



# FSEZ2016 — Low-Power Green-Mode EZ-PSR without Secondary Feedback

## Features

- Linearly Decreasing PWM Frequency
- Green Mode Under Light-Load and Zero-Load Conditions
- Constant Voltage (CV) and Constant Current (CC) around  $\pm 25\%$  without Secondary Side Feedback Circuitry
- Precise Constant Voltage (CV) at  $\pm 5\%$  by Secondary Side Feedback Circuitry
- Low Startup Current:  $8\mu\text{A}$
- Low Operating Current:  $3.6\text{mA}$
- Leading-Edge Blanking (LEB)
- Constant Power Limit
- Universal AC Input Range
- Synchronized Slope Compensation
- $140^\circ\text{C}$  OTP Sensor with Hysteresis
- $V_{\text{DD}}$  Over-Voltage Clamping
- Cycle-by-Cycle Current Limiting
- Under-Voltage Lockout (UVLO)
- Fixed PWM Frequency with Hopping
- Gate Output Maximum Voltage Clamped at  $17\text{V}$

## Applications

General-purpose switching-mode power supplies and flyback power converters, such as:

- Battery Chargers for Cellular Phones, Cordless Phones, PDAs, Digital Cameras, Power Tools
- Power Adapters for Ink Jet Printers, Video Game Consoles, Portable Audio Players
- Open-Frame SMPS for TV/DVD Standby and Auxiliary Supplies, Home Appliances, Consumer Electronics
- Replacement for Linear Transformers and RCC SMPS
- PC 5V Standby Power

## Description

This highly integrated PWM controller provides several features to enhance the performance of low-power flyback converters. To minimize standby power consumption, a proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency under light-load and zero-load conditions. This green mode enables the power supply to meet international power conservation requirements. The supply voltage  $V_{\text{DD}}$  is also used for feedback compensation, to regulate the output voltage without requiring a conventional TL431 and a photo-coupler. A typical output CV/CC characteristic is shown in Figure 1.

Another advantage of the FSEZ2016 is that the typical startup current is only  $8\mu\text{A}$ , while the typical operating current can be as low as  $3.6\text{mA}$ . A large startup resistance can be used to achieve even higher power conversion efficiency.

FSEZ2016 integrates frequency hopping function internally to reduce EMI emissions with minimum line filters. Also, built-in synchronized slope compensation maintains the stability of peak current-mode control. Proprietary internal compensation ensures constant output power limiting over a universal range of AC input voltages, from  $90\text{V}_{\text{AC}}$  to  $264\text{V}_{\text{AC}}$ .

The FSEZ2016 provides many protection functions. Pulse-by-pulse current limiting ensures constant output current, even if a short circuit occurs. The internal protection circuit disables PWM output if  $V_{\text{DD}}$  exceeds  $22.7\text{V}$ . The gate output is clamped at  $17\text{V}$  to protect the power MOS from over-voltage damage. The built-in over-temperature protection (OTP) function shuts down the controller at  $140^\circ\text{C}$  with a  $30^\circ\text{C}$  hysteresis.

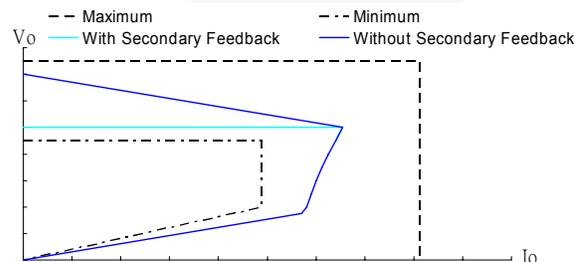


Figure 1. Typical Output V-I Characteristic

### Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FSEZ2016NY	-40°C to +105°C	7-Lead, Dual Outline Package (DIP-7)	Tube

