DC/DC OPERATION DESCRIPTION

Detailed Description

The NCP1529 uses a constant frequency, current mode step−down architecture. Both the main (P−Channel MOSFET) and synchronous (N−Channel MOSFET) switches are internal.

The output voltage is set by an external resistor divider in the range of 0.9 V to 3.9 V and can source at least 1A.

The NCP1529 works with two modes of operation; PWM/PFM depending on the current required. In PWM mode, the device can supply voltage with a tolerance of ±3% and 90% efficiency or better. Lighter load currents cause the device to automatically switch into PFM mode to reduce current consumption and extended battery life.

Additional features include soft−start, undervoltage protection, current overload protection and thermal shutdown protection. As shown on Figure 1, only six external components are required. The part uses an internal reference voltage of 0.6 V. It is recommended to keep NCP1529 in shutdown mode until the input voltage is 2.7 V or higher.

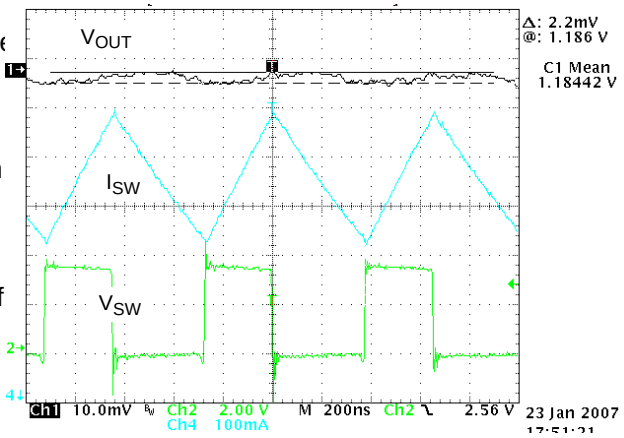


Figure 26. PWM Switching Waveforms (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 600 mA, Temperature = 25°C)

PWM Operating Mode

In this mode, the output voltage of the device is regulated by modulating the on−time pulse width of the main switch Q1 at a fixed 1.7 MHz frequency.

The switching of the PMOS Q1 is controlled by a flip−flop driven by the internal oscillator and a comparator that compares the error signal from an error amplifier with the sum of the sensed current signal and compensation ramp.

The driver switches ON and OFF the upper side transistor (Q1) while the lower side transistor is switched OFF then ON.

At the beginning of each cycle, the main switch Q1 is turned ON by the rising edge of the internal oscillator clock. The inductor current ramps up until the sum of the current sense signal and compensation ramp becomes higher than the error amplifier's voltage. Once this has occurred, the PWM comparator resets the flip−flop, Q1 is turned OFF while the synchronous switch Q2 is turned ON. Q2 replaces the external Schottky diode to reduce the conduction loss and improve the efficiency. To avoid overall power loss, a certain amount of dead time is introduced to ensure Q1 is completely turned OFF before Q2 is being turned ON.

PFM Operating Mode

Under light load conditions, the NCP1529 enters in low current PFM mode of operation to reduce power consumption. The output regulation is implemented by pulse frequency modulation. If the output voltage drops below the threshold of PFM comparator a new cycle will be initiated by the PFM comparator to turn on the switch Q1. Q1 remains ON during the minimum on time of the structure while Q2 is in its current source mode. The peak inductor current depends upon the drop between input and output voltage. After a short dead time delay where Q1 is switched OFF, Q2 is turned in its ON state. The negative current detector will detect when the inductor current drops below zero and sends a signal to turn Q2 to current source mode to prevent a too large deregulation of the output voltage. When the output voltage falls below the threshold of the PFM comparator, a new cycle starts immediately.

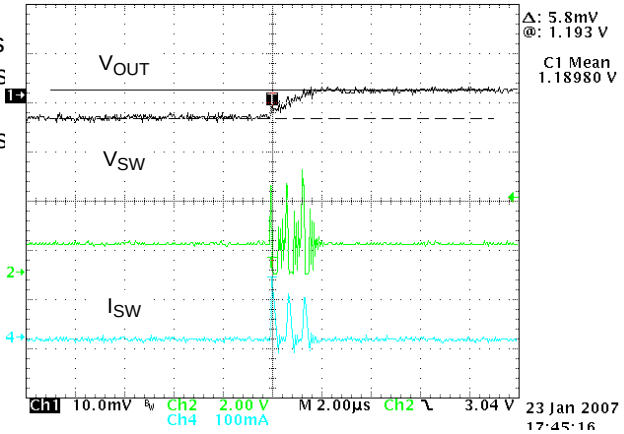


Figure 27. PFM Switching Waveforms (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 0 mA, Temperature = 25°C)

