Nuvoton
Current-Limited, Power Distribution Switches
NCT3520W

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Revision A7

-Table of Content-

1. GENERAL DESCRIPTION

The NCT3520W is high-side current-limited switch with enable and error flag functions, optimized for general purpose power distribution and Universal Serial Bus (USB) requiring circuit protection.

The devices incorporate a 70 mΩ N-channels MOSFET power switch controlled by a logic enable input. It can handle up to 1.0A/1.5A/2.0A continuous output current and operate under a supply voltage ranging from 4.5 to 5.5V. NCT3520W power switches are optimized for self-powered and bus-powered USB application and also can be used in where heavy capacitive loads and short circuits are likely to occur devices.

The NCT3520W possess an 8 ms OC# blanking timeout feature allowing momentary fault to be ignored. For example, current surges caused by hot-plugging into a capacitive load or when the device is powering up, thus prevent fault alarm from being relayed to the host system. The devices also supports output discharge function that provides a controlled discharge of the output voltage stored on the output capacitor.

Any of the fault conditions, reverse voltage, over-current or over-temperature is transmitted via the OC# pin to a local USB controller. The output current is limited when the output load reaches the current-limit threshold or a short condition occurs.

When continuous heavy overloads or short-circuits causes the junction temperature to rise, an over-temperature protection mechanism (OTP) will be activated to shut the switch off to prevent catastrophic failure. Recovery from the OTP is automatic when the junction temperature returns in a reasonable range. The under-voltage lockout (UVLO) can ensure the switch is in off state unless there is a valid input voltage.

2. FEATURES

General

- 70-mΩ High–Side MOSFET Switch
- Compliant to USB Specification
- Guaranteed 1.0 A / 1.5 A / 2.0 A Continuous Load Current
- Accurate Current Limit
- Reverse Current Flow Blocking (no body diode)
- Reverse Voltage Protection
- Output Discharge Function
- Short-Circuit and Thermal Protection with Over-current Flag Logic Output
- Under voltage Lockout
- No Over-current (OC#) Signal During Power-up and 8ms Internal OC# blanking timeout
- Operating Range: 4.5 V to 5.5 V
- Logic-Level Enable Input, Available with Active High/ Low Versions
- 1.5 ms Typical Rise Time
- 1 uA Maximum Standby Supply Current
- UL Approved File Number: E346668
- CB certified

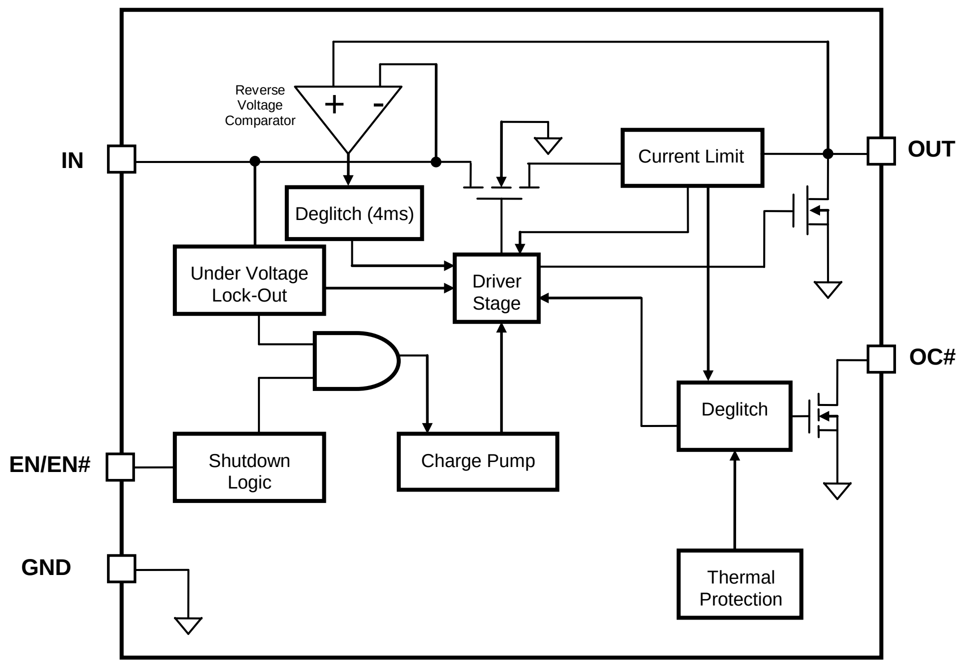
Package

- Provides MSOP-8 Green Package
- Lead Free (ROHS Compliant) and Halogen Free

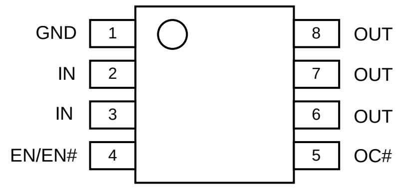
Applications

- High-Side Power Protection Switch
- Notebook, PC Computers
- USB Power Management
- USB Hubs
- Hot Plug-in Power Supplies
- Docking Stations

3. BLOCK DIAGRAM



4. PIN CONFIGURATION AND TYPICAL APPLICATION CIRCUIT



NCT3520WW-XXX

MSOP-8

(TOP VIEW)

