with any type of output capacitor of 2.2 $\mu$ F or more. A precision reference and feedback control deliver 2% accuracy over load, line, and operating temperature ranges. The NK-AP7173 is available in both DFN3030-10 and SO-8EP packages.

## Features

- Low  $V_{IN}$  and wide  $V_{IN}$  range: 1.0V to 5.5V
- Bias voltage ( $V_{VCC}$ ) range: 2.7V to 5.5V
- Low  $V_{OUT}$  range: 0.8V to 3.3V
- Low dropout: 165mV typical at 1.5A,  $V_{VCC} = 5V$
- 2% accuracy over line, load and temperature range
- Power-Good (PG) output for supply monitoring and for sequencing of other supplies
- Programmable soft-start provides linear voltage startup
- Bias supply permits low  $V_{IN}$  operation with good transient response
- Stable with any output capacitor  $\geq 2.2\mu F$
- DFN3030-10 and SO-8EP: available in "Green" molding compound (No Br, Sb)
- Lead-free finish/ RoHS Compliant (Note 1)

## Pin Assignments



## Applications

- PCs, Servers, Modems, and Set-Top-Boxes
- FPGA Applications
- DSP Core and I/O Voltages
- Post-Regulation Applications
- Applications With Sequencing Requirements

## Typical Application Circuit

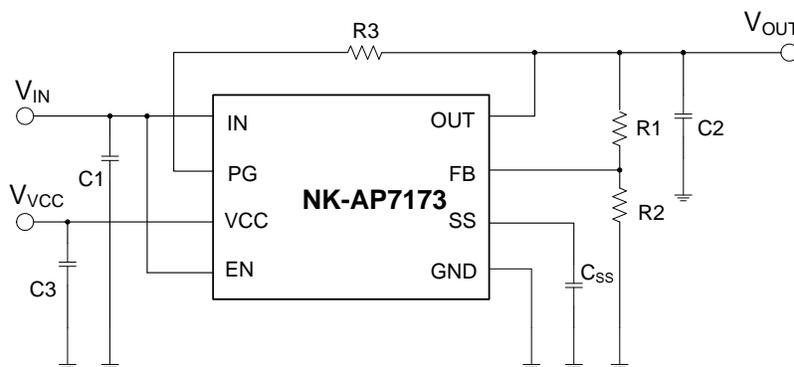


Figure 1. Typical Application Circuit (Adjustable Output)

### Typical Application Circuit (Continued)

**Table 1. Resistor Values for Programming the Output Voltage (Note 2)**

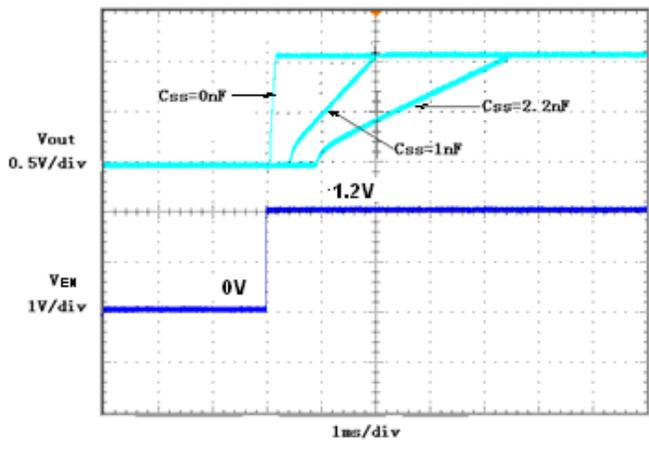
R <sub>1</sub> (kΩ)	R <sub>2</sub> (kΩ)	V <sub>OUT</sub> (V)
Short	Open	0.8
0.619	4.99	0.9
1.13	4.53	1
1.37	4.42	1.05
1.87	4.99	1.1
2.49	4.99	1.2
4.12	4.75	1.5
3.57	2.87	1.8
3.57	1.69	2.5
3.57	1.15	3.3

Note: 2  $V_{OUT} = 0.8 \times (1 + R_1 / R_2)$

**Table 2. Capacitor Values for Programming the Soft-Start Time (Note 3)**

CSS	SOFT-START TIME
Open	0.1ms
270pF	0.5ms
560pF	1ms
2.7nF	5ms
5.6nF	10ms
0.01μF	18ms

Note: 3.  $t_{ss}(s) = 0.8 \times C_{ss}(F) / (4.4 \times 10^{-7})$

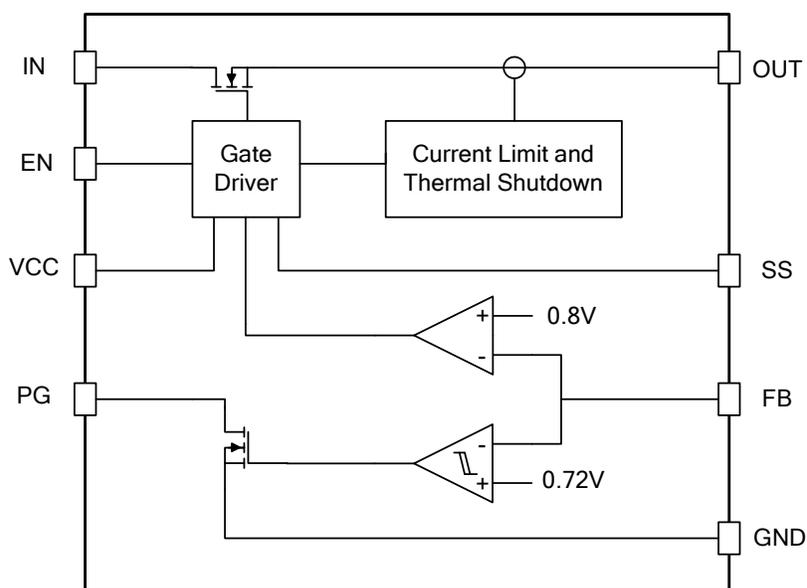


**Figure 2. Turn-On Response**

## Pin Descriptions

Pin Name	PIN #		Description
	SO-8EP	DFN3030-10	
IN	1	1, 2	Power Input pin.
PG	2	3	Power-Good pin, open-drain output. When the $V_{OUT}$ is below the PG threshold the PG pin is driven low; when the $V_{OUT}$ exceeds the threshold, the PG pin goes into a high-impedance state. To use the PG pin, use a 10k $\Omega$ to 1M $\Omega$ pull-up resistor to pull it up to a supply of up to 5.5V, which can be higher than the input voltage.
VCC	3	4	Bias Input pin, provides input voltage for internal control circuitry. This voltage should be higher than the $V_{IN}$ .
EN	4	5	Enable pin. This pin should be driven either high or low and must not be floating. Driving this pin high enables the regulator, while pulling it low puts the regulator into shutdown mode.
GND	5	6	Ground.
SS	6	7	Soft-Start pin. Connect a capacitor between this pin and the ground to set the soft-start ramp time of the output voltage. If no capacitor is connected, the soft-start time is typically 100 $\mu$ S.
FB	7	8	Feedback pin. Connect this pin to an external voltage divider to set the output voltage.
OUT	8	9, 10	Regulated Output pin.
Thermal Pad	—	—	Solder this pad to large ground plane for increased thermal performance.

