FAIRCHILD SEMICONDUCTOR®

August 2009

FAN5307
High-Efficiency Step-Down DC-DC Converter

Features

- 95% Efficiency, Synchronous Operation
- Adjustable Output Voltage Option: 0.7V to $0.8V_{IN}$
- 2.5V to 5.5V Input Voltage Range
- Customized Fixed Output Voltage Options
- Up to 300mA Output Current
- Fixed Frequency 1MHz PWM Operation
- High-Efficiency, Power-Save Mode
- 100% Duty Cycle Low Dropout Operation
- Soft Start
- Dynamic Output Voltage Positioning
- 15µA Quiescent Current
- Excellent Load Transient Response
- 5-Lead SOT-23 Package
- 6-Lead MLP 3x3mm Package

Applications

- Pocket PCs, PDAs
- Cell Phones
- Battery-Powered Portable Devices
- Digital Cameras
- Low Power DSP Supplies

Description

The FAN5307, a high-efficiency, low-noise synchronous PWM current mode and Pulse Skip (Power-Save) mode DC-DC converter, is designed for battery-powered applications. It provides up to 300mA of output current over a wide input range from 2.5V to 5.5V. The output voltage can be either internally fixed or externally adjustable over a wide range of 0.7V to $0.8V_{IN}$ by an external voltage divider. Custom output voltages are also available. Contact a Fairchild sales representative for customized output voltage options.

At moderate and light loads, pulse skipping modulation is used. Dynamic voltage positioning is applied, and the output voltage is shifted 0.8% above nominal value, for increased headroom during load transients. At higher loads, the system automatically switches to current mode PWM control, operating at 1 MHz. A current mode control loop with fast transient response ensures excellent line and load regulation. In Power-Save mode, the quiescent current is reduced to 15µA to achieve high efficiency and ensure long battery life. In shutdown mode, the supply current drops below 1µA.

The device is available in 5-lead SOT-23 and 6-lead MLP 3x3mm packages.

Ordering Information

Part Number	Operating Temperature Range	V_{OUT} (V)	Package	Eco Status	Packing Method
FAN5307S18X	-40 to +85°C	1.8	5-Lead SOT-23	RoHS	Tape and Reel
FAN5307MP18X	-40 to +85°C	1.8	6-lead 3x3mm Molded Leadless Package (MLP)	Green	Tape and Reel
FAN5307S15X	-40 to +85°C	1.5	5-Lead SOT-23	RoHS	Tape and Reel
FAN5307MP15X	-40 to +85°C	1.5	6-lead 3x3mm Molded Leadless Package (MLP)	Green	Tape and Reel
FAN5307SX	-40 to +85°C	Adjustable	5-Lead SOT-23	RoHS	Tape and Reel
FAN5307MPX	-40 to +85°C	Adjustable	6-lead 3x3mm Molded Leadless Package (MLP)	Green	Tape and Reel

For Fairchild's definition of Eco Status, please visit: http://www.fairchildsemi.com/company/green/rohs_green.html.

Typical Applications

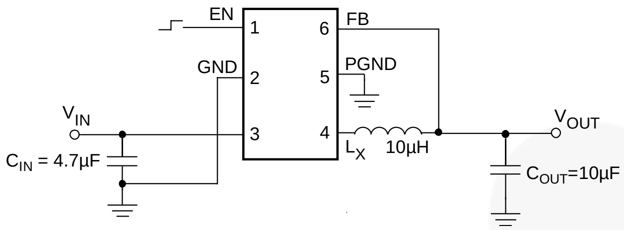

Figure 1. 6-Lead 3x3mm (MLP)

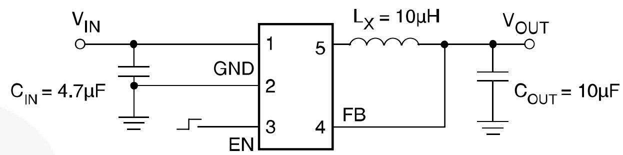

Figure 2. 5-Lead SOT-23

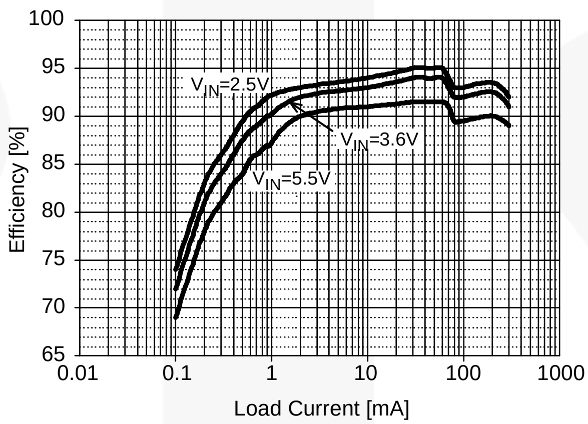

Figure 3. Efficiency vs. Load Current (V_{OUT}=1.8V)

