

NCP1597, NCP1597A

Product Preview

1 MHz, 2.0 A Synchronous Buck Regulator

The NCP1597/A family is fixed 1 MHz frequency, high-output-current, synchronous PWM converters that integrate low-resistance, high-side P-channel MOSFET and low-side N-channel MOSFET. The NCP1597/A utilizes current mode control to provide fast transient response and excellent loop stability. It regulates input voltages from 2.7 V to 6.0 V down to an output voltage as low as 0.8 V and is able to supply up to 2.0 A.

The NCP1597/A has features including fixed internally switching frequency (F_{sw}), and an internal soft-start to limit inrush currents. Using the EN pin, shutdown supply current is reduced to 1 μ A maximum.

Other features include cycle-by-cycle current limiting; short-circuit protection, low dropout mode, power saving mode and thermal shutdown.

Features

- Input Voltage Range: from 4.0 V to 5.5 V
- Internal 200 m Ω High-Side Switching P-Channel MOSFET and 135 m Ω Low-Side N-Channel MOSFET
- Fixed 1 MHz Switching Frequency
- Cycle-by-Cycle Current Limiting
- Hiccup Mode Short-Circuit Protection
- Overtemperature Protection
- Internal Soft-Start
- Adjustable Output Voltage Down to 0.8 V
- Power Saving Mode During Light Load
- Low Dropout Mode Operation to Extend the Battery Life
- These are Pb-Free Devices

Applications

- DSP Power
- Hard Disk Drivers
- Computer Peripherals
- Home Audio
- Set-Top Boxes
- Networking Equipment
- LCD TV
- Wireless and DSL/Cable Modem
- USB Power Devices



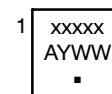
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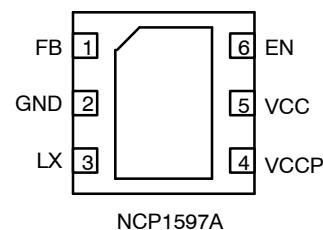
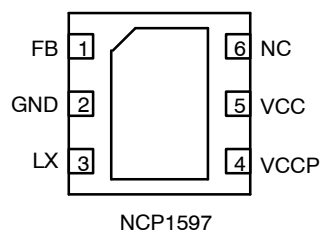
1
DFN6
CASE 506AH

MARKING DIAGRAM



xxxxx = 1597, 1597A
A = Assembly Location
Y = Year
WW = Work Week
▪ = Pb-Free Package

PIN CONNECTIONS



ORDERING INFORMATION

Device	Package	Shipping†
NCP1597MNRG	DFN6 (Pb-Free)	3000 / Tape & Reel
NCP1597AMNR2G	DFN6 (Pb-Free)	3000 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

This document contains information on a product under development. ON Semiconductor reserves the right to change or discontinue this product without notice.

