

**NUVOTON**  
**12V DC/PWM Fan Driver**  
**NCT3947S-A**

**DATE: OCT., 2016**  
Revision: A1

Nuvoton Confidential

**-Table of Content-**

1. GENERAL DESCRIPTION .....	1
2. FEATURES.....	1
3. BLOCK DIAGRAM .....	2
4. PIN CONFIGURATION AND TYPICAL APPLICATION CIRCUIT .....	2
5. PIN DESCRIPTION.....	3
6. FUNCTIONAL DESCRIPTION.....	4
7. ELECTRICAL CHARACTERISTICS .....	7
8. TYPICAL OPERATING CHARACTERISTICS AND WAVEFORMS .....	10
9. PACKAGE DIMENSION .....	11
10. ORDERING INFORMATION.....	12
11. TOP MARKING SPECIFICATION.....	12
12. REVISION HISTORY .....	13

Nuvoton Confidential

Nuvoton Confidential

## 1. GENERAL DESCRIPTION

The NCT3947S-A is a 12V fan driver which can drive 4-wire Pulse Width Modulation (PWM) fan or 3-wire DC fan. This device can detect automatically external fan type to determine the operating mode. In PWM mode, the fan speed is controlled by PWMIN duty. In DC mode, the fan speed is controlled by DCIN voltage level. The NCT3947S-A also provides VIN under voltage lockout (UVLO), over-current, short-circuits and over temperature protections.

