# Onsemi

# **Fixed-Output Synchronous** TinyBoost<sup>®</sup> Regulator FAN48615

# Description

The FAN48615 is a low-power PWM only boost regulator designed to provide a minimum voltage-regulated rail from a standard single-cell Li-Ion battery and advanced battery chemistries. Even below the minimum system battery voltage, the device maintains the output voltage regulation for an output load current of 1000 mA. The combination of built-in power transistors, synchronous rectification, and low supply current suit the FAN48615 for battery-powered applications.

The FAN48615 is available in a 9-bump, 0.4 mm pitch, (1.215 x 1.215 mm) Wafer-Level Chip-Scale Package (WLCSP).

# Features

- Input Voltage Range: 2.7 V to 5.5 V
- Output Voltage: 5.25 V and 5.4 V
- 1000 mA Max. Load Capability
- PWM Only
- Up to 97% Efficient
- Forced Pass-Through Operation via EN Pin
- Internal Synchronous Rectification
- True Load Disconnect
- Short-Circuit Protection
- Year = Work = Pb-Fre work; Microdot may be in FORMATION FORMATION - Inductor, SENTATIVE • Three External Components: 2016 (Metric) 0.47 µH Inductor, 0402 Input and 0603 Output Capacitors
- This is a Pb-Free Device

# Applications

- Class–D Audio Amplifier
- Boost for Low-Voltage Li-Ion Batteries
- Smart Phones, Tablets, Portable Devices
- RF Applications
- NFC Applications



Figure 1. Typical Application

# **ORDERING INFORMATION**

Part Number	V <sub>OUT</sub>	Operating Temperature	Package	Packing	Device Marking
FAN48615UC08X	5.25 V	–40°C to 85°C	9–Bump, 0.4 mm Pitch,	3000 / Tape & Reel	KY
FAN48615UC11X	5.40 V		WLCSP Package		KZ





CASE 567QW

**MARKING DIAGRAM** 

Kx

AWLYYWW-

= Fab Indicator

= Wafer Lot

= Work Week

Note: Microdot may be in either location)

= Specific Device Code

= Assembly Location

= Pb-Free Package

10

KY / KZ

F

A

WL

# **Block Diagram**



Figure 2. IC Block Diagram

# **Table 1. RECOMMENDED COMPONENTS**

Component	Description	Vendor	Parameter	Typical Value	Unit
L1	20%, 5.3 A, 2016, 1.0 mm Height	DFE201610E-R47M	Inductance	470	nH
		TOKO	DCR (Series R)	26	mΩ
C <sub>IN</sub>	20%, 6.3 V, X5R, 0402 (1005)	C1005X5R0J106M050BC TDK	Capacitance	10	μF
C <sub>OUT</sub>	20%, 10 V, X5R, 0603 (1608)	C1608X5R1A106K080AC TDK	Capacitance	10	μF
THIS	DEVICE IS NOTED	TATIVE			

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# **Pin Configuration**



(Bumps Down)

(Bumps Up)

Figure 3. Pin Assignment

# **Pin Definitions**

# **Table 2. PIN DEFINITIONS**

Pin Definitions Table 2. PIN DEFIN	TIONS	DESIGN
Pin #	Name	Description
A1	VOUT	Output Voltage. This pin is the output voltage terminal; connect directly to $C_{OUT}$ .
A2		
A3	VIN	Input Voltage. Connect to Li-Ion battery input power source and CIN.
B1	SW	Switching Node. Connect to inductor.
B2		CNV IR 2N
B3	EN	<b>Enable</b> . When this pin is HIGH, the circuit is enabled. After part is engaged, pin forces part into Forced-Pass-Through Mode when EN pin is pulled LOW.
C1	PGND	Power Ground. This is the power return for the IC. $\mathrm{C}_{\mathrm{OUT}}$ capacitor should be returned
C2		with the shortest path possible to these pins.
C3	AGND	Analog Ground. This is the signal ground reference for the IC. All voltage levels are measured with respect to this pin – connect to PGND at a single point.
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### **Table 3. ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter			Max	Unit
V <sub>IN</sub>	Voltage on VIN Pin		-0.3	6.0	V
V <sub>OUT</sub>	Voltage on VOUT Pin		-0.3	6.0	V
V <sub>SW</sub>	SW Node	DC	-0.3	6.0	V
		Transient: 10 ns, 3 MHz	-1.0	8.0	
V <sub>CC</sub>	Voltage on Other Pins			6.0 <sup>(1)</sup>	V
ESD	Electrostatic Discharge Protection Level	c Discharge Protection Level Human Body Model, ANSI/ESDA/ 2.0 JEDEC JS-001-2012		.0	kV
	Charged Device Model, JESD22-C101		1.0		
TJ	Junction Temperature		-40	150	°C
T <sub>STG</sub>	Storage Temperature		-65	150	°C
TL	Lead Soldering Temperature, 10 Seconds			260	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected. A DESK