## Functional Block Diagram



## Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Ratings	Unit	
ESD HBM	Human Body Model ESD Protection	4000	V	
ESD MM	Machine Model ESD Protection	350	V	
$V_{IN}, V_{VCC}$	Input Voltage Range	-0.3 to +6	V	
$V_{EN}$	Enable Voltage Range	-0.3 to +6	V	
$V_{PG}$	Power-Good Voltage Range	-0.3 to +6	V	
$V_{SS}$	Soft-Start Voltage Range	-0.3 to +6	V	
$V_{FB}$	Feedback Voltage Range	-0.3 to +6	V	
$V_{OUT}$	Output Voltage Range	-0.3 to $V_{IN} + 0.3$	V	
$I_{OUT}$	Maximum Output Current	Internally Limited		
$P_D$	Continuous Total Power Dissipation (Note 5)	DFN3030-10	3690	mW
		SO-8EP	5650	
$T_J$	Junction Temperature Range	-40 to +150	°C	
$T_{ST}$	Storage Junction Temperature Range	-65 to +150	°C	

- Notes:
- Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
  - Ratings apply to ambient temperature at 25°C. The JEDEC High-K board design used to derive this data was a 2 inch x 2 inch multilayer board with 1-ounce internal power and ground planes and 2-ounce copper traces on the top and bottom of the board.

## Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
$V_{IN}$	Input Voltage (Note 6)	1.0	5.5	V
$V_{VCC}$	Bias Voltage	2.7	5.5	V
$I_{OUT}$	Output Current	0	1.5	A
$T_A$	Operating Ambient Temperature	-40	85	°C

- Note: 6. At  $V_{IN} = 1V$ , the maximum load currents may be lower than 1.5A.

## Electrical Characteristics

At  $V_{EN} = 1.1V$ ,  $V_{IN} = V_{OUT} + 0.5V$ ,  $C_{VCC} = 0.1\mu F$ ,  $C_{IN} = C_{OUT} = 10\mu F$ ,  $I_{OUT} = 50mA$ ,  $V_{VCC} = 5.0V$ , and  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ .

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Unit	
$V_{IN}$	Input Voltage Range		$V_{OUT} + V_{DO}$		5.5	V	
$V_{VCC}$	Bias Pin Voltage Range (Note 7)		2.7		5.5	V	
$V_{REF}$	Internal Reference (Adj.)	$T_A = +25^{\circ}C$	0.792	0.8	0.808	V	
$V_{OUT}$	Output Voltage Range	$V_{IN} = 5V$ , $I_{OUT} = 1.5A$	0.8		3.3	V	
	Accuracy (Note 8)	$2.97V \leq V_{VCC} \leq 5.5V$ , $50mA \leq I_{OUT} \leq 1.5A$	-2	$\pm 0.5$	2	%	
$\Delta V_{OUT} / \Delta V_{IN} / V_{OUT}$	Line Regulation	$V_{OUT(NOM)} + 0.5 \leq V_{IN}$ , 5.5V		0.03		%/V	
$\Delta V_{OUT} / V_{OUT} / \Delta I_{OUT}$	Load Regulation	$50mA \leq I_{OUT} \leq 1.5A$		0.09		%/A	
$V_{DO}$	Dropout Voltage (Note 9)	$I_{OUT} = 1.5A$ , $V_{VCC} - V_{OUT(NOM)} \geq 3.25V$		165	270	mV	
		$I_{OUT} = 1.5A$ , $V_{IN} = V_{VCC}$		1.5	1.7	V	
$I_{CL}$	Current Limit	$V_{OUT} = 80\% \times V_{OUT(NOM)}$	2	3	4	A	
$I_{SHORT}$	Short-Circuit Current	$V_{OUT} < 0.2V$	0.6	1		A	
$I_{VCC}$	Bias Pin Current			1	2	mA	
$I_{SHDN}$	Shutdown Supply Current ( $I_{GND}$ )	$V_{EN} \leq 0.4V$		1	50	$\mu A$	
$I_{FB}$	Feedback Pin Current		-1	0.1	1	$\mu A$	
PSRR	Power-Supply Rejection ( $V_{IN}$ to $V_{OUT}$ )	1KHz, $I_{OUT} = 1A$ , $V_{IN} = 1.8V$ , $V_{OUT} = 1.5V$		60		dB	
		300KHz, $I_{OUT} = 1A$ , $V_{IN} = 1.8V$ , $V_{OUT} = 1.5V$		30			
	Power-Supply Rejection ( $V_{VCC}$ to $V_{OUT}$ )	1KHz, $I_{OUT} = 1A$ , $V_{IN} = 1.8V$ , $V_{OUT} = 1.5V$			50		dB
		300KHz, $I_{OUT} = 1A$ , $V_{IN} = 1.8V$ , $V_{OUT} = 1.5V$			30		
$T_{ST}$	Startup Time	$R_{LOAD}$ for $I_{OUT} = 1.0A$ , $C_{SS} = open$		100		$\mu S$	
$I_{SS}$	Soft-Start Charging Current	$V_{SS} = 0.4V$		440		nA	
$V_{EN, HI}$	Enable Input High Level		1.1		5.5	V	
$V_{EN, LO}$	Enable Input Low Level		0		0.4	V	
$V_{EN, HYS}$	Enable Pin Hysteresis			50		mV	
$I_{EN}$	Enable Pin Current	$V_{EN} = 5V$		0.1	1	$\mu A$	
$V_{PG, TH}$	PG Trip Threshold	$V_{OUT}$ decreasing	85	90	94	$\%V_{OUT}$	
$V_{PG, HYS}$	PG Trip Hysteresis			3		$\%V_{OUT}$	
$V_{PG, LO}$	PG Output Low Voltage	$I_{PG} = 1mA$ (sinking), $V_{OUT} < V_{PG, TH}$			0.3	V	
$I_{PG, LKG}$	PG Leakage Current	$V_{PG} = 5.25V$ , $V_{OUT} > V_{PG, TH}$		0.1	1	$\mu A$	
$T_{SD}$	Thermal Shutdown Temperature	Shutdown, temperature increasing		+150		$^{\circ}C$	
		Reset, temperature decreasing		+130			
$\theta_{JA}$	Thermal Resistance Junction-to-Ambient	DFN3030-10 (Note 10)		35		$^{\circ}C/W$	
		SO-8EP (Note 11)		23			
$\theta_{JC}$	Thermal Resistance Junction-to-Case	DFN3030-10 (Note 10)		4.9		$^{\circ}C/W$	
		SO-8EP (Note 11)		1.8			

