FAIRCHILD SEMICONDUCTOR®

November 2011

FL7732
Single-Stage PFC Primary-Side-Regulation Offline LED Driver

Features

- Cost-Effective Solution: No Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction
- Accurate Constant-Current (CC) Control, Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control Improves Efficiency and Simplifies Design
- Open-LED Protection
- Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20µA
- Low Operating Current: 5mA
- Frequency Hopping for Better EMI Performance
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package

Applications

- LED Lighting System

Description

This highly integrated PWM controller provides several features to enhance the performance of low-power flyback converters. The proprietary topology enables simplified circuit design for LED lighting applications.

By using single-stage topology with primary-side regulation, a LED lighting board can be implemented with few external components and minimized cost. No input bulk capacitor or feedback circuitry is required. To implement good power factor and low THD, constant on-time control is utilized with an external capacitor connected to the COMI pin.

Precise constant-current control regulates accurate output current versus changes in input voltage and output voltage. The operating frequency is proportionally adjusted by the output voltage to guarantee DCM operation with higher efficiency and simpler design.

FL7732 provides open-LED, short-LED, and over-temperature protection features. The current limit level is automatically reduced to minimize output current and protect external components in a short-LED condition.

FL7732 also has a frequency-hopping function in the oscillator for better EMI performance. The FL7732 controller is available in an 8-pin SOP package.

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FL7732M	-40°C to +125°C	8-Lead, Small Outline Integrated Circuit Package (SOIC)	Tape & Reel

