FAIRCHILD SEMICONDUCTOR®

July 2010

FAN301

PWM Controller for Low Standby Power Charger Applications

Features

- Ultra-Low Standby Power Under 20mW at 264V_{AC}
- Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Green Mode: PWM Frequency Linearly Decreasing
- Fixed PWM Frequency at 45kHz with Frequency Hopping to Solve EMI Problems
- High-Voltage Startup
- Low Operating Current: 3mA
- Peak-Current-Mode Control in CV Mode
- Cycle-by-Cycle Current Limiting
- V_{DD} Over-Voltage Protection (Auto-Restart)
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 15V
- Fixed Over-Temperature Protection (Auto-Restart)

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, FAN301, provides 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 is the result, compared to a conventional design or a linear transformer.

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

By using FAN301, a charger can be implemented with fewer external components and minimized cost. A typical output CV/CC characteristic envelope is shown in Figure 1.

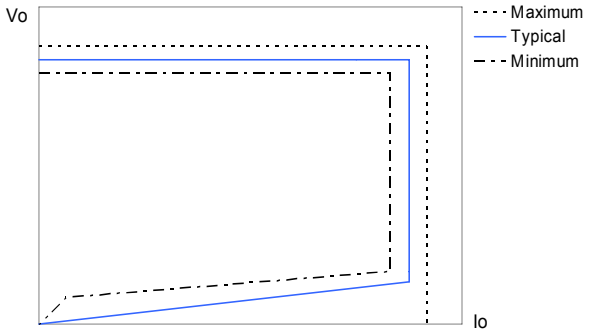


Figure 1. Typical Output V-I Characteristic (without Cable)

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FAN301MY	-40°C to +105°C	8-Lead, Small Outline Package	Tape & Reel

Application Diagram

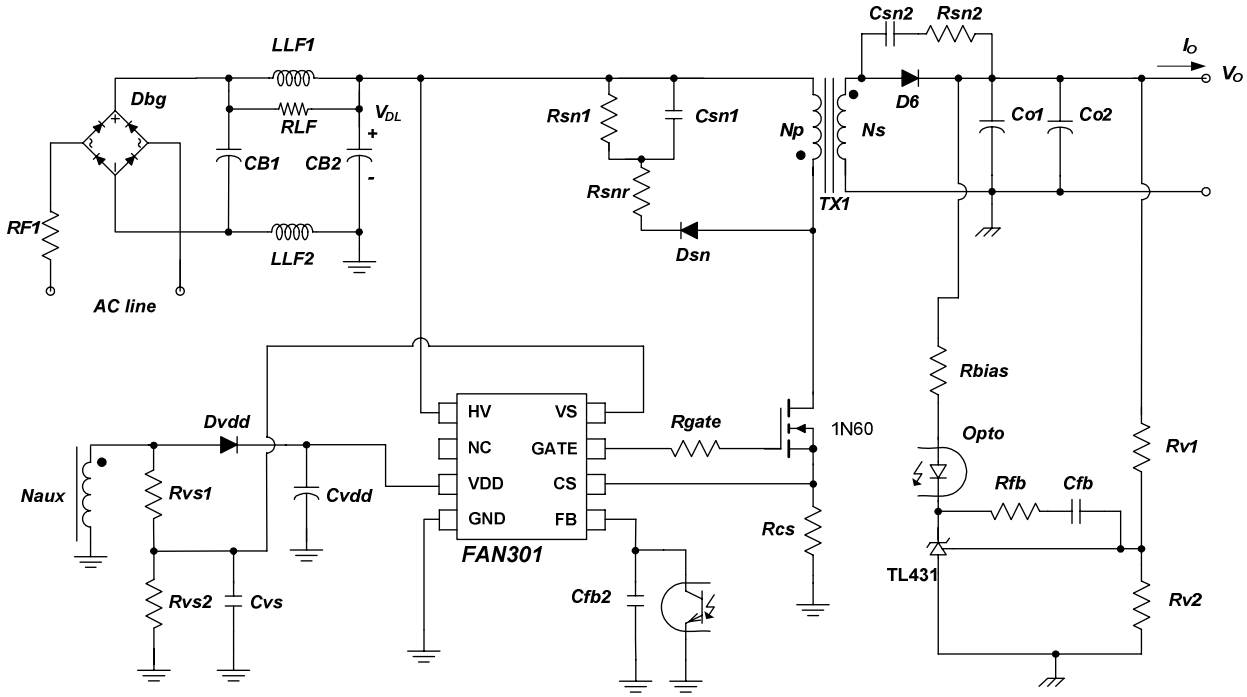


Figure 2. Typical Application

Internal Block Diagram

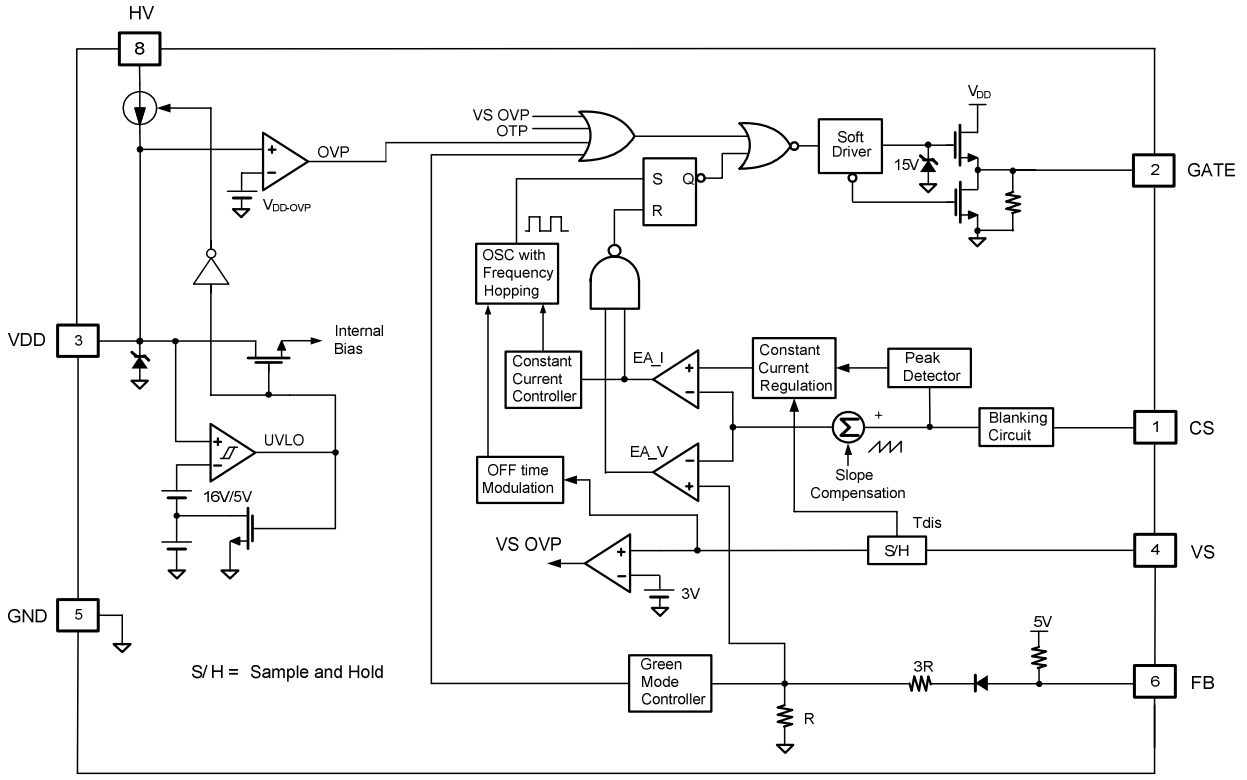
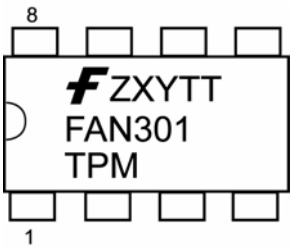