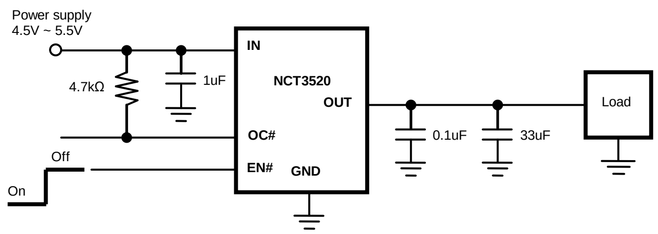


Figure 1 Typical application

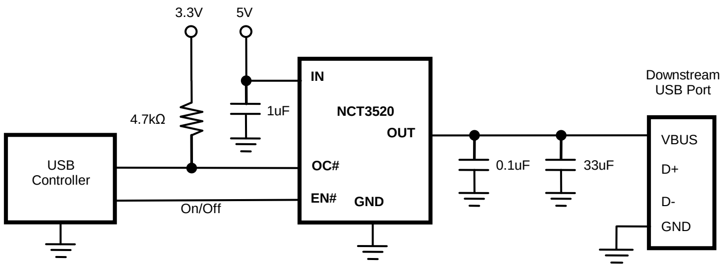


Figure 2 Self-Powered Hub

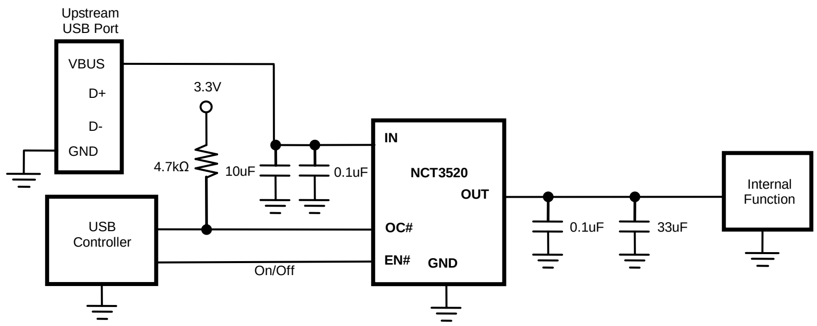


Figure 3 Bus-Powered Function

5. PIN DESCRIPTION

SYMBOL	I/O	FUNCTION
EN/EN#	I	Enable input, turns on/off power switch. EN is active high, EN# is active low.
GND		Ground
IN	I	Input voltage pin for control logic circuit and drain terminal of power MOSFET.
OC#	OD	Active low open drain output, asserted during any fault event, over current, over temperature, or reverse voltage. Connect a 4.7kΩ resistor is recommended.
OUT	O	Power-switch output

6. FUNCTIONAL DESCRIPTION

Power Switch

The power switch is a high-side N-channel MOSFET with low on-state resistance. The power switch prevents current flow from IN to OUT and OUT to IN when disabled. The power switch supplies a minimum current of 1A/1.5A/2A.

Charge Pump

An internal charge pump supplies power to the driver circuit and provides the necessary voltage to pull the gate of the MOSFET above the source. The charge pump operates from input voltage as low as 4.5V and requires small operating current.

Driver

The driver controls the gate voltage of the power switch. To limit large current surges, the driver incorporates circuitry that controls rise time and fall time of the output voltage.

Enable Input

The enable input, EN or EN#, can NOT be left floating that may lead to an unknown operation of ON/OFF of the internal power switch. This input is usually connected to a TTL/CMOS level output of a controller. If it is desired to switch the internal power switch always on, you can always present the EN a high logic or the EN# a low logic.

OC# Response

The device provides an open-drain output (OC#) to indicate when any of the following conditions occur:

- Over-current fault persists beyond the 8 ms deglitch timeout.
- The chip temperature exceeds the thermal shut down temperature limit of 150°C.
- Reverse voltage persists beyond the 4 ms deglitch timeout.

The device features deglitch timeout to blank OC# assertion when an over-current condition (8 ms) or reverse voltage condition (4 ms) occurs. Once the deglitch time has elapsed this output remains asserted (active low) until the over-current condition or reverse voltage condition is removed. Blanking allows momentary over-current to be ignored, for example, current surges caused by hot-plugging into a capacitive load or when the device is powering up, thus prevent fault alarm from being relayed to the host system. The internal over-current deglitch eliminates the need for external components to remove unwanted pulses. OC# is not deglitched when the switch is turned off due to an over-temperature shutdown.

Current Limiting and short-circuit Protection

The current limit circuitry prevents damage to the power switch and the hub downstream port but can deliver load current through power switch up to the current limit threshold. The minimum current limit threshold is 1.5A for -X10, 2.0A for -X12 and 2.5A for -X15. When a heavy load or short circuit is applied to an enabled switch, a large transient current any flow until the current limit circuitry responses. Once this current limit threshold is exceeded the device enters constant current mode until the thermal shutdown occurs or the fault is removed.

Thermal Shut Down

The device implements a Thermal Sense to monitor the chip temperature. When the chip temperature exceeds 150°C for any reasons, the Thermal Shutdown function turns off the power switch and signals an error flag via OC# pin. A Hysteresis of 50°C prevents the switch turning back on until the temperature drops below 100°C.

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.

Reverse Voltage Protection

The reverse voltage protection turns off the N-channel MOSFET whenever the output voltage exceeds the input voltage by 100 mV (typ) for 4 ms (typ). It prevents damage to devices on the input side of the NCT3520W by preventing significant current from sinking into the input capacitance. The N-channel MOSFET is allowed to turn-on once the output voltage goes below the input voltage for the 4 ms deglitch time. The reverse-voltage comparator also asserts the OC# (active-low) after 4 ms. The comparator will active to disable N-channel power MOSFET when OUT-IN > 100 mV for delay 4ms.

Supply Filtering/ Bypass Capacitor

Place a 1uF bypass capacitor between IN to GND, close to the device, is recommended to reduce power-supply transients that may cause ringing on the input. Furthermore, without the bypass capacitor, an output short may cause the input ringing (due to the inductance from power supply to IN) to destroy the internal control circuitry. Additionally, bypassing the output with a 0.01~0.1uF capacitor improves the immunity of the device to short-circuit transients.