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BLOCK DIAGRAM

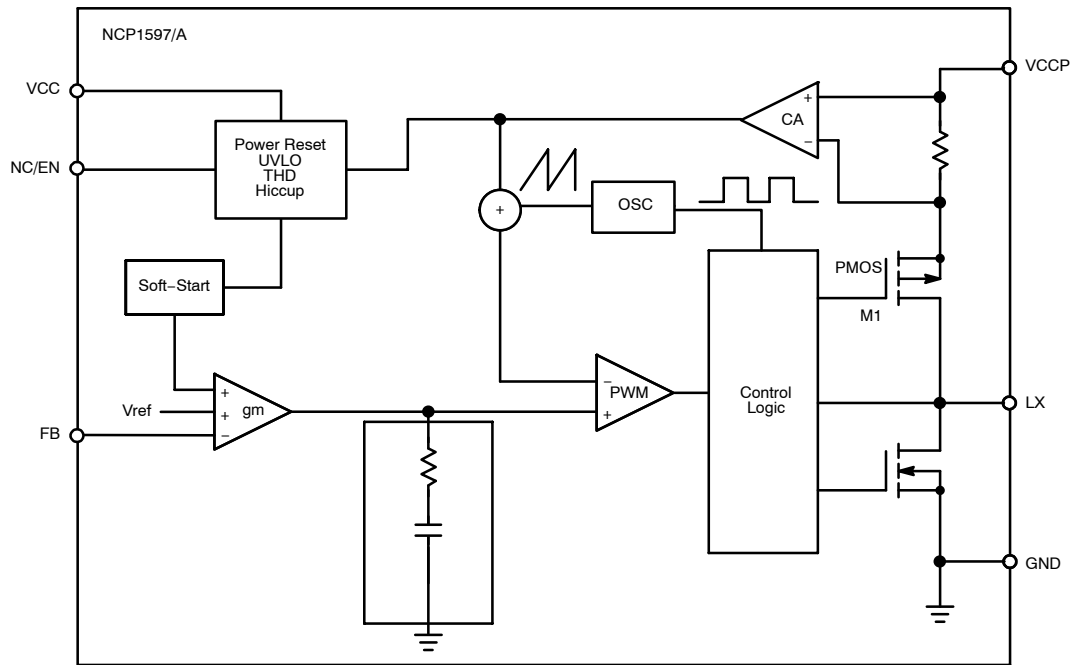


Figure 1. Block Diagram

PIN DESCRIPTIONS

Pin No	Symbol	Description
1	FB	Feedback input pin of the Error Amplifier. Connect a resistor divider from the converter's output voltage to this pin to set the converter's output voltage.
2	GND	Ground pin. Connect to thermal pad.
3	LX	The drains of the internal MOSFETs. The output inductor should be connected to this pin.
4	V _{CCP}	Power input for the power stage
5	V _{CC}	Input supply pin for internal bias circuitry. A 0.1 μ F ceramic bypass capacitor is preferred to connect to this pin.
6	NC	No connection for NCP1597
	EN	Logic input to enable the part. Logic high to turn on the part and logic low to shut off the part. For NCP1597A only
EP	PAD	Exposed pad of the package provides both electrical contact to the ground and good thermal contact to the PCB. This pad must be soldered to the PCB for proper operation.

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APPLICATION CIRCUIT

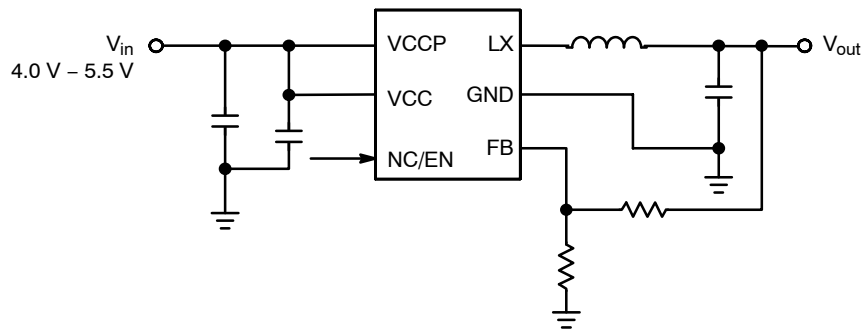


Figure 2. NCP1597/A

ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Pin (Pin 4, 5) to GND	V_{in}	-0.3 V (DC) to 7.0 V -1.0 V For $T < 100$ ns	
LX to GND		-0.6 V to $V_{in} + 0.3$ V, -1.0 V For $T < 100$ ns	
All other pins		-0.3 V to 6.5 V, -1.0 V For $T < 100$ ns	
Operating Temperature Range	T_A	-40 to +85	°C
Junction Temperature	T_J	-40 to +150	°C
Storage Temperature Range	T_S	-55 to +150	°C
Pkg Power Dissipation ($T_A = +25^\circ\text{C}$)	P_D	68.5	°C/W

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

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ELECTRICAL CHARACTERISTICS

($V_{in} = 4.0\text{ V} - 5.5\text{ V}$, $V_{out} = 1.2\text{ V}$, $T_A = +25^\circ\text{C}$ for typical value; $-40^\circ\text{C} < T_A < 85^\circ\text{C}$ for min/max values unless noted otherwise)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
V_{in} Input Voltage Range	V_{in}		4.0		5.5	V
V_{CC} UVLO Threshold			3.5	3.7	3.9	V
UVLO Hysteresis				200		mV
V_{CC} Quiescent Current	I_{inVCC}	$V_{in} = 5.0\text{ V}$, $V_{FB} = 1.5\text{ V}$, (No Switching)		0.9	1.0	mA
V_{CCP} Quiescent Current	I_{inVCCP}	$V_{in} = 5.0\text{ V}$, $V_{FB} = 1.5\text{ V}$, (No Switching)			10	μA
V_{in} Shutdown Supply Current	I_{QSHDN}	$EN = 0\text{ V}$			1.0	μA

