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May 2015

FL6632
Primary-Side-Regulated LED Driver with Power Factor Correction

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: 20 µA
- Low Operating Current: 5 mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8 Package
- Application Voltage Range: 80 V_{AC} ~ 308 V_{AC}

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.

FL6632 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.

The FL6632 controller is available in an 8-pin Small-Outline Package (SOP).

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FL6632MX	-40°C to +125°C	8-Lead, Small Outline Integrated Circuit Package (SOIC)	Tape & Reel

Application Diagram

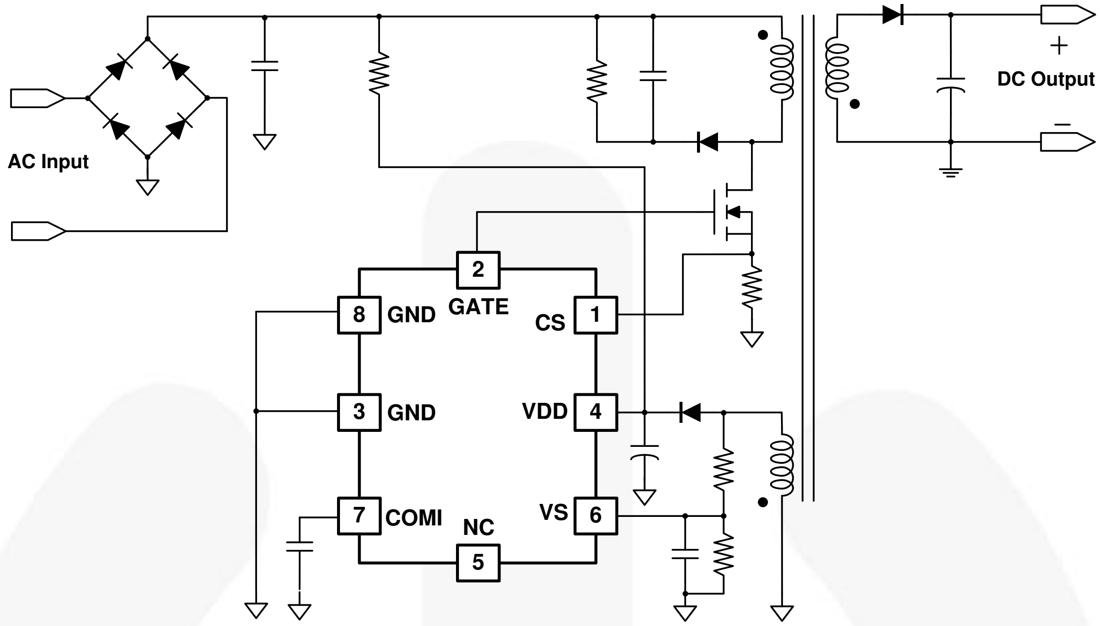


Figure 1. Typical Application

Block Diagram

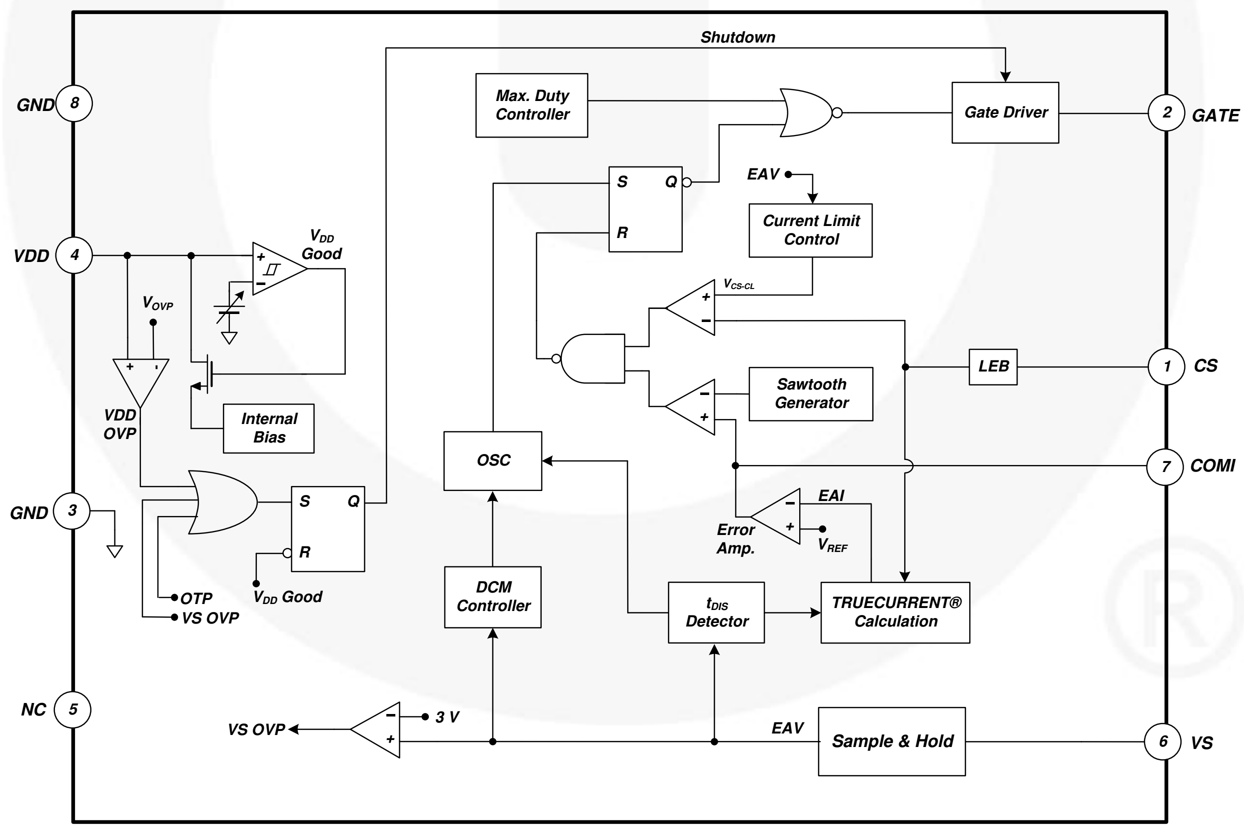
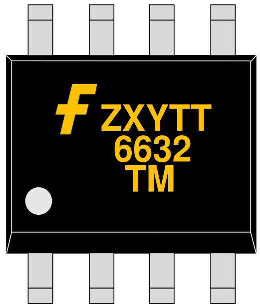


Figure 2. Functional Block Diagram

