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November 2016

FAN49100 — 2.5 A, 1.8 MHz, TinyPower™ Buck-Boost Regulator

Features

- 24 µA Typical PFM Quiescent Current
- Above 95% Efficiency
- Total Layout Area = 11.61 mm^2
- Input Voltage Range: 2.5 V to 5.5 V
- 1.8 MHz Fixed-Frequency Operation in PWM Mode
- Automatic / Seamless Step-up and Step-down Mode Transitions
- Forced PWM and Automatic PFM/PWM Mode Selection
- 0.5 µA Typical Shutdown Current
- Low Quiescent Current Pass-Through Mode
- Internal Soft-Start and Output Discharge
- Low Ripple and Excellent Transient Response
- Internally Set, Automatic Safety Protections (UVLO, OTP, SCP, OCP)
- Package: 20 Bump, 0.4 mm Pitch WLCSP

Applications

- Smart Phones
- Tablets, Netbooks®, Ultra-Mobile PCs
- Portable Devices with Li-ion Battery
- 2G/3G/4G Power Amplifiers
- NFC Applications

Description

The FAN49100 is a high efficiency buck-boost switching mode regulator which accepts input voltages either above or below the regulated output voltage. Using full-bridge architecture with synchronous rectification, the FAN49100 is capable of delivering up to 2.5 A at 3.6 V input while regulating the output at 3.3 V. The FAN49100 exhibits seamless transition between step-up and step-down modes reducing output disturbances.

At moderate and light loads, Pulse Frequency Modulation (PFM) is used to operate the device in power-save mode to maintain high efficiency. In PFM mode, the part still exhibits excellent transient response during load steps. At moderate to heavier loads or Forced PWM mode, the regulator switches to PWM fixed-frequency control. While in PWM mode, the regulator operates at a nominal fixed frequency of 1.8 MHz, which allows for reduced external component values.

The FAN49100 is available in a 20-bump 1.615 mm x 2.015 mm with 0.4 mm pitch WLCSP.

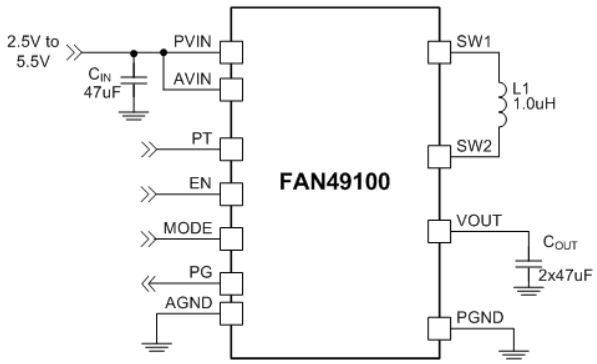

Figure 1. Typical Application

Ordering Information

Part Number	Output Voltage(1)	Output Discharge	Temperature Range	Package	Packing Method	Device Marking
FAN49100AUC330X	3.3 V	Yes	-40 to 85°C	20-Ball (WLCSP)	Tape and Reel	FD
FAN49100AUC360X	3.6 V					FE

Note:

1. Additional VOUT values are available, contact ON representative.

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Block Diagram

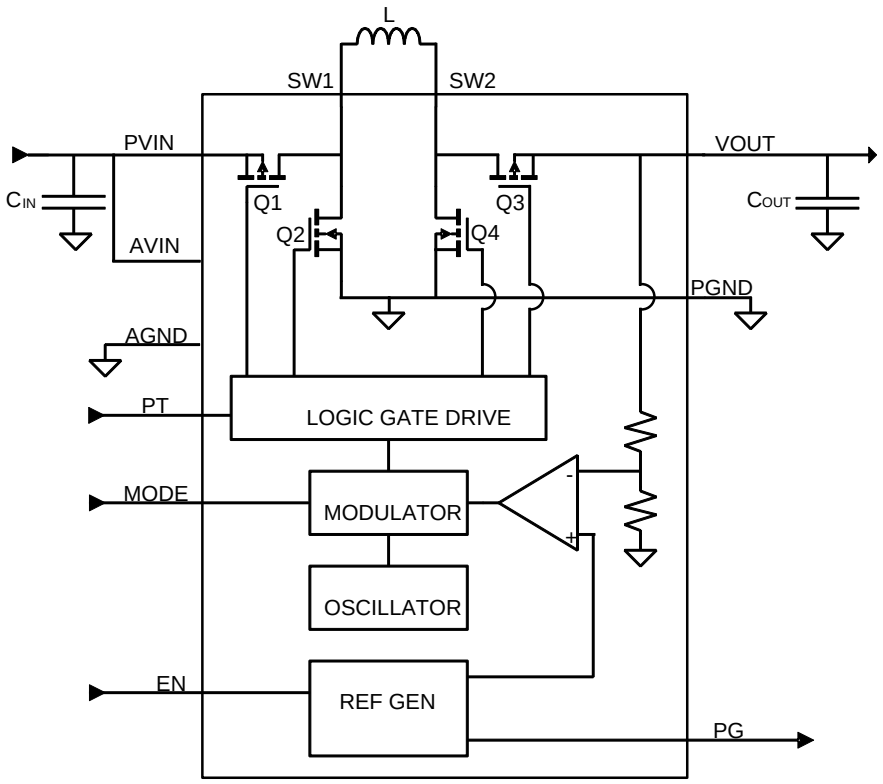

Figure 2. Block Diagram

Pin Configuration

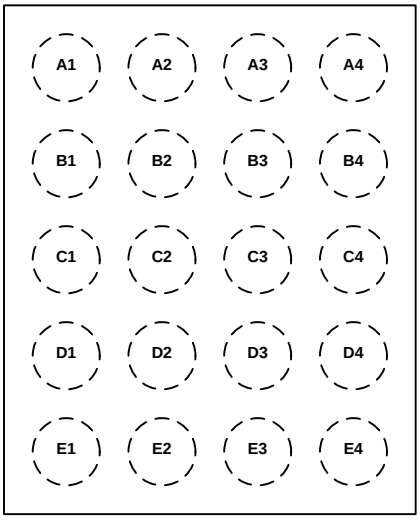

Figure 3. Top View (bump down)

Pin Definitions[2]

Pin #	Name	Description
A3, A4	PVIN	**Power Input Voltage.** Connect to input power source. Connect to C_{IN} with minimal path.
A1	AVIN	**Analog Input Voltage.** Analog input for device. Connect to C_{IN} and PVIN.
A2	EN	**Enable.** A HIGH logic level on this pin forces the device to be enabled. A LOW logic level forces the device into shutdown. EN pin can be tied to VIN or driven via a GPIO logic voltage.
B3, B4	SW1	**Switching Node 1.** Connect to inductor L1.
E1	AGND	**Analog Ground.** Control block signal is referenced to this pin. Short AGND to PGND at GND pad of C_{OUT}.
B1, C1, C2, C3, C4, D1	PGND	**Power Ground.** Low-side MOSFET of buck and main MOSFET of boost are referenced to this pin. C_{IN} and C_{OUT} should be returned with a minimal path to these pins.
D2	MODE	**Forced PWM / AUTO Mode.** HIGH logic level on this pin forces the chip to stay in PWM mode, while LOW logic level allows the chip to automatically switch between PFM and PWM modes. Don't leave the pin floating.
D3, D4	SW2	**Switching Node 2.** Connect to inductor L1.
E2	PG	**Power Good.** This is an open-drain output and normally High Z. An external pull-up resistor from VOUT can be used to generate a logic HIGH. PG is pulled LOW if output falls out of regulation due to current overload or if thermal protection threshold is exceeded. If EN is LOW, PG is high impedance.
B2	PT	**Pass-Through.** HIGH logic level forces Pass-Through mode. A LOW logic level forces normal operation. Don't leave the pin floating.
E3, E4	VOUT	**Output Voltage.** Buck-Boost Output. Connect to output load and C_{OUT}.