Notes: 7.  $V_{VCC}$  should be higher or equal to  $V_{IN}$  in this chip.

8. Tested at 0.8V; resistor tolerance is not taken into account.

9. Dropout is defined as the voltage from  $V_{IN}$  to  $V_{OUT}$  when  $V_{OUT}$  is 3% below nominal.

10. Test condition for DFN3030-10: Device mounted on FR-4 substrate (2s2p), 2\*\*2" PCB, with 2oz copper trace thickness and large pad pattern.

11. Test condition for SOP-8L-EP: Device mounted on FR-4 substrate (2s2p), 2\*\*2" PCB, with 2oz copper trace thickness and large pad pattern.

## Typical Characteristics

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(TYP)} + 0.3\text{V}$ ,  $V_{VCC} = 5\text{V}$ ,  $I_{OUT} = 50\text{mA}$ ,  $V_{EN} = V_{IN}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{VCC} = 4.7\mu\text{F}$ , and  $C_{OUT} = 10\mu\text{F}$ , unless otherwise noted.

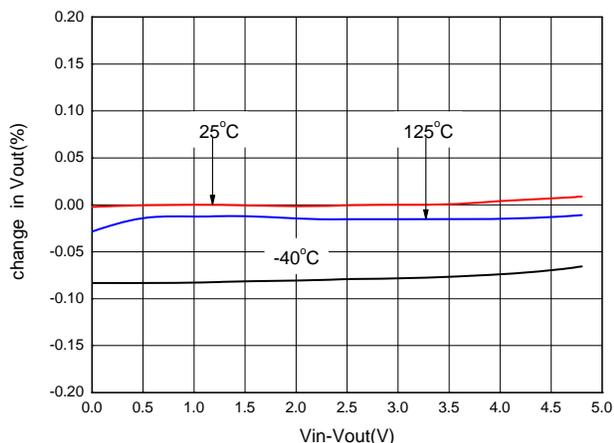


Figure 3  $V_{IN}$  Line Regulation

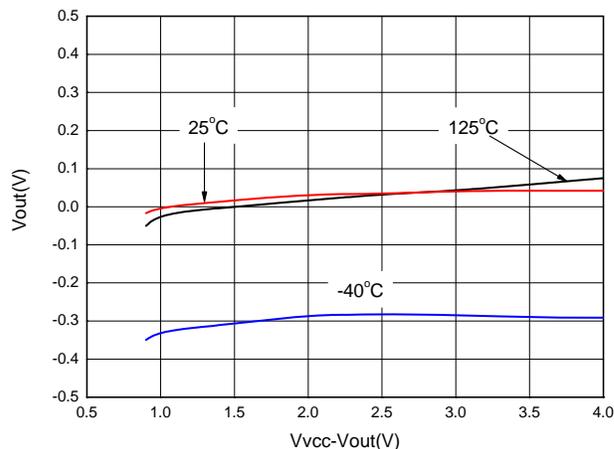


Figure 4  $V_{CC}$  Line Regulation

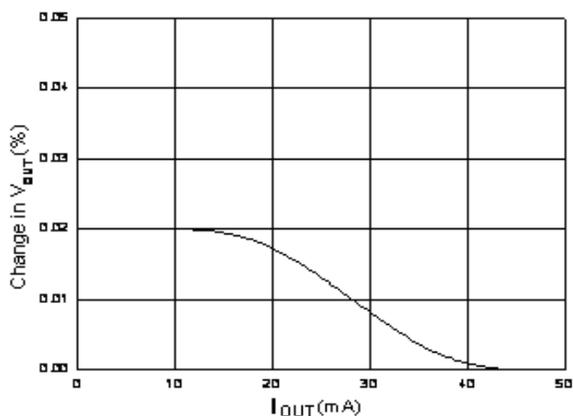


Figure 5 Load Regulation

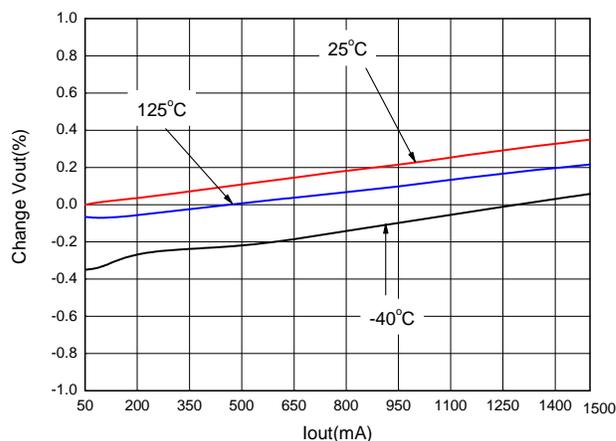


Figure 6 Load Regulation

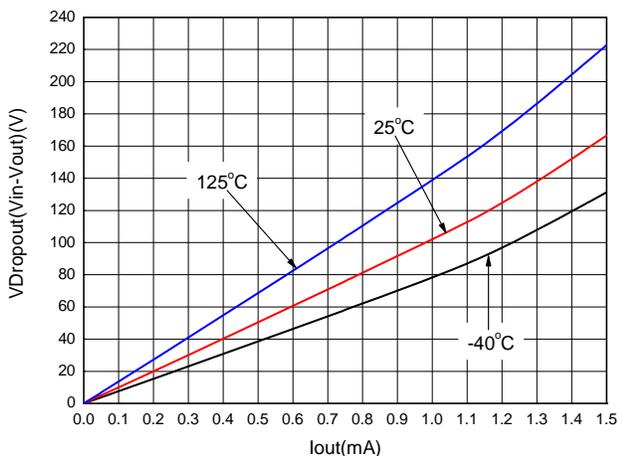


Figure 7  $V_{IN}$  Dropout Voltage vs.  $I_{OUT}$  and Temperature ( $T_A$ )