Pin Configuration

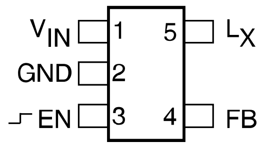

Figure 4. 5-Lead SOT-23

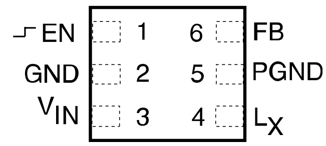

Figure 5. 6-Lead 3x3mm MLP

Pin Definitions

5-Lead SOT-23

Pin #	Name	Description
1	V_{IN}	**Supply Voltage Input**.
2	GND	**Ground**.
3	EN	**Enable Input**. Logic HIGH enables the chip; logic LOW disables the chip and reduces supply current to <1µA. Do not float this pin. If the EN pin is tied to V_{IN}, V_{IN} must be ramped up faster than 5V/ms for V_{OUT} to enter regulation.
4	FB	**Feedback Input**. In case of fixed-voltage options, connect this pin directly to the output. For an adjustable voltage option, connect this pin to the resistor divider.
5	L_X	**Inductor Pin**. This pin is connected to the internal MOSFET switches.

6-Lead 3x3mm MLP

Pin #	Name	Description
1	EN	**Enable Input**. Logic HIGH enables the chip; logic LOW disables the chip and reduces supply current to <1µA. Do not float this pin. If the EN pin is tied to V_{IN}, V_{IN} must be ramped up faster than 5V/ms for V_{OUT} to enter regulation.
2	GND	**Reference Ground**.
3	V_{IN}	**Supply Voltage Input**.
4	L_X	**Inductor Pin**. This pin is connected to the internal MOSFET switches
5	PGND	**Power Ground**. The internal N-channel MOSFET is connected to this pin.
6	FB	**Feedback Input**. In case of fixed-voltage options, connect this pin directly to the output. For an adjustable voltage option, connect this pin to the resistor divider.

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
V_{IN}	Supply Voltage		-0.3	6.5	V
	Input Voltage on PVIN and Any Other Pin		GND-0.2	V_{IN}+0.3	V
θ_{JC}	Thermal Resistance(1)	Junction-to-Case, SOT-23		130	°C/W
		Junction-to-Tab, MLP 3x3		8	
T_L	Lead Soldering Temperature, 10 Seconds			+260	°C
T_{STG}	Storage Temperature		-65	+150	°C
ESD(2)	Human Body Model, JESD22-A114		4		kV
	Charged Device Model, JESD22-C101		1		

Notes:
1. Junction-to-ambient thermal resistance, θ_{JA}, is a strong function of PCB material, board thickness, thickness and number of copper planes, number of via used, diameter of via used, available copper surface, and attached heat sink characteristics.
2. Using Mil Std. 883E, method 3015.7 (Human Body Model) and EIA/JESD22C101-A (Charged Device Model).

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. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{IN}	Supply Voltage Range	2.5		5.5	V
V_{OUT}	Output Voltage Range, Adjustable Version	0.7		$0.8V_{IN}$	V
I_{OUT}	Output Current			300	mA
L	Inductor(3)		10		µH
C_{IN}	Input Capacitor(3)		4.7		µF
C_{OUT}	Output Capacitor(3)		10		µF
T_A	Operating Ambient Temperature Range	-40		+85	°C
T_J	Operating Junction Temperature Range	-40		+125	°C

Note:
3. Refer to the *Applications* section for details.

Electrical Characteristics

V_{IN}=2.5V to 5.5V, I_{OUT}=200mA, EN=V_{IN}, C_{IN}=4.7µF, C_{OUT}=22µF, L_X=10µH, T_A=-40°C to +85°C, unless otherwise noted. Typical values are at T_A=25°C.

