FAIRCHILD
SEMICONDUCTOR®

December 2008

FAN8303
2A 23V Non-Synchronous Step-Down DC/DC Regulator

Features

- 2A Output Current
- 0.22Ω Internal Power MOSFET Switch
- Wide 5V to 23V Operating Input Range
- Output Adjustable from 0.6 to 20V
- Stable with Low ESR Output Ceramic Capacitors
- Up to 90% Efficiency
- Less than 40µA Shutdown Current
- Fixed 370kHz Frequency
- Thermal Shutdown with Hysteresis
- Cycle-by-Cycle Over-Current Protection
- Available in 8-Pin SOIC Package

Applications

- Set-Top Box
- DSL and Cable Modems
- Distributed Power Systems
- Consumer Appliances (DVD)
- Auxiliary supplies

Description

The FAN8303 is a monolithic, non-synchronous, step-down (buck) regulator with internal power MOSFETs. It achieves 2A continuous output current over a wide input supply range with excellent load and line regulation. Current-mode operation provides fast transient response and eases loop stabilization. Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. The regulator draws less than 40µA shutdown current. FAN8303 requires a minimum number of readily available standard external components.

External compensation, enable, and programmable soft-start features allow design optimization and flexibility. Cycle-by-cycle current limit, frequency foldback, and thermal shutdown provide protection against shorted outputs.

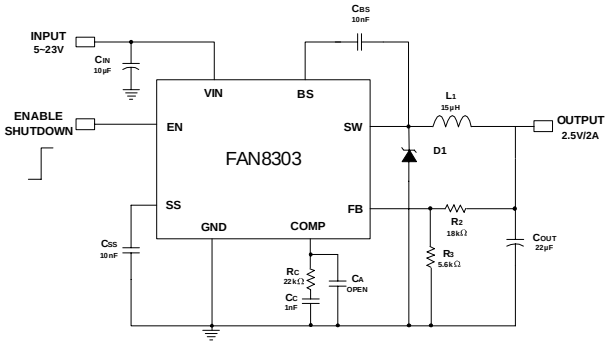

Figure 1. Typical Application

Ordering Information

Part Number	Eco Status	Operating Temperature Range	Package	Packing Method
FAN8303MX	RoHS	-40°C to +85°C	8-SOIC	Reel

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

© 2008 Fairchild Semiconductor Corporation

Typical Performance Characteristics (Continued)

V_{IN} = 12V, V_{OUT} = 5V, L1 = 15μH, C_{IN} = 10μF, C_{OUT} = 22μF, T_A = +25°C, unless otherwise noted.

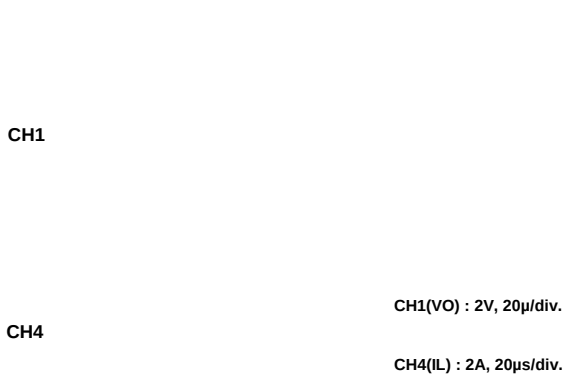

Figure 10. Hard-Short at Output (OCP)

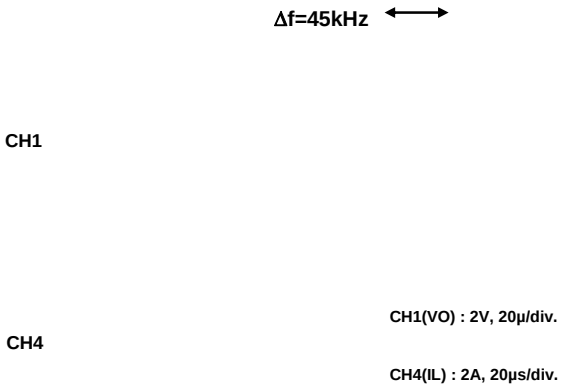

Figure 11. Overload at Output (OCP)