## 2. FEATURES

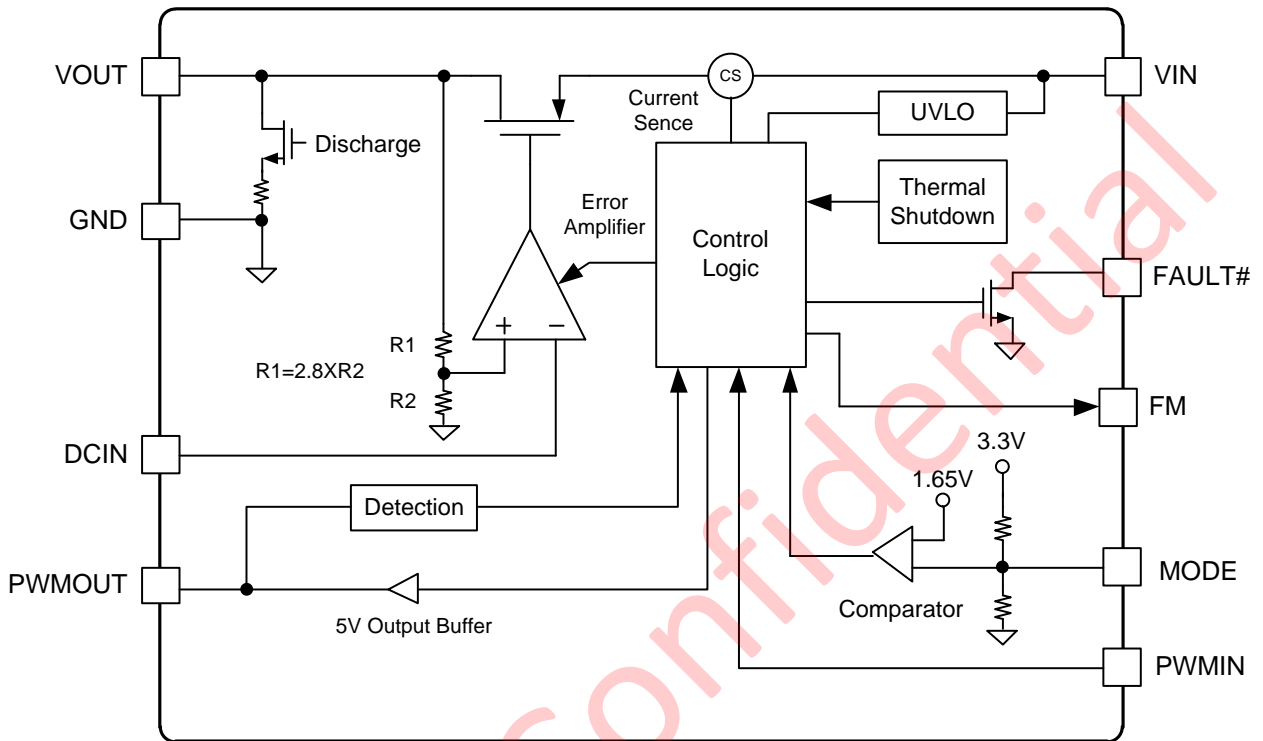
### General

- Fan Type Auto-Detection, TW Patten: I344591
- VIN Voltage: 12V  $\pm$  10%
- DCIN Voltage Range: 0V to 5.5V
- PWM Signal Input Range: 0Hz ~ 30kHz
- Guarantee Output Current: 2A
- 300mV Dropout @ 2A
- VOUT=3.8 X DCIN in DC Mode Operating
- Internal Soft-start
- Manual Operating Mode Setting
- Requires Minimum Output Capacitance of 10uF MLCC
- Integrated Power P-MOSFET
- Low External Component Count
- Low Output Voltage Offset
- Over Current Protection
- Over Temperature Protection
- -40°C to 85°C Ambient Operating Temperature Range
- 8 Pins SOP 150mil with Exposed Pad Package (SOP8-EP)
- Lead Free (ROHS Compliant) and Halogen Free

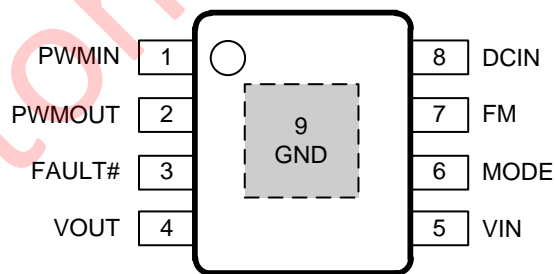
### Applications

- Desktop PCs, Notebooks, and Workstations
- Projectors
- Peripheral Add-in Cards
- Set Top Boxes, Digital TVs and Printers

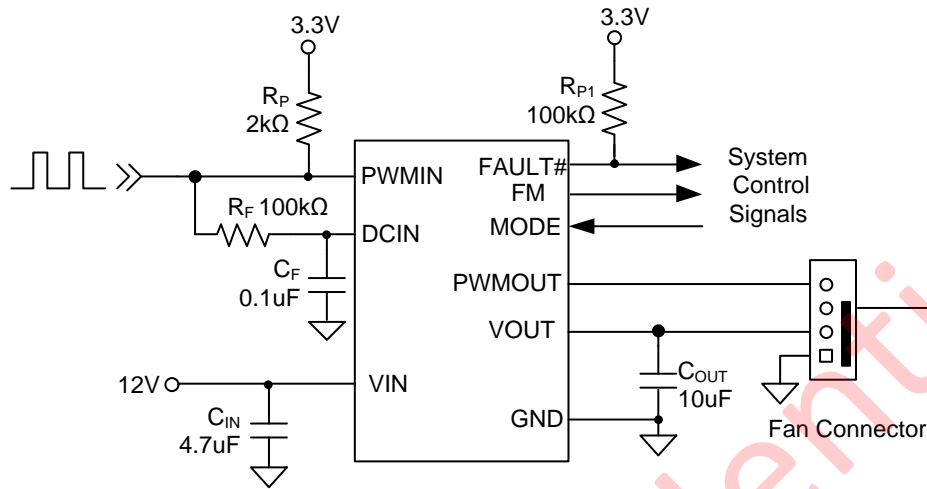
3. BLOCK DIAGRAM



4. PIN CONFIGURATION AND TYPICAL APPLICATION CIRCUIT



NCT3947S-A  
(Top View)



NCT3947S-A  
Typical Application Circuit

5. PIN DESCRIPTION

SYMBOL	PIN	I/O	FUNCTION
PWMIN	1	I	PWM signal input pin. The fan speed is controlled by PWMIN duty.
PWMOUT	2	I/O	This is a bidirectional pin. The initial state is input pin. During VOUT ramps up, this pin will detect fan type. After fan type is determined, this pin transfers to output type. If 4-wire PWM fan is detected, the output type is push-pull and output state follows PWMIN signal. If 3-wire DC fan is detected, the output type is push-pull and outputs 5V voltage. The output type can change by cycling the VIN below the UVLO to reset the device. External pull up/down resistor is not allowed.
FAULT#	3	OD	Active low open drain output, asserted during the fault event when over-current, short circuits or over temperature occurred.
VOUT	4	O	Output voltage pin. PWM Mode operating: the internal power MOSFET operates as power switch and VOUT voltage follows VIN voltage. DC Mode operating: the internal power MOSFET operates as linear regulator and VOUT voltage is regulated to 3.8 times DCIN voltage.
VIN	5	I	Supply voltage input pin.
MODE	6	I	Operating mode manual setting. Internal pull-up to 1.65V (typ.). Floating this pin to choose Auto-detection Mode operating. Pull-up this pin to 3.3V to force PWM Mode operating.

