Highly Integrated Current Mode PWM Controller

FEATURES

- **Built-in Soft Start Function**
- **Very Low Start-up Current**
- **Proprietary "Smooth Frequency Foldback" and Burst Mode Operation for Green Mode Operation**
- **Proprietary "Hybrid Frequency Jittering"**
- **Proprietary "Constant Power Limiting" (Full AC Input Range)**
- **High Voltage CMOS Process with Excellent ESD Protection**
- **Improved EMI**
- **Current Mode Control**
- **Built-in Slope Compensation**
- **Leading Edge Blanking (LEB)**
- **Programmable Switching Frequency**
- **All Pins Floating Protection**
- **Audio Noise Free Operation**
- **800mA Gate Drive Capability**
- **External Programmable Over Temperature Protection (OTP)**
- **OVP (Over Voltage Protection) on VDD**
- **OLP (Over Load Protection)**
- **Cycle-by-cycle Current Limiting (OCP)**

APPLICATIONS

Offline AC/DC flyback converter for

- **Power Adaptors**
- **Open-frame SMPS**
- **ATX Standby Power**
- **Battery Charger**

GENERAL DESCRIPTION

COX3165 is a highly integrated current mode PWM controller for medium to large offline power converter applications.

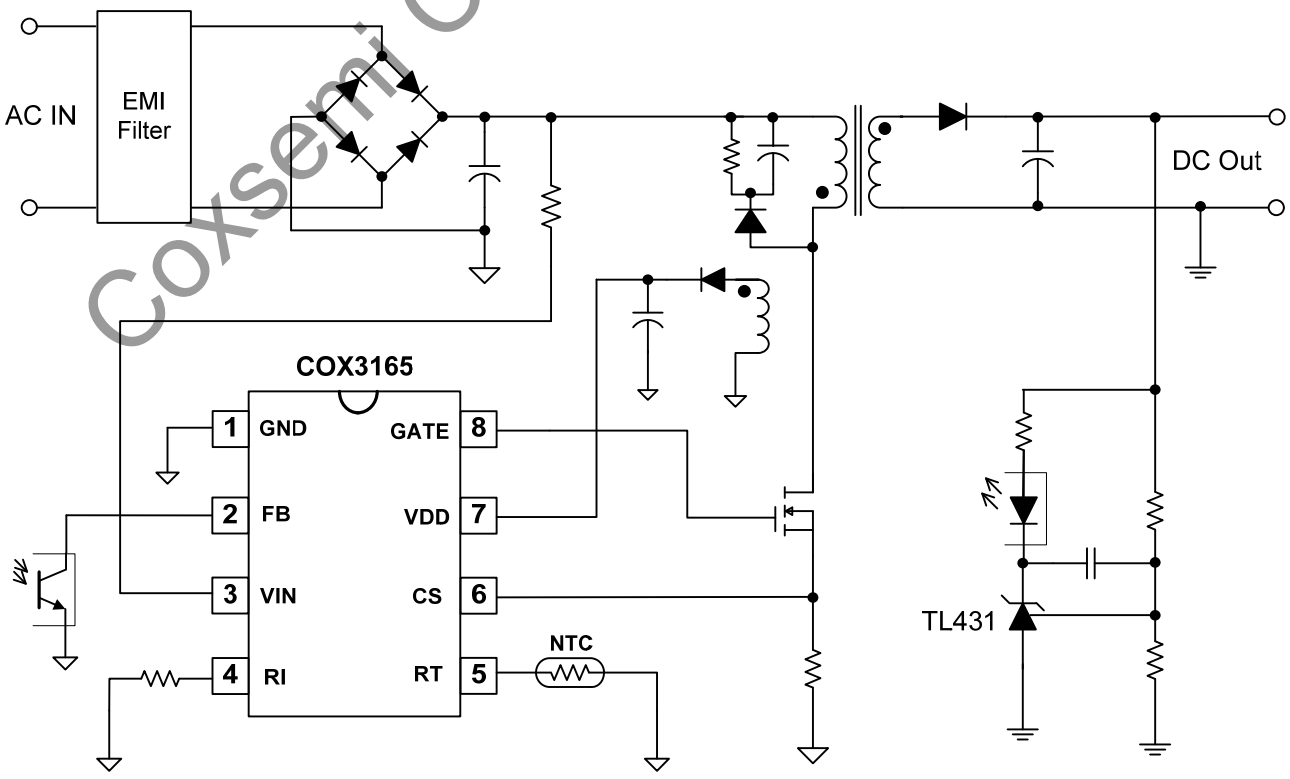
In COX3165, the PWM switching is internally trimmed to tight range. To improve EMI performance, the IC integrates Coxsemi's Proprietary "Hybrid Frequency Jittering" for the oscillator to reduce conduction EMI emission of a power supply. When the output power demands decrease, the IC enters into Coxsemi's Proprietary "Smooth Frequency Foldback" for high power conversion efficiency without audio noise generated. When the current set-point falls below a given value, e.g. the output power demand diminishes, the IC automatically enters into burst mode and provides excellent efficiency without audio noise.