Figure 3. Functional Block Diagram

Marking Information



F- Fairchild Logo
Z: Assembly Plant Code
X: Year Code
Y: Week Code
TT: Die-Run Code
T: M=SOP
P: Y= Green Package
M: Manufacture Flow Code

Figure 4. Top Mark

Pin Configuration

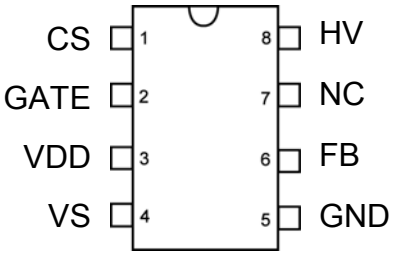


Figure 5. Pin Configuration

Pin Definitions

Pin #	Name	Description
1	CS	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	GATE	The totem-pole output driver to drive the power MOSFET.
3	VDD	Power supply
4	VS	Feedback. The VS pin provides feedback information for output-current regulation in CC mode.
5	GND	Power ground
6	FB	Feedback. The FB pin provides feedback information to the internal PWM comparator. This feedback is used to control the duty cycle.
7	NC	No connection
8	HV	For startup. This pin is pulled HIGH to the line input or bulk capacitor via resistors.

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_{HV}	HV Pin Input Voltage			500	V
V_{VDD}	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_{FB}	FB Pin Input Voltage		-0.3	7.0	V
P_D	Power Dissipation (T_A=25°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		-40	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[3]	Human Body Model: JEDEC:JESD22_A114	5.50		kV
		Charged Device Model: JEDEC:JESD22_C101	1.75		

Notes:

1. All voltage values, except differential voltages, are given with respect to GND pin.
2. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
3. All pins excluding HV pin. All pins including HV pin: HBM=1000V, CDM=750V

Electrical Characteristics

V_{DD}=15V, TA=25°C, unless noted.

Symbol	Parameter		Conditions	Min.	Typ.	Max.	Units
HV Section							
V_{HV-MIN}	Minimum Startup Voltage on HV Pin					50	V
I_{HV}	Supply Current Drawn from HV Pin		V_{AC}=90V; V_{DD}=0V, Controller Off		1.5	2.0	mA
I_{HV-LC}	Leakage Current Drawn from HV Pin		With Auxiliary Supply; V_{HV}=500V, V_{DD}=15V, Controller on		0.8	3.0	µA
VDD Section							
V_{OP}	Continuously Operation Voltage					25	V
V_{DD-ON}	Turn-On Threshold Voltage				16		V
V_{DD-OFF}	Turn-Off Threshold Voltage				5		V
I_{DD-ST}	Startup Current		V_{DD}=V_{DD-ON} – 0.16V		450		µA
I_{DD-OP}	Operating Supply Current		V_{DD}=20V, f=f_{OSC}, C_L=1nF		3		mA
$I_{DD-BURST}$	Burst-Mode Operating Supply Current		V_{DD}=20V, C_L=1nF		200		µA
V_{DD-OVP}	V_{DD} Over-Voltage Protection Level		Auto-Restart	27	28	29	V
$t_{D-VDDOVP}$	V_{DD} Over-Voltage Protection Debounce Time		f=45kHz		100		µs
Oscillator Section							
f_{OSC}	Frequency	Center Frequency		41	45	49	kHz
		Hopping Range			±1.55		
t_{FHR}	Frequency Hopping Period				2.84		ms
f_{OSC-G}	Green-Mode Frequency				20		kHz
$f_{OSC-CM-MIN}$	Minimum Frequency if CCM (Continuous Current Mode)				21.5		kHz
$f_{OSC-CCM}$	Minimum Frequency in CC Mode (Constant Current Mode)				24.5		kHz
Feedback input Section							
A_V	FB Input to Current Comparator Attenuation				1/3		V/V
Z_{FB}	Input Impedance				42		kΩ
$Z_{FB-BURST}$	Input Impedance at Burst Mode				49.5		kΩ
$V_{FB-OPEN}$	Output High Voltage		FB Pin Open	5.0	5.3		V
V_{FB-N}	Green-Mode Entry Voltage				3		V
V_{FB-G}	Green-Mode Ending Voltage				2.4		V
V_{FBL}	Enter Zero Duty Cycle of FB Voltage				1.4		V
V_{FBH}	Exit Zero Duty Cycle of FB Voltage				1.5		V

Continued on the following page…

Electrical Characteristics (Continued)

