FAIRCHILD SEMICONDUCTOR®

August 2008

FAN102
Primary-Side-Control PWM Controller

Features

- Constant-Voltage (CV) and Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Green Mode: PWM Frequency Linearly Decreasing
- Fixed PWM Frequency at 42kHz with Frequency Hopping to Solve EMI Problem
- Cable Compensation in CV Mode
- Low Startup Current: 10µA
- Low Operating Current: 3.5mA
- Peak-Current-Mode Control in CV Mode
- Cycle-by-Cycle Current Limiting
- V_{DD} Over-Voltage Protection with Auto-Restart
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- Fixed Over-temperature Protection with Latch
- SOP-8 Package Available

Applications

- Battery chargers for cellular phones, cordless phones, PDA, digital cameras, power tools
- Replaces linear transformer and RCC SMPS

Description

This highly integrated PWM controller, FAN102, provides several features to enhance the performance of low-power flyback converters. The proprietary topology enables simplified circuit design for battery charger applications. A low-cost, smaller and lighter charger results when compared to a conventional design or a linear transformer. The startup current is only 10µA, which allows use of large startup resistance for further power saving.

To minimize the standby power consumption, the proprietary green-mode function provides off-time modulation to linearly decrease PWM frequency under light-load conditions. This green-mode function assists the power supply in meeting the power conservation requirements.

Using FAN102, a charger can be implemented with fewer external components and minimized cost. A typical output CV/CC characteristic envelope is shown in Figure 1.

FAN102 controller is available in 8-pin SOP package.

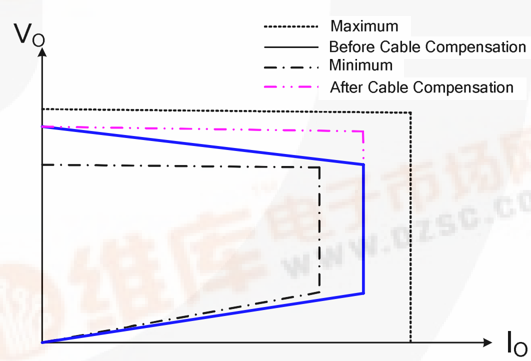


Figure 1. Typical Output V-I Characteristic

Ordering Information

Part Number	Operating Temperature Range	Eco Status	Package	Packing Method
FAN102MY	-40°C to +105°C	Green	8-Lead, Small Outline Package (SOP-8)	Tape & Reel