The IC also integrates Coxsemi's Proprietary "Constant Power Limiting" block to achieve constant output power limit from 90VAC to 264VAC.

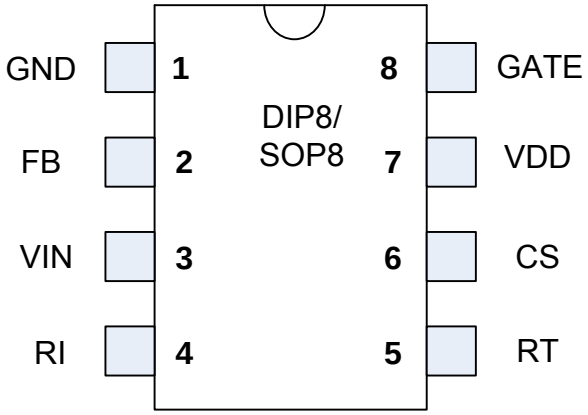
COX3165 integrates functions and protections of Under Voltage Lockout (UVLO), VDD Over Voltage Protection (OVP), Soft Start, External Programmable Over Temperature Protection (OTP), Cycle-by-cycle Current Limiting (OCP), Over Load Protection (OLP), All Pins Floating Protection, RI Pin Short-to-GND Protection, GATE Clamping, VDD Clamping, Leading Edge Blanking (LEB).

COX3165 is available in SOP-8 and DIP-8 packages.