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

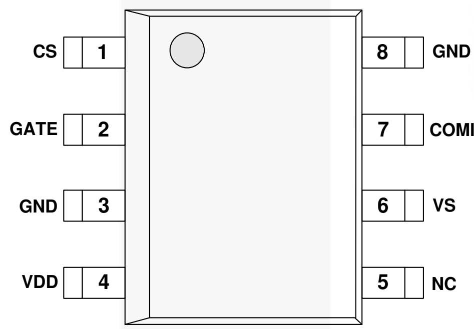


Figure 4. Pin Configuration (Top View)

Pin Descriptions

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	NC	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
T_J	Maximum Junction Temperature		150	°C
T_{STG}	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 GND pin.

Thermal Impedance

T_A=25°C, unless otherwise specified.

Symbol	Parameter	Value	Unit
θ_{JA}	Junction-to-Ambient Thermal Impedance	158	°C/W
θ_{JC}	Junction-to-Case Thermal Impedance	39	°C/W

Note:
3. Referenced the JEDEC recommended environment, JESD51-2, and test board, JESD51-3, 1S1P with minimum land pattern.

ESD Capability

Symbol	Parameter	Value	Unit
ESD	Human Body Model, ANSI/ESDA/JEDEC JS-001-2012	4	kV
	Charged Device Model, JESD22-C101	2	

Note:
4. Meets JEDEC standards JESD22-A114 and JESD 22-C101.

