

# NCP81042

## Precise Low Voltage Synchronous Buck Controller with Power Saving Mode

The NCP81042 is a simple single phase solution with differential phase current sensing, power saving operation, and gate drivers to provide accurately regulated power.

The adaptive non overlap gate drive and power saving operation circuit provide a low switching loss and high efficiency solution for server, notebook, and desktop systems. A high performance operational error amplifier is provided to simplify compensation of the system. The NCP81042 features also include soft-start sequence, accurate overvoltage and over current protection, UVLO for VCC and VCCP, and thermal shutdown.

### Features

- High Performance Operational Error Amplifier
- Internal Soft-Start/Stop
- $\pm 0.5\%$  Internal Voltage Accuracy, 0.8 V voltage reference
- OCP accuracy, Four Re-entry Times Before Latch
- “Lossless” Differential Inductor Current Sensing
- Internal High Precision Current Sensing Amplifier
- Oscillator Frequency Range of 100 kHz – 1000 kHz
- 20 ns Adaptive FET Non-overlap Time of Internal Gate Driver
- 5.0 V to 12 V Operation
- Support 1.5 V to 19 V  $V_{in}$
- $V_{out}$  from 0.8 V to 3.3 V (5 V with 12 V $_{CC}$ )
- Chip Enable through OSC pin
- Latched Over Voltage Protection (OVP)
- Internally Fixed OCP Threshold
- Guaranteed Startup Into Pre-Charged Loads
- Thermally Compensated Current Monitoring
- Thermal Shutdown Protection
- Integrated MOSFET Drivers
- Integrated BOOST Diode with internal  $R_{bst} = 2.2 \Omega$
- Automatic Power Saving Mode to Maximize Efficiency During Light Load Operation
- Sync Function
- Remote Ground Sensing
- This is a Pb-Free Device\*

### Applications

- Desktop and Server Systems

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



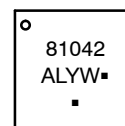
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### MARKING DIAGRAMS



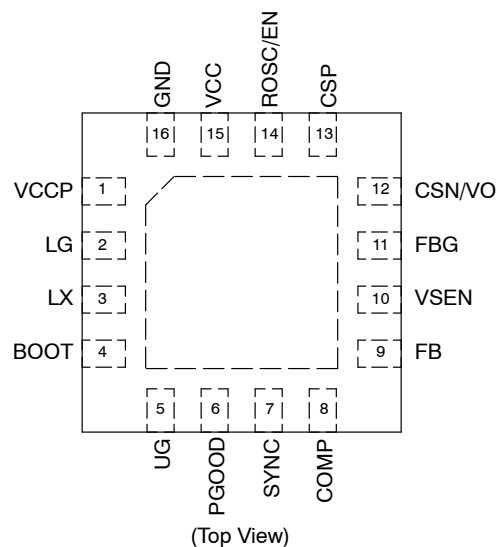
QFN16  
CASE 485G



81042 = Specific Device Code  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

(\*Note: Microdot may be in either location)