V_{DD}=15V, T_A=25°C, unless noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Voltage-Sense Section						
I_{TC}	Bias Current	V_{CS}=5V	9	10	11	µA
$V_{VS-CM-MIN}$	Minimum V_S Threshold Voltage of ZCD Undetectable Protection			0.55		V
$V_{VS-CM-MAX}$	Maximum V_S Threshold Voltage of ZCD Undetectable Protection			0.75		V
$V_{VS-BLANK}$	ZCD Blanking Time			2.45		µs
V_{VS-UVP}	Brownout Protection Voltage			0.685		V
$V_{VS-OFFSET}$	ZCD Turn-Off Threshold		100	200	300	mV
V_{VS-OVP}	Output Over-Voltage Protection			3		V
t_{VS-OVP}	Output Over-Voltage Protection Debounce Time	f=45kHz		240		µs
Current-Sense Section						
V_{VR}	Reference Voltage		2.475	2.500	2.525	V
V_{CCR}	Variation Test voltage on CS Pin for Constant Current Output	V_{CS}=0.47V		2.43		V
V_{SN-CC}	Starting Voltage of Frequency Decreasing of CC	V_{CS}=5V, f_{S1}=f_{OSC}-2KHz		2.1		V
V_{SG-CC}	Ending Voltage of Frequency Decreasing of CC	V_{CS}=5V, f_{S2}=f_{OSC}+2KHz		0.76		V
S_{G-CC}	Frequency Decreasing Rate of CC	S_{G-CC}= (f_{S1}-f_{S2})/(V_{FBN-CC}-V_{FBG-CC})	10.00	12.75	15.00	Hz/mV
V_{STH}	Threshold Voltage for Current Limit			0.8		V
V_{STH-VA}	Threshold Voltage for Current Limit when ZCD undetectable	V_{VS}=0.3V, V_{COMV}=5V		0.3		V
t_{PD}	Propagation Delay to GATE Output			180		ns
t_{MIN}	Minimum On Time	V_{VS}=-0.5V, V_{CS}=1.5V		530		ns
t_{LEB}	Leading Edge Blanking Time			350		ns
V_{SLOPE}	Slope Compensation	Maximum Duty		0.3		V
GATE Section						
DCY_{MAX}	Maximum Duty Cycle		54	57	60	%
V_{GATE-L}	Output Voltage Low	V_{DD}=25V, I_O=10mA			1.5	V
V_{GATE-H}	Output Voltage High	V_{DD}=8V, I_O=1mA	5			V
V_{GATE-H}	Output Voltage High	V_{DD}=5.5V, I_O=1mA	4			V
$V_{MOS-OFF}$	Output Voltage Turn-Off Voltage		8.9	9.5	10.1	V
V_{MOS-ON}	Output Voltage Turn-On Voltage		6.9	7.5	8.1	V
t_r	Rising Time	V_{DD}=25V, C_L=1nF		140		ns
t_f	Falling Time	V_{DD}=25V, C_L=1nF		50		ns
$V_{GATE-CLAMP}$	Output Clamp Voltage	V_{DD}=25V	14	15	18	V
Over-Temperature-Protection Section						
T_{OTP}	Threshold Temperature for Over-Temperature Protection			140		°C
$T_{OTP-RESTART}$	Restart Threshold Temperature for Over-Temperature Protection			110		°C

Typical Performance Characteristics

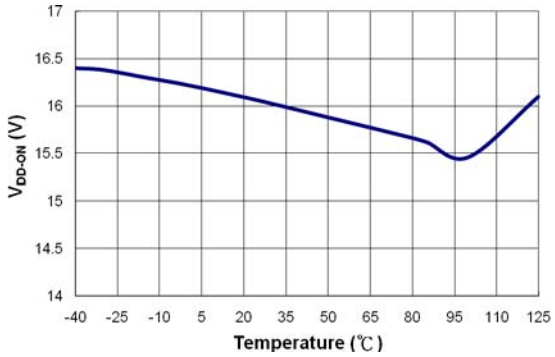


Figure 6. Turn-on Threshold Voltage (V_{DD-ON}) vs. Temperature

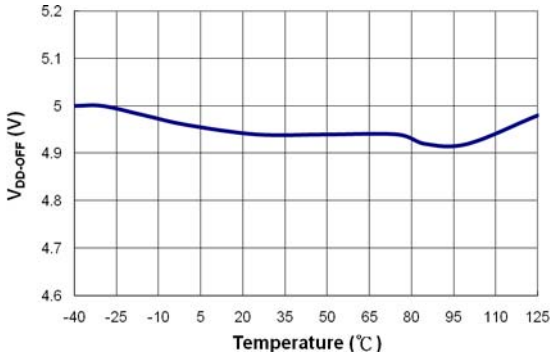


Figure 7. Turn-off Threshold Voltage (V_{DD-OFF}) vs. Temperature

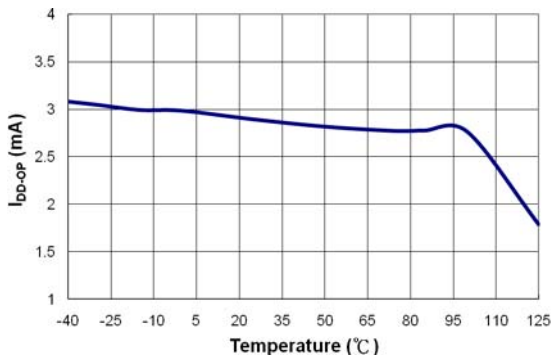


Figure 8. Operating Supply Current (I_{DD-OP}) vs. Temperature

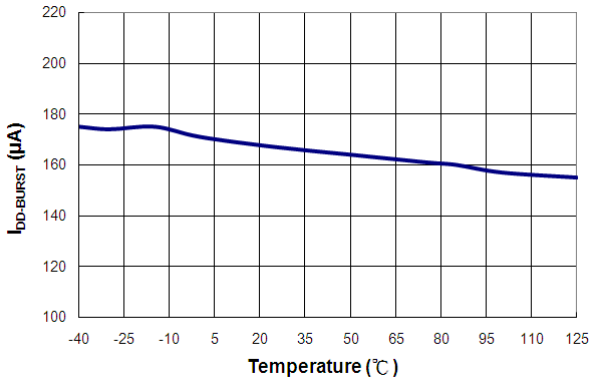


Figure 9. Burst-mode Operating Supply Current ($I_{DD-BURST}$) vs. Temperature

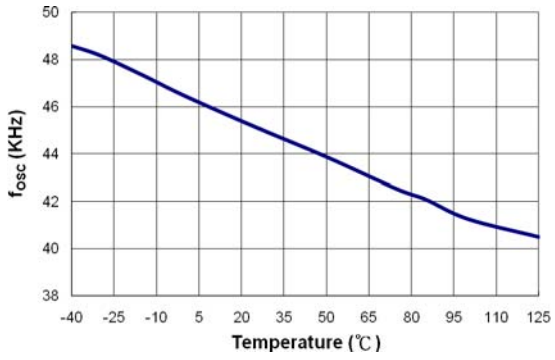


Figure 10. Center Frequency (f_{OSC}) vs. Temperature

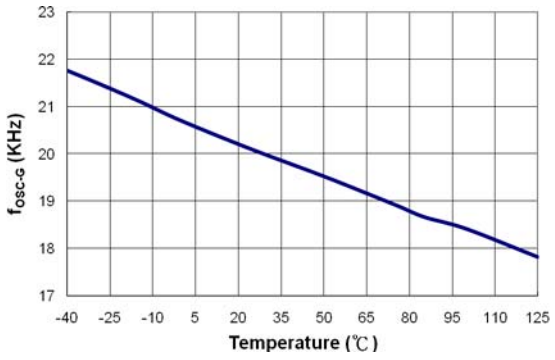


Figure 11. Green-Mode Frequency (f_{OSC-G}) vs. Temperature

Typical Performance Characteristics (Continued)