1. Lesser of 6.0 V or  $V_{IN}$  + 0.3 V.

# **Table 4. RECOMMENDED OPERATING CONDITIONS**

Symbol	Parameter	Min Max	Unit
V <sub>IN</sub>	Supply Voltage for Boost & Auto Pass Through Operation (2)	2)7 5.5	V
I <sub>OUT</sub>	Maximum Output Current	01000	mA
T <sub>A</sub>	Ambient Temperature	-40 85	°C
TJ	Junction Temperature	<b>O</b> –40 125	°C

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.
When V<sub>IN</sub> nears V<sub>OUT</sub> the part will automatically go into pass through mode, depending on load current.

# Table 5. THERMAL PROPERTIES

Symbol	Parameter	Typical	Unit
$\theta_{JA}$	Junction-to-Ambient Thermal Resistance	50	°C/W

NOTE: Junction-to-ambient thermal resistance is a function of application and board layout. This data is measured with four-layer 2s2p boards with vias in accordance to JEDEC standard JESD51. Special attention must be paid not to exceed junction temperature, THIS DE  $T_{J(max)}$ , at a given ambient temperature,  $T_A$ .

# FAN48615

# **Table 6. ELECTRICAL CHARACTERISTICS**

Recommended operating conditions, unless otherwise noted, circuit per Figure 1, V<sub>OUT</sub> = 5.40 V. Typical, minimum and maximum values are given at  $V_{IN}$  = 3.6 V,  $T_A$  = 25°C, -40°C and +85°C.

Symbol	Parameter	Conditions	Min	Тур	Max	Unit
Power Supply	/					
Ι <sub>Q</sub>	V <sub>IN</sub> Quiescent Current	I <sub>OUT</sub> = 0 mA, EN = 1.8 V, No Switching		95		μA
		Forced Pass–Through EN = 0 V, $V_{OUT} = V_{IN}$		3.5		
V <sub>UVLO</sub>	Under-Voltage Lockout	V <sub>IN</sub> Rising		2.20		V
V <sub>UVLO_HYS</sub>	Under-Voltage Lockout Hysteresis			150		mV
Inputs						
VIH	Enable HIGH Voltage		1.05			V
V <sub>IL</sub>	Enable LOW Voltage				0.4	V
Outputs	•					
V <sub>REG</sub>	Output Voltage Accuracy DC (3)	$2.7 \text{ V} \leq \text{V}_{\text{IN}} \leq 4.5 \text{ V}$	-2		+2	%
Timing	•				S	
f <sub>SW</sub>	Switching Frequency	I <sub>OUT</sub> = 300 mA	1.8	2.3	2.8	MHz
t <sub>SS</sub> <sup>(4)</sup>	EN HIGH to 95% of Regulation	I <sub>OUT</sub> = 150 mA		440		μs
t <sub>RST</sub> <sup>(4)</sup>	FAULT Restart Timer		12	20		ms
Power Stage	•		2r			
R <sub>DS(ON)N</sub>	N-Channel Boost Switch R <sub>DS(ON)</sub>		i.	63		mΩ
R <sub>DS(ON)P</sub>	P-Channel Sync. Rectifier R <sub>DS(ON)</sub>			52		mΩ
3. DC I <sub>LOAD</sub> fro 4. Guaranteed	om 0 to 1 A. V <sub>OUT</sub> measured from mid- by design and characterization; not tes	point of output voltage ripple. Effective capacitanted in production.	nce of Co	UT ≥ 2.2 μ	F.	

