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FLS3217 / FLS3247

Single-Stage PFC Primary-Side-Regulation Offline LED Driver with Integrated Power MOSFET

Features

- Cost-Effective Solution without Input Bulk Capacitor and Feedback Circuitry
- Power-Factor Correction (PFC)
- Integrated Power MOSFET
- Accurate Constant-Current (CC) Control Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control for Increased Efficiency
- Open / Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20 μ A
- Low Operating Current: 5mA
- V_{DD} Over-Voltage Protection (OVP)
- V_{DD} Under-Voltage Lockout (UVLO)
- Application Voltage Range: 80 V_{AC} ~ 308 V_{AC}

Description

This highly integrated PWM controller with power MOSFET, FLS3217 / FLS3247, 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 the single-stage topology with primary-side regulation, an LED lighting board can be implemented with the few external components and minimized cost; requiring no input bulk capacitor or feedback circuitry. To implement good power factor and low THD, constant on-time control is utilized with an external capacitor connected to COM1.

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

FLS3217 and FLS3247 provide protection features such as open-LED, short-LED, and over-temperature protection. The current-limit level is automatically reduced to minimize the output current and protect external components in short-LED condition.

Applications

- LED Lighting System

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FLS3217M	-40°C to +125°C	7-Lead, Small Outline Package (SOIC)	Tape & Reel
FLS3217N		7-Lead, Small Outline Package (DIP)	Tube
FLS3247N			

