

**Nuvoton**  
**4 Times Linear Fan Driver**  
**NCT3941S/S-A**

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## 1. GENERAL DESCRIPTION

The NCT3941S/S-A is a simply linear fan driver. It is designed for noise-sensitive or power-sensitive applications that require system cooling. The NCT3941S/S-A is a low quiescent current, low dropout linear regulator which is designed with a P-channel MOSFET to power a DC fan and delivers output current up to 500mA. The output voltage follows the 4 times on the voltage of VSET pin to dynamic adjust the DC fan speed. NCT3941S supports enable pin to control the output voltage. NCT3941S-A supports fully turn-on function. NCT3941S/S-A is available in SOP8-EP package.

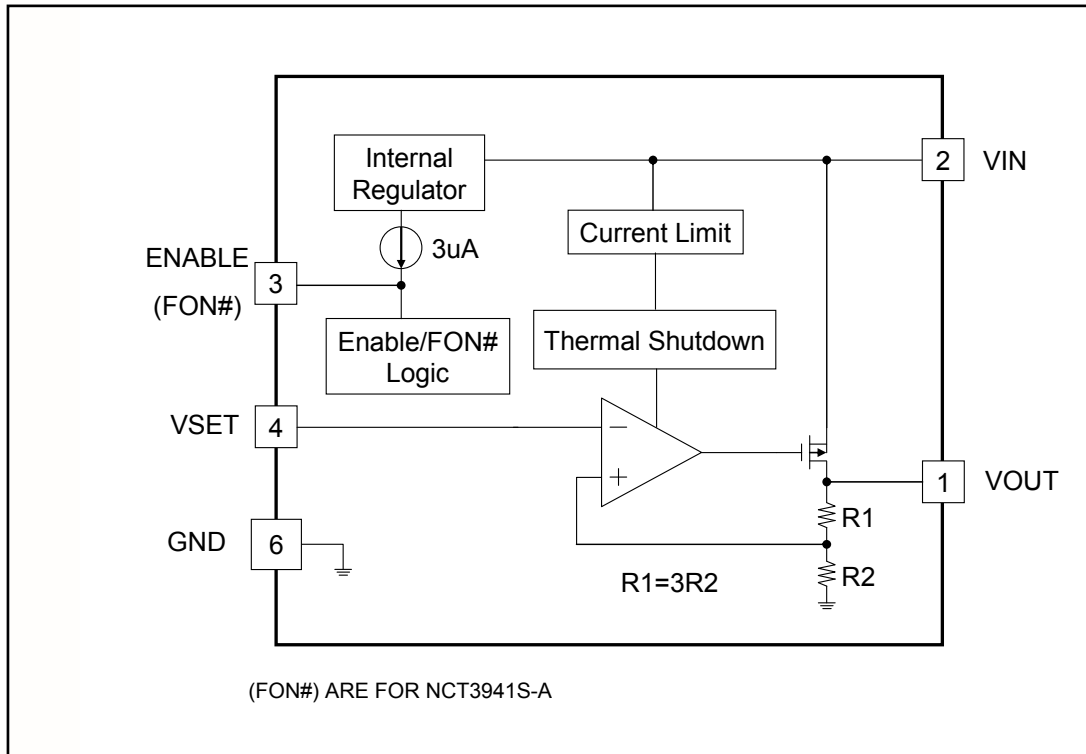
## 2. FEATURES

- VOUT Follows 4 Times of VSET
- 0.5V Dropout @ 0.5A Output Current
- Continues current up to 500mA, current limit trip threshold 1.6A
- Enable Function (NCT3941S)
- Full Turn On Function (NCT3941S-A)
- Short Circuit and Over Temperature Protections
- Low External Component Count
- Low Cost and Easy to Use
- SOP8 150mil with Exposed Pad Package
- Green Package (Lead Free and Halogen Free)