# **Typical Performance Characteristics**

Unless otherwise specified;  $V_{IN} = 3.8$  V,  $V_{OUT} = 5.40$  V,  $T_A = 25^{\circ}$ C, and circuit according to Figure 1.

Components:  $C_{IN} = 10 \ \mu F$  (0402, X5R, 6.3 V, C1005X5R0J106M050BC),  $C_{OUT} = 10 \ \mu F$  (0603, X5R,

10 V, C1608X5R1A106K080AC), L1 = 470 nH (2016, 26 mΩ, DFE201610E–R47M ).



Figure 4. Quiescent Current (Switching) vs. Input Voltage and Temperature







Figure 8. Switching Frequency vs. Load Current and Input Voltage





Figure 7. Efficiency vs. Load Current and Temperature



Figure 9. Switching Frequency vs. Load Current and Temperature

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Figure 10. Output Regulation vs. Load Current and Input Voltage







10 V, C1608X5R1A106K080AC), L1 = 470 nH (2016, 26 mΩ, DFE201610E-R47M ).





40.0µs 2.50GS/s 20M points

🌀 1.00 V 🔍

S 3.60 V

100mV %

# **Typical Performance Characteristics**

Unless otherwise specified;  $V_{IN} = 3.8 \text{ V}$ ,  $V_{OUT} = 5.40 \text{ V}$ ,  $T_A = 25^{\circ}\text{C}$ , and circuit according to Figure 1.

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10 V, C1608X5R1A106K080AC), L1 = 470 nH (2016, 26 mΩ, DFE201610E-R47M ).



# **CIRCUIT DESCRIPTION**

FAN48615 is a synchronous PWM Only boost regulator. The regulator's Pass–Through Mode automatically activates when VIN is above the boost regulator's set point.

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Mode	Description	Invoked When:
LIN	Linear Startup	V <sub>IN</sub> > V <sub>OUT</sub>
SS	Boost Soft-Start	V <sub>IN</sub> < V <sub>OUT</sub> < V <sub>OUT(TARGET)</sub>
BST	Boost Operating Mode	$V_{OUT} = V_{OUT(TARGET)}$
PT	Pass-Through Mode	V <sub>IN</sub> > V <sub>OUT(TARGET)</sub> or when EN is pulled LOW after initial startup

### Table 7. OPERATING MODES

### **Boost Mode Regulation**

The FAN48615 uses a current-mode modulator to achieve excellent transient response.

**Table 8. BOOST STARTUP SEQUENCE** 

Start Mode	Entry	Exit	End Mode	Timeout (μs)
LIN1	V <sub>IN</sub> >	$V_{OUT} > V_{IN} - 300 \text{ mV}$	SS	
	EN = 1	Timeout	LIN2	512
LIN2	LIN1 Exit	$V_{OUT} > V_{IN} - 300 \text{ mV}$	SS	
		Timeout	FAULT	1024
SS	LIN1 or LIN2 Exit	V <sub>OUT</sub> = V <sub>OUT(TARGET)</sub>	BST	
		Overload Timeout	FAULT	64

### LIN Mode

When EN is HIGH and  $V_{IN} > V_{UVLO}$ , the regulator first attempts to bring  $V_{OUT}$  within 300 mV of  $V_{IN}$  by using the internal fixed-current source from VIN (Q2). The current is limited to the LIN1 set point.

If  $V_{OUT}$  reaches  $V_{IN}$ -300 mV during LIN1 Mode, the SS Mode is initiated. Otherwise, LIN1 times out after 512  $\mu$ s and LIN2 Mode is entered.