Electrical Characteristics

V_{DD}=15 V, T_J=-40 to +125°C, unless otherwise specified. Currents are defined as positive into the device and negative out of device.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
VDD 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=1 nF	3	4	5	mA
I_{DD-ST}	Startup Current	V_{DD}=V_{DD-ON} – 0.16 V		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}=20 V, I_{GATE}= -1 mA			1.5	V
V_{OH}	Output Voltage High	V_{DD}=10 V, I_{GATE}= +1 mA	5			V
I_{source}	Peak Sourcing Current	V_{DD}=10 ~ 20 V		60		mA
I_{sink}	Peak Sinking Current	V_{DD}=10 ~ 20 V		180		mA
t_r	Rising Time	C_L=1 nF	100	150	200	ns
t_f	Falling Time	C_L=1 nF	20	60	100	ns
V_{CLAMP}	Output Clamp Voltage		12	15	18	V
Oscillator SECTION						
f_{MAX-CC}	Maximum Frequency in CC	VDD=10 V, 20 V	60	65	70	kHz
f_{MIN-CC}	Minimum Frequency in CC	VDD=10 V, 20 V	21.0	23.5	26.0	kHz
$t_{ON(MAX)}$	Maximum Turn-On Time		12	14	16	µs
CURRENT-ERROR-AMPLIFIER SECTION						
V_{RV}	Reference Voltage		2.475	2.500	2.525	V
V_{CCR}	EAI Voltage for CC Regulation	V_{CS}=0.44 V	2.38	2.43	2.48	V
t_{LEB}	Leading-Edge Blanking Time			300		ns
t_{MIN}	Minimum On Time in CC	V_{COMI}=0 V		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		µmho
$I_{COMI-SINK}$	COMI Sink Current	V_{EAI}=3 V, V_{COMI}=5 V	25		38	µA
$I_{COMI-SOURCE}$	∣COMI Source Current∣	V_{EAI}=2 V, V_{COMI}=0 V	25		38	µA
$V_{COMI-HGH}$	COMI High Voltage	V_{EAI}=2 V	4.9			V
$V_{COMI-LOW}$	COMI Low Voltage	V_{EAI}=3 V			0.1	V

Electrical Characteristics (Continued)

V_{DD}=15 V, T_J=-40 to +125°C, unless otherwise specified. Currents are defined as positive into the device and negative out of device.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
VOLTAGE-SENSE SECTION						
V_{OCP}	V_{CS} Threshold Voltage for OCP		0.63	0.70	0.77	V
V_{LowOCP}	V_{CS} Threshold Voltage for Low OCP		0.15	0.20	0.25	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
V_{VS-OVP}	V_S Level for Output Over-Voltage Protection		2.9	3.0	3.1	V
OVER-TEMPERATURE-PROTECTION SECTION						
T_{OTP}	Threshold Temperature for OTP(5)		140	150	160	°C
$T_{OTP-HYS}$	Restart Junction Temperature Hysteresis			10		°C

Note:
5. The Ensured by design. Not tested in production.