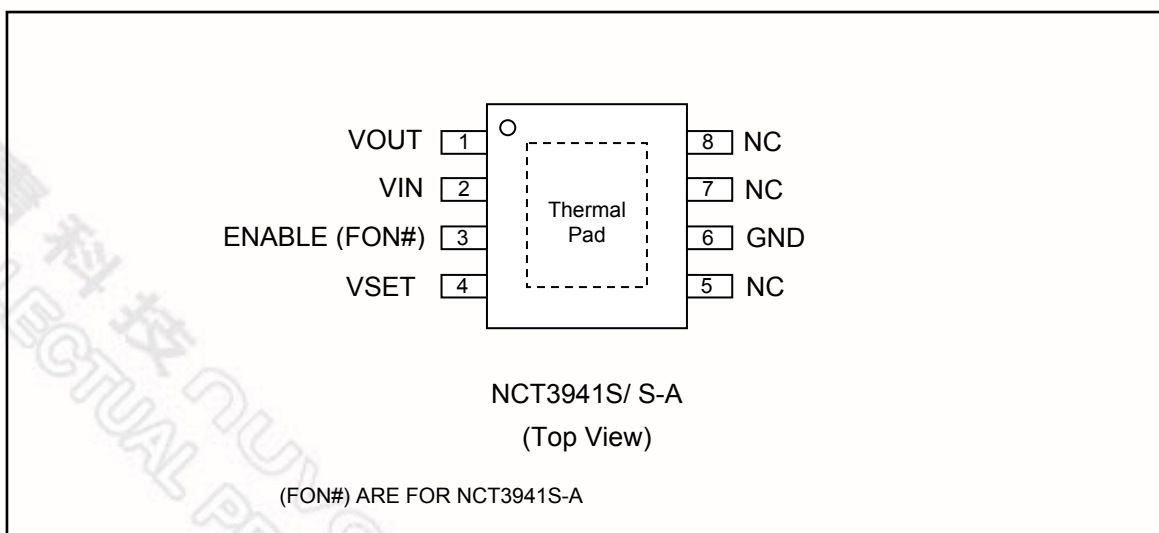
## 3. APPLICATION

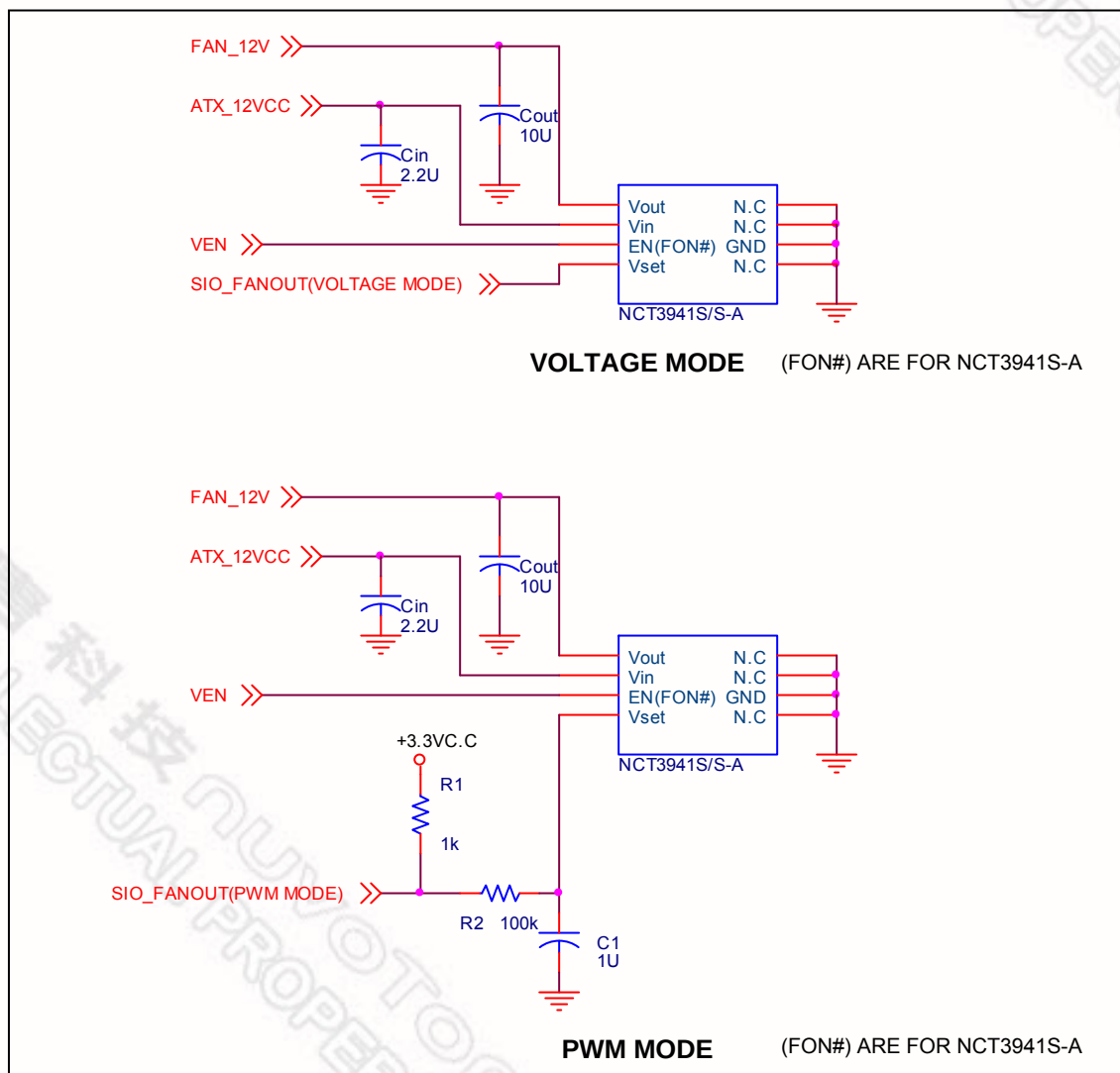
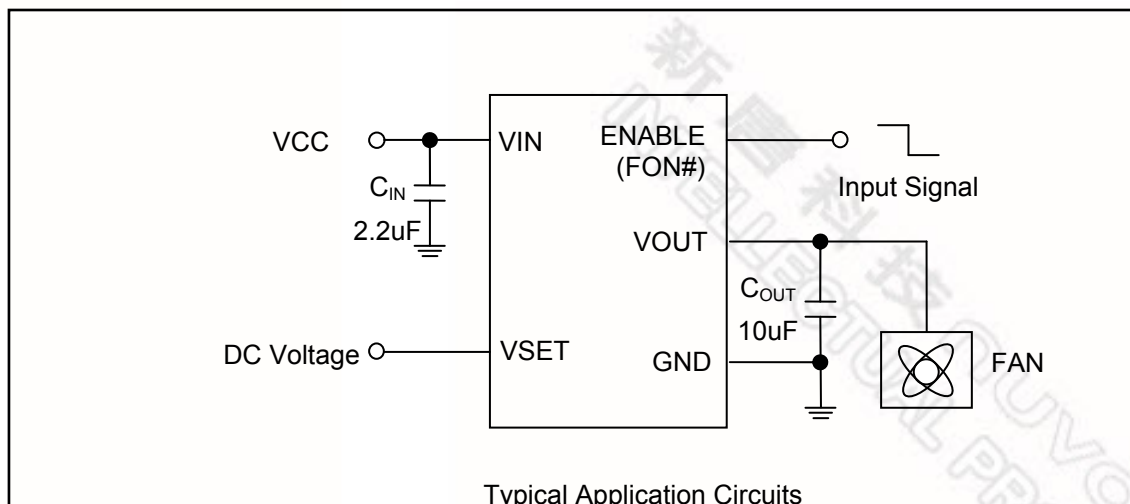
- Projectors
- Peripheral Add-in Cards
- Motherboards
- Battery Powered Systems

#### 4. BLOCK DIAGRAM



#### 5. PIN CONFIGURATION AND TYPICAL APPLICATION CIRCUIT





## 6. PIN DESCRIPTION

| PIN NAME | NO       |            | PIN TYPE | DESCRIPTION                                                                                                                                                                                                        |
|----------|----------|------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | NCT3941S | NCT3941S-A |          |                                                                                                                                                                                                                    |
| VOUT     | 1        | 1          | AO       | Voltage output pin. Connect a low ESR ceramic capacitor (10uF, typically) to ground to assure stability.                                                                                                           |
| VIN      | 2        | 2          | POWER    | DC power supply input. Connect a bypass capacitor (2.2uF, typically) is recommended.                                                                                                                               |
| ENABLE   | 3        |            | I        | Enable pin. Output voltage follows 4 times of VSET pin voltage when ENABLE pin at high level. Internal pull high is implemented.                                                                                   |
| FON#     |          | 3          | I        | Full On mode selection pin. Output voltage follows 4 times of VSET pin voltage when FON# pin at high level. The internal power MOSFET full turns on when FON# pin at low level. Internal pull high is implemented. |
| VSET     | 4        | 4          | AIN      | Output voltage setting pin. The inputs could be DC voltage. The input voltage must be larger than 1V.                                                                                                              |
| GND      | 6        | 6          | GROUND   | Power supply ground.                                                                                                                                                                                               |
| NC       | 5, 7, 8  | 5, 7, 8    |          | No internal connection.                                                                                                                                                                                            |

| PIN TYPE | PIN Attribute               |
|----------|-----------------------------|
| AO       | Output pin (Analog)         |
| AIN      | Input pin (Analog)          |
| I        | Input pin (Digital)         |
| POWER    | Positive power supply input |
| GROUND   | Power supply ground         |

## 7. FUNCTIONAL DESCRIPTION

### 7.1 VSET Setting

The output voltage is 4 times of VSET pin voltage. When the VSET voltage exceeds 1V, the output voltage will follow 4 times of VSET voltage.

## 7.2 Enable Function

This function is for NCT3941S only. The input voltage level of ENABLE pin can control the internal regulator turn on or turn off. When pulling this pin below 0.3V, the regulator will be turned off. When pulling this pin above 1V, the regulator will be turned on.

## 7.3 Full On Function

This function is for NCT3941S-A only. The input voltage level of FON# can control the internal regulator fully turn on or following 4 times of VSET voltage. When pulling this pin below 0.3V, the regulator will be fully turned on. When pulling this pin above 1.6V, the output voltage will follow 4 times of VSET voltage.

