FSEZ1016A
Primary-Side-Regulation PWM Integrated Power MOSFET

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 43 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 (OTP) with Auto-Restart
- Brownout Protection with Auto-Restart
- VDD Over-Voltage Protection (OVP) with Auto-Restart
- VDD Under-Voltage Lockout (UVLO)
- SOIC-7 Package

Description
This primary-side PWM integrated power MOSFET significantly simplifies power supply designs that require CV and CC regulation capabilities. FSEZ1016A controls the output voltage and current precisely with only the information in the primary side of the power supply, not only removing the output current sensing loss, but also eliminating all 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 conventional secondary-side regulation approach; the FSEZ1016A can reduce total cost, component count, size, and weight; while simultaneously increasing efficiency, productivity, and system reliability.

FSEZ1016A is available in a 7-pin SOIC package.

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

Applications
- Battery Chargers for Cellular Phones, Cordless Phones, PDAs, 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

Figure 1. Typical Output V-I Characteristic

Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Operating Temperature Range</th>
<th>MOSFET BV&lt;sub&gt;DSS&lt;/sub&gt;</th>
<th>MOSFET R&lt;sub&gt;DSON&lt;/sub&gt; (Typical)</th>
<th>Package</th>
<th>Packing Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSEZ1016AMY</td>
<td>-40°C to +125°C</td>
<td>600 V</td>
<td>9.3 Ω</td>
<td>7-Lead, Small Outline Integrated Circuit Package (SOIC)</td>
<td>Tape &amp; Reel</td>
</tr>
</tbody>
</table>

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

![Marking Information Diagram]

Figure 4. Top Mark

Pin Configuration

![Pin Configuration Diagram]

Figure 5. Pin Configuration

Pin Definitions

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CS</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>3</td>
<td>COMI</td>
<td>Constant Current Loop Compensation. This pin connects a capacitor and a resistor between COMI and GND for compensation current loop gain.</td>
</tr>
<tr>
<td>4</td>
<td>COMV</td>
<td>Constant Voltage Loop Compensation. This pin connects a capacitor and a resistor between COMV and GND for compensation voltage loop gain.</td>
</tr>
<tr>
<td>5</td>
<td>VS</td>
<td>Voltage Sense. This pin detects the output voltage information and discharge time base on voltage of auxiliary winding. This pin connected two divider resistors and one capacitor.</td>
</tr>
<tr>
<td>6</td>
<td>VDD</td>
<td>Supply. The power supply pin. IC operating current and MOSFET driving current are supplied using this pin. This pin is connected to an external VDD 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.</td>
</tr>
<tr>
<td>7</td>
<td>NC</td>
<td>No connection.</td>
</tr>
<tr>
<td>8</td>
<td>DRAIN</td>
<td>Drain. This pin is the high-voltage power MOSFET drain.</td>
</tr>
</tbody>
</table>
## 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.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$</td>
<td>DC Supply Voltage$^{(1,2)}$</td>
<td>30 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{VS}$</td>
<td>VS Pin Input Voltage</td>
<td>-0.3 V</td>
<td>7.0 V</td>
<td></td>
</tr>
<tr>
<td>$V_{CS}$</td>
<td>CS Pin Input Voltage</td>
<td>-0.3 V</td>
<td>7.0 V</td>
<td></td>
</tr>
<tr>
<td>$V_{COMV}$</td>
<td>Voltage-Error Amplifier Output Voltage</td>
<td>-0.3 V</td>
<td>7.0 V</td>
<td></td>
</tr>
<tr>
<td>$V_{COMI}$</td>
<td>Voltage-Error Amplifier Output Voltage</td>
<td>-0.3 V</td>
<td>7.0 V</td>
<td></td>
</tr>
<tr>
<td>$V_{DS}$</td>
<td>Drain-Source Voltage</td>
<td>600 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_D$</td>
<td>Continuous Drain Current</td>
<td>$T_C=25^\circ\text{C}$</td>
<td>1.0 A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_C=100^\circ\text{C}$</td>
<td>0.6 A</td>
<td></td>
</tr>
<tr>
<td>$I_{DM}$</td>
<td>Pulsed Drain Current</td>
<td>4 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_{AS}$</td>
<td>Single Pulse Avalanche Energy</td>
<td>33 mJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{AR}$</td>
<td>Avalanche Current</td>
<td>1 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_D$</td>
<td>Power Dissipation ($T_A&lt;50^\circ\text{C}$)</td>
<td>660 mW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Theta_{JA}$</td>
<td>Thermal Resistance (Junction-to-Air)</td>
<td>153 °C/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Theta_{JC}$</td>
<td>Thermal Resistance (Junction-to-Case)</td>
<td>39 °C/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_J$</td>
<td>Operating Junction Temperature</td>
<td>-40 °C</td>
<td>+150 °C</td>
<td></td>
</tr>
<tr>
<td>$T_{STG}$</td>
<td>Storage Temperature Range</td>
<td>-55 °C</td>
<td>+150 °C</td>
<td></td>
</tr>
<tr>
<td>$T_L$</td>
<td>Lead Temperature (Wave Soldering or IR, 10 Seconds)</td>
<td>+260 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic Discharge Capability</td>
<td>Human Body Model, JEDEC: JESD22-A114</td>
<td>2 kV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Charged Device Model, JEDEC: JESD22-C101</td>
<td>2 kV</td>
<td></td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_A$</td>
<td>Operating Ambient Temperature</td>
<td>-40 °C</td>
<td>+125 °C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Electrical Characteristics