Soft−Start

The NCP1529 uses soft−start to limit the inrush current when the device is initially powered up or enabled. Soft start is implemented by gradually increasing the reference voltage until it reaches the full reference voltage. During startup, a pulsed current source charges the internal soft−start capacitor to provide gradually increasing reference voltage. When the voltage across the capacitor ramps up to the nominal reference voltage, the pulsed current source will be switched off and the reference voltage will switch to the regular reference voltage.

Cycle−by−Cycle Current Limitation

From the block diagram, an I_{LIM} comparator is used to realize cycle−by−cycle current limit protection. The comparator compares the SW pin voltage with the reference voltage, which is biased by a constant current. If the inductor current reaches the limit, the I_{LIM} comparator detects the SW voltage falling below the reference voltage and releases the signal to turn off the switch Q1. The cycle−by−cycle current limit is set at 1600 mA (nom).

Low Dropout Operation

The NCP1529 offers a low input to output voltage difference. The NCP1529 can operate at 100% duty cycle.

In this mode the PMOS (Q1) remains completely ON. The minimum input voltage to maintain regulation can be calculated as:

$$V_{out} = V_{OUT(max)} + \left(I_{OUT}\left(R_{DS(on)} + R_{INDUCTOR}\right)\right) \quad \text{(eq. 1)}$$

- V_{OUT}: Output Voltage (V)
- I_{OUT}: Max Output Current
- $R_{DS(on)}$: P−Channel Switch $R_{DS(on)}$
- $R_{INDUCTOR}$: Inductor Resistance (DCR)

Undervoltage Lockout

The Input voltage V_{IN} must reach 2.4 V (typ) before the NCP1529 enables the DC/DC converter output to begin the start up sequence (see soft−start section). The UVLO threshold hysteresis is typically 100 mV.

Shutdown Mode

Forcing this pin to a voltage below 0.4 V will shut down the IC. In shutdown mode, the internal reference, oscillator and most of the control circuitries are turned off. Therefore, the typical current consumption will be 0.3 mA (typical value). Applying a voltage above 1.2 V to EN pin will enable the DC/DC converter for normal operation. The device will go through soft−start to normal operation.

Thermal Shutdown

Internal Thermal Shutdown circuitry is provided to protect the integrated circuit in the event that the maximum junction Temperature is exceeded. If the junction temperature exceeds 180°C, the device shuts down. In this mode all power transistors and control circuits are turned off. The device restarts in soft−start after the temperature drops below 140°C. This feature is provided to prevent catastrophic failures from accidental device overheating.

Short Circuit Protection

When the output is shorted to ground, the device limits the inductor current. The duty cycle is minimum and the consumption on the input line is 550 mA (typ). When the short circuit condition is removed, the device returns to the normal mode of operation.

USB or 5 V Rail Powered Applications

For USB or 5 V rail powered applications, NCP1529 is able to supply voltages up to 3.9 V, 600 mA, operating in PWM mode only, with high efficiency (Figure 28), low output voltage ripple and good load regulation results over all current range (Figure 29).

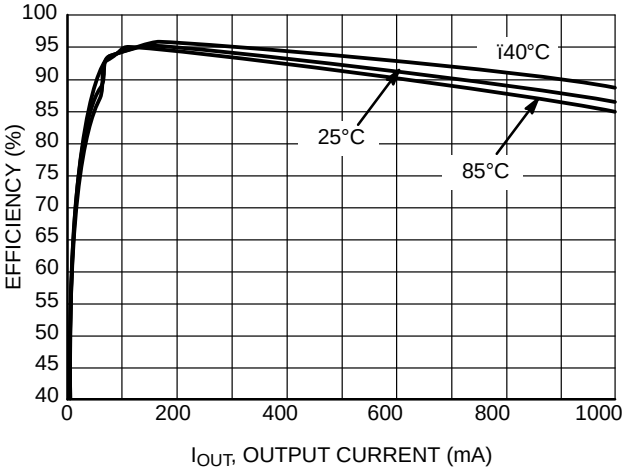


Figure 28. Efficiency vs. Output Current (V_{IN} = 5.0 V, V_{OUT} = 3.9 V)