Application Diagram

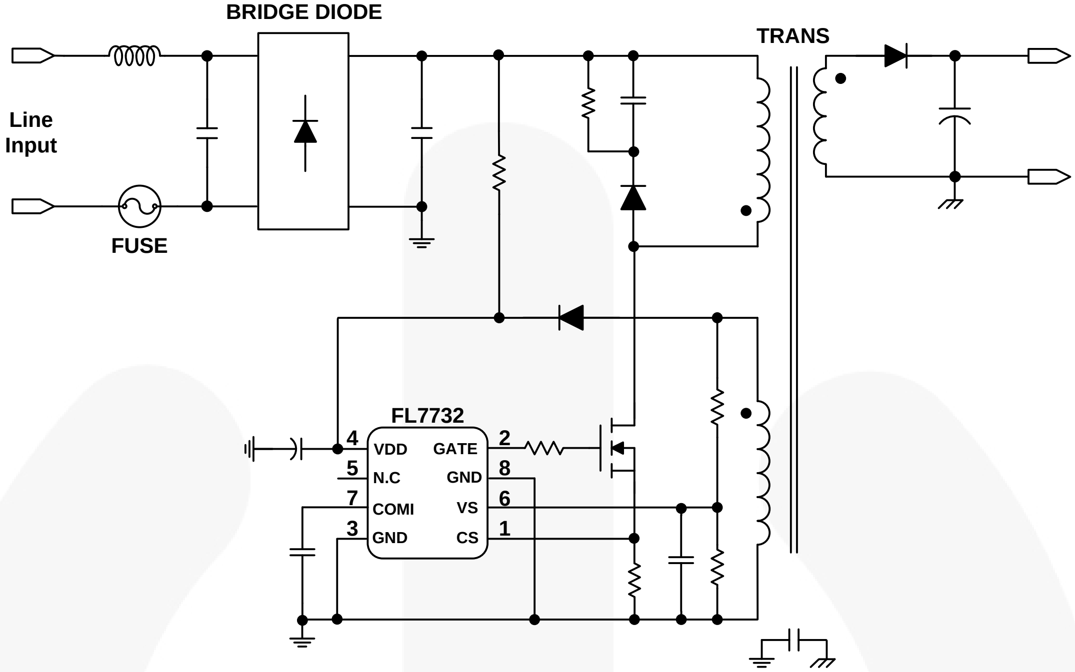


Figure 1. Typical Application

Internal Block Diagram

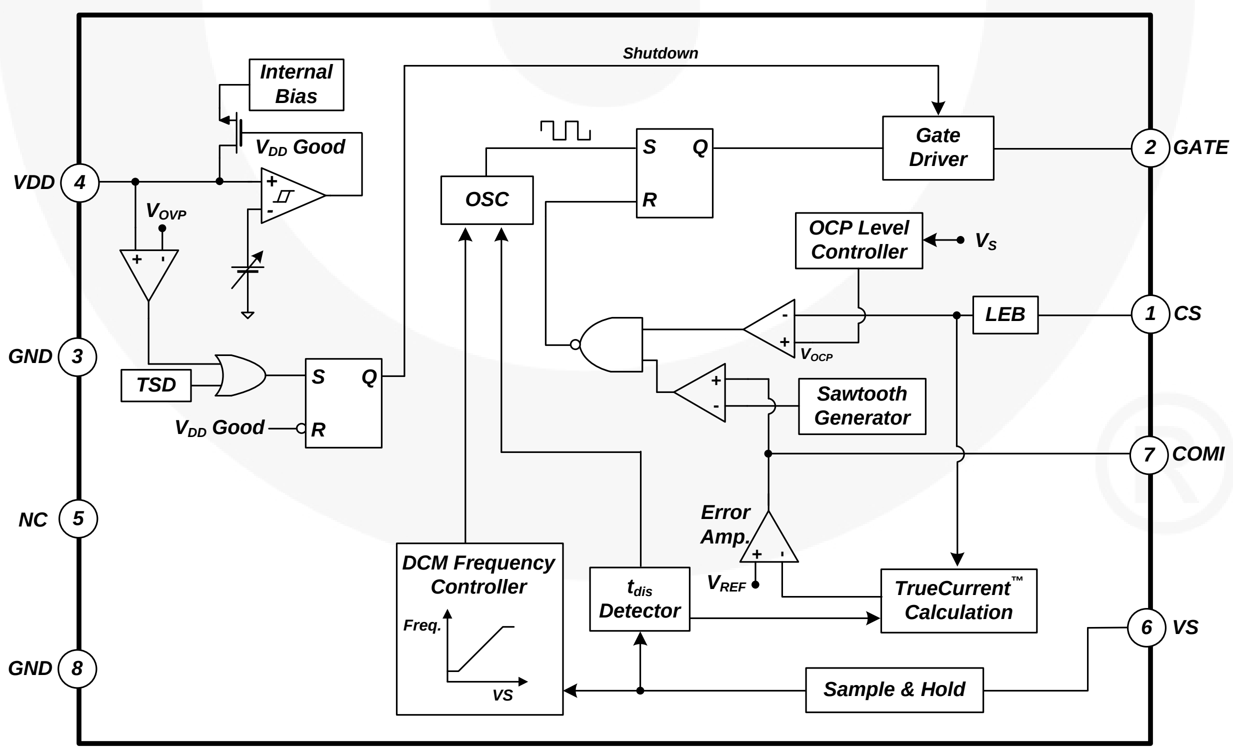
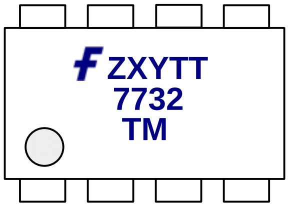


Figure 2. Functional Block Diagram

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)
M: Manufacture Flow Code

Figure 3. Top Mark

Pin Configuration

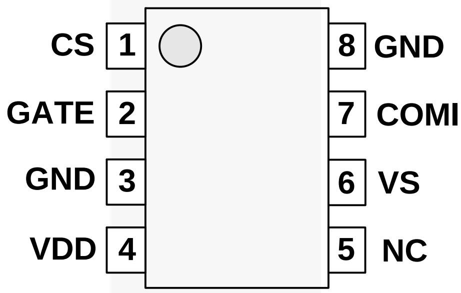


Figure 4. Pin Configuration

Pin Definitions

Pin #	Name	Description
1	CS	**Current Sense**. This pin connects a current-sense resistor to detect the MOSFET current for the output-current regulation in constant-current regulation.
2	GATE	**PWM Signal Output**. This pin uses the internal totem-pole output driver to drive the power MOSFET.
3	GND	Ground
4	VDD	**Power Supply**. IC operating current and MOSFET driving current are supplied using this pin.
5	N.C	No Connect
6	VS	**Voltage Sense**. This pin detects the output voltage information and discharge time for maximum frequency control and constant current regulation. This pin is connected to an auxiliary winding of the transformer via resistors of the divider.
7	COMI	**Constant Current Loop Compensation**. This pin is connected to a capacitor between the COMI and GND pin for compensation current loop gain.
8	GND	Ground

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_{VDD}	DC Supply Voltage[1,2]			30	V
V_{VS}	VS Pin Voltage		-0.3	7	V
V_{CS}	CS Pin Input Voltage		-0.3	7	V
V_{COMI}	COMI Pin Input Voltage		-0.3	7	V
V_{GATE}	GATE Pin Input Voltage		-0.3	30	V
P_D	Power Dissipation ($T_A < 50°C$)			633	mW
Θ_{JA}	Thermal Resistance (Junction to Air)			158	°C /W
Θ_{JC}	Thermal Resistance (Junction to Case)			39	°C /W
T_J	Maximum Junction Temperature			150	°C
T_{STG}	Storage Temperature Range		-55	150	°C
T_L	Lead Temperature (Soldering 10s)			260	°C
ESD	Electrostatic Discharge Capability	Charged Device Model, JESD22-C101		5	KV
		Human Body Model, JESD22-A114		2	KV

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 the GND pin.