			Pull-down this pin to ground to force DC Mode operating.
FM	7	O	Operating mode indicator. 3.3V push-pull output. PWM Mode operating: output 3.3V. DC Mode operating: output 0V.
DCIN	8	I	DC voltage input pin. Connect to negative input of internal error amplifier as a reference voltage. Place a low pass R-C filter and close to this this pin is recommended. This pin cannot be left floating.
GND	9	--	Ground pin.

## 6. FUNCTIONAL DESCRIPTION

### PWM Signal Input, PWMIN

This input is usually connected to a TTL/CMOS level output of a controller. This signal is used to control fan speed of PWM fan by duty cycle variance. The common input frequency is about 25 kHz.

### PWM Signal Output and Fan Type Detection, PWMOUT

This pin's behavior in initial is an input function. During VOUT ramps up, it will detect which type of fan is plugged in fan connector.

If 4-wire PWM fan is plugged in, this pin's behavior is a push-pull output pin. The output state follows PWMIN signal.

If 3-wire DC fan is plugged in, this pin's behavior is a push-pull output pin. It would output 5V all the time.

Once the output type is determined, it only can change by cycling the VIN below the UVLO to reset the device.

Do not place any resistor on this pin to prevent wrong fan type detection.

### Reference Voltage, DCIN

In DC Mode operating, the output voltage, VOUT, is regulated to DCIN. Connect an external low pass filter is suggested. It could reduce the inherent noise from environment and also transfer PWM signal into DC level.

### Output Voltage, VOUT

In DC Mode operating, the NCT3947S-A works as a linear regulator and the output voltage, VOUT, is regulated to 3.8 times DCIN.

In PWM Mode operating, the NCT3947S-A works as a power switch. The output voltage follows input voltage.

$$VOUT = VIN - [IOUT \times R_{DS(on)}]$$

### Operating Mode Indicator, FM

This pin is push-pull output. When the NCT3947S-A operates in DC Mode, FM pin outputs low logic level. When the device operates in PWM Mode, FM outputs high logic level.

### Operating Mode Manual Setting, MODE

The input logic level determines operating mode. Floating this pin, the NCT3947S-A operates in auto-detection mode. Pulls this pin up to logic high level, the NCT3947S-A operates in PWM Mode. Pulls this pin down to logic low level, the NCT3947S-A operates in DC Mode.

### Application for 4-pin Fan Detection

In certain 4-wire PWM fans' design, there is no internal pull-up on Fan-Control pin. For correctly fan speed control, it is recommended to set MODE pin to high logic level before VIN POR to force the device to operate in PWM mode. System can compare the variation of rotation speed by changing PWMIN duty, such as 50% to 100% or vice versa. If there is not variation which means 3-wire DC fan is plugged indeed. Then assert MODE pin to low logic level to let the device operates in DC mode. By changing DCIN voltage to control fan speed.

**Power Saving**

In DC mode operating, if DCIN voltage is below 0.1V; the internal regulator would be turned off. This could save power consumption when fan cooling is not necessary or no fan plugged condition. System can read the rotation speed from fan's sense pin to judge if fan plugged or not.

**Fault Indication**

NCT3947S-A provides the state indicate on FAULT# pin. The FAULT# is an open-drain type output. The FAULT# is set to high impedance at normal state. The FAULT# is pulled low immediately when OCP, SCP or OTP event occurred.

**Under-voltage Lockout (UVLO)**

An under-voltage lockout circuit prevents the power switch from turning on until input voltage reaches the UVLO turn off threshold. Built in hysteresis prevents unwanted on/off cycling due to voltage drop from large current surges.

**Over Current Protection**

The NCT3947S-A provides a current limit circuitry, which monitors the current from VIN to VOUT and controls MOSFET's gate voltage to limit the output current. The over current protection is a non-latch protection.