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

Application Diagram

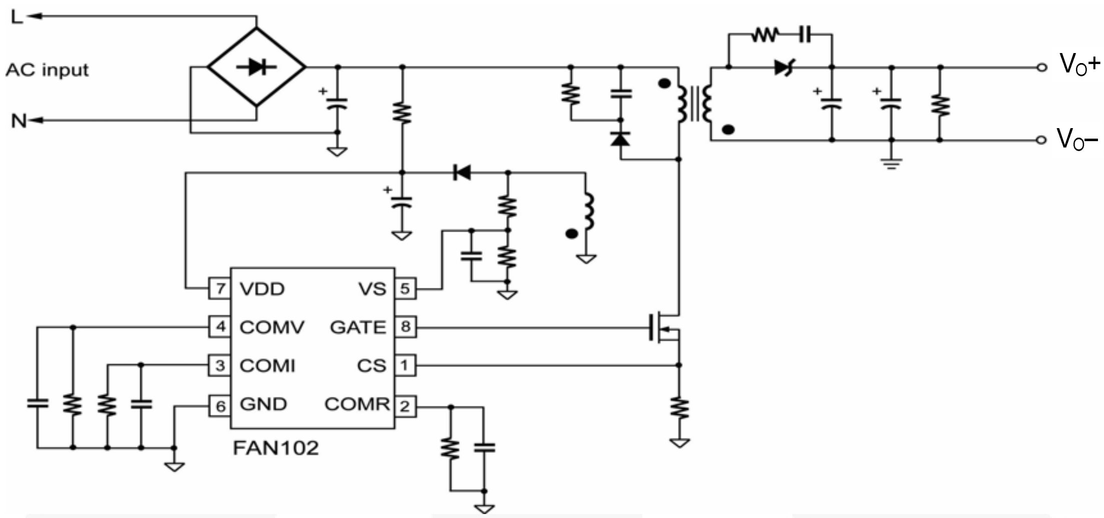


Figure 2. Typical Application

Internal Block Diagram

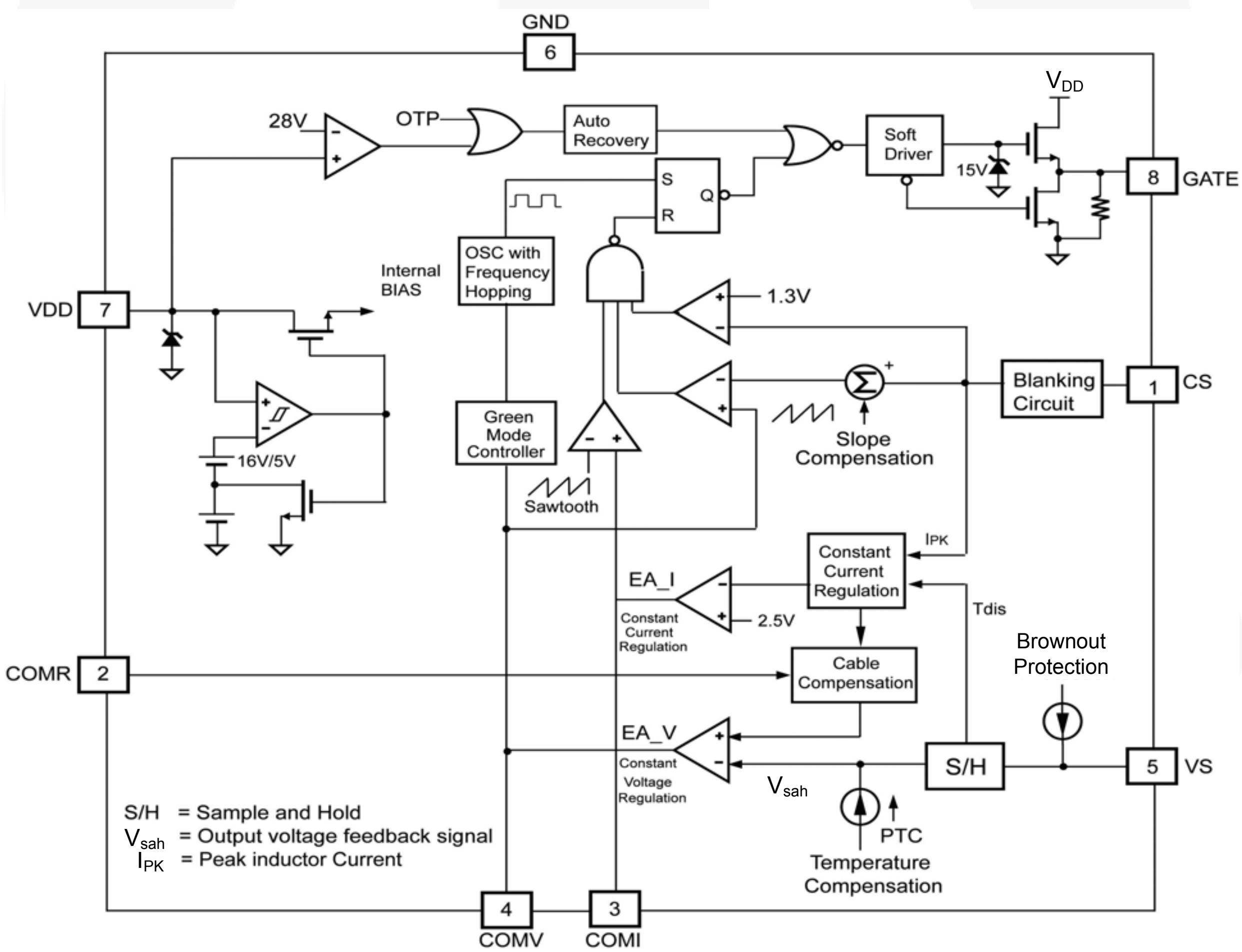
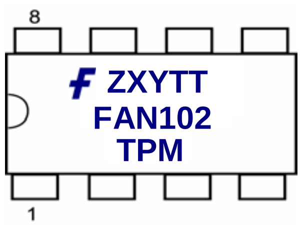


Figure 3. Functional Block Diagram

Marking Information



F- Fairchild logo
Z- Plant code
X- 1 digit year code
Y- 1 digit week code
TT: 2 digits die run code
T: Package type (M=SOP)
P: Z: Pb free, Y: Green package
M: Manufacture flow code

Figure 4. Top Mark

Pin Configuration

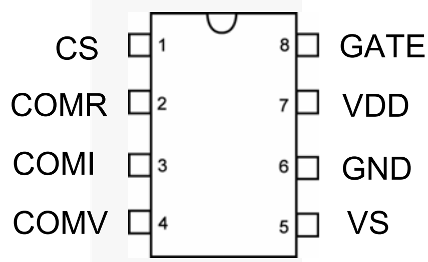


Figure 5. Pin Configuration

Pin Definitions

Pin #	Name	Description
1	CS	Analog input, current sense. Connected to a current-sense resistor for peak-current-mode control in CV mode. The current-sense signal is also provided for output-current regulation in CC mode.
2	COMR	Analog output, cable compensation. Connect a resistor between COMR and GND for cable loss compensation in CV mode.
3	COMI	Analog output, current compensation. Output of the current error amplifier. Connect a capacitor between COMI pin and GND for frequency compensation.
4	COMV	Analog output, voltage compensation. Output of the voltage error amplifier. Connect a capacitor between the COMV pin and GND for frequency compensation.
5	VS	Analog input, voltage sense. Output-voltage-sense input for output-voltage regulation.
6	GND	Voltage reference, ground.
7	VDD	Supply, power supply.
8	GATE	Driver output. The totem-pole output driver to drive the power MOSFET.

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_{DD}	DC Supply Voltage[1,2]		30	V
V_{VS}	VS Pin Input Voltage	-0.3	7.0	V
V_{CS}	CS Pin Input Voltage	-0.3	7.0	V
V_{COMV}	Voltage Error Amplifier Output Voltage	-0.3	7.0	V
V_{COMI}	Voltage Error Amplifier Output Voltage	-0.3	7.0	V
P_D	Power Dissipation ($T_A < 50°C$)		660	mW
θ_{JA}	Thermal Resistance (Junction-to-Air)		150	°C /W
θ_{JC}	Thermal Resistance (Junction-to-Case)		39	°C /W
T_J	Operating Junction Temperature		+150	°C
T_{STG}	Storage Temperature Range	-55	+150	°C
T_L	Lead Temperature (Wave Soldering or IR, 10 Seconds)		+260	°C
ESD	Electrostatic Discharge Capability, Human Body Model (JEDEC- JESD22_A114)		4.5	KV
	Electrostatic Discharge Capability, Charged Device Model (JEDEC- JESD22_C101)		1250	V

Notes:
1. Stresses beyond those listed under ”absolute maximum ratings” may cause permanent damage to the device.
2. All voltage values, except differential voltages, are given with respect to GND pin.