In LIN2 Mode, the current source is incremented. If  $V_{OUT}$  fails to reach  $V_{IN}$ -300 mV after 1024  $\mu$ s, a fault condition is declared and the device waits 20 ms to attempt an automatic restart.

# Soft-Start (SS) Mode

Upon the successful completion of LIN Mode ( $V_{OUT} \ge V_{IN}$ - 300 mV), the regulator begins switching with boost pulses current limited to 50% of nominal level.

During SS Mode, if  $V_{OUT}$  fails to reach regulation during the SS ramp sequence for more than 64  $\mu$ s, a fault is declared. If large  $C_{OUT}$  is used, the reference is automatically stepped slower to avoid excessive input current draw.

# Boost (BST) Mode

This is a normal operating mode of the regulator.

# Pass-Through Mode

The device allows the user to force the device in Forced Pass–Through Mode through the EN pin. If the EN pin is pulled HIGH, the device starts operating in Boost Mode. Once the EN pin is pulled LOW, the device is forced into Pass–Through Mode. To disable the device, the input supply voltage must be removed. The device cannot startup in Forced Pass–Through Mode (*see Figure 18*). During startup, keep the EN pulled HIGH for at least 350 µs before pulling it LOW in order to make sure that the device enters Pass–Through Mode reliably.

In normal operation, the device automatically transitions from Boost Mode to Pass–Through Mode if VIN goes above the target  $V_{OUT}$ . In Pass–Through Mode, the device fully enhances Q2 to provide a very low impedance path from VIN to VOUT. Entry to the Pass–Through Mode is triggered by condition where  $V_{IN} > V_{OUT}$  and no switching has occurred during the past 5 µs. To soften the entry into Pass–Through Mode, Q2 is driven as a linear current source for the first 5 µs. Pass–Through Mode exit is triggered when  $V_{OUT}$  reaches the target  $V_{OUT}$  voltage. During Automatic Pass–Through Mode, the device is short–circuit protected by a voltage comparator tracking the voltage drop from  $V_{IN}$ to  $V_{OUT}$ ; if the drop exceeds 300 mV, a fault is declared.



Figure 18. Pass-Through Profile

# **Current Limit Protection**

The FAN48615 has valley current limit protection in case of overload situations. The valley current limit will prevent high current from causing damage to the IC and the inductor. The current limit is halved during soft–start.

When starting into a fault condition, the input current will be limited by LIN1 and LIN2 current threshold.

# Fault State

The regulator enters Fault State under any of the following conditions:

- V<sub>OUT</sub> fails to achieve the voltage required to advance from LIN Mode to SS Mode.
- V<sub>OUT</sub> fails to achieve the voltage required to advance from SS Mode to BST Mode.

- Boost current limit triggers for 2 ms during BST Mode.
- V<sub>IN</sub> V<sub>OUT</sub> > 300 mV; this fault can occur only after successful completion of the soft–start sequence.
- $V_{IN} < V_{UVLO}$

Once a fault is triggered, the regulator stops switching and presents a high–impedance path between VIN and VOUT. After waiting 20 ms, an automatic restart is attempted.

# **Over-Temperature**

The regulator shuts down if the die temperature exceeds  $150^{\circ}$ C and restarts when the IC cools by ~ $20^{\circ}$ C.

# Layout Recommendation

The layout recommendations below highlight various top-copper pours by using different colors.

To minimize spikes at VOUT, COUT must be placed as close as possible to PGND and VOUT, as shown in Figure 19.

For best thermal performance, maximize the pour area for all planes other than SW. The ground pour, especially, should fill all available PCB surface area and be tied to internal layers with a cluster of thermal vias.





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# Table 9. PRODUCT-SPECIFIC PACKAGE DIMENSIONS

The following information applies to the WLCSP package dimensions on the next page.

Product	D (mm)	E (mm)	X (mm)	Y (mm)
FAN48615UC08X	$1.215\pm0.030$	1.215 ± 0.030	0.2075	0.2075
THIS DE	NCE IS NOTE NCE PLEASE REPRESE	ECONTACTOR CONTACTOR		

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