August 2010

FAN4603
600mA, Fully Integrated, Buck Power Supply Module

Features

- Solder and Play DC/DC Converter; No External Components Required
- Up to 91% Efficiency
- 600mA Output Current Capability
- 2.3V to 5.5V Input Voltage Range
- Fixed Output Voltages from 1.0V to 1.8V
- 35µA PFM Quiescent Current
- Best-in-Class Load and Line Transient Response
- ±2% PWM DC Voltage Accuracy
- No External Components Required
- High-Efficiency, Low-Ripple, Light-Load PFM
- Thermal Shutdown (TSD), Under-Voltage Lockout, (UVLO), and Short-Circuit (SCP) Protection
- 4.0 x 2.5mm MLP Package
- Maximum Height: 1.1mm

Applications

- POL and Distributed DC-DC Module Applications
- Small Form Factor, Battery-Powered Applications
- POL Core Power for FPGA, DSP, CPU, and GPU with Fast-Transient, Wide Dynamic Load Requirements
- Wireless Cards, Meters, Hearing Aids, Bluetooth Headsets, POS Equipment, VOIP, PDAs, MIDs, Netbooks, and Servers

Description

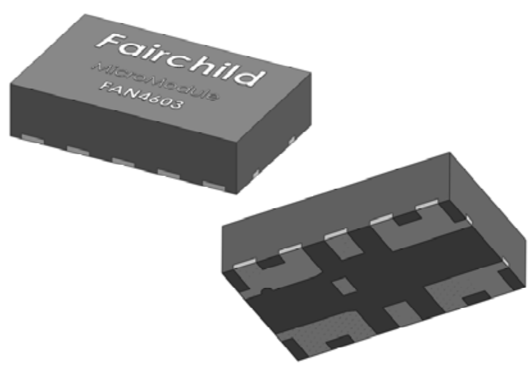
The FAN4603 is a fully integrated synchronous DC/DC buck converter that provides up to 600mA of output current over an input voltage ranging from 2.3V to 5.5V. It provides a fixed output voltage level ranging from 1.0V to 1.8V. Other voltage options are available on request.

The FAN4603 converter is offered as an ultra-miniature “Solder and Play” solution that requires no external components and is able to achieve a DC accuracy of ±2% PWM and an output ripple less than 12mV.

Total footprint is 4.0 x 2.5mm with a maximum height of 1.1mm. It can be used in small battery-powered devices and applications with distributed DC POL requirements.

At moderate and light loads, pulse frequency modulation is used to operate the device in power-save mode with a typical quiescent current of 35µA. Even with such a low quiescent current, the part exhibits excellent transient response during large load swings. At higher loads, the system automatically switches to fixed-frequency control.

In shutdown mode, the supply current drops below 2µA, reducing power consumption.



Ordering Information

Part Number	Output Voltage[1]	Package	Temperature Range	Packing
FAN4603MM18X	1.82V	6-Lead Molded Leadless Package (MLP), 4 x 2.5 x 1mm	–40 to 85°C	Tape and Reel
FAN4603MM15X	1.5V			
FAN4603MM13X	1.3V			
FAN4603MM12X	1.23V			
FAN4603MM10X	1.0V			

Note:
1. Other voltage options are available on request. Contact a Fairchild representative.

Typical Application

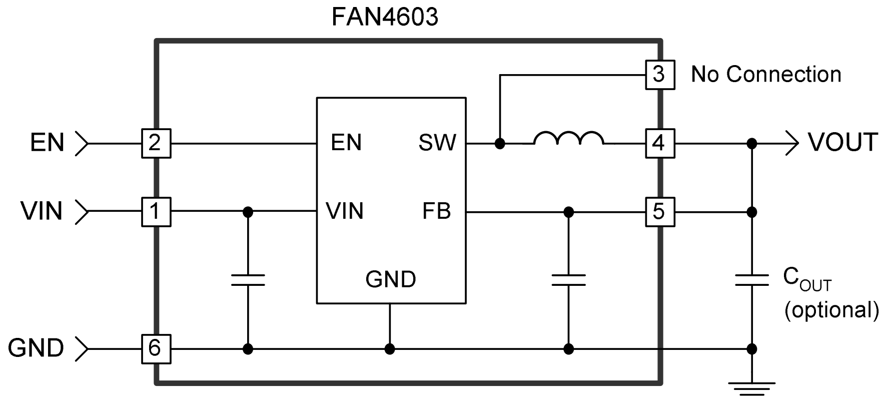


Figure 1. Typical Application

Pin Configuration

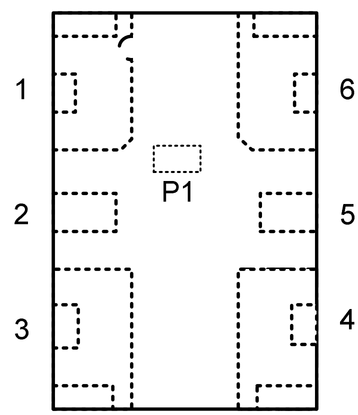


Figure 2. MLP 4.0 x 2.5 mm (Top View)

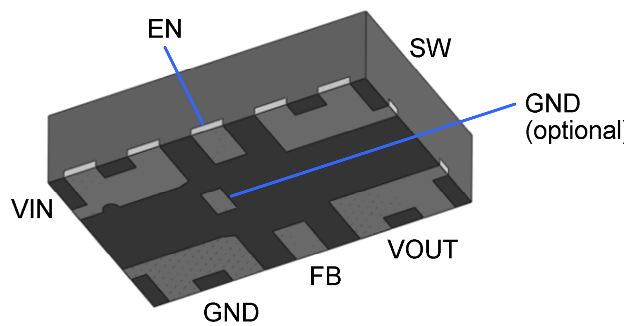


Figure 3. 3D Package View

Pin Definitions

Pin #	Name	Description
1	VIN	**Input Voltage**. Connect to input power source
2	EN	**Enable**. The device is in shutdown mode when voltage to this pin is <0.4V and enabled when >1.2V. Do not leave this pin floating.
3	SW	**Switching Node**. Leave this pin floating.
4	VOUT	**Output Voltage**. Connect to Load.
5	FB	**Feedback/V_{OUT}**. This pin must be shorted directly to VOUT (Pin 4).
6	GND	**Ground**. Power and IC ground. All signals are referenced to this pin.
P1	GND	**Optional Ground Connection**. Not typically used.

