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FAIRCHILD SEMICONDUCTOR®

June 2013

FLS0116
MOSFET Integrated Smart LED Lamp Driver IC with PFC Function

Features

- Built-in MOSFET(1 A / 550 V)
- Digitally Implemented Active-PFC Function
- No Additional Circuit for Achieving High PF
- Application Input Range: 80 V_{AC} ~ 308 V_{AC}
- Built-In HV Supplying Circuit: Self Biasing
- AOCP Function with Auto-Restart Mode
- Built-In Over-Temperature Protection (OTP)
- Cycle-by-Cycle Current Limit
- Current Sense Pin Open Protection
- Low Operating Current: 0.85 mA (Typical)
- Under-Voltage Lockout with 5 V Hysteresis
- Programmable Oscillation Frequency
- Programmable LED Current
- Analog Dimming Function
- Soft-Start Function
- Precise Internal Reference: ±3%

Applications

- LED Lamp for Decorative Lighting
- LED Lamp for Low-Power Lighting Fixture

Description

The FLS0116 LED lamp driver is a simple IC with integrated MOSFET and PFC function. The special “adopted digital” technique automatically detects input voltage condition and sends an internal reference signal to achieve high power factor. When AC input is applied to the IC, the PFC function is automatically enabled. When DC input is applied to the IC, the PFC function is automatically disabled. The FLS0116 does not need a bulk (electrolytic) capacitor for supply rail stability, which significantly improves LED lamp life.

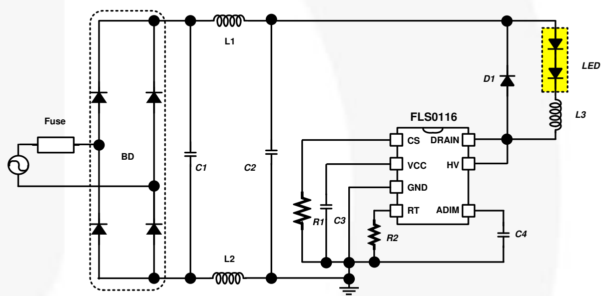


Figure 1. Typical Application

Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FLS0116MX	-40°C to +125°C	7-Lead, Small-Outline Integrated Circuit (SOIC), JEDEC MS-012, .150-inch, Narrow Body	Tape & Reel

Block Diagram

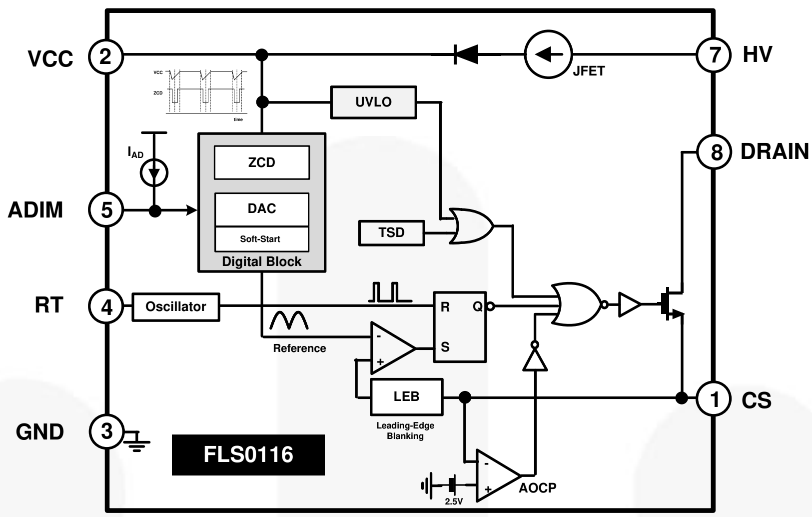


Figure 2. Block Diagram

Pin Configuration

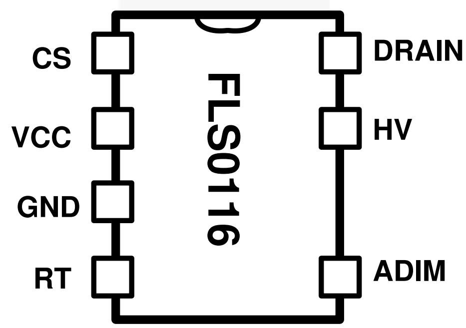


Figure 3. Pin Configuration

Pin Definitions

Pin #	Name	Description
1	CS	**Current Sense**. Limits output current, depending on the sensing resistor voltage. The CS pin is also used to set the LED current regulation.
2	VCC	**VCC**. Supply pin for stable IC operation; ZCD signal detection used for accurate PFC function.
3	GND	**GROUND**. Ground for the IC
4	RT	**RT**. Programmable operating frequency using an external resistor; the IC has pre-fixed frequency when this pin is open or floating.
5	ADIM	**Analog Dimming**. Connect to the internal current source. Use to change the output current using an external resistor. If ADIM is not used, connect a 0.1 µF bypass capacitor between the ADIM and GND.
7	HV	**High Voltage**. Connect to the high-voltage line and supply current to the IC.
8	DRAIN	**DRAIN**. The drain pin of internal MOSFET