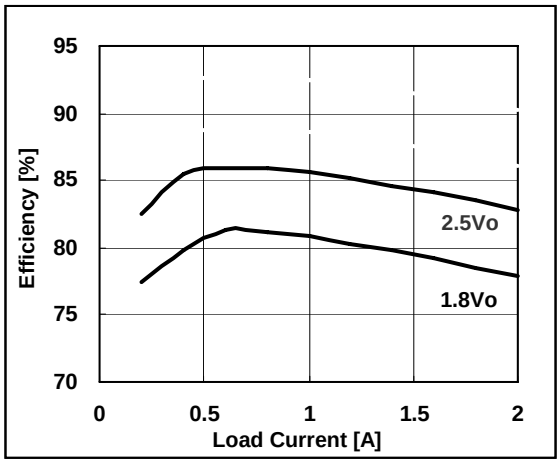

Figure 12. Efficiency Curve

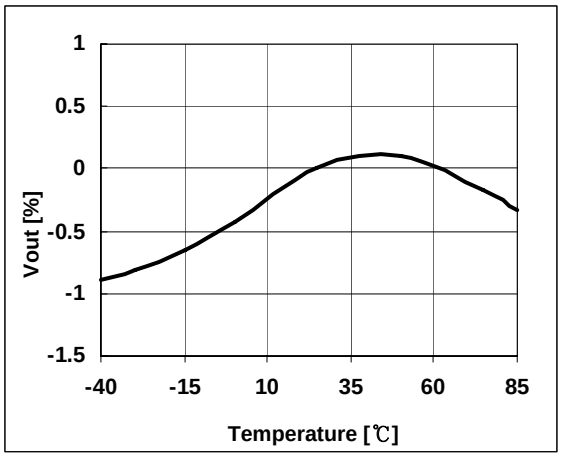

Figure 13. Normalized Output Voltage vs. Temperature

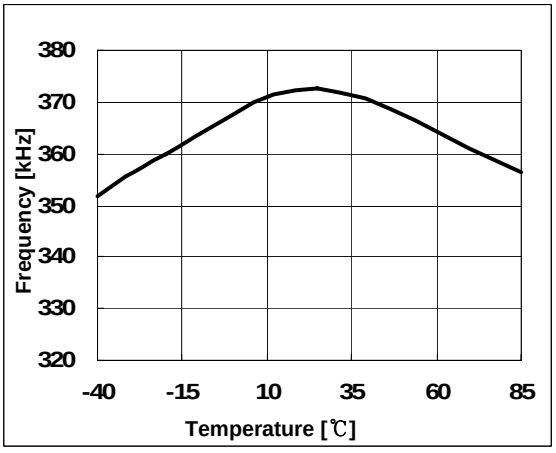

Figure 14. Oscillator Frequency vs. Temperature

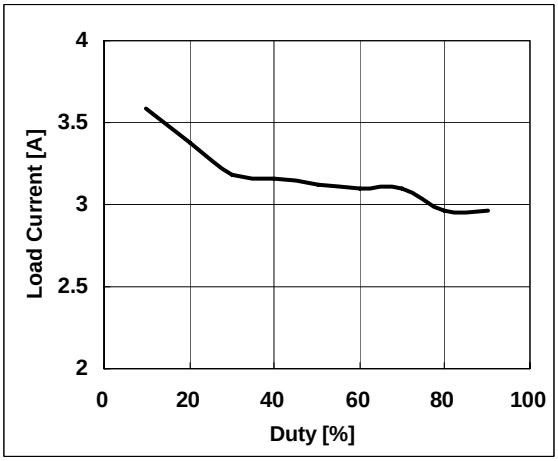

Figure 15. Current Limited Level vs. Duty Ratio

Functional Description

The FAN8303 is a monolithic, non-synchronous, current-mode, step-down regulator with internal power MOSFETs. It achieves 2A continuous output current over a wide input supply range from 5V to 23V with excellent load and line regulation. The output voltage can be regulated as low as 0.6V. The FAN8303 uses current-mode operation that provides fast transient response and eases loop stabilization. The FAN8303 requires a minimum number of readily available standard external components.

Current Mode PWM Control Loop

FAN8303 uses current-mode PWM control scheme. The peak inductor current is modulated in each switching cycle by an internal op-amp output signal to achieve the output voltage regulation. An internal slope compensation circuit is included to avoid sub-harmonic oscillation at duty cycle greater than 50%. Current-mode control provides cycle-by-cycle current limit protection and superior regulation control loop response compared to the traditional voltage-mode control.