**Over Temperature Protection**

The NCT3947S-A monitors its junction temperature. If the device junction temperature exceeds its threshold value, the VOUT is shut off. The thermal shutdown is a non-latch protection.

**Thermal Design**

The ability to remove heat from the die is different for each package type, presenting different consideration in the PCB layout. The PCB area around the device that is free to the ambient air. Power dissipation depends on input voltage and load conditions. Power dissipation  $P_D$  is equal to the product of the output current times the voltage drop across the output pass element (VIN to VOUT):

$$P_D = [(VIN - VOUT) \times I_{OUT}] + (VIN \times I_{GND})$$

Power dissipation can be minimized by using the lowest possible input voltage necessary to assure the required output voltage.

The maximum power dissipation depends on the thermal resistance of IC package and can be calculated by following formula:

$$P_{D(max)} = \frac{T_{J(max)} - T_A}{\theta_{JA}}$$

Where  $T_{J(max)}$  is the maximum operation junction temperature,  $T_A$  is the ambient temperature and  $\theta_{JA}$  is the junction to ambient thermal resistance. Since the thermal resistance of SOP8-EP package is 50°C/W and the maximum power dissipation can be calculated by following equation:

$$\begin{aligned} P_{D(max)} &= \frac{125^\circ C - 25^\circ C}{50^\circ C/W} \\ &= 2W \end{aligned}$$

$\theta_{JA}$  highly depends on IC package, PCB layout, the airflow. Thermal resistance  $\theta_{JA}$  can be improved by adding copper under the exposed pad of SOP8-EP while the IC package is fixed. The copper

under the exposed pad of SOP8-EP is an effective heatsink and is useful for improving thermal conductivity.

**Input Capacitor**

Depend on the trace impedance between the VIN bulk power supply to the device, a transient increase of source current is supplied mostly by the charge from the VIN input capacitor. If the NCT3947S-A is located near the bulk capacitor(s) for upstream voltage regulator, the input capacitor may not be required. Use a 10uF (or greater) capacitor to supply this transient charge. Provide more input capacitance as more output capacitance is used at VOUT.

**Output Capacitor**

For stable operation, the total capacitance of the VOUT terminal must be greater than 10uF. Total output capacitors value including MLCC and AL electrolytic capacitors should be larger than 10uF.

**Layout Consideration**

Consider the following points before starting the NCT3947S-A layout design. Fig. 6-1 shows the suggestion of minimum land pattern. Using larger copper patterns on the top layer can increase efficiency of heat dissipating.

- 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.
- The voltage divider resistors and R-C filter should be placed as close as possible to the pin.
- 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.

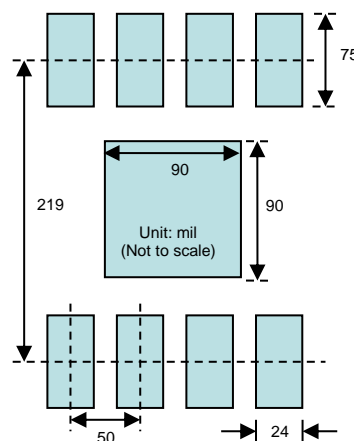


Fig. 6-1 Recommended Land Pattern

## 7. ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings <sup>(Note1)</sup>

ITEM		RATING	UNITS	
Input Voltage, VIN		-0.3 to 19	V	
Voltage on MODE, PwMIN & DCIN		-0.3 to 7	V	
Voltage on PWMOUT		-0.3 to 13.5	V	
PwMIN Frequency		0 to 35	kHz	
Electrostatic discharge protection <sup>(Note2)</sup>	Human Body Mode	VOUT	±8	KV
		Other Pins	±2	KV
	Machine Mode		±200	V
	Latch-Up		±100	mA
Storage Temperature Range		-65 to 150	°C	
Soldering Temperature		Refer to IPC/JEDEC J-STD-020 Specification		

Note1. 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 or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

Note2. Devices are ESD sensitive. Handling precaution recommended.

### Thermal Information

ITEM		RATING	UNITS
Power Dissipation, P <sub>D</sub> @ T <sub>A</sub> =25°C		2	W
Package Thermal Resistance	Junction to Ambient, θ <sub>JA</sub>	50	°C/W
	Junction to Case, θ <sub>JC</sub>	15	°C/W

Note1. The junction to ambient thermal resistance under nature convection is obtained in a simulation on a JEDEC standard as specified in JEDEC51-5.