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_{CC}	IC Supply Voltage			20	V
HV	High Voltage Sensing			550	V
DRAIN	Internal Drain Voltage			550	V
V_{ADIM}	Analog Dimming			5	V
V_{RT}	RT Pin Voltage			5	V
V_{CS}	Allowable Current Sensing Detection Voltage			5	V
T_A	Operating Ambient Temperature Range		-40	+125	°C
T_J	Operating Junction Temperature		-40	+150	°C
T_{STG}	Storage Temperature Range		-65	+150	°C
θ_{JA}	Thermal Resistance Junction-Air[1,2]			135	°C/W
P_D	Power Dissipation			660	mW
ESD	Electrostatic Discharge Capability	Human Body Model, JESD22-A114		2000	V
		Charged Device Model, JESD22-C101		1000	

Notes:
1. Thermal resistance test board. Size: 76.2 mm x 114.3 mm x 1.6 mm (1S0P); JEDEC standard: JESD51-2, JESD51-3.
2. Assume no ambient airflow.

Electrical Characteristics

Typical values are at T_A = +25°C. Specifications to -40°C ~ 125°C are guaranteed by design based on final characterization results.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{CC} Bias Section						
V_{CC}	V_{CC} Regulator Output Voltage	V_{HV}=100 V_{DC}	14.0	15.5	17.0	V
V_{CCST+}	UVLO Positive-Going Threshold	V_{CC} Increasing	12	13	14	V
V_{CCST-}	UVLO Negative-Going Threshold	V_{CC} Decreasing	7	8	9	V
V_{CCHYS}	UVLO Hysteresis		4	5	6	V
I_{HV}	HV Pin Current	V_{HV}=100 V_{DC}, RT=Open		0.85	1.20	mA
I_{ST}	Startup Current			120	150	μA
Switching Section						
f_{OSC}	Operating Frequency	R_T=5.95 kΩ	200	250	300	kHz
		R_T=87 kΩ	16	20	24	kHz
		R_T Open	40.5	45.0	49.5	kHz
t_{MIN}	Minimum On Time(3)			400		ns
D_{MAX}	Maximum Duty Cycle			50		%
t_{LEB}	Leading Edge Blanking Time(3)			350		ns
V_{RT}	Voltage Reference of RT Pin			1.5		V
Soft-Start Section						
t_{ss}	Soft-Start Time(3)	DC Mode	48	60	72	ms
		AC Mode		7		Periods
Reference Section						
V_{CS1}	Internal Reference Voltage of CS Pin	DC Mode	0.354	0.365	0.376	V
V_{CS2}		AC Mode(3)	0.485	0.500	0.515	
Protection Section						
OVP_{VCC}	Over-Voltage Protection on VCC Pin		17.7	18.7	19.7	V
V_{AOCP}	Abnormal OCP Level at CS Pin(3)			2.5		V
t_{AOCP}	Abnormal Detection Time(3)			70		ns
T_{TSDH}	Thermal Shutdown Threshold(3)		140	150		°C
T_{TSDHY}	Thermal Shutdown Threshold Hysteresis(3)			50		°C
Dimming Section						
$V_{ADIM(ST+)}$	Analog Dimming Positive Going Threshold(3)		3.15	3.50	3.85	V
$V_{ADIM(ST-)}$	Analog Dimming Negative Going Threshold(3)			0.50	0.75	V
I_{AD}	Internal Current Source for ADIM Pin		9	12	15	μA

Continued on the following page…

Electrical Characteristics (Continued)

Typical values are at T_A = +25°C. Specifications to -40°C ~ 125°C are guaranteed by design based on final characterization results.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
MOSFET Section						
BV_{DSS}	Breakdown Voltage	V_{CC}=0 V, I_D=250 μA	550			V
I_{LKMOS}	Internal MOSFET Leakage Current	V_{DS}=550 V_{DC}, V_{GS}=0 V			250	μA
$R_{ON(ON)}$	Drain-Source On Resistance(3)	V_{GS}=10 V, V_{DGS}=0 V, T_C=25°C		7.3	10.0	Ω
C_{ISS}	Input Capacitance(3)	V_{GS}=0 V,V_{DS}=25 V, f=1 MHz		135		pF
C_{OSS}	Output Capacitance(3)	V_{GS}=0 V,V_{DS}=25 V, f=1 MHz		21		pF
C_{RSS}	Reverse Transfer Capacitance(3)	V_{GS}=0 V,V_{DS}=25 V, f=1 MHz		3.2		pF
$t_{d(ON)}$	Turn-On Delay(3)	V_{DD}=350 V, I_D=1 A		10		ns
t_r	Rise Time(3)	V_{DD}=350 V, I_D=1 A		13.4		ns
$t_{d(OFF)}$	Turn-Off Delay(3)	V_{DD}=350 V, I_D=1 A		14.9		ns
t_f	Fall Time(3)	V_{DD}=350 V, I_D=1 A		36.8		ns

Note:
3. These parameters, although guaranteed, are not 100% tested in production.

