

May 2012

# 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
- V<sub>DD</sub> Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package
- Application Voltage Range: 80V<sub>AC</sub> ~ 308V<sub>AC</sub>

# 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, TRUECURRENT® 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 overtemperature protection features. The current limit level is automatically reduced to minimize output current and protect external components in a short-LED condition.

The FL7732 controller is available in an 8-pin Small-Outline Package (SOP).

# **Ordering Information**

Part Number	Operating Temperature Range	Package	Packing Method
FL7732M_F116	-40°C to +125°C	8-Lead, Small Outline Integrated Circuit Package (SOIC)	Tape & Reel

# **Application Diagram**

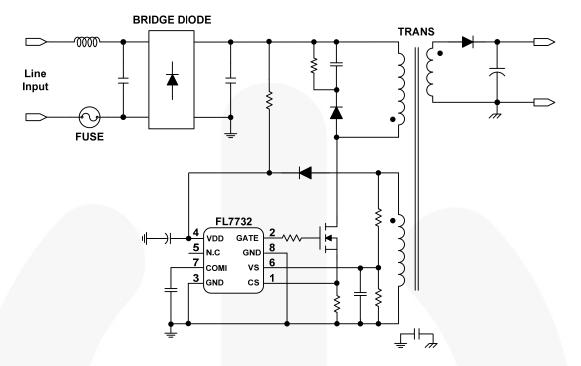


Figure 1. Typical Application

# **Internal Block Diagram**

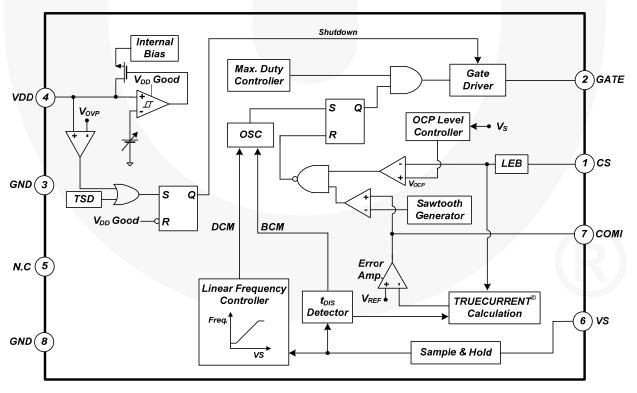
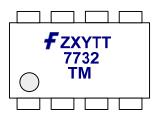


Figure 2. Functional Block Diagram

# **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**

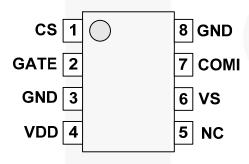


Figure 4. Pin Configuration

# **Pin Definitions**

Pin#	Name	Description		
1	CS	<b>Current Sense</b> . This pin connects a current-sense resistor to detect the MOSFET current for the output-current regulation in constant-current regulation.		
2	GATE	<b>PWM Signal Output</b> . 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	NC	No Connect		
6	VS	<b>Voltage Sense</b> . 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	<b>Constant Current Loop Compensation</b> . 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 <sup>(1,2)</sup>		30	V
V <sub>VS</sub>	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 <sub>A</sub> < 50°C)		633	mW
$\Theta_{JA}$	Thermal Resistance (Junction-to-Air)		158	°C /W
$\Theta_{\sf JC}$	Thermal Resistance (Junction-to-Case)		39	°C /W
TJ	Maximum Junction Temperature		150	°C
T <sub>STG</sub>	Storage Temperature Range	-55	150	°C
$T_L$	Lead Temperature (Soldering 10s)		260	°C