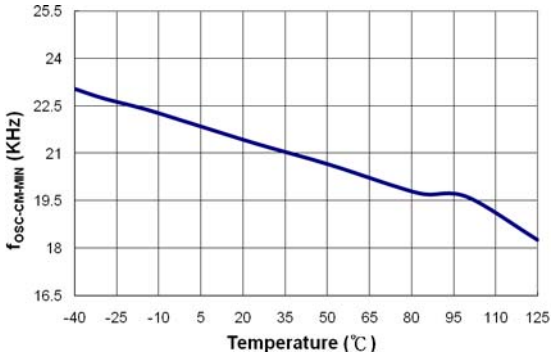


Figure 12. Minimum Frequency if CCM ($f_{OSC-CM-MIN}$) vs. Temperature

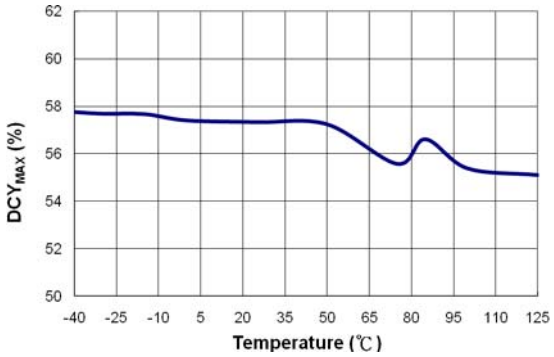


Figure 13. Maximum Duty Cycle (DCY_{MAX}) vs. Temperature

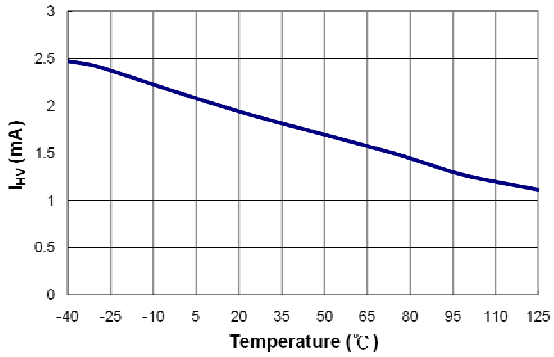


Figure 14. Supply Current Drawn from HV Pin (I_{HV}) vs. Temperature

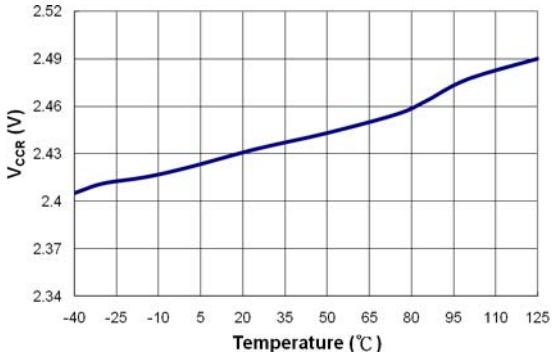


Figure 15. Variation Test Voltage on CS Pin for Constant Current Output (V_{CCR}) vs. Temperature

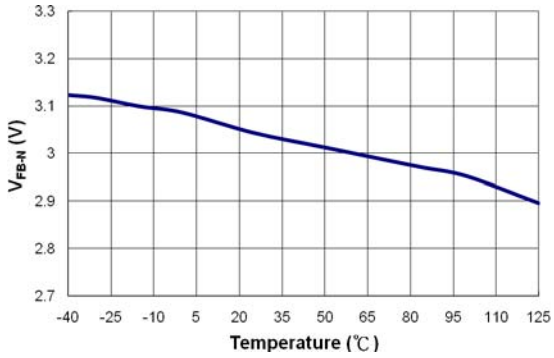


Figure 16. Green-Mode Entry Voltage (V_{FB-N}) vs. Temperature

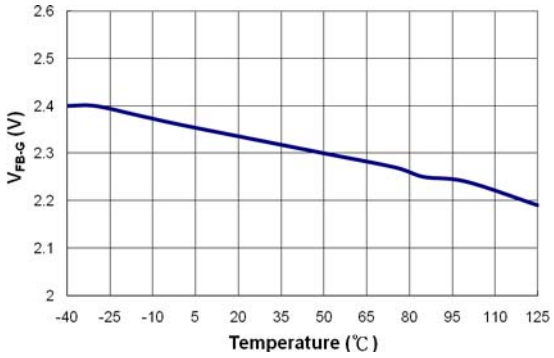


Figure 17. Green-Mode Exit Voltage (V_{FB-G}) vs. Temperature

Typical Performance Characteristics (Continued)