### Application Diagram

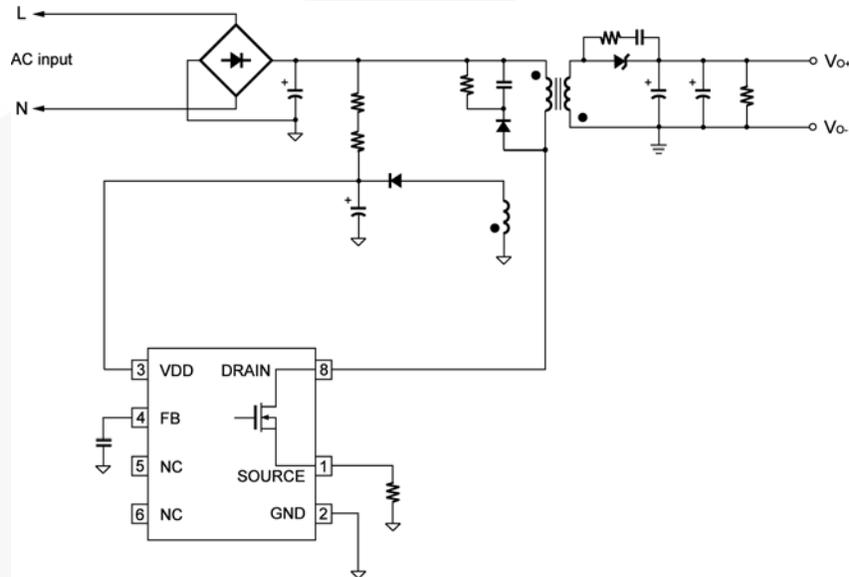


Figure 2. Typical Application

### Internal Block Diagram

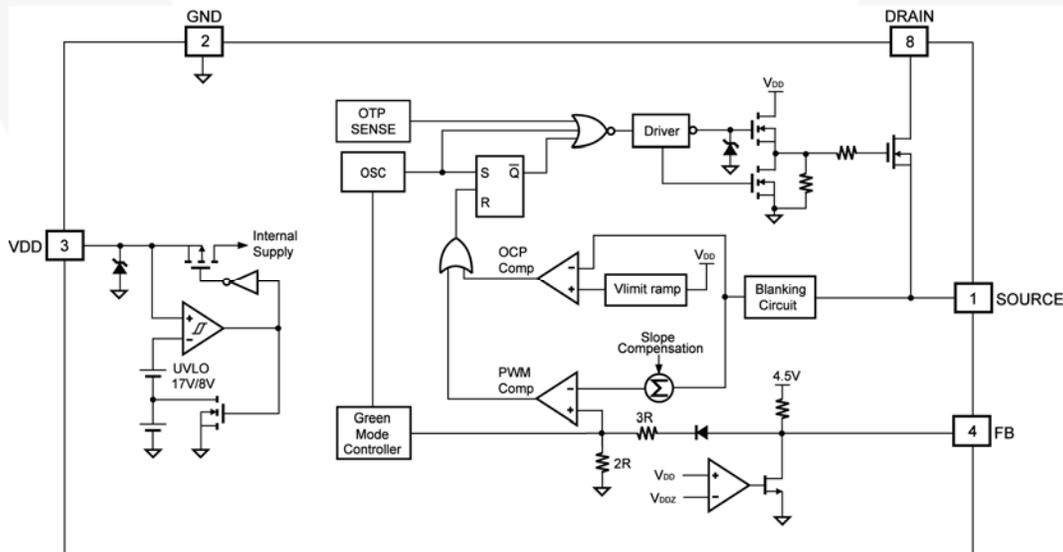
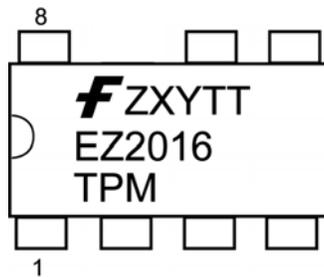


Figure 3. Functional Block Diagram

## Marking Information



1<sup>st</sup> line  
 Z: Assembly plant code  
 X: Year code  
 Y: Week code  
 TT: Die run code  
 3<sup>rd</sup> line  
 T: Package type (N=DIP)  
 P: Y=Green package  
 M: Manufacture flow code

Figure 4. Top Mark

## Pin Configuration

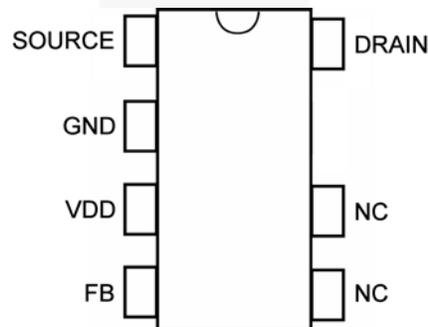


Figure 5. Pin Assignments

## Pin Definitions

Pin #	Name	Description
1	SOURCE	Power MOSFET source. This is the high-voltage power MOSFET source.
2	GND	Ground
3	VDD	Power supply
4	FB	The FB pin provides feedback information to the internal PWM comparator. This feedback is used to control the duty cycle. When no feedback is provided, this pin is left open.
5	NC	No connection
6	NC	No connection
8	DRAIN	Power MOSFET drain. This is the high-voltage power MOSFET drain.

## 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 <sup>(1, 2)</sup>			30	V
$V_{FB}$	Input Voltage to FB Pin		-0.3	7.0	V
$V_{SENSE}$	Input Voltage to Sense Pin		-0.3	7.0	V
$P_D$	Power Dissipation ( $T_A=25^{\circ}\text{C}$ )			1.2	W
$\theta_{JA}$	Thermal Resistance (Junction-to-Air)			98.7	$^{\circ}\text{C}/\text{W}$
$T_J$	Operating Junction Temperature		-40	+150	$^{\circ}\text{C}$
$T_{STG}$	Storage Temperature Range		-55	+150	$^{\circ}\text{C}$
$T_L$	Lead Temperature (Wave Soldering or IR, 10 Seconds)			+260	$^{\circ}\text{C}$
ESD	Electrostatic Discharge Capability	Human Body Model, JEDEC:JESD22_A114		2	KV
		Charged Device Model, JEDEC:JESD22_C101		1	