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.	Units
V_{IN}	Input Voltage with Respect to GND		-0.3	6.0	V
	Voltage on Any Other Pin with Respect to GND		-0.3	V_{IN}	V
T_J	Junction Temperature		-40	+150	°C
T_{STG}	Storage Temperature		-65	+150	°C
T_L	Lead Temperature (Soldering, 10 Seconds)			+260	°C
ESD	Electrostatic Discharge Capability	Human Body Model JESD22-A114	6		kV
		Charged Device Model, JESD22-C101	2		

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.	Max.	Units
V_{CC}	Supply Voltage Range	2.3	5.5	V
I_{OUT}	Output Current	0	600	mA
T_A	Operating Ambient Temperature	-40	+85	°C
T_J	Operating Junction Temperature	-40	+125	°C

Thermal Properties

Symbol	Parameter	Typical	Units
Θ_{JA}	Junction-to-Ambient Thermal Resistance(2)	120	°C/W

Note:

2. Junction-to-ambient thermal resistance is a function of application and board layout. This data is measured with a two-layer 2s0p board in accordance to the JESD51- JEDEC standard. Special attention must be paid not to exceed junction temperature $T_{J(max)}$ at a given ambient temperature T_A.

Electrical Specifications

Unless otherwise noted, V_{IN} = 2.5 to 5.5V, EN = V_{IN}. T_A = -40°C to +85°C, using circuit of Figure 1. Typical values are at 3.6V_{IN}, T_A = 25°C.

Symbol	Parameter		Conditions	Min.	Typ.	Max.	Units
Power Supplies							
I_Q	Quiescent Current				35	55	µA
I_{SD}	Shutdown Supply Current		V_{IN} = 3.6V, EN = GND		0.1	2.0	µA
V_{UVLO}	Under-Voltage Lockout Threshold		Rising V_{IN}		2.15	2.25	V
V_{UVHYST}	Under-Voltage Lockout Hysteresis				150		mV
V_{ENH}	Enable HIGH-Level Input Voltage			1.05			V
V_{ENL}	Enable LOW-Level Input Voltage					0.4	V
V_{EN_HYS}	Enable Logic Input Hysteresis				100		mV
I_{EN}	Enable Input Leakage Current		EN = V_{IN} or GND		0.01	1.00	µA
Oscillator							
f_{OSC}	Oscillator Frequency(3)		PWM Mode	5.4	6.0	6.6	MHz
Regulation							
V_O	Output Voltage Accuracy	1.82V	I_{LOAD} = 0 to 600mA	1.784	1.820	1.890	V
			PWM Mode	1.784	1.820	1.856	
		1.50V	I_{LOAD} = 0 to 600mA	1.470	1.500	1.560	
			PWM Mode	1.470	1.500	1.530	
		1.30V	I_{LOAD} = 0 to 600mA	1.274	1.300	1.352	
			PWM Mode	1.274	1.300	1.326	
		1.23V	I_{LOAD} = 0 to 600mA	1.207	1.233	1.283	
			PWM Mode	1.207	1.233	1.260	
		1.00V	I_{LOAD} = 0 to 600mA	0.975	1.000	1.050	
			PWM Mode	0.975	1.000	1.025	
t_{SS}	Soft-Start Time		Rising EN to V_{OUT} Regulation		180	300	µs
Protection							
I_{LIM}	Peak Input Current Limit			850	1050	1250	mA
T_{TSD}	Thermal Shutdown				+150		°C
T_{HYS}	Thermal Shutdown Hysteresis				+15		°C

Note:

3. PWM frequency may be lower than specified when limited by $t_{ON\text{-}min}$ (minimum on-time) or t_{OFF_min} (minimum off-time), at duty cycle extremes, but output regulation is maintained.