Electrical Characteristics

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{DD} Section						
V_{DD-ON}	Turn-On Threshold Voltage		14.5	16.0	17.5	V
V_{DD-OFF}	Turn-Off Threshold Voltage		6.75	7.75	8.75	V
I_{DD-OP}	Operating Current	At Maximum Frequency C_L=1nF	3	4	5	mA
I_{DD-ST}	Startup Current	V_{DD}=V_{DD-ON} – 0.16V		2	20	μA
V_{OVP}	V_{DD} Over-Voltage-Protection Level		22.0	23.5	25.0	V
Gate Section						
V_{OL}	Output Voltage Low	V_{DD}=20V, I_{GATE}=-1mA			1.5	V
V_{OH}	Output Voltage High	V_{DD}=10V, I_{GATE}=+1mA	5			V
I_{source}	Peak Sourcing Current	V_{DD}=10 ~ 20V		60		mA
I_{sink}	Peak Sinking Current	V_{DD}=10 ~ 20V		180		mA
t_r	Rising Time	C_L=1nF	100	150	200	ns
t_f	Falling Time	C_L=1nF	20	60	100	ns
V_{CLAMP}	Output Clamp Voltage		12	15	18	V
Oscillator Section						
f_{MAX-CC}	Maximum Frequency in CC	V_{DD}=10V, 20V	60	65	70	kHz
f_{MIN-CC}	Minimum Frequency in CC	V_{DD}=10V, 20V	21.0	23.5	26.0	kHz
VS_{MAX-CC}	V_S for Maximum Frequency in CC	f=f_{MAX}-2kHz	2.25	2.35	2.45	V
VS_{MIN-CC}	V_S for Minimum Frequency in CC	f=f_{MIN} +2kHz	0.55	0.85	1.15	V
$f_{HOPPING}$	Frequency Hopping Range		±1.8	±2.9	±4.0	kHz
$t_{HOPPING}$	Frequency Hopping Period			2		ms
$t_{ON(MAX)}$	Maximum Turn-On Time		12	14	16	µs
Current-Sense Section						
V_{RV}	Reference Voltage		2.475	2.500	2.525	V
V_{CCR}	EAI Voltage for CC Regulation	V_{CS}=0.44V	2.38	2.43	2.48	V
t_{LEB}	Leading-Edge Blanking Time			300		ns
t_{MIN}	Minimum On Time in CC	V_{COMI}=0V		600		ns
t_{PD}	Propagation Delay to GATE		50	100	150	ns
$t_{DIS-BNK}$	t_{DIS} Blanking Time of VS			1.5		µs
I_{VS-BNK}	VS Current for VS Blanking			100		µA
Current-Error-Amplifier Section						
Gm	Transconductance			85		Mho
$I_{COMI-SINK}$	COMI Sink Current	V_{EAI}=3V, V_{COMI}=5V	25		38	µA
$I_{COMI-SOURCE}$	COMI Source Current	V_{EAI}=2V, V_{COMI}=0V	25		38	µA
$V_{COMI-HGH}$	COMI High Voltage	V_{EAI}=2V	4.9			V
$V_{COMI-LOW}$	COMI Low Voltage	V_{EAI}=3V			0.1	V

Continued on the following page…

Electrical Characteristics (Continued)

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Over-Current Protection Section						
V_{OCP}	V_{CS} Threshold Voltage for OCP		0.60	0.67	0.74	V
V_{LowOCP}	V_{CS} Threshold Voltage for Low OCP		0.13	0.18	0.23	V
$V_{LowOCP-EN}$	V_S Threshold Voltage to Enable Low OCP Level			0.4		V
$V_{LowOCP-DIS}$	V_S Threshold Voltage to Disable Low OCP Level			0.6		V
Over-Temperature Protection Section						
T_{OTP}	Threshold Temperature for OTP(3)		140	150	160	°C
$T_{OTP-HYS}$	Restart Junction Temperature Hysteresis			10		°C

Note:

3. If over-temperature protection is activated, the power system enters Auto-Recovery Mode and output is disabled. Device operation above the maximum junction temperature is NOT guaranteed. OTP is guaranteed by design.

Functional Description

FL7732 is AC-DC dimmable PWM controller for LED lighting applications. TRUECURRENT™ technique and internal line compensation regulate accurate LED current independent or input voltage, output voltage, and magnetizing inductance variations. The TRIAC dimming function block provides smooth brightness control compatible with a conventional TRIAC dimmer. The linear frequency control in the oscillator reduces conduction loss and maintains DCM operation in the wide range of output voltage, which implements high power factor correction in a single-stage flyback topology. A variety of protections, such as short/open-LED protection, over-temperature protection, and cycle-by-cycle current limitation stabilize system operation and protect external components.

Startup

Powering at startup is slow due to the low feedback loop bandwidth in PFC converter. To boost powering during startup, an internal oscillator counts 12ms to define Startup Mode. During Startup Mode, turn-on time is determined by Current-Mode control with a $0.2V_{CS}$ voltage limit and transconductance becomes 14 times larger, as shown in Figure 5. After startup, turn-on time is controlled by Voltage Mode using COMI voltage and error amplifier transconductance is reduced to 85Mho.