### 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.

## Electrical Characteristics

Unless otherwise noted,  $V_{DD}=15V$  and  $T_A=25^\circ C$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
<b>V<sub>DD</sub> Section</b>						
V <sub>DD-OP</sub>	Continuously Operation Voltage	With Secondary Feedback			20.0	V
		Without Secondary Feedback			22.7	
V <sub>DD-ON</sub>	Turn-On Threshold Voltage		16	17	18	V
V <sub>DD-OFF</sub>	Turn-Off Threshold Voltage		7.5	8.0	8.5	V
I <sub>DD-ST</sub>	Startup Current	$V_{DD}=V_{DD-ON} - 0.1V$		8	20	μA
I <sub>DD-OP</sub>	Operating Supply Current	$C_L=1nF$		3.6	4.6	mA
V <sub>DD-G-OFF</sub>	V <sub>DD</sub> Low-Threshold Voltage to Exit Green-Off Mode			V <sub>DD-OFF</sub> +1.3		V
<b>Feedback Input Section</b>						
A <sub>V</sub>	Input-Voltage to Current-Sense Attenuation			0.35		V/V
Z <sub>FB</sub>	Input Impedance	$I_{FB}=0.1mA$ to $0.2mA$		4.6		kΩ
V <sub>FB-OPEN</sub>	Open-Loop Voltage		4.5			V
V <sub>DD-FB</sub>	V <sub>DD</sub> Feedback Threshold Voltage	FB is Open	20.7	22.7	24.7	V
		$I_{FB}=0.4mA$	18.4	20.4	22.4	V
<b>Current-Sense Section</b>						
t <sub>PD</sub>	Propagation Delay			100	150	ns
V <sub>STHVA</sub>	Current Limit Valley Threshold Voltage	V <sub>DD</sub> =18V		0.83		V
		V <sub>DD</sub> =15V		0.74		
		V <sub>DD</sub> =10V		0.59		
V <sub>STHFL</sub>	Current Limit Flat Threshold Voltage	V <sub>DD</sub> =18V		1.15		V
		V <sub>DD</sub> =15V		1.04		
		V <sub>DD</sub> =10V		0.84		
t <sub>LEB</sub>	Leading-Edge Blanking Time		220	310	400	ns