In normal operation, the high-side MOSFET is turned on at the beginning of each switching cycle, which causes the current in the inductor to build up. The current-control loop senses the inductor current by sensing the voltage across the high-side senseFET during on time. The output of the current-sense amplifier is summed with the slope compensation signal and the combined signal is compared with the error amplifier output to generate the PWM signal. As the inductor current ramps up to the controlled value, the high-side MOSFET is turned off and the inductor current reaches zero through a freewheeling diode. In light-load condition, the high-side switch may be kept off for several cycles to improve efficiency.

Short-Circuit Protection

The FAN8303 protects output short circuit by switching frequency fold-back. The oscillator frequency is reduced to about 45kHz when the output is shorted to ground. This frequency fold-back allows the inductor current more time to decay to prevent potential run-away condition. The oscillator frequency switches to 370kHz as V_{OUT} rises gradually from 0V back to regulated level.

Slope Compensation and Inductor Peak Current

The slope compensation provides stability in constant frequency architecture by preventing sub-harmonic oscillations at high duty cycles. It is accomplished internally by adding a compensating ramp to the inductor current signal at duty cycles in excess of 50%.

Maximum Load Current at Low V_{IN}

The FAN8303 is able to operate with input supply voltage as low as 5V, although the maximum allowable output current is reduced as a function of duty cycle *(see Figure 15)*. Additionally, at this low input voltage; if the duty cycle is greater than 50%, slope compensation reduces allowable output current.

Inductor Selection

A higher inductor value lowers ripple current. The inductor value can be calculated as:

$$L = \frac{V_{OUT}}{f_S \cdot \Delta I_L}\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (1)$$

where:

f_s is the switching frequency;

V_{OUT} is the output voltage;

V_{IN} is the input supply voltage; and

ΔI_L Is the inductor ripple current.

Considering worst case, the equation is changed to:

$$L = \frac{V_{OUT}}{f_S \cdot \Delta I_{L,MAX}}\left(1 - \frac{V_{OUT}}{V_{IN,MAX}}\right) \quad (2)$$

Input Capacitor Selection

To prevent high-frequency switching current passing to the input, the input capacitor impedance at the switching frequency must be less than input source impedance. High-value, small, inexpensive, lower-ESR ceramic capacitors are recommended. 10µF ceramic capacitors should be adequate for 2A applications.

Output Capacitor Selection

A larger output capacitor value keeps the output ripple voltage smaller. The formula of output ripple ΔV_{OUT} is:

$$\Delta V_{OUT} \cong \Delta I_L\left(ESR + \frac{1}{8 \cdot C_{OUT} \cdot f_S}\right) \quad (3)$$

where C_{OUT} is the output capacitor and ESR is the equivalent series resistance of the output capacitor.

Output Voltage Programming

The output voltage is set by a resistor divider, according to the following equation:

$$V_{OUT} = 0.6\left(1 + \frac{R2}{R3}\right) \quad (4)$$

Freewheeling Diode

An output freewheeling diode carries load current when the high-side switch is turned off. Therefore, use a Schottky diode to reduce loss due to diode forward voltage and recovery time. The diode should have at least 2A current rating and a reverse blocking voltage greater than the maximum input voltage. The diode should be close to the SW node to keep traces short and reduce ringing.

© 2008 Fairchild Semiconductor Corporation

Soft-Start

A capacitor, C_{SS}, connected between the SS pin and GND helps control the rate of rise on the output voltage. When EN is HIGH and V_{IN} is within the operating range, a trimmed bias current charges the capacitor connected to the SS pin, causing the voltage to rise.

The time it takes this voltage to reach 0.6V and the PWM output to reach regulation is given by:

$$t_{RISE}(ms) \approx 0.1 \bullet C_{SS} \quad (5)$$

where C_{SS} is in nF.

Loop Compensation

The goal of the compensation design is to shape the converter frequency response to achieve high DC gain and fast transient, while maintaining loop stability. FAN8303 employs peak current-mode control for fast transient response and to help simplify the loop to a one-pole and one-zero system.

The system pole is calculated by the equation:

$$f_{P1} = \frac{1}{2\pi \cdot C_{OUT} \cdot R_L} \quad (6)$$

where R_L is the load resistor value (V_{OUT}/I_{OUT}).

The system zero is due to the output capacitor and its ESR system zero is calculated by following equation:

$$f_{z1} = \frac{1}{2\pi \cdot C_{OUT} \cdot ESR} \quad (7)$$

The characteristics of the control system are controlled by a series capacitor and resistor network connected to the COMP pin to set the pole and zero.