Functional Description

The FLS0116 is a basic PWM controller for buck converter topology in Continuous Conduction Mode (CCM) with an intelligent PFC function that uses a digital control algorithm. An internal self-biasing circuit uses the high-voltage switching device. The IC does not need an auxiliary powering path to the VCC pin typical in flyback control ICs or PSR product family.

When the input voltage applied to the HV pin is within operating range (25 V to 500 V), the FLS0116 maintains a 15.5 V DC voltage at the VCC pin for stable operation. The UVLO block functions such that when the V_{CC} voltage rises higher than V_{CCST+}, the internal UVLO block releases and starts operation. Otherwise, the V_{CC} goes down to the V_{CCST-} and IC operation stops. Normally, the hysteresis function provides stable operation even if the input voltage is operating under very noisy or unstable circumstances.

The FLS0116 has a "smart" internal digital block for determining input condition: AC or DC. When an AC source with 50 Hz or 60 Hz is applied to the IC, the IC automatically changes its internal reference signal, which is similar to input signal, for creating high power factor. When a DC source connects to the IC, the internal reference immediately changes to DC.

Soft-Start Function

The FLS0116 has an internal soft-start function to reduce inrush current at startup. When the IC starts operation following an internal sequence, the internal reference slowly increases for a pre-determined fixed time. After this transient period, the internal reference goes to a steady-state level. In this time, the IC continually tries to find phase information from the VCC pin. If the IC succeeds in getting phase information, it automatically follows a similar shape reference made during the transient times, 7 periods. If not, the IC has a DC reference level.

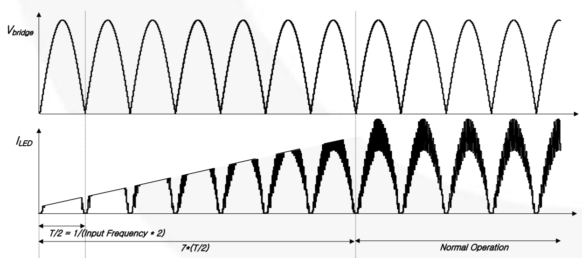


Figure 4. Soft-Start Function in AC Input Mode

Internal PFC Function: How to Achieve High Power Factor

The FLS0116 has a simple, "smart", internal PFC function that does not require additional pins for detecting input phase information or an electrolytic capacitor for supply voltage stabilization. For achieving high PF, the FLS0116 does not use the rectification capacitor after the bridge diode. This is important because the IC instead uses fluctuation in the signal on the VCC pin. Basically, the VCC pin, which is supplies power for the IC, has voltage ripple as well as the rectification voltage after bridge, changing voltage level according to the V_{CC} capacitor value. Using this kind of voltage fluctuation on the VCC pin, the IC can detect the time reference and create the internal ZCD signal.

For precise and reliable internal reference for input voltage signal, the FLS0116 uses a digital technique (sigma/delta modulation) and creates a new internal signal (DAC_OUT) that has the same phase as the input voltage, as shown in Figure 5. This signal enters the final comparator and is compared with current information from the sensing resistor.

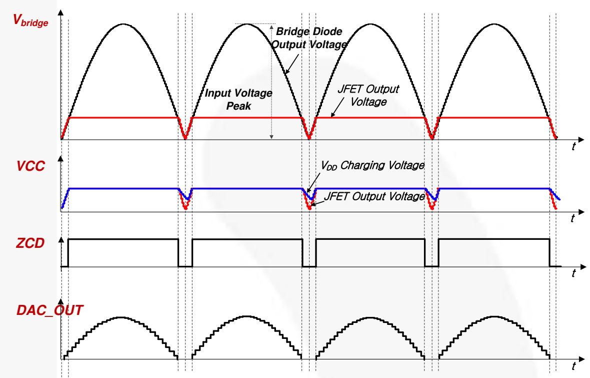


Figure 5. Internal PFC Function

Self-Biasing Function

The self-biasing function, using an HV device, can supply enough operating current to the IC and guarantee similar startup time across the whole input voltage range (80 V~308 V_{AC}). However, self-biasing has a weakness in high-voltage condition. Normally, the HV device acts as constant current source, so the internal HV device has power loss when high input voltage connects to the HV pin. This power loss is proportional to input voltage. To reduce this power loss, one of the possible solutions is an additional resistor between the input voltage source and the HV pin, as shown in Figure 6.