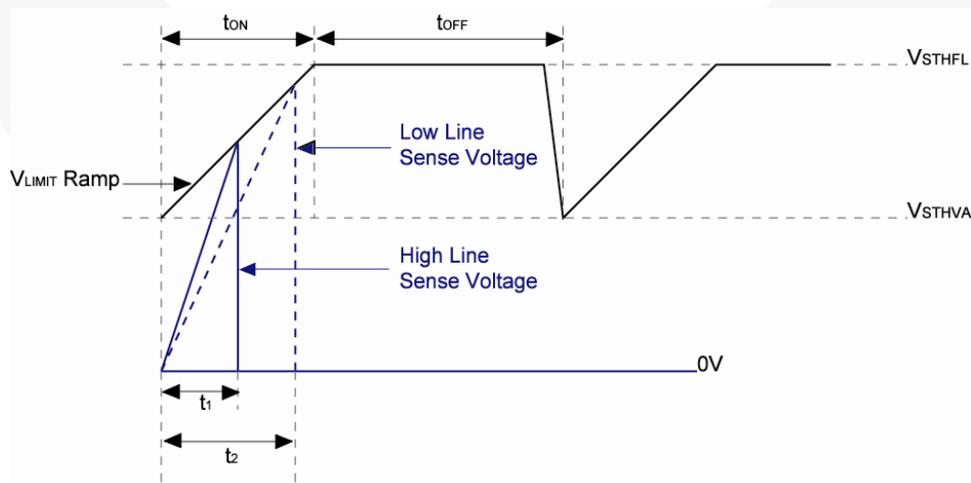


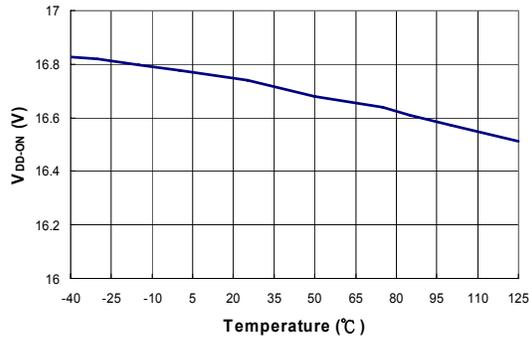
Figure 6. Saw Limit

### Electrical Characteristics (Continued)

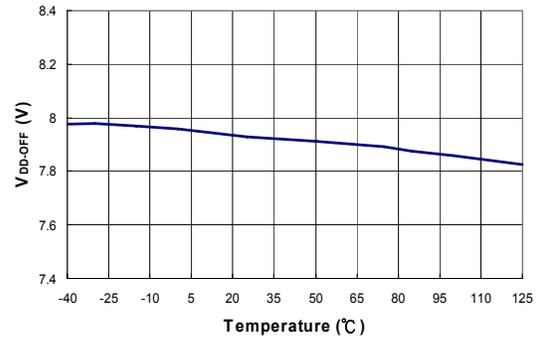
Unless otherwise noted,  $V_{DD}=15V$  and  $T_A=25^{\circ}C$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
<b>Oscillator Section</b>						
$f_{OSC}$	Frequency	Center Frequency	60	65	70	kHz
		Hopping Range	$\pm 4.1$	$\pm 4.7$	$\pm 5.3$	
$t_{HOP}$	Hopping Period			4		ms
$f_{OSC-G}$	Green-Mode Frequency		14.5	17.0	19.5	KHz
$V_{FB-N}$	Green-Mode Entry FB Voltage		2.3	2.6	2.9	V
$V_{FB-G}$	Green-Mode Ending FB Voltage			$V_{FB-N} - 0.75$		V
$V_{FB-Z}$	Zero Duty Cycle FB Voltage			1.4		V
$S_G$	Green-Mode Modulation Slope		40	70	100	Hz/mV
$f_{DV}$	Frequency Variation vs. $V_{DD}$ Deviation	$V_{DD}=10$ to $22V$			5	%
$f_{DT}$	Frequency Variation vs. Temperature Deviation	$T_A = -20$ to $85^{\circ}C$		1.5	5.0	%
<b>Internal MOSFET Section</b>						
$DCY_{MAX}$	Maximum Duty Cycle		69	74	79	%
$BV_{DSS}$	Drain-Source Breakdown Voltage		$I_D=250\mu A, V_{GS}=0V$	600		V
$\Delta BV_{DSS}/\Delta T_J$	Breakdown Voltage Temperature Coefficient		$I_D=250\mu A,$ Referenced to $25^{\circ}C$	0.6		$V/^{\circ}C$
$I_S$	Maximum Continuous Drain-Source Diode Forward Current				1	A
$I_{SM}$	Maximum Pulsed Drain-Source Diode Forward Current				4	A
$R_{DS(ON)}$	Static Drain-Source On-Resistance		$I_D=0.5A, V_{GS}=10V$	9.3	11.5	$\Omega$
$I_{DSS}$	Drain-Source Leakage Current		$V_{DS}=600V, V_{GS}=0V,$ $T_C=25^{\circ}C$		5	$\mu A$
			$V_{DS}=480V, V_{GS}=0V,$ $T_C=100^{\circ}C$		10	$\mu A$
$t_{D-ON}$	Turn-On Delay Time		$V_{DS}=300V, I_D=1.1A,$ $R_G=25\Omega$	7	24	ns
$t_r$	Rise Time			21	52	ns
$t_{D-OFF}$	Turn-Off Delay Time			13	36	ns
$t_f$	Fall Time			27	64	ns
$C_{ISS}$	Input Capacitance		$V_{GS}=0V, V_{DS}=25V,$ $f_s=1MHz$	130	170	pF
$C_{OSS}$	Output Capacitance			19	25	pF
<b>Over Temperature Protection (OTP)</b>						
$T_{OTP}$	Protection Junction Temperature			140		$^{\circ}C$
$T_{OTP-RESTART}$	Restart Junction Temperature			110		$^{\circ}C$

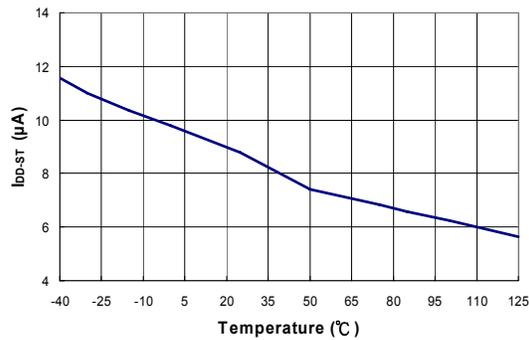
## Typical Performance Characteristics



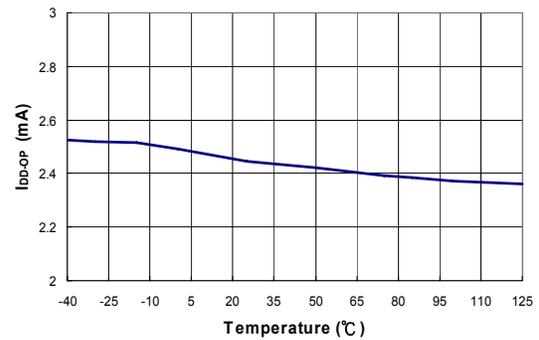
**Figure 7. Turn-On Threshold Voltage (V<sub>DD-ON</sub>) vs. Temperature**



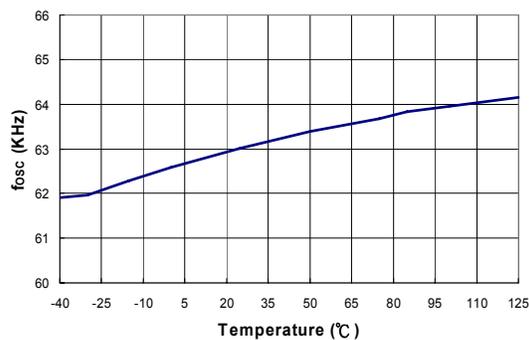
**Figure 8. Turn-Off Threshold Voltage (V<sub>DD-OFF</sub>) vs. Temperature**



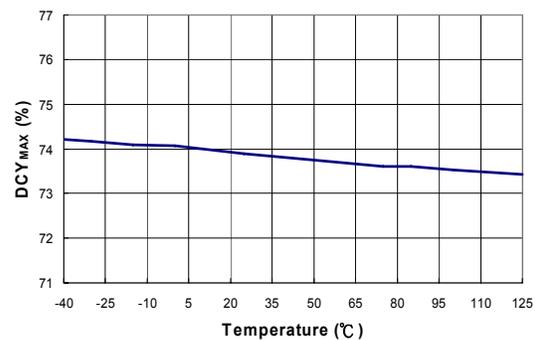
**Figure 9. Startup Current (I<sub>DD-ST</sub>) vs. Temperature**