FEEDBACK VOLTAGE

Reference Voltage	V_{ref}	$V_{FB} = COMP$	0.788	0.800	0.812	V
Feedback Input Bias Current	I_{FB}	$V_{FB} = 0.8\text{ V}$		10	100	nA
Feedback Voltage Line Regulation		$V_{FB} = V_{comp}$, $V_{in} = 2.7\text{ V to }6.0\text{ V}$			0.03	%/V

GM AMPLIFIER

Gm Amp Open Loop Voltage Gain (Note 1)	AV_{gm}		55			dB
Gm Amp Transconductance	gm_{COMP}	$V_{FB} > 0.75\text{ V}$, $\Delta I_{COMP} = \pm 10\ \mu\text{A}$	190	200	210	$\mu\text{A/V}$

PWM

Maximum Duty Cycle					100	%
Minimum Controllable ON Time					50	ns

CURRENT SENSE AMPLIFIER

Current Sense to COMP Transconductance	gm_{POWER}			0.88		A/V
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PULSE-BY-PULSE CURRENT LIMIT

Pulse-by-Pulse Current Limit	I_{LIM}		2.6	3.0	3.4	A
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OSCILLATOR

Oscillator Frequency	F_{SW}		0.87	1.0	1.13	MHz
Oscillator Frequency Accuracy					± 13	%

MOSFET

High Side MOSFET ON Resistance	$R_{DS(on)HS}$	$I_{DS} = 100\text{ mA}$, $V_{GS} = 5\text{ V}$		200		m Ω
		$I_{DS} = 100\text{ mA}$, $V_{GS} = 3.3\text{ V}$		250		
High Side MOSFET Leakage (Note 1)		$V_{EN} = 0\text{ V}$, $V_{SW} = 0\text{ V}$			10	μA
Low Side MOSFET ON Resistance	$R_{DS(on)LS}$	$I_{DS} = 100\text{ mA}$, $V_{GS} = 5\text{ V}$		135		m Ω
		$I_{DS} = 100\text{ mA}$, $V_{GS} = 3.3\text{ V}$		150		
Low Side MOSFET Leakage (Note 1)		$V_{EN} = 0\text{ V}$, $V_{SW} = 5\text{ V}$			10	μA

ENABLE

EN HI Threshold	ENHI		1.4			V
EN LO Threshold	ENLO				0.4	V
EN Hysteresis				300		mV
EN Input Voltage					5.5	V
EN Pull-Down Resistor				100		k Ω

SOFT-START

Soft-Start Ramp Time	t_{SS}	$F_{SW} = 1\text{ MHz}$	0.8	1.0	1.2	ms
Hiccup Timer			1.6	2.0	2.4	ms

THERMAL SHUTDOWN

Thermal Shutdown Threshold				160		$^\circ\text{C}$
Thermal Shutdown Hysteresis				40		$^\circ\text{C}$

1. Guaranteed by design.

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DETAILED DESCRIPTION

Overview

The NCP1597/A is a synchronous PWM controller that incorporates all the control and protection circuitry necessary to satisfy a wide range of applications. The NCP1597/A employs current mode control to provide fast transient response, simple compensation, and excellent stability. The features of the NCP1597/A include a precision reference, fixed 1 MHz switching frequency, a transconductance error amplifier, an integrated high-side P-channel MOSFET and low-side N-channel MOSFET, internal soft-start, and very low shutdown current. The protection features of the NCP1597/A include internal soft-start, pulse-by-pulse current limit, hiccup mode short-circuit protection, and thermal shutdown.

Reference Voltage

The NCP1597/A incorporates an internal reference that allows output voltages as low as 0.8 V. The tolerance of the internal reference is guaranteed over the entire operating temperature range of the controller. The reference voltage is trimmed using a test configuration that accounts for error amplifier offset and bias currents.