Symbol	Parameter		Conditions	Min.	Typ.	Max.	Units
V_{IN}	Input Voltage			2.5		5.5	V
I_Q	Quiescent Current		I_{OUT}=0mA, Device is not switching		15	30	µA
I_{SD}	Shutdown Supply Current		EN=GND		0.1	1.0	µA
V_{ENH}	Enable High Input Voltage			1.3			V
V_{ENL}	Enable Low Input Voltage					0.5	V
I_{EN}	En Input Bias Current		EN=V_{IN} or GND		0.01	0.10	µA
$R_{DS\text{-}ON}$	PMOS On Resistance		V_{IN}=V_{GS}=3.6V		530	690	mΩ
			V_{IN}=V_{GS}=2.5V		670	850	
	NMOS On Resistance		V_{IN}=V_{GS}=3.6V		430	540	mΩ
			V_{IN}=V_{GS}=2.5V		530	660	
I_{LIM}	P-channel Current Limit		2.5V < V_{IN} < 5.5V	400	520	700	mA
$I_{lkg\_(N)}$	N-channel Leakage Current		V_{DS}=5.5V		0.1	1.0	µA
$I_{lkg\_(P)}$	P-channel Leakage Current		V_{DS}=5.5V		0.1	1.0	µA
	Switching Frequency			800	1000	1200	kHz
R_{LINE}	Line Regulation		V_{IN}=2.5 to 5.5, I_{OUT}=10mA		0.16		% / V
R_{LOAD}	Load Regulation	6-Lead MLP	100mA ≤ I_{OUT} ≤ 300mA		0.0014		% / mA
		5-Lead SOT-23	100mA ≤ I_{OUT} ≤ 300mA		0.0022		% / mA
V_{OUT}	Output Voltage Accuracy	6-Lead MLP	V_{IN}=2.5 to 5.5V, 0mA ≤ I_{OUT} ≤ 300mA	-4		4	%
		5-Lead SOT-23	V_{IN}=2.5 to 4.5V, 0mA ≤ I_{OUT} ≤ 300mA	-4		4	
			V_{IN}=2.5 to 5.5V, 0mA ≤ I_{OUT} ≤ 300mA	-5		4	
I_{LEAK}	Leakage Current into Pin SW		V_{IN}>V_{OUT}, 0V ≤ V_{SW} ≤ V_{IN}		0.1	1.0	µA
I_{LEAK_R}	Reverse Leakage Current into Pin SW		V_{IN}=Open, EN=GND, V_{SW}=5.5		0.1	1.0	µA

Electrical Characteristics for Adjustable Version

V_{IN}=2.5V to 5.5V, I_{OUT} = 200mA, EN=V_{IN}, C_{IN}=4.7µF, C_{OUT}=22µF, L_X=10µH, T_A=25°C.

Symbol	Parameter	Min.	Typ.	Max.	Units
V_{FB}	Feedback Voltage		0.5		V

Electrical Characteristics for Fixed V_{OUT}=1.8 Version

V_{IN}=2.5V to 5.5V, I_{OUT}=200mA, EN=V_{IN}, C_{IN}=4.7µF, C_{OUT}=22µF, L_X=10µH, T_A=-40°C to +85°C, unless otherwise noted. Typical values are at T_A=25°C.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
V_{PFM_PWM}	PFM to PWM Transition Voltage(4)	V_{IN}=3.7V, T_A=25°C, 0.1mA ≤ I_{OUT} ≤ 300mA			72	mV
		V_{IN}=4.2V, T_A=25°C, 0.1mA ≤ I_{OUT} ≤ 300mA				
V_{OUT_TRANS}	Output Voltage During Mode Transition(5,6)		1.70		1.93	V
V_{OUT_CLAMP}	Over-Voltage Clamp Threshold	Includes Line, Load, Load Transients, and Temperature		1.878	1.930	V

Note:
4. Transition voltage is defined as the difference between the output voltage measured at 0.1mA (PFM mode) and 300mA (PWM mode), respectively.
5. See Figure 6.
6. These limits also apply to any mode transition caused by any kind of load transition within specified output current range.

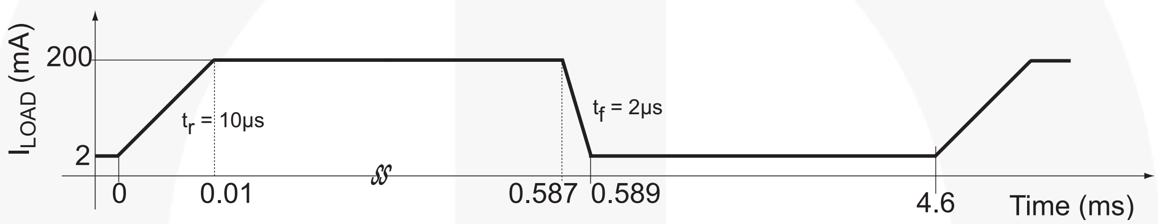

Figure 6. Load Transient Response Test Waveform

Typical Performance Characteristics

T_A=25°C, C_{IN}=C_{OUT}=10µF, L=10µH, V_{OUT}=1.8V, unless otherwise noted.