Typical Performance

Unless otherwise specified, V_{IN} = 3.7V, T_A = 25°C, V_{IN} = V_{EN}

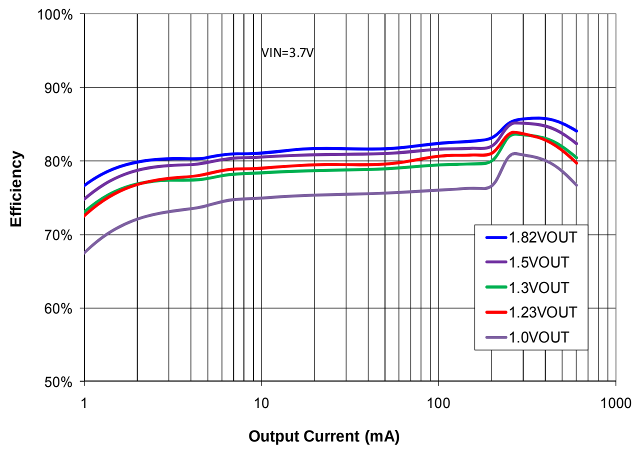


Figure 4. Efficiency, V_{IN}=3.7V

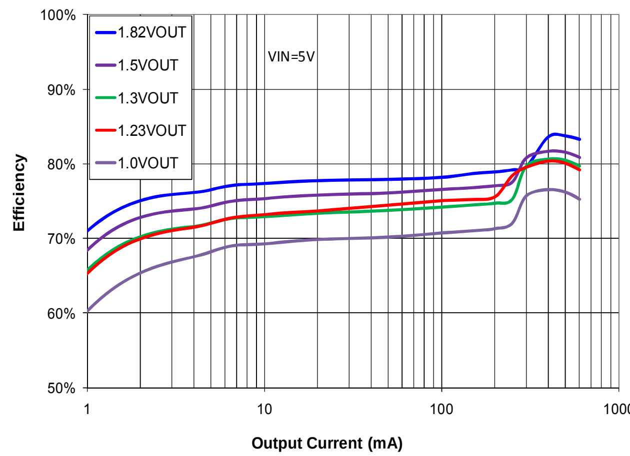


Figure 5. Efficiency, V_{IN}=5V

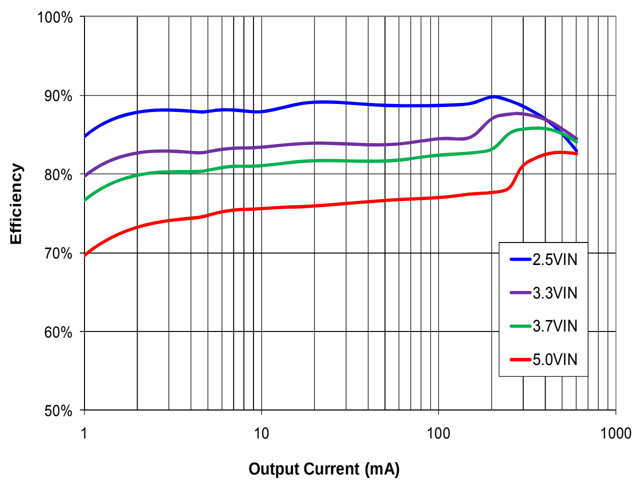


Figure 6. 1.82V_{OUT} Efficiency

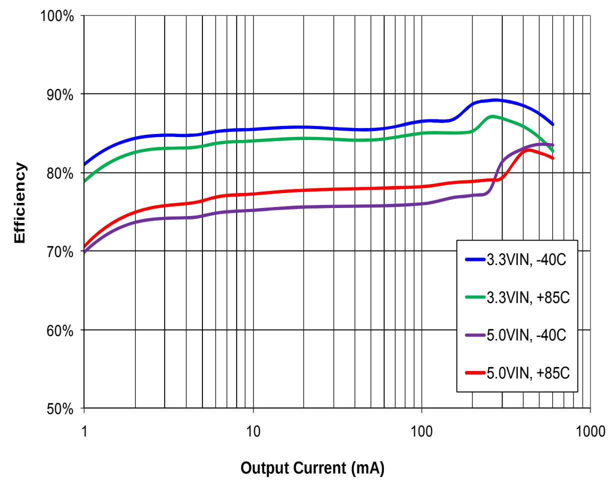


Figure 7. 1.82 V_{OUT} Efficiency Over Temperature

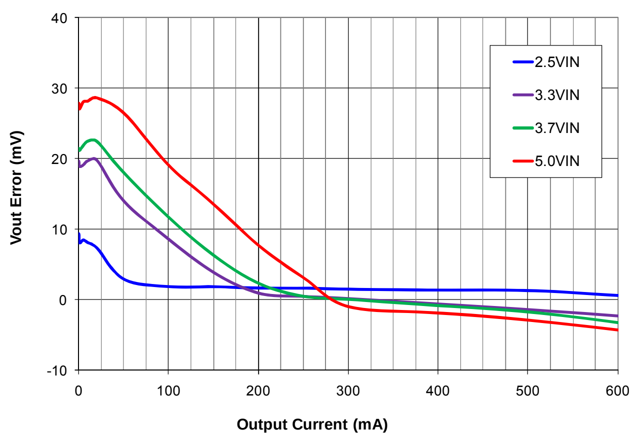


Figure 8. 1.82V_{OUT} Regulation (Normalized)

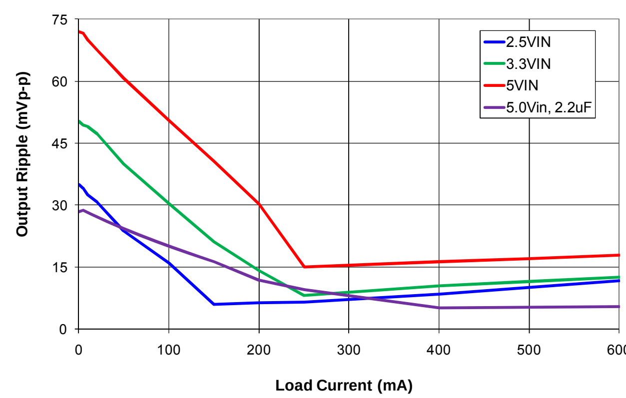


Figure 9. 1.82V_{OUT} Output Ripple with Optional 2.2μF C_{OUT} (1.5μF Actual)

Typical Performance

Unless otherwise specified, V_{IN} = 3.7V, T_A = 25°C,V_{IN} = V_{EN}

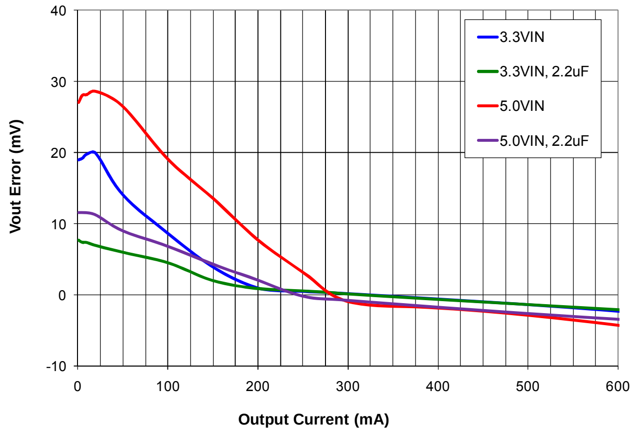


Figure 10. 1.82V_{OUT} Regulation (Normalized) with Optional 2.2µF C_{OUT} (1.5µF Actual)