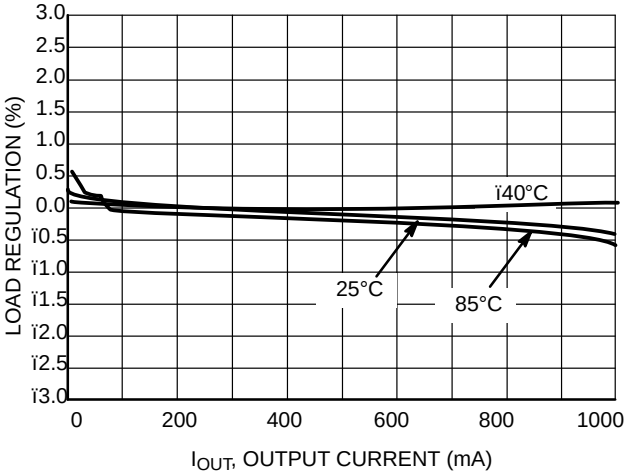


Figure 29. Load Regulation vs. Output Current (V_{IN} = 5.0 V, V_{OUT} = 3.9 V)

APPLICATION INFORMATION

Output Voltage Selection

In case of adjustable versions, the output voltage is programmed through an external resistor divider connected from V_{OUT} to FB then to GND.

For low power consumption and noise immunity, the resistor from FB to GND (R2) should be in the [100 k − 600 k] range. If R2 is 200 k given the V_{FB} is 0.6 V, the current through the divider will be 3.0 A.

The formula below gives the value of V_{OUT}, given the desired R1 and the R1 value:

$$V_{out} = V_{FB} \times (1 + R1/R2) \quad \text{(eq. 2)}$$

- V_{OUT}: Output Voltage (V)
- V_{FB}: Feedback Voltage = 0.6 V
- R1: Feedback Resistor from V_{OUT} to FB
- R2: Feedback Resistor from FB to GND

Input Capacitor Selection

In PWM operating mode, the input current is pulsating with large switching noise. Using an input bypass capacitor can reduce the peak current transients drawn from the input supply source, thereby reducing switching noise significantly. The capacitance needed for the input bypass capacitor depends on the source impedance of the input supply.

The maximum RMS current occurs at 50% duty cycle with maximum output current, which is IO, max/2.

For NCP1529, a low profile ceramic capacitor of 4.7 F should be used for most of the cases. For effective bypass results, the input capacitor should be placed as close as possible to the VIN Pin

Table 1. LIST OF INPUT CAPACITORS

Manufacturer	Part Number	Case Size	Value (μF)	DC Bias (V)	Technology
MURATA	GRM15 series	0402	4.7	6.3	X5R
MURATA	GRM18 series	0603	4.7	10	X5R
TDK	C1608 series	0603	4.7	6.3	X5R
TDK	C1608 series	0603	4.7	10	X5R

Output Lï C Filter Design Considerations

The NCP1529 operates at 1.7 MHz frequency and uses current mode architecture. The correct selection of the output filter ensures good stability and fast transient response.

Due to the nature of the buck converter, the output L filter must be selected to work with internal compensation. For NCP1529, the internal compensation is internally fixed and it is optimized for an output filter of L = 2.2 H and C_{OUT} = 10 F.

The corner frequency is given by:

$$f = \frac{1}{2\sqrt{L \times C_{OUT}}} = \frac{1}{2\sqrt{2.2\ \text{H} \times 10\ \text{F}}} = 34\ \text{kHz} \quad \text{(eq. 3)}$$

The device operates with inductance value of 2.2 H. If the corner frequency is moved, it is recommended to check the loop stability depending of the accepted output ripple voltage and the required output current. Take care to check the loop stability. The phase margin is usually higher than 45°.