### Recommended Operating Conditions

ITEM	SYMBOL	MIN	MAX	UNITS
Input Voltage	VIN	10.8	13.2	V
	PwMIN	0	5.5	
	DCIN	0	3.6	
	MODE	0	3.6	
Output Current	IOUT	0	2	A
PwMIN Frequency	f <sub>PWM</sub>	0	30	kHz
PWMOUT High Level Output Current	I <sub>OH</sub>		-5	mA
PWMOUT Low Level Output Current	I <sub>OL</sub>		10	mA
Capacitance of VIN Decoupling Capacitor, MLCC	C <sub>IN</sub>	4.7	100	uF
Capacitance of VOUT Regulation Capacitor, MLCC	C <sub>OUT</sub>	10	100	uF
Operating Temperature Range	T <sub>OPT</sub>	-40	85	°C
Junction Temperature Range <sup>(Note1)</sup>	T <sub>J</sub>	-40	125	°C

Note1. At elevated temperatures, devices must be de-rated based on thermal resistance. The device in the SOP8-EP package must be de-rated at θ<sub>JA</sub>=50°C/W junction to ambient with minimum PCB footprint.

**DC Characteristics**

Typicals and limits appearing in normal type apply for  $T_j = 25^\circ\text{C}$ . Limits appearing in **Boldface** type apply over the entire junction temperature range for operation,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  (Note1).  $V_{IN} = 12\text{V}$ ,  $C_{OUT} = 10\mu\text{F}$ , all voltage outputs unloaded (unless otherwise noted).

PARAMETER		SYM.	TEST CONDITION	MIN	TYP	MAX	UNITS
<b>Input</b>							
VIN Operating Current	DC Mode	$I_{VIN\_DC}$	$I_{OUT}=0\text{A}$ , $f_{PWM}=0\text{Hz}$ , $V_{DCIN}=4\text{V}$ , $V_{MODE}=L$ , $V_{OUT}=12\text{V}$			<b>1</b>	mA
	PWM Mode	$I_{VIN\_PWM}$	$I_{OUT}=0\text{A}$ , $f_{PWM}=25\text{kHz}$ , $V_{MODE}=H$ , $V_{OUT}=12\text{V}$			<b>0.8</b>	mA
VIN Shutdown Current		$I_{SD}$	$V_{IN}=12\text{V}$ , $V_{DCIN}=0\text{V}$			<b>150</b>	$\mu\text{A}$
On Resistance (Note3)		$R_{DS(ON)}$	$V_{OUT}=12\text{V}$ , $I_{OUT}=2\text{A}$		<b>150</b>	<b>200</b>	$\text{m}\Omega$
DCIN Input Threshold		$V_{DCINR}$	Rising	<b>0.25</b>			V
		$V_{DCINF}$	Falling			<b>0.05</b>	V
Input Leakage Current		$I_{LEAK}$	$V_{P\_MIN} / V_{DCIN}=5.5\text{V}$ or $0\text{V}$	<b>-1</b>		<b>1</b>	$\mu\text{A}$
UVLO Threshold		$V_{IN\_UV}$	VIN Rising		<b>9.5</b>	<b>10.7</b>	V
UVLO Hysteresis		$V_{IN\_TH}$			<b>200</b>		mV
<b>Output</b>							
Load Regulation			$I_{OUT}=10\text{mA}$ to $2\text{A}$ (Note2), $T_A=25^\circ\text{C}$	<b>-3</b>		<b>3</b>	%
Line Regulation			$V_{OUT}+0.5\text{V} < V_{IN} < 13.2\text{V}$ , $I_{OUT}=10\text{mA}$		<b>0.3</b>	<b>0.5</b>	%/V
Output Voltage / DCIN				<b>3.6</b>	<b>3.8</b>	<b>4</b>	V/V
Soft-start Period		$T_{SS}$			<b>1.5</b>	<b>3</b>	ms
Off State Leakage		$I_{OUT\_OFF}$	$V_{IN}=12\text{V}$ , $V_{DCIN}=0\text{V}$ , $V_{OUT}=0\text{V}$		<b>0</b>		$\mu\text{A}$
			$V_{IN}=12\text{V}$ , $V_{DCIN}=0\text{V}$ , $V_{OUT}=0.3\text{V}$		<b>30</b>		$\mu\text{A}$
<b>Logic Input Level, PWMIN, MODE</b>							
Input Voltage Level		$V_{IH}$	High	<b>2.0</b>			V
		$V_{IL}$	Low			<b>0.8</b>	V
Input Voltage Hysteresis		$V_{ITH}$			<b>200</b>		mV
Pull-down Source Current		$I_{PD}$	$V_{IN}=12\text{V}$ , $V_{MODE}=0\text{V}$		<b>10</b>		$\mu\text{A}$
Pull-up Voltage		$V_{MODE}$	$V_{IN}=12\text{V}$	<b>1.5</b>	<b>1.65</b>	<b>1.8</b>	V
<b>Logic Output Level, FM</b>							
Output Voltage High Level		$V_{OH}$	$V_{IN}=12\text{V}$ , $I_{OH}=-5\text{mA}$	<b>2.4</b>			V
Output Voltage Low Level		$V_{OL}$	$V_{IN}=12\text{V}$ , $I_{OL}=10\text{mA}$			<b>0.4</b>	V
<b>FAULT#</b>							
FAULT# Sink Capability		$I_{FAULT\#-SINK}$	$V_{FAULT\#}=0.3\text{V}$	<b>10</b>	<b>15</b>		mA
FAULT# Off Current		$I_{FAULT\#-OFF}$	$V_{FAULT\#}=5\text{V}$			<b>1</b>	$\mu\text{A}$
FAULT# Delay Time		$T_D$	From fault condition to FAULT# Assertion		<b>5</b>		mS
<b>PWMOUT</b>							
Pull-down Resistance					<b>500</b>		$\text{k}\Omega$
Propagation Delay		$t_{PD}$	$f_{PWM}=25\text{kHz}$			<b>0.5</b>	$\mu\text{s}$
Output Voltage High Level		$V_{OH}$	$V_{IN}=12\text{V}$ , $P_{WMIN}=V_{IH}$ , $I_{OH}=-5\text{mA}$	<b>4.4</b>			V