#### 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.	Тур.	Max.	Unit
V <sub>DD</sub> Section	•					
$V_{\text{DD-ON}}$	Turn-On Threshold Voltage		14.5	16.0	17.5	V
$V_{DD\text{-}OFF}$	Turn-Off Threshold Voltage		6.75	7.75	8.75	V
I <sub>DD-OP</sub>	Operating Current	At Maximum Frequency C <sub>L</sub> =1nF	3	4	5	mA
I <sub>DD-ST</sub>	Startup Current	V <sub>DD</sub> =V <sub>DD-ON</sub> - 0.16V		2	20	μA
$V_{OVP}$	V <sub>DD</sub> Over-Voltage-Protection Level		22.0	23.5	25.0	V
Gate Section	1					
$V_{OL}$	Output Voltage Low	V <sub>DD</sub> =20V, I <sub>GATE</sub> =-1mA			1.5	V
V <sub>OH</sub>	Output Voltage High	V <sub>DD</sub> =10V, I <sub>GATE</sub> =+1mA	5			V
I <sub>source</sub>	Peak Sourcing Current	V <sub>DD</sub> =10 ~ 20V		60		mA
I <sub>sink</sub>	Peak Sinking Current	V <sub>DD</sub> =10 ~ 20V		180		mA
t <sub>r</sub>	Rising Time	C <sub>L</sub> =1nF	100	150	200	ns
$t_f$	Falling Time	C <sub>L</sub> =1nF	20	60	100	ns
$V_{CLAMP}$	Output Clamp Voltage		12	15	18	V
Oscillator So	ection					
f <sub>MAX-CC</sub>	Maximum Frequency in CC	V <sub>DD</sub> =10V, 20V	60	65	70	kHz
f <sub>MIN-CC</sub>	Minimum Frequency in CC	V <sub>DD</sub> =10V, 20V	21.0	23.5	26.0	kHz
VS <sub>MAX-CC</sub>	V <sub>S</sub> for Maximum Frequency in CC	f=f <sub>MAX</sub> -2kHz	2.25	2.35	2.45	V
VS <sub>MIN-CC</sub>	V <sub>S</sub> for Minimum Frequency in CC	f=f <sub>MIN</sub> +2kHz	0.55	0.85	1.15	V
t <sub>ON(MAX)</sub>	Maximum Turn-On Time		12	14	16	μS
Current-Sen	se Section					
$V_{RV}$	Reference Voltage		2.475	2.500	2.525	V
V <sub>CCR</sub>	EAI Voltage for CC Regulation	V <sub>CS</sub> =0.44V	2.38	2.43	2.48	V
t <sub>LEB</sub>	Leading-Edge Blanking Time		7	300		ns
t <sub>MIN</sub>	Minimum On Time in CC	V <sub>COMI</sub> =0V	- //	600	9/	ns
t <sub>PD</sub>	Propagation Delay to GATE		50	100	150	ns
t <sub>DIS-BNK</sub>	t <sub>DIS</sub> Blanking Time of VS			1.5	3/1	μS
I <sub>VS-BNK</sub>	VS Current for VS Blanking			100		μА
Current-Erro	or-Amplifier Section	·				
Gm	Transconductance			85		μmho
I <sub>COMI-SINK</sub>	COMI Sink Current	V <sub>EAI</sub> =3V, V <sub>COMI</sub> =5V	25		38	μА
I <sub>COMI-SOURCE</sub>	COMI Source Current	V <sub>EAI</sub> =2V, V <sub>COMI</sub> =0V	25		38	μА
V <sub>COMI-HGH</sub>	COMI High Voltage	V <sub>EAI</sub> =2V	4.9			V
V <sub>COMI-LOW</sub>	COMI Low Voltage	V <sub>EAI</sub> =3V			0.1	V

Continued on the following page...

# **Electrical Characteristics** (Continued)

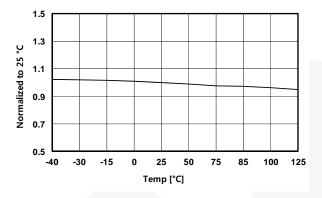
 $V_{DD}$ =15V and  $T_A$ =25°C, unless otherwise specified.

Symbol	Parameter	Condition	Min.	Тур.	Max.	Unit	
Over-Curren	Over-Current Protection Section						
V <sub>OCP</sub>	V <sub>CS</sub> Threshold Voltage for OCP		0.60	0.67	0.74	V	
V <sub>LowOCP</sub>	V <sub>CS</sub> Threshold Voltage for Low OCP		0.13	0.18	0.23	V	
V <sub>LowOCP-EN</sub>	V <sub>S</sub> Threshold Voltage to Enable Low OCP Level			0.4		٧	
V <sub>LowOCP-DIS</sub>	V <sub>S</sub> Threshold Voltage to Disable Low OCP Level			0.6		٧	
Over-Tempe	rature Protection Section						
T <sub>OTP</sub>	Threshold Temperature for OTP <sup>(3)</sup>		140	150	160	°C	
T <sub>OTP-HYS</sub>	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.