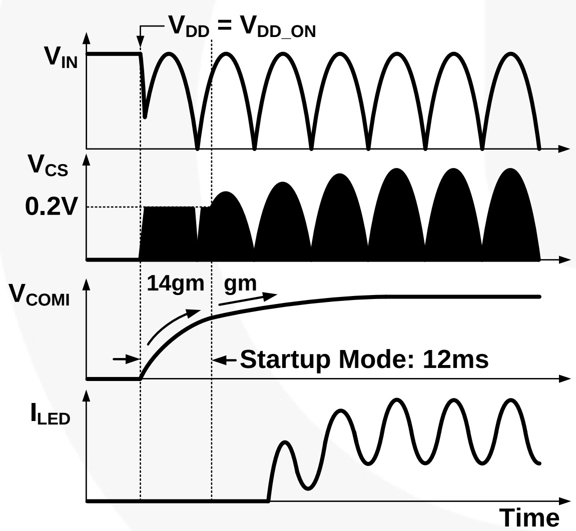


Figure 5. Startup Sequence

Constant-Current Regulation

The output current can be estimated using the peak drain current and inductor current discharge time since output current is same as the average of the diode current in steady state. The peak value of the drain current is determined by the CS pin and the inductor discharge time (t_{dis}) is sensed by t_{dis} detector. By using three points of information (peak drain current, inductor discharging time, and operating switching period); TRUECURRENT™ calculation block estimates output current. The output of the calculation is compared with an internal precise reference to generate an error voltage (V_{COMI}), which determines turn-on time in Voltage-Mode control. With Fairchild's innovative TRUECURRENT™ technique, constant-current output can be precisely controlled.

PFC and THD

In a conventional boost converter, Boundary Conduction Mode (BCM) is generally used to keep input current in-phase with input voltage for PF and THD. In flyback/buck boost topology, constant turn-on time and constant frequency in Discontinuous Conduction Mode (DCM) can implement high PF and low THD, as shown in Figure 6. Constant turn-on time is maintained by the internal error amplifier and a large external capacitor (typically over 1μF) at the COMI pin. Constant frequency and DCM operation are managed by linear frequency control.

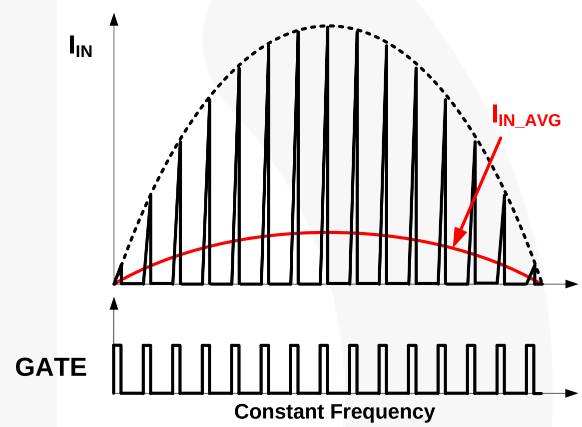


Figure 6. Input Current and Switching

Linear Frequency Control

As mentioned above, DCM should be guaranteed for high power factor in flyback topology. To maintain DCM across the wide range of output voltage, frequency is linearly adjusted by output voltage in linear frequency control. Output voltage is detected by the auxiliary winding and the resistive divider connected to the VS pin, as shown in Figure 7.

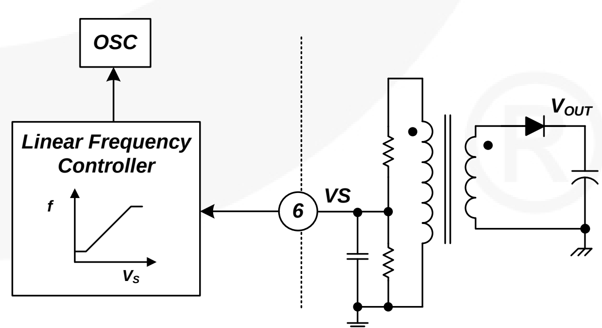


Figure 7. Linear Frequency Control

When output voltage decreases, secondary diode conduction time is increased and the linear frequency control lengthens the switching period, which retains DCM operation in the wide output voltage range, as shown in Figure 8. The frequency control lowers the primary rms current with better power efficiency in the full-load condition.