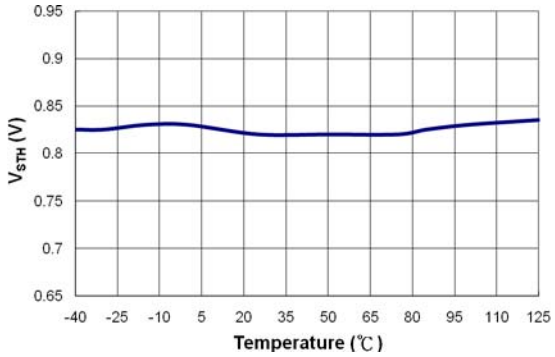


Figure 18. Threshold Voltage for Current Limit (V_{STH}) vs. Temperature

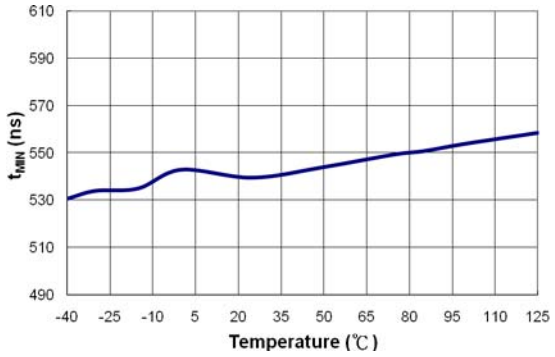


Figure 19. Minimum On Time (t_{MIN}) vs. Temperature

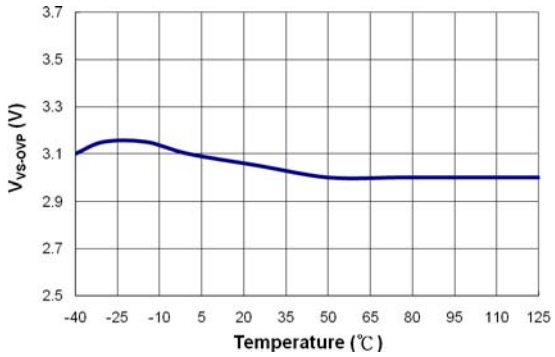


Figure 20. Output Over-Voltage Protection (V_{VS-OVP}) vs. Temperature

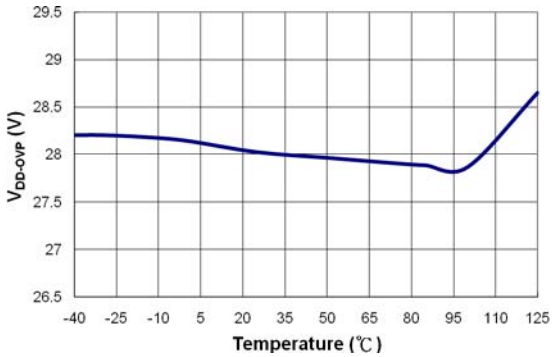


Figure 21. V_{DD} Over-Voltage Protection Level (V_{DD-OVP}) vs. Temperature

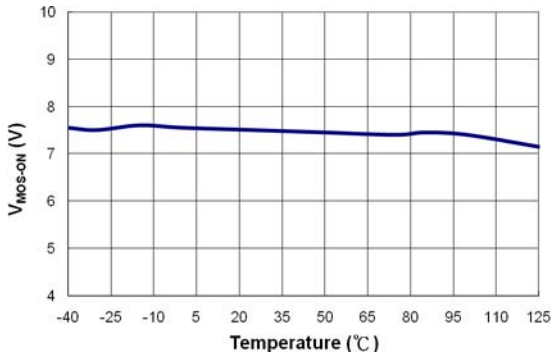


Figure 22. Output Voltage Turn-On Voltage (V_{MOS-ON}) vs. Temperature

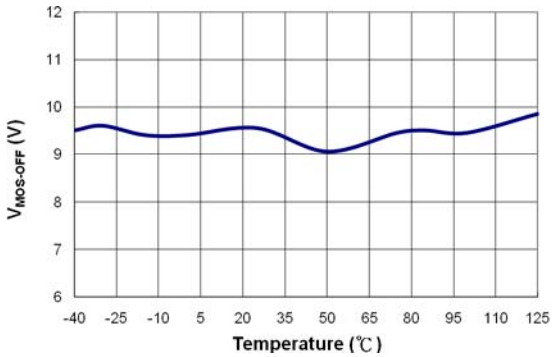


Figure 23. Output Voltage Turn-Off Voltage ($V_{MOS-OFF}$) vs. Temperature

Operation Description

The FAN301H is an innovative ultra-low standby power IC with Constant Voltage (CV) / Constant Current (CC).

When the system operates in CV mode, PWM duty modulation is controlled by the FB pin, which receives a secondary-side signal through an opto-coupler.

When the system changes to CC mode, the proprietary Primary Side Regulation (PSR) topology simplifies circuit design without secondary feedback circuitry, especially for battery charger applications. The CC mode achieved through Fairchild's PSR technique uses a mixed signal algorithm to detect the primary-side current and sampling the voltage through primary-side auxiliary winding, then calculates the average current on the secondary side.

Figure 24 shows the basic circuit diagram of a flyback converter with typical waveforms shown in Figure 25. Generally, discontinuous conduction mode (DCM) operation is preferred for constant-current control since it allows better output regulation. The operation principles of DCM flyback converter are as follows:

During the MOSFET on time (t_{ON}), input voltage (V_{DL}) is applied across the primary-side inductor (L_m). Then MOSFET current (I_{ds}) increases linearly from zero to the peak value (I_{pk}). During this time, the energy is drawn from the input and stored in the inductor.

When the MOSFET is turned off, the energy stored in the inductor forces the rectifier diode (D) to be turned on. While the diode is conducting, the output voltage (V_o), together with diode forward-voltage drop (V_F), is applied across the secondary-side inductor ($L_m \times N_s^2 / N_p^2$) and the diode current (I_D) decreases linearly from the peak value ($I_{pk} \times N_p / N_s$) to zero. At the end of inductor current discharge time (t_{DIS}), all the energy stored in the inductor has been delivered to the output.

When the diode current reaches zero, the transformer auxiliary winding voltage (V_w) begins to oscillate by the resonance between the primary-side inductor (L_m) and the effective capacitor loaded across MOSFET.

During the inductor current discharge time, the sum of output voltage and diode forward-voltage drop is reflected to the auxiliary winding side as $(V_o+V_F) \times N_a/N_s$. This voltage signal is proportional to the secondary winding, so it provides the controller the feedback signal from the secondary side and achieves a constant voltage output property. In constant current output operation, this voltage signal is detected and examined by the precise constant-current regulation controller. The on-time of the MOSFET is determined to control input power and provide a constant current output property. With feedback voltage V_{CS} across the current-sense resistor, the controller can obtain the input power of power supply. Therefore, the region of constant-current output operation can be adjusted by a current-sense resistor.