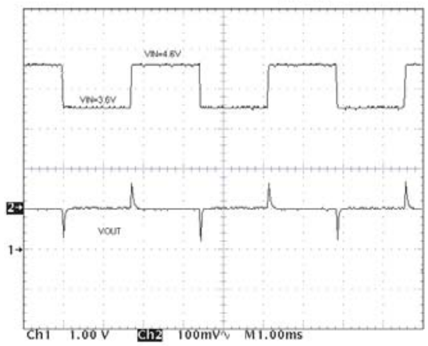

Figure 7. Line Transient Response

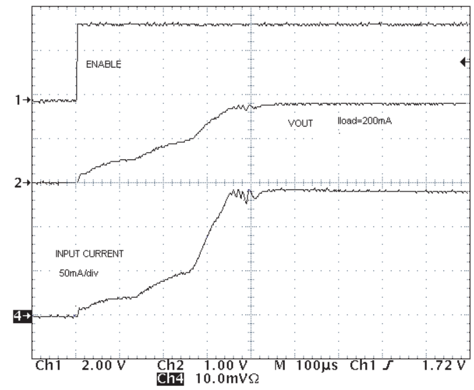

Figure 8. Startup

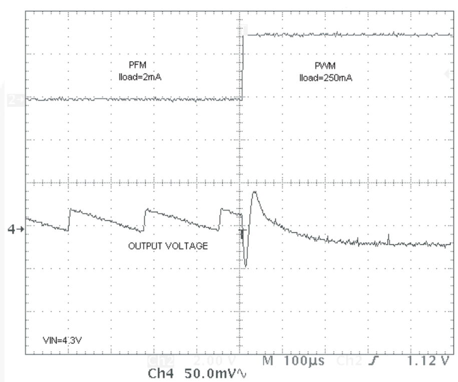

Figure 9. Load Transient Response

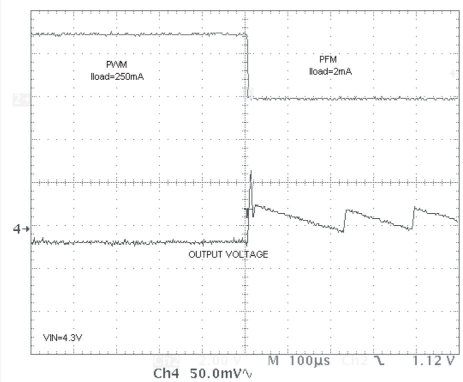

Figure 10. Load Transient Response

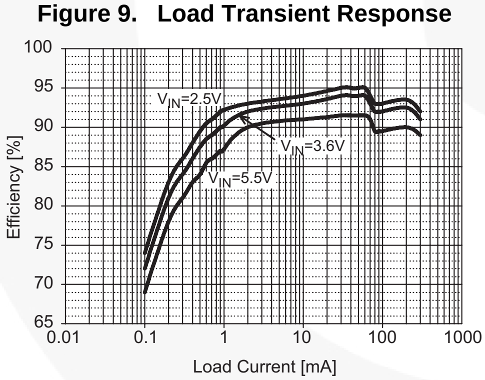

Figure 11. Efficiency vs. Load Current (V_{OUT}=1.8V)