Oscillator Frequency

A fixed precision oscillator is provided. The oscillator frequency range is 1 MHz with $\pm 13\%$ variation.

Transconductance Error Amplifier

The transconductance error amplifier's primary function is to regulate the converter's output voltage using a resistor divider connected from the converter's output to the FB pin of the controller, as shown in the applications Schematic. A series RC compensation network must be connected from the error amplifier's output (COMP pin) to GND to stabilize the converter. In some applications, a lower value capacitor may be connected from the COMP pin to GND to reduce the loop gain at higher frequencies. However, if this capacitor is too large the phase margin of the converter will be reduced. If a Fault occurs, the COMP pin is immediately pulled to GND and PWM switching is inhibited.

Internal Soft-Start

To limit the startup inrush current, an internal soft start circuit is used to ramp up the reference voltage from 0 V to its final value linearly. The internal soft start time is 1 ms typically.

Output MOSFETs

The NCP1597/A includes low $R_{DS(on)}$, both high-side P-channel and low-side N-channel MOSFETs capable of delivering up to 2.0 A of current. When the controller is disabled or during a Fault condition, the controller's output stage is tri-stated by turning OFF both the upper and lower MOSFETs.

Adaptive Dead Time Gate Driver

In a synchronous buck converter, a certain dead time is required between the low side drive signal and high side drive signal to avoid shoot through. During the dead time, the body diode of the low side FET freewheels the current. The body diode has much higher voltage drop than that of the MOSFET, which reduces the efficiency significantly. The longer the body diode conducts, the lower the efficiency. In NCP1597/A, the drivers and MOSFETs are integrated in a single chip. The parasitic inductance is minimized. Adaptive dead time control method is used in NCP1597/A to prevent the shoot through from happening and minimizing the diode conduction loss at the same time.

Pulse Width Modulation

A high-speed PWM comparator, capable of pulse widths as low as 50 ns, is included in the NCP1597/A. The inverting input of the comparator is connected to the output of the error amplifier. The non-inverting input is connected to the current sense signal. At the beginning of each PWM cycle, the CLK signal sets the PWM flip-flop and the upper MOSFET is turned ON. When the current sense signal rises above the error amplifier's voltage then the comparator will reset the PWM flip-flop and the upper MOSFET will be turned OFF.

When input and output voltage gets close to each other, the high side FET will be ON all the time (100% duty cycle) and the part operates in a low dropout mode.

Low Dropout Mode operation

When the input voltage and output voltage come close to each other, the NCP1597/A enters into LDO (low dropout) mode. The high side FET is turned on 100% for one or more cycles. With further decreasing of input voltage, the high side FET will be on completely. In this case, the converter offers a low voltage difference. This is particularly useful in battery-powered applications to achieve longest operation time by taking full advantage of the whole battery voltage range.

Power Save Mode

If the load current decreases, the converter will enter power save mode operation automatically. During power save mode, the converter skips switching and operates with reduced frequency, which minimizes the quiescent current and maintain high efficiency.

Current Sense Amplifier

A high-bandwidth current sense amplifier monitors the current in the upper MOSFET. The current signal is required by the PWM comparator, the pulse-by-pulse current limiter, and the hiccup mode/over current counter.

PROTECTIONS

Undervoltage Lockout (UVLO)

The under voltage lockout feature prevents the controller from switching when the input voltage is too low to power the internal power supplies and reference. Hysteresis must be incorporated in the UVLO comparator to prevent IxR drops in the wiring or PCB traces from causing ON/OFF cycling of the controller during heavy loading at power up or power down.

Overcurrent Protection (OCP)

NCP1597/A detects high side switch current and then compares to a voltage level representing the overcurrent threshold limit. If the current through high side FET exceeds the overcurrent threshold limit, overcurrent protection is triggered. The system ignores the overcurrent signal for the leading edge blanking time at the beginning of each cycle to avoid any turn-on noise glitches.

Then the high side MOSFET is turned-off for the rest of cycle after a propagation delay. This cycle-by-cycle current limit circuit limits peak current to 3.0 A during overload and short circuit conditions.