Output Filter Capacitor

A low ESR 150uF AL electrolytic or tantalum capacitor between OUT and GND is strongly recommended to meet 330mV maximum droop requirement in the hub V_{BUS} (Per USB2.0, output ports must have a minimum 120uF of low ESR bulk capacitance per hub). Standard bypass methods should be used to minimize inductance and resistance between downstream connector to reduce EMI and decouple voltage droop caused when downstream cables are hot insertion transients. Ferrite beads in series with V_{BUS}, the ground line and the 0.1uF bypass capacitors at the power connector pins are recommended for EMI and ESD protection. The bypass capacitor itself should have a low dissipation factor to allow decoupling at higher frequency.

Power Dissipation and Junction Temperature

The low on-resistance on the N-channel MOSFET allows the small surface mount devices to pass large currents. The thermal resistances of the packages are highly compared to those of power packages. Power dissipation can be calculated based on the output current and the on-resistance of switch as below:

$P_D = R_{DS(ON)} \times I_{OUT}^2$

Although the devices are rated of output current but the application may limit the amount of output current based on the total power dissipation and the ambient temperature. The final operating junction temperature for any set of conditions can be estimated by the following thermal equation:

$P_{D(max)} = (T_{J(max)} – T_A) \div \theta_{JA}$

Where $T_{J(max)}$ is the maximum operating junction temperature 125°C, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance. The junction to ambient thermal resistance is layout dependent.

For MSOP8 package, the thermal resistance is 160°C/W. The maximum power dissipation at T_A =25°C can be calculated by following formula:

$P_{D(max)} = (125°C – 25°C) \div 160°C/W = 0.625W$

Universal Serial Bus (USB) & Power Distribution

The USB interface is a high speed and multiplexed serial bus designed for low to medium bandwidth PC peripherals. The four-wire USB interface is conceived for hot plug-unplug of peripherals. Two lines are provided for differential data and the other two lines are provided for 5V power distribution.

USB data is a 3.3V level signal, but power is distributed at 5V to allow for voltage drops in cases where power is distributed through more than one hub across long cables. Each function must provide its own regulated 3.3V from the 5V input or its own internal power supply.

The USB specification defines the following five classes of devices, each differentiated by power consumption requirements:

- Hosts/self-powered bus
- Bus-powered hubs
- Low power, bus powered functions
- High power, bus powered functions
- Self-powered functions

Layout Consideration

The PCB layout should be carefully handled to maximize thermal dissipation and to minimize voltage drop, droop and EMI. The following guidelines have to be considered:

- Place the input capacitor(s) near the IN pin as close as possible.
- Output decoupling capacitor(s) have to be placed near the load as close as possible for decoupling high frequency ripple.
- Keep IN and OUT traces wide and short.
- The GND should be connected to a strong ground plane for heat sink.

7. ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings (Note1)

ITEM	SYMBOL	RATING	UNITS
Input Voltage	$V_{I(IN)}$	-0.3 to 6	V
Input Voltage	$V_{I(EN)}$, $V_{I(EN\#)}$	-0.3 to 6	V
Output Voltage	$V_{O(OUT)}$	-0.3 to 6	V
OC# Pull up Voltage	$V_{OC\#}$	-0.3 to 6	V
Continuous output current, $I_{O(OUT)}$		Internal Limited	A
Electrostatic discharge protection (Note2)	Human Body Mode	±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_D @ T_A=25°C	MSOP8	0.625	W
Package Thermal Resistance, Junction to Ambient, θ_{JA}	MSOP8	160	°C/W

Recommended Operating Conditions

ITEM	SYMBOL	MIN	MAX	UNITS
Input Voltage	IN	4.5	5.5	V
	EN/EN#	0	5.5	
Continuous Current	15	0	2	A
	12	0	1.5	A
	10	0	1	A
OC# Pull-up Voltage	$V_{OC\#}$	2.5	5.5	V
OC# Pull-up Resistance	R_{PULLUP}	1	10	kΩ
Capacitance of VIN Decoupling Capacitor	C_{IN}	1	47	uF
Capacitance of VOUT Regulation Capacitor, MLCC	C_{OUT}	1	330	uF
Ambient Temperature Range	T_{OPT}	-40	85	°C
Junction Temperature Range (Note3)	T_J	-40	125	°C

Note3. At elevated temperatures, devices must be de-rated based on thermal resistance.

DC Characteristics

Typicals and limits appearing in normal type apply for Tj = 25°C. Limits appearing in **Boldface** type apply over the entire junction temperature range for operation, -40°C to 85°C (Note4). VIN=5V, C_{OUT}=10uF, all voltage outputs unloaded (unless otherwise noted).