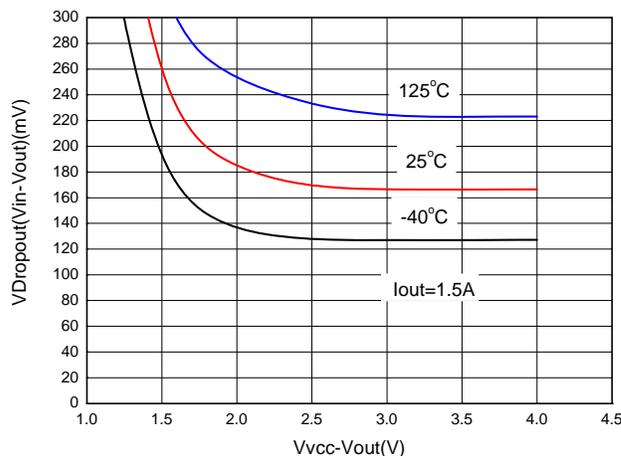
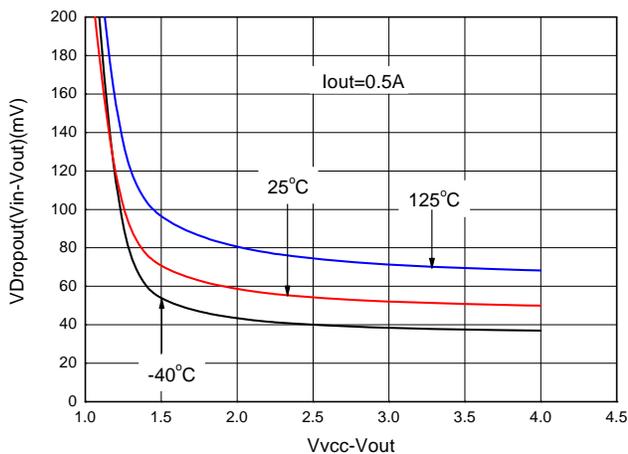


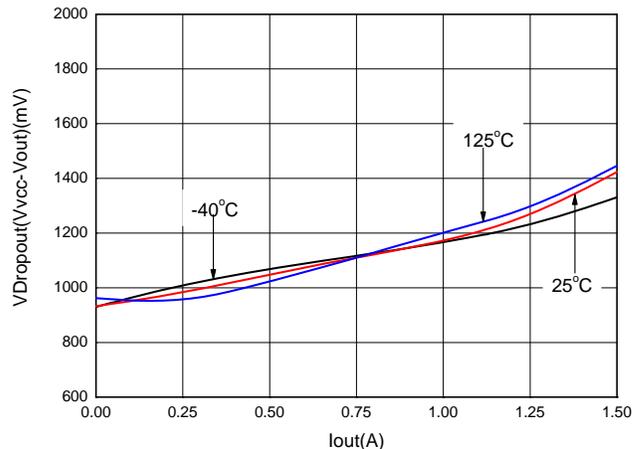
Figure 8  $V_{IN}$  Dropout Voltage vs.  $(V_{CC}-V_{OUT})$  and Temperature ( $T_A$ )

## Typical Characteristics (Continued)

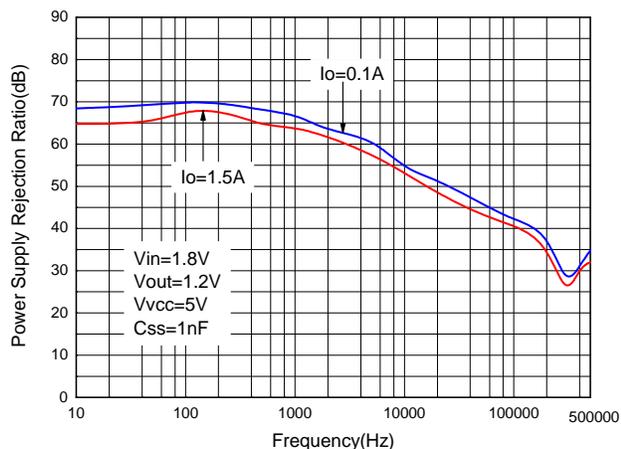
At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(TYP)} + 0.3\text{V}$ ,  $V_{VCC} = 5\text{V}$ ,  $I_{OUT} = 50\text{mA}$ ,  $V_{EN} = V_{IN}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{VCC} = 4.7\mu\text{F}$ , and  $C_{OUT} = 10\mu\text{F}$ , unless otherwise noted.



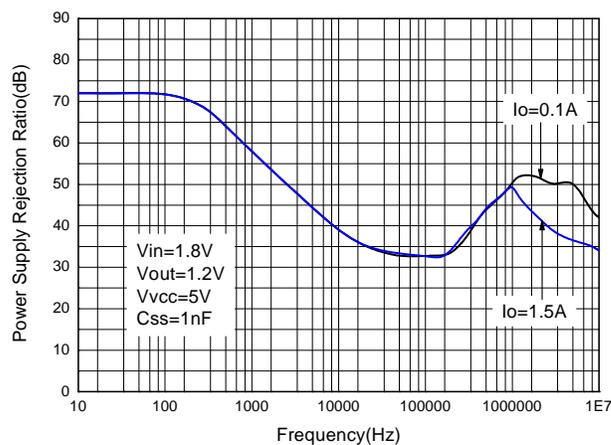
**Figure 9**  $V_{IN}$  Dropout Voltage vs.  $(V_{VCC}-V_{OUT})$  and Temperature ( $T_A$ )



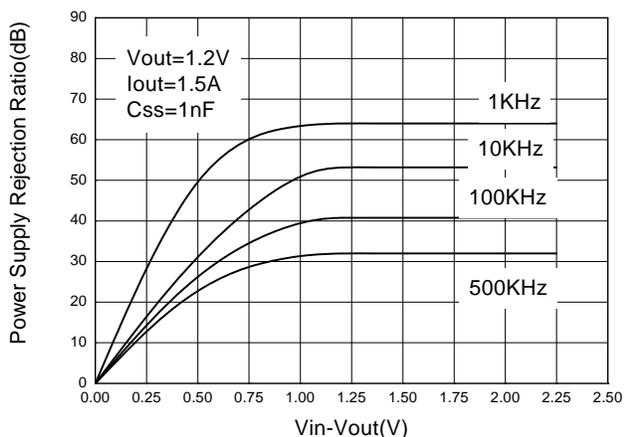
**Figure 10**  $V_{VCC}$  Dropout Voltage vs.  $I_{OUT}$  and Temperature ( $T_A$ )