Table 2. Lï C FILTER EXAMPLE

Inductance (L)	Output Capacitor (C_{OUT})
2.2 H	10 F
4.7 H	4.7 F

Inductor Selection

The inductor parameters directly related to device performances are saturation current and DC resistance and inductance value. The inductor ripple current I_L decreases with higher inductance:

$$I_L = \frac{V_{OUT}}{L \times f_{SW}}\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad \text{(eq. 4)}$$

- I_L: Peak to peak inductor ripple current
- L: Inductor value
- f_{SW}: Switching frequency

The saturation current of the inductor should be rated higher than the maximum load current plus half the ripple current:

$$I_{L(max)} = I_{O(max)} + \frac{I_L}{2} \quad \text{(eq. 5)}$$

- $I_{L(max)}$: Maximum inductor current
- $I_{O(max)}$: Maximum Output current

The inductor's resistance will factor into the overall efficiency of the converter. For best performances, the DC resistance should be less than 0.8 for good efficiency.

Table 3. LIST OF INDUCTORS

Manufacturer	Part Number	Case Size (mm)	Height Max (mm)	L (μH)	DCR Typ (Ω)	DCR Max (Ω)	Rated Current (mA) Inductance Drop	Rated Current (mA) Temperature Drop	Structure
COILCRAFT	DO1605T-222	5.5 x 4.2	1.8	2.2	NA	0.070	1800 (-10%)	1700 (+40°C)	Wire Wound
COILCRAFT	EPL3015-222	3.0 x 3.0	1.5	2.2	0.082	0.094	1600 (-30%)	2000 (+40°C)	Wire Wound
COILCRAFT	EPL2014-222	2.0 x 2.0	1.4	2.2	0.120	0.132	1300 (-30%)	1810 (+40°C)	Wire Wound
MURATA	LQM2HPN2R2	2.5 x 2.0	1.0	2.2	0.080	0.100	NA	1300 (+40°C)	Multilayer
MURATA	LQH3NPN2R2	3.0 x 3.0	1.2	2.2	0.065	0.085	1150 (-30%)	1460 (+40°C)	Wire Wound
MURATA	LQH44PN2R2	4.0 x 4.0	1.8	2.2	0.049	0.059	2500 (-30%)	1800 (+40°C)	Wire Wound
TDK	MLP2520S2R2L	2.5 x 2.0	1.0	2.2	0.080	0.104	1300 (-30%)	NA	Multilayer
TDK	VLS252010T2R2	2.0 x 1.6	1.2	2.2	0.158	0.190	1400 (-30%)	1100 (+40°C)	Wire Wound
WURTH ELEC	744 029 002	2.8 x 2.8	1.35	2.2	0.088	0.105	1150 (-35%)	1700 (+40°C)	Wire Wound

Output Capacitor Selection

Selecting the proper output capacitor is based on the desired output ripple voltage. Ceramic capacitors with low ESR values will have the lowest output ripple voltage and are strongly recommended. The output capacitor requires either an X7R or X5R dielectric.

The output ripple voltage in PWM mode is given by:

$$V_{OUT} = I_L \times \left(\frac{1}{4 \times f_{SW} \times C_{OUT}} + ESR \right) \quad \text{(eq. 6)}$$

Table 4. LIST OF OUTPUT CAPACITORS

Manufacturer	Part Number	Case Size	Value (μF)	DC Bias (V)	Technology
MURATA	GRM15 series	0402	4.7	6.3	X5R
MURATA	GRM18 series	0603	4.7	10	X5R
MURATA	GRM18 series	0603	10	6.3	X5R
TDK	C1608 series	0603	4.7	6.3	X5R
TDK	C1608 series	0603	4.7	10	X5R
TDK	C1608 series	0603	10	6.3	X5R

Feedï Forward Capacitor Selection (Adjustable Only)

The feed-forward capacitor sets the feedback loop response and acts on soft-start time. A minimum 18 pF feed-forward capacitor is needed to ensure loop stability. Having feed-forward capacitor of 1 nF or higher can increase soft ïstart time and reduce inrush current. Choose a small ceramic capacitor X7R or X5R or COG dielectric.

LAYOUT CONSIDERATIONS

Electrical Layout Considerations

Implementing a high frequency DïDC converter requires respect of some rules to get a powerful portable application. Good layout is key to prevent switching regulators to generate noise to application and to themselves.

Electrical layout guide lines are:

- € Use short and large traces when large amount of current is flowing.
- € Keep the same ground reference for input and output capacitors to minimize the loop formed by high current path from the battery to the ground plane.
- € Isolate feedback pin from the switching pin and the current loop to protect against any external parasitic signal coupling. Add a feedforward capacitor between V_{OUT} and FB which adds a zero to the loop and participates to the good loop stability. A 18 pF capacitor is recommended to meet compensation requirements.