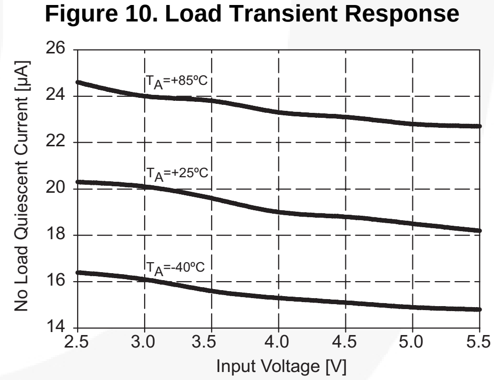

Figure 12. No-Load Quiescent Current vs. V_{IN}

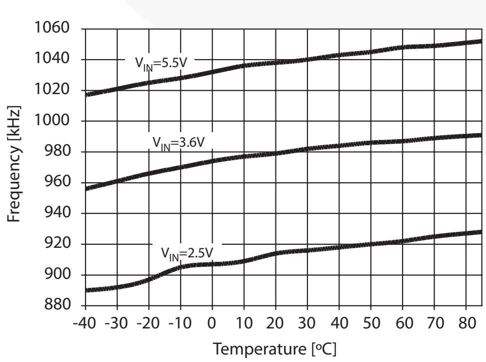

Figure 13. Frequency vs. Temperature

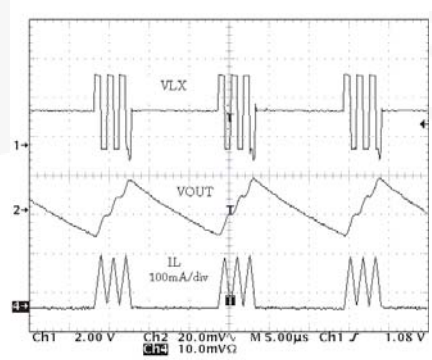

Figure 14. Power Save (PRM) Mode Operation

Block Diagram

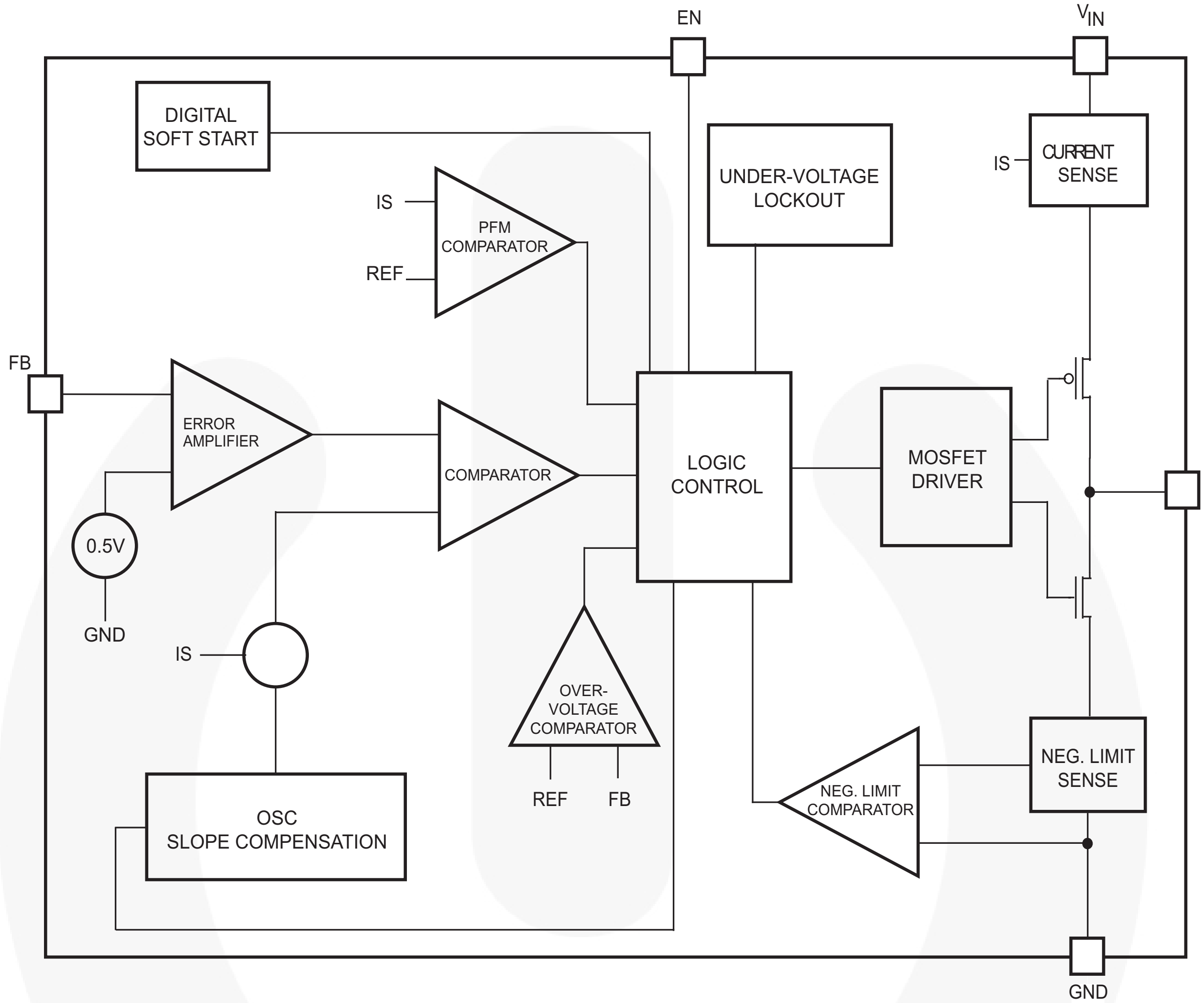

Figure 15. Block Diagram

Detailed Operation Description

The FAN5307 is a step-down converter operating in a current-mode PFM/PWM architecture with a typical switching frequency of 1MHz. At moderate to heavy loads, the converter operates in pulse-width-modulation (PWM) mode. At light loads, the converter enters a power-save mode (PFM pulse skipping) to keep the efficiency high.

PWM Mode

In PWM mode, the device operates at a fixed frequency of 1MHz. At the beginning of each clock cycle, the P-channel transistor is turned on. The inductor current ramps up and is monitored via an internal circuit. The P-channel switch is turned off when the sensed current causes the PWM comparator to trip when the output voltage is in regulation or when the inductor current reaches the current limit (set internally to typically 520mA). After a minimum dead time, the N-channel transistor is turned on and the inductor current ramps down. As the clock cycle is completed, the N-channel switch is turned off and the next clock cycle starts.

FM (Power-Save) Mode

As the load current decreases and the peak inductor current no longer reaches the typical threshold of 80mA, the converter enters pulse-frequency-modulation (PFM) mode. In PFM mode, the device operates with a variable frequency and constant peak current, reducing the quiescent current to a minimum and maintaining high efficiency at light loads. As soon as the output voltage falls below a threshold, set at 0.8% above the nominal value, the P-channel transistor is turned on and the inductor current ramps up. The P-channel switch turns off and the N-channel turns on as the peak inductor current is reached (typical 140mA).

The N-channel transistor is turned off before the inductor current becomes negative. At this time, the P-channel is switched on again, starting the next pulse. The converter continues these pulses until the high threshold is reached (typically 1.6% above nominal value). A higher output voltage in PFM mode gives additional headroom for the voltage drop during a load transient from light to full load. The voltage overshoot during this load transient is minimized due to active regulation during turning on the N-channel rectifier switch. The device stays in sleep mode until the output voltage falls below the low threshold. FAN5307 enters PWM mode as soon as the output voltage can no longer be regulated in PFM with constant peak current.