Application Diagram

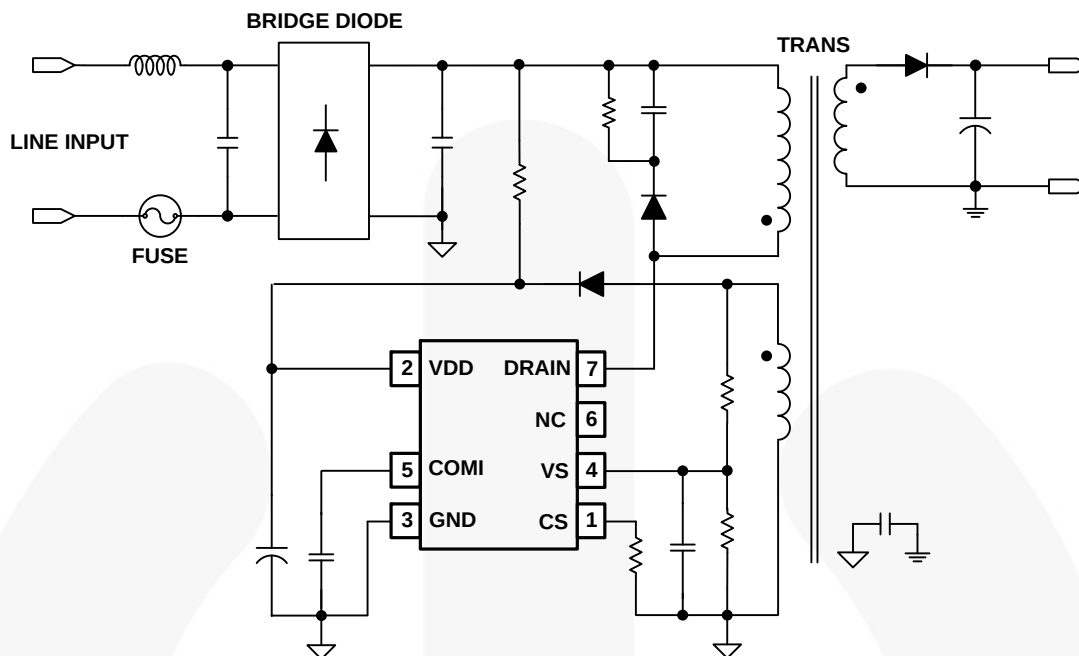


Figure 1. Typical Application

Internal Block Diagram

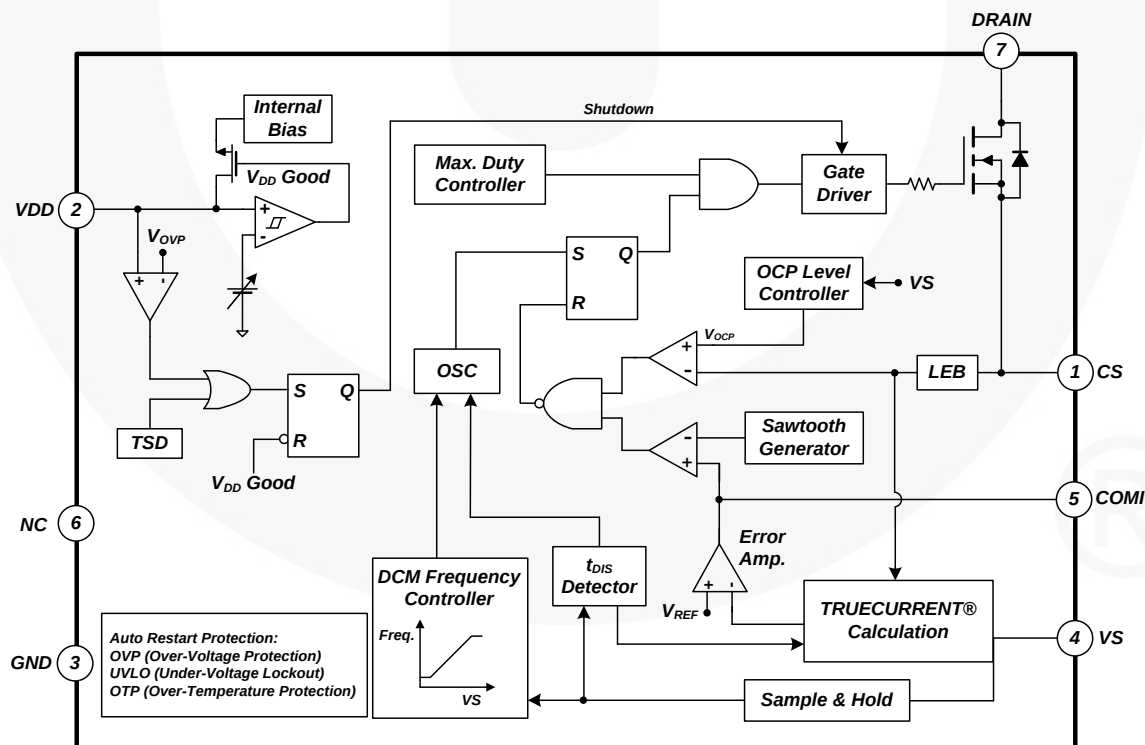


Figure 2. Functional Block Diagram

Marking Information

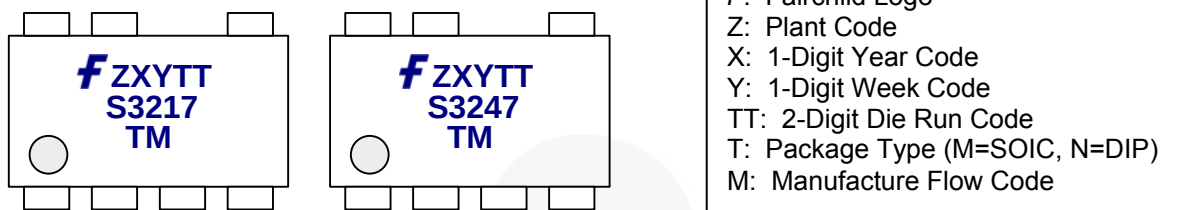


Figure 3. Top Mark

Pin Configuration

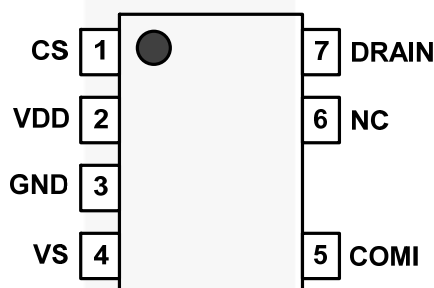


Figure 4. Pin Configuration

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 (CC) regulation.
2	VDD	Power Supply. IC operating current and MOSFET driving current are supplied using this pin.
3	GND	Ground
4	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.
5	COMI	Constant Current Loop Compensation. This pin is connected to a capacitor between the COMI and GND pins for compensation current loop gain.
6	NC	No Connect
7	DRAIN	Power MOSFET Drain. This pin 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 _{VDD}	DC Supply Voltage ^(1,2)			30	V
V _{VS}	VS Pin Input Voltage		-0.3	7.0	V
V _{CS}	CS Pin Input Voltage		-0.3	7.0	V
V _{COMI}	COMI Pin Input Voltage		-0.3	7.0	V
I _D	Continuous Drain Current	T _A =25°C, FLS3217M/N		1	A
		T _A =25°C, FLS3247N		4	
I _{DM}	Pulsed Drain Current	FLS3217M/N		4	A
		FLS3247N		16	
I _{AR}	Avalanche Current	FLS3217M/N	-	1	A
		FLS3247N		4	
P _D	Power Dissipation	SOIC, T _A < 50°C		660	mW
		DIP, T _A < 50°C		1	W
Θ _{JA}	Thermal Resistance (Junction-to-Air)	SOIC, T _A < 50°C		150	°C/W
		DIP, T _A < 50°C		95	
Θ _{JC}	Thermal Resistance (Junction-to-Case)	SOIC, T _A < 50°C		40	°C/W
		DIP, T _A < 50°C		25	
T _J	Maximum Junction Temperature			+150	°C
T _{STG}	Storage Temperature Range		-55	+150	°C
T _L	Lead Temperature (Soldering 10 seconds)			+260	°C
ESD	ESD Capability, Human Body Model			5	V
	ESD Capability, Charged Device Model			2	

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.