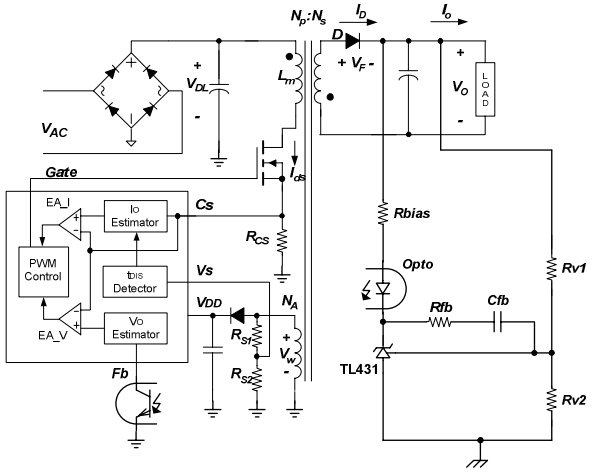


Figure 24. Simplified Flyback Converter Circuit

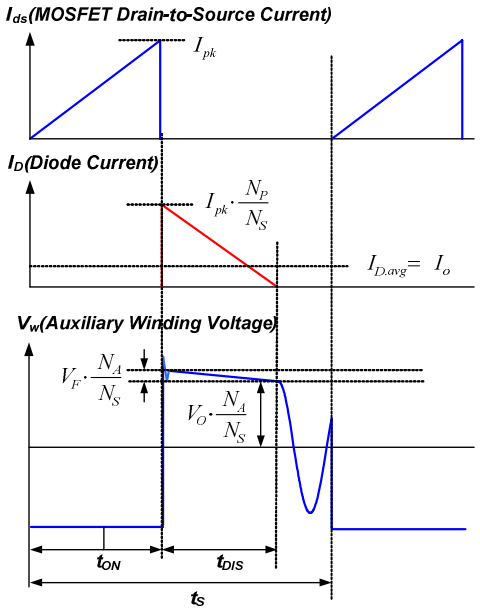


Figure 25. Key Waveforms of DCM Flyback Converter

High-Voltage Startup

Figure 26 shows the HV-startup circuit for FAN301 applications. The HV pin is connected to the line input or bulk capacitor through a resistor, R_{START} (100kΩ is recommended). During startup, the internal startup circuit is enabled. Meanwhile, line input supplies the current, $I_{STARTUP}$, to charge the hold-up capacitor, C_{DD}, through R_{START}. When the V_{DD} voltage reaches V_{DD-ON}, the internal startup circuit is disabled, blocking $I_{STARTUP}$ from flowing into the HV pin. Once the IC turns on, C_{DD} is the only energy source to supply the IC consumption current before the PWM starts to switch. Thus, C_{DD} must be large enough to prevent V_{DD} from dropping to V_{DD-OFF} before the power can be delivered from the auxiliary winding.

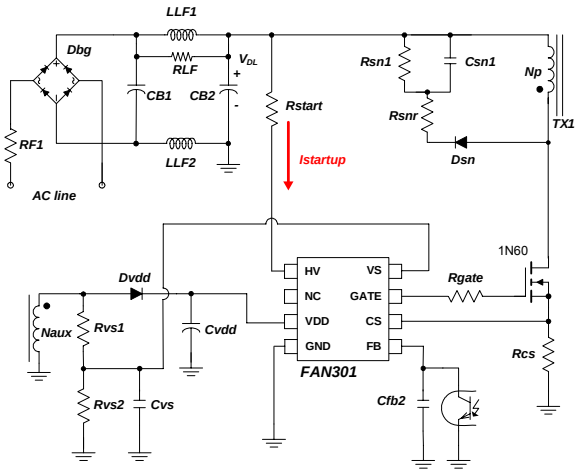


Figure 26. HV Startup Circuit

Operating Current

The operating current has been reduced to 3mA, which results in higher efficiency and reduces the V_{DD} hold-up capacitance requirement. Once FAN301 enters burst mode, the operating current is reduced to 200μA, allowing the power supply to meet the power conservation requirements.

Frequency Hopping

EMI reduction is accomplished by frequency hopping, which spreads the energy over a wider frequency range than the bandwidth measured by the EMI test equipment. FAN301 has an internal frequency-hopping circuit that changes the switching frequency between 41kHz and 49kHz with a period, as shown in Figure 27.

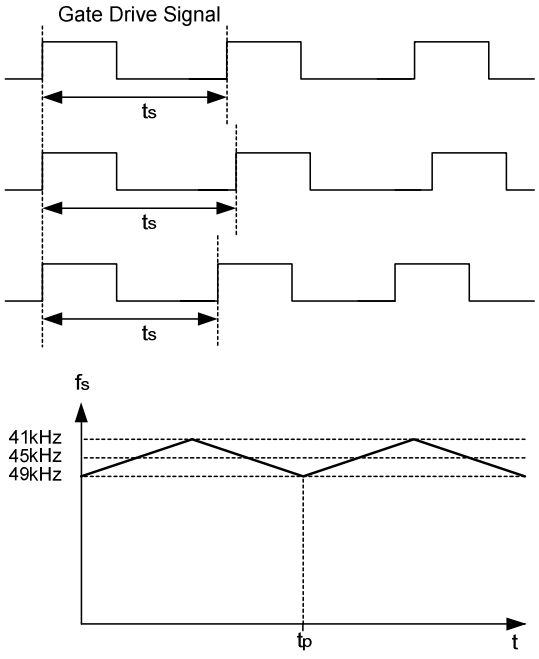


Figure 27. Frequency Hopping

Green-Mode Operation

The proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency, as shown in Figure 28. Under light-load and zero-load conditions, the on-time is limited to provide protection against brownouts and abnormal conditions. Power supplies using FAN301 can meet international restrictions regarding standby power-consumption.

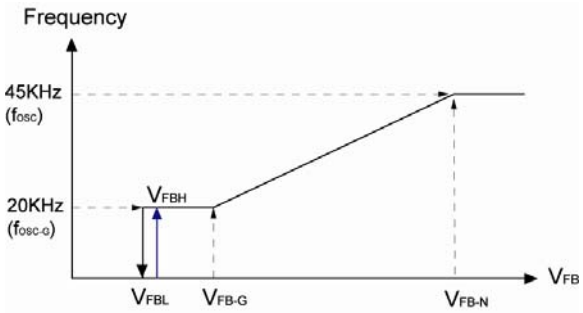


Figure 28. Green-Mode Frequency vs. V_{FB}

Burst-Mode Operation

The power supply enters “burst-mode” in no-load conditions. As shown in Figure 29, when V_{FB} drops below V_{FBL}, the PWM output is shuts off and the output voltage drops at a rate dependent on load current. This causes the feedback voltage to rise. Once V_{FB} exceeds V_{FBH}, the internal circuit starts to provide a switching pulse. The feedback voltage then falls and the process repeats. Burst-mode operation alternately enables and disables switching of the MOSFET, reducing the switching losses in standby mode.

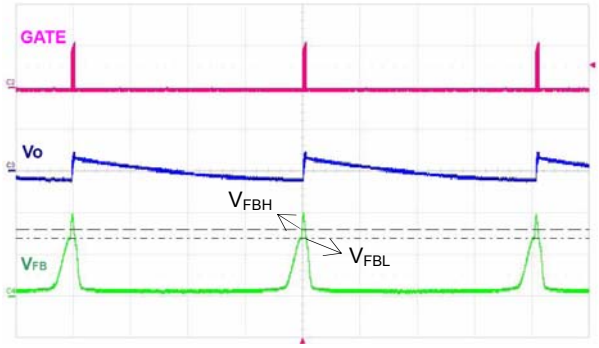


Figure 29. Burst-Mode Operation

Gate Output

The FAN301 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 the power MOSFET transistors against undesired over-voltage gate signals.

Protections

The FAN301 self-protection functions include Over-Voltage Protection (OVP), V_S Over-Voltage Protection, Over-Temperature Protection (OTP), and pulse-by-pulse current limit. All the protections are implemented as auto-restart mode. If an abnormal condition occurs, switching is terminated and the MOSFET remains off, causing V_{DD} to drop. When V_{DD} reaches the V_{DD} turn-off voltage of 5V, the internal startup circuit is enabled again, then the supply current drawn from the HV pin charges the hold-up capacitor. When V_{DD} reaches the turn-on voltage of 16V, normal operation resumes. In this manner, the auto-restart alternately enables and disables the switching of the MOSFET until the abnormal condition is eliminated *(see Figure 30)*.