### PIN CONNECTIONS

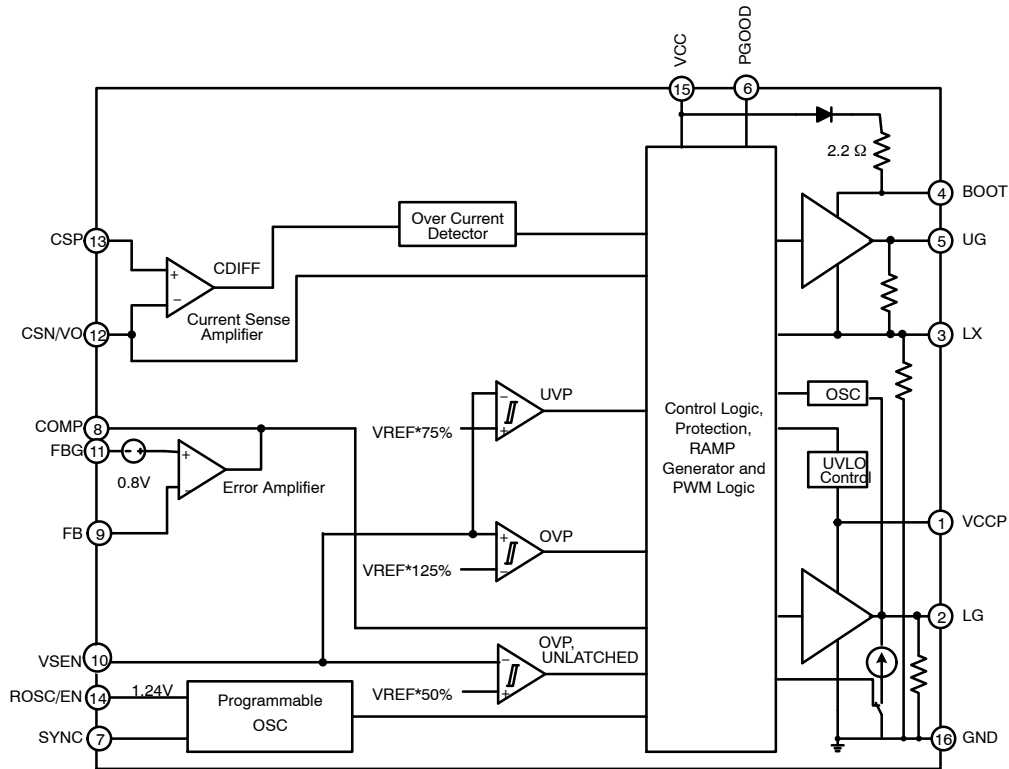


### ORDERING INFORMATION

Device	Package	Shipping
NCP81042MNTXG	QFN16 (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 Specification Brochure, BRD8011/D.

# NCP81042



**Figure 1. NCP81042 BLOCK DIAGRAM**

## PIN DESCRIPTIONS

Pin No.	Symbol	Description
1	VCCP	Power supply for bottom gate MOSFET drivers
2	LG	Bottom gate MOSFET driver pin
3	LX	Switch node
4	BOOT	Supply rail for the floating top gate driver
5	UG	Top gate MOSFET driver pin
6	PGOOD	Power Good. It is an open-drain output, set free after SS (with 3x clock delay) as long as the output voltage monitored through VSEN is within specifications.
7	SYNC	Synchronization Pin. The controller synchronizes on the falling edge of a square wave provided to this pin. Short to GND if not used.
8	COMP	Output of the error amplifier
9	FB	Inverting input to the error amplifier
10	VSEN	Output Voltage Sense
11	FBG	Remote Ground Sense
12	CSN/VO	Inductor differential sense inverting input
13	CSP	Inductor differential sense non-inverting input
14	ROSC/EN	Programs the switching frequency; EN: Pull-low to disable the device
15	VCC	Supply rail for the controller internal circuitry
16	GND	Ground reference
	THERMAL PAD	Connects with the silicon substrate for good thermal contact with the PCB. Connect to GND plane.