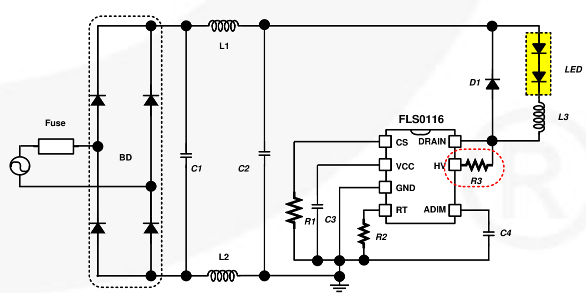


Figure 6. High-Voltage Application

Dimming Function

The FLS0116 uses the ADIM pin for analog or 0 V to 10 V dimming by using a resistive divider. The peak voltage of internal reference, which is DAC_OUT signal in Figure 5, is changed by the V_{ADIM} level, as shown in Figure 7, and has different peak level according to the operating mode.

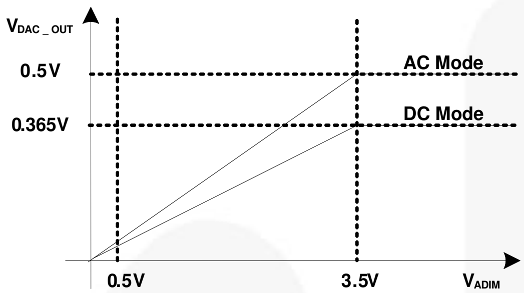


Figure 7. V_{ADIM} vs. $V_{DAC\_OUT(peak)}$

Inductor Design

The fixed internal duty ratio range is below 50%, or around 400 ns, from a timing point of view. The range is dependent on the input voltage and number of LEDs in its string.

Minimum duty is calculated as:

$$D_{\min} = \frac{n \cdot V_f}{\eta \cdot V_{in(\max)}} \tag{1}$$

where:

η = efficiency of system;
$V_{IN(max)}$ = maximum input voltage;
V_f = forward drop voltage of LED; and
n = LED number in series connection.

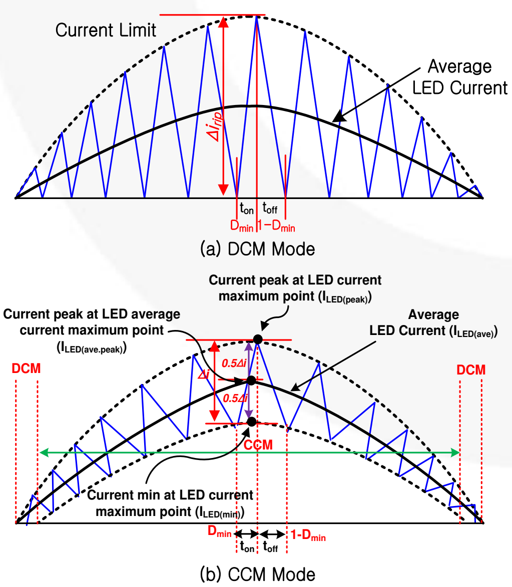


Figure 8. DCM and CCM Operation

In DCM Mode, inductance is:

$$L_m = \frac{n \cdot V_f \cdot (1 - D_{\min})}{f_s \cdot \Delta i_{rip}} \; [H] \tag{2}$$

If the peak current is fixed at 350 mApk, the formula for the peak current is:

$$I_{LED(ave.peak)} = \Delta i_{con} + \frac{\Delta i_{rip}}{2} \quad [A] \tag{3}$$

In FL7701, the LED RMS current determines the inductance parameter. To drive for CCM Mode, define LED RMS current first, as:

$$I_{LED(rms)} = \frac{I_{LED(ave.peak)}}{\sqrt{2}} \quad [A] \tag{4}$$

Substituting Equation (2) for Equation (4), the inductance of inductor is obtained.