Symbol	Parameter	Min.	Max.	Unit
T _A	Operating Ambient Temperature	-40	125	°C

Electrical Characteristics

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

Symbol	Parameter		Condition	Min.	Typ.	Max.	Unit
MOSFET Section							
BV _{DSS}	Drain-Source Breakdown Voltage		I _D =250 μA, V _{GS} =0 V	700			V
R _{DS(ON)}	Static Drain-Source On Resistance	FLS3217M	I _D =0.5 A, V _{GS} =10 V		13	16	Ω
		FLS3217N			8.8	11.0	Ω
		FLS3247N	I _D =1 A, V _{GS} =10 V		2.4	2.8	Ω
C _{ISS}	Input Capacitance	FLS3217M	V _{GS} =0 V, V _{DS} =25 V, f _s =1 MHz		175	200	pF
		FLS3217N			250		pF
		FLS3247N			435		pF
C _{OSS}	Output Capacitance	FLS3217M	V _{GS} =0V, V _{DS} =25V, f _s =1MHz		23	25	pF
		FLS3217N			25		pF
		FLS3247N			51		pF
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		V _S =2.4 V, C _L =MOSFET C _{ISS}	2.85	4.00	5.00	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
Oscillator Section							
f _{MAX-CC}	Maximum Frequency in CC		V _{DD} =10 V, 20 V	60	65	70	kHz
f _{MIN-CC}	Minimum Frequency in CC		V _{DD} =10 V, 20 V	21.0	23.5	26.0	kHz
V _S _{MAX-CC}	VS for Maximum Frequency in CC		Frequency=Maximum Frequency-2 kHz	2.25	2.35	2.45	V
V _S _{MIN-CC}	VS for Minimum Frequency in CC		Frequency=Minimum Frequency +1 kHz	0.55	0.85	1.15	V
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}	Variation Test Voltage on CS Pin for Constant Current Regulation		V _{CS} =0.24 V	2.38	2.43	2.48	V
t _{LEB}	Leading-Edge Blanking Time				300		ns
t _{MIN}	Minimum On Time in CC		V _{VS} =-0.5 V, V _{CS} =1.5 V		600		ns
t _{PD}	Propagation Delay to GATE Output			50	100	150	ns
D _{SAW}	Duty Cycle of SAW Limiter				40		%
t _{DIS-BNK}	t _{DIS} Blanking Time of VS				1.5		μs
I _{VS-BNK}	VS Current for VS Blanking				100		μA

Continued on the following page...

Electrical Characteristics (Continued)Unless otherwise specified, $V_{DD}=15\text{ V}$ and $T_A=25^\circ\text{C}$.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Current-Error-Amplifier Section						
Gm	Transconductance			85		μmho
$I_{\text{COMI-SINK}}$	COMI Sink Current	$V_{\text{EAI}}=3\text{ V}$, $V_{\text{COMI}}=5\text{ V}$	25		38	μA
$I_{\text{COMI-SOURCE}}$	COMI Source Current	$V_{\text{EAI}}=2\text{ V}$, $V_{\text{COMI}}=0\text{ V}$	25		38	μA
$V_{\text{COMI-HIGH}}$	COMI High Voltage	$V_{\text{EAI}}=2\text{ V}$	4.7			V
$V_{\text{COMI-LOW}}$	COMI Low Voltage	$V_{\text{EAI}}=3\text{ V}$			0.1	V
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
$V_{\text{LowOCP-EN}}$	VS Threshold Voltage to Enable LOW OCP Level			0.40		V
$V_{\text{LowOCP-DIS}}$	VS Threshold Voltage to Disable LOW OCP Level			0.60		V
Over-Temperature-Protection Section						
T_{OTP}	Threshold Temperature for OTP ⁽³⁾		140	150	160	$^\circ\text{C}$
$T_{\text{OTP-HYS}}$	Restart Junction Temperature Hysteresis			10		$^\circ\text{C}$

Note:

3. When the over-temperature protection (OTP) is activated, the power system enters Auto-Recovery Mode and output is disabled.