# **Typical Performance Characteristics**



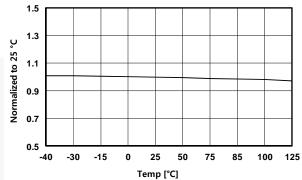
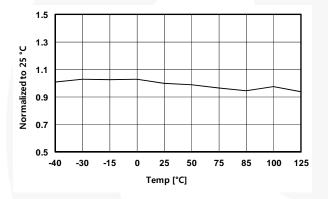


Figure 5.  $V_{DD-ON}$  vs. Temperature

Figure 6. **V<sub>DD-OFF</sub> vs. Temperature** 



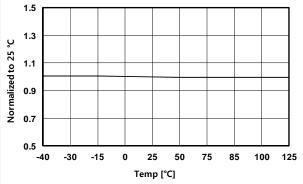
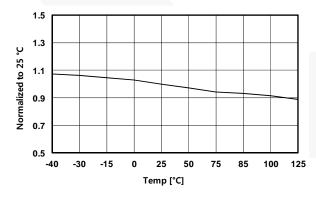


Figure 7. I<sub>DD-OP</sub> vs. Temperature

Figure 8. Vove vs. Temperature



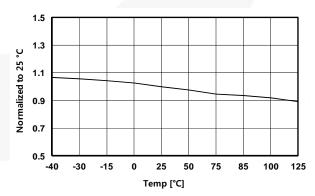
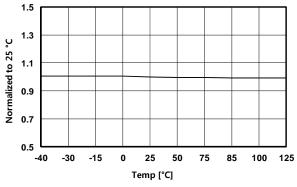
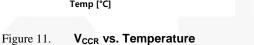


Figure 9. f<sub>MAX\_CC</sub> vs. Temperature

Figure 10. f<sub>MIN\_CC</sub> vs. Temperature

# **Typical Performance Characteristics** (Continued)





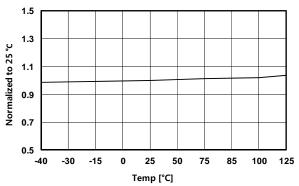


Figure 12. **V<sub>VVR</sub> vs. Temperature** 

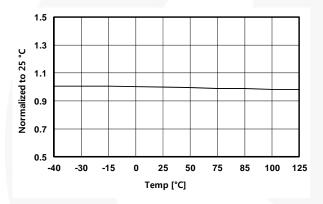


Figure 13. V<sub>OCP</sub> vs. Temperature

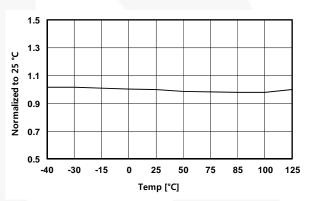


Figure 14. V<sub>OCP\_Low</sub> vs. Temperature

## **Functional Description**

FL7732 is AC-DC PWM controller for LED lighting applications. TRUECURRENT® techniques regulate accurate LED current independent or input voltage, output voltage, and magnetizing inductance variations. 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<sub>CS</sub> voltage limit and transconductance becomes 14 times larger, as shown in Figure 15. After startup, turn-on time is controlled by Voltage Mode using COMI voltage and error amplifier transconductance is reduced to 85µmho.

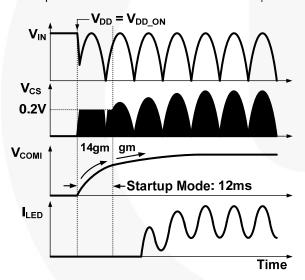


Figure 15. Startup Sequence

#### **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 ( $t_{\rm DIS}$ ) is sensed by  $t_{\rm DIS}$  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 ( $V_{\rm COMI}$ ), 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 inphase 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 16. 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.

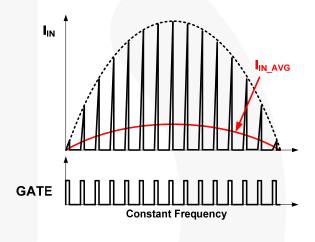


Figure 16. Input Current and Switching

#### **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 17.

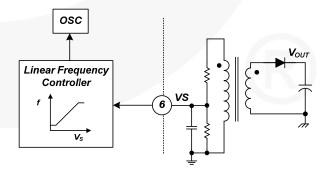


Figure 17. Linear Frequency Control

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 18. The frequency control lowers the primary rms current with better power efficiency in the full-load condition.