Note:

2. Refer to Layout Recommendation section located near the end of the datasheet.

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Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter		Min.	Max.	Unit
PVIN/AVIN	PVIN/AVIN Voltage		-0.3	6.5	V
VOUT	VOUT Voltage		-0.3	6.5	V
SW1, SW2	SW Nodes Voltage		-0.3	7.0	V
	Other Pins		-0.3	6.5	V
ESD	Electrostatic Discharge Protection Level	Human Body Model per JESD22-A114	2000		V
		Charged Device Model per JESD22-C101	1000		
T_J	Junction Temperature		-40	+150	°C
T_{STG}	Storage Temperature		-65	+150	°C
T_L	Lead Soldering Temperature, 10 Seconds			+260	°C

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. ON does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter	Min.	Typ.	Max.	Unit
PVIN	Supply Voltage Range	2.5		5.5	V
I_{OUT}	Output Current[3]	0		2.5	A
L	Inductor[6]		1.0		µH
C_{IN}	Input Capacitance[3,4,5,6]	2	47		µF
C_{OUT}	Output Capacitance[3,4,5,6]	17	47		µF
T_A	Operating Ambient Temperature	-40		+85	°C
T_J	Operating Junction Temperature	-40		+125	°C

Notes:

3. Depends on input and output voltages. Thermal properties of the device should be taken into consideration; refer to Thermal Consideration in the Application Information section.
4. Typical value reflects the capacitor value needed to meet minimum requirement. Minimum passive component values indicate effective capacitance which includes temperature, voltage de-rating, tolerance, and stability.
5. Output capacitance affects load transient response and loop phase margin; see Application Information section.
6. Refer to Additional Application Information section.

Thermal Properties

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
θ_{JA}	Junction-to-Ambient Thermal Resistance[7]		66		°C/W

Note:

7. See Thermal Considerations in the Application Information section.

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Electrical Characteristics [8]

Minimum and maximum values are at PVIN = AVIN = 2.5 V to 5.5 V, T_A = -40°C to +85°C. Typical values are at T_A = 25°C, PVIN = AVIN = V_{EN} = 3.6 V, VOUT = 3.3 V.[9]

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Power Supplies						
I_Q	Quiescent Current	PFM Mode, I_{OUT} = 0 mA[10]		24		µA
		PT Mode, I_{OUT} = 0 mA		27		µA
I_{SD}	Shutdown Supply Current	EN = GND, PVIN = 3.6 V		0.5	5.0	µA
V_{UVLO}	Under-Voltage Lockout Threshold	Falling PVIN	1.95	2.00	2.05	V
V_{UVHYST}	Under-Voltage Lockout Hysteresis			200		mV
EN, MODE, PT						
V_{IH}	HIGH Level Input Voltage		1.1			V
V_{IL}	LOW Level Input Voltage				0.4	V
I_{IN}	Input Bias Current Into Pin	Input Tied to GND or PVIN		0.01	1.00	µA
PG						
V_{PG}	PG LOW	I_{PG} = 5 mA			0.4	V
I_{PG_LK}	PG Leakage Current	V_{PG} = 5 V			1	µA
Switching						
f_{SW}	Switching Frequency	PVIN = 3.6 V, T_A = 25°C	1.6	1.8	2.0	MHz
I_{p_LIM}	Peak PMOS Current Limit	PVIN = 3.6 V	4.6	5.2	5.9	A
Accuracy						
V_{OUT_ACC}	DC Output Voltage Accuracy	PVIN = 3.6 V, Forced PWM, I_{OUT} = 0 mA, VOUT = 3.3 V	3.267	3.300	3.333	V
		PVIN = 3.6 V, PFM Mode, I_{OUT} = 0 mA, VOUT = 3.3 V	3.267	3.375	3.458	

Notes:

8. Refer to Typical Characteristics waveforms/graphs for Closed-Loop data and its variation with input voltage and ambient temperature. Electrical Characteristics reflects Open-Loop steady state data. System Characteristics reflects both steady state and dynamic Close-Loop data associated with the recommended external components.
9. Minimum and Maximum limits are verified by design, test, or statistical analysis. Typical (Typ.) values are not tested, but represent the parametric norm.
10. Device is not switching.

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System Characteristics

The following table is verified by design and bench test while using circuit of Figure 1 with the following external components: L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO). Typical values are at T_A = 25°C, PVIN = AVIN = V_{EN} = 3.6 V, VOUT = 3.3 V. These parameters are not verified in production.

Symbol	Parameter		Min.	Typ.	Max.	Unit
V_{OUT_ACC}	Total Accuracy (Includes DC accuracy and load transient)[11]			±5		%
ΔV_{OUT}	Load Regulation	I_{OUT} = 0.4 A to 2.0 A, PVIN = 3.6 V		-0.10		%/A
ΔV_{OUT}	Line Regulation	3.0 V ≤ PVIN ≤ 4.2 V, I_{OUT} = 1.5 A		-0.06		%/V
V_{OUT_RIPPLE}	Ripple Voltage	PVIN = 4.2 V, VOUT = 3.3 V, I_{OUT} = 1 A, PWM Mode		4		mV
		PVIN = 3.6 V, VOUT = 3.3 V, I_{OUT} = 100 mA, PFM Mode		22		
		PVIN = 3.0 V, VOUT = 3.3 V, I_{OUT} = 1 A, PWM Mode		14		
η	Efficiency	PVIN = 3.0 V, VOUT = 3.3 V, I_{OUT} = 75 mA, PFM		90		%
		PVIN = 3.0 V, VOUT = 3.3 V, I_{OUT} = 500 mA, PWM		96		
		PVIN = 3.8 V, VOUT = 3.3 V, I_{OUT} = 100 mA, PFM		91		
		PVIN = 3.8 V, VOUT = 3.3 V, I_{OUT} = 600 mA, PWM		96		
		PVIN = 3.4 V, VOUT = 3.3 V, I_{OUT} = 300 mA, PWM		93		
T_{SS}	Soft-Start	EN HIGH to 95% of Target VOUT, I_{OUT} = 68 mA		260		µs
ΔV_{OUT_LOAD}	Load Transient	PVIN = 3.4 V, I_{OUT} = 0.5 A ⇔ 1 A, T_R = T_F = 1 µs		±45		mV
		PVIN = 3.4 V, I_{OUT} = 0.5 A ⇔ 2.0 A, T_R = T_F = 1 µs, Pulse Width = 577 µs		±125		
ΔV_{OUT_LINE}	Line Transient	PVIN = 3.0 V ⇔ 3.6 V, T_R = T_F = 10 µs, I_{OUT} = 1 A		±60		mV

Note:

11. Load transient is from 0.5 A <-> 1 A.

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Typical Characteristics

Unless otherwise noted, PVIN = AVIN = V_{EN} = 3.6 V, VOUT = 3.3 V, L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO), AUTO Mode.