The pole is calculated by the following equation:

$$f_{p2} = \frac{G_{EA}}{2\pi \cdot C_C \cdot A_{VEA}} \quad (8)$$

where:

G_{EA} is the error amplifier transconductance (380µA/V);

A_{VEA} is the error amplifier voltage gain (400V/V); and

C_C is the compensation capacitor.

Zero is due to the compensation capacitor (C_C) and resistor (R_C) calculated by the following equation:

$$f_{z2} = \frac{1}{2\pi \cdot C_C \cdot R_C} \quad (9)$$

where R_C is compensation resistor.

The system crossover frequency (f_C), where the control loop has unity gain, is recommended for setting the 1/10th of switching frequency. Generally, higher f_C means faster response to load transients, but can result in instability if not properly compensated.

The first step of the compensation design is choosing the compensation resistor (R_C) to set the crossover frequency by the following equation:

$$R_C = \frac{2\pi \cdot C_{OUT} \cdot f_C \cdot V_{OUT}}{G_{CS} \cdot G_{EA} \cdot V_{FB}} \quad (10)$$

where V_{FB} is reference voltage and G_{CS} is the current sense gain, which is roughly the output current divided by the voltage at COMP (2A/V).

The next step is choosing the compensation capacitor (C_C) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{Z2}, to below one fourth of the crossover frequency provides sufficient phase margin. Determine the (C_C) value by the following equation:

$$C_C = \frac{2}{\pi \cdot R_C \cdot f_C} \quad (11)$$

Determine if the second compensation capacitor (C_A) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency.

$$\frac{1}{2\pi \cdot C_{OUT} \cdot ESR} < \frac{f_S}{2} \quad (12)$$

If required, add the second compensation capacitor (C_A) to set the pole f_{P3} at the location of the ESR zero. Determine the (C_A) value by the equation:

$$C_A = \frac{C_{OUT} \cdot ESR}{R_C} \quad (13)$$

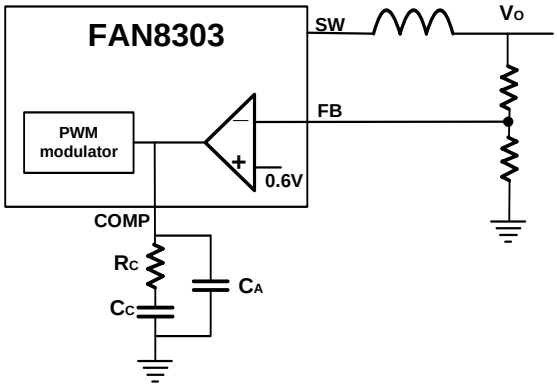

Figure 16. Block Diagram of Compensation

Design example

Assume the V_{IN} voltage is 12V with a 10% tolerance. The maximum load current is 2A and the output voltage is set to 2.5V at 2A maximum load. Calculate the inductor value from the following formula:

$$L = \frac{V_{OUT}}{f_{OSC} \cdot \Delta I_{L,MAX}} \left(1 - \frac{V_{OUT}}{V_{IN,MAX}}\right) \quad (14)$$

Substituting V_{OUT}=2.5V, $V_{IN,MAX}$=12V, Δ $I_{L,MAX}$=0.4A, and f_S = 370kHz in the formula gives:

$$L = \frac{2.5}{370kHz(0.4A)}\left(1 - \frac{2.5}{12}\right) = 13\mu H \quad (15)$$

A 15µH inductor is chosen for this application.

If the V_{OUT} voltage is 2.5V, choose R2=18kΩ(1%), and R3 can be calculated from:

$$R3 = 18k\Omega\left(\frac{0.6}{2.5 - 0.6}\right) = 5.68k\Omega \quad (16)$$

Choose R3=5.6kΩ (1%).

In this application, with the desired crossover frequency at 30kHz, R_C value is calculated as follows:

$$R_C = \frac{2\pi \cdot 22\mu F \cdot 30kHz \cdot 2.5V}{2A/V \cdot 380\mu A/V \cdot 0.6V} \quad (17)$$

If R_C=22.72kΩ , choose 22kΩ for the design.

If R_C=22kΩ , use the following equation to get C_C:

$$C_C = \frac{2}{\pi \cdot 22k\Omega \cdot 30kHz} \quad (18)$$

C_C= 0.965nF, choose 1nF for the design.