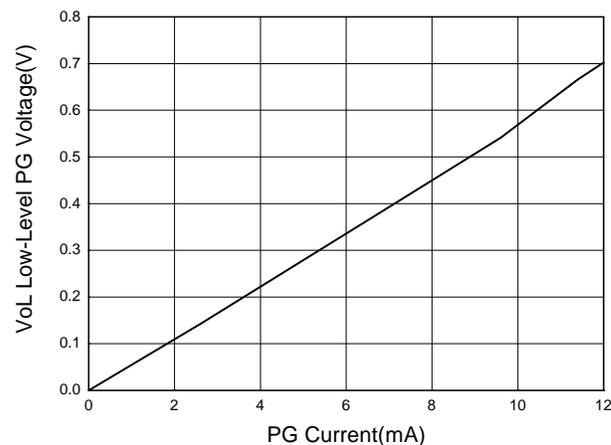
**Figure 11**  $V_{IN}$  PSRR vs. Frequency



**Figure 12**  $V_{VCC}$  PSRR vs. Frequency



**Figure 13**  $V_{IN}$  PSRR vs.  $(V_{IN}-V_{OUT})$



**Figure 14** Low-Level PG Voltage vs Current

### Typical Characteristics (Continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(TYP)} + 0.3\text{V}$ ,  $V_{VCC} = 5\text{V}$ ,  $I_{OUT} = 50\text{mA}$ ,  $V_{EN} = V_{IN}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{VCC} = 4.7\mu\text{F}$ , and  $C_{OUT} = 10\mu\text{F}$ , unless otherwise noted.