Typical Performance Characteristics

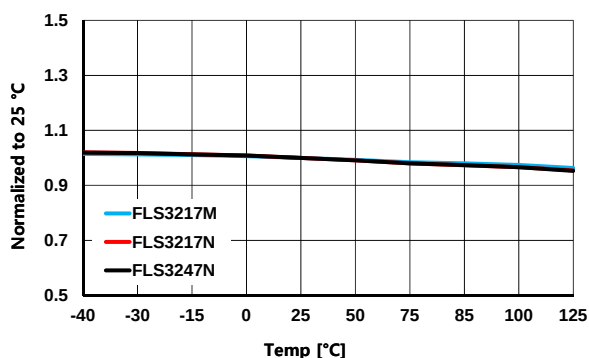


Figure 5. V_{DD-ON} vs. Temperature

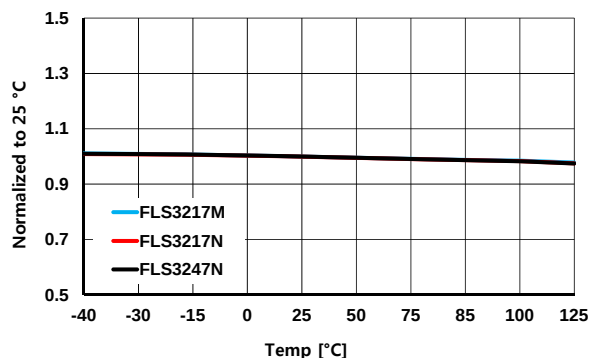


Figure 6. V_{DD-OFF} vs. Temperature

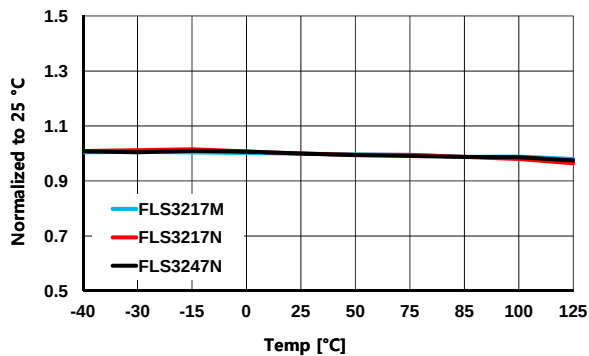


Figure 7. I_{DD-OP} vs. Temperature

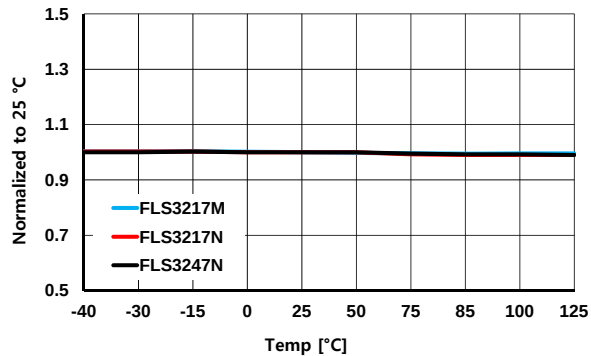


Figure 8. V_{OVP} vs. Temperature

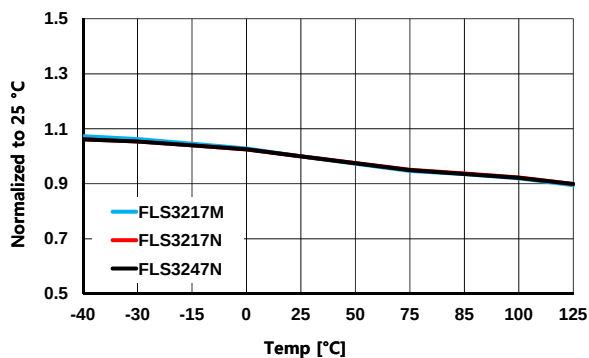


Figure 9. f_{MAX_CC} vs. Temperature

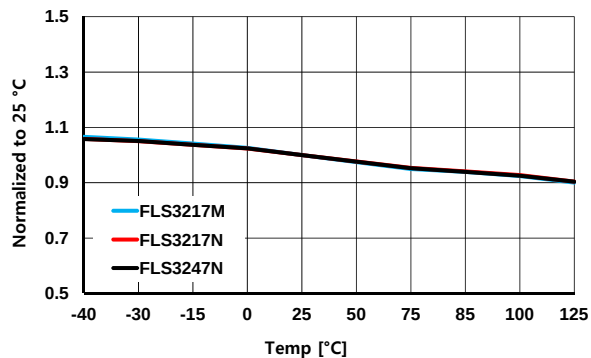


Figure 10. f_{MIN_CC} vs. Temperature

Typical Performance Characteristics (Continued)