**Figure 10. Operating Supply Current (I<sub>DD-OP</sub>) vs. Temperature**

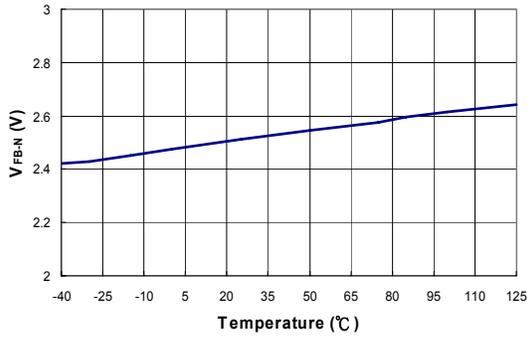


**Figure 11. Center Frequency (f<sub>OSC</sub>) vs. Temperature**

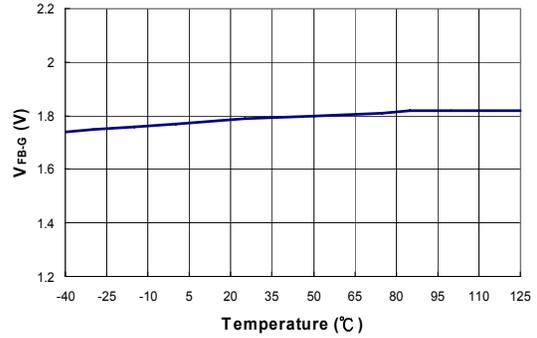


**Figure 12. Maximum Duty Cycle (DCY<sub>MAX</sub>) vs. Temperature**

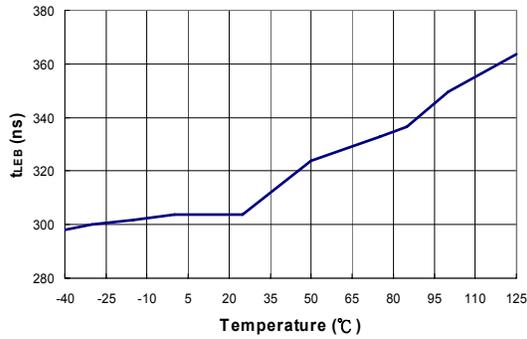
**Typical Performance Characteristics** (Continued)



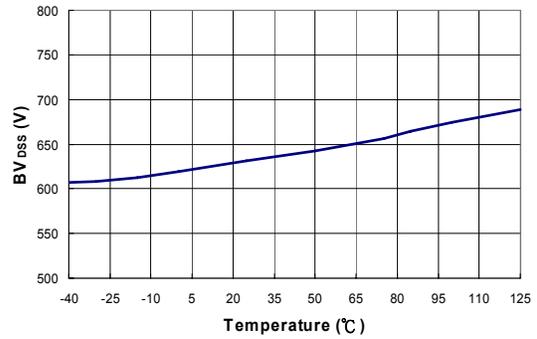
**Figure 13. Green-Mode Entry FB Voltage (V<sub>FB-N</sub>) vs. Temperature**



**Figure 14. Green-Mode Ending FB Voltage (V<sub>FB-G</sub>) vs. Temperature**



**Figure 15. Leading-Edge Blanking Time (t<sub>LEB</sub>) vs. Temperature**



**Figure 16. Drain-Source Breakdown Voltage (BV<sub>DSS</sub>) vs. Temperature**



## Operation Description

FSEZ2016 devices integrate functions for low-power switch-mode power supplies. The following descriptions highlight the key features of the FSEZ2016.

### Startup Current

The required startup current is only 8 $\mu$ A. This allows a high-resistance, low-wattage startup resistor to supply the controller's startup power. A 1.5M $\Omega$ /0.25W startup resistor can be used over a wide input range (100V-240V<sub>AC</sub>) with very little power loss.

### Operating Current

The operating current is normally 3.6mA, which results in higher efficiency and reduces the required V<sub>DD</sub> hold-up capacitance. A 10 $\mu$ F/25V V<sub>DD</sub> hold-up capacitor can be used over a wide input range (90V-264V<sub>AC</sub>) with very little power loss.

### Green-Mode Operation

The proprietary green-mode function provides off-time modulation to linearly decrease the switching frequency under light-load and zero-load conditions. The on-time is limited to provide better protection against brownouts and other abnormal conditions. Power supplies using the FSEZ2016 can meet international restrictions regarding standby power-consumption.

### Constant Voltage (CV) and Constant Current (CC) without Feedback

The FSEZ2016 can tightly regulate the output voltage and provide over-current protection without requiring secondary-side feedback signals. For improved CV and CC accuracy, the transformer leakage inductance should be reduced as much as possible.

### Over-Temperature Protection (OTP)

The FSEZ2016 has a built-in temperature-sensing circuit to shut down PWM output if the junction temperature exceeds 140°C. While PWM output is shut down, the V<sub>DD</sub> voltage gradually drops to the UVLO voltage. Some of the internal circuits are shut down, and V<sub>DD</sub> gradually starts increasing again. When V<sub>DD</sub> reaches 17V, all the internal circuits, including the temperature-sensing circuit, operate 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. The PWM output is then turned back on. The temperature hysteresis window for the OTP circuit is 30°C.

### V<sub>DD</sub> Over-Voltage Clamping

V<sub>DD</sub> over-voltage clamping is built in to prevent damage from over-voltage conditions. When V<sub>DD</sub> exceeds 22.7V, PWM output is shut down. Over-voltage conditions may be caused by an open photo-coupler loop or a short circuit in the output.