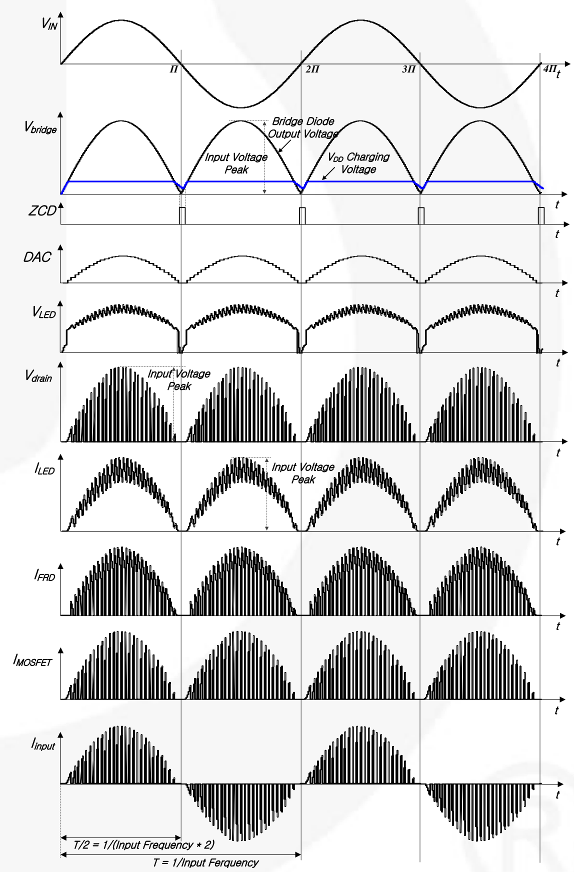


Figure 9. Typical Performance Characteristics

Example Application Circuits

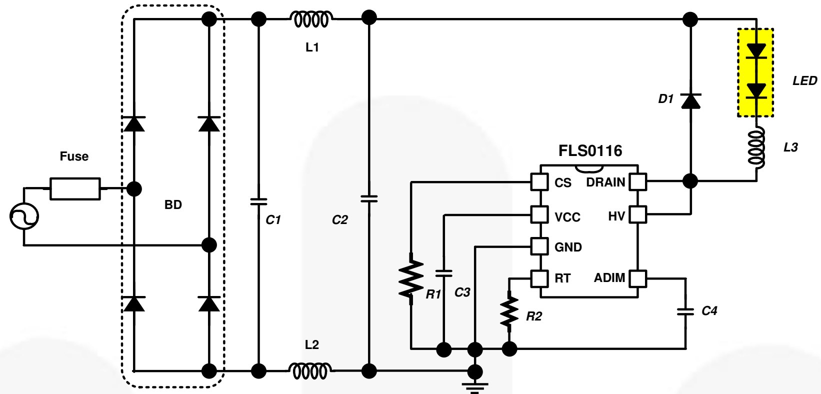


Figure 10. Application Circuit without Electrolytic Capacitor

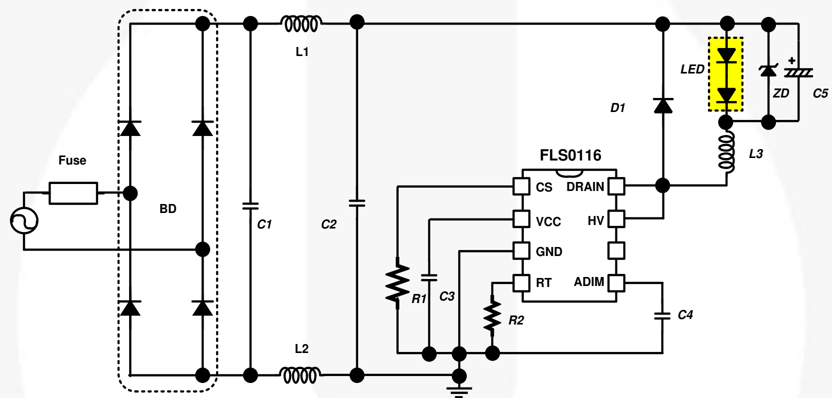


Figure 11. Application Circuit with Electrolytic Capacitor

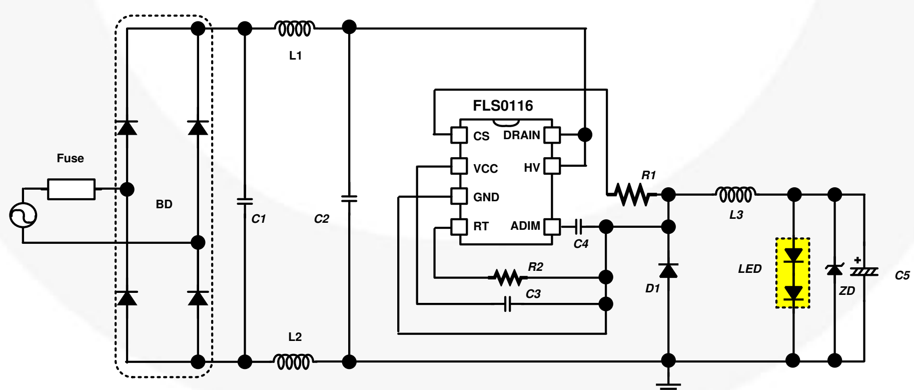


Figure 12. Application Circuit of High-Side Operation with Electrolytic Capacitor