Typical Performance Characteristics

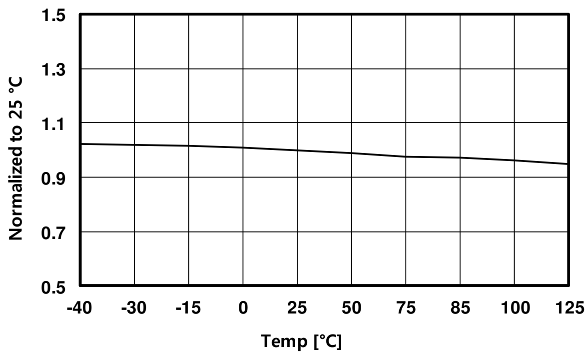


Figure 5. V_{DD-ON} **vs. Temperature**

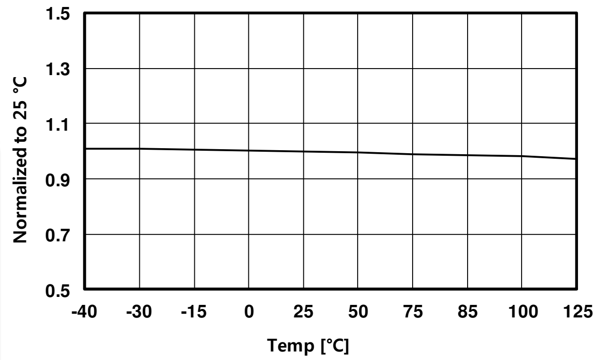


Figure 6. V_{DD-OFF} **vs. Temperature**

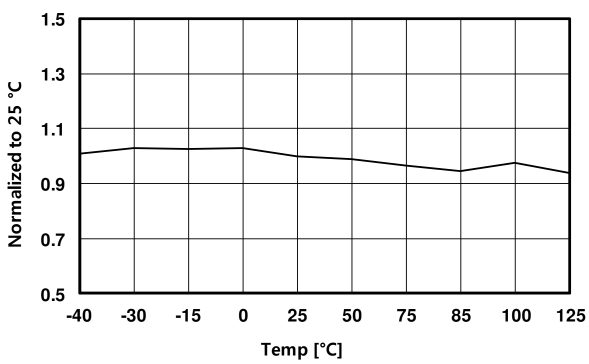


Figure 7. I_{DD-OP} **vs. Temperature**

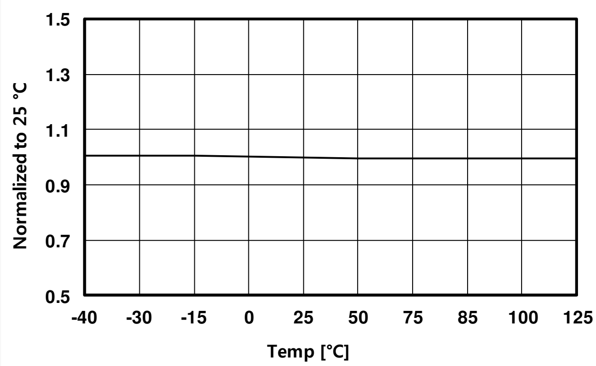


Figure 8. V_{OVP} **vs. Temperature**

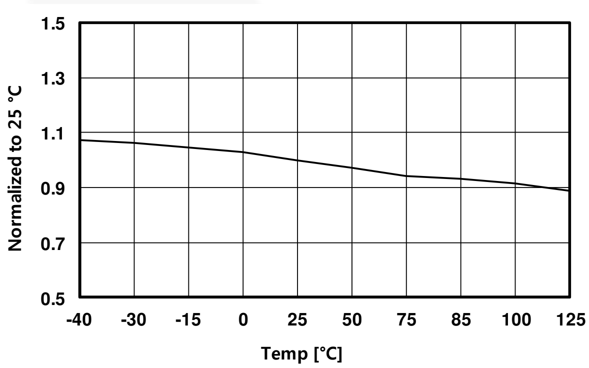


Figure 9. f_{MAX_CC} **vs. Temperature**

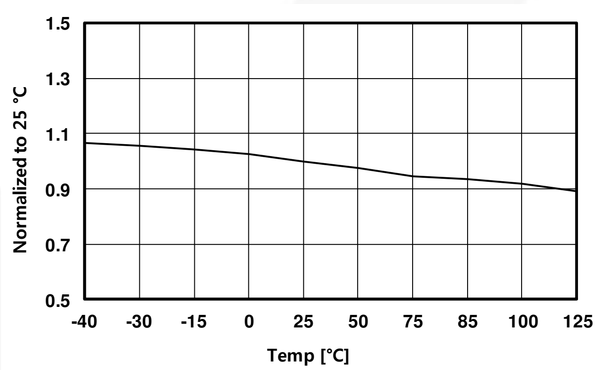


Figure 10. f_{MIN_CC} **vs. Temperature**

Typical Performance Characteristics (Continued)