Output Voltage Low Level	$V_{OL}$	$V_{IN}=12V, P_{WMIN}=V_{IL}, I_{OL}=10mA$	0.5	V
<b>Protection</b>				
Short Circuit Current Limit	$I_{SC}$	VOUT short to ground	1	2
Over Current Trip Threshold	$I_{OC}$	Pulse Load( $T_H:1mS, T_L:1S$ ), VOUT drop below 10V within 1mS	3	4
Thermal Shutdown Temperature	$T_{SD}$	$10.8V < V_{IN} < 13.2V$ (Note4)	125	160 °C

Note1. Limits are 100% production tested at 25°C. Limits over operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate average outgoing quality level.

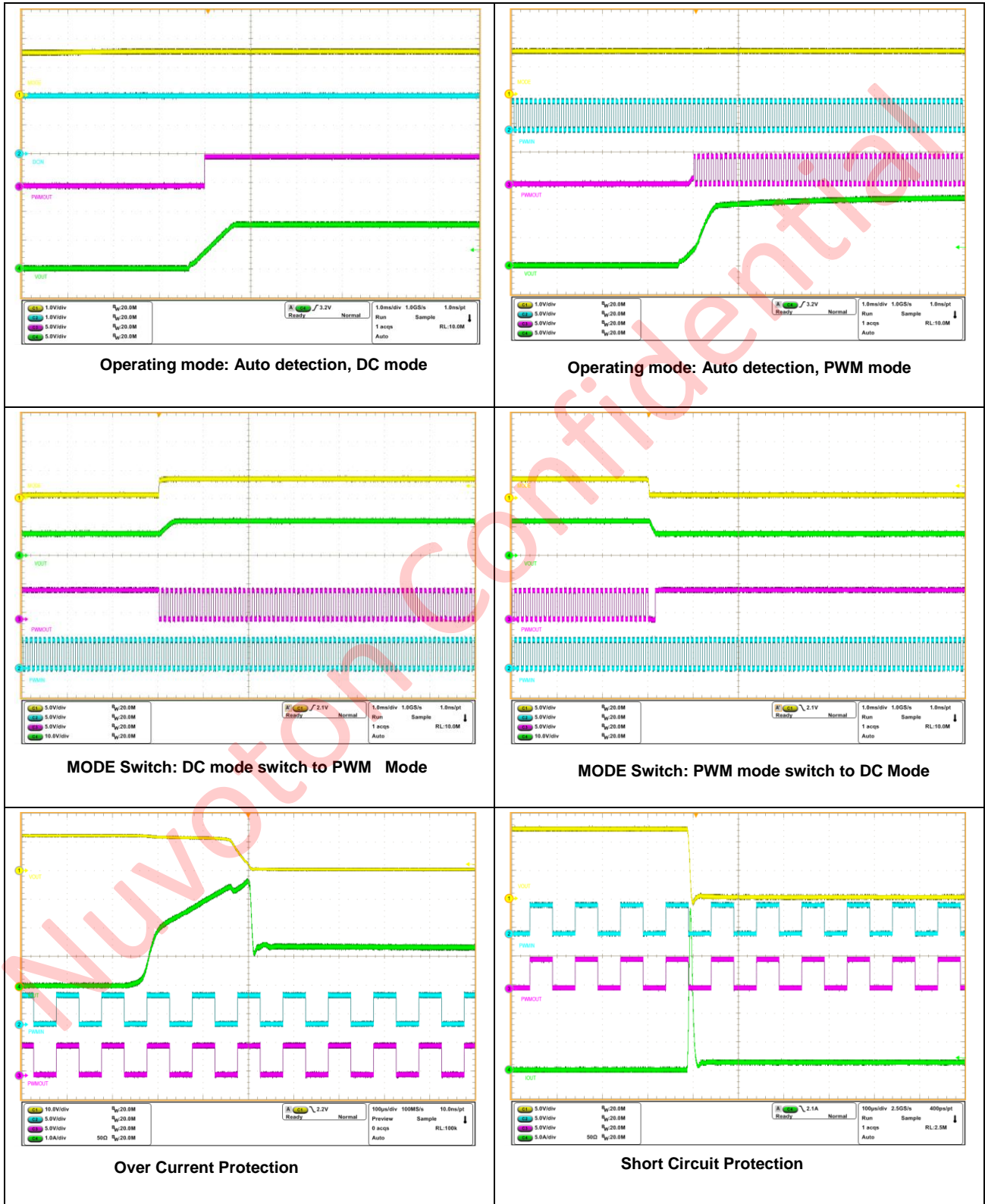