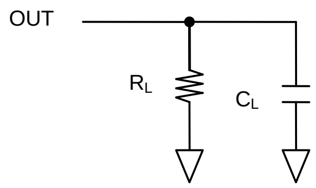
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
Power Switch						
-X10 $R_{DS(on)}$	Static drain-source on-state resistance, 5V operation	$V_{I(IN)}$ = 5V, I_{OUT} = 1 A, T_A = 25°C		70	85	mΩ
		$V_{I(IN)}$ = 5V, I_{OUT} = 1 A, T_A = -40°C to 85°C			**105**	
-X12 $R_{DS(on)}$	Static drain-source on-state resistance, 5V operation	$V_{I(IN)}$ = 5V, I_{OUT} = 1.5 A, T_A = 25°C		70	85	mΩ
		$V_{I(IN)}$ = 5V, I_{OUT} = 1.5 A, T_A = -40°C to 85°C			**105**	
-X15 $R_{DS(on)}$	Static drain-source on-state resistance, 5V operation	$V_{I(IN)}$ = 5V, T_A = 25°C , I_{OUT} = 2 A		70	85	mΩ
		$V_{I(IN)}$ = 5V, I_{OUT} = 2 A, T_A = -40°C to 85°C			**105**	
t_r	Rise time	$V_{I(IN)}$ = 5V, C_L = 1uF , R_L = 5 Ω, T_A = 25 °C		1.5		ms
t_f	Fall time	$V_{I(IN)}$ = 5V,C_L = 1uF , R_L = 5 Ω, T_A =25 °C		10		us
Enable Input EN# or EN						
V_{IH}	High-level input voltage	4.5 V ≤ $V_{I(IN)}$ ≤ 5.5 V	2			V
V_{IL}	Low-level input voltage	4.5 V ≤ $V_{I(IN)}$ ≤ 5.5 V			0.8	V
I_I	Input current	$V_{I(EN\#)}$ = 0 V or $V_{I(EN\#)}$ = $V_{I(IN)}$	-0.5		0 5	uA
T_{on}	Turn-on time	C_L = 100 uF , R_L = 5 Ω		1.5	3	ms
T_{off}	Turn-off time	C_L = 100 uF , R_L = 5 Ω		1	5	
Current Limit						
-X10, I_{OS}	Short-circuit output current	$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = 25 °C	1.0	1.5	2.0	A
		$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = -40 °C to 85 °C	**1.0**		**2.1**	
-X12, I_{OS}	Short-circuit output current	$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = 25°C	1.0	1.5	2.0	A
		$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = -40 °C to 85 °C	**1.0**		**2.1**	
-X15, I_{OS}	Short-circuit output current	$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = 25 °C	1.0	1.5	2.0	A
		$V_{I(IN)}$ = 5 V, OUT connected to GND, Device enabled into short circuit, T_A = -40 ℃ to 85 °C	**1.0**		**2.1**	
-X10,	Over-current Trip	$V_{I(IN)}$ = 5 V, Current Ramp (≤ 100 A/s) on OUT	1.5	2.0	2.5	A

I_{OC_TRIP}	Threshold						
-X12, I_{OC_TRIP}	Over-current Trip Threshold	$V_{I(IN)}$ = 5 V, Current Ramp (≤ 100 A/s) on OUT		2.0	2.3	3.0	A
-X15, I_{OC_TRIP}	Over-current Trip Threshold	$V_{I(IN)}$ = 5 V, Current Ramp (≤ 100 A/s) on OUT		2.5	2.9	3.5	A
t_{IOS}	Response time to short circuit	T_A = 25°C			30		uS
Supply Current							
Supply current, low-level output		No Load on OUT, EN# = $V_{I(IN)}$ or EN=0 V	T_A = 25 °C			1	uA
			-40°C ≤T_A ≤85°C			**5**	
Supply current, high-level output		No Load on OUT, EN# = 0 V or EN= $V_{I(IN)}$	T_A = 25°C		50	80	uA
			-40°C ≤T_A ≤85°C		**50**	**90**	
Leakage current		OUT connected to ground, EN# = 0 V or EN= $V_{I(IN)}$	-40°C ≤T_A ≤85°C		**1**		uA
Reverse leakage current		$V_{I(OUT)}$ = 5 V, IN= 0 V, I_{REV} at IN	-40°C ≤T_A ≤85°C		**0**		uA
Reverse-Voltage Protection							
Reverse voltage comparator trip point		OUT-IN		65	100	135	mV
Time from reverse voltage condition to MOSFET turn off		$V_{I(IN)}$ = 5 V		2	4	8	ms
Under-Voltage Lockout							
Low-level input voltage				2		2.6	V
Hysteresis		T_A = 25°C			100		mV
Over-Current							
Output low voltage		I_{SINK} = 5mA, $V_{I(IN)}$ = 5 V				0.5	V
Off-state current		$V_{I(IN)}$ = $V_{(OC\#)}$ = 5 V				1	uA
OC blanking timeout		From over-current condition to OC# assertion		4	8	15	ms
Shutdown Discharge Resistance							
Discharge resistance		$V_{I(IN)}$=5V, EN=0V, $I_{\_Discharge}$=1mA			15	**50**	Ω
Thermal Shutdown							
Thermal shutdown threshold					150		˚C
Hysteresis					50		˚C

Note4. Pulse testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.

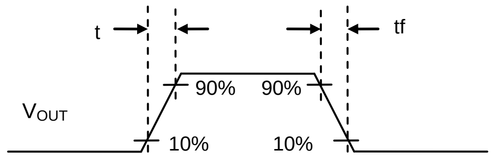
Note5. Limits are 100% production tested at 25˚C. Limits over operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate average outgoing quality level.

