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January 2014

FAN100
Primary-Side-Control PWM Controller

Features

- Constant-Voltage (CV) and Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Accurate Constant Current Achieved by Fairchild's Proprietary *TRUECURRENT*™ Technique
- Green Mode: Frequency Reduction at Light Load
- Fixed PWM Frequency at 42 kHz with Frequency Hopping to Reduce EMI
- Low Startup Current: 10 µA Maximum
- Low Operating Current: 3.5 mA
- Peak-Current-Mode Control in CV Mode
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto-Restart
- Brownout Protection with Auto-Restart
- V_{DD} Over-Voltage Protection with Auto-Restart
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package

Applications

- Battery Chargers for Cellular Phones, Cordless Phones, PDA, Digital Cameras, Power Tools
- Replaces Linear Transformer and RCC SMPS
- Offline High Brightness (HB) LED Drivers

Related Resources

- *AN-6067 — Design Guide for FAN100/102 and FSEZ1016A/1216*

Description

The primary-side PWM controller FAN100 significantly simplifies power supply design that requires CV and CC regulation capabilities. The FAN100 controls the output voltage and current precisely with the information in the primary side of the power supply, not only removing the output current sensing loss, but eliminating secondary feedback circuitry.

The green-mode function with a low startup current (10µA) maximizes the light-load efficiency so the power supply can meet stringent standby power regulations.

Compared with a conventional secondary-side regulation approach, the FAN100 can reduce total cost, component count, size, and weight; while simultaneously increasing efficiency, productivity, and system reliability.

FAN100 controller is available in an 8-pin SOP package.

A typical output CV/CC characteristic envelope is shown in Figure 1.

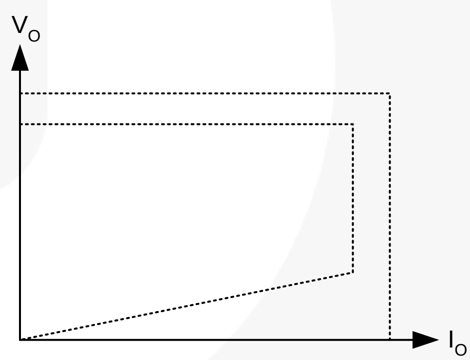


Figure 1. Typical Output V-I Characteristic

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FAN100MY	-40°C to +125°C	8-Lead, Small Outline Package (SOP-8)	Tape & Reel

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

Application Diagram

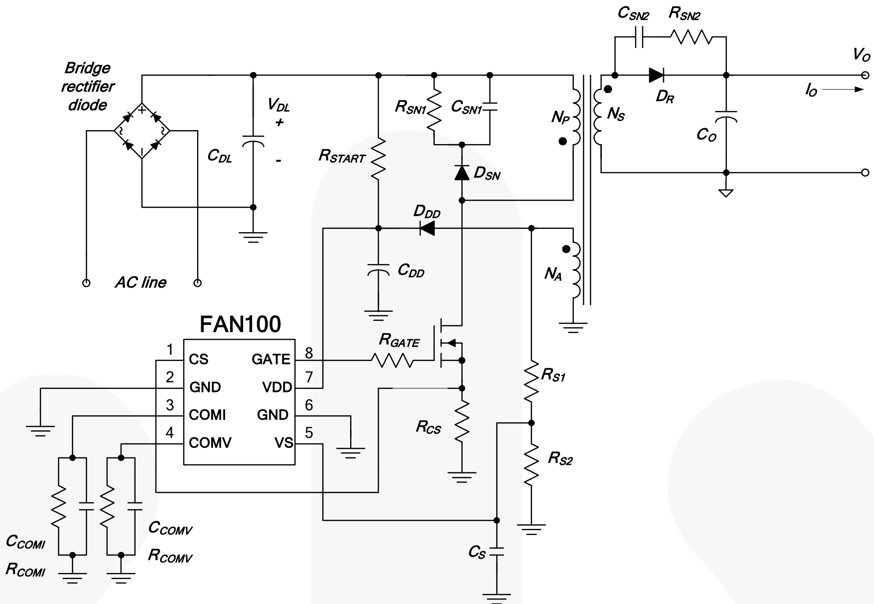


Figure 2. Typical Application

Internal Block Diagram

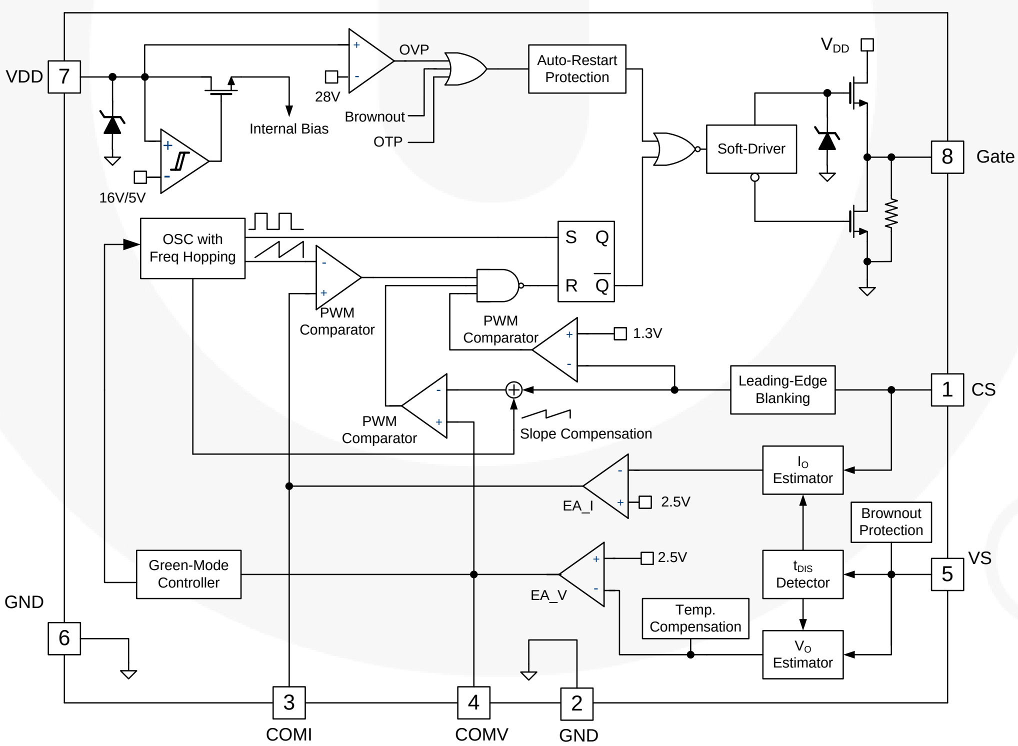
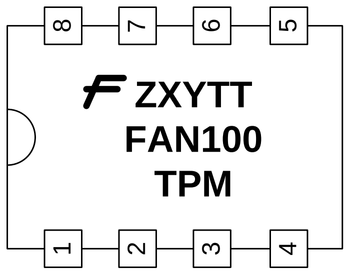