# NCP81042

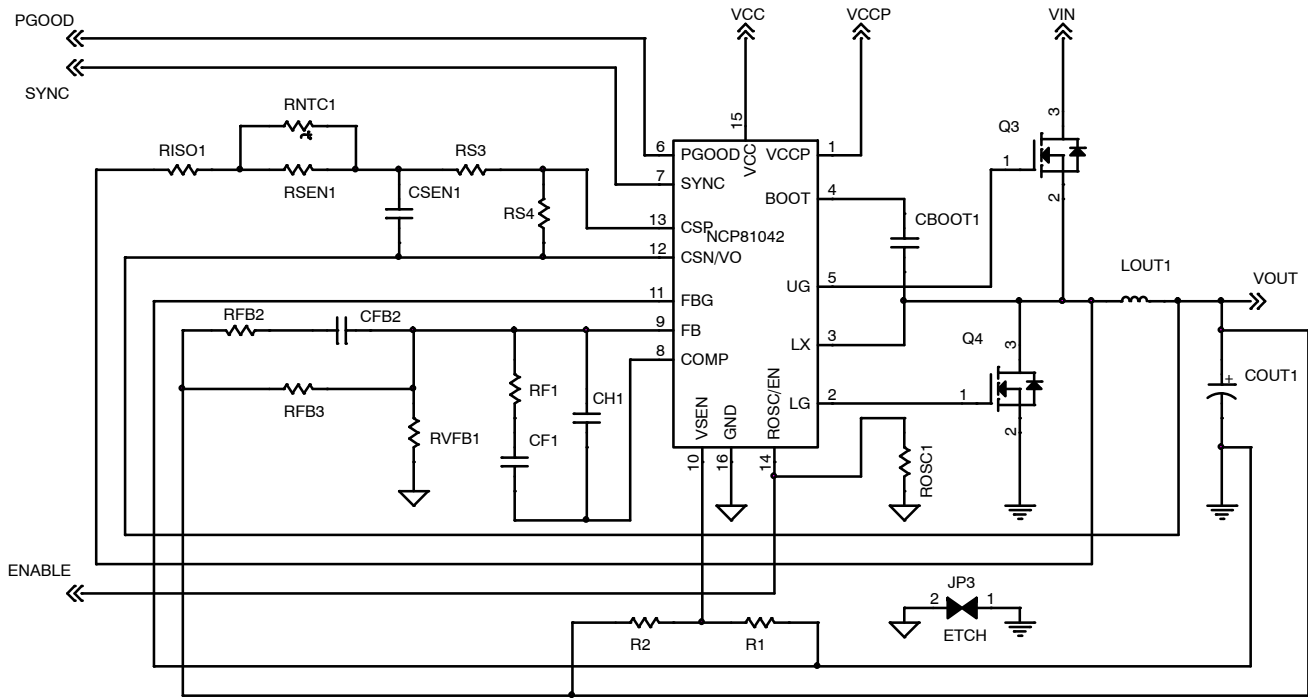


Figure 2. Typical Application Circuit

## ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	V <sub>MAX</sub>	V <sub>MIN</sub>	Unit
Controller Power Supply Voltages to GND	VCC, VCCP	15	-0.3	V
Boost Supply Voltage Input	BOOT	35V wrt/GND 40 V < 100 ns wrt/GND 15 wrt/LX	-0.3	V
High-Side Driver Output (Top Gate)	UG	35 40 V ≤ 50 ns wrt/GND 15 wrt/LX	-0.3 wrt/LX -5 V < 200 ns	V
Switching Node (Bootstrap Supply Return)	LX	35 40 < 100 ns	-5 -10 V < 200 ns	V
Low-Side Driver Output (Bottom Gate)	LG	15	-0.3 -5 V < 200 ns	V
All Other Pins		6	-0.3, -1 V < 1 μs	V
PGOOD	PGOOD	7	-0.3, -1 V < 1 μs	V
SYNC	SYNC	7	-0.3, -1 V < 1 μs	V
Current Sense Amplifier	CSP, CSN/VO with V <sub>CC</sub> = 12 V	10	-0.3, -1 V < 1 μs	V

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.

\*All signals referenced to GND unless noted otherwise.

## THERMAL INFORMATION

Rating	Symbol	Typ	Unit
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	60	°C/W
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	18	°C/W
Operating Junction Temperature Range	$T_J$	0 to 125	°C
Operating Ambient Temperature Range	$T_A$	0 to 85	°C
Maximum Storage Temperature Range	$T_{STG}$	-55 to +150	°C
Moisture Sensitivity Level      QFN Package	MSL	1	–

ELECTRICAL CHARACTERISTICS Unless otherwise stated:  $0^{\circ}\text{C} < T_A < 85^{\circ}\text{C}$ ;  $4.5\text{ V} < V_{CC} < 13.2\text{ V}$ ;  $C_{VCC} = 0.1\text{ }\mu\text{F}$ 

Parameter	Test Conditions	Min	Typ	Max	Unit
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## SUPPLY OPERATING CONDITIONS

VCC Voltage Range		4.5		13.2	V
VCCP Voltage Range		4.5		13.2	V
dV/dt on VCC (Note 1)		-10		10	V/ $\mu\text{s}$
dV/dt on VCCP (Note 1)		-10		10	V/ $\mu\text{s}$

## VCC AND BOOT INPUT SUPPLY CURRENT

VCC Operating Current	$V_{CC} = 5\text{ V}$ , EN = High $V_{CC} = 12\text{ V}$ , EN = High			5.0	mA
VCC Supply Current	$V_{CC} = 5\text{ V}$ , EN = Low $V_{CC} = 12\text{ V}$ , EN = Low			400	$\mu\text{A}$

## VCCP INPUT SUPPLY CURRENT

VCCP Operating Current UG and LG Open	$V_{CCP} = 5\text{ V}$ , EN = High $V_{CCP} = 12\text{ V}$ , EN = High		3.5	5.0	mA
VCCP Supply Current	$V_{CCP} = 5\text{ V}$ , EN = Low $V_{CCP} = 12\text{ V}$ , EN = Low			200	$\mu\text{A}$

## VCC SUPPLY VOLTAGE

VCC UVLO Start Threshold	$V_{CC}$ Rising			4.50	V
VCC UVLO Hysteresis	$V_{CC}$ Rising or Falling		300		mV

## VCCP SUPPLY VOLTAGE

VCCP UVLO Start Threshold				4.2	V
VCCP UVLO Hysteresis			200		mV

## ERROR AMPLIFIER COMP

Open Loop DC Gain (Note 1)			120		dB
Open Loop Unity Gain Bandwidth (Note 1)		15	18		MHz
Slew Rate (Note 1)	COMP pin to GND with 100 pF load		8.0		V/ $\mu\text{s}$

## VREF

Internal Reference Voltage			0.800		V
Output Voltage Accuracy	$V_{out}$ to FBG excluding external resistor divider tolerance	-0.5		0.5	%

## CURRENT SENSE AMPLIFIERS

Common Mode Input Voltage Range (Note 1, GNG, output within 10mV)	$V_{CC} \leq 7.5\text{ V}$	-0.3		3.5	V
Common Mode Input Voltage Range (Note 1, GNG, output within 10 mV)	$V_{CC} > 7.5\text{ V}$	-0.3		5.5	V

1. Guaranteed by design.

2. For propagation delays, "tpdh" refers to the specified signal going high "tpdl" refers to it going low. Reference Gate Timing Diagram.