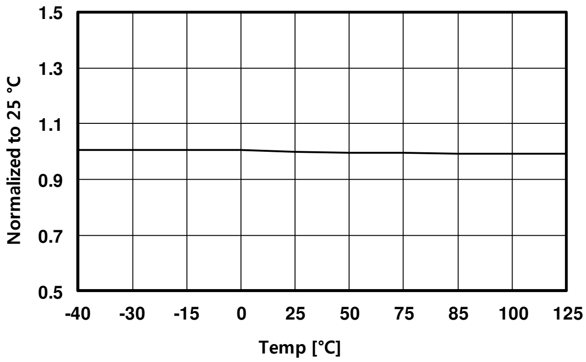


Figure 11. V_{CCR} vs. Temperature

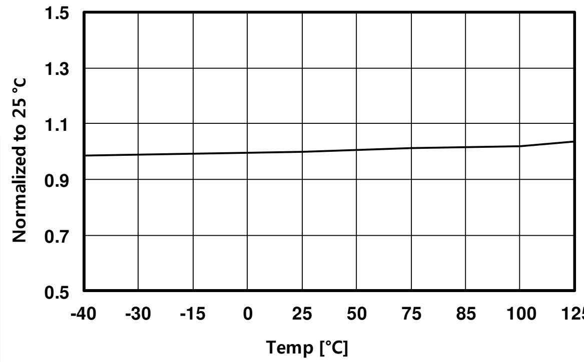


Figure 12. V_{VVR} vs. Temperature

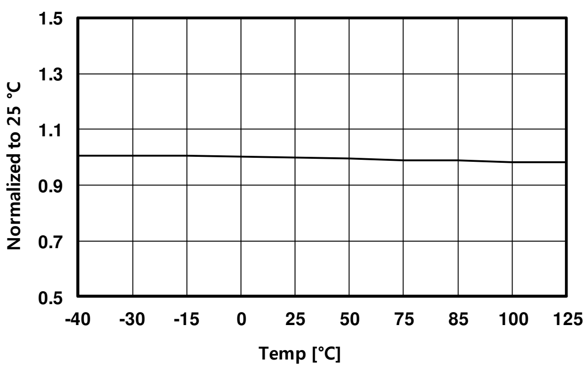


Figure 13. V_{OCP} vs. Temperature

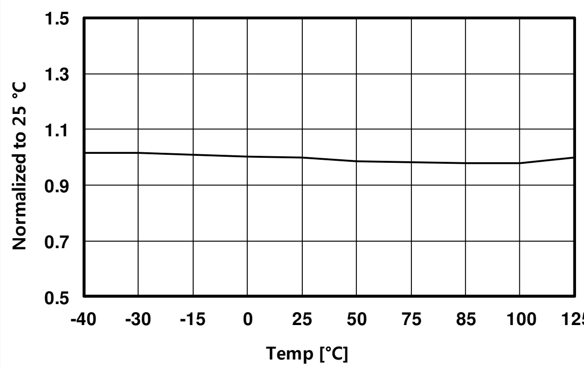


Figure 14. V_{OCP_Low} vs. Temperature

Functional Description

FL6632 is AC-DC PWM controller for LED lighting applications. TRUECURRENT™ techniques regulate accurate LED current independent of 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 0.2 V_{CS} 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 85 μmho.

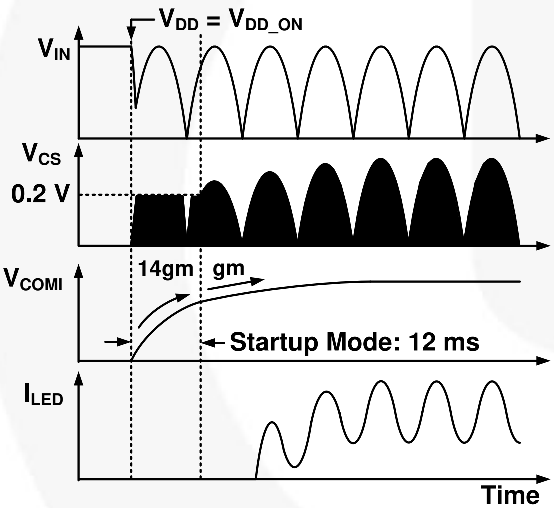


Figure 15. Startup Sequence

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_{dis}) is sensed by t_{dis} detector. By using three points of information (peak drain current, inductor discharging time, and operating switching period); the 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 16. Constant turn-on time is maintained by the internal error amplifier and a large external capacitor (typically over 1 μF) at the COMI pin. Constant frequency and DCM operation are managed by linear frequency control.

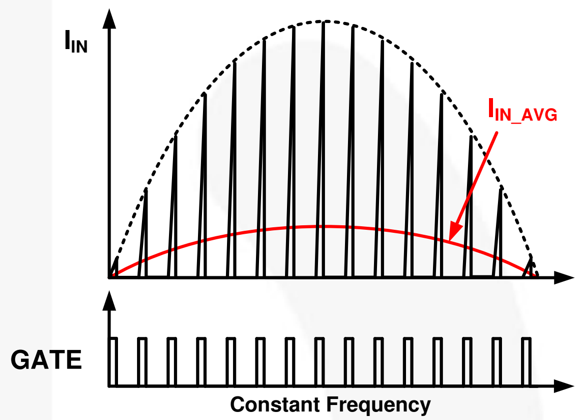


Figure 16. Input Current and Switching

DCM Control

As mentioned above, DCM should be guaranteed for high power factor in flyback topology. To maintain DCM across a wide range of output voltage, the switching frequency is linearly adjusted by the output voltage in linear frequency control in the whole Vs range. Output voltage is detected by the auxiliary winding and the resistive divider connected to the VS pin, as shown in Figure 17. When the output voltage decreases, secondary diode conduction time is increased and the DCM control lengthens the switching period, which retains DCM operation over the wide output voltage range, as shown in Figure 18. The frequency control lowers the primary rms current with better power efficiency in full-load condition.