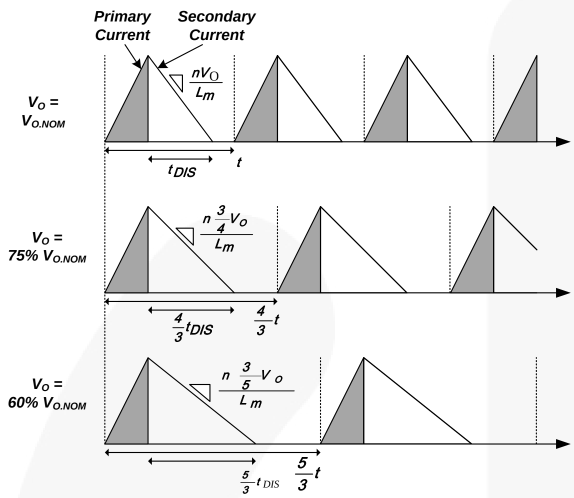


Figure 8. Primary and Secondary Current

BCM Control

The end of secondary diode conduction time is possibly over a switching period set by linear frequency control. In this case, FL7732 doesn't allow CCM and the operation mode changes from DCM to BCM. Therefore, FL7732 eliminates sub-harmonic distortion in CCM.

Short-LED Protection

In case of a short-LED condition, the switching MOSFET and secondary diode are stressed by the high powering current. However, FL7732 changes the OCP level in a short-LED condition. When V_S voltage is lower than 0.4V, OCP level becomes 0.2V from 0.7V, as shown in Figure 10, so powering is limited and external components current stress is reduced.

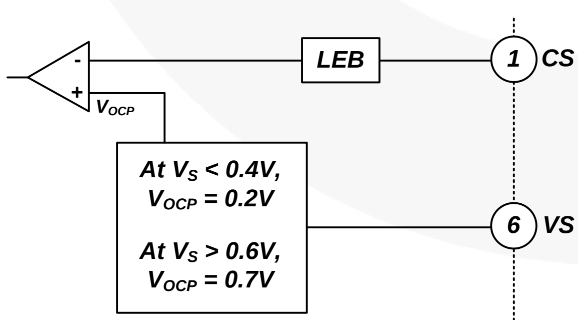


Figure 9. Internal OCP Block

Figure 10 shows operational waveforms in short-LED condition. Output voltage is quickly lowered to 0V right after a short-LED event. Then the reflected auxiliary voltage is also 0V, making V_S less than 0.4V. 0.2V OCP level limits primary-side current and V_{DD} hiccups up and down between UVLO hysteresis.

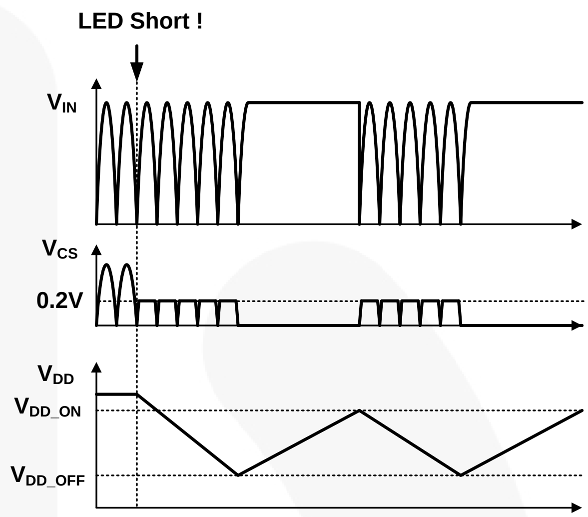


Figure 10. Waveforms in Short-LED Condition

Open-LED Protection

FL7732 protects external components, such as diode and capacitor, at secondary side in open-LED condition. During switch-off, the V_{DD} capacitor is charged up to the auxiliary winding voltage, which is applied as the reflected output voltage. Because the V_{DD} voltage has output voltage information, the internal voltage comparator on the VDD pin can trigger output Over-Voltage Protection (OVP), as shown in Figure 11. When at least one LED is open-circuited, output load impedance becomes very high and output capacitor is quickly charged up to V_{OVP} x N_S / N_A Then switching is shut down and the V_{DD} block goes into Hiccup Mode until the open-LED condition is removed, as shown in Figure 12.