Figure 3. Functional Block Diagram

Marking Information



F- Fairchild logo
Z- Plant Code
X- 1-Digit Year Code
Y- 1-Digit Week Code
TT: 2-Digit 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

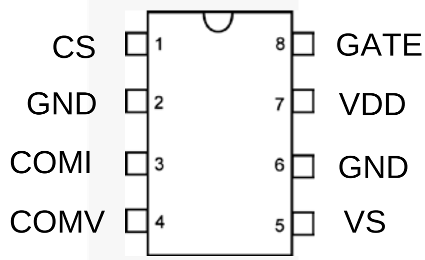


Figure 5. Pin Configuration

Pin Definitions

Pin #	Name	Description
1	CS	**Current Sense**. This pin connects a current-sense resistor to sense the MOSFET current for peak-current-mode control in CV mode and provides for output-current regulation in CC mode.
2	GND	**Ground**.
3	COMI	**Constant Current Loop Compensation**. this pin connects a capacitor and a resistor between COMI and GND for compensation current loop gain.
4	COMV	**Constant Voltage Loop Compensation**. this pin connects a capacitor and a resistor between COMV and GND for compensation voltage loop gain.
5	VS	**Voltage Sense**. This pin detects the output voltage information and discharge time based on voltage of auxiliary winding. This pin connects two divider resistors and one capacitor.
6	GND	**Ground**.
7	VDD	**Supply**. The power supply pin. IC operating current and MOSFET driving current are supplied using this pin. This pin is connected to an external V_{DD} capacitor of typically 10 µF. The threshold voltages for startup and turn-off are 16 V and 5 V, respectively. The operating current is lower than 5 mA.
8	GATE	**PWM Signal Output**. This pin outputs PWM signal and includes the internal totem-pole output driver to drive the external power MOSFET. The clamped gate output voltage is 18 V.

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
		Charged Device Model, JEDEC: JESD22-C101		2.0	

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		+125	°C

Electrical Characteristics

V_{DD}=15 V and T_A=-40°C~+125°C (T_A=T_J), 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}=20 V, f_S=f_{OSC}, V_{VS}=2 V, V_{CS}=3 V, C_L=1 nF		3.5	5.0	mA
I_{DD-ST}	Startup Current		0< V_{DD} < V_{DD-ON}-0.16 V		3.7	10.0	µA
$I_{DD-GREEN}$	Green Mode Operating Supply Current		V_{DD}=20 V, V_{VS}=2.7 V, f_S=$f_{OSC-N-MIN}$, V_{CS}=0 V, C_L=1 nF, V_{COMV}=0 V		1.0	2.5	mA
V_{DD-OVP}	V_{DD} Over-Voltage Protection Level		V_{CS}=3 V, V_{VS}=2.3 V	27	28	29	V
$t_{D-VDDOVP}$	V_{DD} Over-Voltage Protection Debounce Time		f_S=f_{OSC}, V_{VS}=2.3 V	100	250	400	µs
Oscillator Section							
f_{OSC}	Frequency	Center Frequency	T_A=25°C	39.0	42.0	45.0	KHz
		Frequency Hopping Range	T_A=25°C	±1.8	±2.6	±3.6	
t_{FHR}	Frequency Hopping Period		T_A=25°C		3		ms
$f_{OSC-N-MIN}$	Minimum Frequency at No Load		V_{VS}=2.7 V, V_{COMV}=0 V		550		Hz
$f_{OSC-CM-MIN}$	Minimum Frequency at CCM		V_{VS}=2.3 V, V_{CS}=0.5 V		20		KHz
f_{DV}	Frequency Variation vs. V_{DD} Deviation		T_A=25°C, V_{DD}=10 V to 25 V			5	%
f_{DT}	Frequency Variation vs. Temperature Deviation		T_A=-40°C to 125°C			20	%
Voltage-Sense Section							
I_{VS-UVP}	Sink Current for Brownout Protection		R_{VS}=20 KΩ		180		µA
I_{tc}	IC Compensation Bias Current				9.5		µA
$V_{BIAS-COMV}$	Adaptive Bias Voltage Dominated by V_{COMV}		V_{COMV}=0 V, T_A=25°C, R_{VS}=20 KΩ		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}=-0.8 V, R_S=2 KΩ, V_{COMV}=1 V		1100		ns
t_{MINCC}	Minimum On Time in CC Mode		V_{VS}=0 V, V_{COMV}=2 V		300		ns
V_{TH}	Threshold Voltage for Current Limit				1.3		V

Continued on following page…

Electrical Characteristics (Continued)

V_{DD}=15 V and T_A=-40°C~+125°C (T_A=T_J), 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}-2 KHz V_{VS}=2.3 V		2.8		V
V_G	Green Mode Ending Voltage on COMV Pin	f_S=1 KHz		0.8		V
$I_{V\text{-}SINK}$	Output Sink Current	V_{VS}=3 V, V_{COMV}=2.5 V		90		µA
$I_{V\text{-}SOURCE}$	Output Source Current	V_{VS}=2 V, V_{COMV}=2.5 V		90		µA
$V_{V\text{-}HGH}$	Output High Voltage	V_{VS}=2.3 V	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}=3 V, V_{COMI}=2.5 V		55		µA
$I_{I\text{-}SOURCE}$	Output Source Current	V_{CS}=0 V, V_{COMI}=2.5 V		55		µA
$V_{I\text{-}HGH}$	Output High Voltage	V_{CS}=0 V	4.5			V
Gate Section						
DCY_{MAX}	Maximum Duty Cycle			75		%
V_{OL}	Output Voltage Low	V_{DD}=20 V, I_O=10 mA			1.5	V
V_{OH}	Output Voltage High	V_{DD}=8 V, I_O=1 mA	5			V
V_{OH_MIN}	Output Voltage High	V_{DD}=5.5 V, I_O=1 mA	4			V
t_r	Rising Time	V_{DD}=20 V, C_L=1 nF		200	300	ns
t_f	Falling Time	V_{DD}=20 V, C_L=1 nF		80	150	ns
V_{CLAMP}	Output Clamp Voltage	V_{DD}=25 V		15	18	V
Over-Temperature-Protection Section						
T_{OTP}	Threshold Temperature for OTP			+140		°C