- **PARAMETER MEASURE INFORMATION**

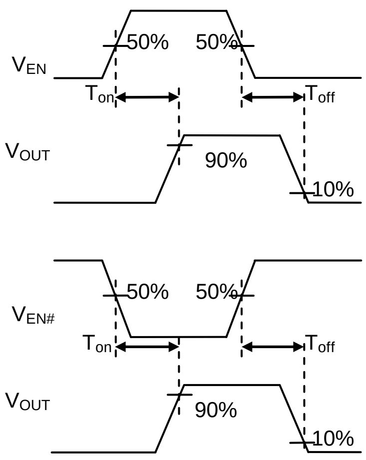


Test Circuit

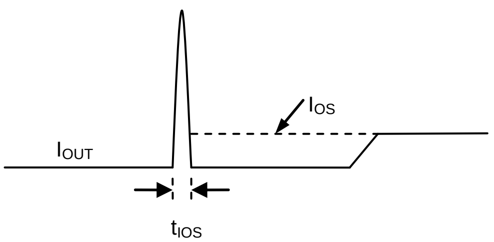
- **TIMING DIAGRAM**



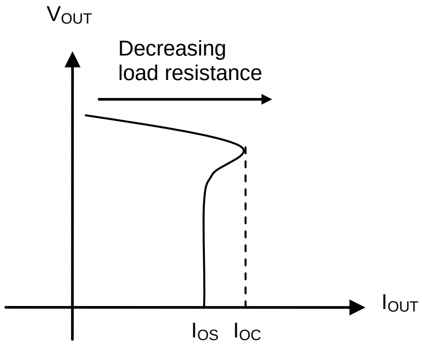
Output Rise and Fall time



Turn-on Time and Turn-off Time



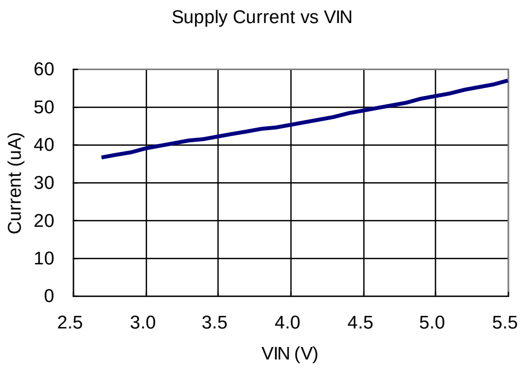
Response time to shirt circuit waveform

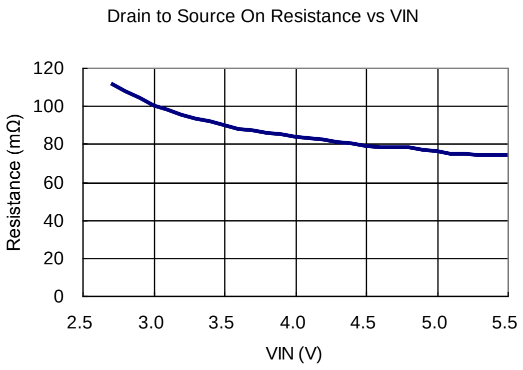


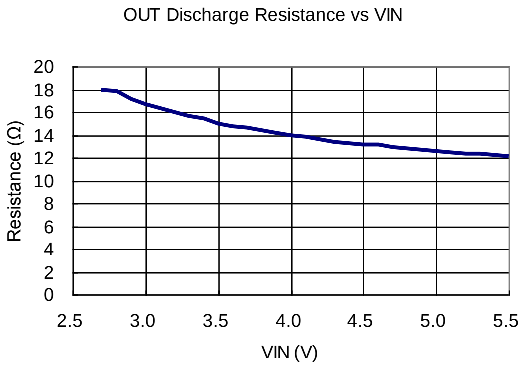
VOUT vs. Current limit threshold

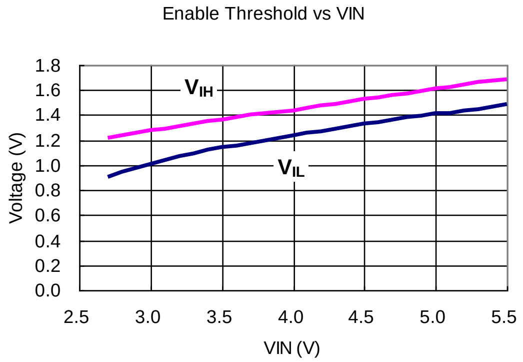
8. TYPICAL OPERATING CHARACTERISTICS AND WAVEFORMS

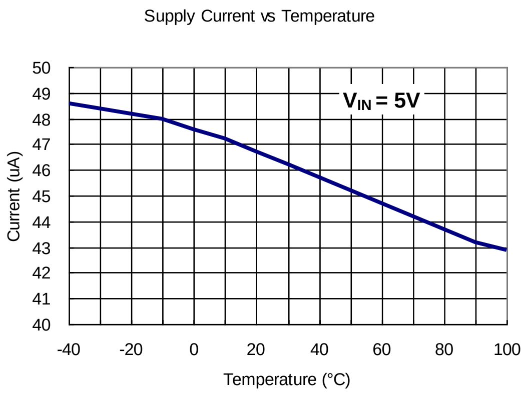