### Oscillator Operation

The oscillation frequency is fixed at 65KHz.

### Leading-Edge Blanking (LEB)

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 310ns leading-edge blanking time is built in. Conventional RC filtering is not necessary. During this blanking period, the current-limit comparator is disabled and cannot switch off the gate drive.

### Constant Output Power Limit

When the SENSE voltage across the sense resistor R<sub>S</sub> reaches the threshold voltage, the output GATE drive is turned off following a small propagation delay, t<sub>PD</sub>. This propagation delay introduces an additional current proportional to t<sub>PD</sub>•V<sub>IN</sub>/L<sub>P</sub>. The propagation delay is nearly constant, regardless of the input line voltage V<sub>IN</sub>. Higher input line voltages result in larger additional currents. Under high input-line voltages, the output power limit is higher than under low input-line voltages. Over a wide range of AC input voltages, the variation can be significant. To compensate for this, the threshold voltage is adjusted by adding a positive ramp (V<sub>limit\_ramp</sub>). This ramp signal can vary from 0.74V to 1.04V and flattens out at 1.04V. A smaller threshold voltage forces the output GATE drive to terminate earlier, reducing total PWM turn-on time and making the output power equal to that of the low line input. This proprietary internal compensation feature ensures a constant output power limit over a wide range of AC input voltages (90V-264V<sub>AC</sub>).

### Under Voltage Lockout (UVLO)

The turn-on/turn-off thresholds are fixed internally at 17V and 8V. To enable the FSEZ2016 during startup, the hold-up capacitor must first be charged to 17V through the startup resistor. The hold-up capacitor continues to supply V<sub>DD</sub> before energy can be delivered from the auxiliary winding of the main transformer. V<sub>DD</sub> must not drop below 8V during this startup process. This UVLO hysteresis window ensures that the hold-up capacitor can adequately supply V<sub>DD</sub> during startup.

### Gate Output

The BiCMOS output stage is a fast totem-pole gate driver. Cross-conduction is avoided to minimize heat dissipation, increase efficiency, and enhance reliability. The output driver is clamped by an internal 17V Zener diode to protect the power MOSFET transistors against any harmful over-voltage gate signals.

## Operation Description (Continued)

### Slope Compensation

The sensed voltage across the current sense resistor is used for current mode control and pulse-by-pulse current limiting. The built-in slope compensation improves power supply stability. Furthermore, it prevents sub-harmonic oscillations that normally would occur because of peak current mode control. A positively sloped, synchronized ramp is activated with every switching cycle. The slope of the ramp is:

$$\frac{0.33 \times \text{Duty}}{\text{Duty}(\text{max.})} \quad (1)$$

### Noise Immunity

Noise from the current sense or the control signal may cause significant pulse-width jitter, particularly in continuous-conduction mode. Slope compensation helps alleviate this problem. Good placement and layout practices should be followed. The designer should avoid long PCB traces and component leads. Compensation and filter components should be located near the FSEZ2016. Finally, increasing the power-MOS gate resistance is advised.

## Applications Information

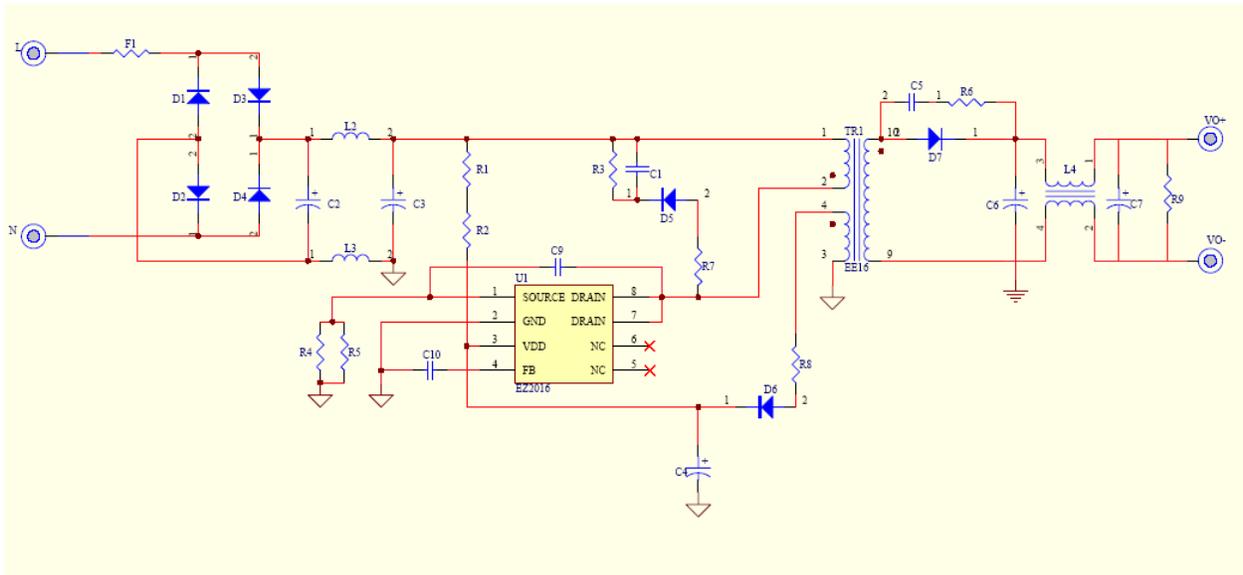


Figure 17. Reference Circuit (without Secondary-Side Feedback)