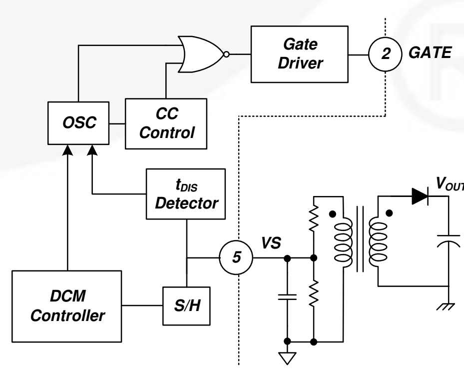


Figure 17. DCM and BCM Control

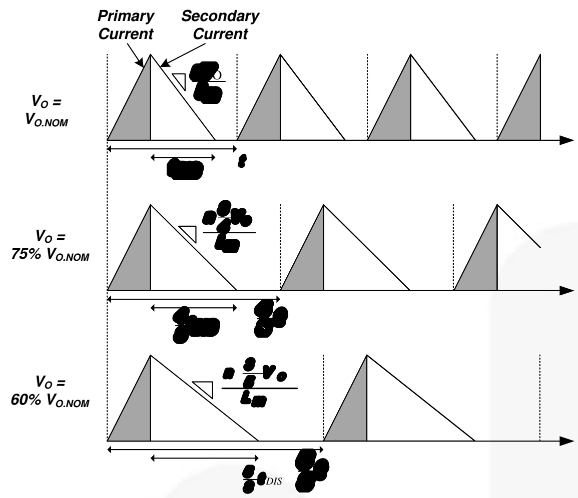


Figure 18. Primary and Secondary Current

BCM Control

The end of secondary diode conduction time could possibly be behind the end of a switching period set by DCM control. In this case, the next switching cycle starts at the end of secondary diode conduction time since FL6632 doesn't allow CCM. Consequently, the operation mode changes from DCM to Boundary Conduction Mode (BCM).

Short-LED Protection

In case of a short-LED condition, the switching MOSFET and secondary diode are stressed by the high powering current. However, FL6632 changes the OCP level in a short-LED condition. When V_S voltage is lower than 0.4 V, OCP level becomes 0.2 V from 0.7 V, as shown in Figure 19, so powering is limited and external components current stress is reduced.

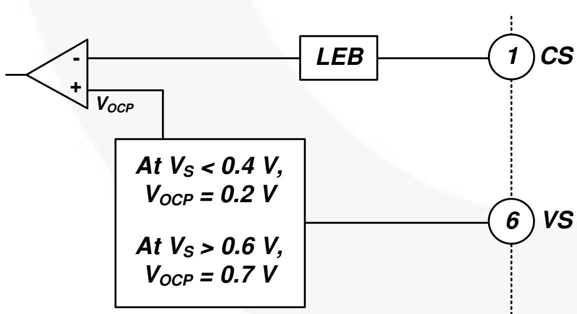


Figure 19. Internal OCP Block

Figure 20 shows operational waveforms in short-LED condition. Output voltage is quickly lowered to 0 V right after a short-LED event. Then the reflected auxiliary voltage is also 0 V, making V_S less than 0.4 V. 0.2 V OCP level limits primary-side current and V_{DD} hiccups up and down between UVLO hysteresis.

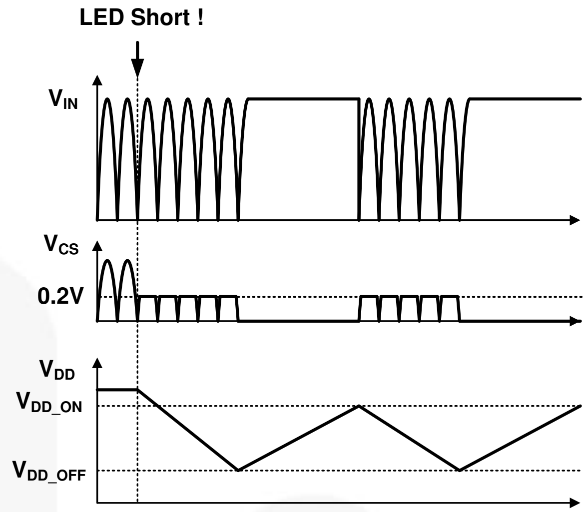


Figure 20. Waveforms in Short-LED Condition

Open-LED Protection

FL6632 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 21. 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 22.