100% Duty Cycle Operation

As the input voltage approaches the output voltage and the duty cycle exceeds the typical 90%, the converter turns the P-channel transistor continuously on. In this mode, the output voltage is equal to the input voltage minus, the voltage drop across the P-channel transistor:

$$V_{OUT} = V_{IN} - I_{LOAD} \times (R_{DSON} + R_L), \text{ where} \quad (1)$$

R_{DSON} = P-channel switch on resistance
I_{LOAD} = Output current
R_L = Inductor DC resistance

Soft Start

The FAN5307 has an internal soft-start circuit that limits the inrush current during start-up. This prevents possible voltage drops of the input voltage and eliminates the output voltage overshoot. The soft-start is implemented as a digital circuit, increasing the switch current in four steps to the P-channel current limit (520mA). Typical start-up time for a 10µF output capacitor and a load current of 200mA is 500µs.

Short-Circuit Protection

Switch peak current is limited, cycle by cycle, to a typical value of 520mA. In an output voltage short circuit, the device operates at minimum duty cycle; therefore, the average input current is typically 100mA.

Application Information

Adjustable Output Voltage Version

The output voltage for the adjustable version is set by the external resistor divider, as shown below:

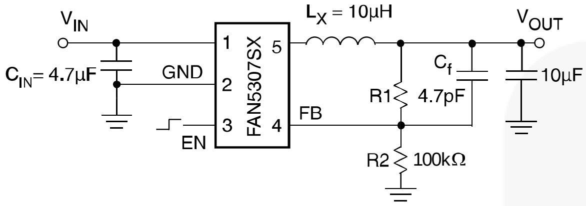

Figure 16. External Resistor Divider

calculated as:

$$V_{OUT} = 0.5V \times \left[1 + \frac{R_1}{R_2}\right] \qquad (2)$$

To reduce noise sensitivity, R1 + R2 should not exceed 1MΩ.

Inductor Selection

The inductor parameters directly related to device performance are saturation current and DC resistance. The FAN5307 operates with a typical inductor value of 10µH. The lower the DC resistance, the higher the efficiency. For saturation current, the inductor should be rated higher than the maximum load current, plus half of the inductor ripple current, calculated as:

$$\Delta I_L = V_{OUT} \times \frac{1 - (V_{OUT} / V_{IN})}{L \times f} \qquad (3)$$

where:
f = Switching frequency
L = Inductor value
ΔI_L = Inductor ripple current

Table 1. Recommended Inductors

Inductor Value	Vendor	Part Number	Performance
10µH	Sumida	CDRH5D28-100	Highest Efficiency
		CDRH5D18-100	
		CDRH4D28-100	
	Murata	LQH66SN100M01L	
6.8µH	Sumida	CDRH3D16-6R8	Smallest Solution
10µH		CDRH4D18-100	
		CR32-100	
		CR43-100	
	Murata	LQH4C100K04	
	Cooper Bussmann	CTX01-17327	

Input Capacitor Selection

For best performances, a low-ESR input capacitor is required. A ceramic capacitor of at least 4.7µF, placed as close to the input pin of the device, is recommended.

Output Capacitor Selection

The FAN5307's switching frequency of 1MHz allows the use of a low-ESR ceramic capacitor with a value of 10µF to 22µF. This provides low output voltage ripple. In power-save mode, the output voltage ripple is independent of the output capacitor value and the ripple is determined by the internal comparator thresholds. The typical output voltage ripple at light load is 1% of the nominal output voltage.

Table 2. Recommended Capacitors

Capacitor Value	Vendor	Part Number
4.7µF	Taiyo Yuden	JMK212BY475MG
10µF		JMK212BJ106MG
		JMK316BJ106KL
	TDK	C12012X5ROJ106K
		C3216X5ROJ106M
22µF	Murata	GRM32DR60J226K

PCB Layout Recommendations

The inherently high peak currents and switching frequency of the power supplies require careful PCB layout design. Use wide traces for the high-current path and place the input capacitor, the inductor, and the output capacitor as close as possible to the integrated circuit terminals. For the adjustable version, the resistor divider should be routed away from the inductor to avoid electromagnetic interference.

The 6-lead MLP version of the FAN5307 separates the high-current ground from the reference ground; therefore, it is more tolerant to the PCB layout design and shows better performance.