TYPICAL APPLICATION

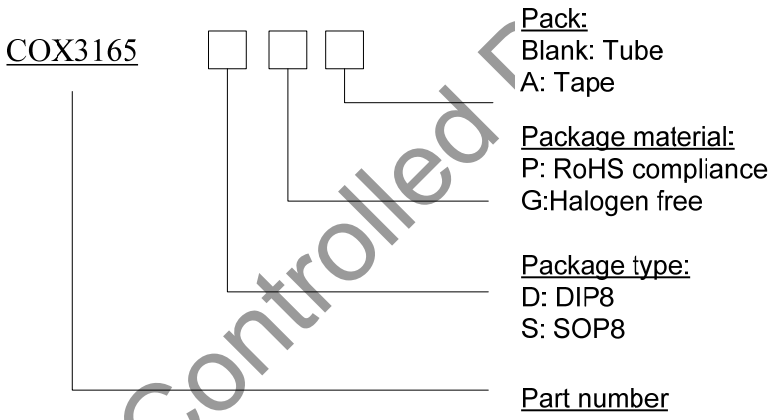


Pin Configuration

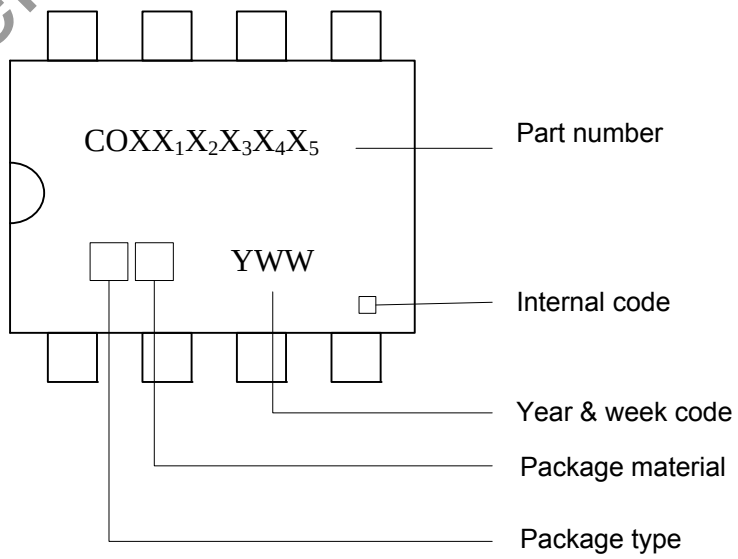


Ordering Information

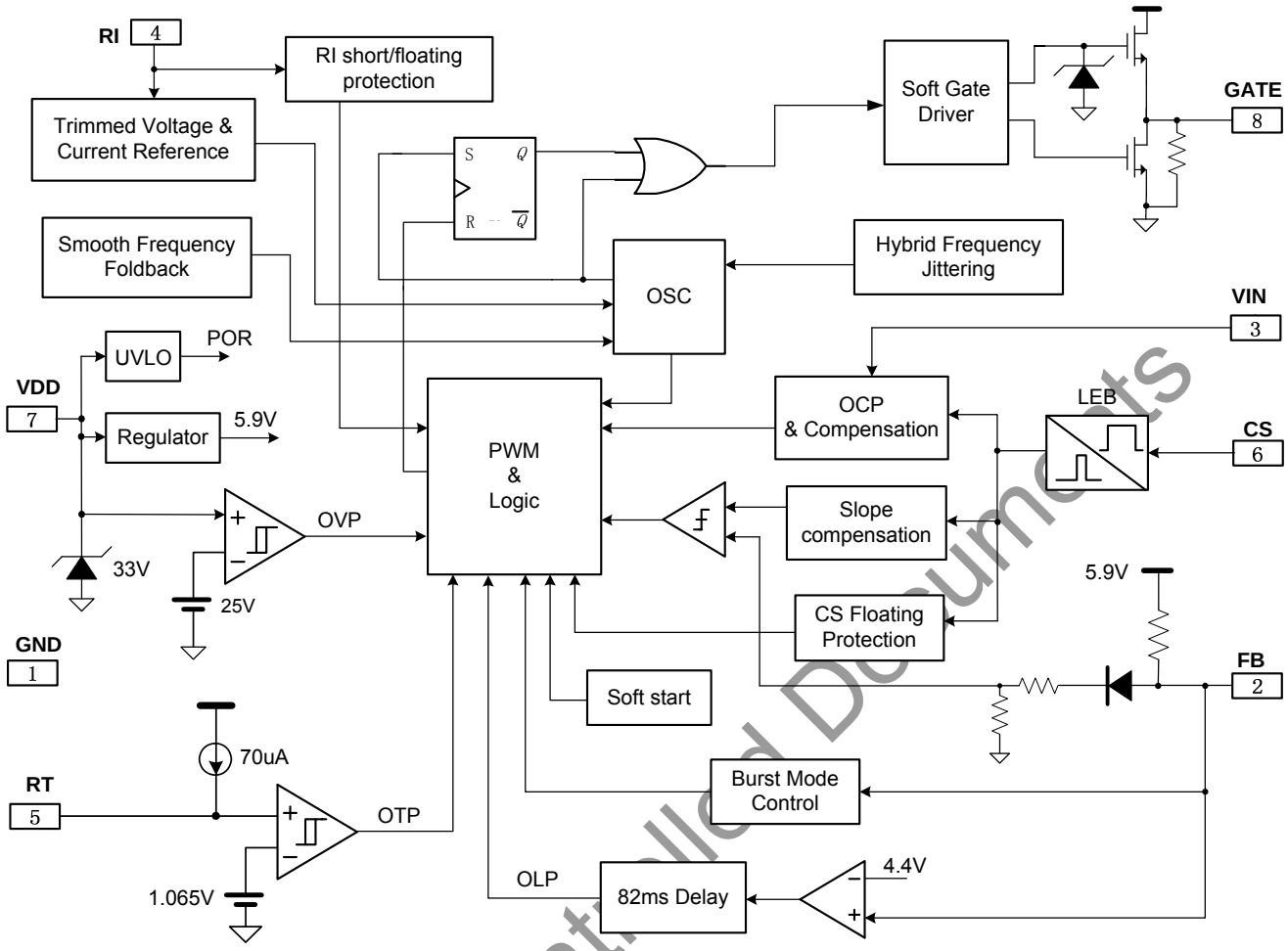
Part Number	Description
COX3165DP	DIP8, RoHS compliance in Tube
COX3165SP	SOP8, RoHS compliance in Tube
COX3165SPA	SOP8, RoHS compliance in T&R