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**ELECTRICAL CHARACTERISTICS** Unless otherwise stated: 0°C < T<sub>A</sub> < 85°C; 4.5 V < V<sub>CC</sub> < 13.2 V; C<sub>VCC</sub> = 0.1 μF

Parameter	Test Conditions	Min	Typ	Max	Unit
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## OSCILLATOR (with no ROSC Resistor Defaults to 200 kHz)

Switching Frequency Accuracy	R <sub>OSC</sub> open	-10		10	%
OSC Gain (Note 1)			10		kHz / μA
Disable threshold	R <sub>OSC</sub> /EN pin, V <sub>dis_th</sub>			0.75	V

## MODULATORS (PWM Comparators)

Minimum Pulse Width	F <sub>sw</sub> = 200 kHz, OSC open		90		ns
Minimum Turn Off Time (LG on)	F <sub>sw</sub> = 200 kHz, OSC open	250	350	450	ns
Magnitude of the PWM Ramp	V <sub>IN</sub> = 5 V or 12 V		1.50		V
Maximum Duty Cycle	OSC/EN = OPEN	80		95	%
Minimum Skip mode frequency	In light load, maximum time for LG to turn on after HG turns off	30			kHz

## SOFT-START

Soft Start Time @ 200 kHz	1024 clock cycles, OSC/EN open		5.12		ms
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## SOFT-OFF

Soft OFF bleeding resistor	R <sub>dis</sub>		120		Ω
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## OVER CURRENT PROTECTION

First Over Current Threshold	CSP-CSN, 4xMasking	17	20	23	mV
Second Over Current Threshold	CSP-CSN, Immediate action		30		mV

## SYNC PIN

Synchronization Input	V <sub>IL</sub> , square wave			1.0	V
Synchronization Input	V <sub>IH</sub> , square wave	2.5			V

## PROTECTION AND PGOOD

Output Voltage	Logic Low, Sinking 4 mA			0.4	V
OVP Threshold	V <sub>SEN</sub> rising above 1.25 * V <sub>ref</sub>	117	125	130	%
UVP Threshold	V <sub>SEN</sub> falling below 0.75 * V <sub>ref</sub>	70	75	80	%
Unlatched Overvoltage Threshold	V <sub>th_disoff</sub> with respect to 0.5 V <sub>ref</sub>	40	50	60	%
Power Good High Delay (Note 1)				50	μs
Power Good Low Delay (Note 1)				1	μs

## ZERO CURRENT DETECTION (LX Pin)

Blanking Time before Zero Current Detection (Note 1)	Blanking Time after LG is < 1.0 V			40	ns
Capture Time for LX Voltage (Note 1)	Time to capture LX voltage once LG is < 1.0 V (must be within dead time limits)			20	ns
Negative LX detection voltage	V <sub>bdl</sub> s	150	300	450	mV
Positive LX detection voltage	V <sub>bdl</sub> hs	0.2	0.5	1.0	V
Time for V <sub>th</sub> adjustment and settling time (Note 1)	300 kHz	3.0		3.7	μs
Initial Negative Current Detection Threshold Voltage Set Point (Note 1)	LX-GND, Includes ± 2 mV Offset Range		1.0		mV
V <sub>th</sub> adjustable Range (Note 1)		-16	0	15	mV

1. Guaranteed by design.
2. For propagation delays, "tpdh" refers to the specified signal going high "tpdl" refers to it going low. Reference Gate Timing Diagram.

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**ELECTRICAL CHARACTERISTICS** Unless otherwise stated:  $0^{\circ}\text{C} < T_A < 85^{\circ}\text{C}$ ;  $4.5\text{ V} < V_{CC} < 13.2\text{ V}$ ;  $C_{VCC} = 0.1\text{ }\mu\text{F}$

Parameter	Test Conditions	Min	Typ	Max	Unit
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## HIGH SIDE DRIVER UG

$R_{H\_TG}$ Output Resistance, Sourcing	$V_{BOOT} - V_{LX} = 12\text{ V}$ , $C_{load} = 3\text{ nF}$		2.5	5	$\Omega$
$R_{H\_TG}$ Output Resistance, Sinking	$V_{BOOT} - V_{LX} = 12\text{ V}$		2.0	2.5	$\Omega$
$T_{rDRVH}$ Transition Time	$C_{LOAD} = 2\text{ nF}$		16		ns
$T_{fDRVH}$ Transition Time	$C_{LOAD} = 2\text{ nF}$		11		
$T_{pdhDRVH}$ Propagation Delay (Notes 1, 2)	Driving High, $C_{LOAD} = 3\text{ nF}$ , $V_{CC} = 12\text{ V}$ , $V_{CCP} = 12\text{ V}$		15	30	ns
UG Internal Resistor to LX	Unbiased, $BOOT - LX = 0$		45		$k\Omega$