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	Conditions	Min.	Typ.	Max.	Unit
T_A	Operating Ambient Temperature		-40		+105	°C

Electrical Characteristics

V_{DD}=15V and T_A=25°C unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
V_{DD} Section						
V_{OP}	Continuously Operating Voltage				25	V
V_{DD-ON}	Turn-On Threshold Voltage		15	16	17	V
V_{DD-OFF}	Turn-Off Threshold Voltage		4.5	5.0	5.5	V
I_{DD-OP}	Operating Current	V_{DD}=20V, f_S=f_{OSC}, V_{VS}=2V, V_{CS}=3V, C_L=1nF		3.5	5.0	mA
$I_{DD-GREEN}$	Green-Mode Operating Supply Current	V_{DD}=20V, V_{VS}=2.7V f_S=$f_{OSC-N-MIN}$, V_{CS}=0V C_L=1nF, V_{COMV}=0V		1	2	mA
V_{DD-OVP}	V_{DD} Over-Voltage Protection Level	V_{CS}=3V, V_{VS}=2.3V	27	28	29	V
$t_{D-VDDOVP}$	V_{DD} Over-Voltage Protection Debounce Time	fs=f_{OSC}, V_{VS}=2.3V	100	250	400	µs
Oscillator Section						
f_{OSC}	Frequency – Center Frequency	T_A=25°C	39	42	45	KHz
	Frequency – Frequency Hopping Range	T_A=25°C	±1.8	±2.6	±3.6	KHz
t_{FHR}	Frequency Hopping Period	T_A=25°C		3		ms
$f_{OSC-N-MIN}$	Minimum Frequency at No Load	V_{VS}=2.7V, V_{COMV}=0V		550		Hz
$f_{OSC-CM-MIN}$	Minimum Frequency at CCM	V_{VS}=2.3V, V_{CS}=0.5V		20		KHz
f_{DV}	Frequency Variation vs. V_{DD} Deviation	V_{DD}=10V to 25V			5	%
f_{DT}	Frequency Variation vs. Temperature Deviation	T_A=-40°C to +85°C			15	%
Voltage-Sense Section						
I_{VS-UVP}	Sink Current for Brownout Protection	R_{VS}=20KΩ		125		µA
I_{tc}	IC Compensation Bias Current			9.5		µA
$V_{BIAS-COMV}$	Adaptive Bias Voltage Dominated by V_{COMV}	V_{COMV}=0V, T_A=25°C, R_{VS}=20KΩ		1.4		V
Current-Sense Section						
t_{PD}	Propagation Delay to GATE Output			100	200	ns
t_{MIN-N}	Minimum On Time at No Load	V_{VS}=-0.8V, R_S=2KΩ, V_{COMV}=1V		1100		ns
t_{MINCC}	Minimum On Time in CC Mode	V_{VS}=0V, V_{COMV}=2V		400		ns
D_{SAW}	Duty Cycle of SAW Limiter			40		%
V_{TH}	Threshold Voltage for Current Limit			1.3		V

Continued on the following page…

Electrical Characteristics

V_{DD}=15V and T_A=25°C unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Voltage-Error-Amplifier Section						
V_{VR}	Reference Voltage		2.475	2.500	2.525	V
V_N	Green Mode Starting Voltage on COMV Pin	f_S=f_{OSC}-2KHz, V_{VS}=2.3V		2.8		V
V_G	Green Mode Ending Voltage on COMV Pin	f_S=1KHz		0.8		V
$I_{V\text{-}SINK}$	Output Sink Current	V_{VS}=3V, V_{COMV}=2.5V		90		µA
$I_{V\text{-}SOURCE}$	Output Source Current	V_{VS}=2V, V_{COMV}=2.5V		90		µA
$V_{V\text{-}HGH}$	Output High Voltage	V_{VS}=2.3V	4.5			V
Current-Error-Amplifier Section						
V_{IR}	Reference Voltage		2.475	2.500	2.525	V
$I_{I\text{-}SINK}$	Output Sink Current	V_{CS}=3V, V_{COMI}=2.5V		55		µA
$I_{I\text{-}SOURCE}$	Output Source Current	V_{CS}=0V, V_{COMI}=2.5V		55		µA
$V_{I\text{-}HGH}$	Output High Voltage	V_{CS}=0V	4.5			V
Cable Compensation Section						
V_{COMR}	Variation Test Voltage on COMR Pin for Cable Compensation	R_{COMR}=100KΩ		0.735		V
Gate Section						
DCY_{MAX}	Maximum Duty Cycle			75		%
V_{OL}	Output Voltage Low	V_{DD}=20V, I_O=10mA			1.5	V
V_{OH}	Output Voltage High	V_{DD}=8V, I_O=1mA	5			V
V_{OH_MIN}	Output Voltage High	V_{DD}=5.5V, I_O=1mA	4			V
t_r	Rising Time	V_{DD}=20V, C_L=1nF		200	300	ns
t_f	Falling Time	V_{DD}=20V, C_L=1nF		80	150	ns
V_{CLAMP}	Output Clamp Voltage	V_{DD}=25V		15	18	V
Over-Temperature-Protection Section						
T_{OTP}	Threshold Temperature for OTP(3)			+140		°C

Note:
3. When over-temperature protection is activated, the power system enters latch mode and output is disabled.