## 7.4 Short Circuit Current Limit

The NCT3941S/S-A provides a current limit circuitry for short circuit protection, which monitors the output current and controls PMOS gate voltage to limit the output current at 200mA.

## 7.5 Thermal Consideration

The NCT3941S/S-A has a thermal shutdown circuitry to limit the junction temperature. When the junction temperature exceeds 150°C, the thermal shutdown circuit disables the output, allowing the device to cool down. The output circuitry is enabled again after the junction temperature cools down by 30°C, resulting in a pulsed output during continuous thermal overload conditions. The thermal protection is designed to protect the IC in the event of over temperature conditions. For reliable operation, the junction temperature cannot exceed 125°C.

The definition of power dissipation in chip is as following equation:

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

$P_D$  represents the power dissipation.

The power dissipation depends on the thermal resistance of chip package, PCB layout, the airflow and temperature difference between junction and ambient. Refers to JEDEC51-1, The power dissipation can be calculated by following equation:

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

Where  $T_{J(MAX)}$  is the maximum operation junction temperature 125°C,  $T_A$  is the ambient temperature and the  $\theta_{JA}$  is the junction to ambient thermal resistance.  $\theta_{JA}$  for ESOP-8 package is 75°C/W on JEDEC51-7 (4 layers, 2S2P) thermal test board with minimum copper area. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated as:

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / 75^\circ\text{C/W} = 1.33\text{W}$$

$\theta_{JA}$  highly depends on IC package, PCB layout, the airflow. Thermal resistance  $\theta_{JA}$  can be improved by adding copper under the exposed pad of ESOP-8 while the IC package is fixed. The copper under the exposed pad of ESOP-8 is an effective heatsink and is useful for improving thermal conductivity. Figure show the relationship between thermal resistance  $\theta_{JA}$  vs. copper area on a standard JEDEC 51-7 (4 layers, 2S2P) thermal test board at  $T_A = 25^\circ\text{C}$ , PCB copper thickness = 2oz. The  $70\text{mm}^2$  copper plane reduce  $\theta_{JA}$  from  $75^\circ\text{C/W}$  to  $45^\circ\text{C/W}$  and increases maximum power dissipation from 1.33W to 2.22W.

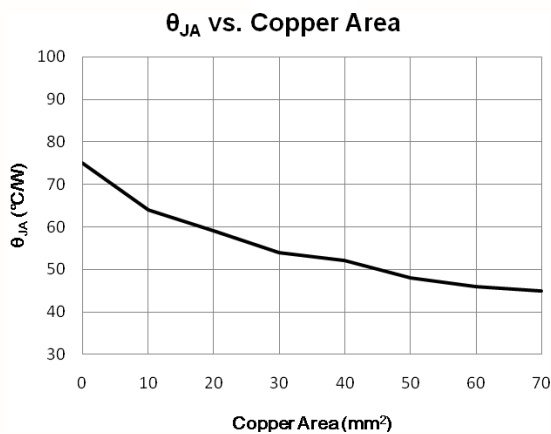


Figure01. Thermal Resistance  $\theta_{JA}$  vs. Copper Area of ESOP Packages

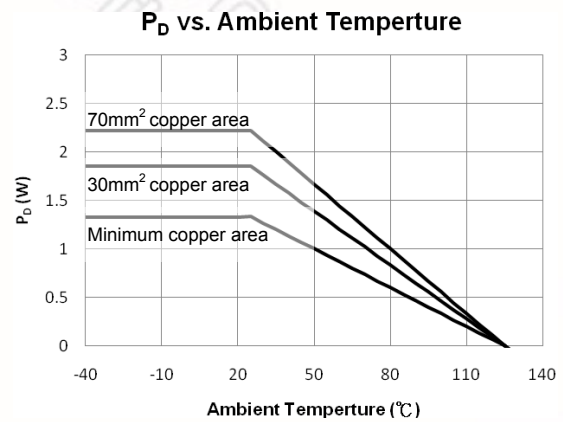


Figure02. Power dissipation vs. ambient temperature

## 7.6 VIN Decoupling

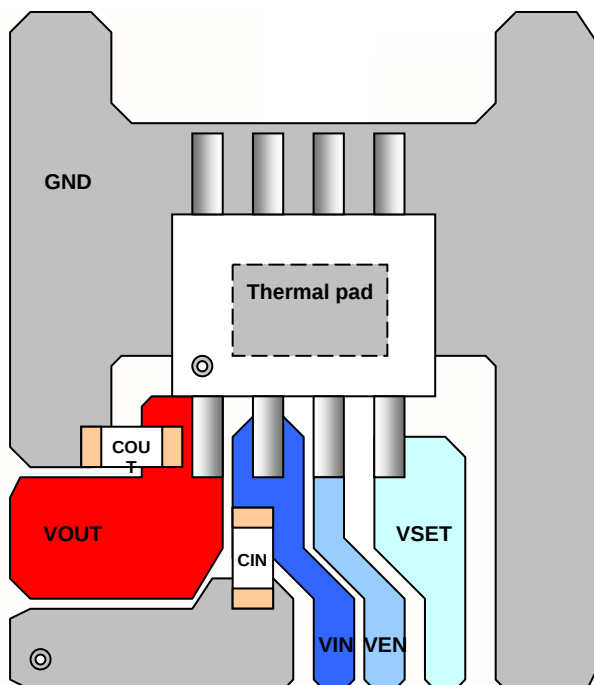
To achieve the best results when using the NCT3941S/S-A, decouple the power supply with a 2.2uF capacitor. Use a high quality ceramic surface mount capacitor if possible. Surface mount components minimize lead inductance, which improves performance, and ceramic capacitors tend to have adequate high frequency response for decoupling applications.

## 7.7 VOUT Stability

To maintain circuit stability and improve transient response over temperature and current, the NCT3941S/S-A needs a suitable output capacitor. In order to insure the circuit stability, the suitable output capacitor should be larger than 10uF.

## 7.8 Layout Consideration

Consider the following points before starting the NCT3941S/S-A layout design.



- The input bypass capacitor for VIN should be placed as close as possible to the pin with short and wide connections.
- The output capacitor for VOUT should be placed close to the pin with short and wide connection in order to avoid ESR and/or ESL trace inductance.
- In order to effectively remove heat from the package, properly prepare the thermal land. Apply solder directly to the package's thermal pad. The wide traces of component and the side copper connected to the thermal land pad help to dissipate heat. The thermal land connected to the ground plane could also be used to help dissipation.

## 8. ELECTRICAL CHARACTERISTIC

### 8.1 Absolute Maximum Ratings

| PARAMETER             |                 | RATING                                     | UNIT |
|-----------------------|-----------------|--------------------------------------------|------|
| Power Supply Voltage  |                 | -0.3 to 19V                                | V    |
| Voltage on Other Pins |                 | -0.3 to 7V                                 | V    |
| Storage Temperature   |                 | -50 to 150                                 | °C   |
| Soldering Temperature |                 | Refer to IPC/JEDEC J-STD-020 Specification |      |
| ESD Protection        | Human Body Mode | 2                                          | kV   |
|                       | Machine Mode    | 200                                        | V    |
|                       | Latch-up        | 100                                        | mA   |

Note: Exposure to conditions beyond those listed under Absolute Maximum Ratings may adversely affect the life and reliability of the device.