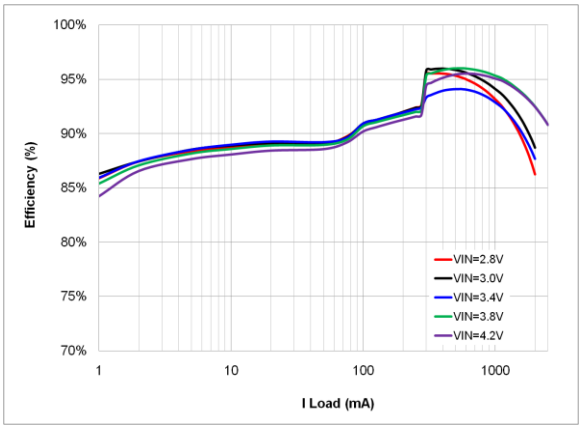

Figure 4. Efficiency vs. Load

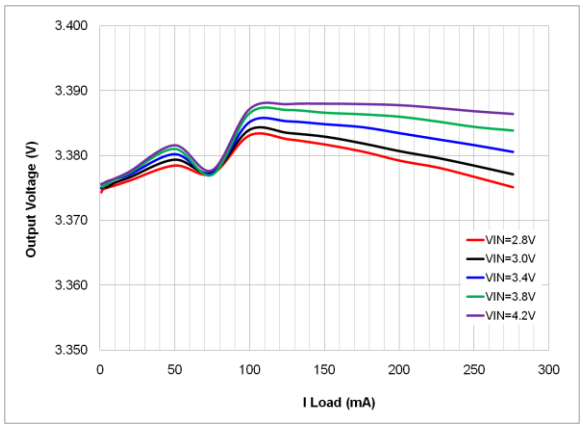

Figure 5. Output Regulation vs. Load

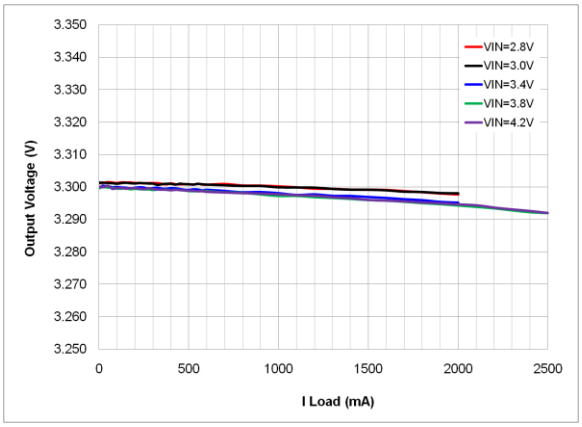

Figure 6. Output Regulation vs. Load, PWM Mode

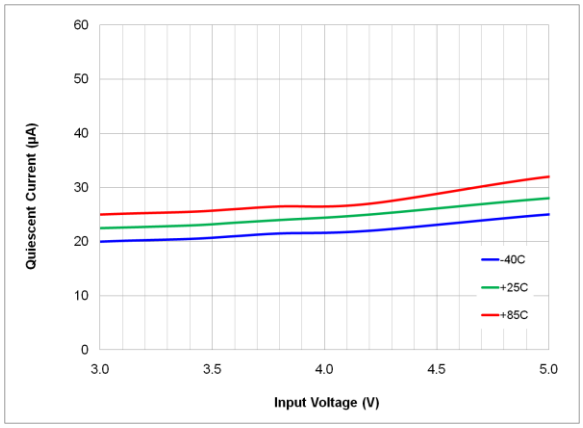

Figure 7. Quiescent Current (No Switching) vs. Input Voltage

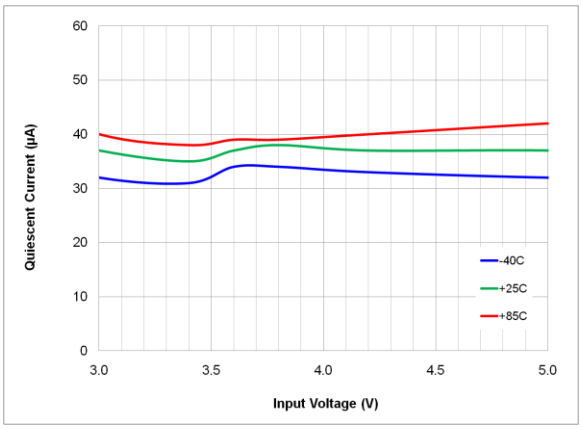

Figure 8. Quiescent Current (Switching) vs. Input Voltage

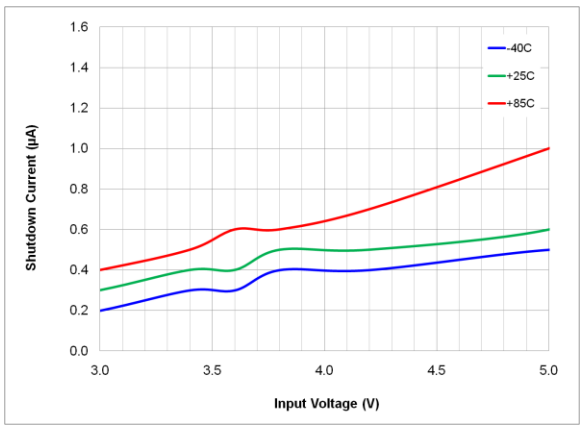

Figure 9. Shutdown Current vs. Input Voltage

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Typical Characteristics (Continued)

Unless otherwise noted, PVIN = AVIN = V_{EN} = 3.6 V, VOUT = 3.3 V, L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO), AUTO Mode.