Marking Information



Block Diagram



Pin Description

Pin Num	Pin Name	I/O	Description
1	GND	P	IC ground pin.
2	FB	I	Voltage feedback pin. The loop regulation is achieved by connecting a photo-coupler to this pin. PWM duty cycle is determined by this pin voltage and the current sense signal at Pin 6.
3	VIN	I	This pin is connected to the rectified line input via a large value resistor. The function of the pin is for startup and line voltage sensing.
4	RI	I	Set the switching frequency by connecting a resistor between RI and GND. This pin has floating/short-to-GND protection.
5	RT	I	This pin is for over temperature protection by connecting an external NTC resistor to ground. Once the pin voltage drops below a fixed limit of 1.065V, PWM output will be disabled.
6	CS	I	Current sense input pin.
7	VDD	P	IC power supply pin.
8	GATE	O	Totem-pole gate driver output to drive the external MOSFET.

Absolute Maximum Ratings (Note 1)

Parameter	Value	Unit
VDD/VIN DC Supply Voltage	33	V
VDD DC Clamp Current	10	mA
GATE pin	20	V
FB, RI, RT, CS voltage range	-0.3 to 7	V

Package Thermal Resistance (DIP-8)	90	°C/W
Package Thermal Resistance (SOP-8)	150	°C/W
Maximum Junction Temperature	150	°C
Operating Temperature Range	-40 to 85	°C
Storage Temperature Range	-65 to 150	°C
Lead Temperature (Soldering, 10sec.)	260	°C
ESD Capability, HBM (Human Body Model)	3	kV
ESD Capability, MM (Machine Model)	250	V

Recommended Operation Conditions (Note 2)

Parameter	Value	Unit
Supply Voltage, VDD	11 to 23	V
Operating Frequency	50 to 130	kHz
Operating Ambient Temperature	-40 to 85	°C

ELECTRICAL CHARACTERISTICS

(T_A = 25°C, RI=24K ohm, VDD=18V, if not otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Supply Voltage (VDD) Section						
I_Startup	VDD Start up Current	VDD =15V, Measure current into VDD		5	20	uA
I_VDD_Op	Operation Current	V_{FB}=3V,GATE=1nF		2.5	3.5	mA
UVLO(ON)	VDD Under Voltage Lockout Exit (Startup)		15.5	16.5	17.5	V
UVLO(OFF)	VDD Under Voltage Lockout Enter		9.5	10.5	11.5	V
VDD_OVP_ON	VDD Over Voltage Protection trigger		23.5	25	26.5	V
VDD_OVP_OFF	VDD Over Voltage Protection trigger		21.5	23	24.5	V
VDD_OVP_Hys	VDD OVP Hysteresis			2		V
V_{DD}_Clamp	VDD Zener Clamp Voltage	I(V_{DD}) = 5mA		33		V
T_Softstart	System Soft Start Time			3		mSec
Feedback Input Section(FB Pin)						
A_{VCS}	PWM Input Gain	$\Delta V_{FB}/\Delta V_{cs}$		2.8		V/V
V_{FB}_Open	FB Open Voltage			5.9		V
I_{FB}_Short	FB short circuit current	Short FB pin to GND, measure current		1.2		mA
VFB_min_duty	FB under voltage gate clock is off.			1.0		V
V_{TH}_PL	Power Limiting FB Threshold Voltage			4.4		V
T_D_PL	Power limiting Debounce Time	Note 3		82		mSec
Z_{FB}_IN	Input Impedance			5		Kohm
Current Sense Input Section (CS Pin)						
T_blanking	SENSE Input Leading Edge Blanking Time			250		nSec
Vth_OC_max	Internal current limiting threshold	I(VIN)=0	0.85	0.9	0.95	V

