

Synchronous-Rectified Buck Controller

General Description

The uP1536 is a compact synchronous-rectified buck controller specifically designed to operate from 5V or 12V supply voltage and to deliver high quality output voltage as low as 0.8V. This device is capable of converting voltage from as low as 2.5 V.

The uP1536 adopts proprietary RCOT™ technology that has easy-to-use, low external component count, fast transient response and quasi constant frequency operation over the operation range features.

The controller integrates a high current capability driver to support high output current application. The bootstrap switch and loop compensator are also built-in to simplify the circuit design and minimize external part count.

The uP1536 supports diode emulation mode operation that yields high efficiency over all the output current range. The device features ultrasonic mode operation, eliminating possible audio noise.

Other features include internal soft-start, power OK indication, over/under-voltage protection, over-current protection and shutdown function. With aforementioned functions, it provides customers a compact, high efficiency, well-protected and cost-effective solutions.

Ordering Information

Order Number	Package	Remark
uP1536ADDA	WDFN3x3-10L	OCP = 200mV
uP1536BDDB		OCP = 140mV
uP1536CDDB		OCP = 100mV
uP1536DDDB		OCP = 80mV
uP1536EDDB		OCP = 40mV
uP1536FDDA		OCP = 240mV

Note: uPI products are compatible with the current IPC/ JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

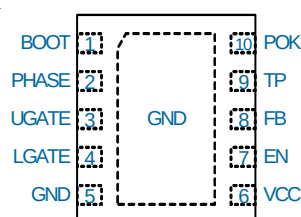
Features

- VCC Supply Voltage from 4.5V to 13.2V
- Support 19VIN Power Conversion with 5VCC
- Integrates Bootstrap Switch
- 0.8V Internal Reference with $\pm 1\%$ Accuracy
- RCOT™ (Robust Constant ON-Time) Control Architecture
 - Easy Design
 - Fast Transient Response
 - Quasi Constant Switching Frequency at 300kHz
- Automatic PWM and USM Operation
- Internal Soft-Start Control
- Power OK Indication
- OVP, UVP, UVLO, OTP
- Internal Fixed OCP Threshold (200mV)
- RoHS Compliant and Halogen Free
- WDFN3x3-10L Package

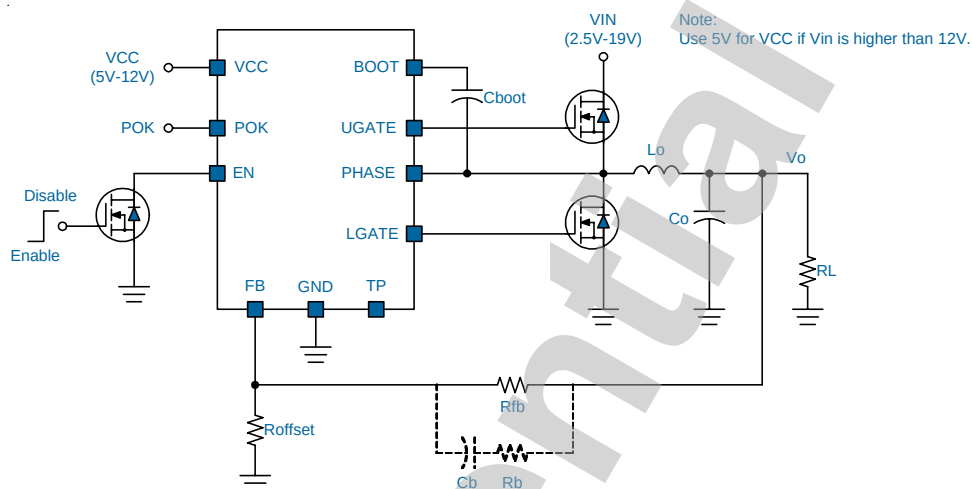
Applications

- Desktop Computers
- Graphics Cards
- Cable Modems, Set Top Boxes, and DSL Modems
- Industrial Power Supplies; General Purpose Supplies
- 5V or 12V Input DC-DC Regulators
- Low-Voltage Distributed Power Supplies