## 8.2 Thermal Information

| ITEM                                               | RATING           | UNIT               |
|----------------------------------------------------|------------------|--------------------|
| Power Dissipation, $P_D$ @ $T_A=25^\circ\text{C}$  | Internal Limited | W                  |
| Package Thermal Resistance, SOP8-EP, $\theta_{JA}$ | 75               | $^\circ\text{C/W}$ |

## 8.3 Recommended Operating Conditions

| PARAMETER             | RATING     | UNIT             |
|-----------------------|------------|------------------|
| Operating Temperature | -20 to 85  | $^\circ\text{C}$ |
| Junction Temperature  | -20 to 125 | $^\circ\text{C}$ |
| Supply Voltage, VCC   | 8 to 17.6  | V                |

## 8.4 Electrical Characteristics

$V_{IN}=13\text{V}$ ,  $V_{SET}=2\text{V}$ ,  $\text{ENABLE}=5\text{V}$ ,  $C_{IN}=2.2\mu\text{F}$ ,  $C_{OUT}=10\mu\text{F}$ ,  $T_a=-20\sim 85^\circ\text{C}$  (Typical value are at  $T_a=25^\circ\text{C}$ )

| PARAMETER                      | SYM.     | MIN. | TYP. | MAX. | UNIT          | CONDITIONS                                                            |
|--------------------------------|----------|------|------|------|---------------|-----------------------------------------------------------------------|
| <b>Supply Input Voltage</b>    |          |      |      |      |               |                                                                       |
| Supply Input Voltage           | $V_{IN}$ | 8    |      | 17.6 | V             |                                                                       |
| <b>ENABLE / FON# Pin</b>       |          |      |      |      |               |                                                                       |
| ENABLE / FON# Voltage High     |          | 1    |      |      | V             |                                                                       |
| ENABLE / FON# Voltage Low      |          |      |      | 0.3  | V             |                                                                       |
| ENABLE / FON# Pin Bias Current |          |      | 3    |      | $\mu\text{A}$ | ENABLE / FON# = 0V                                                    |
| <b>Supply Input Current</b>    |          |      |      |      |               |                                                                       |
| Quiescent Current              | $I_Q$    |      | 3    |      | mA            | ENABLE = 5V, VOUT 12V, No Load                                        |
| Shutdown Current               | $I_{SD}$ |      | 100  |      | $\mu\text{A}$ | ENABLE = 0V                                                           |
| <b>Output Voltage</b>          |          |      |      |      |               |                                                                       |
| VOUT Voltage / VSET Voltage    |          | 3.88 | 4    | 4.12 | V/V           | $V_{IN} = 12\text{V}$<br>$V_{SET} = 1 \sim 3\text{V}$                 |
| Load Regulation(NOTE1)         |          |      | 0.5  | 2    | %             | $V_{SET} = 3\text{V}$<br>$10\text{mA} \leq I_{OUT} \leq 500\text{mA}$ |
| Line Regulation(NOTE1)         |          |      | 0.1  | 0.5  | %             | $V_{in} = 9\text{V to } 14\text{V}$                                   |

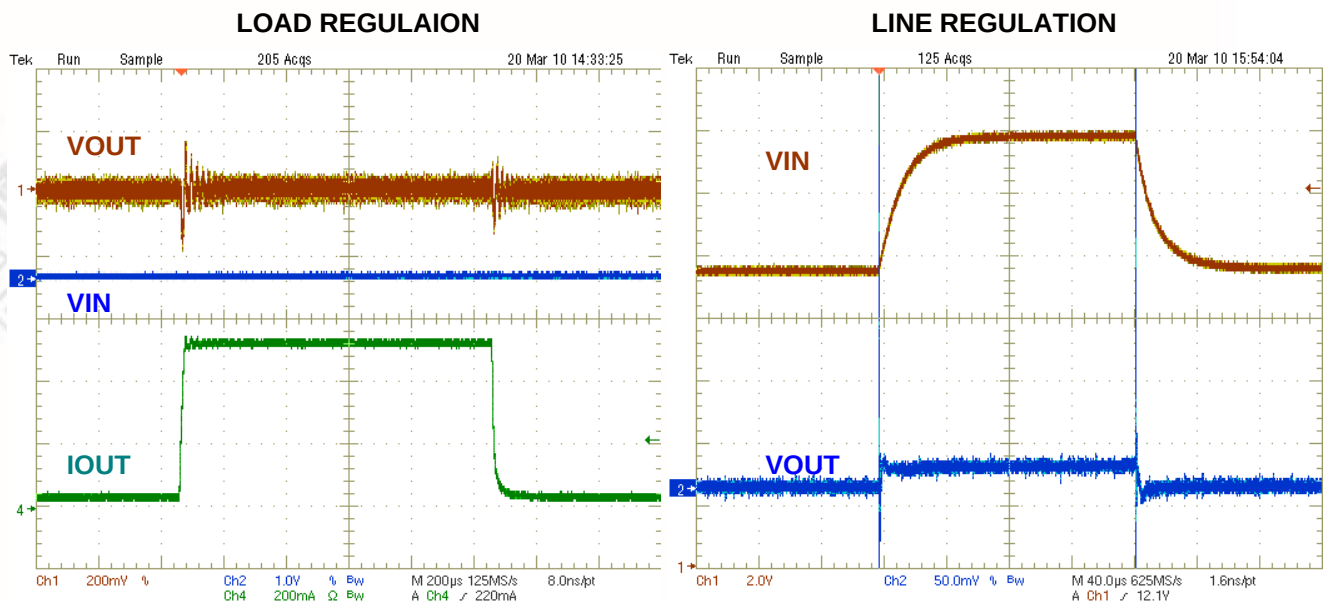
|                                               |           |  |     |     |             |                                     |
|-----------------------------------------------|-----------|--|-----|-----|-------------|-------------------------------------|
| Output Resistance                             |           |  | 0.7 |     | $\Omega$    | $I_{OUT} = 500mA$<br>$V_{SET} = 4V$ |
| Output Leakage(NOTE2)                         |           |  | 0   | 1   | $\mu A$     | ENABLE = 0V                         |
| <b>VSET Pin</b>                               |           |  |     |     |             |                                     |
| VSET Voltage                                  | $V_{SET}$ |  | 1   | 5.5 | V           |                                     |
| VSET pin Current                              |           |  | 100 |     | nA          |                                     |
| <b>Short Circuit Current Limit Protection</b> |           |  |     |     |             |                                     |
| Output Current Limit                          | $I_{LIM}$ |  | 0.7 |     | A           |                                     |
| Current Limit Trigger Point                   | $I_{TR}$  |  | 1.6 |     | A           |                                     |
| Short circuit protection                      | $I_{SH}$  |  | 0.2 |     | A           |                                     |
| <b>Over Temperature Protection</b>            |           |  |     |     |             |                                     |
| Thermal Shutdown Temperature                  |           |  | 150 |     | $^{\circ}C$ |                                     |
| Thermal Shutdown Hysteresis                   |           |  | 30  |     | $^{\circ}C$ |                                     |