An extra short circuit protection circuit provides robust protection even during soft start period. A short circuit counter accumulates 7 consecutive current limit signal then triggers the hiccup mode. During hiccup mode, both FETs

are turned off and soft-start capacitor and COMP Pin is discharged. The hiccup time is 2 ms typical. After the hiccup timer is up, the short circuit timer is reset. After reset, normal soft start is attempted. This scheme reduces input supply current and power dissipation during short circuit. It also allows for much improved system up-time, allowing auto-restart upon removal of a temporary short-circuit.

Pre-Bias Startup

In some applications the controller will be required to start switching when it's output capacitors are charged anywhere from slightly above 0 V to just below the regulation voltage. This situation occurs for a number of reasons: the converter's output capacitors may have residual charge on them or the converter's output may be held up by a low current standby power supply. NCP1597/A supports pre-bias start up by holding Low side FETs off till soft start ramp reaches the FB Pin voltage.

Thermal Shutdown

The NCP1597/A protects itself from over heating with an internal thermal monitoring circuit. If the junction temperature exceeds the thermal shutdown threshold the voltage at the COMP pin will be pulled to GND and both the upper and lower MOSFETs will be shut OFF.

APPLICATION INFORMATION

Programming the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin (see Figure 3). So the output voltage is calculated according to Eq.1.

$$V_{out} = V_{FB} \cdot \frac{R_1 + R_2}{R_2} \quad (eq. 1)$$

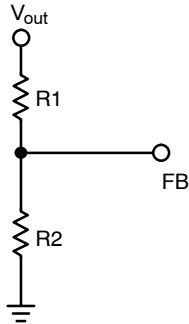


Figure 3. Output divider

Inductor Selection

The inductor is the key component in the switching regulator. The selection of inductor involves trade-offs among size, cost and efficiency. The inductor value is selected according to the equation 2.

$$L = \frac{V_{out}}{f \cdot I_{ripple}} \cdot \left(1 - \frac{V_{out}}{V_{in(max)}} \right) \quad (eq. 2)$$

Where V_{out} – the output voltage;
 f – switching frequency, 1.0 MHz;
 I_{ripple} – Ripple current, usually it's 20% – 30% of output current;
 $V_{in(max)}$ – maximum input voltage.

Choose a standard value close to the calculated value to maintain a maximum ripple current within 30% of the maximum load current. If the ripple current exceeds this 30% limit, the next larger value should be selected.

The inductor's RMS current rating must be greater than the maximum load current and its saturation current should be about 30% higher. For robust operation in fault conditions (start-up or short circuit), the saturation current should be high enough. To keep the efficiency high, the series resistance (DCR) should be less than 0.1 Ω , and the core material should be intended for high frequency applications.

Output Capacitor Selection

The output capacitor acts to smooth the dc output voltage and also provides energy storage. So the major parameter necessary to define the output capacitor is the maximum allowed output voltage ripple of the converter. This ripple is related to capacitance and the ESR. The minimum capacitance required for a certain output ripple can be calculated by Equation 4.

$$C_{OUT(min)} = \frac{I_{ripple}}{8 \cdot f \cdot V_{ripple}} \quad (eq. 3)$$

Where V_{ripple} is the allowed output voltage ripple.

The required ESR for this amount of ripple can be calculated by equation 5.

$$ESR = \frac{V_{ripple}}{I_{ripple}} \quad (eq. 4)$$

Based on Equation 2 to choose capacitor and check its ESR according to Equation 3. If ESR exceeds the value from Eq.4, multiple capacitors should be used in parallel.

Ceramic capacitor can be used in most of the applications. In addition, both surface mount tantalum and through-hole aluminum electrolytic capacitors can be used as well.

Maximum Output Capacitor

NCP1597/A family has internal 1 ms fixed soft-start and overcurrent limit. It limits the maximum allowed output capacitor to startup successfully. The maximum allowed output capacitor can be determined by the equation:

$$C_{out(max)} = \frac{I_{lim(min)} - I_{load(max)} - \frac{\Delta I_{p-p}}{2}}{V_{out}/T_{SS(min)}} \quad (eq. 5)$$

Where $T_{SS(min)}$ is the minimum soft-start period (1ms); ΔI_{pp} is the current ripple.