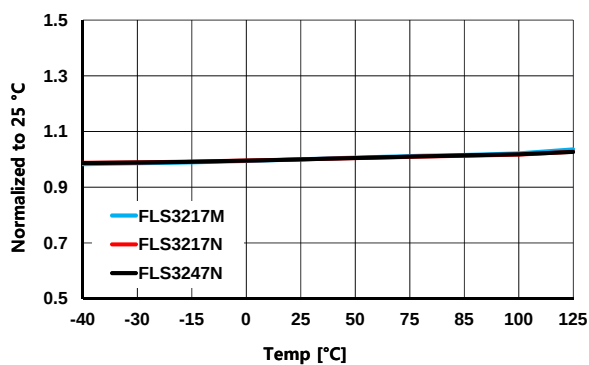


Figure 11. V_{CCR} vs. Temperature

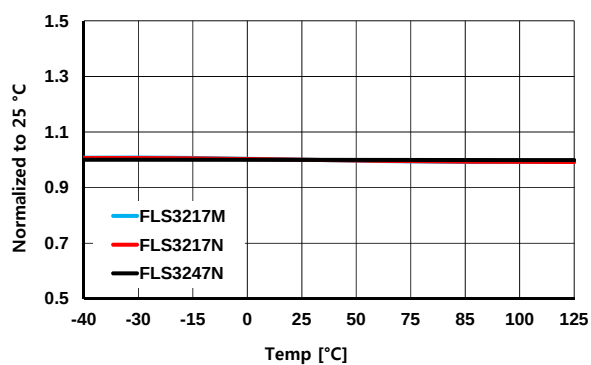


Figure 12. V_{VVR} vs. Temperature

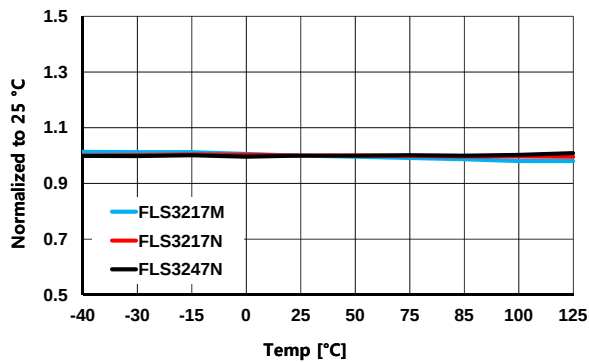


Figure 13. V_{OCP} vs. Temperature

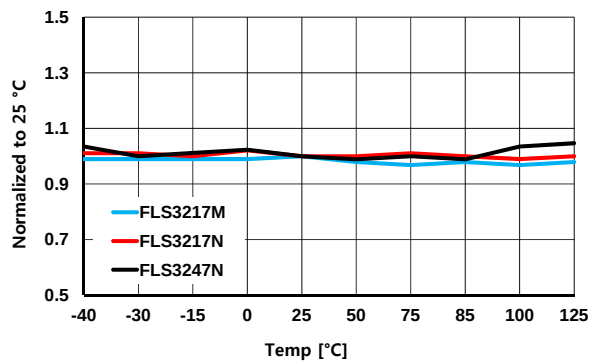


Figure 14. V_{OCP_Low} vs. Temperature

Functional Description

FLS3217 / FLS3247 is an 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 the PFC converter. To increase power during startup, the internal oscillator counts 12ms to define Startup Mode. During Startup Mode, turn-on time is determined by current-mode control with 0.2V voltage limit. Transconductance becomes 14 times bigger, as shown in Figure 15. After Startup Mode, turn-on time is controlled by Voltage Mode, using the COM1 voltage. The error amplifier transconductance is reduced to 85μmho.

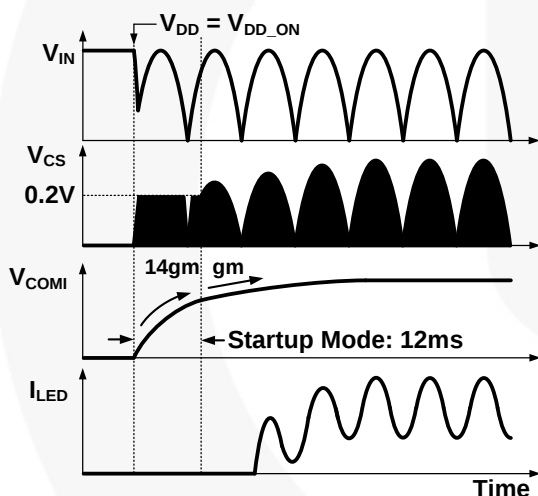


Figure 15. Startup Sequence

Constant Current Regulation

The output current can be estimated using the peak drain current and inductor current discharge time because 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 pieces of information (peak drain current, inductor discharging time, and operating switching period); the TRUECURRENT block calculates estimates the output current. The output of the TRUECURRENT calculation is compared with an internal precise reference to generate an error voltage, V_{COM1} , which determines the turn-on time in Voltage-Mode control. With Fairchild's innovative technique, constant current output can be precisely controlled.