Note2. VOUT load regulation is tested by using a 10ms period and 50% duty cycle current pulse.

Note3. Pulse-testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.

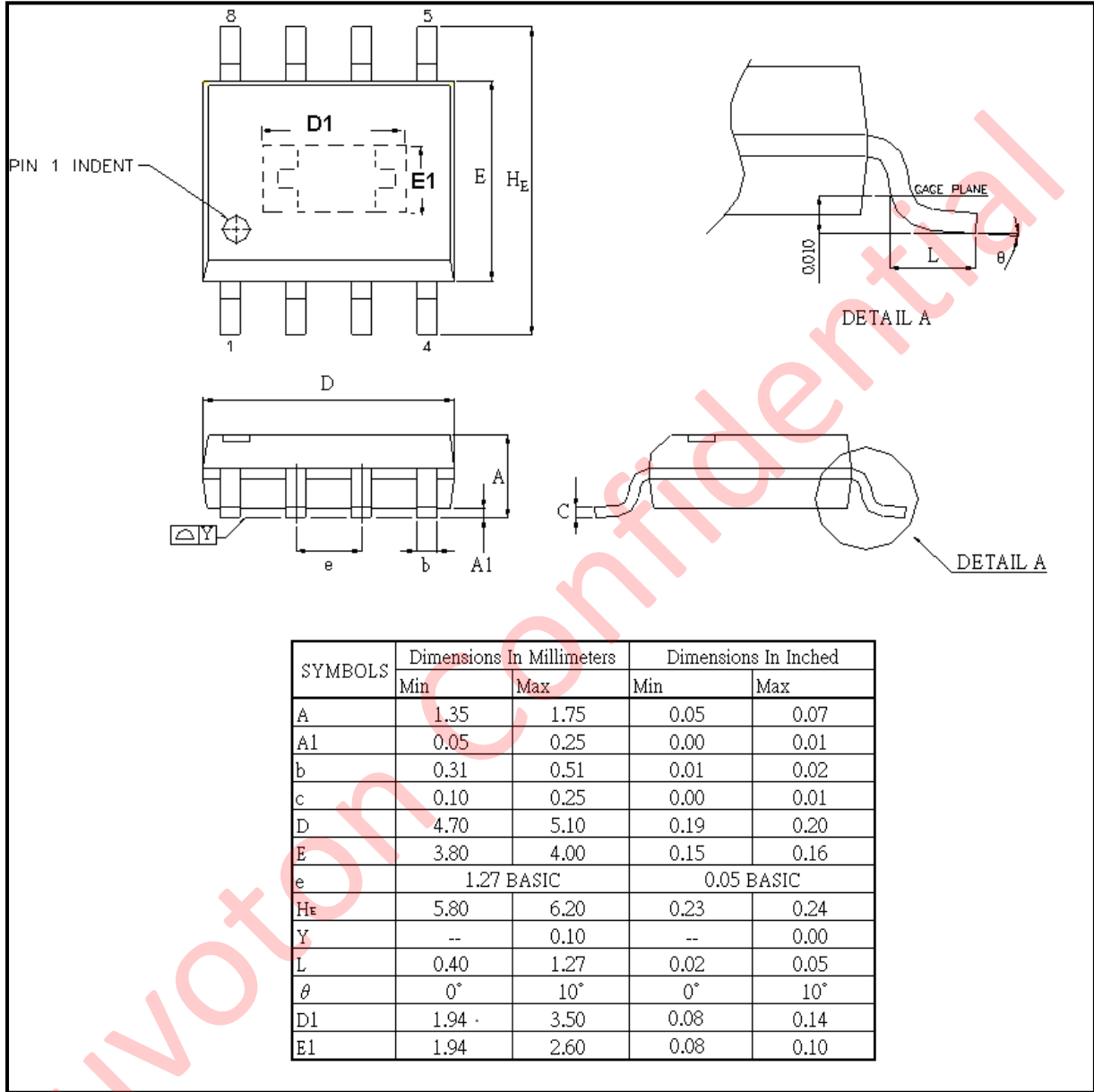
Note4. The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_{J(MAX)}$ , the junction to ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$  exceeding the maximum allowable power dissipation will cause excessive die temperature and the regulator will go into thermal shutdown. Ensured by design, no production tested.