## LOW SIDE DRIVER LG

$R_{H\_BG}$ Output Resistance, Sourcing	$V_{LX} = \text{GND}$ , $C_{load} = 3\text{ nF}$		2.0	3.0	$\Omega$
$R_{L\_BG}$ Output Resistance, Sinking	$V_{LX} = V_{CC}$		1.0	1.5	$\Omega$
$T_{rDRVL}$ Transition Time	$C_{LOAD} = 3\text{ nF}$		16		ns
$T_{fDRVL}$ Transition Time	$C_{LOAD} = 3\text{ nF}$		11		
$T_{pdhDRVL}$ Propagation Delay (Notes 1, 2)	Driving High, $C_{LOAD} = 3\text{ nF}$ , $V_{CCP} = 12\text{ V}$ , $V_{CCP} = 12\text{ V}$	10	20	35	ns
LX Internal Resistor to GND			45		$k\Omega$

## THERMAL SHUTDOWN

$T_{sd}$ Thermal Shutdown (Note 1)		150	180		$^{\circ}\text{C}$
$T_{sdhys}$ Thermal Shutdown Hysteresis (Note 1)			50		$^{\circ}\text{C}$

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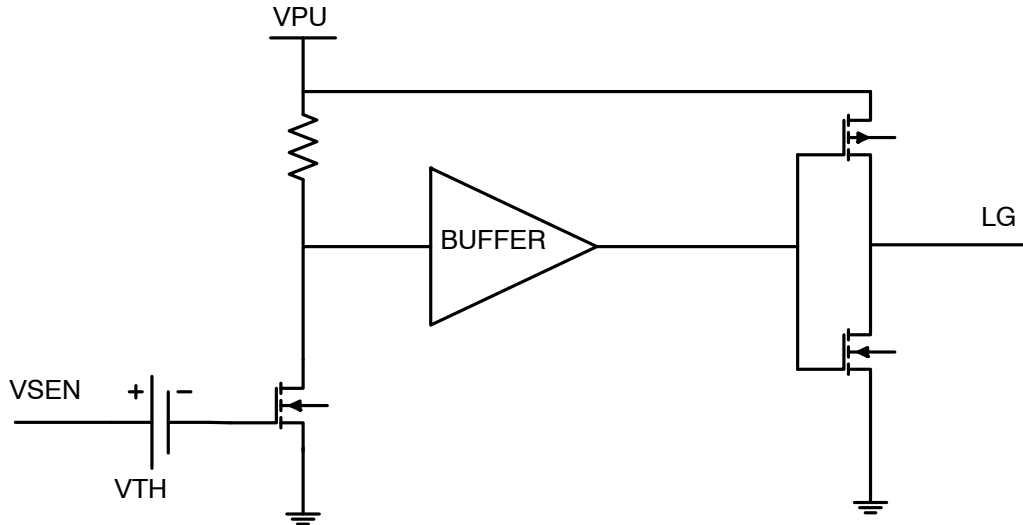


Figure 4. PreOVP circuit

#### Vin Detection

During the soft start after the VSEN pin exceeds 80%  $V_{ref}$ , UV protection will be enabled; If a UV fault is triggered in the softstart, it will restart SS after a fixed delay. The UV protection is to avoid IC to startup without Vin or with insufficient Vin voltage.

#### Overcurrent Protection

NCP81042 measures the differential current sensing signal through CSP and CSN/VO pin. There are two current protection levels: OCP1 and OCP2. If the differential voltage across pin CSP and CSN/VO is over 20 mV (but below 30 mV) for four consecutive cycles, OCP1 will be tripped. Both UG and LG will be forced to low to turn off the high side and low side FETs, it is a latched condition; If the differential voltage across pin CSP and CSN is over 30 mV,

OCP2 will be tripped, the UG and LG will be pulled low and latched immediately. Toggling VCC power or EN will reset the Overcurrent protection.

The current sensing R/C network should be selected to match the inductor time constant as below,

$$(RCS1 // RCS2) \cdot C = \frac{L}{DCR}$$

(Notes: the actual RC network time constant may be slightly higher)