Typical Performance Characteristics

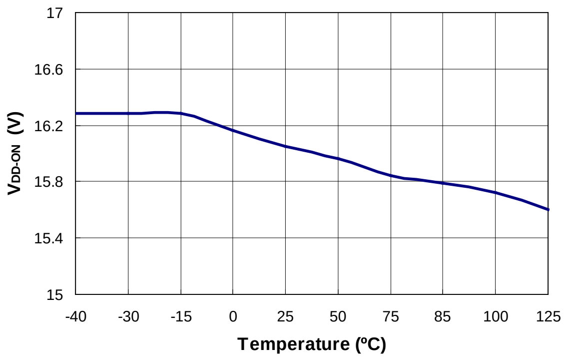


Figure 6. Turn-On Threshold Voltage (V_{DD-ON}) vs. Temperature

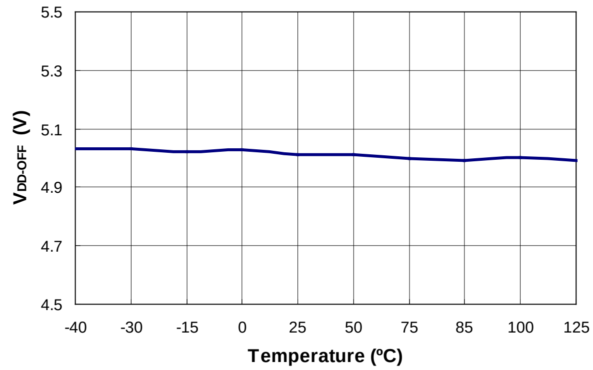


Figure 7. Turn-Off Threshold Voltage (V_{DD-OFF}) vs. Temperature

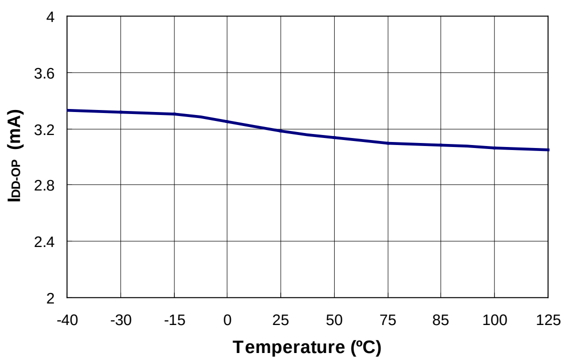


Figure 8. Operating Current (I_{DD-OP}) vs. Temperature

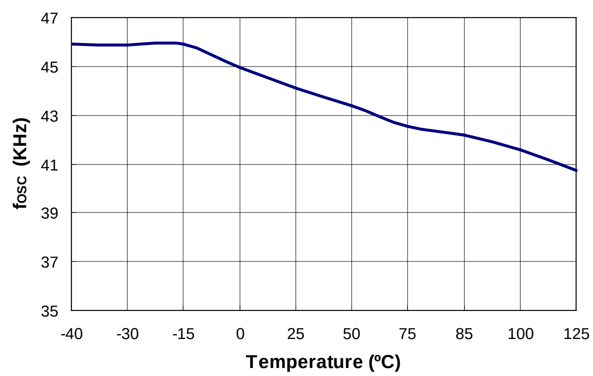


Figure 9. Center Frequency (f_{OSC}) vs. Temperature

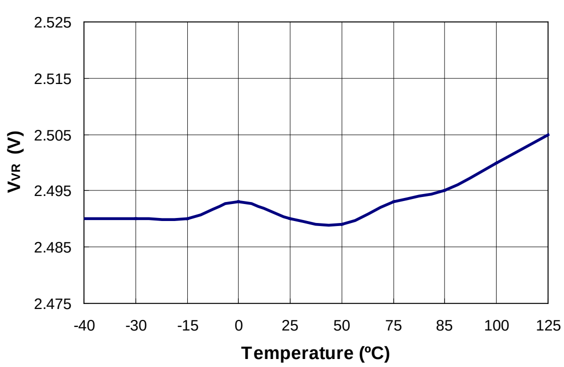


Figure 10. Reference Voltage (V_{VR}) vs. Temperature

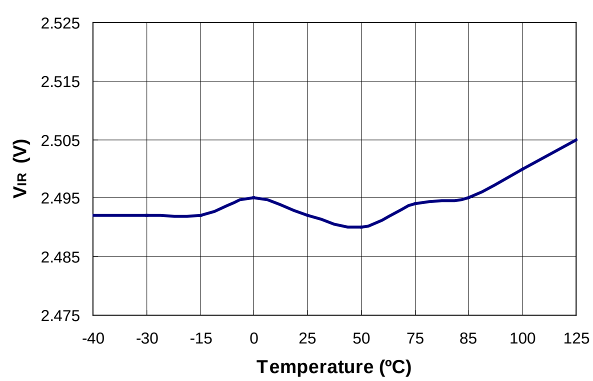


Figure 11. Reference Voltage (V_{IR}) vs. Temperature

Typical Performance Characteristics

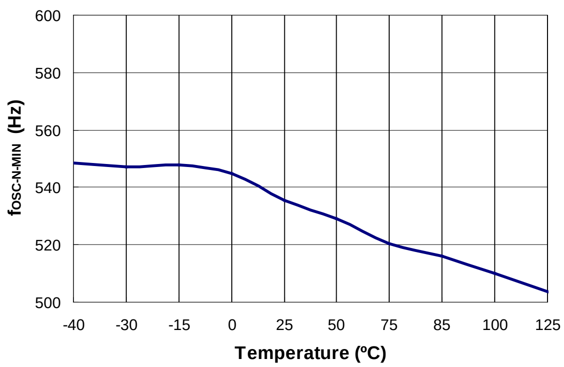


Figure 12. Minimum Frequency at No Load ($f_{OSC-N-MIN}$) vs. Temperature

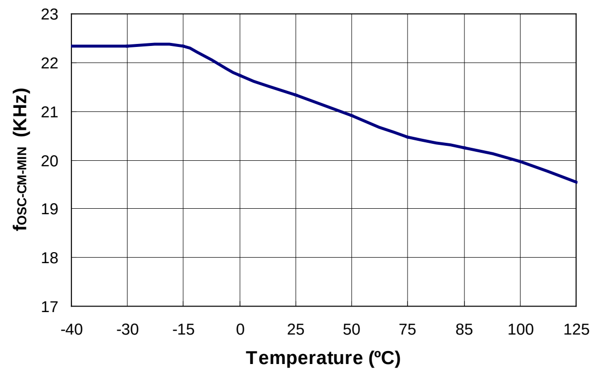


Figure 13. Minimum Frequency at CCM ($f_{OSC-CM-MIN}$) vs. Temperature

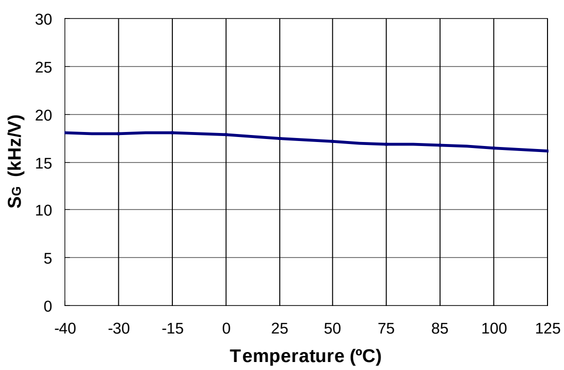


Figure 14. Green Mode Frequency Decreasing Rate (S_G) vs. Temperature

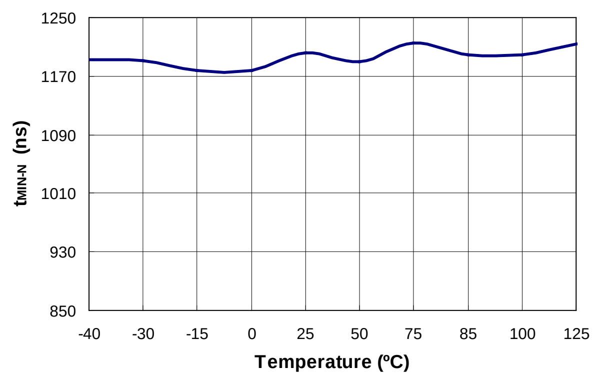


Figure 15. Minimum On Time at No Load (t_{MIN-N}) vs. Temperature

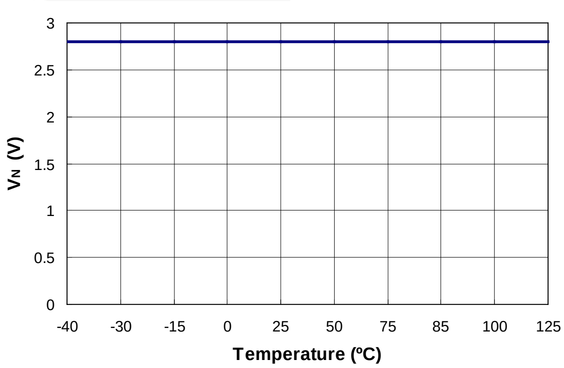


Figure 16. Green Mode Starting Voltage on COMV Pin (V_N) vs. Temperature

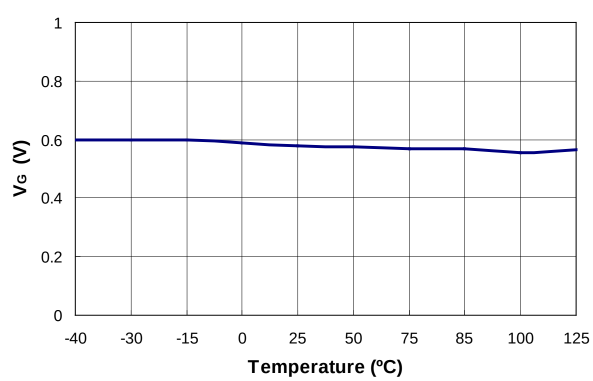


Figure 17. Green Mode Ending Voltage on COMV Pin (V_G) vs. Temperature

Typical Performance Characteristics

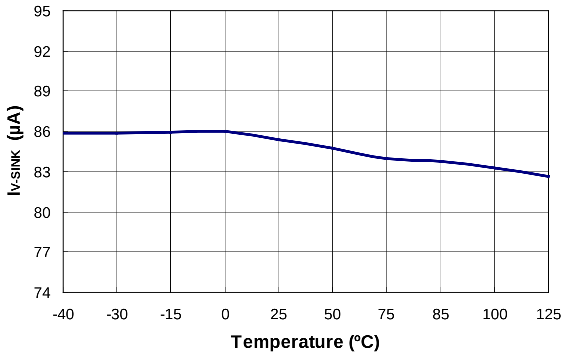


Figure 18. Output Sink Current ($I_{V\text{-}SINK}$) vs. Temperature

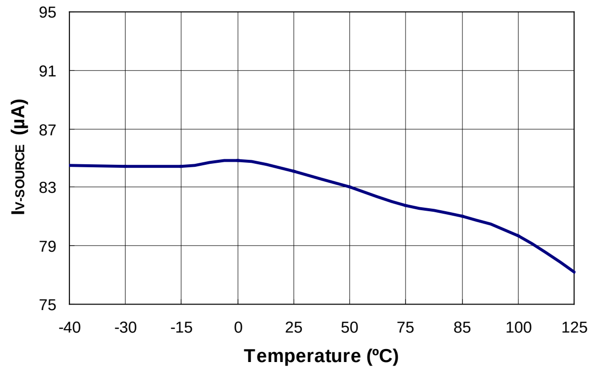


Figure 19. Output Source Current ($I_{V\text{-}SOURCE}$) vs. Temperature

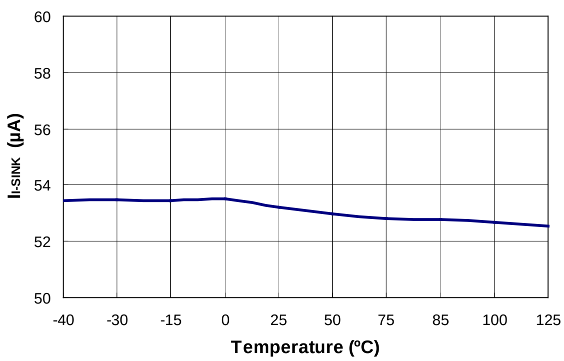