*V_{DD}=15V and T_α=-40°C~+125°C (T_A=T_J), unless otherwise specified.*

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>V_{DD} Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{OP}</td>
<td>Continuously-Operating Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{DD-ON}</td>
<td>Turn-On Threshold Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{DD-OFF}</td>
<td>Turn-Off Threshold Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{DD-ST}</td>
<td>Startup Current</td>
<td>V_{DD}=20 V, f_s=f_{OSC} V_{VS}=2 V, V_{CS}=3 V C_L=1 nF</td>
<td>3.7</td>
<td>10.0</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>I_{DD-OP}</td>
<td>Operating Current</td>
<td>V_{DD}=20 V, V_{VS}=2.7 V C_L=1 nF, V_{COMV}=0 V f_s=f_{OSC-N-MIN}, V_{CS}=0 V</td>
<td>3.5</td>
<td>5.0</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>I_{DD-GREEN}</td>
<td>Green Mode Operating Supply Current</td>
<td>V_{CS}=3 V, V_{VS}=2.3 V</td>
<td>1.0</td>
<td>2.5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>V_{DD-OVP}</td>
<td>V_{DD} OVP Level</td>
<td></td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>V</td>
</tr>
<tr>
<td>t_{VDD-OVP}</td>
<td>V_{DD} OVP Debounce Time</td>
<td>f_s=f_{OSC}, V_{VS}=2.3 V</td>
<td>100</td>
<td>250</td>
<td>400</td>
<td>μs</td>
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<tr>
<td><strong>Oscillator Section</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f_{OSC}</td>
<td>Frequency</td>
<td>T_A=25°C</td>
<td></td>
<td></td>
<td>40</td>
<td>43</td>
</tr>
<tr>
<td>f_{FHR}</td>
<td>Center Frequency</td>
<td>T_A=25°C</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>f_{OSC-N-MIN}</td>
<td>Minimum Frequency at No-Load</td>
<td>V_{VS}=2.7 V, V_{COMV}=0 V</td>
<td>550</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>f_{OSC-CM-MIN}</td>
<td>Minimum Frequency at CCM</td>
<td>V_{VS}=2.3 V, V_{CS}=0.5 V</td>
<td>20</td>
<td></td>
<td></td>
<td>kHz</td>
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<tr>
<td>f_{DV}</td>
<td>Frequency Variation vs. V_{DD} Deviation</td>
<td>T_A=25°C, V_{DD}=10 V to 25 V</td>
<td>5</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>f_{DT}</td>
<td>Frequency Variation vs. Temperature Deviation</td>
<td>T_A=-40°C to +125°C</td>
<td>20</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td><strong>Voltage-Sense Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{VS-UVP}</td>
<td>Sink Current for Brownout Protection</td>
<td>R_{VS}=20 kΩ</td>
<td></td>
<td></td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>I_{IC}</td>
<td>IC Compensation Bias Current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
</tr>
<tr>
<td>V_{BIAS-COMV}</td>
<td>Adaptive Bias Voltage Dominated by V_{COMV}</td>
<td>V_{COMV}=0 V, T_{A}=25°C, R_{VS}=20 kΩ</td>
<td></td>
<td></td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Current-Sense Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t_{PD}</td>
<td>Propagation Delay to Gate Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t_{MIN-N}</td>
<td>Minimum On Time at No-Load</td>
<td>V_{VS}=-0.8 V, R_{CS}=2 kΩ V_{COMV}=1 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t_{MINCC}</td>
<td>Minimum On Time in CC Mode</td>
<td>V_{VS}=0 V, V_{COMV}=2 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>V_{TH}</td>
<td>Threshold Voltage for Current Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Current-Error-Amplifier Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{IR}</td>
<td>Reference Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{SINK}</td>
<td>Output Sink Current</td>
<td>V_{CS}=3 V, V_{COM}=2.5 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{SOURCE}</td>
<td>Output Source Current</td>
<td>V_{CS}=0 V, V_{COM}=2.5 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{HIGH}</td>
<td>Output High Voltage</td>
<td>V_{CS}=0 V</td>
<td>4.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