Typical Performance Characteristics

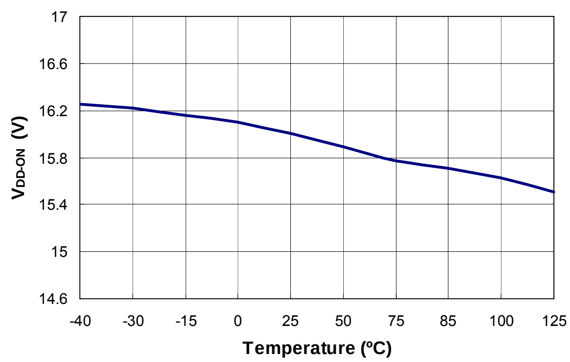


Figure 6. Turn-on Threshold Voltage (V_{DD-ON}) vs. Temperature

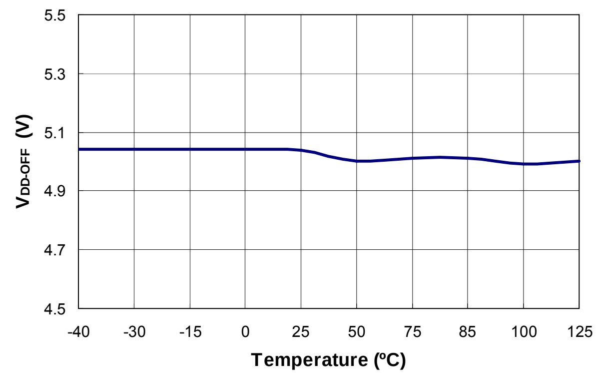


Figure 7. Turn-off Threshold Voltage (V_{DD-OFF}) vs. Temperature

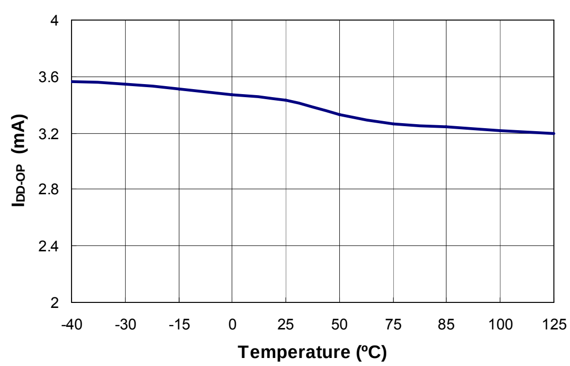


Figure 8. Operating Current (I_{DD-OP}) vs. Temperature

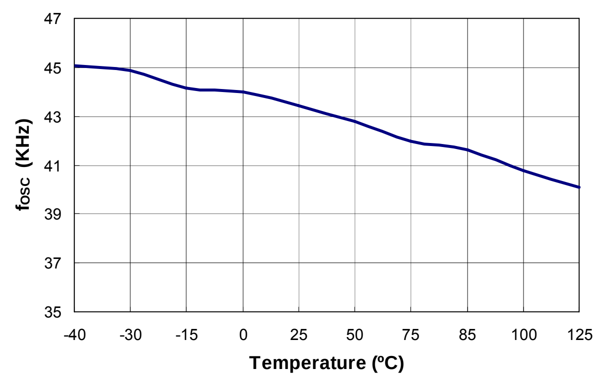


Figure 9. Center Frequency (f_{OSC}) vs. Temperature

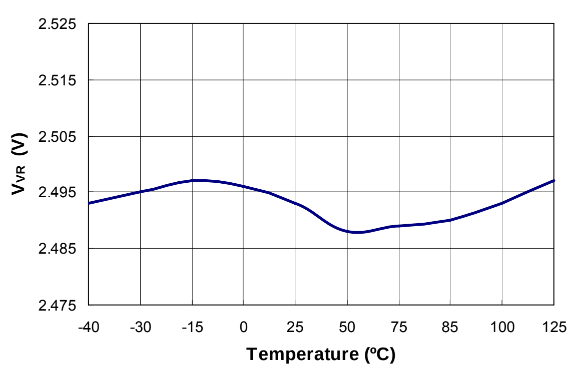


Figure 10. Reference Voltage (V_{VR}) vs. Temperature

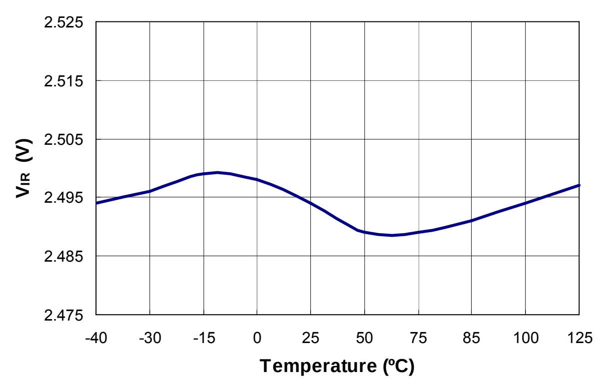


Figure 11. Reference Voltage (V_{IR}) vs. Temperature

Typical Performance Characteristics

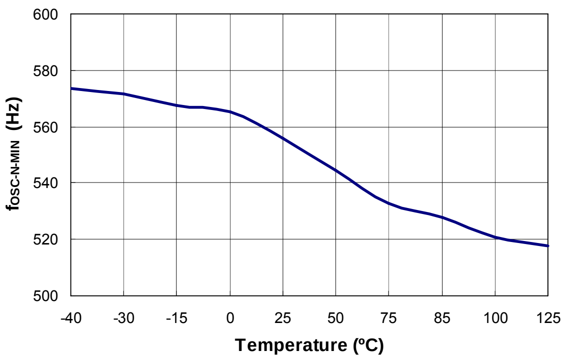


Figure 12. Minimum Frequency at No Load ($f_{OSC-N-MIN}$) vs. Temperature

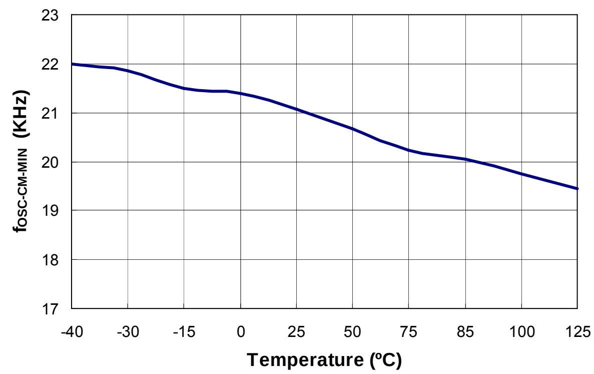


Figure 13. Minimum Frequency at CCM ($f_{OSC-CM-MIN}$) vs. Temperature

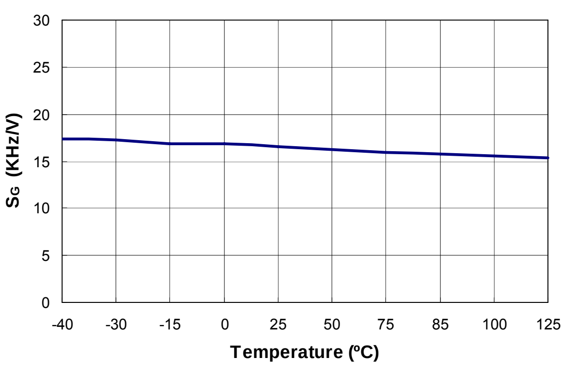


Figure 14. Green Mode Frequency Decreasing Rate (S_G) vs. Temperature

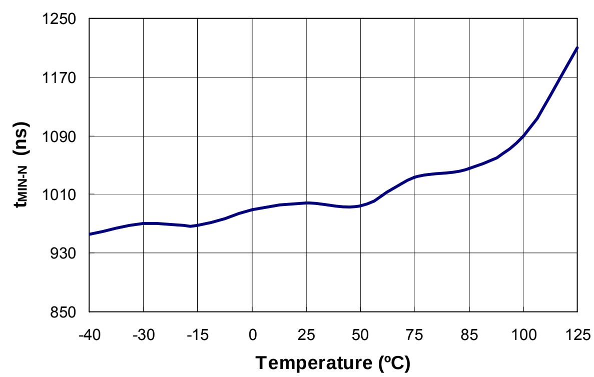


Figure 15. Minimum On Time at No Load (t_{MIN-N}) vs. Temperature

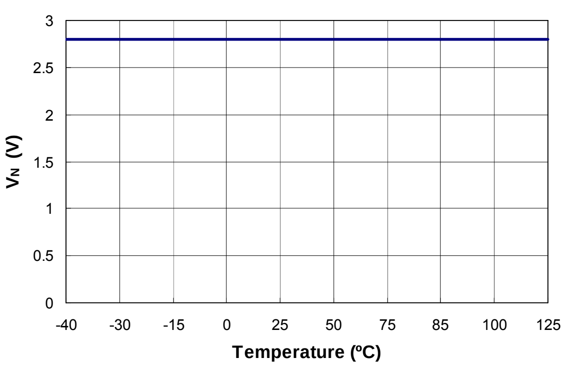


Figure 16. Green Mode Starting Voltage on COMV Pin (V_N) vs. Temperature

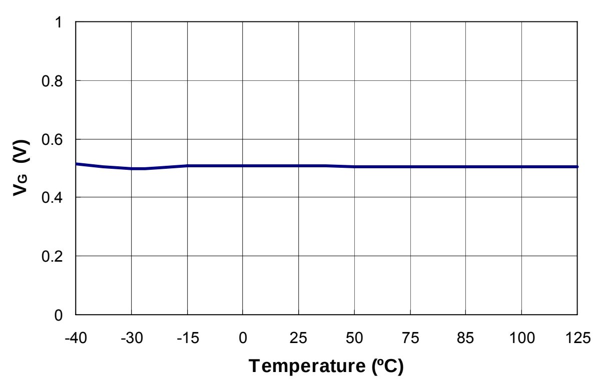


Figure 17. Green Mode Ending Voltage on COMV Pin (V_G) vs. Temperature

Typical Performance Characteristics