T_D_OC	Over Current Detection and Control Delay	GATE=1nF		120		nSec
Oscillator Section						
F_{OSC}	Normal Oscillation Frequency		60	65	70	KHZ
ΔF(shuffle)/Fosc	Frequency shuffling range	Note 4	-4		4	%
Δf_Temp	Frequency Temperature Stability	-40°C to 125°C (Note 4)		5		%
Δf_VDD	Frequency Voltage Stability	VDD = 12-23V (Note 4)		5		%
Duty_max	Maximum Duty cycle		75	80	85	%
RI_range	Operating RI Range		12	24	60	Kohm
V_RI_open	RI open voltage			2.0		V
F_BM	Burst Mode Base Frequency			22		KHz
Over Temperature Protection (RT Pin)						
I_RT	Output Current of RT Pin			70		uA
V_{TH}_OTP	OTP Threshold Voltage		1.015	1.065	1.115	V
V_{TH}_OTP_OFF	OTP Release Voltage			1.165		V
V_{TH}_OTP_Hys	OTP Hysteresis			0.1		V
V_RT_Open	RT Pin Open Voltage			4.6		V
Gate Drive Output						
VOL	Output Low Level	Io = 20 mA (sink)			0.3	V
VOH	Output High Level	Io = 20 mA (source)	11			V
VG_Clamp	Output Clamp Voltage Level	VDD=24V		18		V
T_r	Output Rising Time	GATE = 1nF		120		nSec
T_f	Output Falling Time	GATE = 1nF		50		nSec

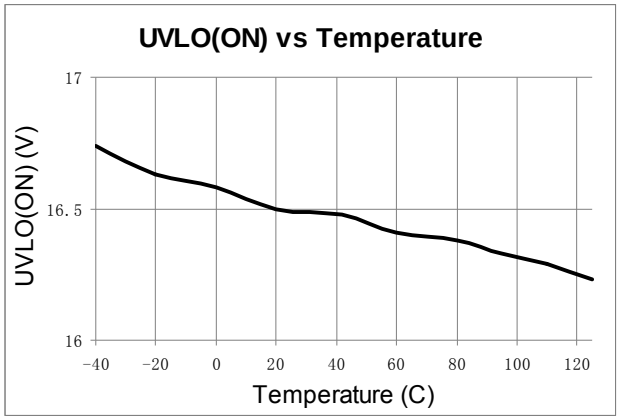
Note 1. Stresses beyond those listed under **"**Absolute Maximum Ratings**"** may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

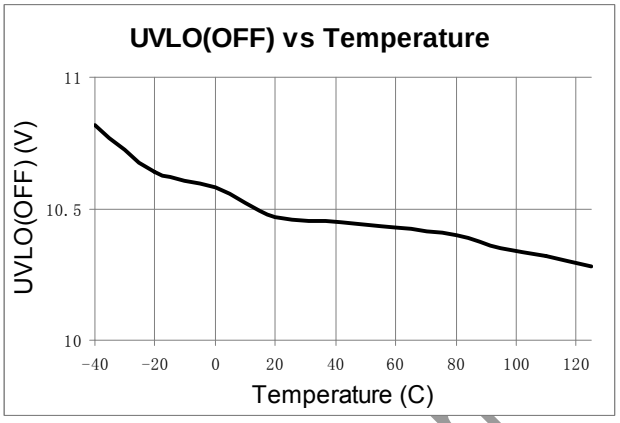
Note 2. The device is not guaranteed to function outside its operating conditions.

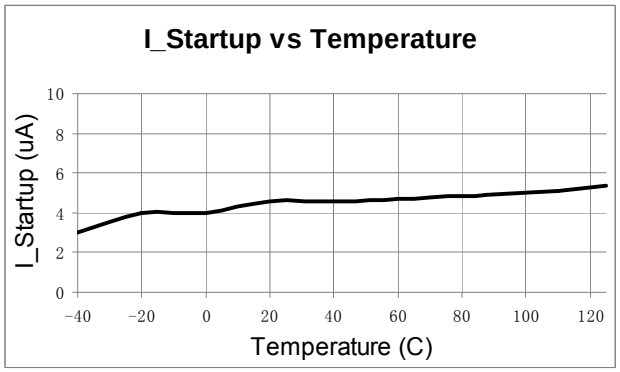
Note 3. The OLP debounce time is proportional to the period of switching cycle.