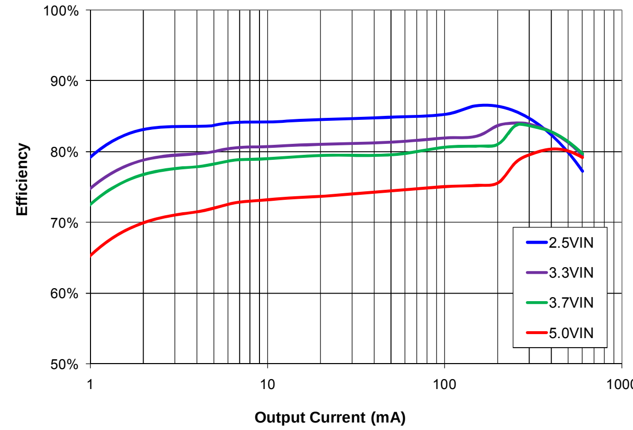


Figure 11. 1.23 V_{OUT} Efficiency

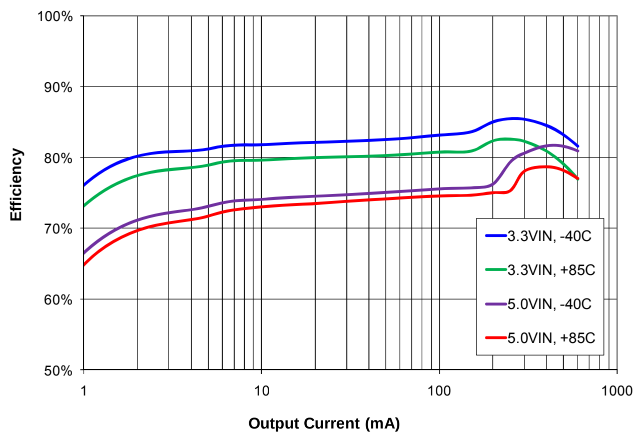


Figure 12. 1.23V_{OUT} Efficiency Over Temperature

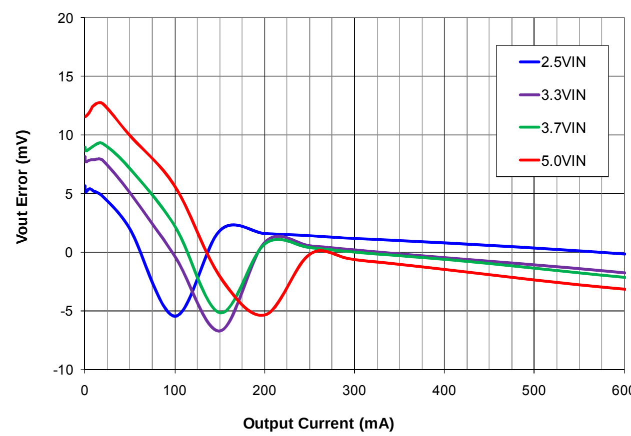


Figure 13. 1.23V_{OUT} Regulation (Normalized)

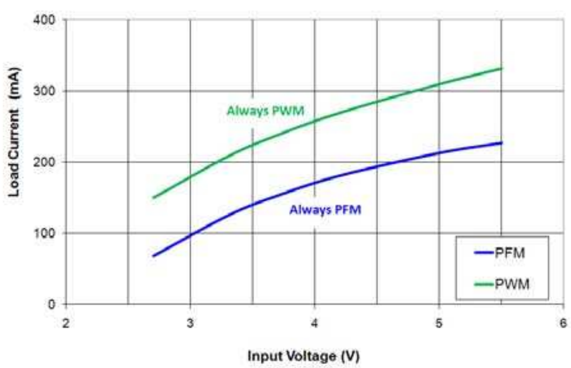


Figure 14. 1.82V_{OUT} PFM / PWM Boundary

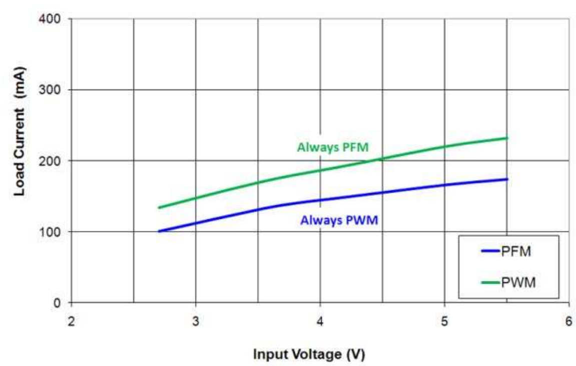


Figure 15. 1.23V_{OUT} PFM / PWM Boundary

Typical Performance

Unless otherwise specified, V_{IN} = 3.7V, T_A = 25°C, V_{IN} = V_{EN}

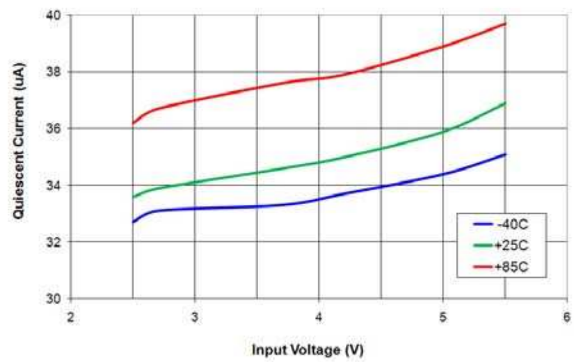


Figure 16. Quiescent Current Over Temperature (EN=V_{IN})