*Continued on the following page…*
### Electrical Characteristics (Continued)

$V_{DD}=15$ V and $T_A=-40^\circ$C to $125^\circ$C ($T_A=T_J$), unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Voltage-Error-Amplifier Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{VR}$</td>
<td>Reference Voltage</td>
<td></td>
<td>2.475</td>
<td>2.500</td>
<td>2.525</td>
<td>V</td>
</tr>
<tr>
<td>$V_N$</td>
<td>Green-Mode Starting Voltage on COMV Pin</td>
<td>$f_S=f_{OSC}=2$ KHz, $V_{VS}=2.3$ V</td>
<td>2.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_G$</td>
<td>Green-Mode Ending Voltage on COMV Pin</td>
<td>$f_S=1$ KHz, $V_{VS}=2.3$ V</td>
<td>0.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{VSINK}$</td>
<td>Output Sink Current</td>
<td>$V_{VS}=3$ V, $V_{COMV}=2.5$ V</td>
<td>90</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{VSOURCE}$</td>
<td>Output Source Current</td>
<td>$V_{VS}=2$ V, $V_{COMV}=2.5$ V</td>
<td>90</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$V_{V-HIGH}$</td>
<td>Output High Voltage</td>
<td>$V_{VS}=2.3$ V</td>
<td>4.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

| **Internal MOSFET Section** | | | | | | |
| $DCY_{MAX}$ | Maximum Duty Cycle | | 75 | | | % |
| $BV_{DSS}$ | Drain-Source Breakdown Voltage | $I_D=250$ μA, $V_{GS}=0$ V | 600 | | | V |
| $\Delta BV_{DSS}/\Delta T_J$ | Breakdown Voltage Temperature Coefficient | $I_D=250$ μA, Referenced to 25°C | 0.6 | | | V/°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 | $I_D=0.5$ A, $V_{GS}=10$ V | 9.3 | 11.5 | | Ω |
| $I_{DSS}$ | Drain-Source Leakage Current | $V_D=600$ V, $V_{GS}=0$ V, $T_C=25^\circ$C | 1 | | | μA |
| | | $V_D=480$ V, $V_{GS}=0$ V, $T_C=100^\circ$C | 10 | | | μA |
| $t_{D-ON}$ | Turn-On Delay Time$^{(3,4)}$ | $V_D=300$ V, $I_D=1.1$ A, $R_G=25$ Ω | 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 | $V_{GS}=0$ V, $f_S=1$ MHz | 130 | 170 | | pF |
| $C_{OSS}$ | Output Capacitance | | 19 | 25 | | pF |

### Over-Temperature-Protection Section

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{OTP}$</td>
<td>Threshold Temperature for OTP</td>
<td></td>
<td>140</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

**Notes:**

3. Pulse Test: pulse width $\leq 300$μs; duty cycle $\leq 2\%$.
4. Essentially independent of operating temperature.
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 (Continued)

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 (Continued)

Figure 18. Output Sink Current (IV-SINK) vs. Temperature

Figure 19. Output Source Current (IV-SOURCE) vs. Temperature

Figure 20. Output Sink Current (I\textsubscript{SINK}) vs. Temperature

Figure 21. Output Source Current (I\textsubscript{SOURCE}) vs. Temperature

Figure 22. Drain-Source Breakdown Voltage (BV\textsubscript{DSS}) vs. Temperature

Figure 23. Maximum Duty Cycle (DCY\textsubscript{MAX}) vs. Temperature
Functional Description

Figure 24 shows the basic circuit diagram of a primary-side regulated flyback converter, with typical waveforms shown in Figure 25. Generally, discontinuous conduction mode (DCM) operation is preferred for primary-side regulation because 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 turn on. While the diode is conducting, the output voltage ($V_O$), together with diode forward-voltage drop ($V_F$), are applied across the secondary-side inductor ($L_m \times N_p^2 / N_s^2$) 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 $(V_O + V_F) \times N_A / N_S$. 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. 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 the average of the diode current in steady state.