Typical Characteristics

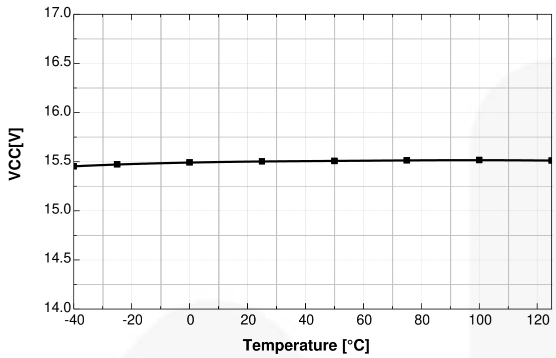


Figure 13. V_{CC} **vs. Temperature**

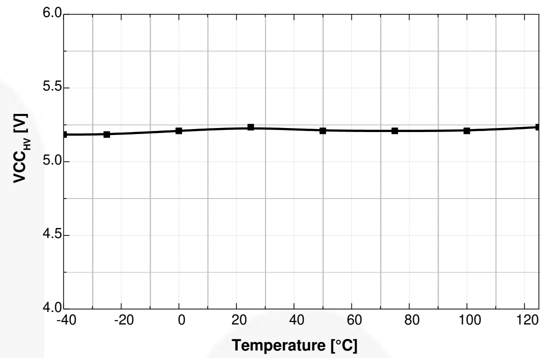


Figure 14. V_{CCHYS} **vs. Temperature**

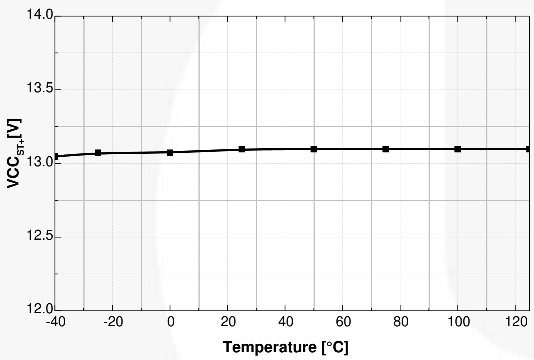


Figure 15. V_{CCST+} **vs. Temperature**

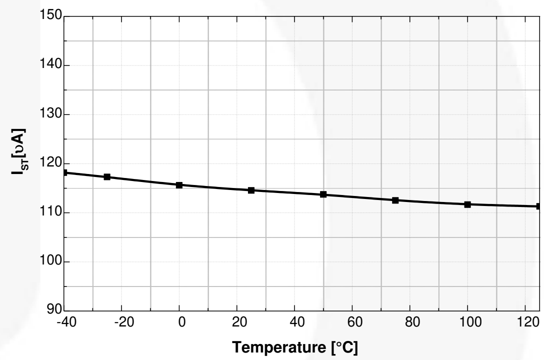


Figure 16. I_{ST} **vs. Temperature**

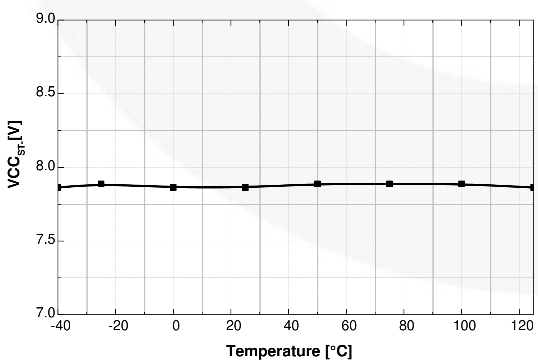


Figure 17. V_{CCST-} **vs. Temperature**

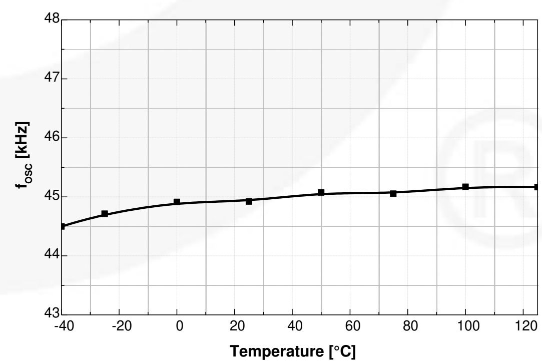


Figure 18. f_{OSC} **vs. Temperature (RT=Open)**

Typical Characteristics

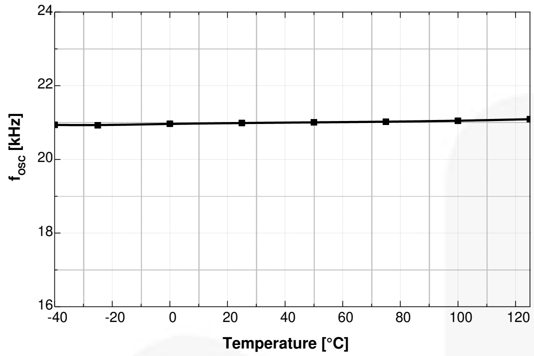


Figure 19. f_{OSC} vs. Temperature (RT=87kΩ)