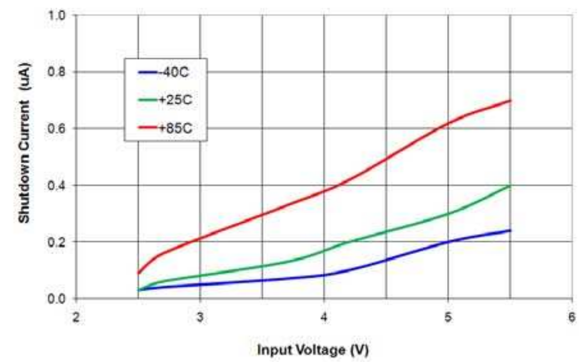


Figure 17. Shutdown Current Over Temperature (EN=0V)

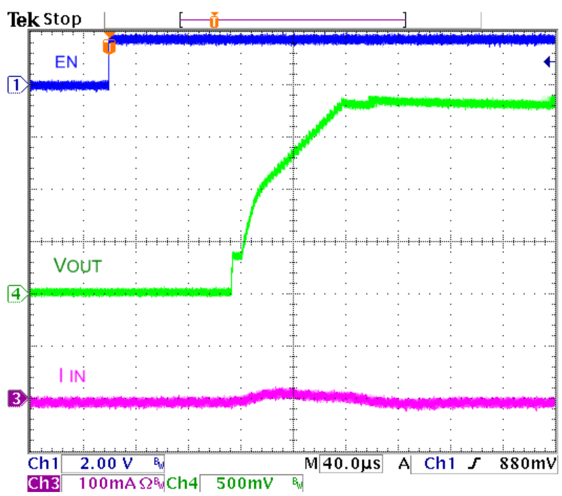


Figure 18. 1.82V_{OUT} Startup, 3.7V_{IN}, No Load

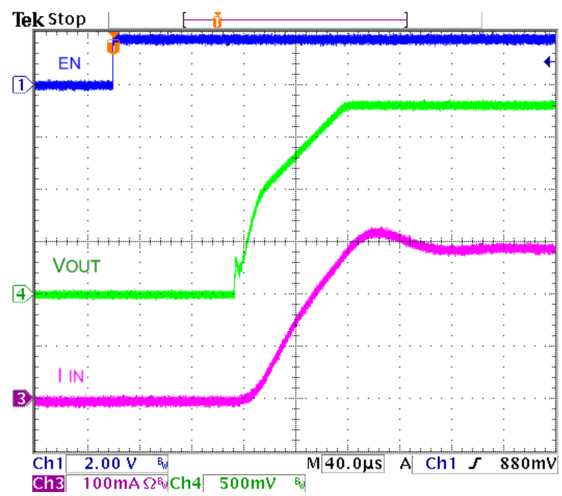


Figure 19. 1.82V_{OUT} Startup, 3.7V_{IN}, 3.6Ω Load

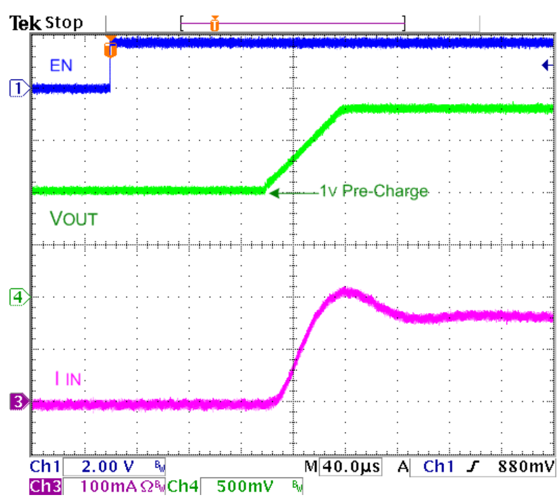


Figure 20. 1.82V_{OUT} Startup into Pre-Charged Output, 3.7V_{IN}, 300mA Load

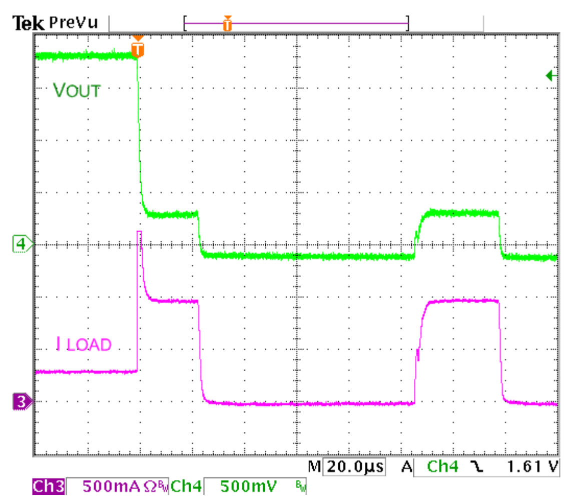


Figure 21. Over-Current Protection, 300mA Load Transition to 300mΩ Fault

Typical Performance

Unless otherwise specified, V_{IN} = 3.7V, T_A = 25°C, V_{IN} = V_{EN}

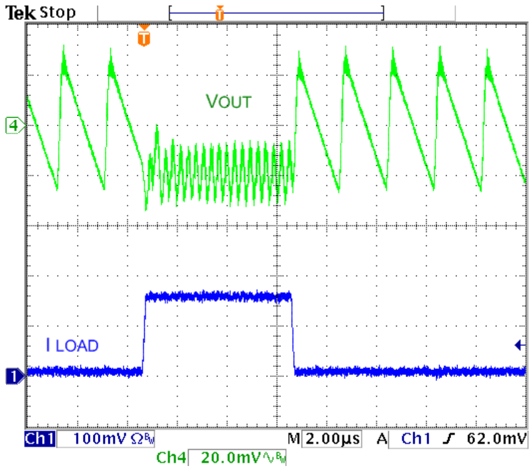


Figure 22. 1.82V_{OUT} Load Transient, 10-160mA, t_R/t_F=100ns

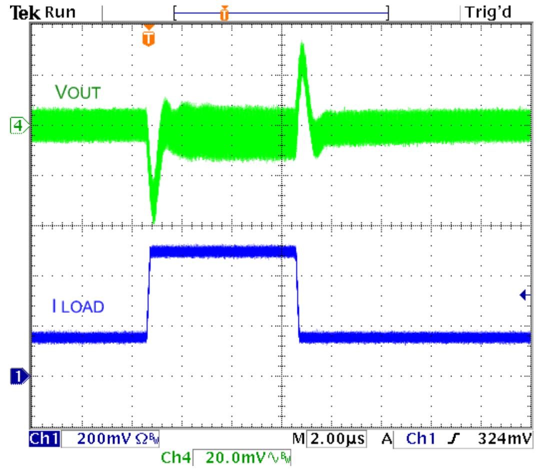


Figure 23. 1.82V_{OUT} Load Transient, 150-500mA, t_R/t_F=100ns

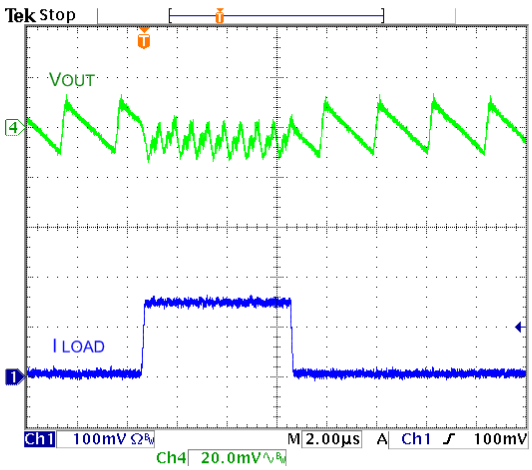


Figure 24. 1.82V_{OUT} Load Transient, 10-160mA, t_R/t_F=100ns with Optional 2.2µF C_{OUT}

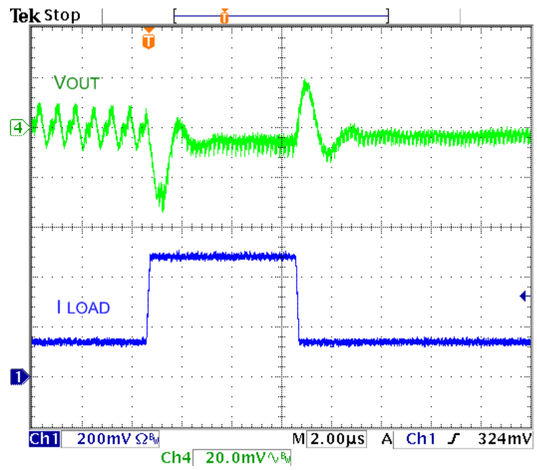


Figure 25. 1.82V_{OUT} Load Transient, 150-500mA, t_R/t_F=100ns with Optional 2.2µF C_{OUT}

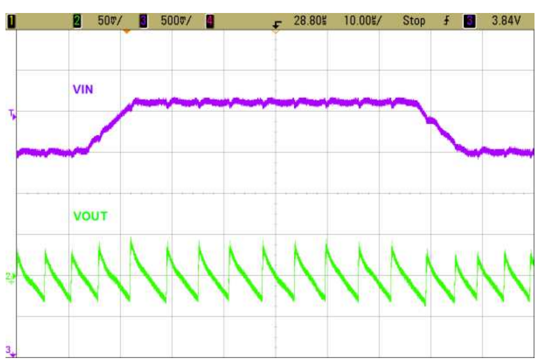