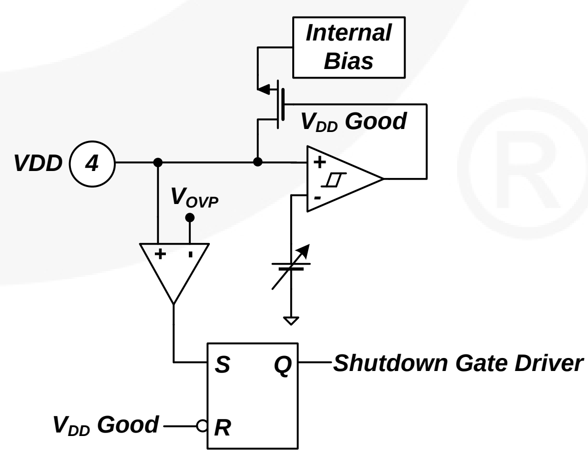


Figure 11. Internal OVP Block

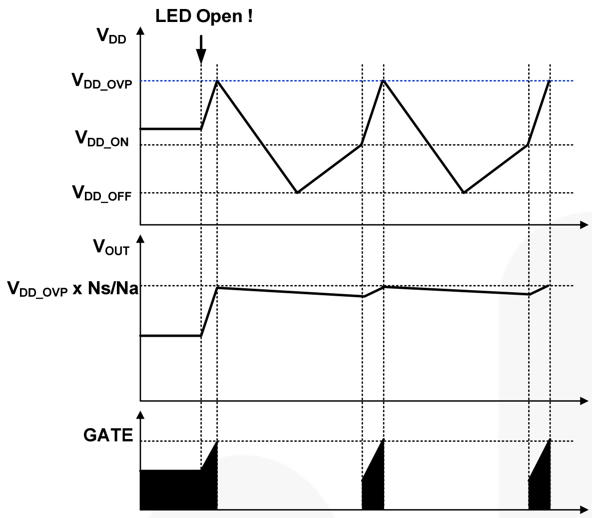


Figure 12. Waveforms in Open-LED Condition

Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds are fixed internally at 16V and7.5V, respectively. During startup, the V_{DD} capacitor must be charged to 16V through the startup resistor to enable the FL7732. The V_{DD} 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 7.5V during this startup process. This UVLO hysteresis window ensures that the V_{DD} capacitor is adequate to supply V_{DD} during startup.

Over-Temperature Protection (OTP)

The FL7732 has a built-in temperature-sensing circuit to shut down PWM output if the junction temperature exceeds 150°C. While PWM output is shut down, the V_{DD} voltage gradually drops to the UVLO voltage. Some of the FL7732's internal circuits are shut down and V_{DD} gradually starts increasing again. When V_{DD} reaches 16V, all the internal circuits start operating. If the junction temperature is still higher than 140°C, the PWM controller is shut down immediately.

Frequency Hopping

EMI reduction is accomplished by frequency hopping, which spreads the energy over a wider frequency range than the bandwidth measured by EMI test equipment. FL7732 has an internal frequency-hopping circuit that changes the switching frequency ±2.9kHz.