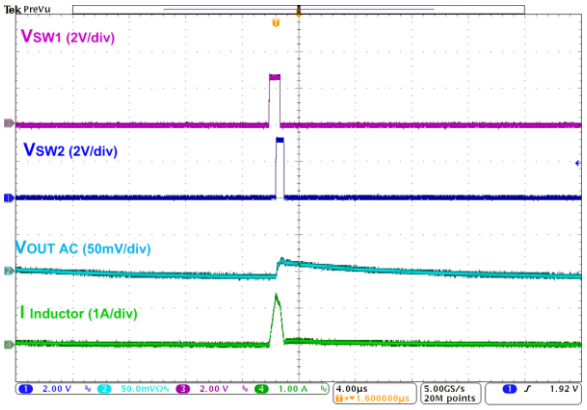

Figure 10. Output Ripple, VIN = 2.8 V, I_{OUT} = 20 mA, Boost Operation

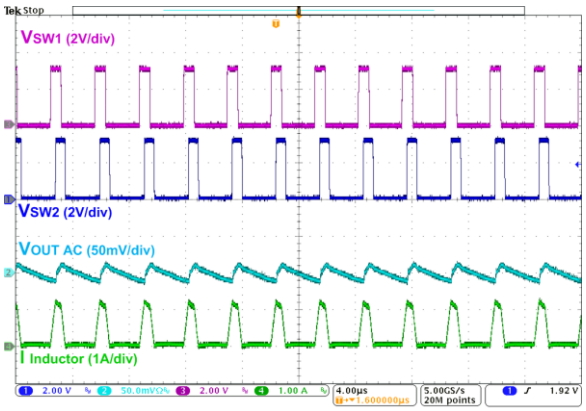

Figure 11. Output Ripple, VIN = 3.3 V, I_{OUT} = 200 mA, Buck-Boost Operation

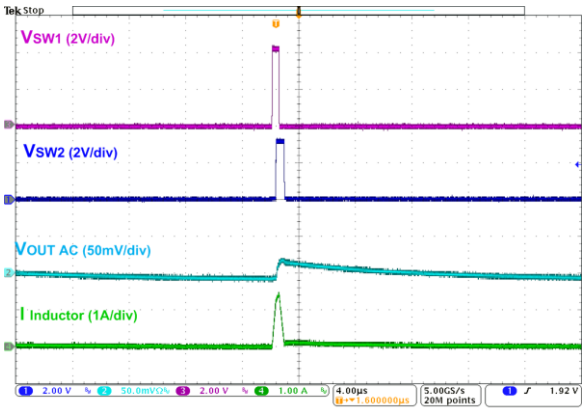

Figure 12. Output Ripple, VIN = 4.2 V, I_{OUT} = 20 mA, Buck Operation

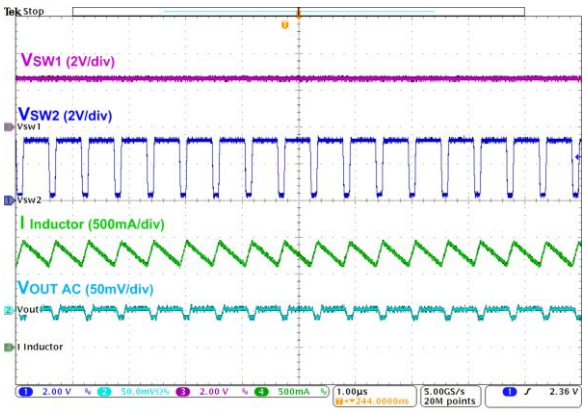

Figure 13. Output Ripple, VIN = 2.5 V, I_{OUT} = 1000 mA, Boost Operation

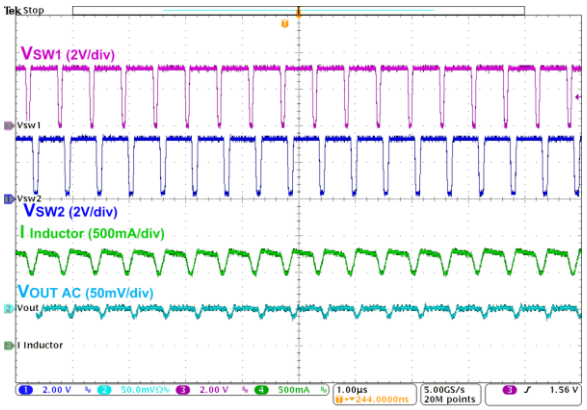

Figure 14. Output Ripple, VIN = 3.3 V, I_{OUT} = 1000 mA, Buck-Boost Operation

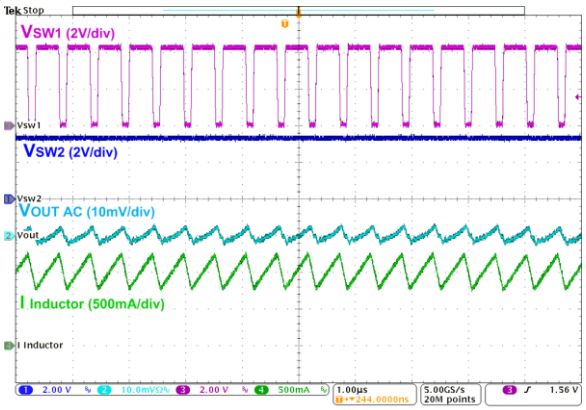

Figure 15. Output Ripple, VIN = 4.5 V, I_{OUT} = 1000 mA, Buck Operation

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Typical Characteristics (Continued)

Unless otherwise noted, PVIN = AVIN = V_{EN} = 3.6 V, VOUT = 3.3 V, L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO), AUTO Mode.