Power-Factor Controller (PFC) and Total Harmonic Distortion (THD)

In a conventional boost converter, Boundary Conduction Mode (BCM) is generally used to keep input current in phase with input voltage for Power Factor (PF) and Total Harmonic Distortion (THD). In flyback / buck boost topology, constant turn-on time and constant frequency / 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 COM1 pin. Constant frequency and DCM operation is managed by linear frequency control.

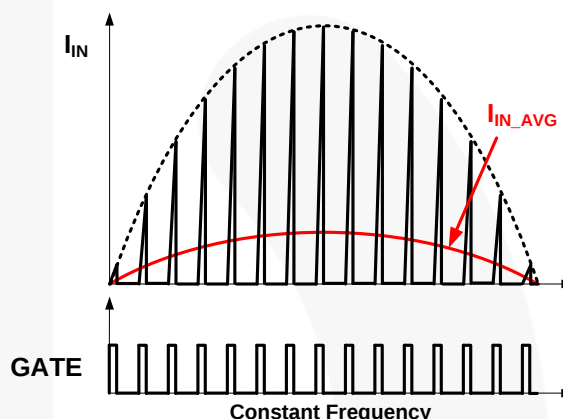


Figure 16. Input Current and Switching

Linear Frequency Control

DCM should be guaranteed for high power factor in flyback topology. To maintain DCM in the wide range of output voltage, frequency is linearly changed by output voltage in linear frequency control. Output voltage is detected by auxiliary winding and a resistive divider connected to the VS pin, as shown in Figure 17.

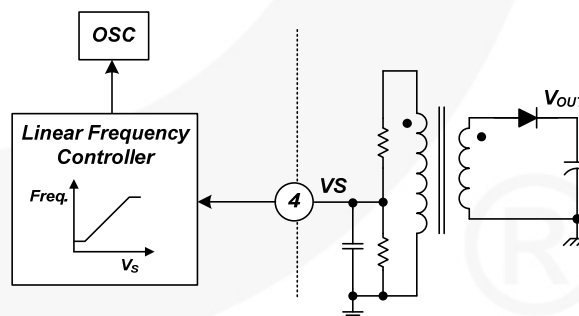


Figure 17. Linear Frequency Control

When the output voltage decreases, the secondary diode conduction time is increased and the linear frequency control lengthens the switching period. This maintains DCM operation in the wide output voltage range, as shown in Figure 18. The frequency control also lowers primary rms current with better power efficiency in full-load condition.

LED Short !

The diagram illustrates the behavior of the LED driver circuit during an LED short event. The three waveforms are:

- V_{IN}** : Input voltage. It shows a series of pulses that stop when the LED short occurs (indicated by a downward arrow). After the short is cleared, the pulses resume.
- V_{CS}** : Current sense voltage. It shows a peak followed by a drop to a low level (0.2V) during the short, then returns to its normal level.
- V_{DD}** : Driver supply voltage. It shows a sawtooth waveform that continues to operate during the short.

The diagram shows a 1-bit DAC circuit. An op-amp is configured with its non-inverting input (+) connected to ground and its inverting input (-) connected to a feedback network. The feedback network consists of a resistor connected to the output and a resistor connected to a DAC block. The DAC block has two inputs: '1' (labeled CS) and '4' (labeled VS). The output of the DAC block is connected to the inverting input of the op-amp. The op-amp output is connected to the '1' input of the DAC block. The DAC block also has a feedback input labeled V_{OCP} connected to the op-amp output. The DAC block contains the following logic:

- At $V_S < 0.4V$, $V_{OCP} = 0.2V$.
- At $V_S > 0.6V$, $V_{OCP} = 0.7V$.