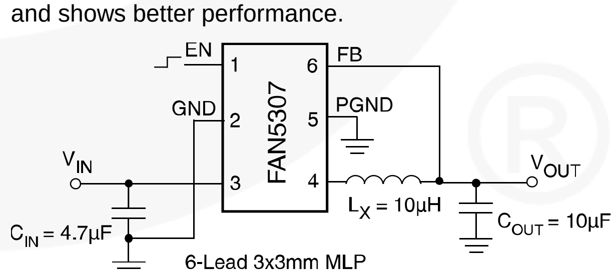

Figure 17. Possible Layout

Physical Dimensions

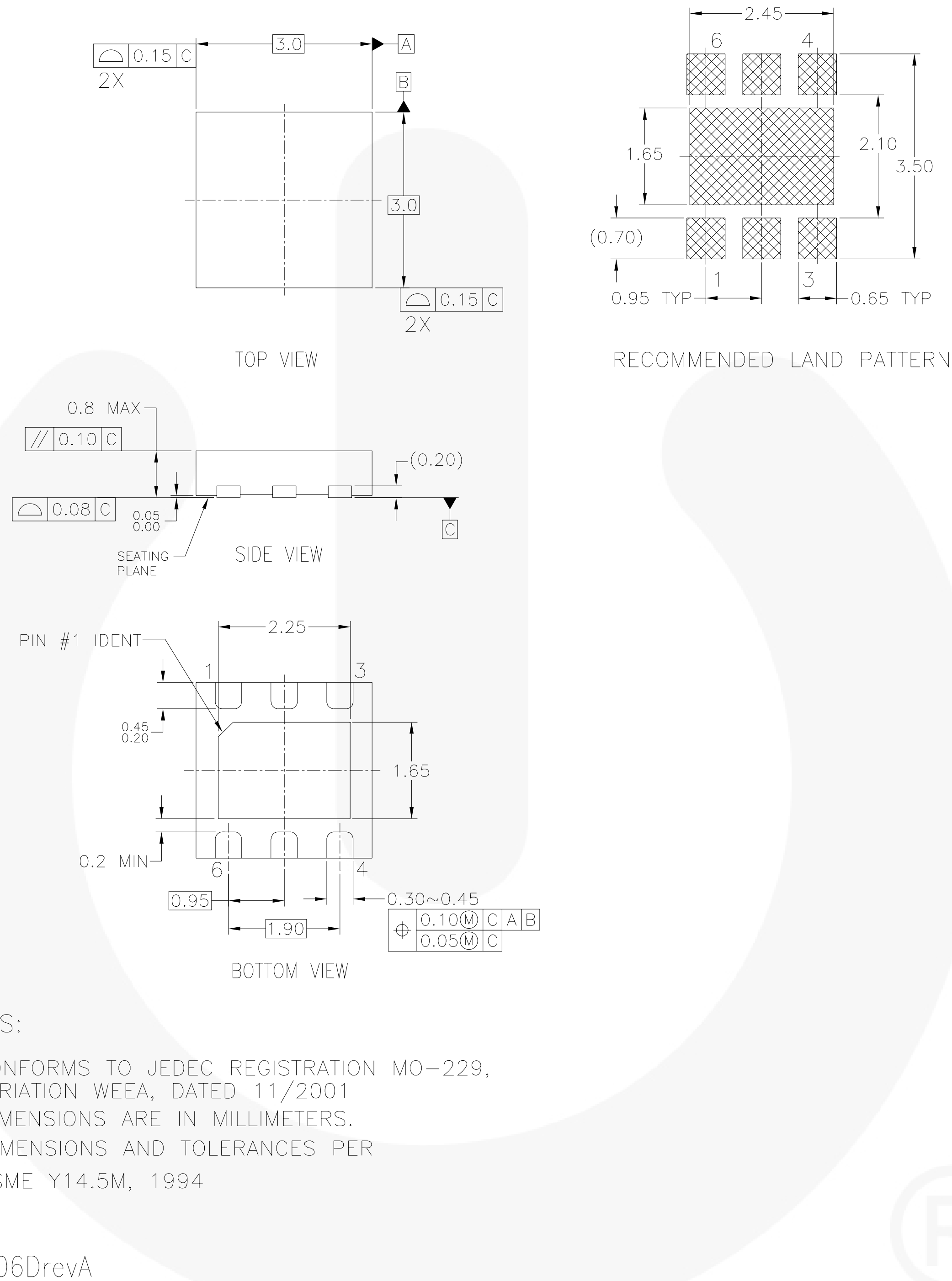

Figure 18. 3x3mm 6-Lead Molded Leadless Package (MLP)

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild's worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