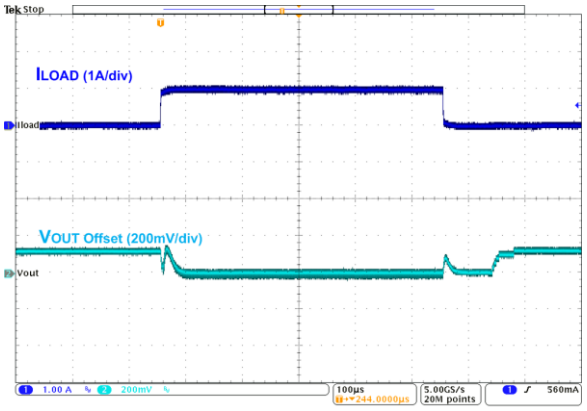

Figure 16. Load Transient, 0 mA <--> 1000 mA, 1 µs Edge, VIN = 3.60 V

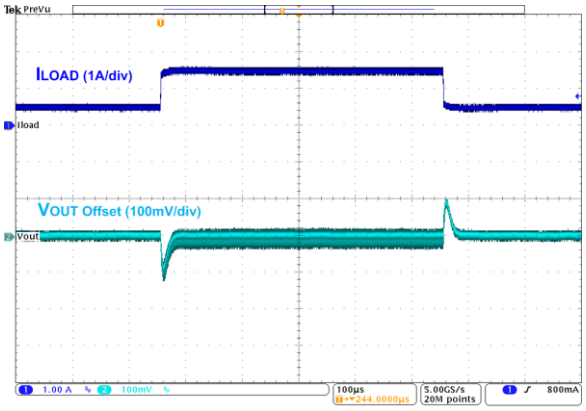

Figure 17. Load Transient, 500 mA <--> 1500 mA, 1 µs Edge, VIN = 3.60 V

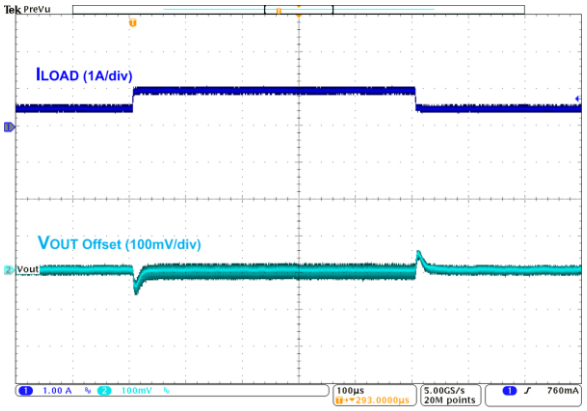

Figure 18. Load Transient, 500 mA <--> 1000 mA, 1 µs Edge, VIN = 3.40 V

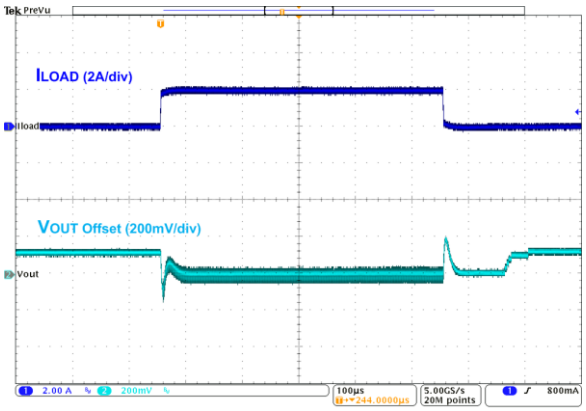

Figure 19. Load Transient, 0 mA <--> 2000 mA, 1 µs Edge, VIN = 3.60 V

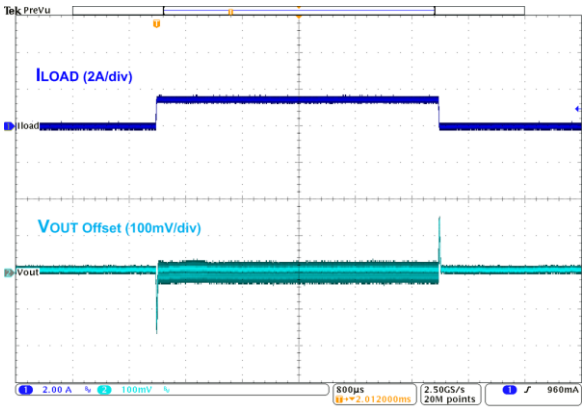

Figure 20. Load Transient, 0 mA <--> 1500 mA, 10 µs Edge, VIN = 2.80 V, PWM Mode

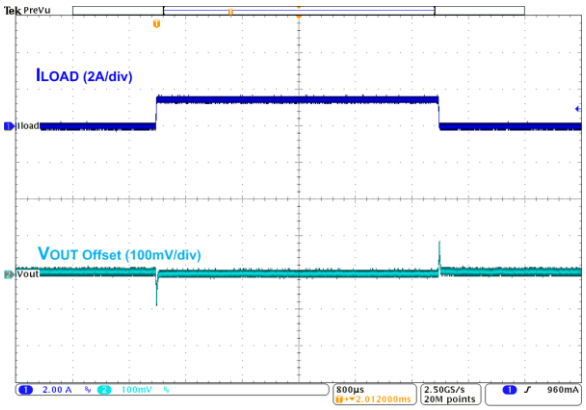

Figure 21. Load Transient, 0 mA <--> 1500 mA, 10 µs Edge, VIN = 4.20 V, PWM Mode

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Typical Characteristics (Continued)

Unless otherwise noted, PVIN = AVIN = VEN = 3.6 V, VOUT = 3.3 V, L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO), AUTO Mode.

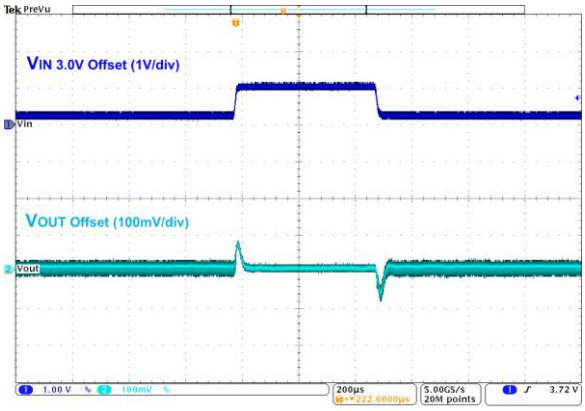

Figure 22. Line Transient, 3.2 <--> 4.0 VIN, 10 µs Edge, 1000 mA Load

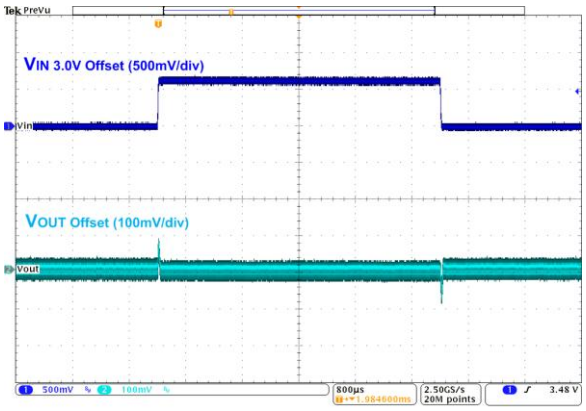

Figure 23. Line Transient, 3.0 <--> 3.6 VIN, 10 µs Edge, 1500 mA Load, PWM

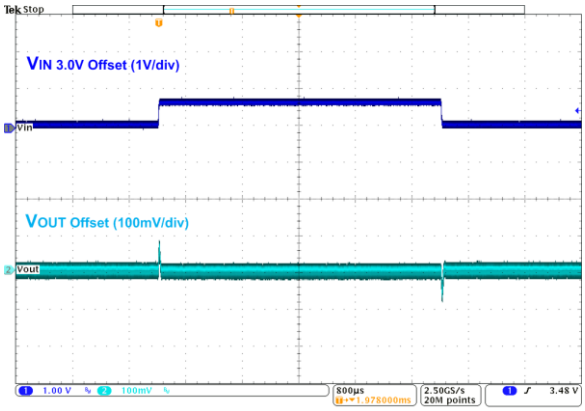

Figure 24. Line Transient, 3.0 <--> 3.6 VIN, 10 µs Edge, 1000 mA Load, PWM

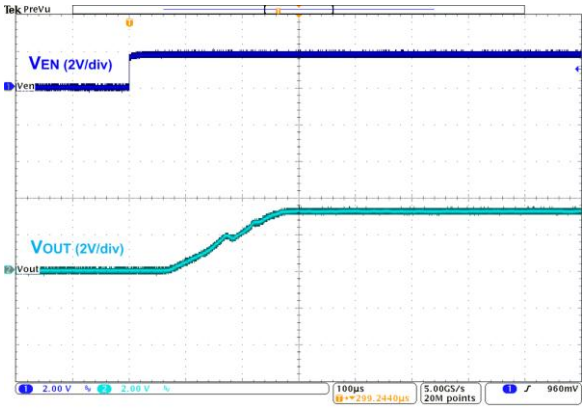

Figure 25. Startup, VIN = 3.6 V, I_{OUT} = 0 mA

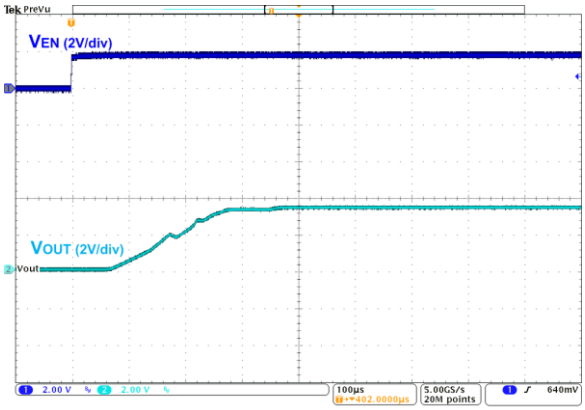

Figure 26. Startup, VIN = 3.6 V, I_{OUT} = 68 mA

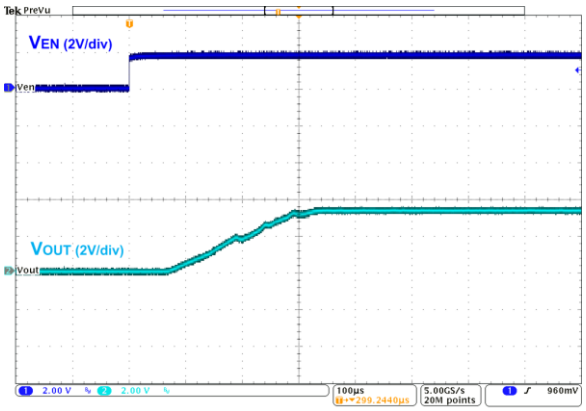

Figure 27. Startup, VIN = 3.6 V, I_{OUT} = 1000 mA

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Typical Characteristics (Continued)

Unless otherwise noted, PVIN = AVIN = VEN = 3.6 V, VOUT = 3.3 V, L = 1.0 µH, DFE201612E-1R0M (TOKO), C_{IN} = 47 µF, C_{OUT} = 2 x 47 µF, 0603 (1608 metric) CL10A476MQ8NZNE (SEMCO), AUTO Mode.