Thus, OCP1 and OCP2 levels can be configured as,

$$OCP1 = \frac{20 \text{ mV}}{DCR} \cdot \frac{RCS1 + RCS2}{RCS2}$$

$$OCP2 = \frac{30 \text{ mV}}{DCR} \cdot \frac{RCS1 + RCS2}{RCS2}$$



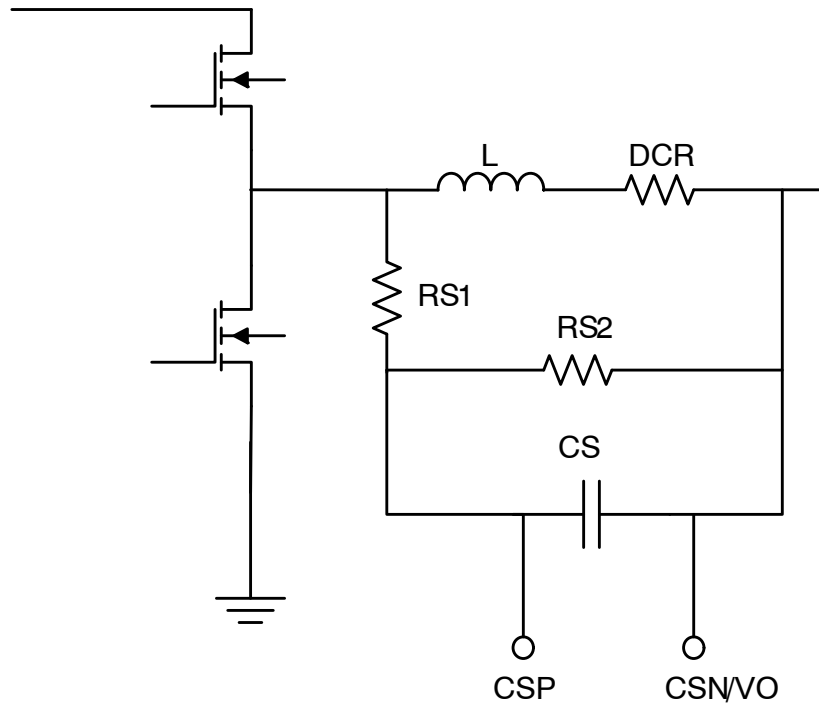


Figure 5. Differential Current Sense Network

#### Light Load Operation

In the light load condition, NCP81042 will work in a diode emulation mode with bottom gate turning off if the inductor current is below zero. The system therefore works in discontinuous conduction mode (DCM). The zero current detection is done by sensing switch node and automatically adjusted to minimize the low side FET body diode conduction time (right after LG turns off) in diode emulation mode.

If the load reduces further, COMP signal will be close or below the internal ramp bottom triggering minimum on time operation, the system will start skipping pulses, working in a reduced frequency range. NCP81042 has an internal ultrasonic timer to keep the device from working in an audio frequency and below. This timer initiates after high side gate off signal and expires after ~30  $\mu$ s.

Normally high side gate signal will reset this ultrasonic timer repeatedly before it expires. In a very light load or load release, if there is no high side gate pulses until the timer expires, the low side MOSFET(s) will be forced to turn on to discharge the output. Through properly compensated network the comp signal will climb up to generate next burst of switching pulses and the converter will regulate the output voltage to its target level. This can last a few cycles or continuously depending on the system load level.

In light load operation, if synchronization is enabled, NCP81042 will also check the SYNC pin input signal cycle by cycle. If the external sync signal is within the synchronization frequency range, the NCP81042 will interleave its switching pulses with it after a proper delay. In

this way, the ripple variation during transition between the discontinuous and continuous current mode can be minimized.

#### Voltage Feedback

The NCP81042 allow the output voltage to be adjusted from 0.8 V to 5 V via an external resistor divider network (R1, R2). The controller will regulate the output voltage to maintain the FB pin voltage to 0.8 V reference voltage. The relation between the resistor divider network and the output voltage is as below;

$$R2 = R1 \cdot \left( \frac{0.8 \text{ V}}{V_{\text{out}} - 0.8 \text{ V}} \right)$$