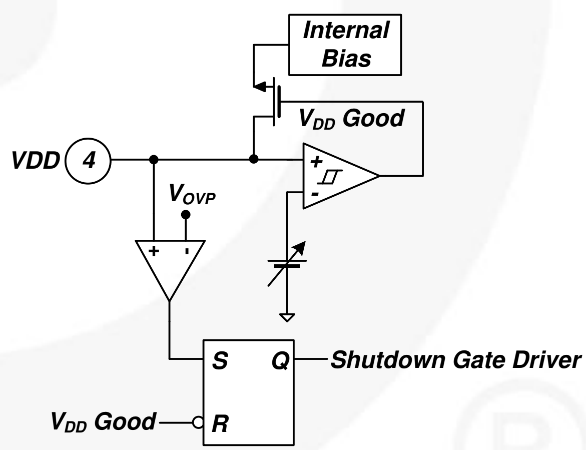


Figure 21. Internal OVP Block

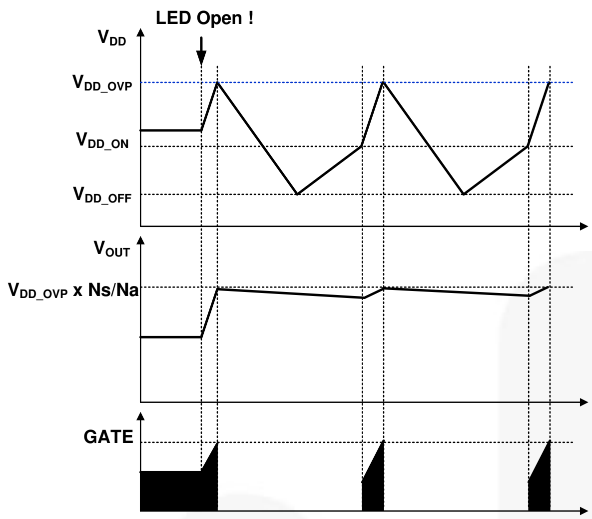


Figure 22. Waveforms in Open-LED Condition

Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds are fixed internally at 16 V and 7.5 V, respectively. During startup, the V_{DD} capacitor must be charged to 16 V through the startup resistor to enable the FL6632. 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 7.5 V 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 FL6632 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 16 V, all the internal circuits start operating. If the junction temperature is still higher than 140°C, the PWM controller is shut down immediately.

PCB Layout Guidance

PCB layout for a power converter is as important as circuit design because PCB layout with high parasitic inductance or resistance can lead to severe switching noise with system instability. PCB should be designed to minimize switching noise into control signals.

1. The signal ground and power ground should be separated and connected only at one position (GND pin) to avoid ground loop noise. The power ground path from the bridge diode to the sensing resistors should be short and wide.
2. Gate-driving current path (GATE – R_{GATE} – MOSFET – R_{CS} – GND) must be as short as possible.
3. Control pin components; such as C_{COMI}, C_{VS}, and R_{VS2}; should be placed close to the assigned pin and signal ground.
4. High-voltage traces related to the drain of MOSFET and RCD snubber should be kept far way from control circuits to avoid unnecessary interference.
5. If a heat sink is used for the MOSFET, connect this heat sink to power ground.
6. The auxiliary winding ground should be connected closer to the GND pin than the control pin components' ground.