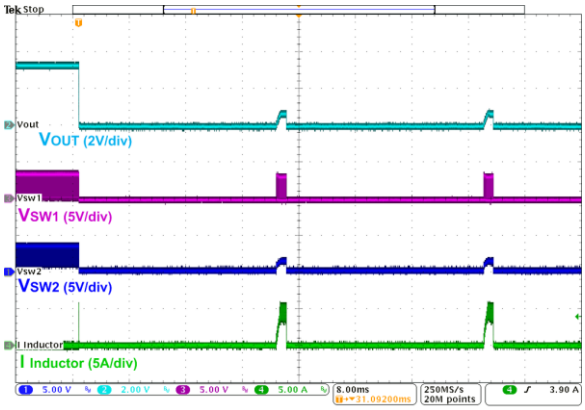

Figure 28. Short-Circuit Protection

Application Information

Functional Description

FAN49100 is a fully integrated synchronous, full bridge DC-DC converter that can operate in buck operation (during high PVIN), boost operation (for low PVIN) and a combination of buck-boost operation when PVIN is close to the target VOUT value. The PWM/PFM controller switches automatically and seamlessly between buck, buck-boost and boost modes.

The FAN49100 uses a four-switch operation during each switching period when in the buck-boost mode. Mode operation is as follows: referring to the power drive stage shown in Figure 29, if PVIN is greater than target VOUT, then the converter is in buck mode: Q3 is ON and Q4 is OFF continuously leaving Q1, Q2 to operate as a current-mode controlled PWM converter. If PVIN is lower than target VOUT then the converter is in boost mode with Q1 ON and Q2 OFF continuously, while leaving Q3, Q4 to operate as a current-mode boost converter. When PVIN is near VOUT, the converter goes into a 3-phase operation in which combines a buck phase, a boost phase and a reset phase; all switches are switching to maintain an average inductor volt-second balance.

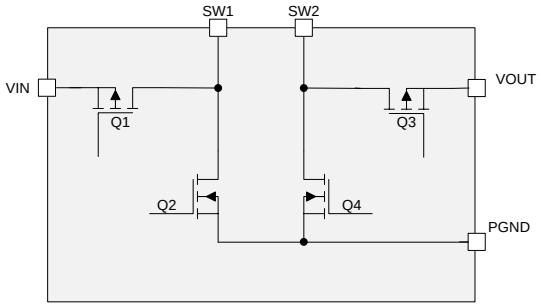

Figure 29. Simplified Block Diagram

PFM/PWM Mode

The FAN49100 uses a current-mode modulator to achieve smooth transitions between PWM and PFM operation. In Pulsed Frequency Modulation (PFM), frequency is reduced to maintain high efficiency. During PFM operation, the converter positions the output voltage typically 75 mV higher than the nominal output voltage during PWM operation, allowing additional headroom for voltage drop during a load transient from light to heavy load. As the load increased from light loads, the converter enters PWM operation typically at 300 mA of current load. The converter switching frequency is typically 1.8 MHz during PWM operation for moderate to heavy load currents.

PT (Pass-Through) Mode

In Pass-Through mode, all of the switches are not switching and VOUT tracks PVIN (VOUT = PVIN – I_{OUT} *($Q1_{RDSON}$ + $Q3_{RDSON}$ +L_{DCR}) In PT mode only Over-Temperature (OTP) and Under Voltage Lockout (UVLO) protection circuits are activated. There is no Over-Current Protection (OCP) in PT mode.

Shutdown and Startup

When the EN pin is LOW, the IC is shut down, all internal circuits are off, and the part draws very little current. During shutdown, VOUT is isolated from PVIN. Raising EN pin activates the device and begins the soft-start cycle. During soft-start, the modulator's internal reference is ramped slowly to minimize surge currents on the input and prevent overshoot of the output voltage. If VOUT fails to reach target VOUT value after 1 ms, a FAULT condition is declared.

Over-Temperature (OTP)

The regulator shuts down when the die temperature exceeds 150°C. Restart occurs when the IC has cooled by approximately 20°C.

Output Discharge

When the regulator is disabled and driving the EN pin LOW, a 230 Ω internal resistor is activated between VOUT and GND. The Output Discharge is not activated during a FAULT state condition.

Over-Current Protection (OCP)

If the peak current limit is activated for a typical 700 µs, a FAULT state is generated, so that the IC protects itself as well as external components and load.

FAULT State

The regulator enters the FAULT state under any of the following conditions:

- VOUT fails to achieve the voltage required after soft-start.
- Peak current limit triggers.
- OTP or UVLO are triggered.

Once a FAULT is triggered, the regulator stops switching and presents a high-impedance path between PVIN and VOUT. After waiting 30 ms, a restart is attempted.

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Power Good

PG, an open-drain output, is LOW during FAULT state and HIGH for Power Good.

The PG pin is provided for signaling the system when the regulator has successfully completed soft-start and no FAULTs have occurred. PG pin also functions as a warning flag for high die temperature and overload conditions.

- PG is released HIGH when the soft-start sequence is successfully completed.
- PG is pulled LOW when a FAULT is declared.

Any FAULT condition causes PG to be de-asserted.

Thermal Considerations

For best performance, the die temperature and the power dissipated should be kept at moderate values.

The maximum power dissipated can be evaluated based on the following relationship:

$$P_{D(max)} = \left\{ \frac{T_{J(max)} - T_A}{\Theta_{JA}} \right\} \quad (1)$$

where $T_{J(max)}$ is the maximum allowable junction temperature of the die; T_A is the ambient operating temperature; and θ_{JA} is dependent on the surrounding PCB layout and can be improved by providing a heat sink of surrounding copper ground.

The addition of backside copper with through-holes, stiffeners, and other enhancements can help reduce θ_{JA}. The heat contributed by the dissipation of devices nearby must be included in design considerations. Following the layout recommendation may lower the θ_{JA}.