A four layer PCB with a ground plane and a power plane will help NCP1529 noise immunity and loop stability.

Thermal Layout Considerations

High powerdissipation in small package leads to thermal consideration such as:

- € Enlarge V_{IN} trace and added several vias connected to power plane.
- € Connect GND pin to top plane.
- € Join top, bottom and each ground plane together using several free vias in order to increase radiator size.

For high ambient temperature and high power dissipation requirements, UDFN6 package using exposed pad connected to main radiator is recommended. Refer to Notes 7, 8, and 9.

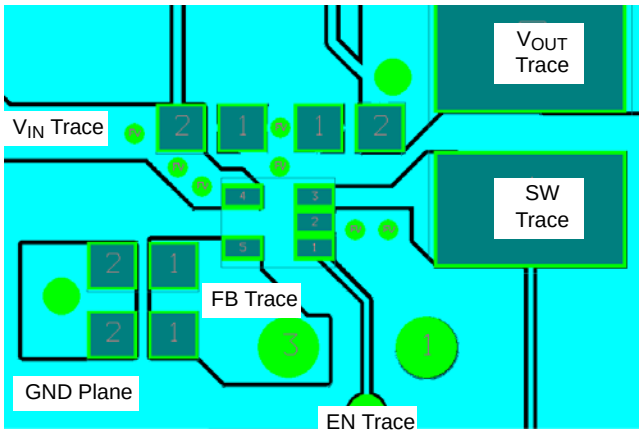


Figure 30. TSOPï 5 Recommended Board Layout

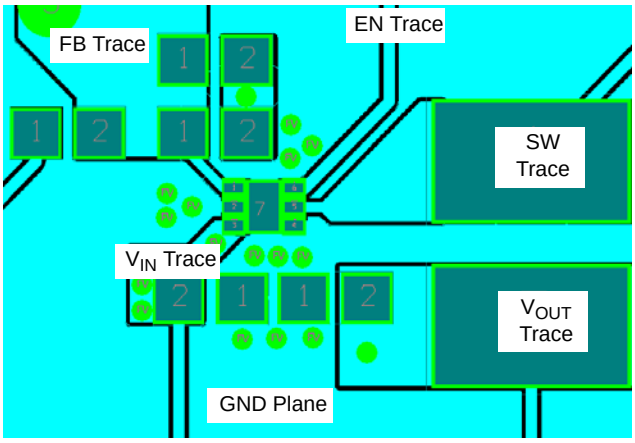


Figure 31. UDFN6 Recommended Board Layout

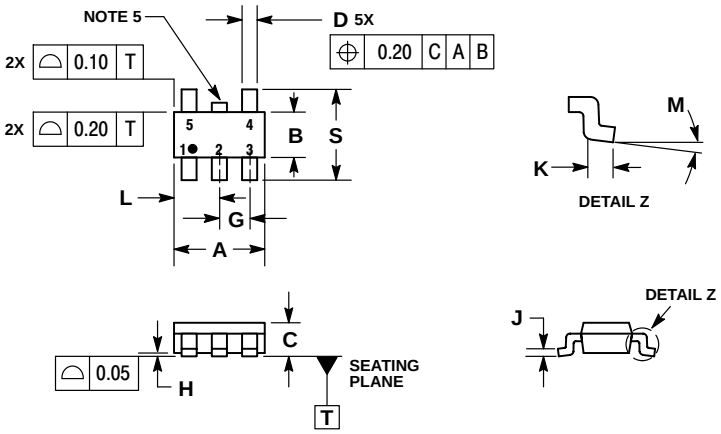
ORDERING INFORMATION

Device	Nominal Output Voltage	Marking	Package	Shipping†
NCP1529ASNT1G	Adj	DXJ	TSOP ï5	3000 / Tape & Reel
NCP1529MUTBG	Adj	TL	UDFN6	3000 / Tape & Reel
NCP1529MU12TBG	1.2 V	TC		
NCP1529MU135TBG	1.35 V	RC		

†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.