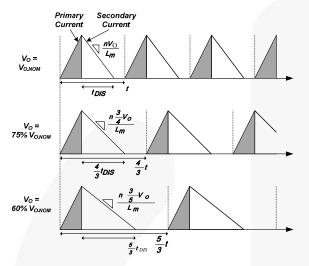


Figure 18. Primary and Secondary Current

#### **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  $V_{\rm S}$  voltage is lower than 0.4V, OCP level becomes 0.2V from 0.7V, as shown in Figure 19, so powering is limited and external components current stress is reduced.

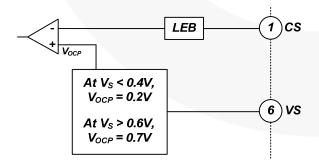


Figure 19. Internal OCP Block

Figure 20 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  $V_{\text{S}}$  less than 0.4V. 0.2V OCP level limits primary-side current and  $V_{\text{DD}}$  hiccups up and down between UVLO hysteresis.

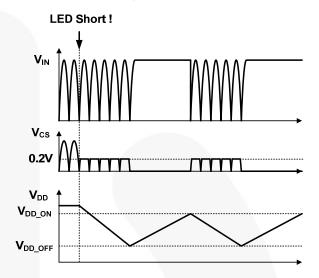


Figure 20. Waveforms in Short-LED Condition

#### **Open-LED Protection**

FL7732 protects external components, such as diode and capacitor, at secondary side in open-LED condition. During switch-off, the  $V_{\rm DD}$  capacitor is charged up to the auxiliary winding voltage, which is applied as the reflected output voltage. Because the  $V_{\rm DD}$  voltage has output voltage information, the internal voltage comparator on the VDD pin can trigger output Over-Voltage Protection (OVP), as shown in Figure 21. When at least one LED is open-circuited, output load impedance becomes very high and output capacitor is quickly charged up to  $V_{\rm OVP}$  x  $N_{\rm S}$  /  $N_{\rm A}$  Then switching is shut down and the  $V_{\rm DD}$  block goes into Hiccup Mode until the open-LED condition is removed, as shown in Figure 22.

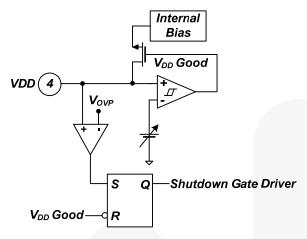


Figure 21. Internal OVP Block

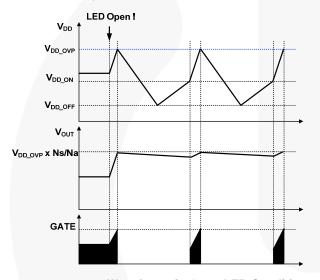


Figure 22. Waveforms in Open-LED Condition

# **Under-Voltage Lockout (UVLO)**

The turn-on and turn-off thresholds are fixed internally at 16V and 7.5V, 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 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.

#### 5.00 4.80 0.653.81 8 1.75 6.20 4.00 5.60 5.80 3.80 PIN ONE **INDICATOR** 1.27 1.27 (0.33)0.25(M)С В LAND PATTERN RECOMMENDATION SEE DETAIL A 0.25 0.10 0.25 С 1.75 MAX 0.19 0.51 0.33 0.10 OPTION A - BEVEL EDGE 0.50 0.25 x 45° R0.10 **GAGE PLANE** OPTION B - NO BEVEL EDGE R0.10 0.36 NOTES: UNLESS OTHERWISE SPECIFIED A) THIS PACKAGE CONFORMS TO JEDEC MS-012, VARIATION AA, ISSUE C, 0.90 SEATING PLANE B) ALL DIMENSIONS ARE IN MILLIMETERS. C) DIMENSIONS DO NOT INCLUDE MOLD 0.40 FLASH OR BURRS. (1.04)D) LANDPATTERN STANDARD: SOIC127P600X175-8M. **DETAIL A** E) DRAWING FILENAME: M08AREV13 SCALE: 2:1

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

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild's worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

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**Physical Dimensions** 



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