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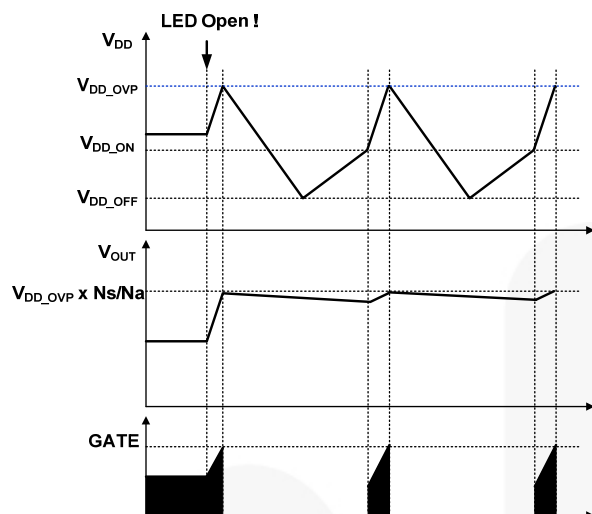


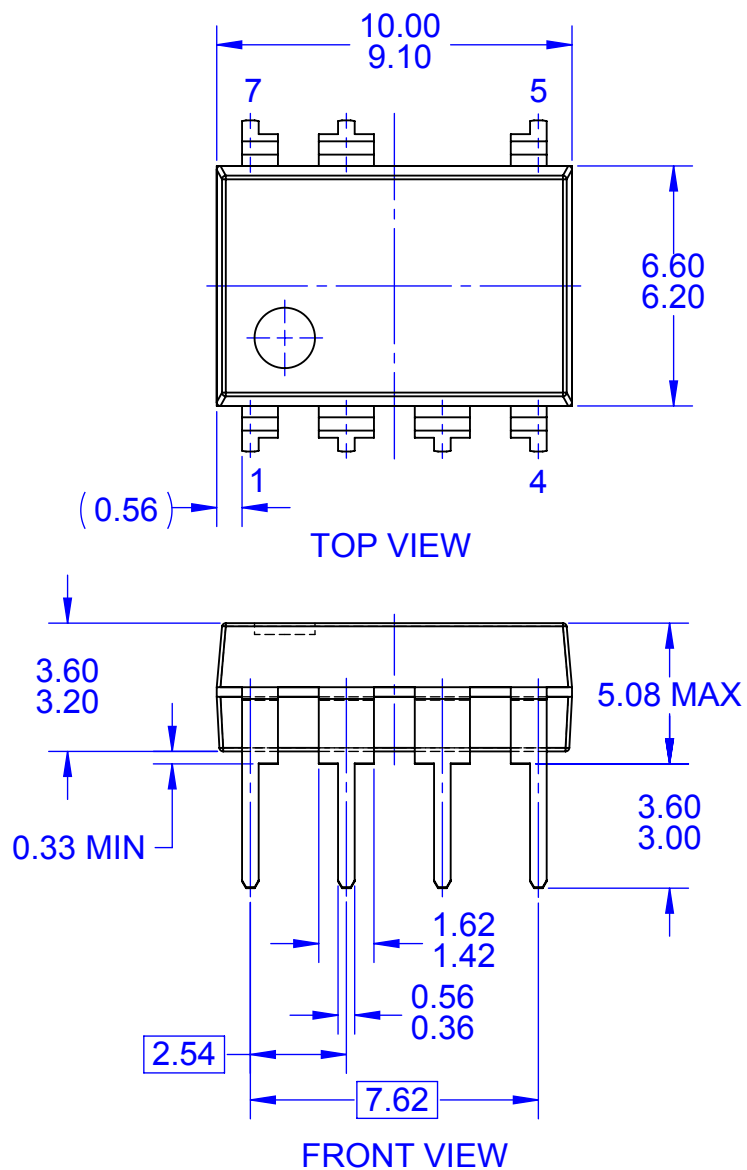
Figure 22. Waveforms at Open-LED Condition

Over-Temperature Protection (OTP)

The built-in temperature-sensing circuit shuts down PWM output once the junction temperature exceeds 150°C. While PWM output is off, VDD gradually drops to the UVLO voltage. Some of the internal circuits are shut down and VDD gradually increases again. When VDD reaches 16 V, all the internal circuits start operating. If the junction temperature is still higher than 140°C, the PWM controller shuts down immediately.

Under-Voltage Lockout (UVLO)