## BOM

Reference	Component	Reference	Component
C1	CC 4.7nF/1kV	F1	R 1Ω/1W
C2	EC 4.7µF/400V 105°C	L2	Inductor 4.7µH
C3	EC 4.7µF/400V 105°C	L3	Inductor 470µH
C4	EC 10µF/50V 105°C	L4	Inductor 80µH
C5	CC 1nF/1kV	R1	R 750kΩ
C6	EC 560µF/10V	R2	R 750kΩ
C7	EC 560µF/10V	R3	R 100kΩ
C9	Open	R4	R 10Ω
C10	CC 1nF	R5	R 2.2Ω
D1	Diode 1N4007	R6	R 47Ω
D2	Diode 1N4007	R7	R 270Ω
D3	Diode 1N4007	R8	R 0Ω
D4	Diode 1N4007	R9	R 2kΩ
D5	Diode FR107	T1	Transformer EE-16
D6	Diode FR102	U1	IC FSEZ2016
D7	Diode SB560		

## Applications Information (Continued)

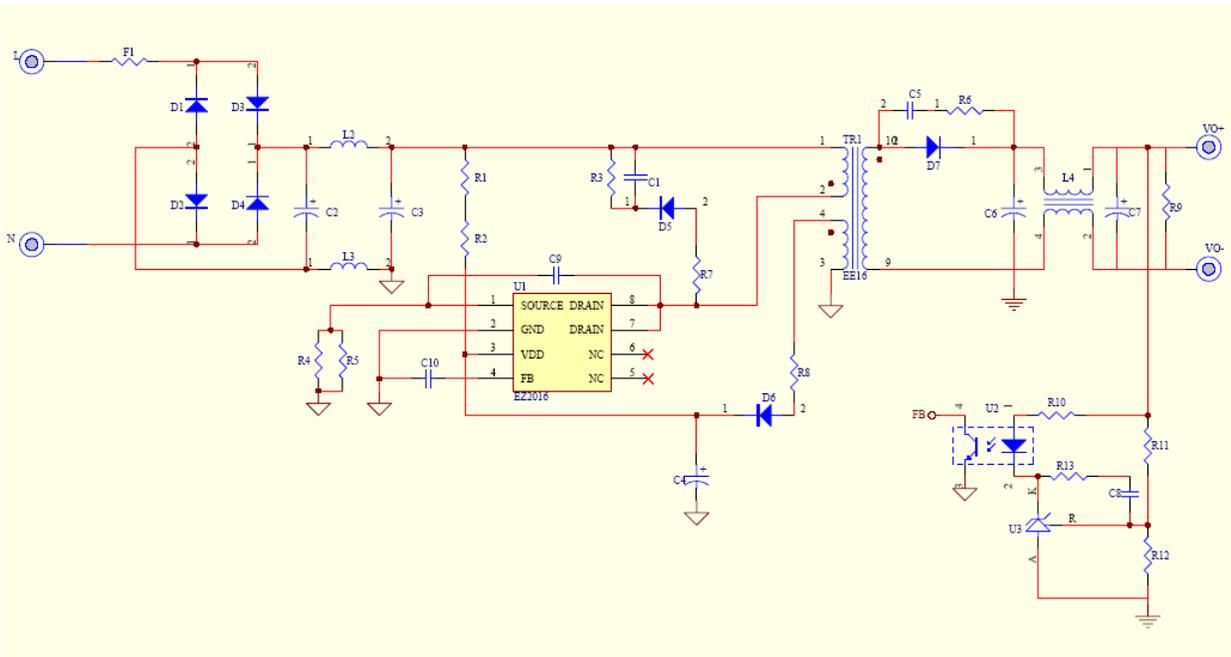
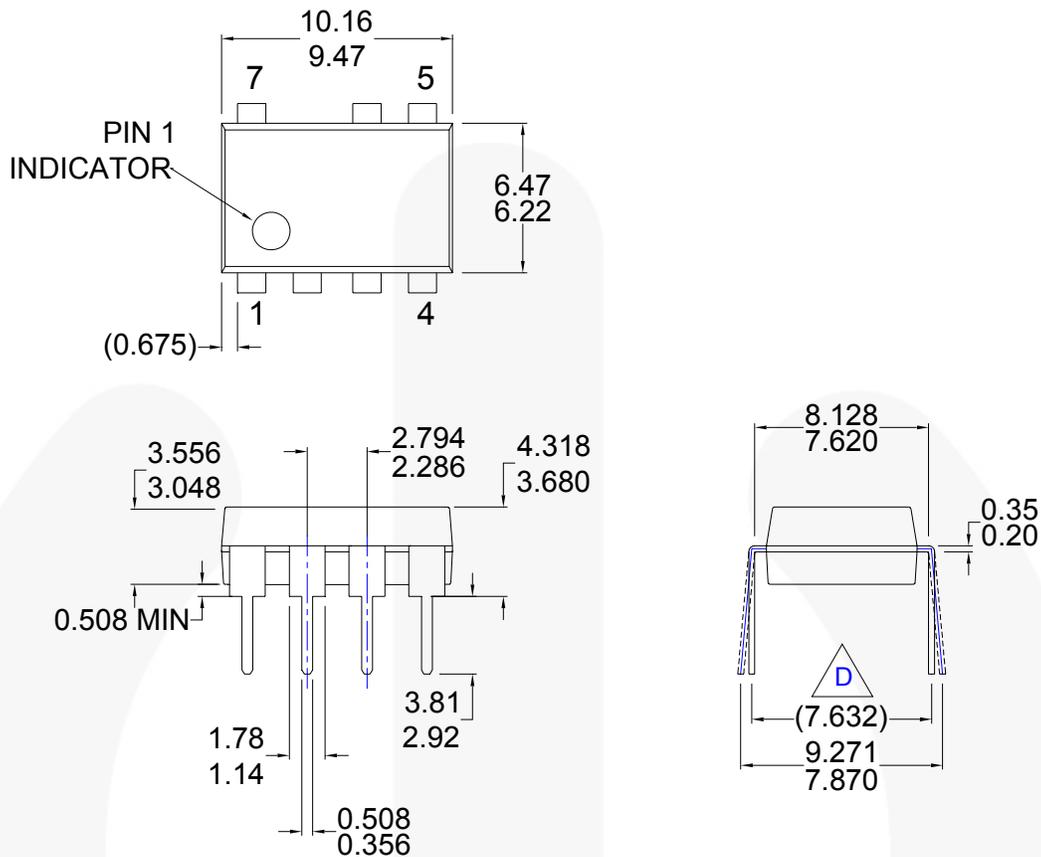