Nuvoton Confidential

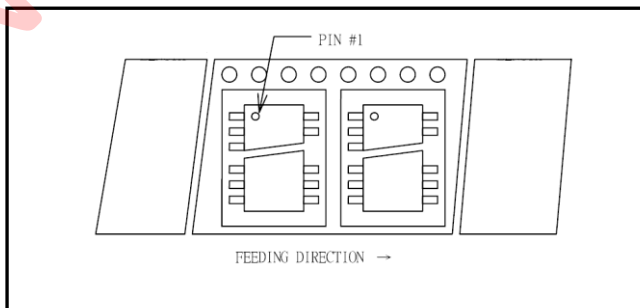
8. TYPICAL OPERATING CHARACTERISTICS AND WAVEFORMS



9. PACKAGE DIMENSION



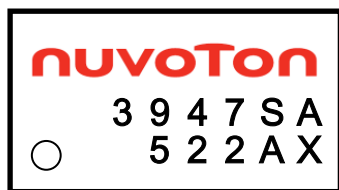
➤ TAPING SPECIFICATION



**10. ORDERING INFORMATION**

Part Number	Package Type	Supplied as	Operating Temperature
NCT3947S-A	SOP8-EP (Green Package)	T Shape: 2,500 units/T&R	Commercial, -40°C to +85°C

**11. TOP MARKING SPECIFICATION**



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

2<sup>nd</sup> Line: 3947SA

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

- 522: Packages assembled in Year 2015, week 22
- A: Assembly house ID
- X: Internal use only

Nuvoton Confidential

**12. REVISION HISTORY**

VERSION	DATE	PAGE	DESCRIPTION
A0	July. 2016	All	First release
A1	Oct. 2016	3,4	Modify typo

Nuvoton Confidential

### Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, "Insecure Usage".

Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, the control or operation of dynamic, brake or safety systems designed for vehicular use, traffic signal instruments, all types of safety devices, and other applications intended to support or sustain life.

All Insecure Usage shall be made at customer's risk, and in the event that third parties lay claims to Nuvoton as a result of customer's Insecure Usage, customer shall indemnify the damages and liabilities thus incurred by Nuvoton.

---

*Please note that all data and specifications are subject to change without notice.  
All the trademarks of products and companies mentioned in this datasheet belong to their respective owners.*