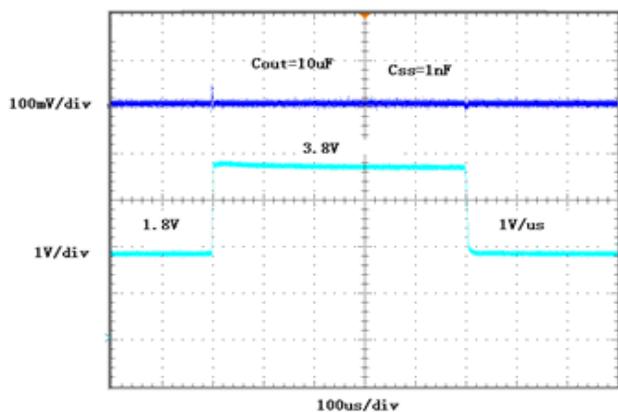


Figure. 15  $V_{IN}$  Line Transient

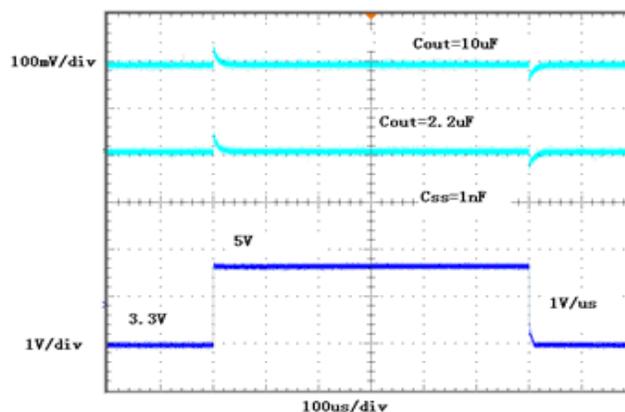


Figure. 16  $V_{CC}$  Line Transient

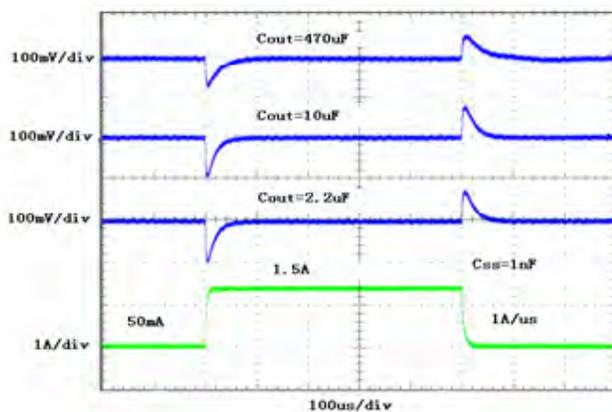


Figure. 17 Output Load Transient

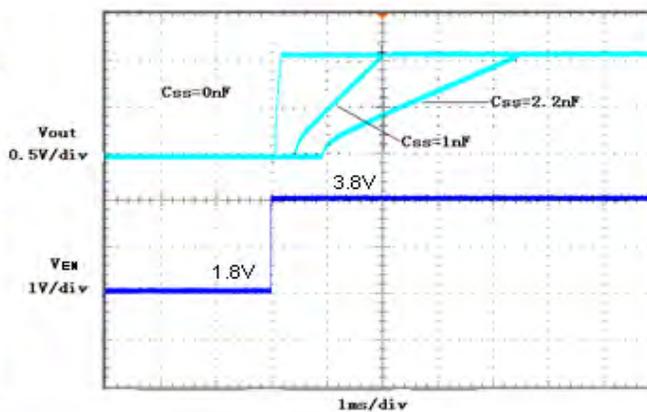


Figure. 18 Turn-On Response

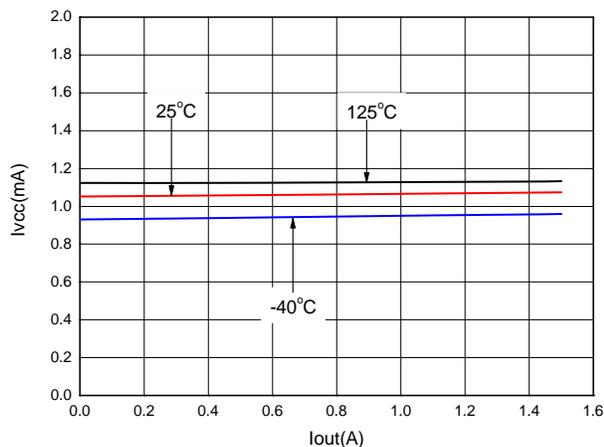


Figure. 19  $V_{CC}$  Pin Current vs.  $I_{OUT}$  and Temperature

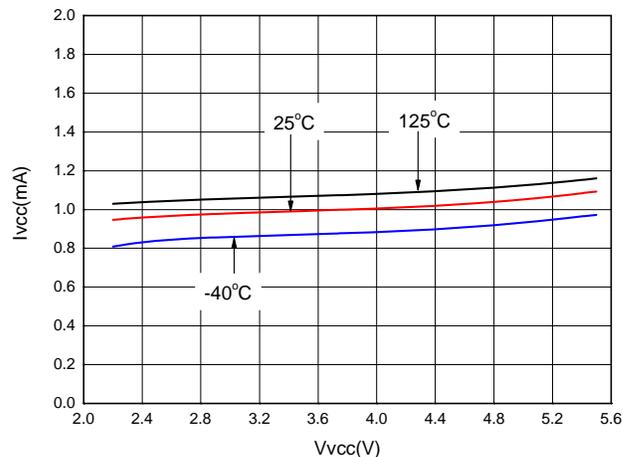


Figure. 20  $V_{CC}$  Pin Current vs.  $V_{VCC}$  and Temperature

## Typical Characteristics (Continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(TYP)} + 0.3\text{V}$ ,  $V_{VCC} = 5\text{V}$ ,  $I_{OUT} = 50\text{mA}$ ,  $V_{EN} = V_{IN}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{VCC} = 4.7\mu\text{F}$ , and  $C_{OUT} = 10\mu\text{F}$ , unless otherwise noted.