Figure 18. Reference Circuit (with Secondary-Side Feedback)

## BOM

Reference	Component	Reference	Component
C1	CC 4.7nF/1kV	L3	Inductor 470μH
C2	EC 4.7μF/400V 105°C	L4	Inductor 80μH
C3	EC 4.7μF/400V 105°C	R1	R 750kΩ
C4	EC 10μF/50V 105°C	R2	R 750kΩ
C5	CC 1nF/1kV	R3	R 100kΩ
C6	EC 560μF/10V	R4	R 10Ω
C7	EC 560μF/10V	R5	R 2.2Ω
C8	CC 2.2nF	R6	R 47Ω
C9	Open	R7	R 270Ω
C10	CC 1nF	R8	R 0Ω
D1	Diode 1N4007	R9	R 2kΩ
D2	Diode 1N4007	R10	R 560Ω
D3	Diode 1N4007	R11	R 20kΩ
D4	Diode 1N4007	R12	R 20kΩ
D5	Diode FR107	R13	R 20kΩ
D6	Diode FR102	T1	Transformer EE-16
D7	Diode SB560	U1	IC FSEZ2016
F1	R 1Ω/1W	U2	IC PC817
L2	Inductor 4.7μH	U3	IC TL431

## Physical Dimensions



### NOTES:

- A) THIS PACKAGE CONFORMS TO JEDEC MS-001 VARIATION AA EXCEPT LEAD COUNT.
- B) ALL DIMENSIONS ARE IN MILLIMETERS.
- C) DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS.
-  D) DIMENSION WITH TERMINALS CONSTRAINED PERPENDICULAR TO PRINTED CIRCUIT BOARD.
- E) DRAWING FILE NAME: MKT-N07CREV1

**Figure 19. 7-Pin Dual In-line Package (DIP-7)**

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| Auto-SPM™                | FRFET®                   | PowerTrench®                         |  |
| Build it Now™            | Global Power Resource SM | PowerXS™                             |  |
| CorePLUS™                | Green FPS™               | Programmable Active Droop™           |  |
| CorePOWER™               | Green FPS™ e-Series™     | QFET®                                |  |
| CROSSVOL™                | Gmax™                    | QS™                                  |  |
| CTL™                     | GTO™                     | Quiet Series™                        |  |
| Current Transfer Logic™  | IntelliMAX™              | RapidConfigure™                      |  |
| DEUXPEED®                | ISOPLANAR™               | ™                                    |  |
| Dual Cool™               | MegaBuck™                | Saving our world, 1mW/WkW at a time™ |  |
| EcoSPARK®                | MICROCOUPLER™            | SignalWise™                          |  |
| EfficientMax™            | MicroFET™                | SmartMax™                            |  |
| ESBC™                    | MicroPak™                | SMART START™                         |  |
| Fairchild®               | MicroPak2™               | SPM®                                 |  |
| Fairchild Semiconductor® | MillerDrive™             | STEALTH™                             |  |
| FACT Quiet Series™       | MotionMax™               | SuperFET™                            |  |
| FACT®                    | Motion-SPM™              | SuperSOT™.3                          |  |
| FAST®                    | OptoHIT™                 | SuperSOT™.6                          |  |
| FastvCore™               | OPTOLOGIC®               | SuperSOT™.8                          |  |
| FETBench™                | OPTOPLANAR®              | SupreMOS®                            |  |
| FlashWriter®             | PDP SPM™                 | SyncFET™                             |  |
| FPST™                    |                          | Sync-Lock™                           |  |

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2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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**PRODUCT STATUS DEFINITIONS**

**Definition of Terms**

Datasheet Identification	Product Status	Definition
Advance Information	Formative / In Design	Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
No Identification Needed	Full Production	Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.
Obsolete	Not In Production	Datasheet contains specifications on a product that is discontinued by Fairchild Semiconductor. The datasheet is for reference information only.

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