Typical Performance Characteristics

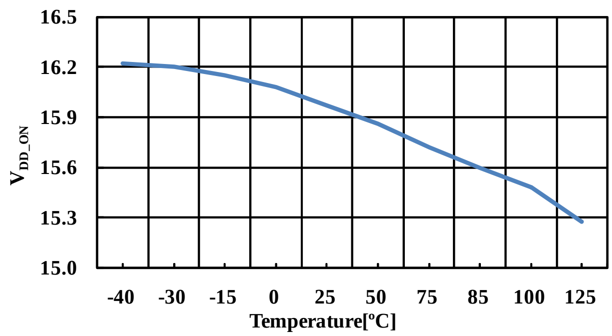


Figure 13. V_{DD-ON} vs. Temperature

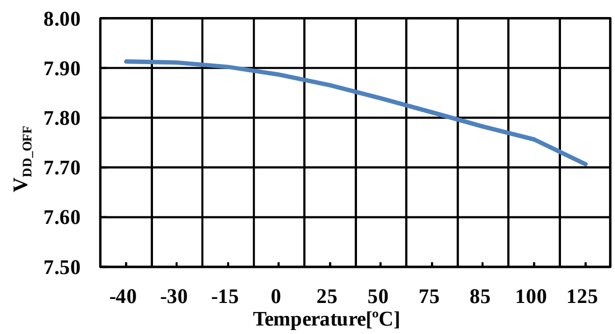


Figure 14. V_{DD-OFF} vs. Temperature

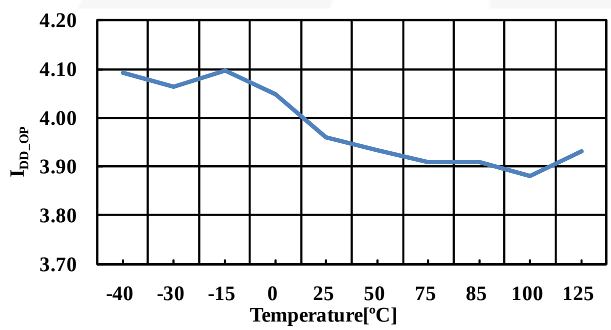


Figure 15. I_{DD-OP} vs. Temperature

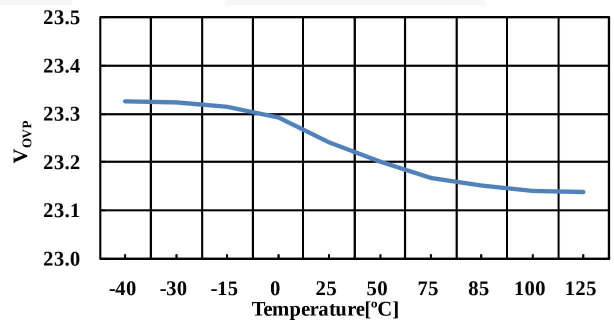


Figure 16. V_{OVP} vs. Temperature

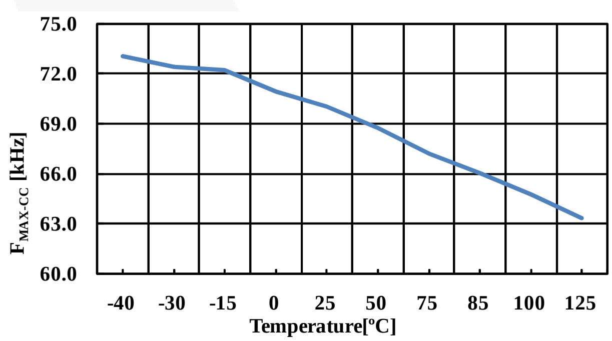


Figure 17. f_{MAX_CC} vs. Temperature

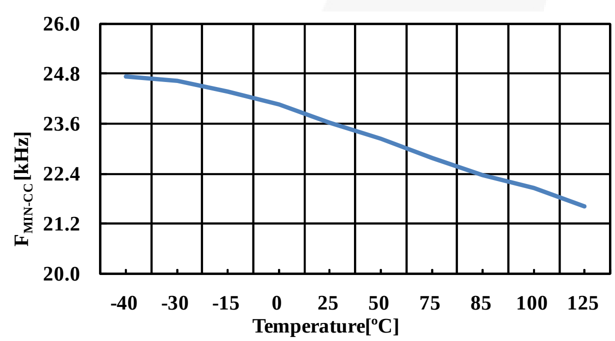


Figure 18. f_{MIN_CC} vs. Temperature

Typical Performance Characteristics (Continued)