This is assuming that a constant load is connected. For example, with 3.3 V/2.0 A output and 20% ripple, the max allowed output capacitors is 90 μ F.

Input Capacitor Selection

The input capacitor can be calculated by Equation 6.

$$C_{in(min)} = I_{out(max)} \cdot D_{max} \cdot \frac{1}{f \cdot V_{in(ripple)}} \quad (eq. 6)$$

Where $V_{in(ripple)}$ is the required input ripple voltage.

$$D_{max} = \frac{V_{out}}{V_{in(min)}} \text{ is the maximum duty cycle.} \quad (eq. 7)$$

Power Dissipation

The NCP1597/A is available in a thermally enhanced 6-pin, DFN package that dissipates up to 1.0 W at $T_A = +70^\circ\text{C}$. When the die temperature reaches $+165^\circ\text{C}$, the NCP1597/A shuts down (see the *Thermal-Overload Protection* section). The power dissipated in the device is the sum of the power dissipated from supply current (PQ), power dissipated due to switching the internal power MOSFET (P_{SW}), and the power dissipated due to the RMS current through the internal power MOSFET (PON). The total power dissipated in the package must be limited so the junction temperature does not exceed its absolute maximum rating of $+150^\circ\text{C}$ at maximum ambient temperature.

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Calculate the power lost in the NCP1597/A using the following equations:

1. High side MOSFET

The conduction loss in the top switch is:

$$P_{\text{HSON}} = I_{\text{RMS_HSFET}}^2 \times R_{\text{DS(on)HS}} \quad (\text{eq. 8})$$

Where:

$$I_{\text{RMS_FET}} = \sqrt{\left(I_{\text{out}}^2 + \frac{\Delta I_{\text{PP}}^2}{12} \right) \times D} \quad (\text{eq. 9})$$

ΔI_{PP} is the peak-to-peak inductor current ripple.

The power lost due to switching the internal power high side MOSFET is:

$$P_{\text{HSSW}} = \frac{V_{\text{in}} \cdot I_{\text{out}} \cdot (t_{\text{r}} + t_{\text{f}}) \cdot f_{\text{SW}}}{2} \quad (\text{eq. 10})$$

t_{r} and t_{f} are the rise and fall times of the internal power MOSFET measured at SW node.

2. Low side MOSFET

The power dissipated in the top switch is:

$$P_{\text{LSON}} = I_{\text{RMS_LSFET}}^2 \cdot R_{\text{DS(on)LS}} \quad (\text{eq. 11})$$

Where:

$$I_{\text{RMS_LSFET}} = \sqrt{\left(I_{\text{out}}^2 + \frac{\Delta I_{\text{PP}}^2}{12} \right) \cdot (1 - D)} \quad (\text{eq. 12})$$

ΔI_{PP} is the peak-to-peak inductor current ripple.

The switching loss for the low side MOSFET can be ignored.

The power lost due to the quiescent current (I_{Q}) of the device is:

$$P_{\text{Q}} = V_{\text{in}} \cdot I_{\text{Q}} \quad (\text{eq. 13})$$

I_{Q} is the switching quiescent current of the NCP1597/A.

$$P_{\text{TOTAL}} = P_{\text{HSON}} + P_{\text{HSSW}} + P_{\text{LSON}} + P_{\text{Q}} \quad (\text{eq. 14})$$

Calculate the temperature rise of the die using the following equation:

$$T_{\text{J}} = T_{\text{C}} + (P_{\text{TOTAL}} \cdot \theta_{\text{JC}}) \quad (\text{eq. 15})$$

θ_{JC} is the junction-to-case thermal resistance equal to 1.7°C/W. T_{C} is the temperature of the case and T_{J} is the junction temperature, or die temperature. The case-to-ambient thermal resistance is dependent on how well heat can be transferred from the PC board to the air. Solder the underside-exposed pad to a large copper GND plane. If the die temperature reaches +160°C the NCP1597/A shut down and does not restart again until the die temperature cools by 40°C.