Pin Configuration



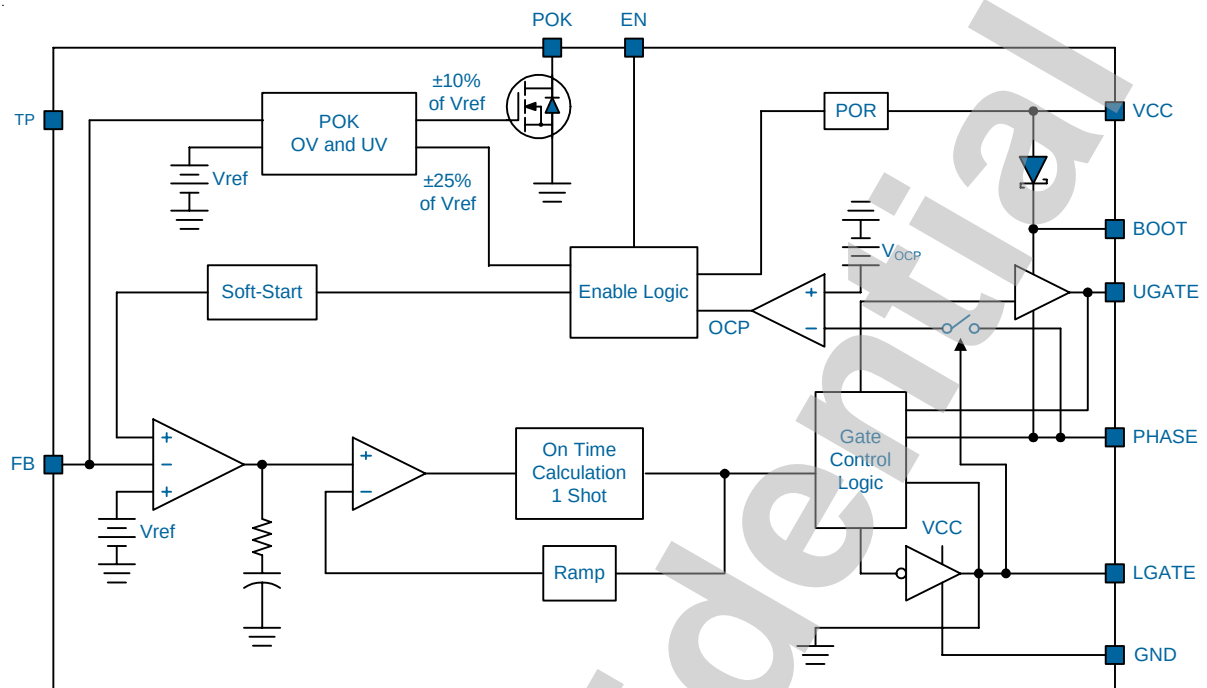
Typical Application Circuit



Functional Pin Description

No.	Pin Name	Pin Function
1	BOOT	Bootstrap Supply for the Floating Upper MOSFET Gate Driver. Connect the bootstrap capacitor C_{BOOT} between BOOT pin and the PHASE pin to form a bootstrap circuit. The bootstrap capacitor provides the charge to turn on the upper MOSFET. Ensure that C_{BOOT} is placed near the IC.
2	PHASE	Switch Node. Connect this pin to the source of the upper MOSFET and the drain of the lower MOSFET. This pin is used as the sink for the UGATE driver. This pin is also monitored by the adaptive shoot-through protection circuitry to determine when the upper MOSFET has turned off. A Schottky diode between this pin and ground is recommended to reduce negative transient voltage which is common in a power supply system.
3	UGATE	Upper MOSFET Gate Driver Output. Connect this pin to the gate of upper MOSFET. This pin is monitored by the adaptive shoot-through protection circuitry to determine when the upper MOSFET has turned off.
4	LGATE	Lower MOSFET Gate Driver Output. Connect this pin to the gate of lower MOSFET. This pin is monitored by the adaptive shoot-through protection circuitry to determine when the lower MOSFET has turned off.
5	GND	Ground.
6	VCC	Supply Voltage for the IC. This pin provides bias voltage for the IC and gate driver. Connect this pin to 5V or 12V voltage source and bypass it with a R/C filter.
7	EN	Chip Enable. Short to GND to disable the device.
8	FB	Feedback Input. This pin is the inverting input to the error amplifier. A resistor divider from output to GND is used to set regulator voltage.
9	TP	Test Pin. This pin can be left open, connected to GND (directly or through a resistor), or tied to a voltage source less than 5V(for VCC = 5V application only).
10	POK	Power OK Indicator. This pin is an open-drain output.
Exposed Pad		Ground. The exposed pad dominates heat conduction path and should be well soldered to PCB for optimal thermal performance.