Figure 26. 1.82V_{OUT} Line Transient, 3.6-4.2V_{IN}, t_R/t_F=10µs, with 10mA Load

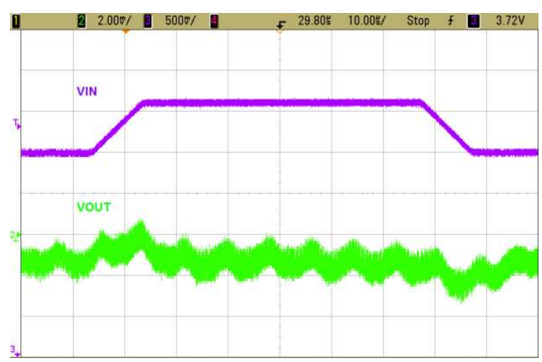


Figure 27. 1.82V_{OUT} Line Transient, 3.6-4.2V_{IN}, t_R/t_F=10µs, with 300mA Load

Operation Description

The FAN4603 is a 600mA, step-down, switching-voltage regulator that delivers a fixed output from an input voltage supply of 2.3V to 5.5V. Using a proprietary architecture with synchronous rectification, the FAN4603 is capable of delivering a peak efficiency of >90%, while maintaining efficiency over 80% at load currents as low as 1mA. The regulator operates at a nominal PWM frequency of 6MHz.

Control Scheme

The FAN4603 uses a proprietary, non-linear, fixed-frequency PWM modulator to deliver a fast load transient response, while maintaining a constant switching frequency over a wide range of operating conditions. Regulator stability is not dependent on output capacitor ESR, which allows the use of ceramic capacitors. Although this type of operation normally results in a switching frequency that varies with input voltage and load current, an internal frequency loop holds the switching frequency constant over a large range of input voltages and load currents.