Operating Characteristics

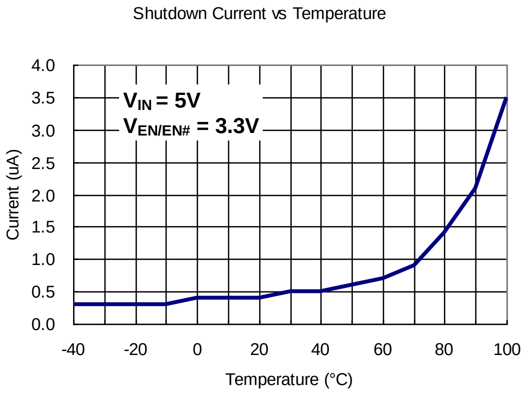




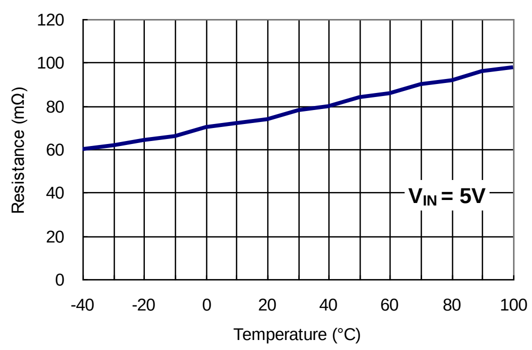




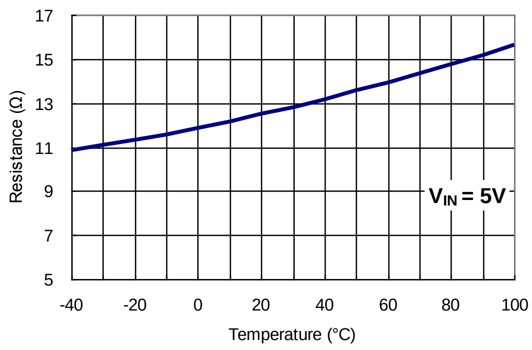




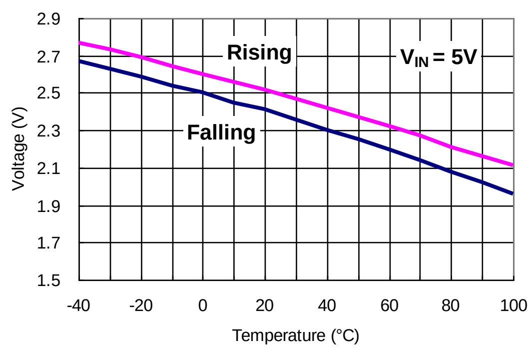
Drain to Source On Resistance vs Temperature



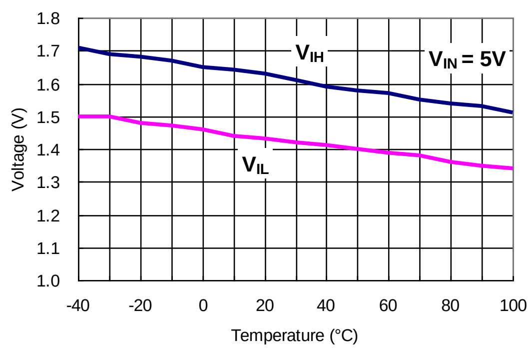
OUT Discharge Resistance vs Temperature

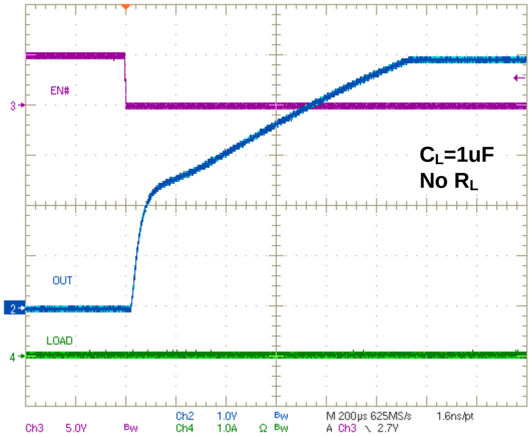


UVLO Threshold vs Temperature

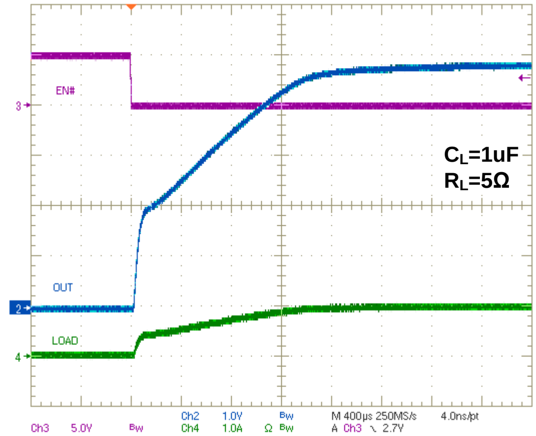


Enable Threshold vs Temperature

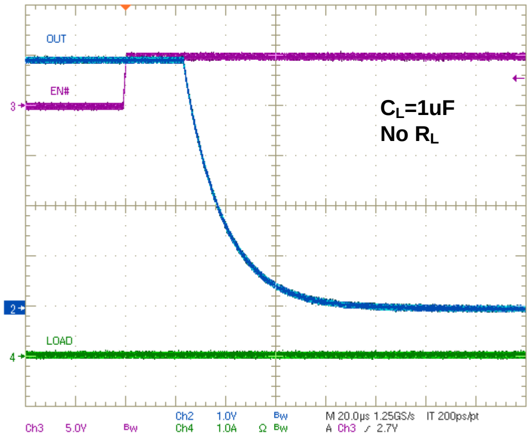




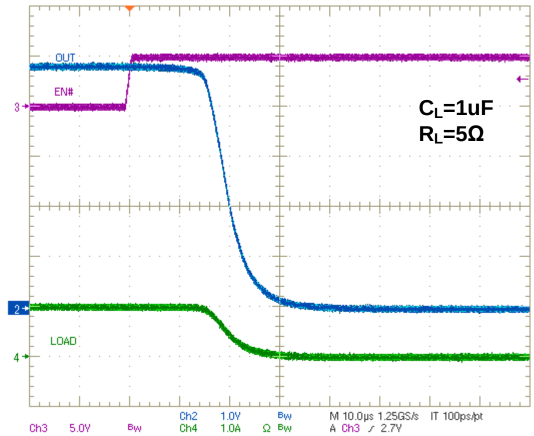
Turn on Delay and Rise Time with 1uF, No Load