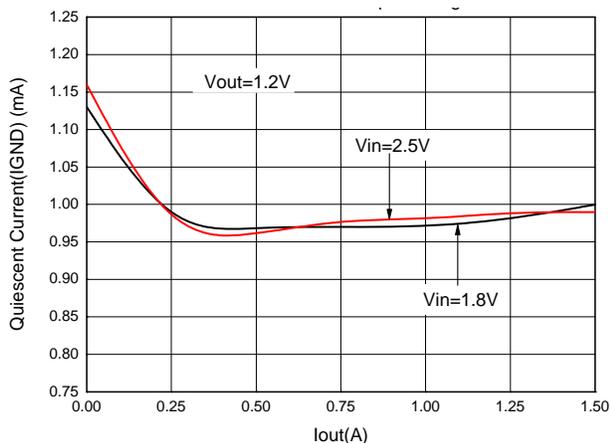


Figure 21 Quiescent Current vs.  $I_{OUT}$

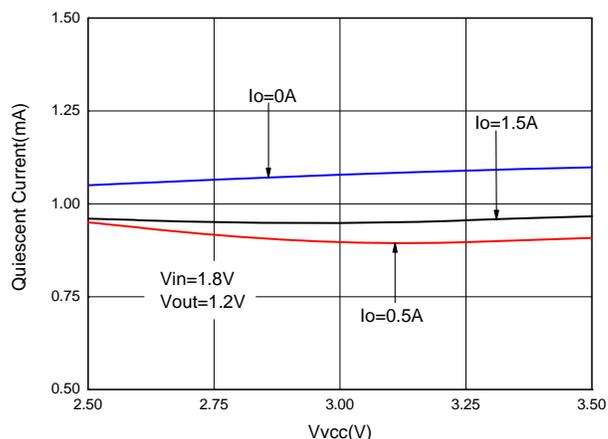


Figure 22. Quiescent Current vs.  $V_{VCC}$

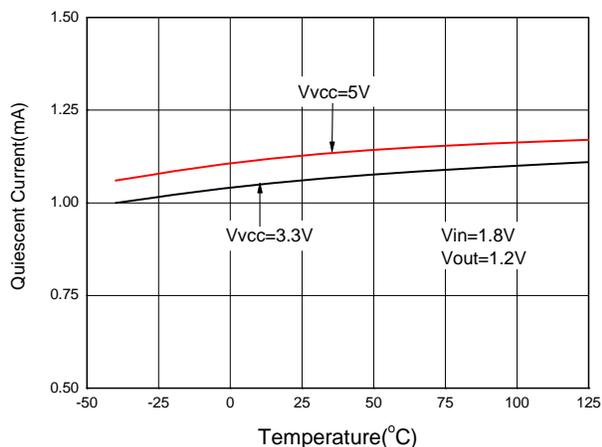


Figure 23 Quiescent Current vs. Temperature

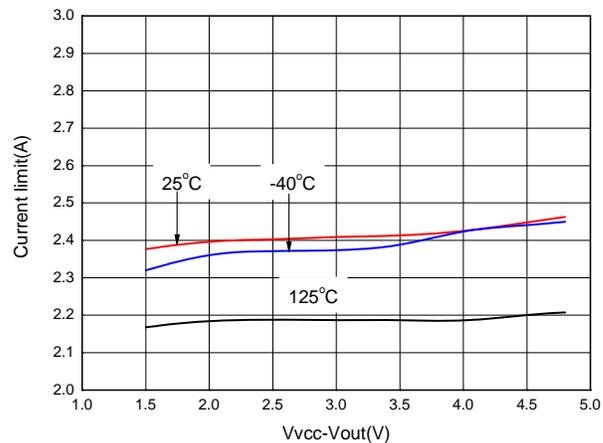


Figure 24 Current Limit vs.  $(V_{VCC} - V_{OUT})$

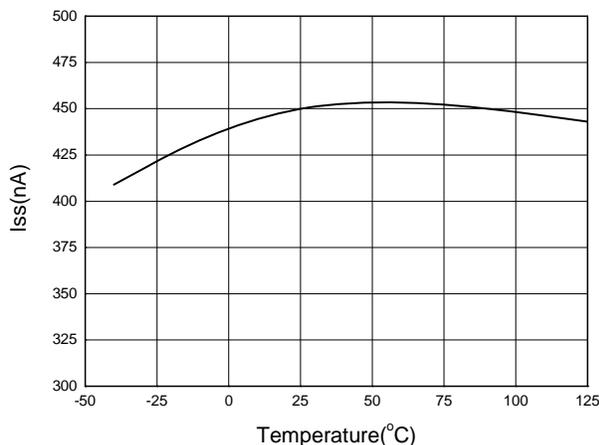


Figure 25 Soft-Start Charging Current ( $I_{SS}$ ) vs. Temperature

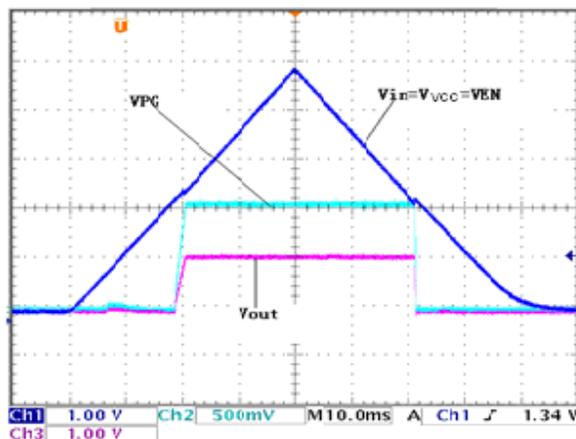


Figure 26 Power-Up/Power-Down

## Application Notes

### BIAS VOLTAGE $V_{VCC}$

The NK-AP7173 is a low  $V_{IN}$ , low dropout regulator that uses an NMOS pass FET. The VCC pin must be connected to a DC bias supply  $V_{VCC}$  for the internal control circuitry and the gate drive of the pass FET to function properly and to obtain low dropout. The  $V_{VCC}$  needs to be equal to or higher than the  $V_{IN}$  and in the range of 2.7V-5.5V. Figure 27 illustrates the typical application circuit for the NK-AP7173.

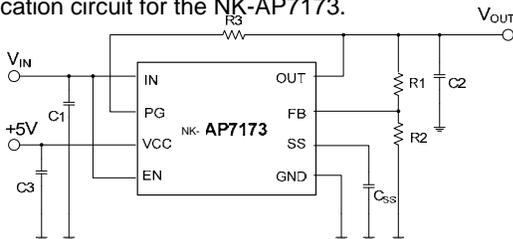


Figure 27. Typical Application Circuit for NK-AP7173

### ADJUSTABLE OUTPUT VOLTAGE

With an external voltage divider, the NK-AP7173 can provide output voltage from 0.8V to 3.3V. R1 and R2 can be calculated for any output voltage using the following equation, where  $V_{REF}=0.8$  is the NK-AP7173's internal reference voltage. Refer to Table 1 for resistor combinations for commonly used output voltages. For maximum voltage accuracy, R2 should be  $\leq 5k\Omega$ .

$$V_{OUT} = V_{REF} \times (1 + R1/R2)$$

### INPUT $V_{IN}$ AND BIAS $V_{VCC}$ CAPACITORS

It is important to keep the IN and VCC pins clear of large ripples, glitches and other noises by connecting capacitors to the IN and VCC pins. The required capacitance on these pins is strongly dependent on source and wiring impedance of the supplies.

To provide good decoupling for the input power supply  $V_{IN}$ , it is recommended that a ceramic capacitor with capacitance of at least  $1\mu F$  is connected between the IN and GND pins at a location as close to them as possible. High quality, low ESR capacitors should be used for better performance.

It is critical to provide good decoupling to the VCC pin for the NK-AP7173's internal control circuitry to function properly. The minimum recommended capacitance for the  $V_{VCC}$  is  $1\mu F$  when the  $V_{VCC}$  and  $V_{IN}$  are separate supplies. If the  $V_{IN}$  and  $V_{VCC}$  are connected to the same supply, the recommended minimum capacitance for  $V_{VCC}$  is  $4.7\mu F$ . Again good quality, low ESR capacitors should be used for optimum performance.

### OUTPUT CAPACITOR

The output capacitor affects the stability and transient response of the LDO. The NK-AP7173 is designed to be stable for all types of output capacitors  $\geq 2.2\mu F$ , single or multiple in parallel.

Using high quality, low ESR capacitors and placing them close to the OUT and GND pins can improve performance.

### DROPOUT VOLTAGE

The very low dropout makes the NK-AP7173 well suited for high-current, low  $V_{IN}$ /low  $V_{OUT}$  applications. To achieve the specified low-dropout performance for such applications, the VCC pin should be connected to a separate supply of at least 3.25V higher than  $V_{OUT}$ . Figure 28 shows an application circuit where  $V_{VCC}$  is 5V and  $V_{OUT}$  is 1.2V.

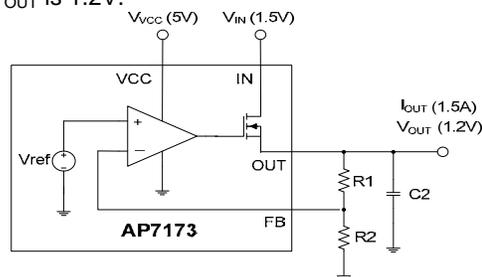


Figure 28 Typical Application Circuit for NK-AP7173 Using Separate VCC and IN Rails

For applications where low dropout is not required or a separate  $V_{VCC}$  supply is not available, the IN and VCC pins can be tied together. In this situation, a voltage difference of at least 1.7V between the  $V_{VCC}$  and  $V_{OUT}$  has to be maintained for the  $V_{VCC}$  to provide enough gate drive to the pass FET. Therefore, the  $V_{OUT}$  needs to be 1.7V or more below  $V_{IN}$ , as shown in Figure 29.

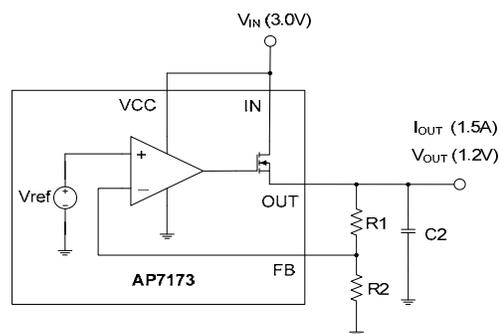


Figure 29 Typical Application Circuit for NK-AP7173 Without an Auxiliary VCC Rail

### PROGRAMMABLE SOFT-START

The NK-AP7173 features a voltage-controlled soft-start that is programmable with an external capacitor ( $C_{SS}$ ). The NK-AP7173 achieves a monotonic soft-start by tracking the voltage ramp of the external soft-start capacitor until the ramp voltage reaches the internal reference voltage.