For very light loads, FAN4603 incorporates a discontinuous current (DCM) single-pulse PFM mode, which produces lower output ripple when compared with other PFM architectures. Transition between PWM and PFM is seamless, with a glitch of less than 20mV at V_{OUT} during the transition between DCM and CCM modes.

Combined with exceptional transient response characteristics, the very low quiescent current of the controller (35µA) maintains high efficiency; even at very light loads, while preserving fast transient response for applications requiring tight output regulation.

Enable and Soft-Start

When EN is LOW, all circuits in FAN4603 are off and the IC draws ~100nA of current. When EN is HIGH and V_{IN} is above its UVLO threshold, the regulator begins a soft-start cycle. The output ramp during soft-start is a fixed slew rate of 50mV/µs from 0 to 1 V_{OUT}, then 12.5mV/µs until the output reaches its setpoint.

PWM mode operation is prohibited during the soft-start cycle to prevent C_{OUT} from being discharged. This allows glitchless starting into a pre-charged output.

Startup into Large C_{OUT}

The IC may fail to start if heavy load is applied during startup and a large external C_{OUT} is present. This is due to the current-limit fault response, which protects the IC in an over-current condition during soft-start.

The current required to charge C_{OUT} during soft-start, referred to as "displacement current," is given as:

$$I_{DISP} = C_{OUT} \bullet \frac{dV}{dt} \quad (1)$$

where $\frac{dV}{dt}$ refers to the soft-start slew rate.

To prevent shutdown during soft-start, the following condition must be met:

$$I_{DISP} + I_{LOAD} < I_{MAX(DC)} \quad (2)$$

where $I_{MAX(DC)}$ is the maximum load current the IC is guaranteed to support (600mA).

Table 1 shows combinations of external C_{OUT} that allow the IC to start successfully with the minimum R_{LOAD} that can be supported at each.

Table 1. Minimum R_{LOAD} Values for Soft-Start with Various External C_{OUT} Values

C_{OUT}	Minimum R_{LOAD}
2.2µF, 0402	V_{OUT} / 0.55
4.7µF, 0402	V_{OUT} / 0.50
10µF, 0603	V_{OUT} / 0.45

Multiple soft-start cycles may be required for C_{OUT}>10µf (15µf with no load). The IC shuts down for 85µs when I_{DISP}+ I_{LOAD} exceeds I_{LIMIT} for more than 21µs of current limit. The IC then begins a new soft-start cycle. Subsequent soft-start cycles begin with any charge retained by C_{OUT} while the IC is off, allowing V_{OUT} to incrementally reach regulation over multiple soft-start attempts.

Current Limit, Fault Shutdown, and Restart

A heavy load or short circuit on the output causes the current to increase until a maximum current threshold is reached. Upon reaching this point, the high-side switch turns off, preventing high currents from causing damage. The regulator continues to limit the current cycle-by-cycle. After 21µs of current limit, the regulator triggers an over-current fault, causing the regulator to shut down for about 85µs before attempting an automatic restart.

If the fault is caused by short circuit, the soft-start circuit attempts to restart and produces an over-current fault after about 32µs, which results in a duty cycle of less than 30%, limiting power dissipation.

Under-Voltage Lockout (UVLO)

When EN is HIGH, the under-voltage lockout keeps the part from operating until the input supply voltage rises high enough to properly operate. This ensures no misbehavior of the regulator during startup or shutdown.

Thermal Shutdown

When the die temperature increases, due to a high load condition and/or a high ambient temperature, the output switching is disabled until the temperature on the die has fallen sufficiently. The junction temperature at which the thermal shutdown activates is nominally 150°C with 15°C hysteresis. After cooling, the IC automatically restarts, with a soft-start cycle.

Reducing PFM Output Ripple

PFM output ripple amplitude can be reduced by adding external C_{OUT}, with negligible impact on efficiency.

Reduced output ripple also results in less DC voltage excursion at very light loads. Maximum PFM ripple occurs at no load and is V_{IN} and V_{OUT} proportional.

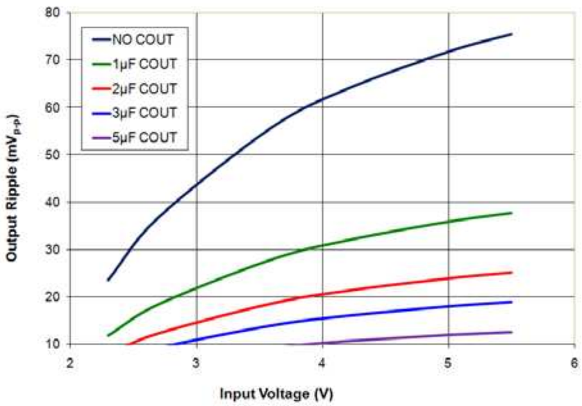


Figure 28. Typical 1.82V_{OUT} No Load PFM Ripple vs. V_{IN}

Note:

4. Ripple is less for lower V_{OUT} levels.

The effective value of external C_{OUT} for a desired ripple amplitude can be determined using:

$$C_{OUT.}(\mu F) = \left(\frac{(V_{IN} - V_{OUT}) \bullet V_{OUT} \bullet 62}{V_{IN} \bullet V_R} \right) - 1 \qquad (3)$$

where V_R is the desired output ripple amplitude in mV and V_{IN} and V_{OUT} are in Volts.

The simplified equation above is representative of nominal component values and does not account for device tolerances. The bias level effects associated with case size, voltage rating, and dielectric type of ceramic capacitors should be considered when selecting C_{OUT}.

Minimum Off-Time Effect on Switching Frequency

$t_{OFF(MIN)}$ is 50ns, while $t_{ON(MIN)}$ is 35nS This imposes constraints on the maximum/minimum $\frac{V_{OUT}}{V_{IN}}$ that the FAN4603 can provide while maintaining a fixed switching frequency in PWM mode.