Functional Block Diagram



Functional Description

Supply Voltage

The VCC pin receives a well-decoupled 4.5V to 13.2V supply voltage to power the control circuit, the lower gate driver and the bootstrap circuit for the higher gate driver. A minimum 1uF ceramic capacitor is recommended to bypass the supply voltage. Place the bypassing capacitor physically near the IC.

The uP1536 integrates MOSFET gate drives that are powered from the VCC pin and support 12V + 12V and 5V + 19V driving capability.

Power On Reset and Chip Enable

A power on reset (POR) circuitry continuously monitors the supply voltage at VCC pin. Once the rising POR threshold is exceeded, the uP1536 is reset and preparing the PWM for operation.

The rising POR threshold is typically 4.2V at VCC rising. The EN pin allows for power sequencing between the controller bias voltage and another voltage rail. The uP1536 remains in shutdown if the EN pin is pulled "Lo". When EN pin rises above the V_{ENABLE} trip point, the uP1536 will begin a new initialization and soft-start cycle.

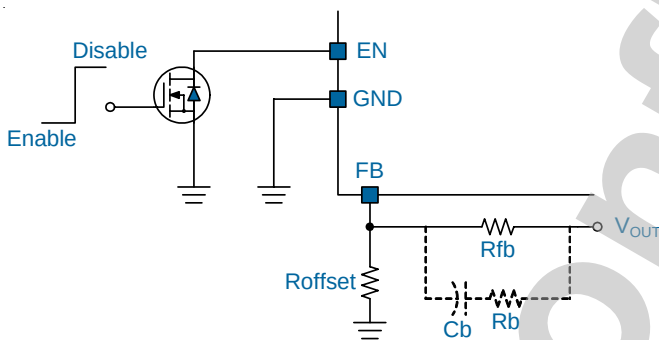


Figure 1.

Soft-Start

A built-in soft-start is used to prevent surge current from power supply input during turn on (referring to the Functional Block Diagram).

The error amplifier is a three-input device. Reference voltage (V_{REF}) or the internal soft-start voltage (V_{SS}) whichever is smaller dominates the behavior of the non-inverting input of the error amplifier.

V_{SS} internally ramps up to VCC after the soft-start cycle is initiated. The ramp is created digitally with numerous small discrete steps. Each step is with about 10mV incremental. Accordingly, the output voltage traces the V_{SS} signal and ramps up smoothly to its target level. Reference voltage V_{REF} takes over behavior of the error amplifier after $V_{SS} > V_{REF}$. The rise time of output voltage is about 2ms for uP1536.

Power Input Detection

The uP1536 detects PHASE voltage for the present of power input when the UGATE trigger minimum pulse in the beginning. If the PHASE voltage does not exceed 1.5V

during the UGATE on, the uP1536 asserts that power input is not ready and stops the soft-start cycle. However, the internal SS continues ramping up to VCC. After that, another soft-start is initiated. The hiccup period is about 2ms.

Output Voltage Selection

The lower limitation of output voltage is caused by the internal reference.

The upper limitation of the output voltage is caused by the maximum available duty cycle (Considering the maximum duty by minimum off time).

This is to leave enough time for over current detection.

Output voltage out of this range is not allowed.

A voltage divider sets the output voltage (refer to the Typical Application Circuit on page 6 for detail).

In real applications, choose R_{FB} in 1k Ω ~ 10k Ω range and choose appropriate Rocset according to the desired output voltage.

Power OK Indication

The POK is an open-drain output pin to indicate the output voltage status. It is set high-impedance after soft-start end and no fault occurs.

Ultrasonic Mode (USM) Operation

The uP1536Q features ultrasonic mode operation that maintains minimum switching frequency higher than 30kHz and out of audio frequency band. This eliminates the audio noise that may occur in pulse skipping mode at very light load condition. In USM, the lower MOSFET turns on to induce a negative inductor current and discharge the output capacitor if the switching frequency is lower than 30kHz. The control loop will initiate an on-time to turn on upper MOSFET depends on internal COMP. When the on-time operation expires, the controller re-enables the lower MOSFET until the inductor current drops below the zero-crossing threshold.

Over current Protection (OCP)

The uP1536 detects voltage drop across the lower MOSFET (V_{PHASE}) for over current protection when it is turned on. If V_{PHASE} is continuously lower than the OCP threshold (200mV typ.) for two clocks, the uP1536 asserts OCP and shuts down. During OCP, both UGATE and LGATE are latched "Lo". It could be reset by POR or toggling the EN pin. The OCP current can be calculated according the on-resistance of the lower MOSFET used.

$$I_{OCP} = \frac{V_{OCP}}{R_{DS(ON)}}$$

Inductor current ripple should be taken into consideration. The current near the valley of the ripple current is used for OCP, resulting the averaged OCP level a little higher than the calculated value.