NOTE1 : Slew rate will effect transient response, use  $T_R < 10\mu s$ ,  $T_F < 10\mu s$  measurement load regulation and line regulation

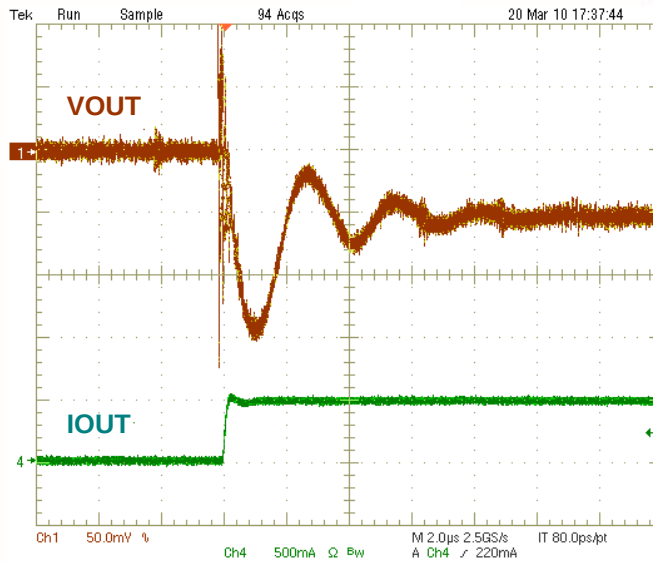
NOTE2 : .NCT3941S-A is full-on when enable=0, measurement output leakage current using  $V_{SET} < 0.3V$  to disable output voltage

## 9. OPERATING CHARACTERISTICS

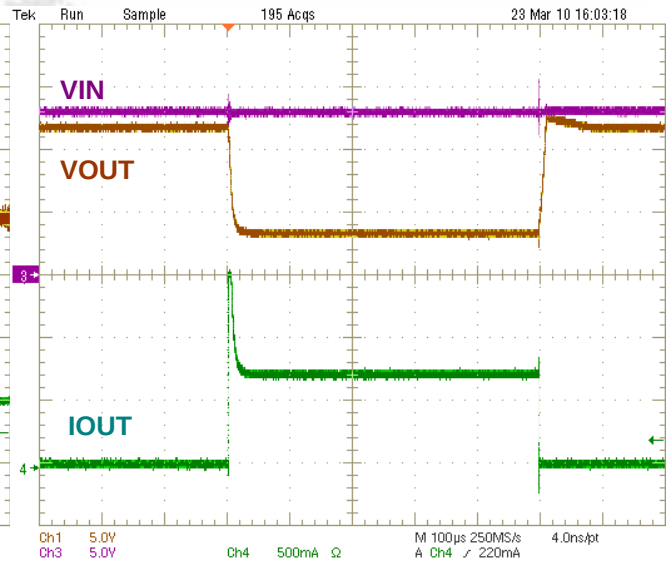
( $C_{IN}=2.2\mu f$ ,  $C_{out}=10\mu f$ ,  $V_{IN}=13V$ ,  $V_{SET}=2V$ ,  $V_{EN}=5V$ ,  $T_a=25^{\circ}C$ )