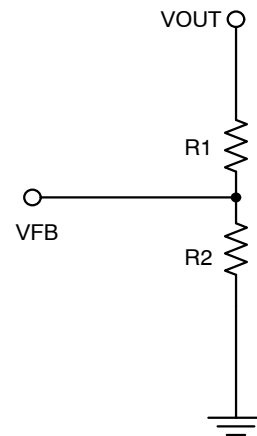


Figure 6. Feedback Voltage

# NCP81042

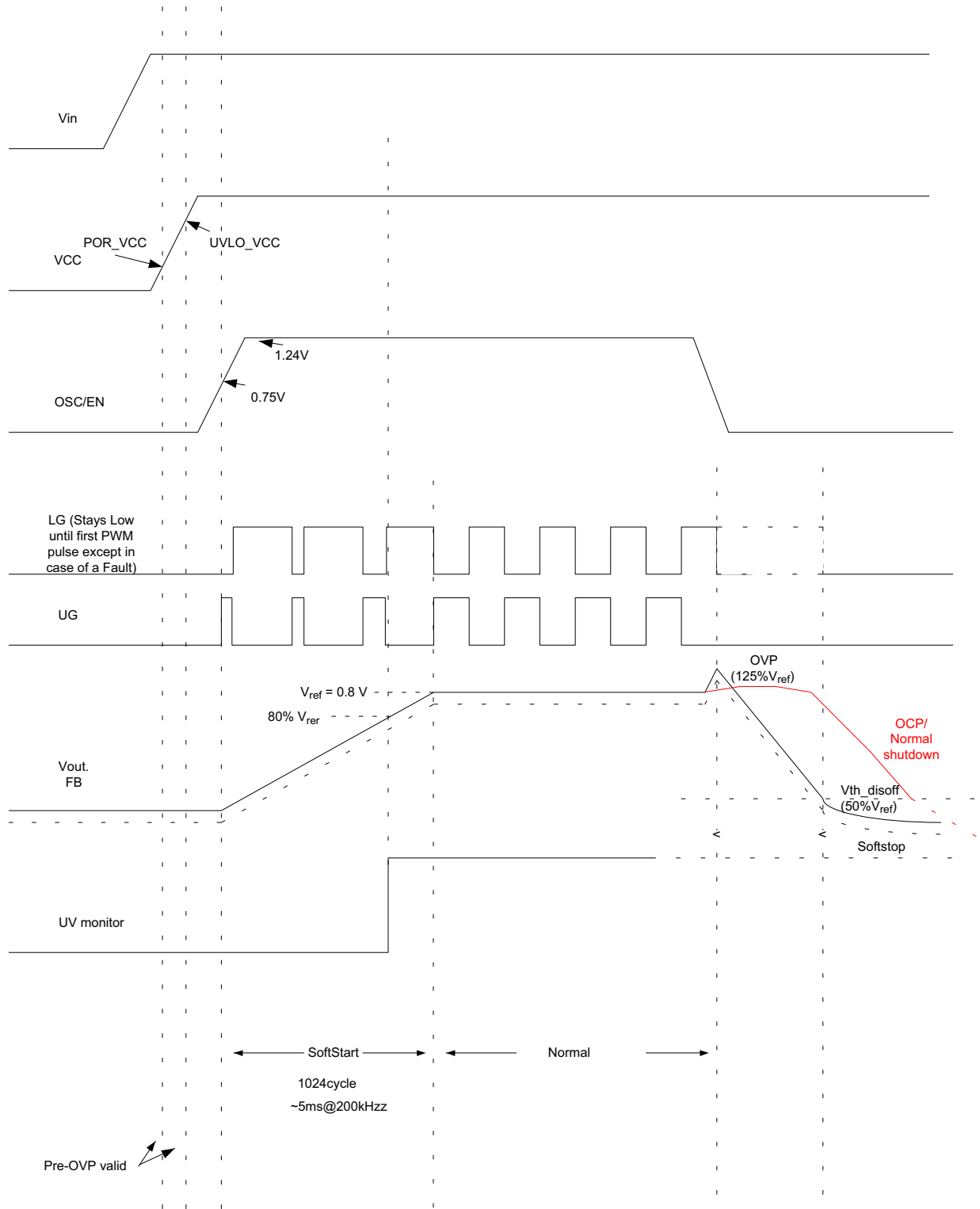


Figure 7. Start Up and Shutdown Timing Diagram

# NCP81042

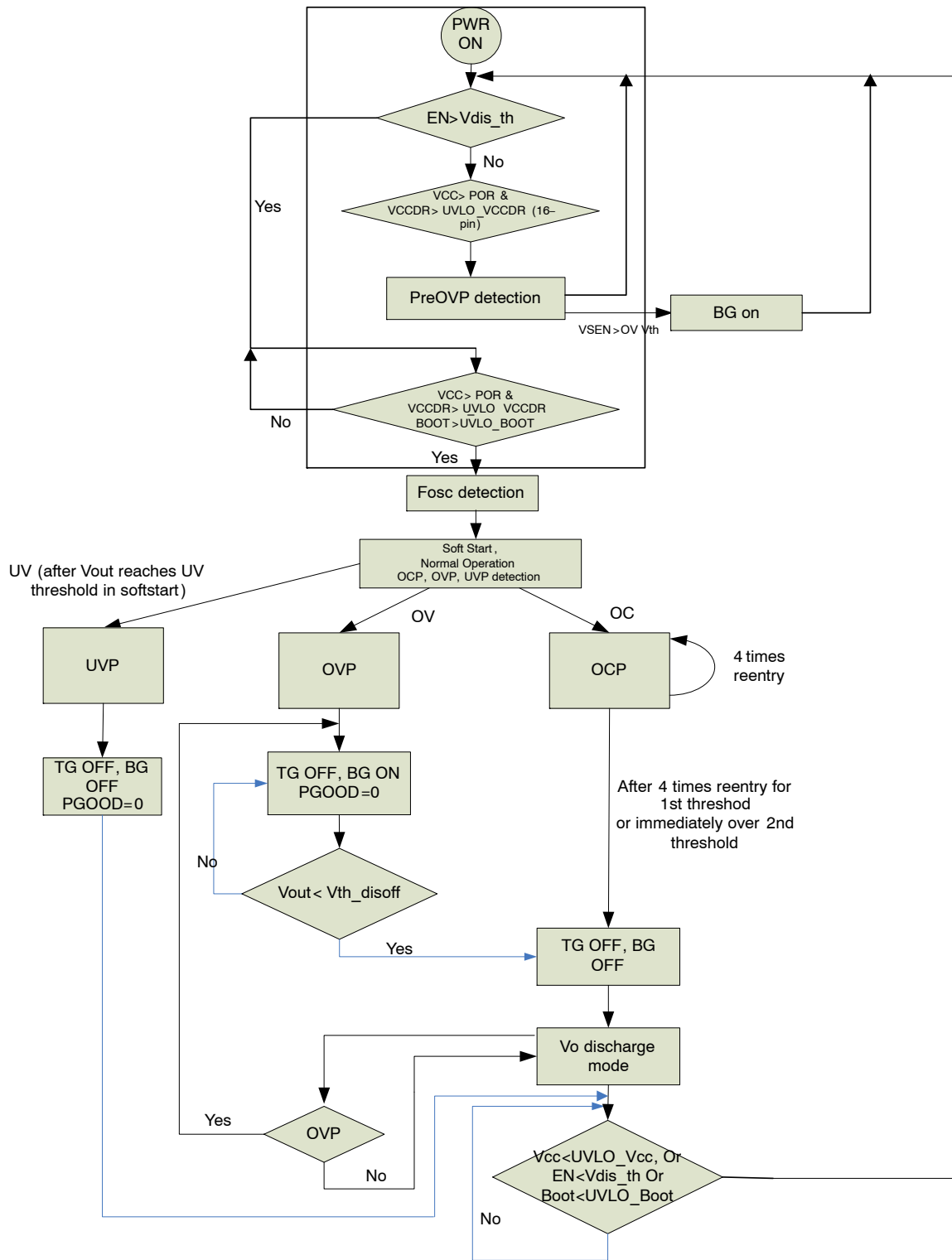
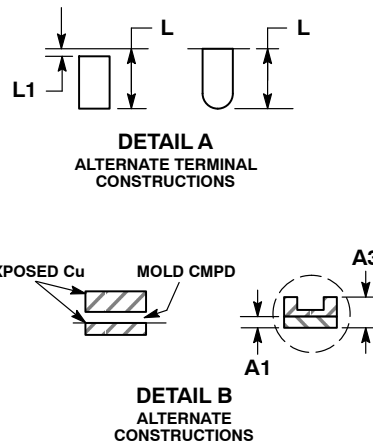
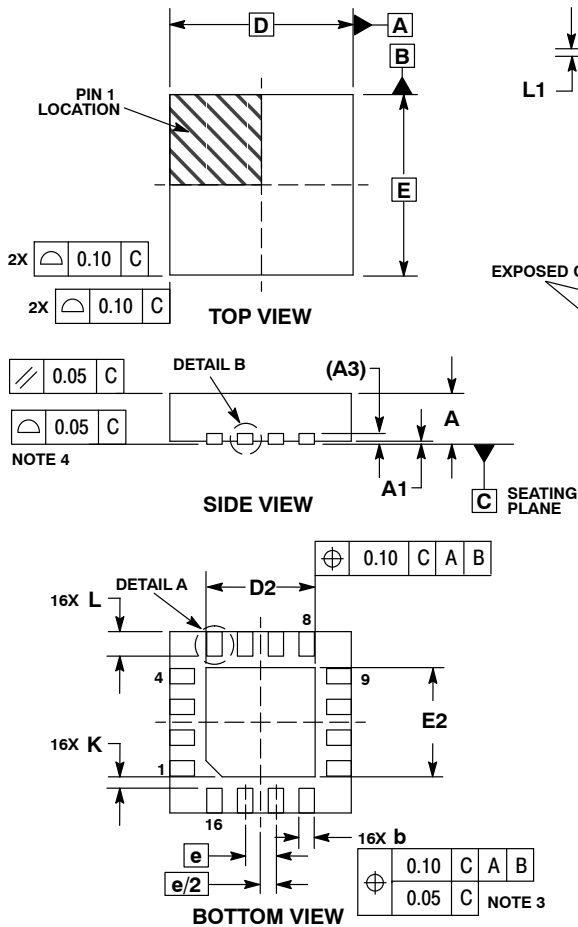


Figure 8. State Diagram

# NCP81042

## PACKAGE DIMENSIONS

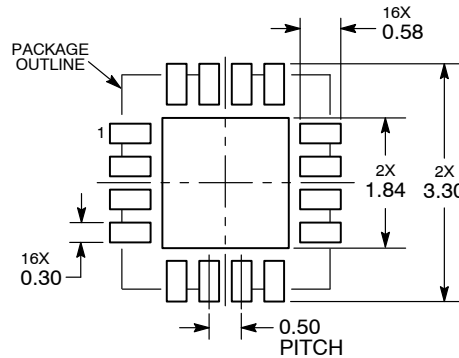
### QFN16 3x3, 0.5P CASE 485G ISSUE F



- 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 0.25 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	0.18	0.24	0.30
D	3.00 BSC		
D2	1.65	1.75	1.85
E	3.00 BSC		
E2	1.65	1.75	1.85
e	0.50 BSC		
K	0.18 TYP		
L	0.30	0.40	0.50
L1	0.00	0.08	0.15

### RECOMMENDED SOLDERING FOOTPRINT\*



DIMENSIONS: MILLIMETERS

\*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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