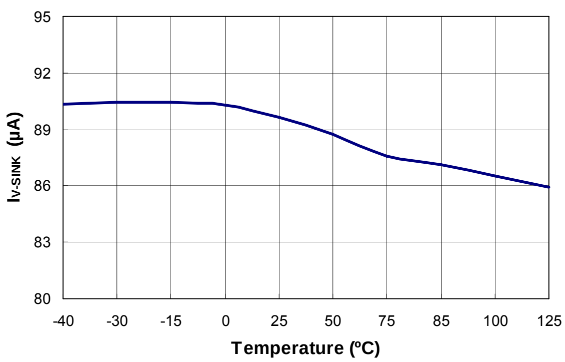


Figure 18. Output Sink Current ($I_{V\text{-}SINK}$) vs. Temperature

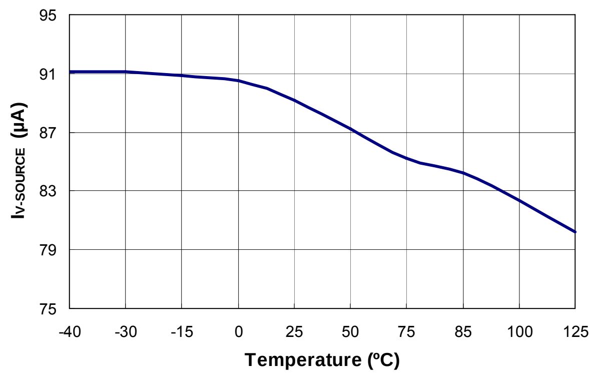


Figure 19. Output Source Current ($I_{V\text{-}SOURCE}$) vs. Temperature

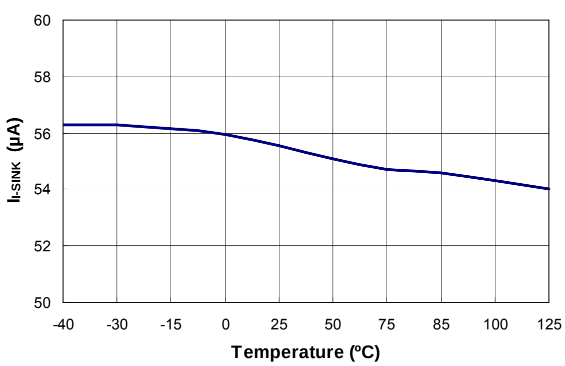


Figure 20. Output Sink Current ($I_{I\text{-}SINK}$) vs. Temperature

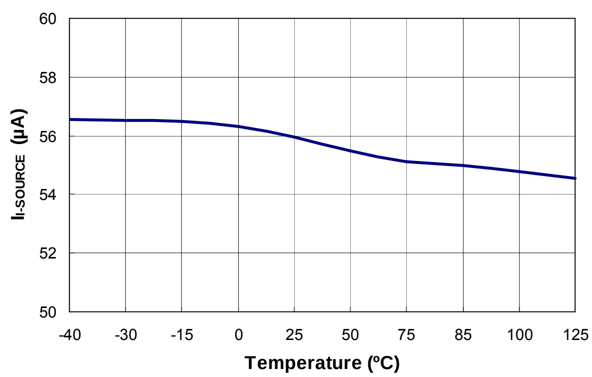


Figure 21. Output Source Current ($I_{I\text{-}SOURCE}$) vs. Temperature

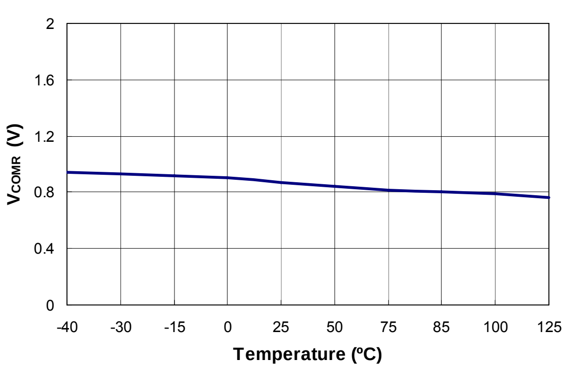


Figure 22. Variation Test Voltage on COMR Pin for Cable Compensation (V_{COMR}) vs. Temperature

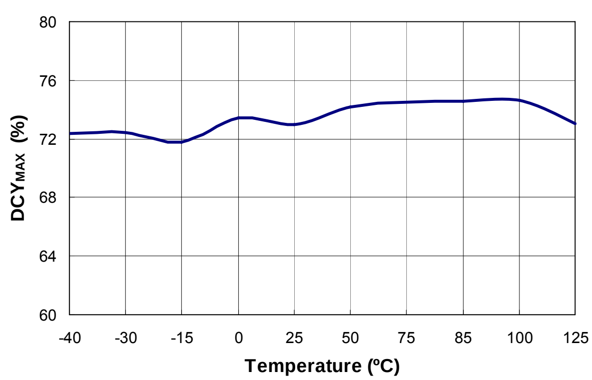


Figure 23. Maximum Duty Cycle (DCY_{MAX}) vs. Temperature

Functional Description

The proprietary topology of FAN102 enables most simplified circuit design for battery charger applications. Without secondary feedback circuitry, the CV and CC control are achieved accurately. As shown in Figure 24, with the frequency-hopping PWM operation, EMI problems can be solved by using minimized filter components. FAN102 also provides many protection functions. The VDD pin is equipped with over-voltage protection and under-voltage lockout. Pulse-by-pulse current limiting and CC control ensure over-current protection at heavy loads. The GATE output is clamped at 15V to protect the external MOSFET from over-voltage damage. Also, the internal over-temperature-protection function shuts down the controller with latch when overheated.