## Application Notes (Continued)

### PROGRAMMABLE SOFT-START (cont.)

The relationship between the soft-start time and the soft-start charging current ( $I_{SS}$ ), soft-start capacitance ( $C_{SS}$ ), and the internal reference voltage ( $V_{REF}$ ) is

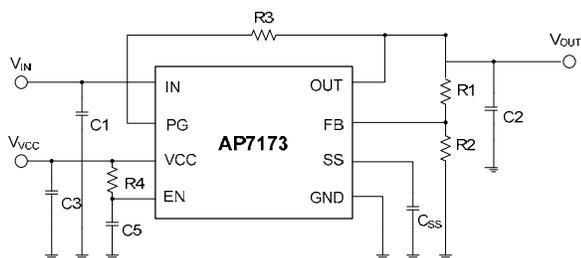
$$t_{SS} = (V_{REF} \times C_{SS}) / I_{SS}$$

Refer to Table 2 for suggested soft-start capacitor values

### ENABLE/SHUTDOWN

The EN pin can be used with standard digital signals or relatively slow-ramping analog signals. Pulling the  $V_{EN}$  below 0.4V turns the regulator off, while driving the  $V_{EN}$  above 1.1V turns the regulator on. Figure 30 shows an example where an RC circuit is used to delay start the NK-AP7173.

If not used, the EN pin can be connected to the VCC or IN pin when the  $V_{IN}$  is greater than 1.1V, as long as good decoupling measures are taken for the EN pin.



**Figure 30. Delayed Start Using an RC Circuit to Enable NK-AP7173**

### POWER-GOOD

The power-good (PG) pin is an open-drain output and can be pulled up through a resistor of 10kΩ to 1MΩ to  $V_{IN}$ ,  $V_{OUT}$  or any other rail that is 5.5V or lower. When the  $V_{OUT} \geq V_{PG,TH} + V_{PG,HYS}$ , the PG output is high-impedance; if the  $V_{OUT}$  drops to below  $V_{PG,TH}$ ,  $V_{VCC} \leq 1.9V$  or the device is disabled, the PG pin is pulled to low by an internal MOSFET.

### OVER-CURRENT AND SHORT-CIRCUIT PROTECTION

The NK-AP7173 features a factory-trimmed, temperature and supply voltage compensated internal current limit and an

over-current protection circuitry to protect the device against overload conditions. It limits the device current to a typical value of 3A and reduces the  $V_{OUT}$  when the load tries to pull more current.

For more effective protection against short-circuit failure, the NK-AP7173 also includes a short-circuit foldback mechanism that lowers the current limit to a typical value of 1.0A when the  $V_{FB}$  drops to below 0.2V.

### THERMAL PROTECTION

Thermal shutdown limits the NK-AP7173 junction temperature and protects the device from damage as a result of overheating.

Thermal protection turns off the  $V_{OUT}$  when the NK-AP7173's

junction temperature rises to approximately +150°C, allowing it to cool down. When the junction temperature drops to approximately +130°C, the output is re-enabled. Therefore, the thermal protection circuit may cycle on and off at a rate dependent on the power dissipation, thermal resistance, and ambient temperature.

### POWER DISSIPATION

Thermal shutdown is intended to protect the NK-AP7173 against abnormal overheating. For normal operation, excessive power dissipation should be avoided and good heatsinking should be provided. Power dissipation in the device is the product of the device dropout voltage and the load current,

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

As can be seen, power dissipation can be minimized by using the lowest input voltage necessary to achieve the required output voltage regulation.

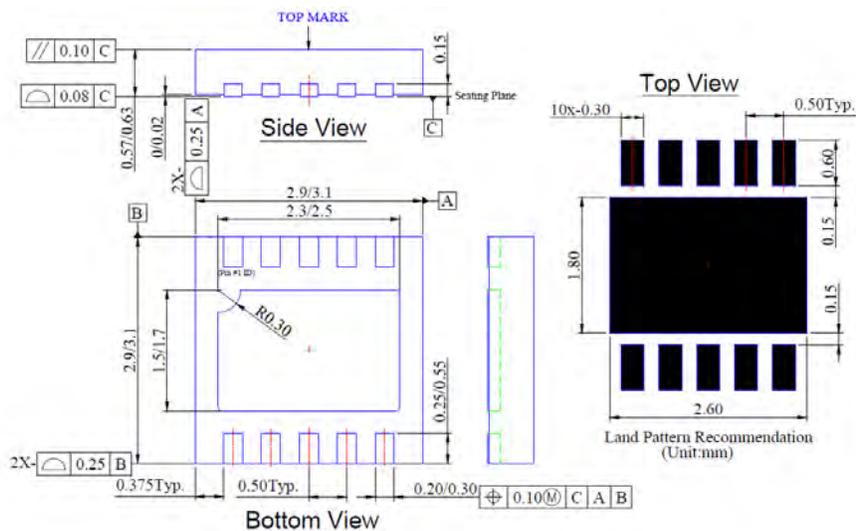
To ensure that the device junction temperature does not exceed the specified limit of 125°C, an application should provide heat conduction paths that have junction-to-ambient thermal resistance lower than the calculated value here:

$$R_{\theta JA} = (125^\circ\text{C} - T_A) / P_D$$

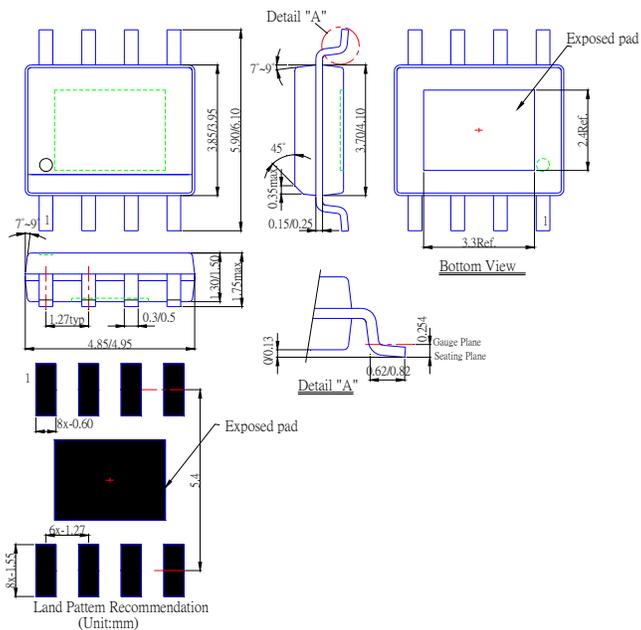
For the DFN package with exposed pad, the primary conduction path for heat is through the exposed pad to the printed circuit board (PCB). The pad should be attached to an appropriate amount of copper PCB area to ensure that the device does not overheat.

**Package Outline Dimensions (All Dimensions in mm)**

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



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



## Tape Orientation

For DFN3030-10