Figure 20. Output Sink Current ($I_{I\text{-}SINK}$) vs. Temperature

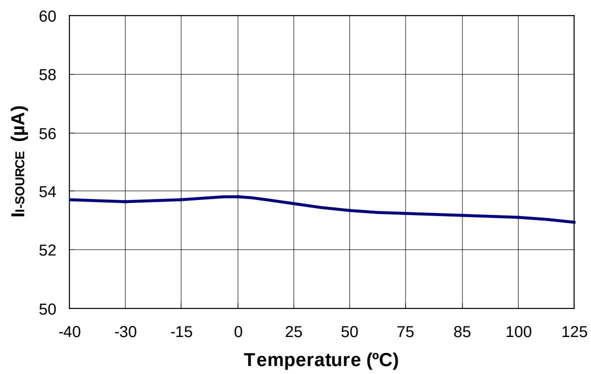


Figure 21. Output Source Current ($I_{I\text{-}SOURCE}$) vs. Temperature

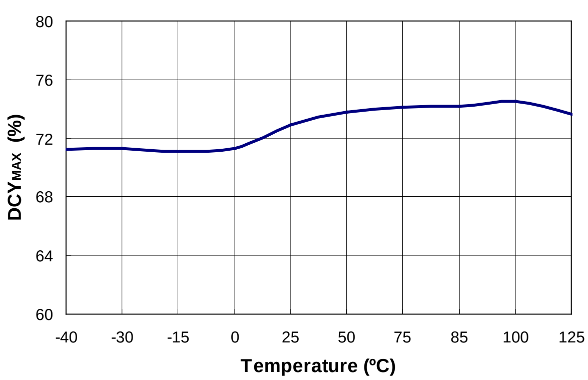


Figure 22. Maximum Duty Cycle (DCY_{MAX}) vs. Temperature

Functional Description

Figure 23 shows the basic circuit diagram of a primary-side regulated flyback converter and its typical waveforms are shown in Figure 24. Generally, discontinuous conduction mode (DCM) operation is preferred for primary-side regulation 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 the 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 $(V_o+V_F) \times N_a/N_s$. Since the diode forward-voltage drop decreases as current decreases, the auxiliary winding voltage reflects the output voltage best at the end of diode conduction time where the diode current diminishes to zero. Thus, by sampling the winding voltage at the end of the diode conduction time, the output voltage information can be obtained. The internal error amplifier for output voltage regulation (EA_V) compares the sampled voltage with internal precise reference to generate error voltage (V_{COMV}), which determines the duty cycle of the MOSFET in CV mode.

Meanwhile, the output current can be estimated using the peak drain current and inductor current discharge time since output current is the same as average of the diode current in steady state.