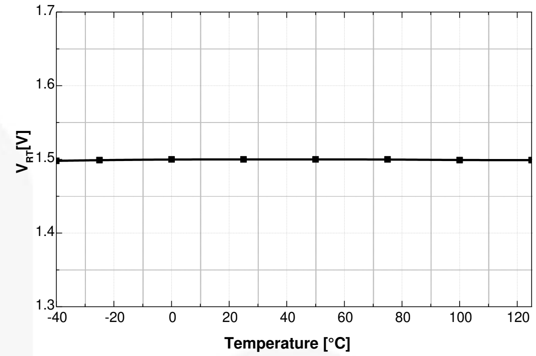


Figure 20. V_{RT} vs. Temperature

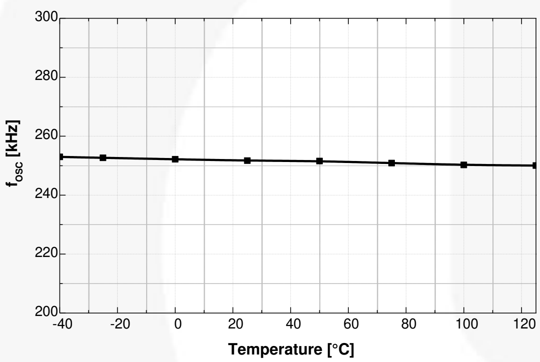


Figure 21. f_{OSC} vs. Temperature (RT=5.95kΩ)