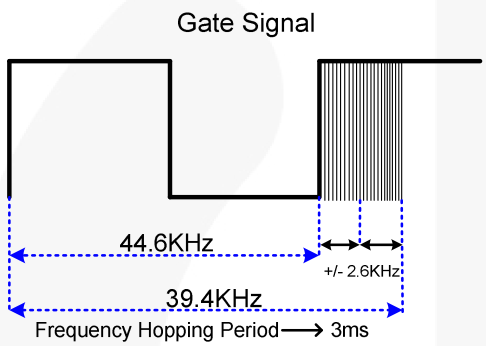


Figure 24. Frequency Hopping

Startup Current

The startup current is 10µA. Low startup current allows a startup resistor with a high resistance and a low-wattage to supply the startup power for the controller. A 1.5MΩ, 0.25W, startup resistor and a 10µF/25V V_{DD} hold-up capacitor are sufficient for an AC-to-DC power adapter with a wide input range ($100V_{AC}$ to $240V_{AC}$)

Operating Current

The operating current has been reduced to 3.5mA. The low operating current results in higher efficiency and reduces the VDD hold-up capacitance requirement. Once FAN102 enters "deep" green mode, the operating current is reduced to 1.2mA, which assists the power supply in meeting the power conservation requirements.

Green-Mode Operation

Figure 25 shows the characteristics of the PWM frequency vs. the output voltage of the error amplifier (V_{COMV}). The FAN102 uses the positive, proportional, output load parameter (V_{COMV}) as an indication of the output load for modulating the PWM frequency. In heavy load conditions, the PWM frequency is fixed at 42KHz. Once V_{COMV} is lower than V_N, the PWM frequency starts to linearly decrease from 42KHz to 550Hz, providing further power savings and meeting international power conservation requirements.