The output current estimator detects the peak value of the drain current with a peak detection circuit and calculates the output current using the inductor discharge time (t_{DIS}) and switching period (t_s). This output information is compared with the internal precise reference to generate error voltage (V_{COMI}), which determines the duty cycle of the MOSFET in CC mode. With Fairchild's innovative technique, TRUECURRENT™, constant current (CC) output can be precisely controlled.

Of the two error voltages, V_{COMV} and V_{COMI}, the smaller determines the duty cycle. During constant voltage regulation mode, V_{COMV} determines the duty cycle while V_{COMI} is saturated to HIGH. During constant current regulation mode, V_{COMI} determines the duty cycle while V_{COMV} is saturated to HIGH.

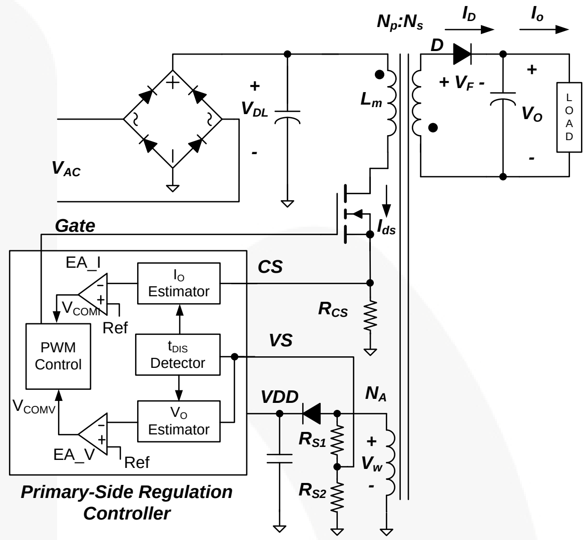


Figure 23. Simplified PSR Flyback Converter Circuit

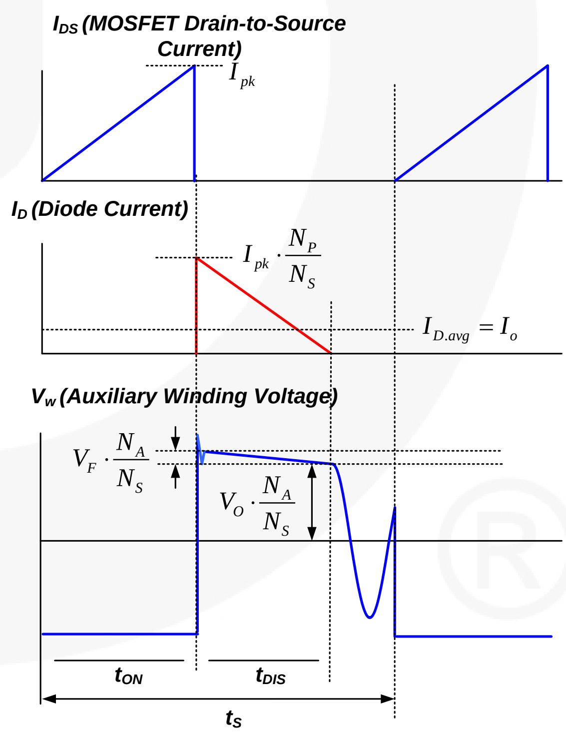


Figure 24. Key Waveforms of DCM Flyback Converter

Temperature Compensation

Built-in temperature compensation provides constant voltage regulation over a wide range of temperature variation. This internal compensation current compensates the forward-voltage drop variation of the secondary side rectifier diode.

Green-Mode Operation

The FAN100 uses voltage regulation error amplifier output (V_{COMV}) as an indicator of the output load and modulates the PWM frequency as shown in Figure 25 such that the switching frequency decreases as load decreases. In heavy-load conditions, the switching frequency is fixed at 42 KHz. Once V_{COMV} decreases below 2.8 V, the PWM frequency starts to linearly decrease from 42 KHz to 550Hz to reduce the switching losses. As V_{COMV} decreases below 0.8V, the switching frequency is fixed at 550Hz and FAN100 enters into "deep green" mode, where the operating current reduces to 1mA, reducing the standby power consumption.