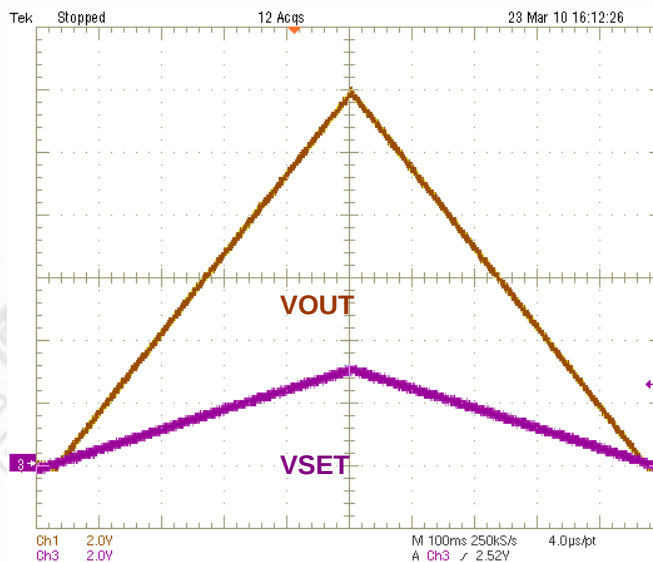
## LOAD TRANSIENT



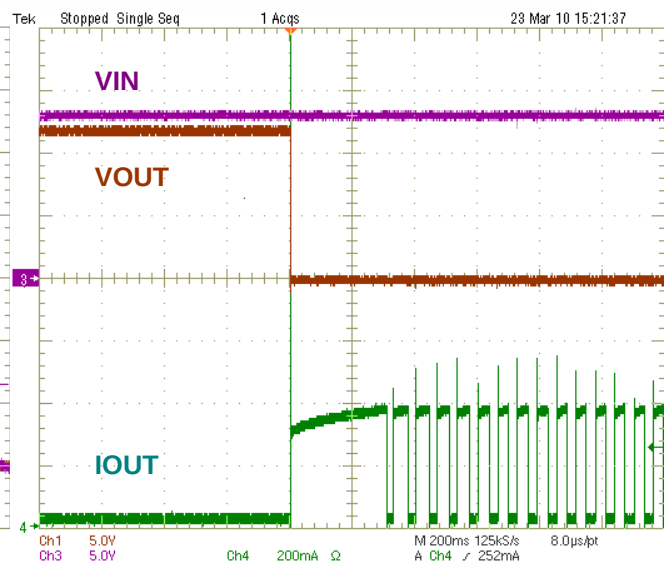
## CURRENT LIMIT BEHAVIOR



## VSET V.S. VOUT

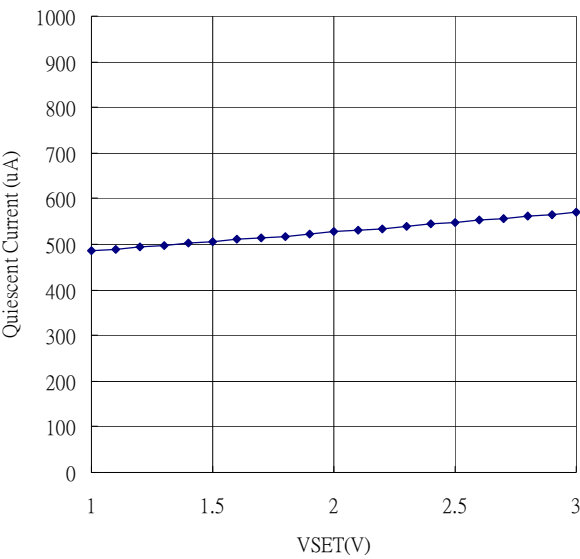


## SHORT CIRCUIT BEHAVIOR

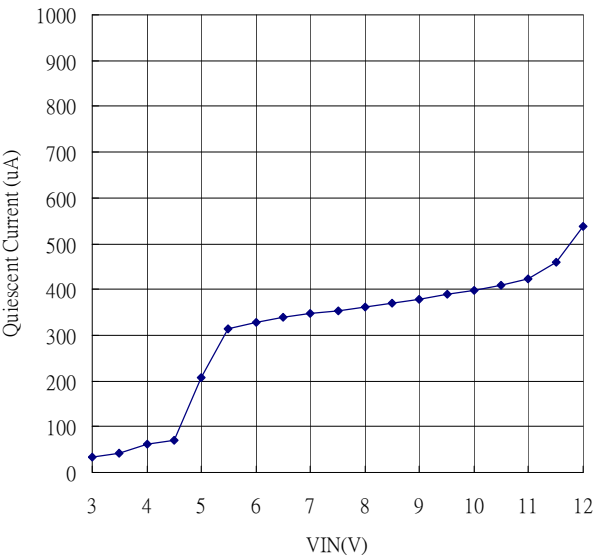




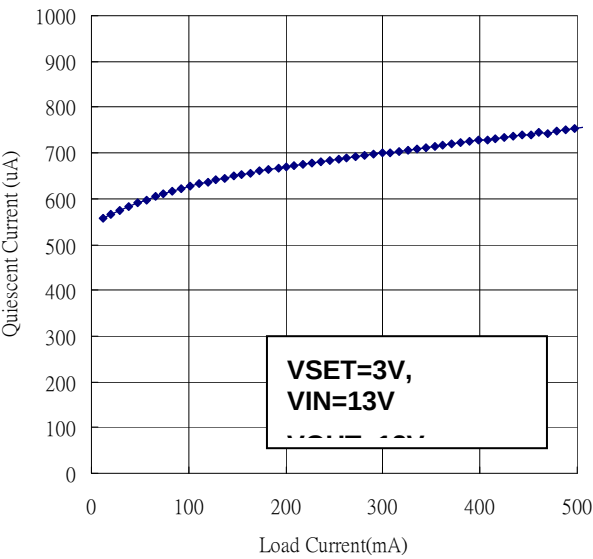
VSET V.S. QUIESCENT CURRENT



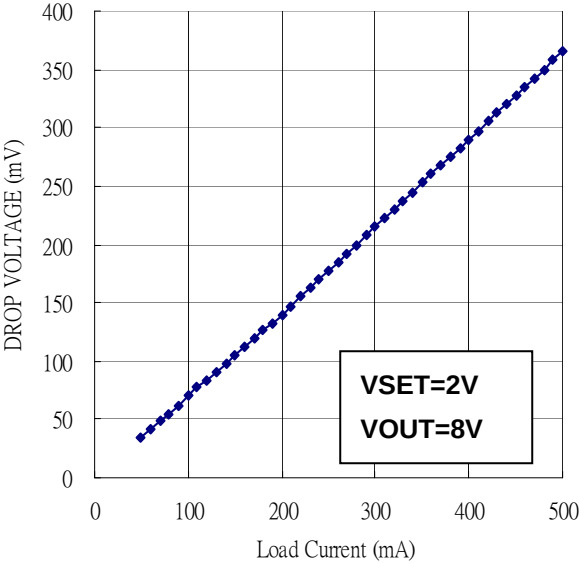
VIN V.S. QUIESCENT CURRENT



LOAD CURRENT V.S. QUIESCENT CURRENT

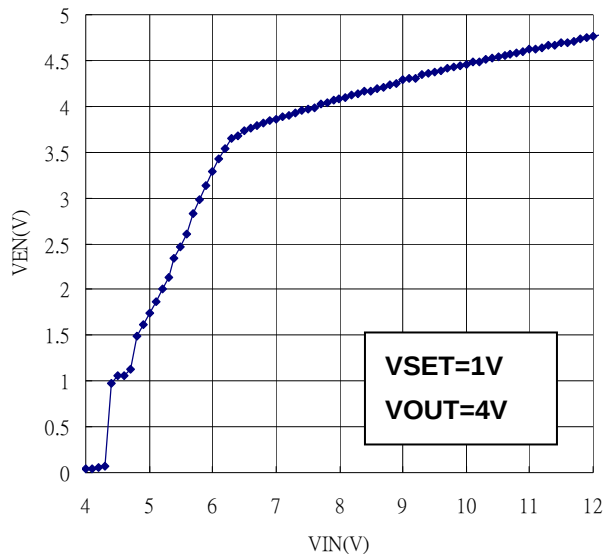


LOAD CURRENT V.S. DROP VOLTAGE

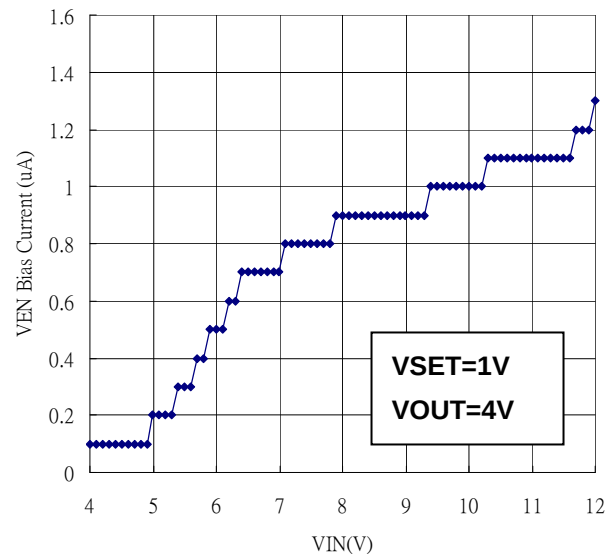




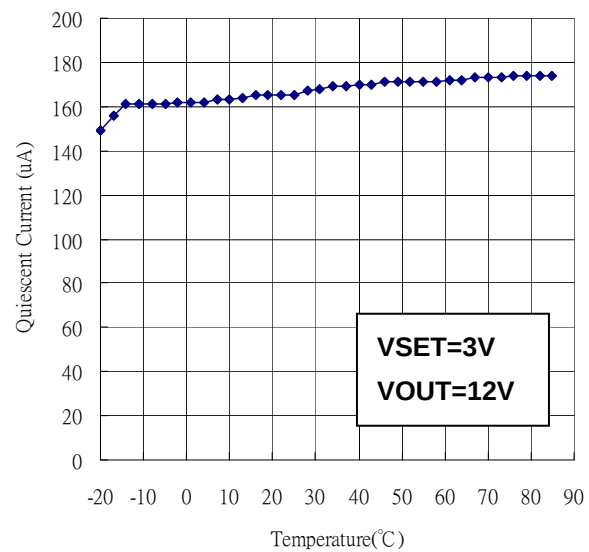
VIN V.S. VEN



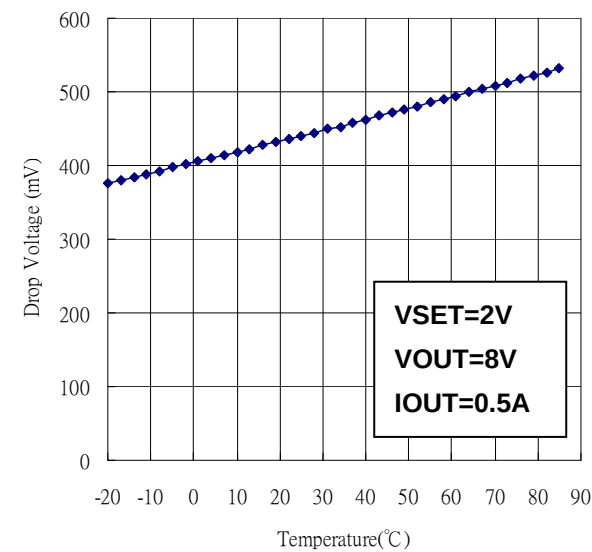
VIN V.S. VEN PIN BIAS CURRENT



QUIESCENT CURRENT V.S TEMPERATURE

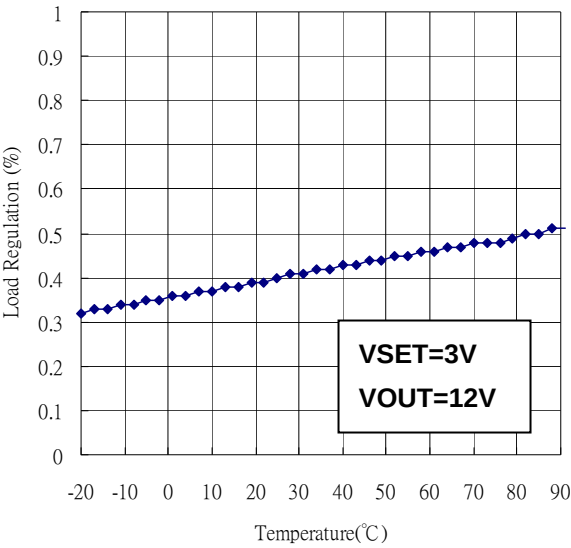


DROP VOLTAGE V.S TEMPERATURE

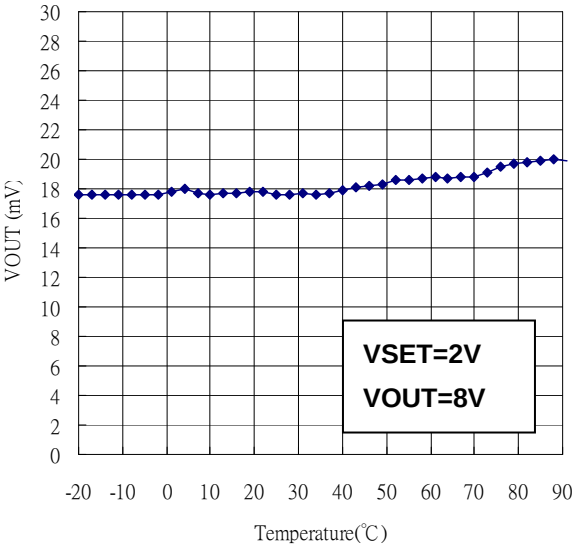




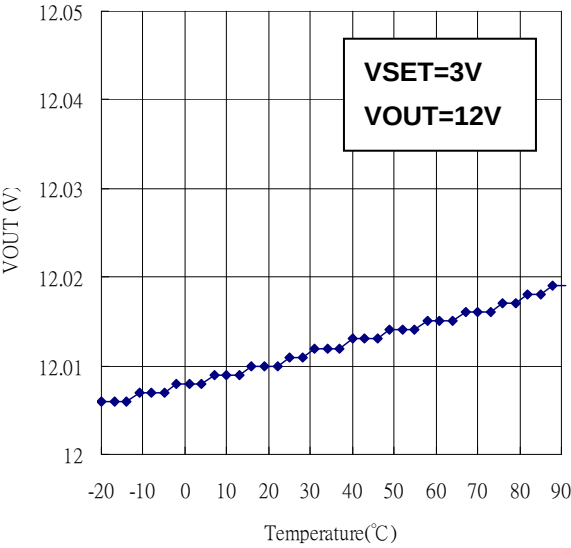
LOAD REGULATION V.S TEMPERATURE



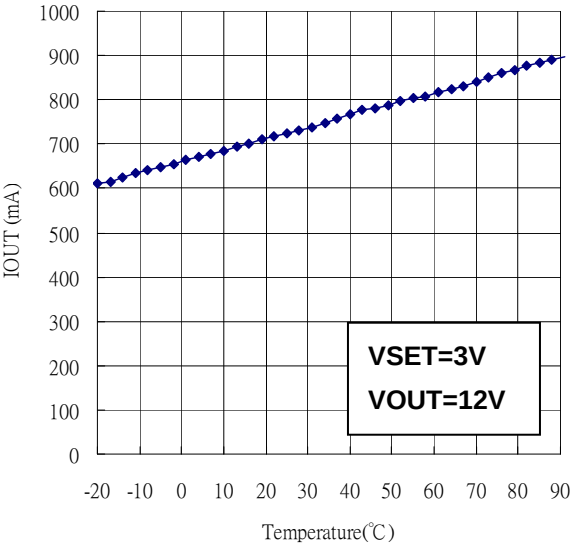
LINE REGULATION V.S TEMPERATURE



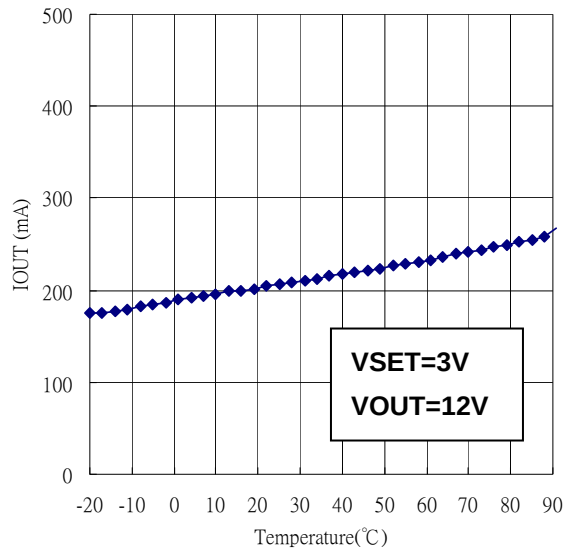
VOUT V.S TEMPERATURE



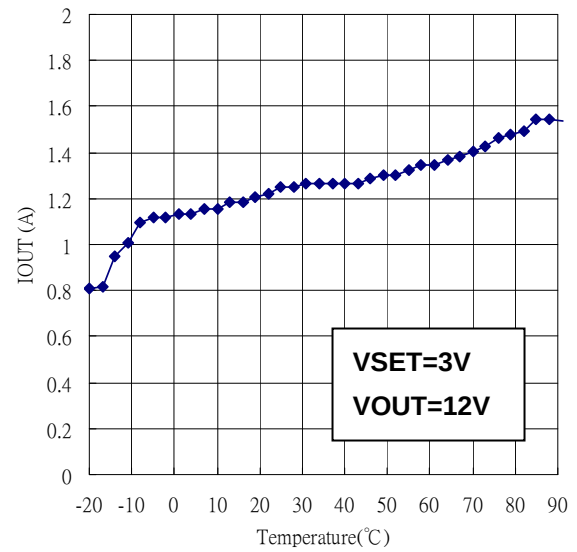
OVER CURRENT LIMIT V.S. TEMPERATURE



SHORT CIRCUIT LIMIT V.S. TEMPERATURE

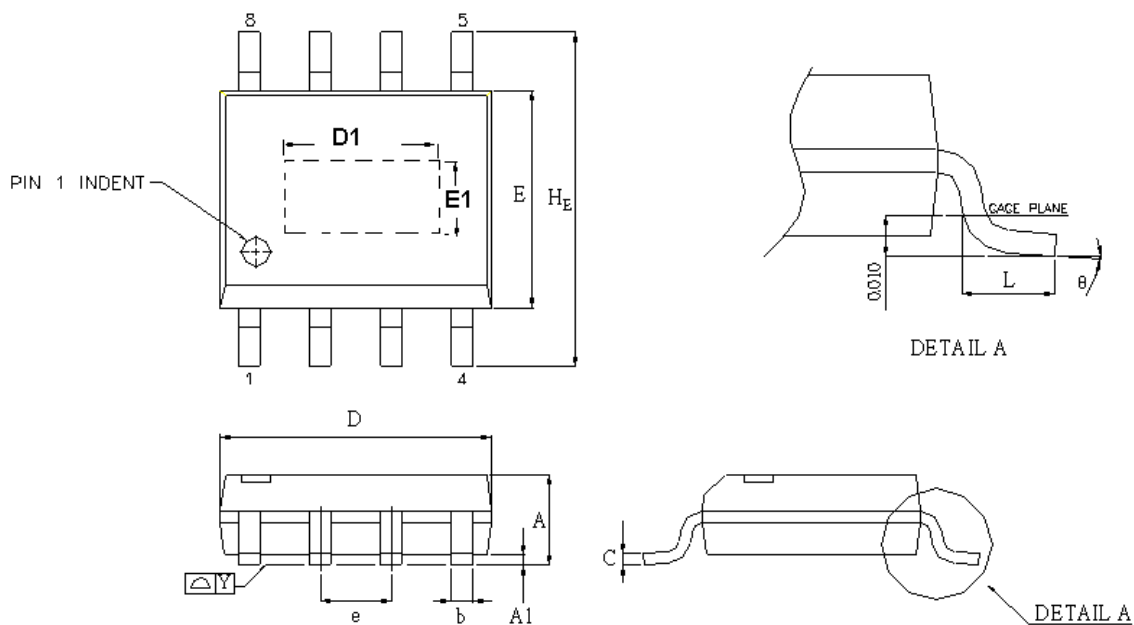


OVER CURRENT TRIGGER POINT V.S. TEMPERATURE



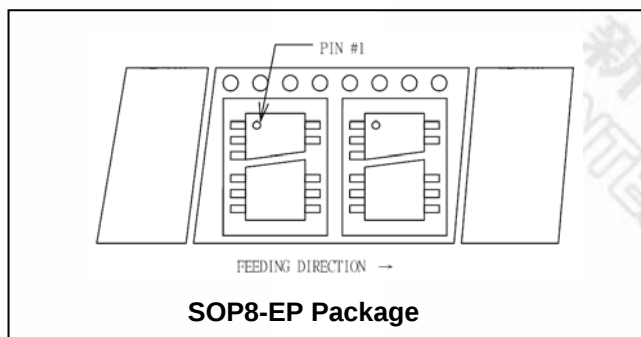