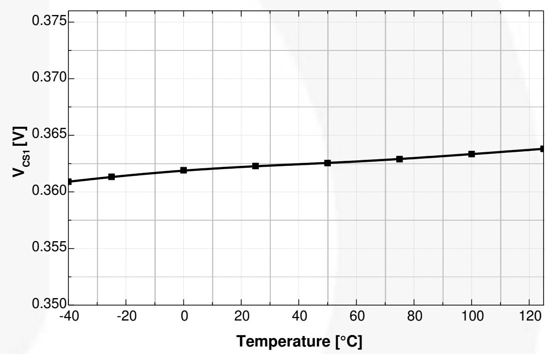


Figure 22. V_{CS} vs. Temperature

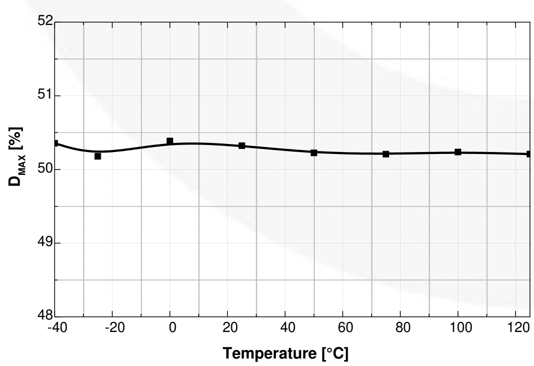


Figure 23. D_{MAX} vs. Temperature

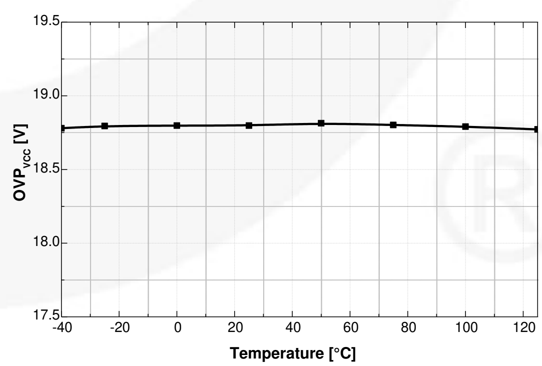


Figure 24. OVP_{VCC} vs. Temperature

Typical Characteristics

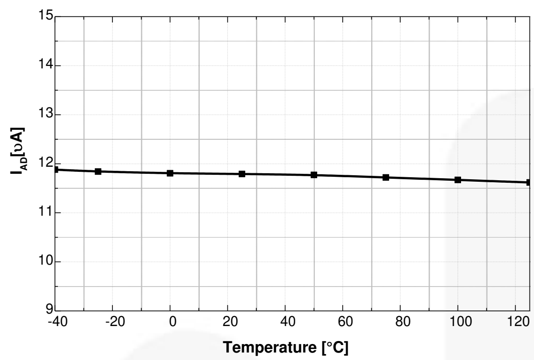


Figure 25. I_{AD} vs. Temperature

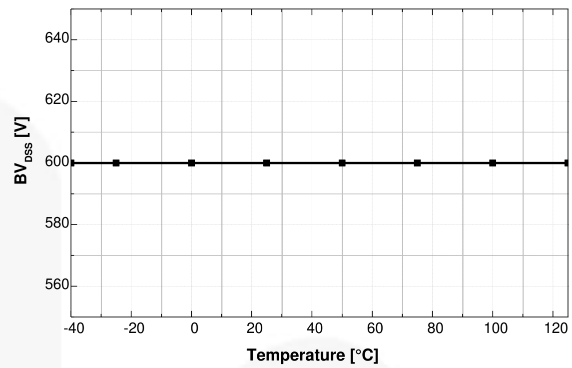


Figure 26. BV_{DSS} vs. Temperature

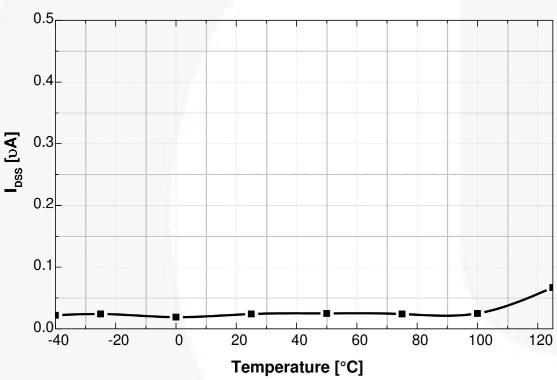
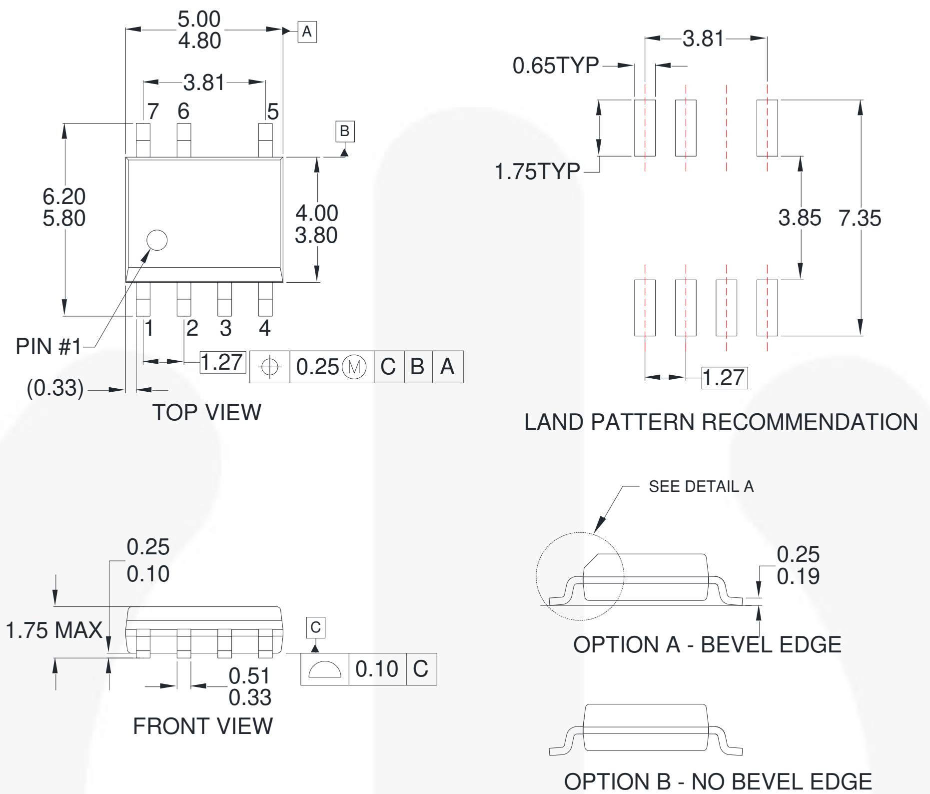
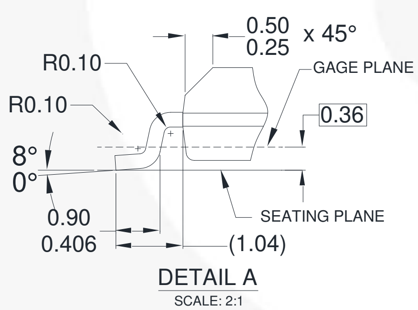


Figure 27. I_{DSS} vs. Temperature

Physical Dimensions





NOTES:

A) THIS PACKAGE DOES NOT FULLY CONFORMS TO JEDEC MS-012 VARIATION AA.

B) ALL DIMENSIONS ARE IN MILLIMETERS.

C) DIMENSIONS DO NOT INCLUDE MOLD FLASH OR BURRS.

D) DRAWING FILENAME : M07Brev3

Figure 28. 7-Lead, Small-Outline Integrated Circuit (SOIC), JEDEC MS-012, .150-Inch Narrow Body

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MicroFET™
MicroPak™
MicroPak2™
MillerDrive™
MotionMax™
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SuperSOT™-6
SuperSOT™-8
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TinyBuck™
TinyCalc™
TinyLogic®
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TinyPower™
TinyPWM™
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