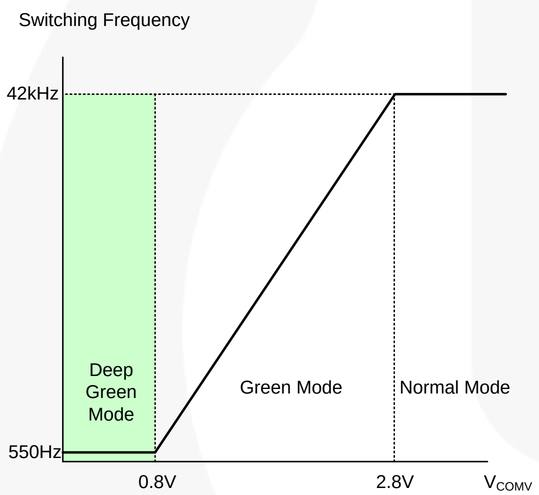


Figure 25. Switching Frequency in Green Mode

Leading-Edge Blanking (LEB)

At the instant the MOSFET is turned on, a high-current spike occurs through the MOSFET, caused by primary-side capacitance and secondary-side rectifier reverse recovery. Excessive voltage across the R_{CS} resistor can lead to premature turn-off of the MOSFET. FAN100 employs an internal leading edge blanking (LEB) circuit to inhibit the PWM comparator for a short time after the MOSFET turns on. External RC filtering is not required.

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. FAN100 has an internal frequency-hopping circuit that changes the switching frequency between 39.4 kHz and 44.6 kHz with a period of 3 ms, as shown in Figure 26.

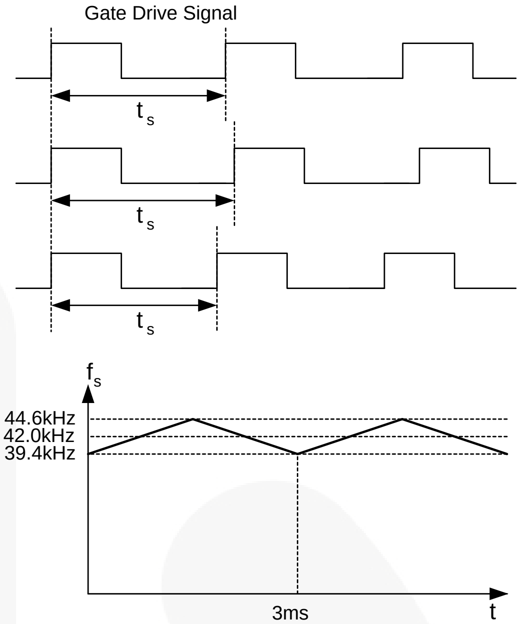


Figure 26. Frequency Hopping

Startup

Figure 27 shows the typical startup circuit and transformer auxiliary winding for FAN100 application. Before FAN100 begins switching, it consumes only startup current (maximum 10 µA) and the current supplied through the startup resistor charges the V_{DD} capacitor (C_{DD}). When V_{DD} reaches turn-on voltage of 16 V ($V_{DD\text{-}ON}$), FAN100 begins switching, and the current consumed increases to 3.5 mA. Then, the power required for FAN100 is supplied from the transformer auxiliary winding. The large hysteresis of V_{DD} provides more hold-up time, which allows using small capacitor for V_{DD}.

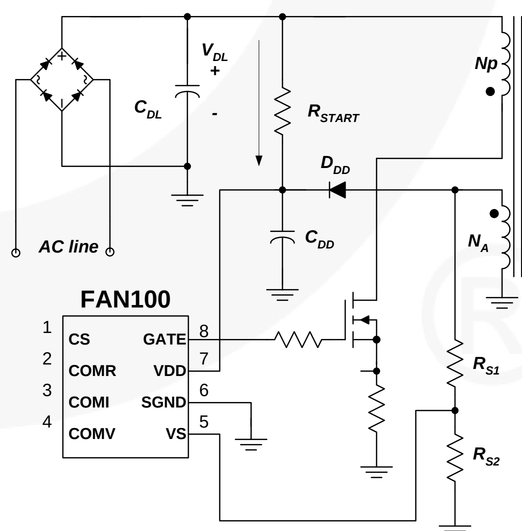


Figure 27. Startup Circuit

Protections

The FAN100 has several self-protective functions, such as Over-Voltage Protection (OVP), Over-Temperature Protection (OTP), and brownout protection. All the protections are implemented as auto-restart mode. When auto-restart protection is triggered, switching is terminated and the MOSFET remains off. This causes V_{DD} to fall. When V_{DD} reaches the V_{DD} turn-off voltage of 5 V, the current consumed by FAN100 reduces to the startup current (maximum 10 µA) and the current supplied startup resistor charges the V_{DD} capacitor. When V_{DD} reaches the turn-on voltage of 16 V, FAN100 resumes normal operation. In this manner, the auto-restart alternately enables and disables the switching of the MOSFET until the fault condition is eliminated (*see Figure 28*).

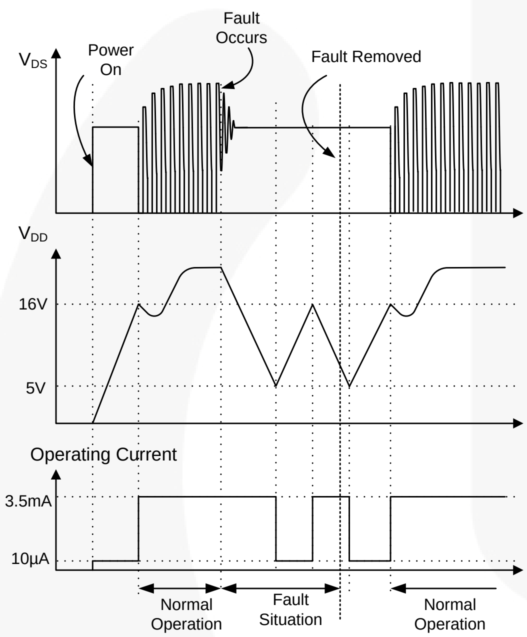


Figure 28. Auto-Restart Operation

V_{DD} Over-Voltage Protection (OVP)

V_{DD} over-voltage protection prevents damage from over-voltage conditions. If the V_{DD} voltage exceeds 28 V by open-feedback condition, OVP is triggered. The OVP has a debounce time (typical 250 µs) to prevent false triggering by switching noise. It also protects other switching devices from over voltage.