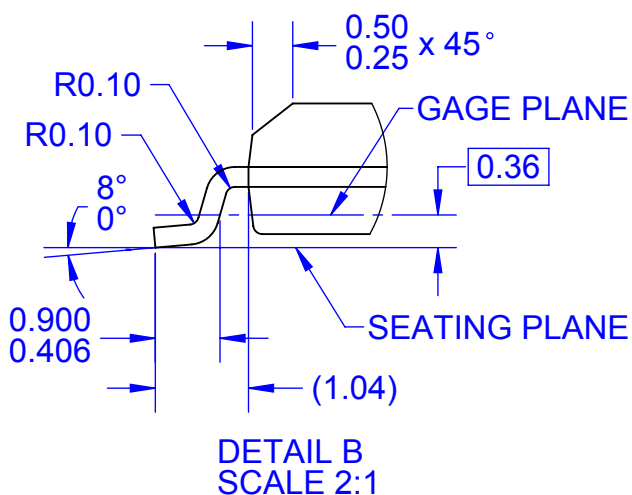
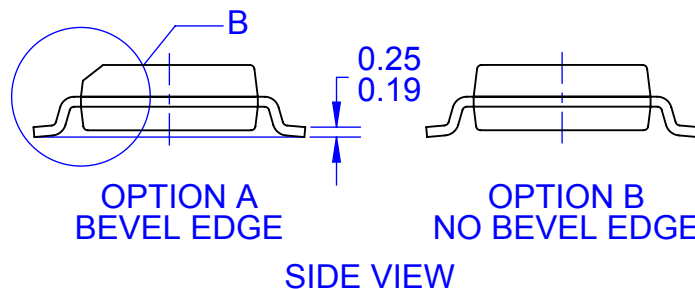
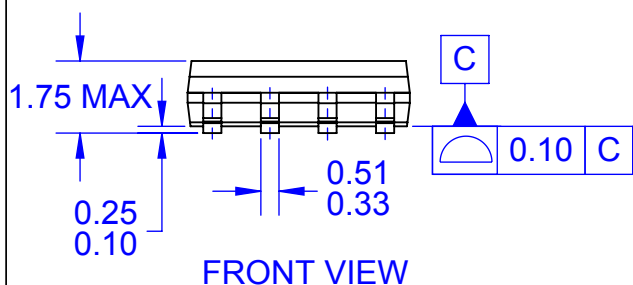
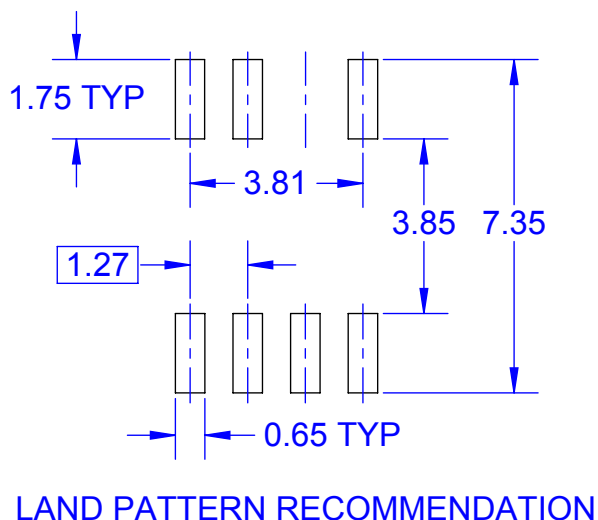
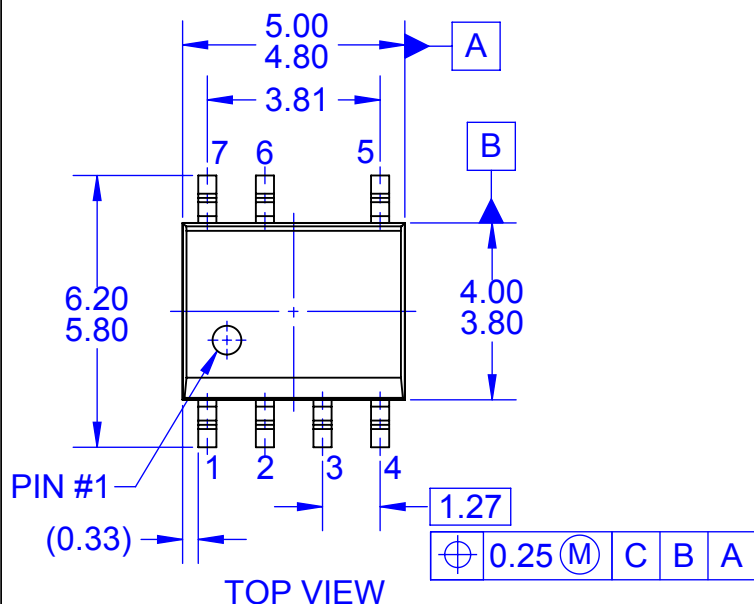
The turn-on and turn-off thresholds are fixed internally at 16 V and 7.5 V, respectively. During startup, the VDD capacitor must be charged to 16 V through the startup resistor, so that the FLS32x7 is enabled. The VDD capacitor supplies VDD until power can be delivered from the auxiliary winding of the main transformer. VDD must not drop below 7.5 V during startup. The UVLO hysteresis window ensures that the VDD capacitor is adequate to supply VDD during startup.



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