Table 1. Recommended Compensation Values (V_{IN}=12V)

V_O	L	C_{OUT}	R_2	R_3	R_C	C_C
1.8V	10µH	22µF MLCC	18kΩ	9kΩ	16kΩ	1.5nF
2.5V	15µH			5.6kΩ	22kΩ	1nF
3.3V	15µH			4kΩ	27kΩ	820pF
5V	22µH			2.45kΩ	43kΩ	560pF

Layout Consideration

As with all switching power supplies, careful attention to PCB layout is important to the design. A few design rules should be implemented to ensure good layout:

- Keep the high-current traces and load connections as short as possible.
- Place the input capacitor, the inductor, the freewheeling diode, and the output capacitor as close as possible to the IC terminals.
- Keep the loop area between the SW node, freewheeling diode, inductor, and output capacitor as small as possible. Minimizing ground loops reduces EMI issues.
- Route high-dV/dt signals, such as SW node, away from the error amplifier input/output pins. Keep components connected to these pins close to the pins.
- To effectively remove heat from the MOSFETs, use wide land areas with appropriate thermal vias.

Figure 17.Recommended PCB Layout

© 2008 Fairchild Semiconductor Corporation

Physical Dimensions

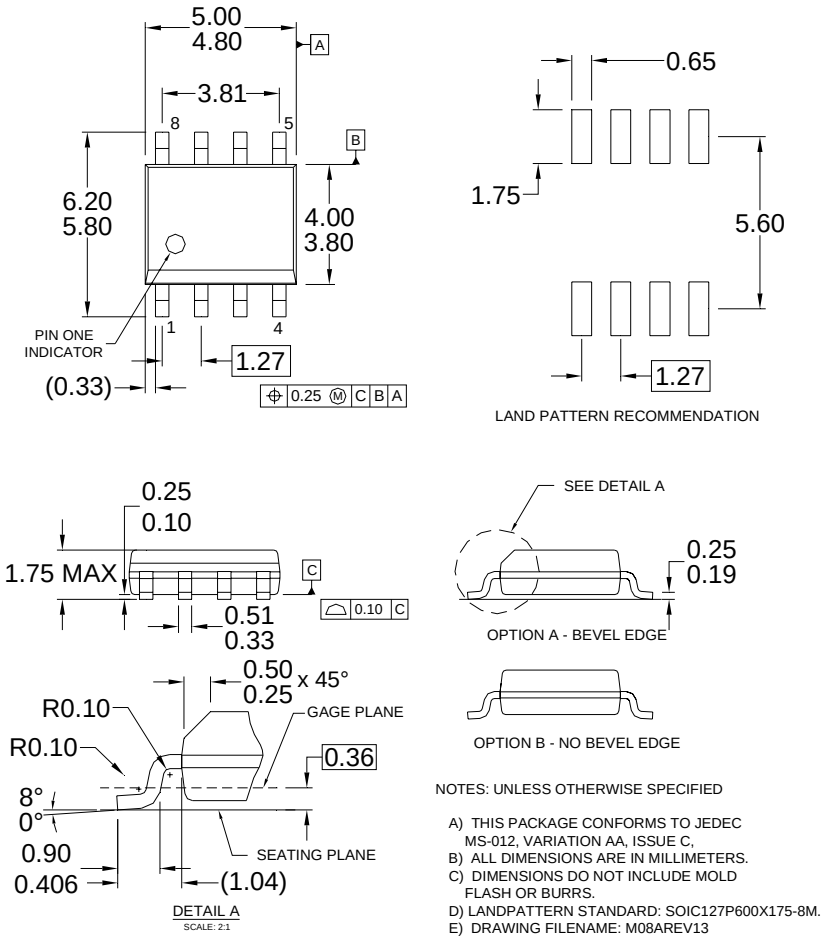

Figure 18.8-Lead, Small Outline Integrated Circuit (SOIC-8)

Dimensions

Symbol	Millimeter			Inch		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.346		1.752	0.053		0.069
A1	0.101		0.254	0.004		0.010
b		0.406			0.016	
c		0.203			0.008	
D	4.648		4.978	0.183		0.196
E	3.810		3.987	0.150		0.157
e		1.270			0.050	
F		0.381X45˚			0.015X45˚	
H	5.791		6.197	0.228		0.244
L	0.406		1.270	0.016		0.050
θ˚	0˚		8˚	0˚		8˚

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.

Always visit Fairchild Semiconductor's online packaging area for the most recent package drawings:
http://www.fairchildsemi.com/packaging/.

© 2008 Fairchild Semiconductor Corporation

© 2008 Fairchild Semiconductor Corporation