Over-Temperature Protection (OTP)

The built-in temperature-sensing circuit shuts down PWM output if the junction temperature exceeds 140°C.

Brownout Protection

FAN100 detects the line voltage using auxiliary winding voltage since the auxiliary winding voltage reflects the input voltage when the MOSFET is turned on. VS pin is clamped at 1.15 V while the MOSFET is turned on and brownout protection is triggered if the current out of VS pin is less than $I_{VS\text{-}UVP}$ (typical 180 µA) during the MOSFET conduction.

Pulse-by-pulse Current Limit

When the sensing voltage across the current sense resistor exceeds the internal threshold of 1.3 V, the MOSFET is turned off for the remainder of the switching cycle. In normal operation, the pulse-by-pulse current limit is not triggered since the peak current is limited by the control loop.

Typical Application Circuit (Primary-Side Regulated Offline LED Driver)

Application	Fairchild Devices	Input Voltage Range	Output
Offline LED Driver	FAN100	90~265 V_{AC}	24 V/0.35 A (8.4 W)

Features

- High Efficiency (>77% at Full Load)
- Tight Output Regulation (CC:±5%)

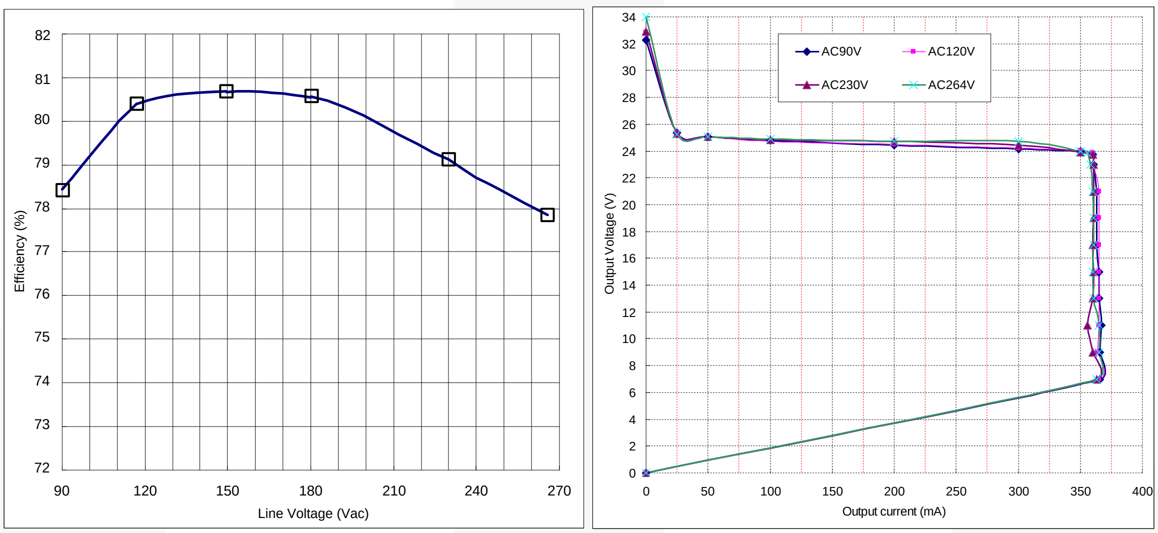


Figure 29. Measured Efficiency and Output Regulation

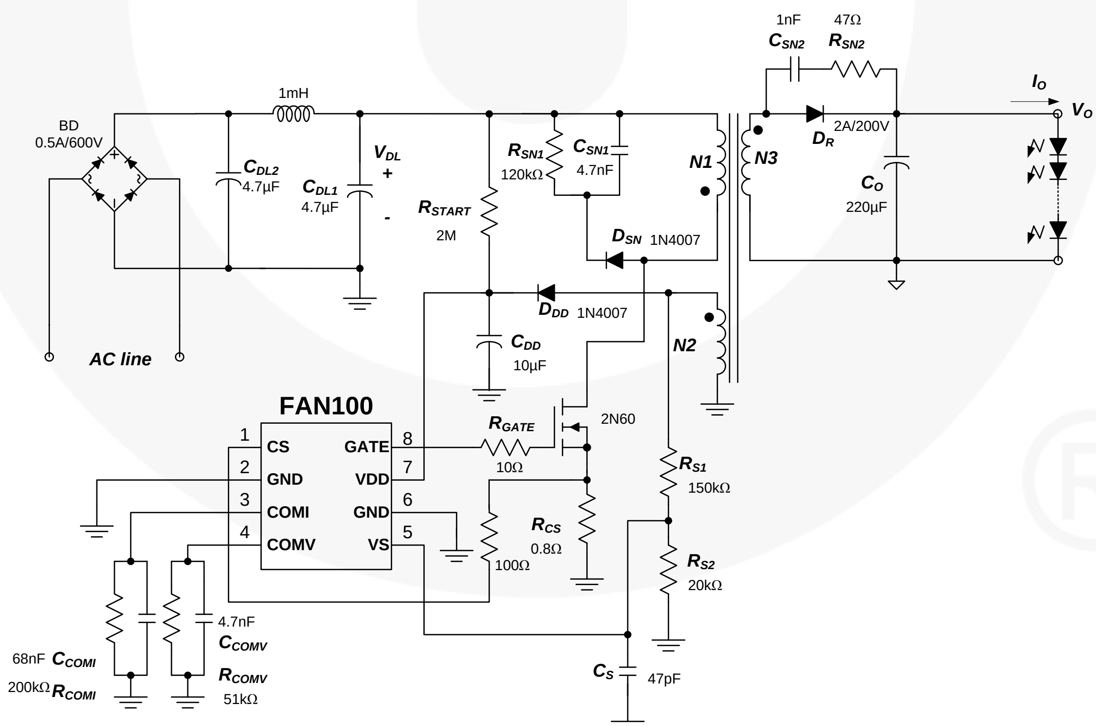
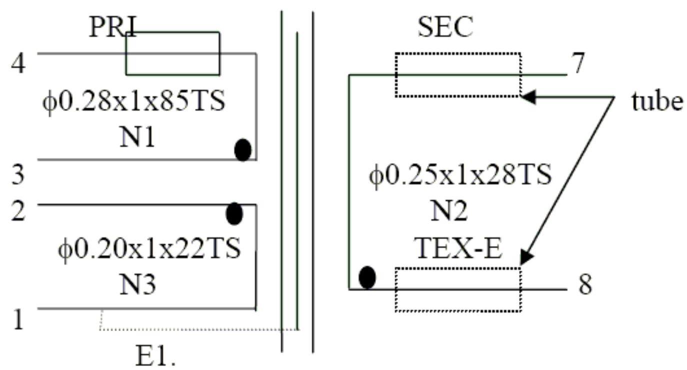