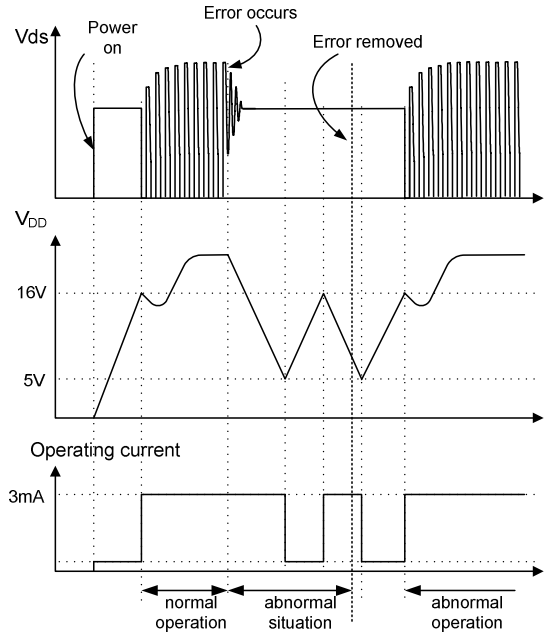


Figure 30. Auto-Restart Operation

Under-Voltage Lockout (UVLO)
The turn-on and turn-off thresholds are fixed internally at 16V and 5V, respectively. During startup, the hold-up capacitor must be charged to 16V through the startup resistor to enable the FAN301. 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 the hold-up capacitor is adequate to supply V_{DD} during startup.

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

V_S Over-Voltage Protection
When the V_S voltage exceeds 3V due to abnormal conditions, PWM pulses are disabled until the V_{DD} voltage drops below the UVLO threshold, then start again. V_S over-voltage conditions are usually caused by open feedback loops or VS pin resistor abnormality.

Over-Temperature Protection (OTP)
The FAN301 temperature-sensing circuit shuts down PWM output if the junction temperature exceeds 140°C (T_{OTP}). The PWM pulses are disabled until the junction temperature drops below the $T_{OTP\text{-}RESTART}$ threshold.

Leading-Edge Blanking
Each time the power MOSFET is switched on, a turn-on spike occurs at the sense resistor. To avoid premature termination of the switching pulse, a 350ns leading-edge blanking time is built in, which allows conventional RC filtering to be omitted. During this blanking period, the current-limit comparator is disabled and cannot switch off gate driver.

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 FAN301 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 FAN301, and increasing the power MOS gate resistance are advised.

Typical Application Circuit

Application	Fairchild Devices	Input Voltage Range	Output	Output DC Cable
Cell Phone Charger	FAN301	90~264V_{AC}	5V/0.89A	AWG26, 1.8 Meter

Features

- High efficiency (>68.17% at full load) meeting Energy Star V2.0 regulation with enough margin
- Low standby power <15mW at no-load condition
- Tight output regulation (CV:±5%, CC:±5%)

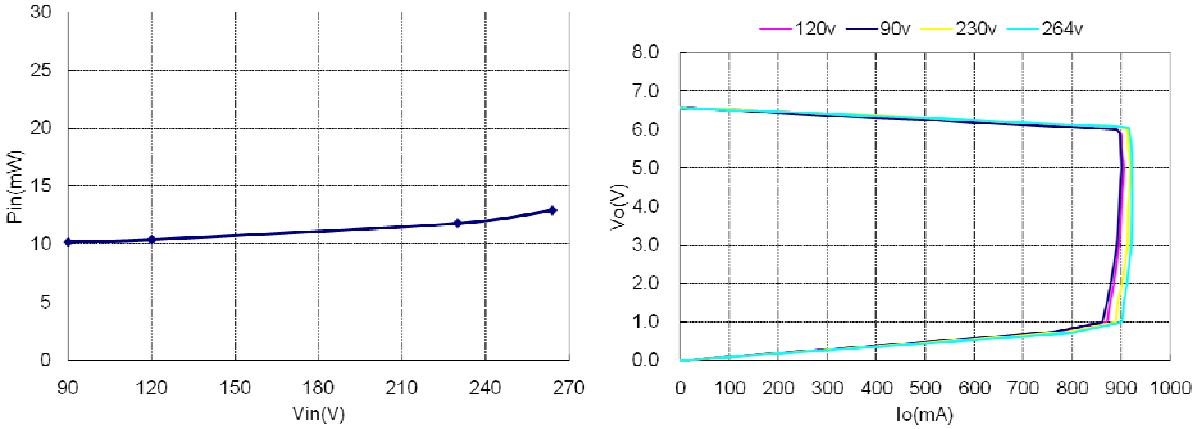


Figure 31. Measured Standby Power and Output Regulation

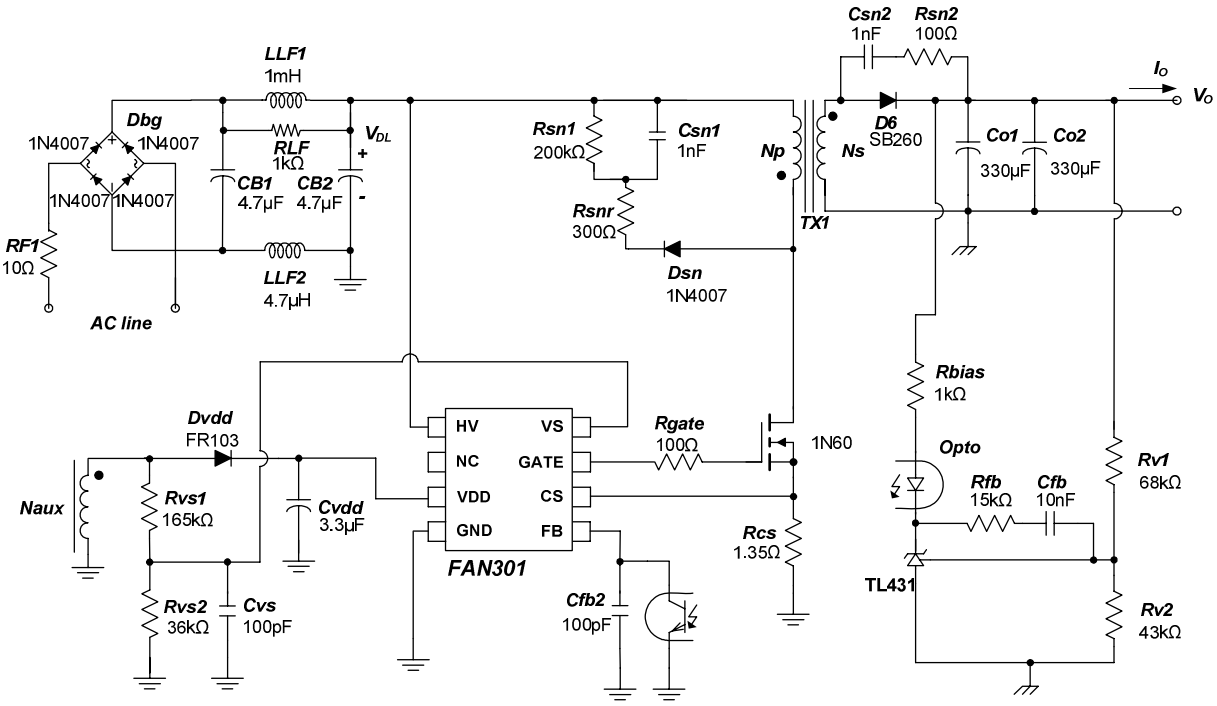


Figure 32. Schematic of Typical Application Circuit

Typical Application Circuit (Continued)