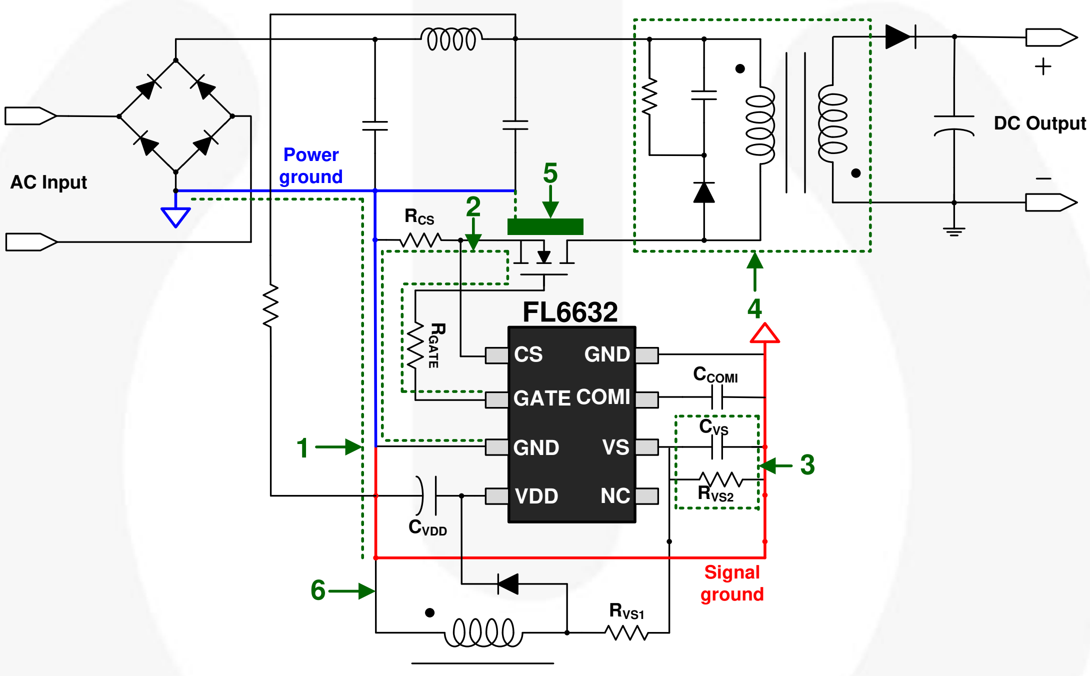
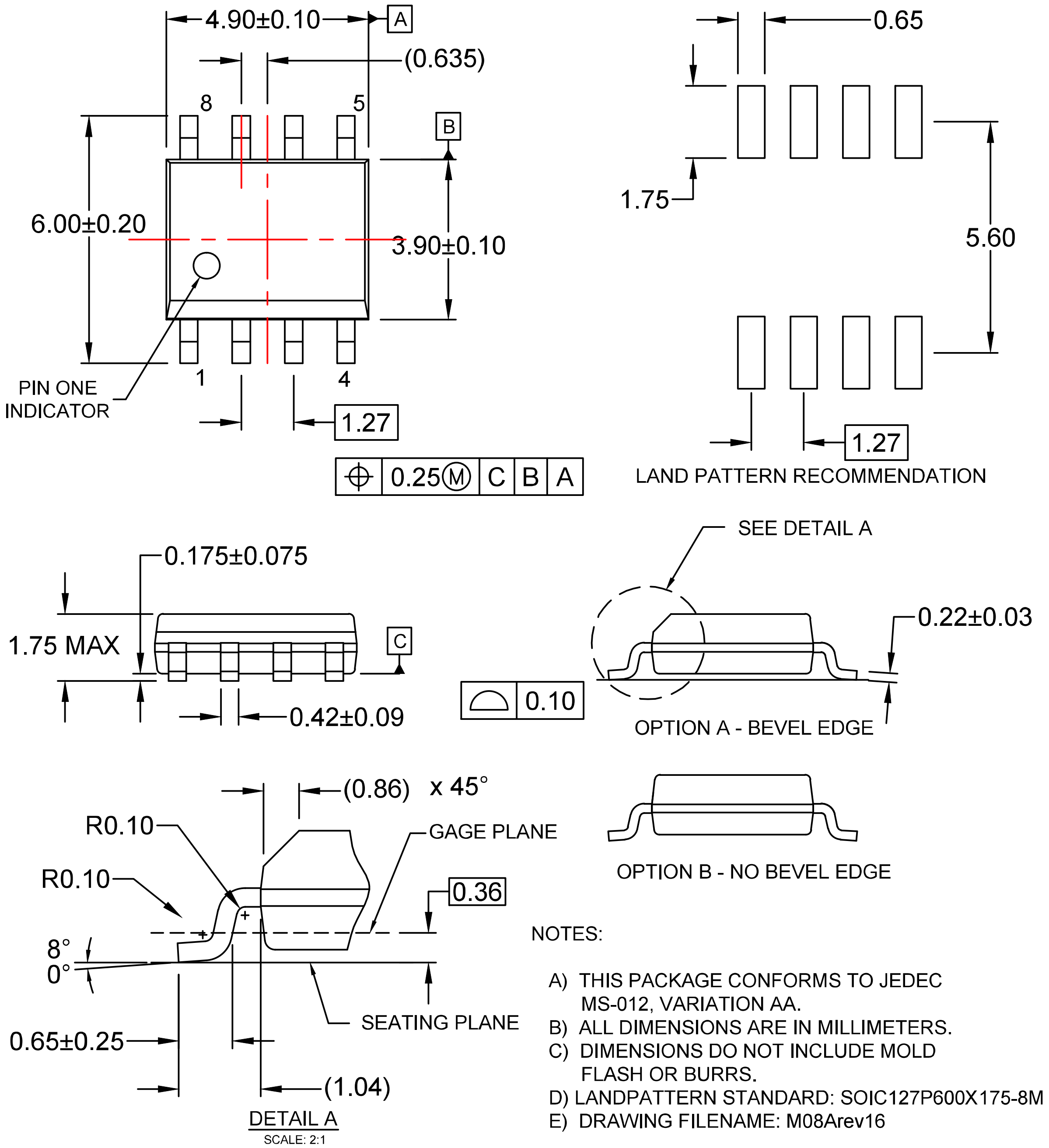


Figure 23. Layout Example



NOTES:

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

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