The output current estimator detects the peak value of the drain current by a peak detection circuit and calculates the output current by 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.
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 FSEZ1016A uses voltage regulation error amplifier output (V_{COMV}) as an indicator of the output load and modulates the PWM frequency, as shown in Figure 26, such that the switching frequency decreases as load decreases. In heavy-load conditions, the switching frequency is fixed at 43 kHz. Once V_{COMV} decreases below 2.8 V, the PWM frequency starts to linearly decrease from 43 kHz to 550 Hz to reduce the switching losses. As V_{COMV} decreases below 0.8 V, the switching frequency is fixed at 550 Hz and FSEZ1016A enters “deep green” mode, where the operating current drops to 1 mA, reducing the standby power consumption.

startup
Figure 28 shows the typical startup circuit and transformer auxiliary winding for a FSEZ1016A application. Before FSEZ1016A begins switching, it consumes only startup current (typically 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-ON}), FSEZ1016A begins switching, and the current consumed increases to 3.5 mA. Then, the power required for FSEZ1016A is supplied from the transformer auxiliary winding. The large hysteresis of V_{DD} provides more hold-up time, which allows using a small capacitor for V_{DD}.

Leading-Edge Blanking (LEB)
At the instant the MOSFET is turned on, there is a high-current spike 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. FSEZ1016A employs an internal leading-edge blanking (LEB) circuit to inhibit the PWM comparator for a short time after the MOSFET is turned 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. FSEZ1016A has an internal frequency-hopping circuit that changes the switching frequency between 40.4 kHz and 45.6 kHz with a period of 3 ms, as shown in Figure 27.

Green Mode Normal Mode Deep Green Mode

43kHz
550Hz
0.8V 2.8V

Figure 26. Switching Frequency in Green Mode

Figure 27. Frequency Hopping

Figure 28. Startup Circuit
The FSEZ1016A 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 the auto-restart protection is triggered, switching is terminated and the MOSFET remains off. This causes VDD to fall. When VDD reaches the VDD turn-off voltage of 5 V, the current consumed by FSEZ1016A reduces to the startup current (maximum 10 µA) and the current supplied startup resistor charges the VDD capacitor. When VDD reaches the turn-on voltage of 16 V, FSEZ1016A 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 29).

VDD Over-Voltage Protection (OVP)
VDD over-voltage protection prevents damage from over-voltage conditions. If the VDD 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)
A built-in temperature-sensing circuit shuts down PWM output if the junction temperature exceeds 140°C.

Brownout Protection
FSEZ1016A detects the line voltage using auxiliary winding voltage since the auxiliary winding voltage reflects the input voltage when the MOSFET is turned on. The VS pin is clamped at 1.15 V while the MOSFET is turned on and brownout protection is triggered if the current out of the VS pin is less than I VS-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.

![Figure 29. Auto-Restart Operation](image)
Typical Application Circuit (Primary-Side Regulated Offline LED Driver)

<table>
<thead>
<tr>
<th>Application</th>
<th>Fairchild Devices</th>
<th>Input Voltage Range</th>
<th>Output</th>
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<td>Offline LED Driver</td>
<td>FSEZ1016A</td>
<td>90~265 V&lt;sub&gt;AC&lt;/sub&gt;</td>
<td>12 V/0.35 A (4.2 W)</td>
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Features

- High Efficiency (>74% at Full Load)
- Tight Output Regulation (CC:±5%)

Figure 30. Measured Efficiency and Output Regulation

Figure 31. Schematic of Typical Application Circuit
Typical Application Circuit (Continued)

Transformer Specification

- Core: EE16
- Bobbin: EE16

<table>
<thead>
<tr>
<th>Pin</th>
<th>Specifications</th>
<th>Remark</th>
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<tr>
<td>2–1</td>
<td>1.95 mH ± 8% 100 kHz, 1 V</td>
<td>100 kHz, 1 V</td>
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<tr>
<td>2–1</td>
<td>60 μH Maximum</td>
<td>Short one of the secondary windings</td>
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Physical Dimensions

Figure 33. 7-Lead, Small-Outline Integrated Circuit Package (SOIC)

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<th>Definition</th>
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