Layout Consideration

As with all high frequency switchers, when considering layout, care must be taken in order to achieve optimal electrical, thermal and noise performance. For 1.0MHz switching frequency, switch rise and fall times are typically in few nanosecond range. To prevent noise both radiated and conducted the high speed switching current path must be kept as short as possible. Shortening the current path will also reduce the parasitic trace inductance of approximately 25 nH/inch. At switch off, this parasitic inductance produces a flyback spike across the NCP1597/A switch. When operating at higher currents and input voltages, with poor layout, this spike can generate voltages across the NCP1597/A that may exceed its absolute maximum rating. A ground plane should always be used under the switcher circuitry to prevent interplane coupling and overall noise.

The COMP and FB components should be kept as far away as possible from the switch node. The ground for these components should be separated from the switch current path. Failure to do so will result in poor stability or subharmonic like oscillation.

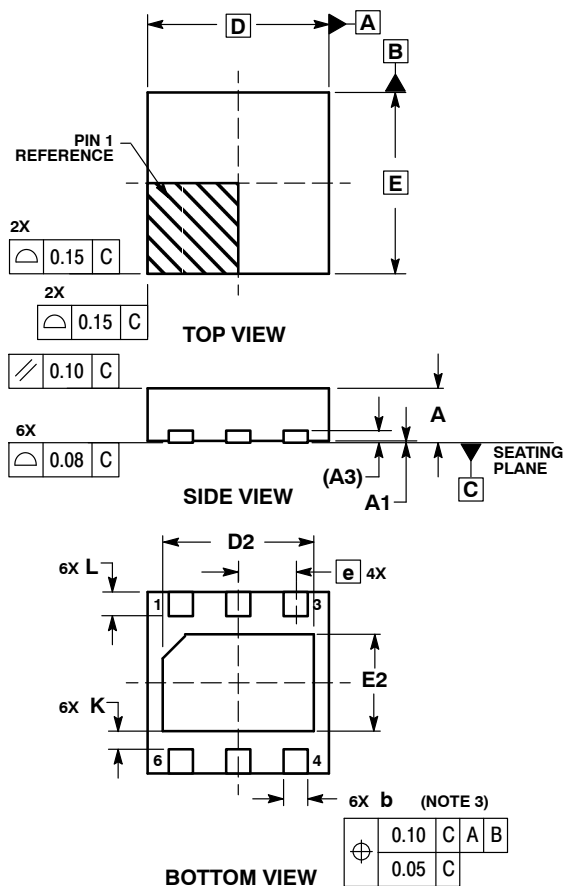
Board layout also has a significant effect on thermal resistance. Reducing the thermal resistance from ground pin and exposed pad onto the board will reduce die temperature and increase the power capability of the NCP1597/A. This is achieved by providing as much copper area as possible around the exposed pad. Adding multiple thermal vias under and around this pad to an internal ground plane will also help. Similar treatment to the inductor pads will reduce any additional heating effects.

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PACKAGE DIMENSIONS

DFN6 3*3 MM, 0.95 PITCH
CASE 506AH-01
ISSUE O

SCALE 2:1

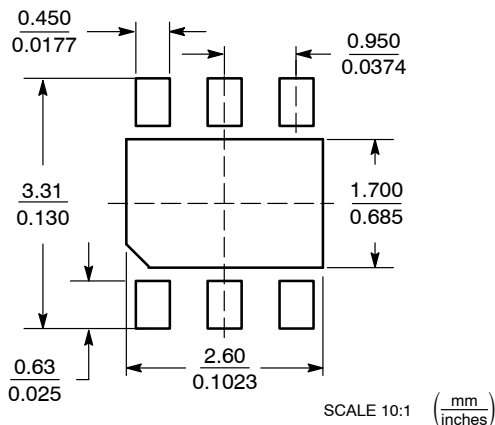


NOTES:

1. DIMENSIONS AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM FROM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

MILLIMETERS			
DIM	MIN	NOM	MAX
A	0.80	0.90	1.00
A1	0.00	0.03	0.05
A3	0.20 REF		
b	0.35	0.40	0.45
D	3.00 BSC		
D2	2.40	2.50	2.60
E	3.00 BSC		
E2	1.50	1.60	1.70
e	0.95 BSC		
K	0.21	---	---
L	0.30	0.40	0.50

SOLDERING FOOTPRINT*



*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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