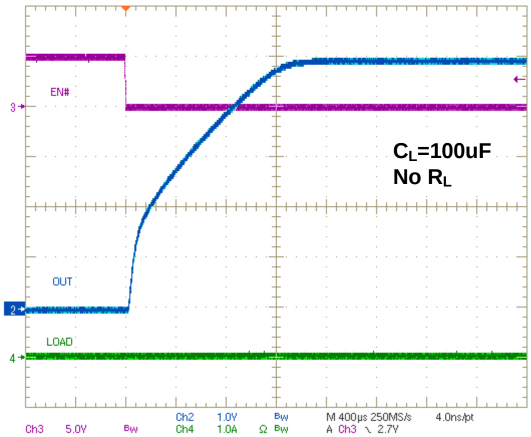
Turn on Delay and Rise Time with 1uF Load



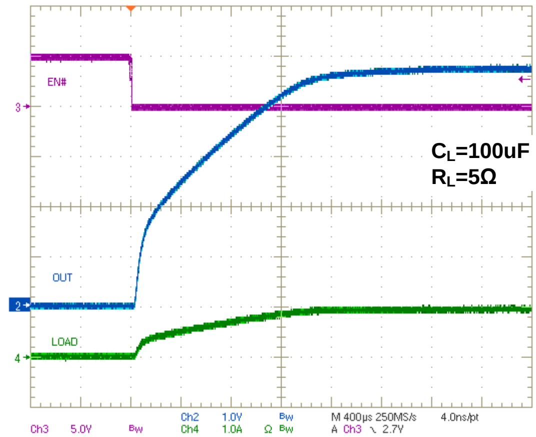
Turn ff Delay and Fall Time with 1uF, No Load



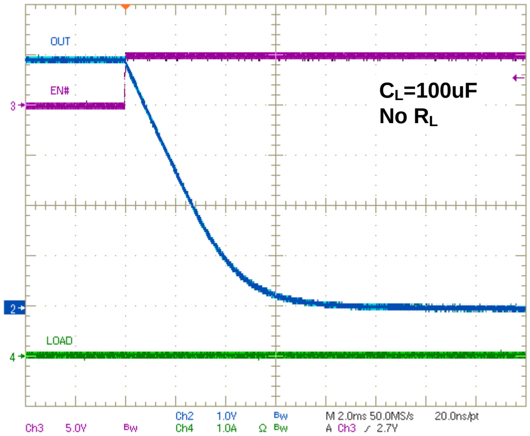
Turn 0ff Delay and Fall Time with 1uF Load



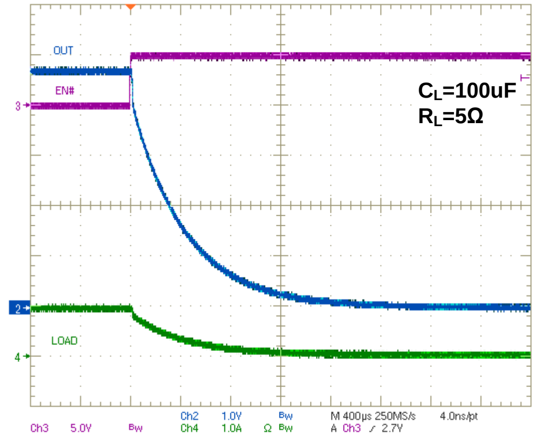
Turn on Delay and Rise Time with 100uF, No Load



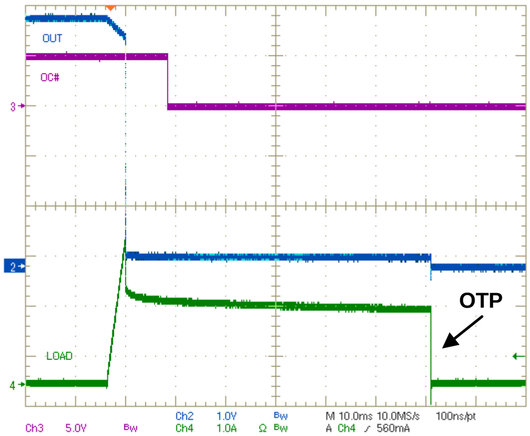
Turn on Delay and Rise Time with 100uF Load



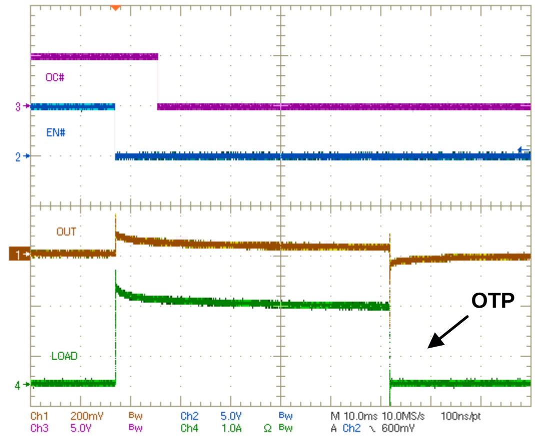
Turn ff Delay and Fall Time with 100uF, No Load



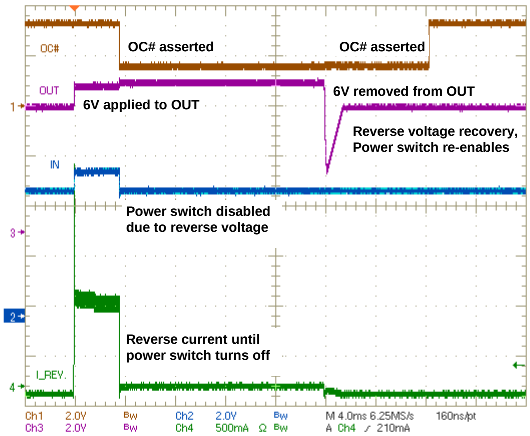
Turn 0ff Delay and Fall Time with 100uF Load