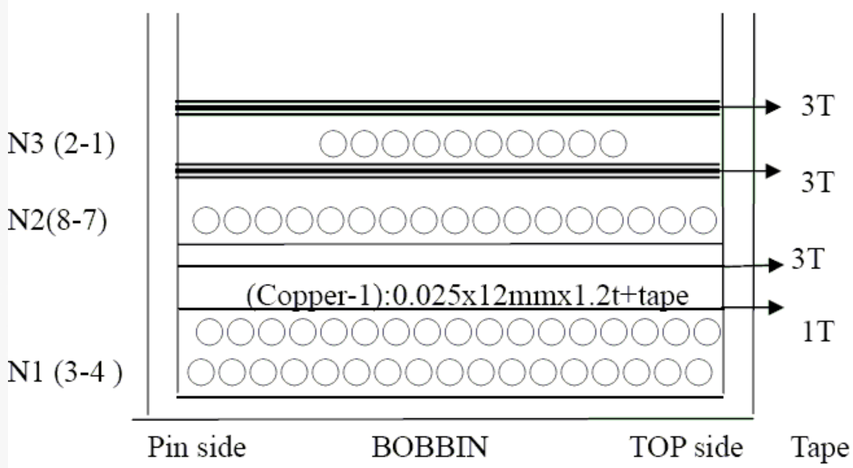
Figure 30. Typical Application Circuit Schematic

Typical Application Circuit (Continued)

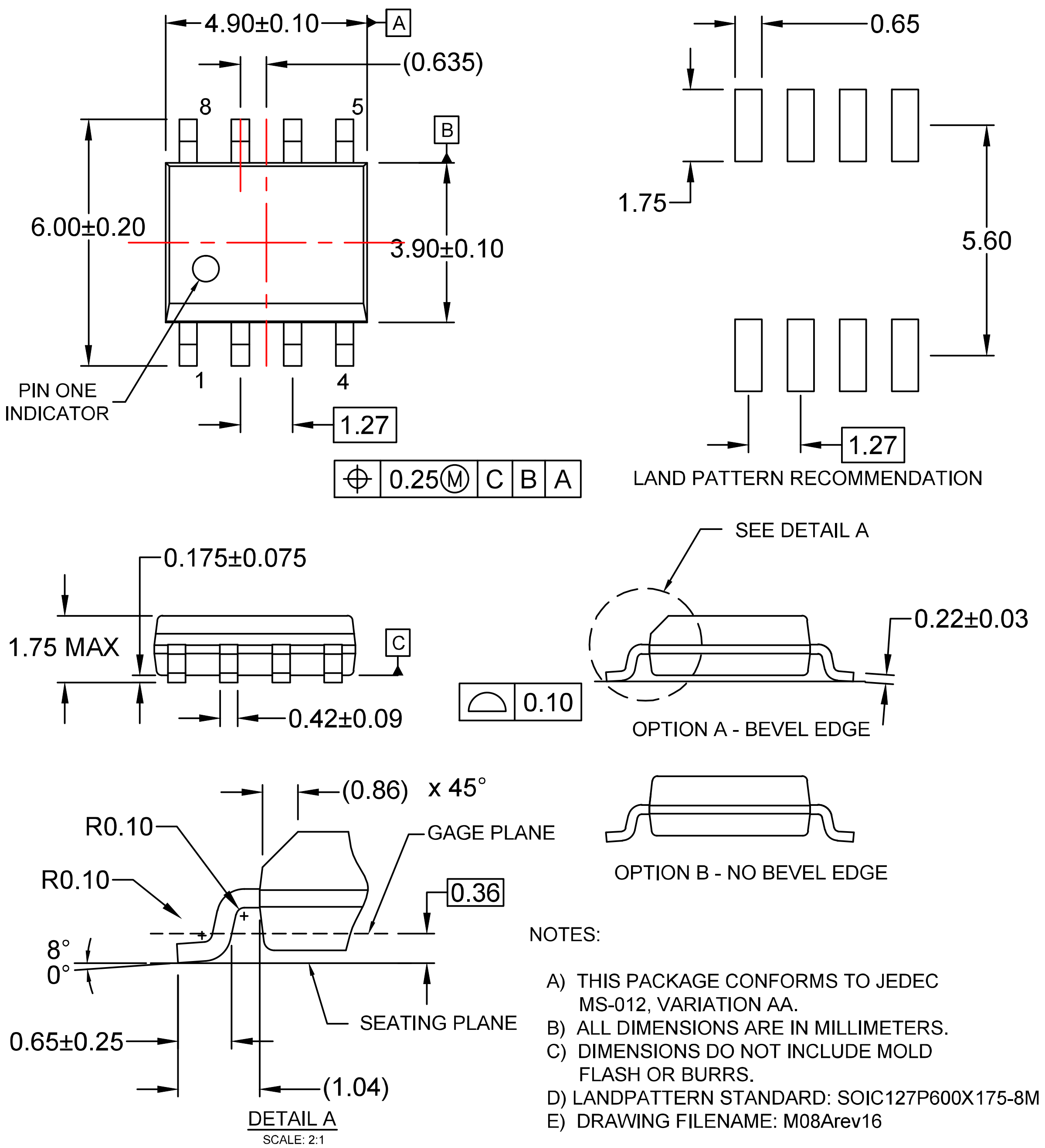
Transformer Specification

- Core: EFD-20
- Bobbin: EFD-20





	Pin	Specification	Remark
Primary-Side Inductance	3 – 4	1.08 mH ± 5%	100 kHz, 1 V
Primary-Side Effective Leakage	3 – 4	35 µH ± 5%.	Short one of the secondary windings



NOTES:

A) THIS PACKAGE CONFORMS TO JEDEC MS-012, VARIATION AA.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DIMENSIONS DO NOT INCLUDE MOLD FLASH OR BURRS.
D) LANDPATTERN STANDARD: SOIC127P600X175-8M
E) DRAWING FILENAME: M08Arev16

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