When V_{IN} is LOW, fixed switching is maintained as long as

$$\frac{V_{OUT}}{V_{IN}} \le 1 - t_{OFF(MIN)} \bullet f_{SW} \approx 0.7 .$$

When V_{IN} is HIGH, fixed switching is maintained as long as

$$\frac{V_{OUT}}{V_{IN}} \ge t_{ON(MIN)} \bullet f_{SW} \approx 0.2$$

The switching frequency drops when the regulator cannot provide sufficient duty cycle at 6MHz to maintain regulation. Lowering the switching frequency allows V_{OUT} to remain in regulation, even at very low or very high duty cycle.

PCB Layout Guideline

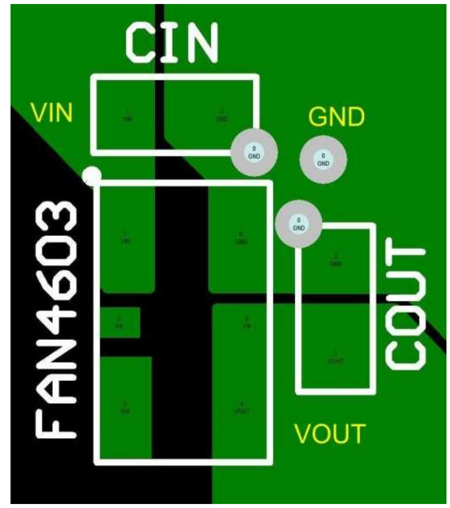


Figure 29. Recommended PCB Layout

FB (pin 5) must be directly connected to VOUT (pin 4).

Figure 29 shows the recommended locations of optional C_{IN} and C_{OUT}, shown as 0603 size devices.

Pad P1, shown in Figure 30 “Land Pattern,” is an optional GND pin. Connection is not required on the PCB.

Physical Dimensions

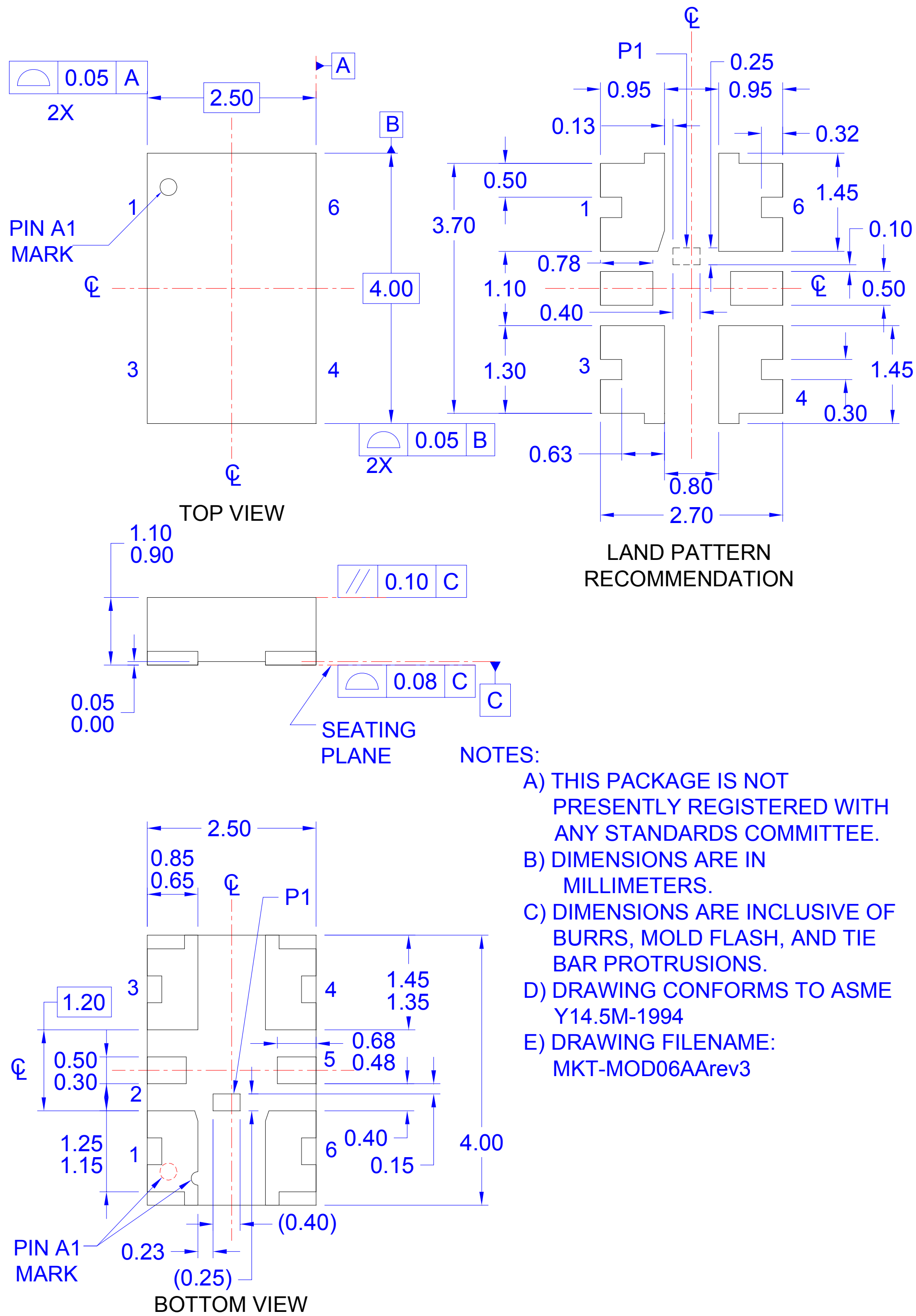


Figure 30.6-Lead, MicroModule QFN 2.5 x 4 x 1mm

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Definition of Terms

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