0.83 Ω Load Connect to Enabled Device induce OTP

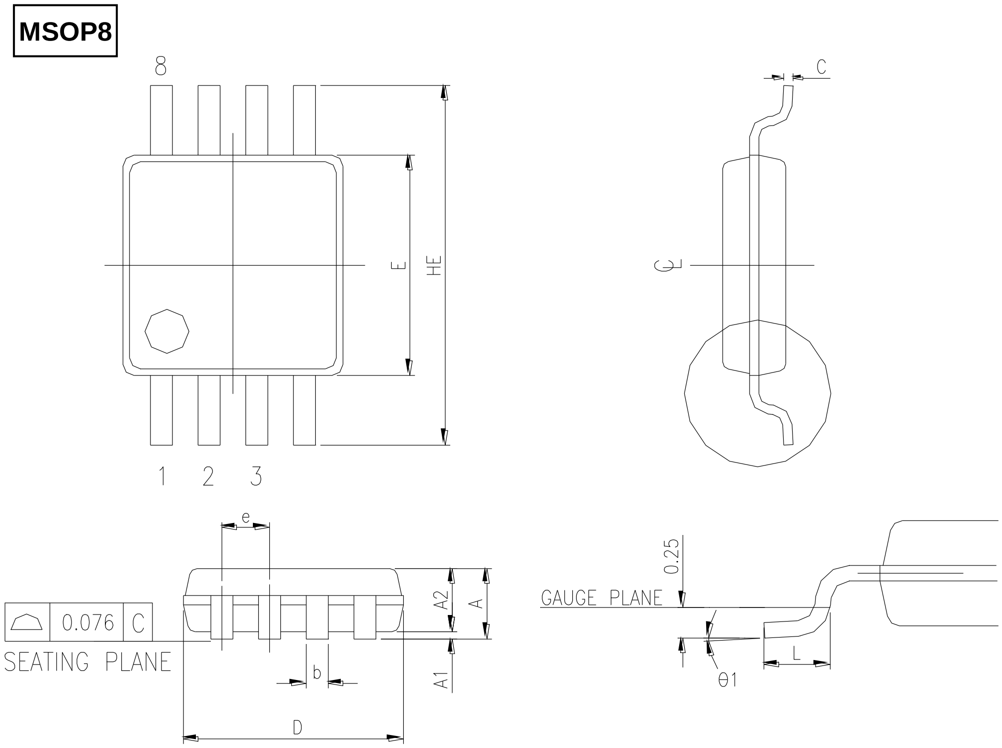


Short Circuit Current, Device Enabled into Short induced OTP



Reverse Voltage Protection Response and Recovery

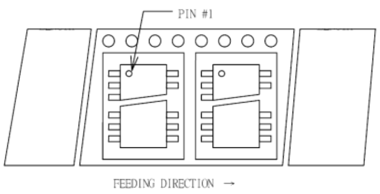
9. PACKAGE DIMENSION



CONTROLLING DIMENSION : MILLIMETERS

SYMBOL	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	---	---	1.10	---	---	0.043
A1	0.05	---	0.15	0.002	---	0.006
A2	0.81	0.86	0.91	0.032	0.034	0.036
c	0.13	---	0.23	0.005	---	0.009
b	0.25	---	0.40	0.0098	---	0.0157
D	2.90	3.00	3.10	0.114	0.118	0.122
E	2.90	3.00	3.10	0.114	0.118	0.122
HE	4.90 BSC			0.193 BSC		
L	0.445	0.55	0.648	0.0175	0.0217	0.0255
θ1	0°		6°	0°		6°
e	0.65 BSC			0.026 BSC		

➢ TAPING SPECIFICATION



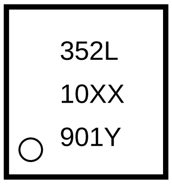
8 Pin MSOP Package

10. ORDERING INFORMATION

PART NUMBER	EN	MIN. OC TRIP THRESHOLD	SUPPLIED AS	PACKAGE TYPE	OPERATING TEMPERATURE, T_A
NCT3520W-H15	H	2.5A	T Shape: 4,000 units/T&R	8 PIN MSOP (Green package)	Commercial, -40°C to 85°C
NCT3520W-L15	L	2.5A			
NCT3520W-H12	H	2.0A			
NCT3520W-L12	L	2.0A			
NCT3520W-H10	H	1.5A			
NCT3520W-L10	L	1.5A			

11. TOP MARKING SPECIFICATION

NCT3520W-XXX (MSOP-8)



1st Line: **352** (NCT3520W), **L means "Active Low"; H means "Active High".**

2nd Line: **Current Limit Threshold (See ordering information)**

XX: Internal use only

3rd Line: **Tracking Code**

901: packages assembled in Year 09', week 01

Y: Internal use only

12. REVISION HISTORY

VERSION	DATE	PAGE	DESCRIPTION
A0	05/30/2008	All	New Create
A1	03/30/2009	17,18 &19	Add Measurement Figure
A2	Aug./2010	All	Omit SOP8 Package Type (NCT3520S) and Re-makeup
A3	Sep./2010	1,7 & 8	Modify some typos
A4	Mar./2011	8-9, 11-14	Modify DC Characteristics, Typical Operating Characteristics and Waveforms and correct typos
A5	Oct./2011	1, 3, 4, 7, 8, 16 & 19	Correct typo, modify operating range & Important Notice
A6	Dec./2011	1	Add UL number.
A7	2012.3.28	1	Add CB certified

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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.