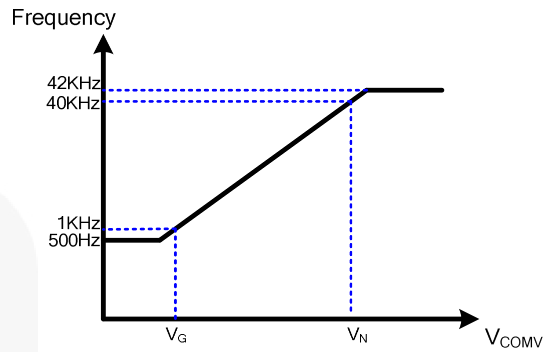


Figure 25. Green Mode Frequency vs. V_{COMV}

Constant Voltage (CV) and Constant Current (CC) Operation

An innovative technique allows the FAN102 to accurately achieve CV / CC characteristic output without secondary-side voltage or current-feedback circuitry. A feedback signal for CV / CC operation from the reflected voltage across the primary auxiliary winding is proportional to secondary winding, so provides the controller the feedback signal from secondary side and achieves constant voltage output property. In constant-current-output operation, this voltage signal is detected and examined by the precise constant current regulation controller, which then determines the on-time of the MOSFET to control input power and provide constant current output property. With feedback voltage V_{CS} across the current-sense resistor, the controller can obtain input power of power supply. Therefore, the region of constant current output operation can be adjusted by the current-sense resistor.

Temperature Compensation

Built-in temperature compensation provides better constant voltage regulation at different ambient temperatures. This internal compensation current is a positive temperature coefficient (PTC) current that can compensate the forward-voltage drop of the secondary diode of varying with temperature. This variation causes output voltage rising at high temperature.

Leading-Edge Blanking (LEB)

Each time the power MOSFET switches on, a turn-on spike occurs at the sense resistor. To avoid premature termination of the switching pulse, a leading-edge blanking time is built in. Conventional RC filtering can be omitted. During this blanking period, the current-limit comparator is disabled and cannot switch off the gate driver.

Functional Description (Continued)

Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds are fixed internally at 16V and 5V. During startup, the hold-up capacitor must be charged to 16V through the startup resistor to enable the FAN102. The hold-up capacitor continues to supply V_{DD} until power can be delivered from the auxiliary winding of the main transformer. V_{DD} must not drop below 5V during this startup process. This UVLO hysteresis window ensures that hold-up capacitor is adequate to supply V_{DD} during startup.

V_{DD} Over-Voltage Protection (OVP)

V_{DD} over-voltage protection prevents damage due to over-voltage conditions. When the V_{DD} voltage exceeds 28V due to abnormal conditions, PWM pulses are disabled until the V_{DD} voltage drops below the UVLO, then start again. Over-voltage conditions are usually caused by open feedback loops.

Over-Temperature Protection (OTP)

The built-in temperature-sensing circuit shuts down PWM output once the junction temperature exceeds 140°C. While PWM output is shut down, the V_{DD} voltage gradually drops to the UVLO voltage. Some of the FAN102's internal circuits are shut down and V_{DD} gradually starts increasing again. When V_{DD} reaches 16V, all the internal circuits, including the temperature-sensing circuit, start operating normally. If the junction temperature is still higher than 140°C, the PWM controller shuts down immediately. This situation continues until the temperature drops below 110°C.

Gate Output

The BiCMOS output stage is a fast totem-pole gate driver. Cross conduction has been avoided to minimize heat dissipation, increase efficiency, and enhance reliability. The output driver is clamped by an internal 15V Zener diode to protect power MOSFET transistors against undesired over-voltage gate signals.

Built-in Slope Compensation

The sensed voltage across the current-sense resistor is used for current-mode control and pulse-by-pulse current limiting. Built-in slope compensation improves stability and prevents sub-harmonic oscillations due to peak-current mode control. The FAN102 has a synchronized, positively-sloped ramp built-in at each switching cycle.

Noise Immunity

Noise from the current sense or the control signal can cause significant pulse-width jitter, particularly in continuous-conduction mode. While slope compensation helps alleviate these problems, further precautions should still be taken. Good placement and layout practices should be followed. Avoiding long PCB traces and component leads, locating compensation and filter components near the FAN102, and increasing the power MOS gate resistance are advised.