Transformer Specification

- Core: EE16
- Bobbin: EE16

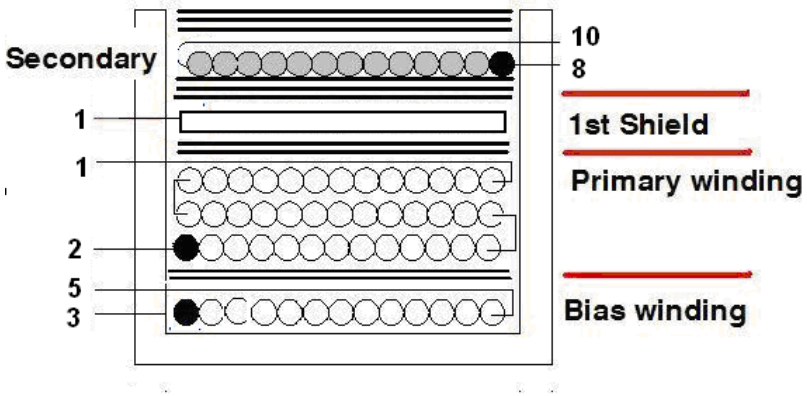
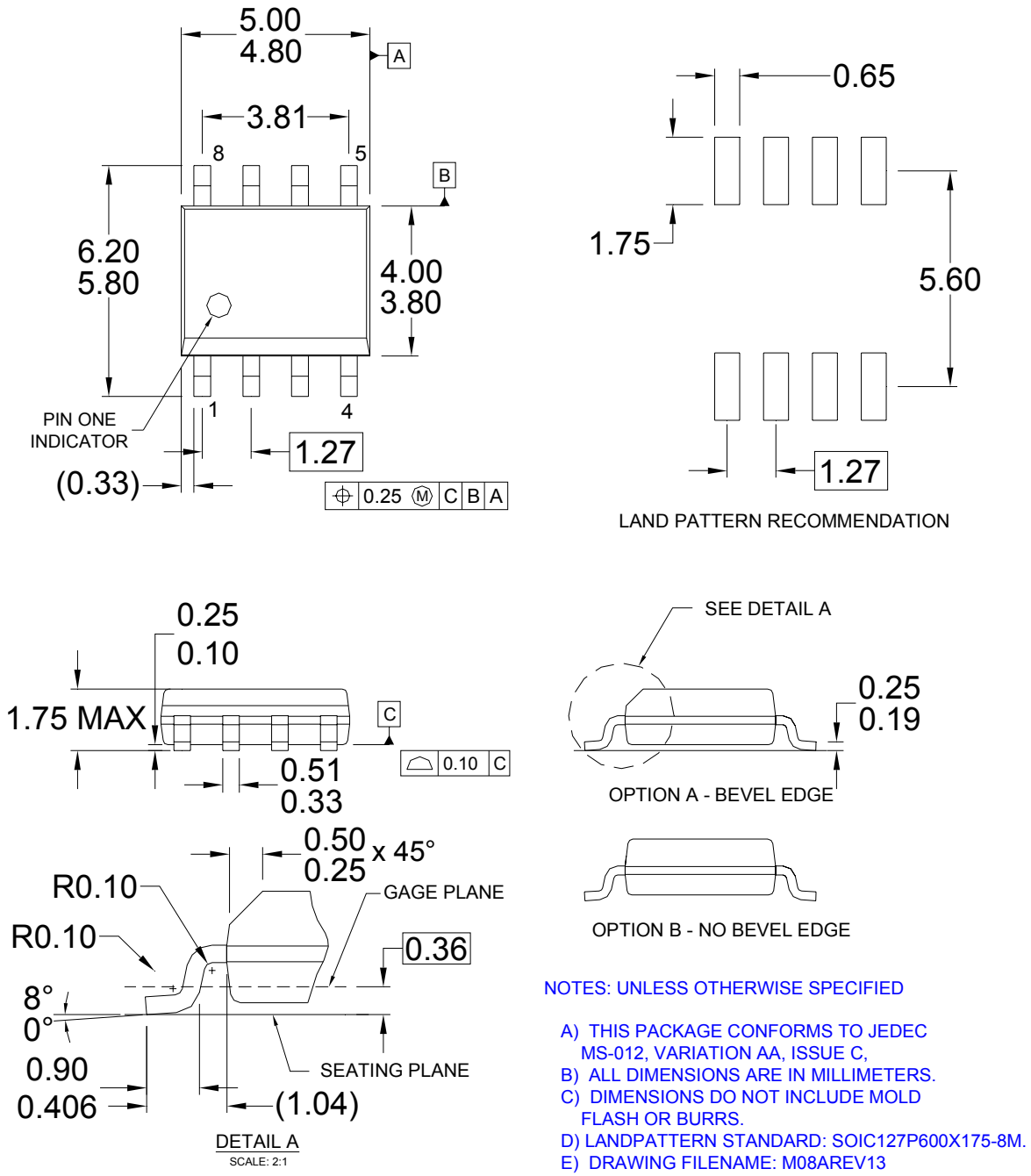


Figure 33. Transformer Diagram

NO.	TERMINAL		WIRE	Ts
	S	F		
W1	3	5	2UEW 0.25*1	27
W2	2	1	2UEW 0.15*1	130
W3	1	-	COPPER SHIELD	1.1
W4r	8	10	TEX-E 0.4*1	12
			CORE ROUNDING TAPE	3
Primary-Side Inductance=2.3mH ± 5%				
Primary-Side Effective Leakage<80μH ± 5%				

Physical Dimensions



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C) DIMENSIONS DO NOT INCLUDE MOLD FLASH OR BURRS.
D) LANDPATTERN STANDARD: SOIC127P600X175-8M.
E) DRAWING FILENAME: M08AREV13

Figure 34. 8-Pin SOP8 Package

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