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Physical Dimensions

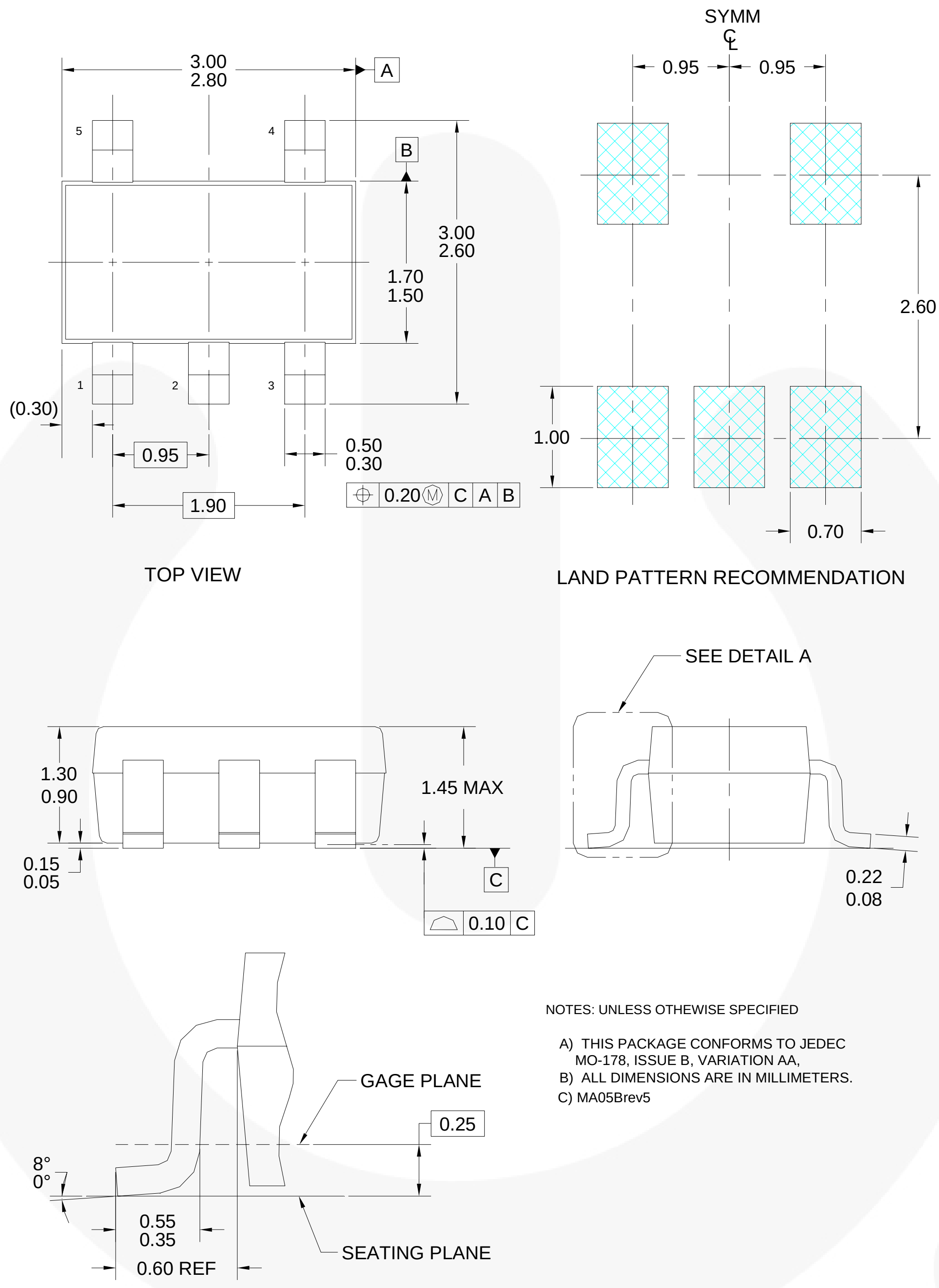

Figure 19. 5-Lead SOT-23 Package

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FETBench™
FlashWriter®*

FPS™
F-PFS™
FRFET®
Global Power Resource℠
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SuperSOT™-6
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TinyLogic®
TINYOPTO™
TinyPower™
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FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.
2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

ANTI-COUNTERFEITING POLICY

Fairchild Semiconductor Corporation's Anti-Counterfeiting Policy. Fairchild's Anti-Counterfeiting Policy is also stated on our external website, www.fairchildsemi.com, under Sales Support.

Counterfeiting of semiconductor parts is a growing problem in the industry. All manufacturers of semiconductor products are experiencing counterfeiting of their parts. Customers who inadvertently purchase counterfeit parts experience many problems such as loss of brand reputation, substandard performance, failed applications, and increased cost of production and manufacturing delays. Fairchild is taking strong measures to protect ourselves and our customers from the proliferation of counterfeit parts. Fairchild strongly encourages customers to purchase Fairchild parts either directly from Fairchild or from Authorized Fairchild Distributors who are listed by country on our web page cited above. Products customers buy either from Fairchild directly or from Authorized Fairchild Distributors are genuine parts, have full traceability, meet Fairchild's quality standards for handling and storage and provide access to Fairchild's full range of up-to-date technical and product information. Fairchild and our Authorized Distributors will stand behind all warranties and will appropriately address any warranty issues that may arise. Fairchild will not provide any warranty coverage or other assistance for parts bought from Unauthorized Sources. Fairchild is committed to combat this global problem and encourage our customers to do their part in stopping this practice by buying direct or from authorized distributors.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative / In Design	Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
No Identification Needed	Full Production	Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.
Obsolete	Not In Production	Datasheet contains specifications on a product that is discontinued by Fairchild Semiconductor. The datasheet is for reference information only.

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