Applications Information

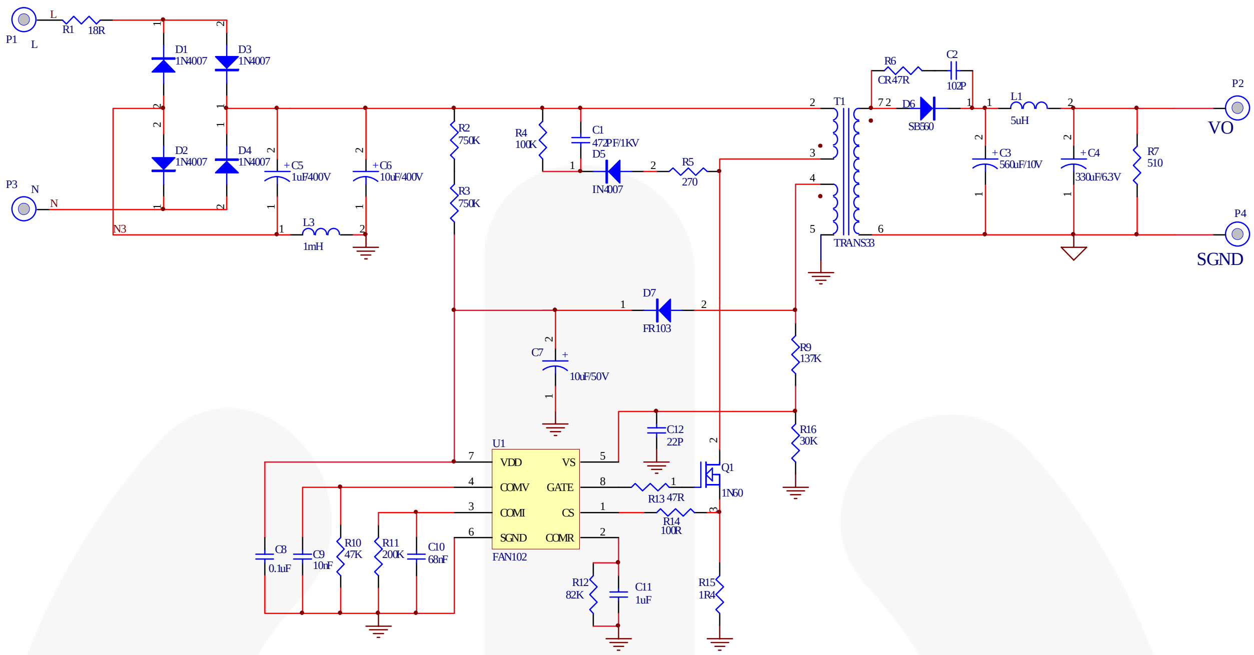


Figure 26. 5W (5V/1A) Application Circuit

BOM

Designator	Part Type	Designator	Part Type
D1, D2, D3, D4, D5	1N4007	R4	R 100KΩ
D6	SB560	R5	R 270Ω
D7	FR103	R6	R 47Ω
C1	CC 4.7nF/1KV	R7	R 510Ω
C2	1nF	R9	R 137KΩ
C3	EC 560µF/10V	R10	R 47KΩ
C4	EC 330µF/6.3V	R11	R 200KΩ
C5	EC 1µF/400V	R12	R 82KΩ
C6	EC 10µF/400V	R13	R 47Ω
C7	EC 10µF/50V	R14	R 100Ω
C8	0.1µF	R15	R 1.4Ω
C9	10nF	R16	R 30KΩ
C10	68nF	L1	5µH
C11	1µF	L3	1mH
C12	22pF	Q1	MOSFET 1A/600V
R1	R 18Ω	T1	EE16 (1.5mH)
R2, R3	R 750KΩ	U1	IC FAN102

Physical Dimensions

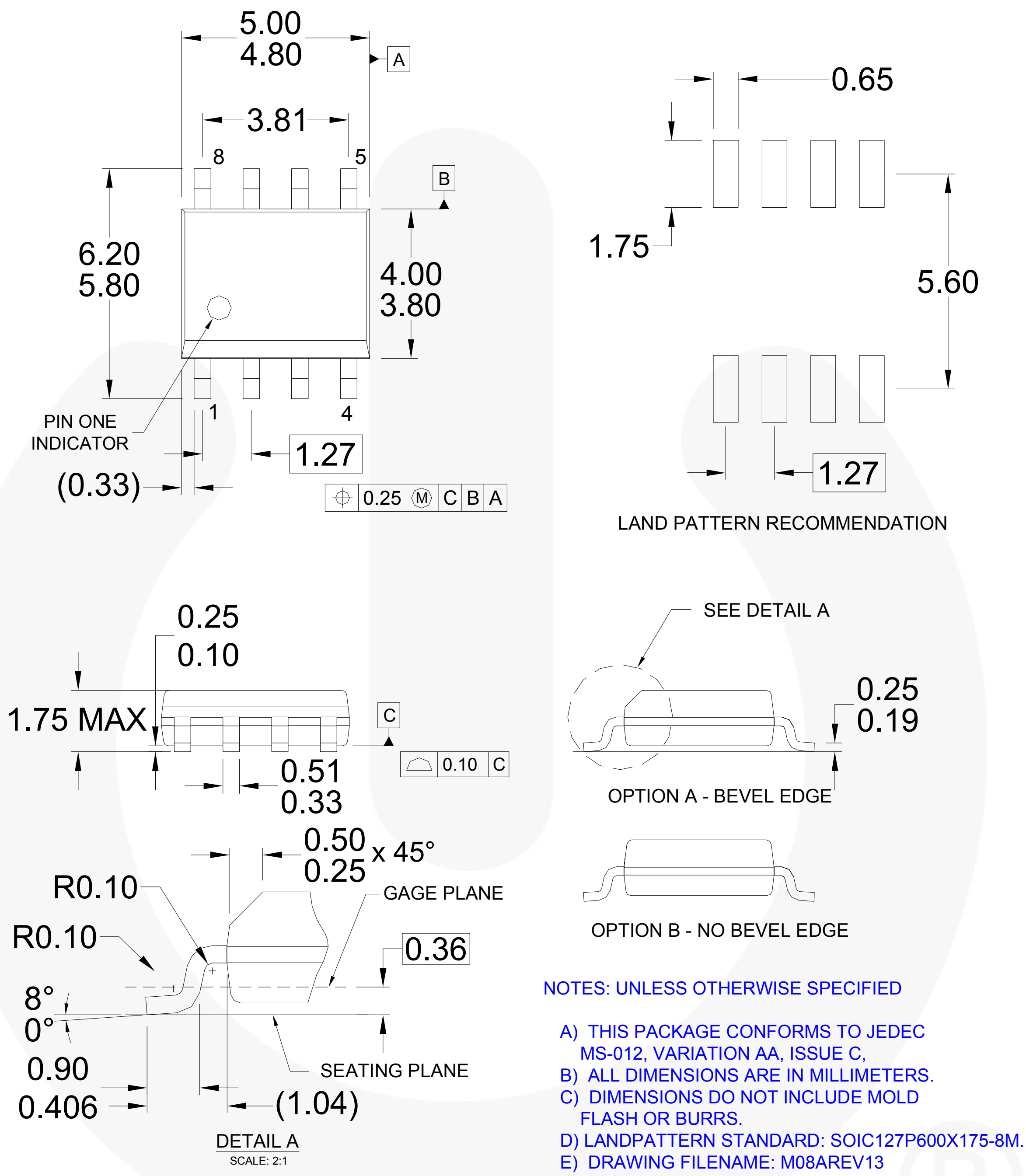


Figure 27. 8-Lead, Small Outline Package (SOP-8)

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