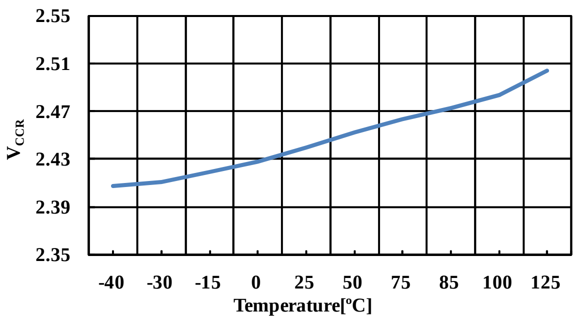


Figure 19. V_{CCR} vs. Temperature

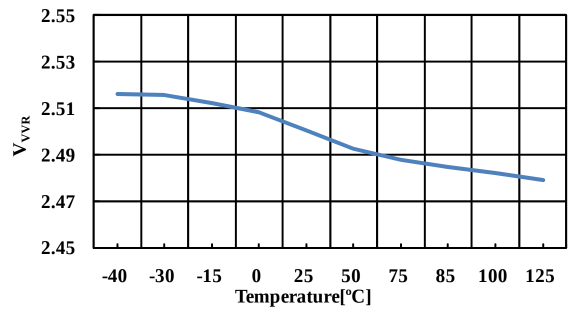


Figure 20. V_{VVR} vs. Temperature

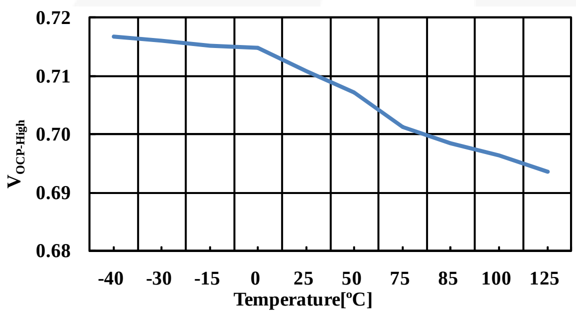


Figure 21. $V_{OCP-HIGH}$ vs. Temperature

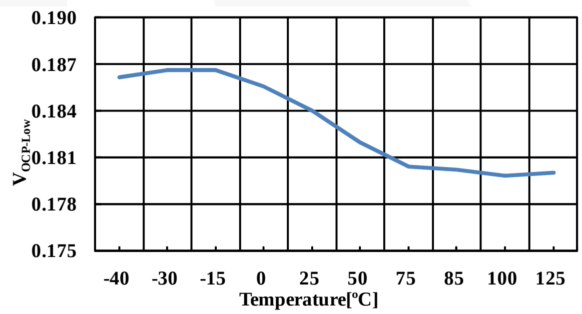


Figure 22. $V_{OCP-LOW}$ vs. Temperature

Physical Dimensions

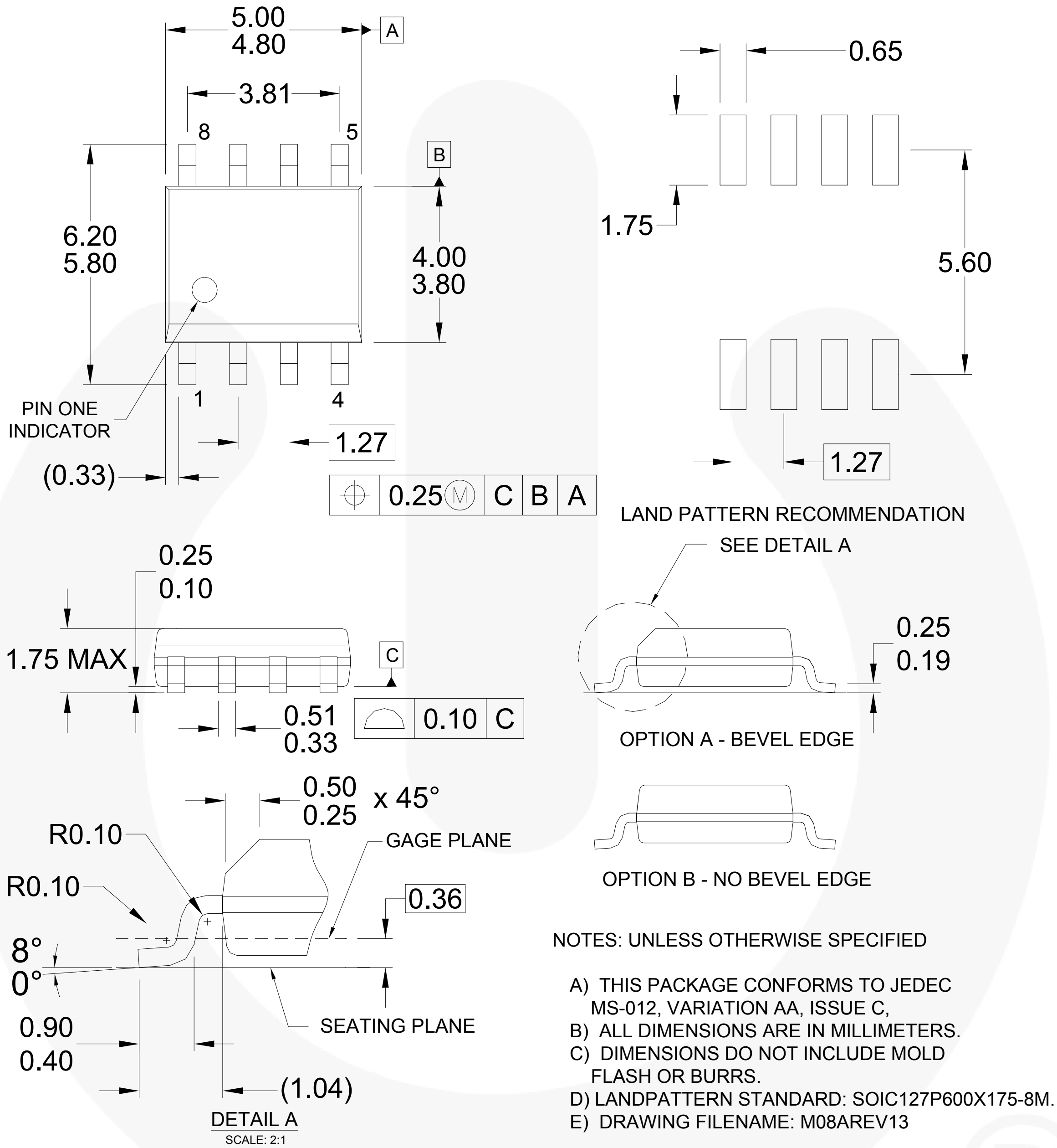


Figure 23. 8-Lead, Small Outline Integrated Circuit Package (SOIC)

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ANTI-COUNTERFEITING POLICY

Fairchild Semiconductor Corporation's Anti-Counterfeiting Policy. Fairchild's Anti-Counterfeiting Policy is also stated on our external website, www.fairchildsemi.com, under Sales Support.

Counterfeiting of semiconductor parts is a growing problem in the industry. All manufacturers of semiconductor products are experiencing counterfeiting of their parts. Customers who inadvertently purchase counterfeit parts experience many problems such as loss of brand reputation, substandard performance, failed applications, and increased cost of production and manufacturing delays. Fairchild is taking strong measures to protect ourselves and our customers from the proliferation of counterfeit parts. Fairchild strongly encourages customers to purchase Fairchild parts either directly from Fairchild or from Authorized Fairchild Distributors who are listed by country on our web page cited above. Products customers buy either from Fairchild directly or from Authorized Fairchild Distributors are genuine parts, have full traceability, meet Fairchild's quality standards for handling and storage and provide access to Fairchild's full range of up-to-date technical and product information. Fairchild and our Authorized Distributors will stand behind all warranties and will appropriately address any warranty issues that may arise. Fairchild will not provide any warranty coverage or other assistance for parts bought from Unauthorized Sources. Fairchild is committed to combat this global problem and encourage our customers to do their part in stopping this practice by buying direct or from authorized distributors.

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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