PACKAGE DIMENSIONS

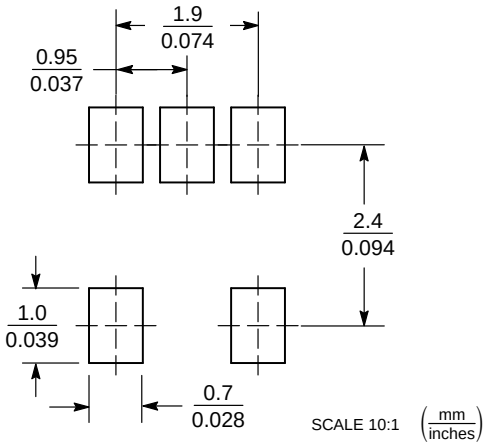
TSOPï 5
CASE 483 ï02
ISSUE G



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH THICKNESS. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.
4. DIMENSIONS A AND B DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS.
5. OPTIONAL CONSTRUCTION: AN ADDITIONAL TRIMMED LEAD IS ALLOWED IN THIS LOCATION. TRIMMED LEAD NOT TO EXTEND MORE THAN 0.2 FROM BODY.

	MILLIMETERS	
DIM	MIN	MAX
A	3.00 BSC	
B	1.50 BSC	
C	0.90	1.10
D	0.25	0.50
G	0.95 BSC	
H	0.01	0.10
J	0.10	0.26
K	0.20	0.60
L	1.25	1.55
M	0	10
S	2.50	3.00

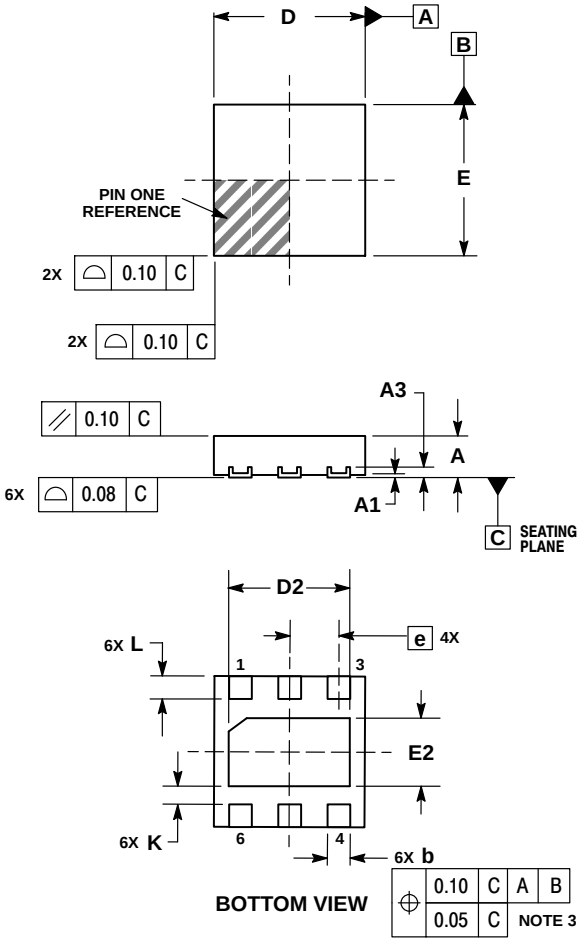
SOLDERING FOOTPRINT*



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

PACKAGE DIMENSIONS

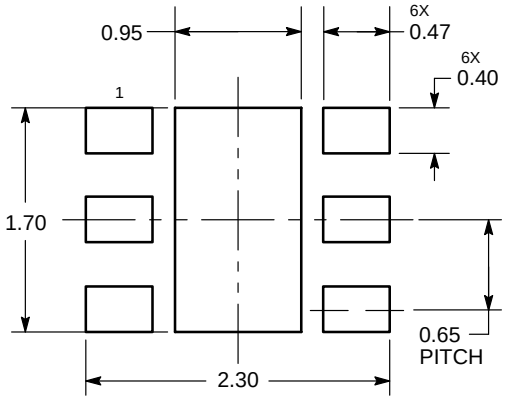
UDFN6 2x2, 0.65P
CASE 517AB ï01
ISSUE A



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.20mm FROM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

	MILLIMETERS	
DIM	MIN	MAX
A	0.45	0.55
A1	0.00	0.05
A3	0.127 REF	
b	0.25	0.35
D	2.00 BSC	
D2	1.50	1.70
E	2.00 BSC	
E2	0.80	1.00
e	0.65 BSC	
K	0.20	---
L	0.25	0.35

SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

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

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