Over Voltage and Under Voltage Protection

The uP1536 asserts over voltage protection if the V_{FB} is higher than 125% of V_{REF} . As OVP asserts, the uP1536 turns off upper MOSFET and turns on lower MOSFET immediately. After that, the uP1536 will turn off lower MOSFETs as the V_{FB} is lower than 30% of V_{REF} .

The uP1536 asserts under voltage protection if the V_{FB} is lower than 65% of V_{REF} after soft-start end. Once the uP1536 detects UVP, both the upper and lower MOSFET are turned off and V_{IN} detection circuit is enabled. If V_{IN} is detected, then the uP1536 re-start up again.

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Absolute Maximum Rating

(Note 1)

Supply Input Voltage, VCC	-0.3V to +15V
BOOT to PHASE	-0.3V to +15V
PHASE to GND	
DC	-5V to +25V
< 100ns	-10V to +40V
BOOT to GND	
DC	-0.3V to +30V
< 100ns	-0.3V to 40V
UGATE to GND	
DC	-0.3V to +30V
<100ns	-5V to +40V
UGATE to PHASE	
DC	-0.3V to +15V
<200ns	-0.5V to (BOOT - PHASE + 0.3V)
LGATE to GND	
DC	-0.3V to +(VCC + 0.3V)
<100ns	-5V to (VCC + 0.3V)
Other Pins	-0.3V to +6V
Storage Temperature Range	-65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 sec)	260°C
ESD Rating (Note 2)	
HBM (Human Body Mode)	2kV
MM (Machine Mode)	200V

Thermal Information

Package Thermal Resistance (Note 3)	
WDFN3x3-16L θ_{JA}	68°C/W
WDFN3x3-16L θ_{JC}	6°C/W
Power Dissipation, P_D @ $T_A = 25^\circ\text{C}$	
WDFN3x3-16L	1.47W

Recommended Operation Conditions

(Note 4)

Operating Junction Temperature Range	-40°C to +125°C
Operating Ambient Temperature Range	-40°C to +85°C
IC Supply Input Voltage, V_{CC}	+4.5V to 13.2V
Converter Input Voltage, V_{IN} (Note 5)	+2.5V to 19V

Note 1. Stresses listed as the above *Absolute Maximum Ratings* may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. Devices are ESD sensitive. Handling precaution recommended.

Note 3. θ_{JA} is measured in the natural convection at $T_A = 25^\circ\text{C}$ on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

Note 5. Use 5V for VCC if V_{IN} is higher than 12V.