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Additional Application Information

Table 1. Recommended Capacitors

Capacitor	Part Number	Vendor	Value	Case Size	Rating
C_{IN}	CL10A476MQ8NZNE	SEMCO	47 µF	0603 (1608 Metric)	6.3 V
C_{OUT}	CL10A476MQ8NZNE	SEMCO	2 x 47 µF	0603 (1608 Metric)	6.3 V

Output Capacitance (C_{OUT}) and Input Capacitance (C_{IN}) Stability

The effective capacitance (C_{EFF}) of small, high-value, ceramic capacitors will decrease as bias voltage increases. FAN49100 is guaranteed for stable operation with the minimum value of 17 µF ($C_{EFF(MIN)}$) output capacitance when using a 1 µH value inductor and a minimum value of 13 µF ($C_{EFF(MIN)}$) output capacitance when using a 0.47 µH value inductor. Furthermore, FAN49100 is guaranteed for stable operation with the minimum value of 2 µF ($C_{EFF(MIN)}$) input capacitance. De-rating factors should be taken into consideration to ensure selected components meet minimum requirement.

Table 2. Minimum C_{EFF}[12] Required for Stability

VOUT (V)	I_{LOAD} (A)	Inductor Value	$C_{EFF(MIN)}$
3.3 V	0 – 2.5 A	1.0 µH	17 µF
3.3 V	0 – 2.5 A	0.47 µH	13 µF

Note:

12. C_{EFF} is defined as the capacitance value during operating conditions and not the capacitor value. A capacitor varies with manufacturer, material, case size, voltage rating and temperature.

Inductor Selection

Recommended nominal inductance value is 1.0 µH. An inductor value of 0.47 µH can be used but higher peak currents could lead to lower efficiency; however, transient response performance may be improved. FAN49100 employs peak current limiting and the peak inductor current can reach typically 5.2 A for a short duration during overload conditions. Therefore, current saturation value should be taken into consideration when choosing an inductor.

Table 3. Recommended Inductors

Part Number	Vendor	Value	Dimension	Isat	DCR
DFE201610E1R0M	TOKO	1.0 µH	2.0 mm x 1.6 mm x 1.0 mm	3.9 A	48 mΩ
DFE201612E1R0M			2.0 mm x 1.6 mm x 1.2 mm	4.4 A	40 mΩ
DFE201610ER47M		0.47 µH[13] (Optional)	2.0 mm x 1.6 mm x 1.0 mm	5.3 A	26 mΩ
DFE201612ER47M			2.0 mm x 1.6 mm x 1.2 mm	6.1 A	20 mΩ

Note:

13. When using 0.47 µH inductor value, one 47 µF (CL10A476MQ8NZNE) capacitor can be used at the output of the regulator.

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Layout Recommendations

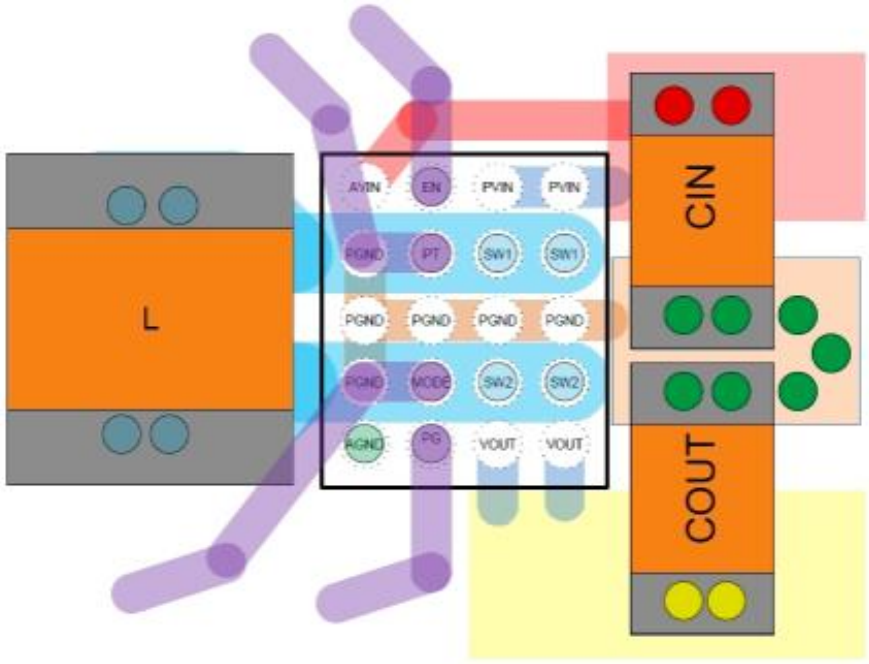

Figure 30. Component Placement and Routing for FAN49100

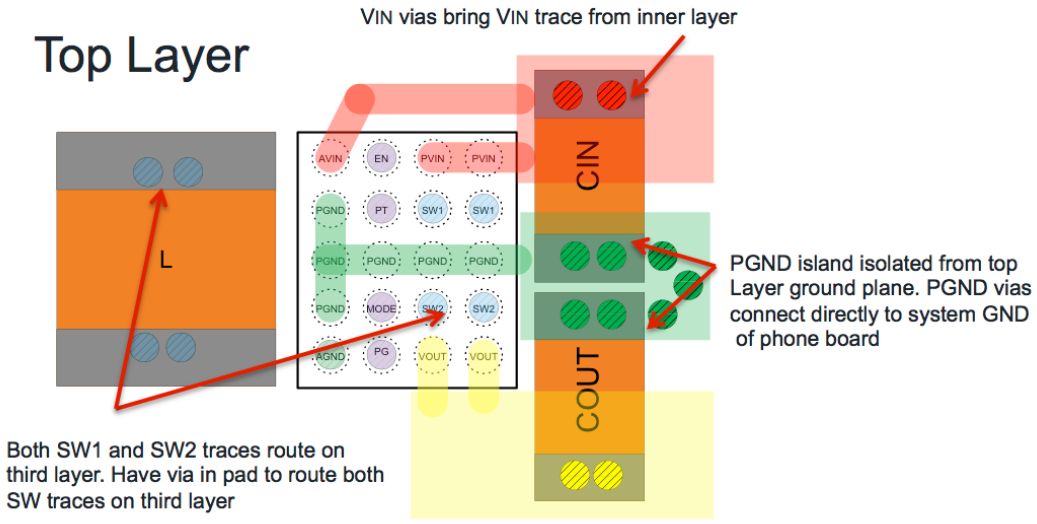

Figure 31. Top Layer Routing for FAN49100

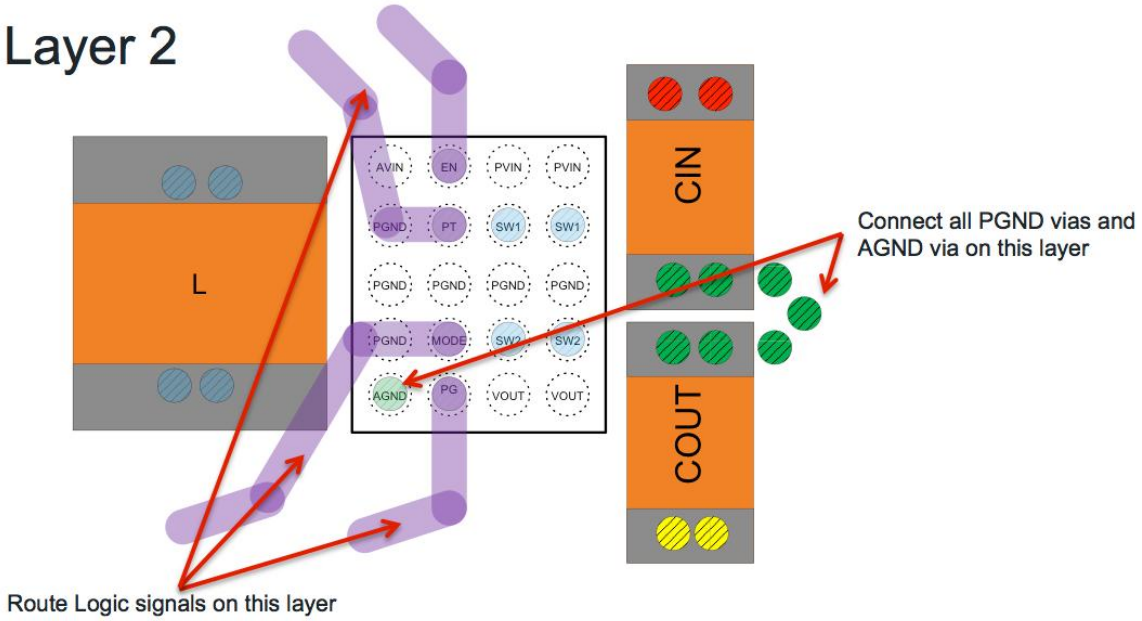

Figure 32. Layer 2 Routing for FAN49100

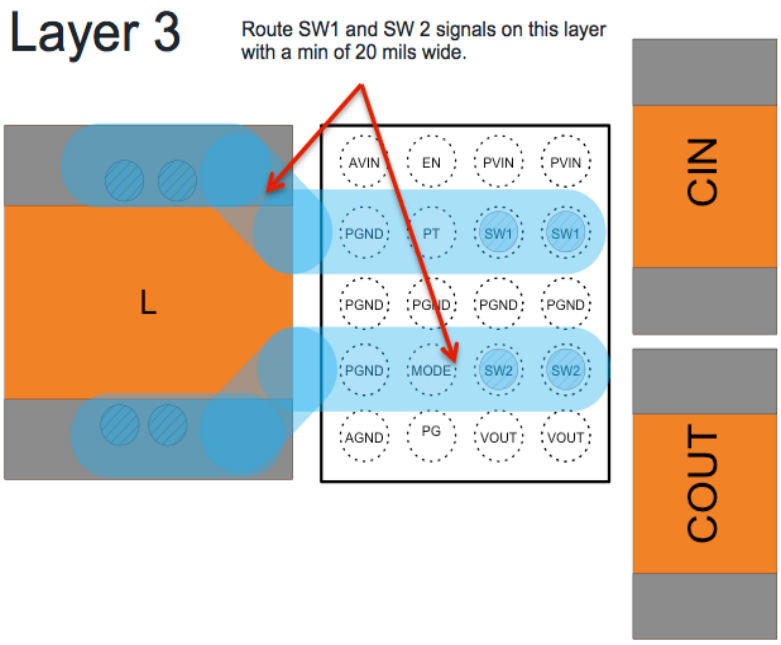

Figure 33. Layer 3 Routing for FAN49100

Physical Dimensions

This table information applies to the Package drawing on the following page.

Product	D	E	X	Y
FAN49100AUC330X	2.015 ±0.030	1.615 ±0.030	0.2075	0.2075
FAN49100AUC360X	2.015 ±0.030	1.615 ±0.030	0.2075	0.2075

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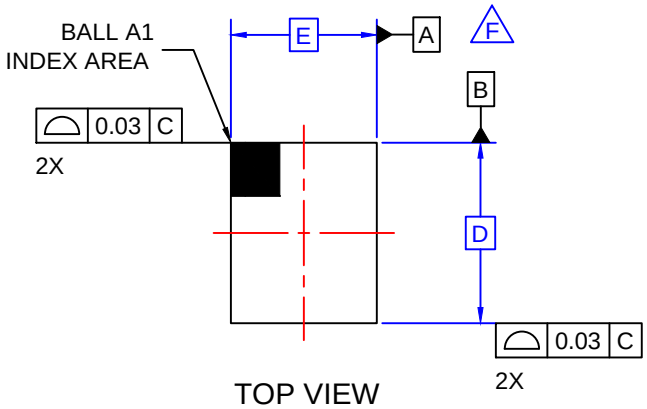
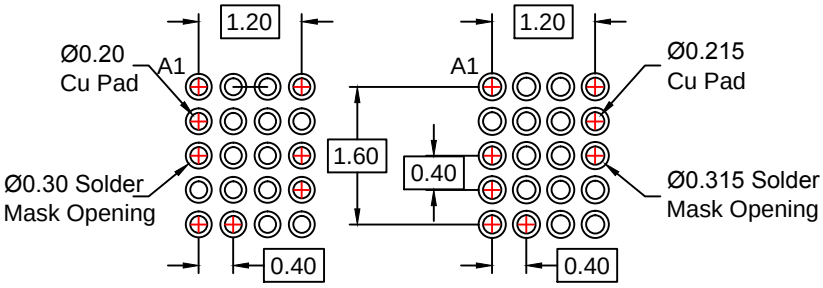
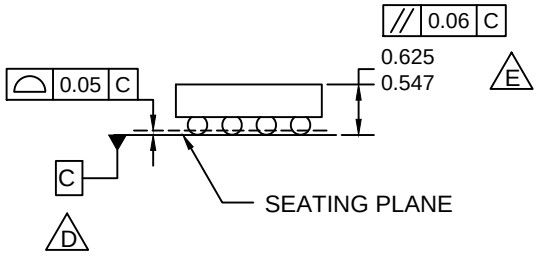
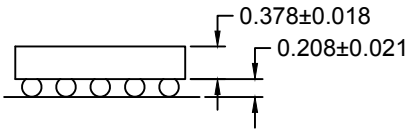


TOP VIEW

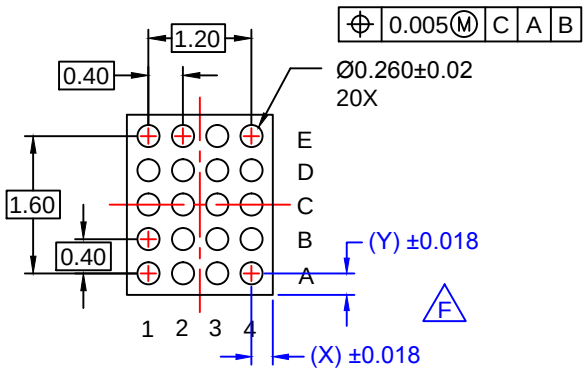


RECOMMENDED LAND PATTERN
(NSMD TYPE)





SIDE VIEWS



BOTTOM VIEW

NOTES:

A. NO JEDEC REGISTRATION APPLIES.
B. DIMENSIONS ARE IN MILLIMETERS.
C. DIMENSIONS AND TOLERANCE PER ASMEY14.5M, 2009.
D. DATUM C IS DEFINED BY THE SPHERICAL CROWNS OF THE BALLS.
E. PACKAGE NOMINAL HEIGHT IS 586 MICRONS ±39 MICRONS (547-625 MICRONS).
F. FOR DIMENSIONS D, E, X, AND Y SEE PRODUCT DATASHEET.
G. DRAWING FILNAME: MKT-UC020AArev4.

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