## 10. PACKAGE DIMENSION

SOP8-EP (150mil)



| SYMBOLS | Dimensions In Millimeters |      | Dimensions In Inched |      |
|---------|---------------------------|------|----------------------|------|
|         | Min                       | Max  | Min                  | Max  |
| A       | 1.35                      | 1.75 | 0.05                 | 0.07 |
| A1      | 0.05                      | 0.25 | 0.00                 | 0.01 |
| b       | 0.31                      | 0.51 | 0.01                 | 0.02 |
| c       | 0.1                       | 0.25 | 0.00                 | 0.01 |
| D       | 4.7                       | 5.10 | 0.19                 | 0.2  |
| E       | 3.8                       | 4.00 | 0.15                 | 0.16 |
| e       | 1.27 BASIC                |      | 0.05 BASIC           |      |
| He      | 5.8                       | 6.20 | 0.23                 | 0.24 |
| Y       | -                         | 0.10 | -                    | 0.00 |
| L       | 0.4                       | 1.27 | 0.02                 | 0.05 |
| θ       | 0°                        | 10°  | 0°                   | 10°  |
| D1      | 3.10                      | 3.50 | 0.12                 | 0.14 |
| E1      | 2.20                      | 2.60 | 0.09                 | 0.10 |

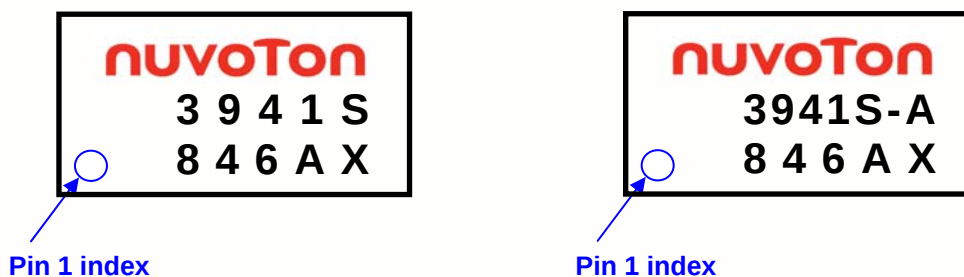
### 10.1 Taping Specification



## 11. ORDERING INFORMATION

| Part Number | Package Type            | Supplied as              | Production Flow             |
|-------------|-------------------------|--------------------------|-----------------------------|
| NCT3941S    | SOP8-EP (Green Package) | T Shape: 2,500 units/T&R | Commercial, -20°C to + 85°C |
| NCT3941S-A  |                         |                          |                             |

## 12. TOP MARKING SPECIFICATION



1<sup>st</sup> Line: Nuvoton logo

2<sup>nd</sup> Line: 3941S (NCT3941S), 3941S-A (NCT3941S-A)

3<sup>rd</sup> line: Tracking code

- 846: packages assembled in Year 2008, week 46
- A: assembly house ID.
- X: IC version. (A means A; B means B and C means C...etc.)

### 13. REVISION HISTORY

| VERSION | DATE       | PAGE      | DESCRIPTION                                |
|---------|------------|-----------|--------------------------------------------|
| A1      | 04/01/2010 | All       | New Create                                 |
| A2      | 05/05/2010 | P.5       | Adding thermal consideration               |
| A3      | 05/06/2010 | P.7       | Revised Maximum supply voltage.            |
| A4      | 25/08/2010 | P.1, P.12 | Modify description of feature and waveform |

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