Electrical Characteristics

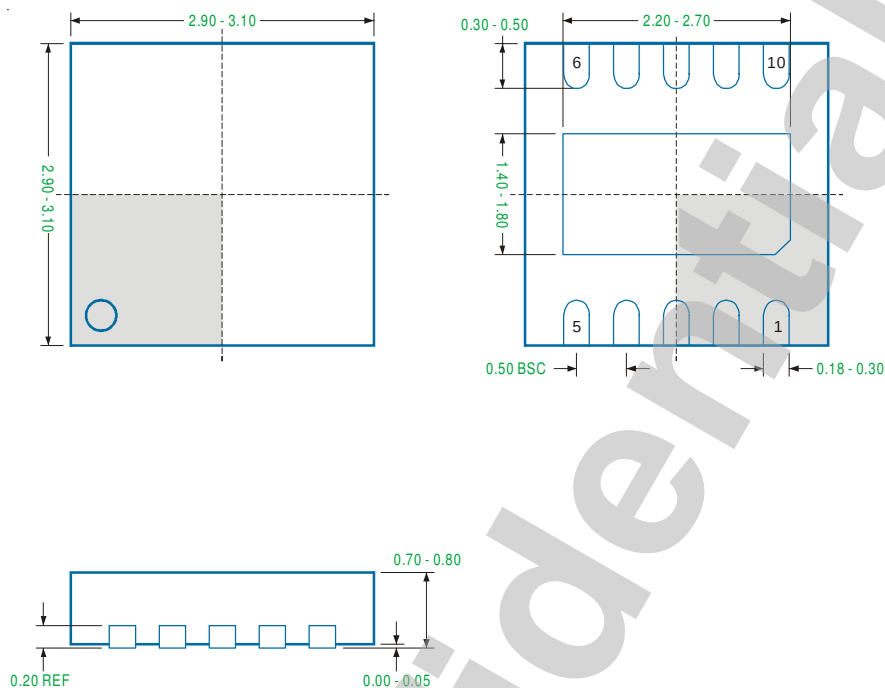
($V_{CC} = 12V$, $T_A = 25^\circ C$, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Input						
Supply Voltage	V _{CC}		4.5	--	13.2	V
VCC Quiescent Supply Current	I _{CC}	No switching, V _{CC} = 13.2V	--	2.5	--	mA
VCC UVLO Threshold	V _{POR}	V _{CC} rising	4	4.2	4.4	V
VCC UVLO Hysteresis	V _{POR_Hys}		--	0.4	--	V
Internal Bootstrap Switch						
Forward Voltage	V _{BST_F}	I _F = 10mA	--	1	--	V
Reverse Leakage Current	I _{BST_LK}	V _{BOOT} - V _{PHASE} = 19V	--	0.01	1.5	uA
Reference						
Reference Voltage	V _{REF}		0.792	0.8	0.808	V
On Time						
Nominal On Time	T _{ON_N}	V _{IN} = 12V, V _{OUT} = 1.05V	--	292	--	ns
Minimum Off Time	T _{OFF(MIN)}		--	360	--	ns
Error Amplifier						
Transconductance	G _{EA}	Guaranteed by design.	--	150	--	uA/V
Gate Drivers						
Upper Gate Source	R _{UGATE_SRC}	I _{UGATE} = 100mA, Source	--	1.36	--	Ω
Upper Gate Sink	R _{UGATE_SNK}	I _{UGATE} = 100mA, Sink	--	1.4	--	Ω
Lower Gate Source	R _{LGATE_SRC}	I _{LGATE} = 100mA, Source	--	1.17	--	Ω
Lower Gate Sink	R _{LGATE_SNK}	I _{LGATE} = 100mA, Sink	--	0.67	--	Ω
UGATE Falling to LGATE Rising Delay	T _D	UGATE-PHASE < 1V, LGATE > 1V Only Valid for CCM Operation Mode	--	25	--	ns
LGATE Falling to UGATE Rising Delay		UGATE-PHASE > 1V, LGATE < 1V Only Valid for CCM Operation Mode	--	30	--	ns
Enable and Soft-Start						
Soft-Start Time (f _{SW} = 300kHz)	T _{SS}	V _{CC} > 4.5V, EN >= Enable Threshold	--	2	--	ms
EN Pin Sourcing Current	I _{EN}	After POR, sourcing current from internal to EN pin.	--	20	--	uA
EN Pin Logic Threshold	V _{EN}	EN high	0.8	--	--	V
		EN low	--	--	0.3	

Electrical Characteristics

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Zero Current Detection						
Zero Crossing Comparator Offset	V_{ZC_OF}		-3	-2	-1	mV
Zero Current Detection Delay Time	T_{ZC}	Guaranteed by design.	--	500	--	ns
POK						
POK Delay Time	T_{POK}		--	50	--	us
POK Threshold	V_{POK}	POK in from lower, V_{FB} with respect to reference, No load.	87	90	93	%
POK Sink Current	I_{POK}	POK = 0.5V	4	--	--	mA
Protection						
OVP Threshold	V_{OVP}	V_{FB} rising	970	1000	1030	mV
LG Turn Off Threshold after OVP	V_{OVP_LATCH}	As trigger OVP; V_{FB} falling	--	0.24	--	V
OVP Delay Time	T_{OVP}		--	10	--	us
UVP Threshold	V_{UVP}	V_{FB} falling	368	525	683	mV
UVP Delay Time	T_{UVP}		--	3	--	us
OCP Trip Level	V_{OCP}	uP1536A	--	200	--	mV
		uP1536B	--	140	--	
		uP1536C	--	100	--	
		uP1536D	--	80	--	
		uP1536E	--	40	--	
		uP1536F	--	240	--	
OTP Threshold	T_{OTP}	Shutdown temperature	--	150	--	°C
		Hysteresis	--	20	--	°C

WDFN3x3 - 10L



Note

1. Package Outline Unit Description:

BSC: Basic. Represents theoretical exact dimension or dimension target

MIN: Minimum dimension specified.

MAX: Maximum dimension specified.

REF: Reference. Represents dimension for reference use only. This value is not a device specification.

TYP: Typical. Provided as a general value. This value is not a device specification.

2. Dimensions in Millimeters.

3. Drawing not to scale.

4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

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