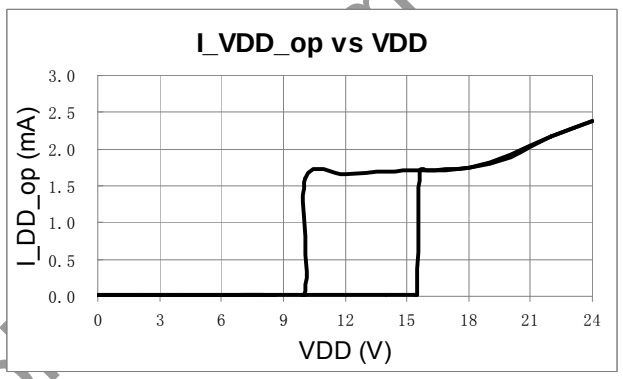
Note 4. Guaranteed by design.

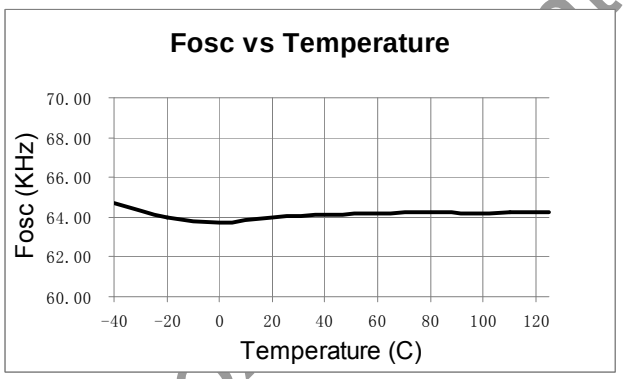
CHARACTERIZATION PLOTS

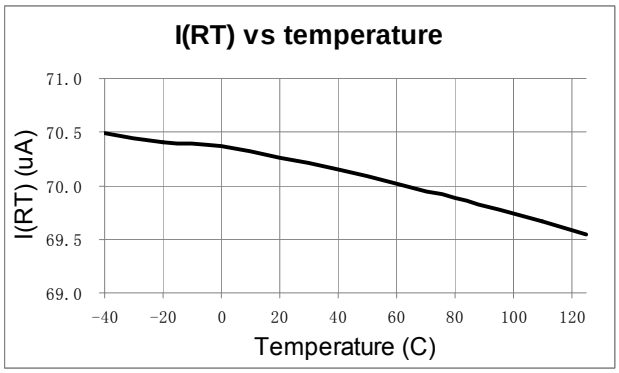


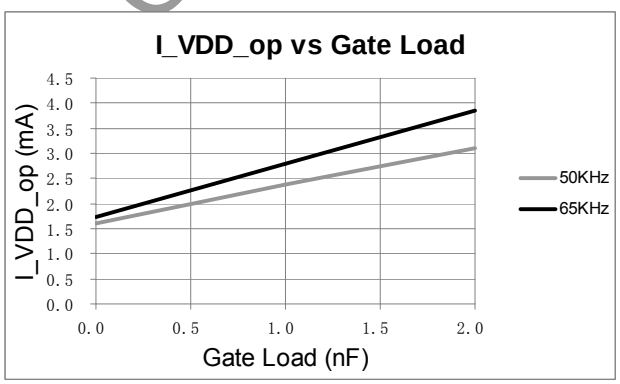


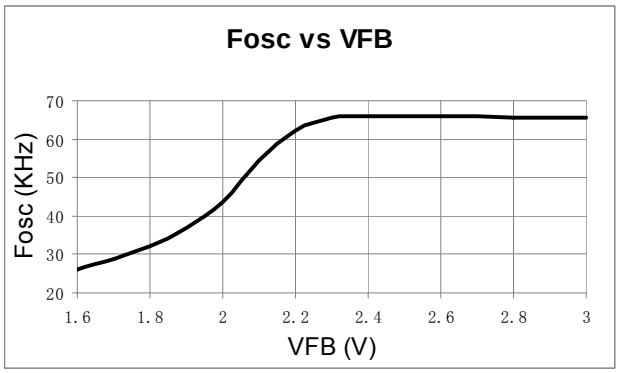


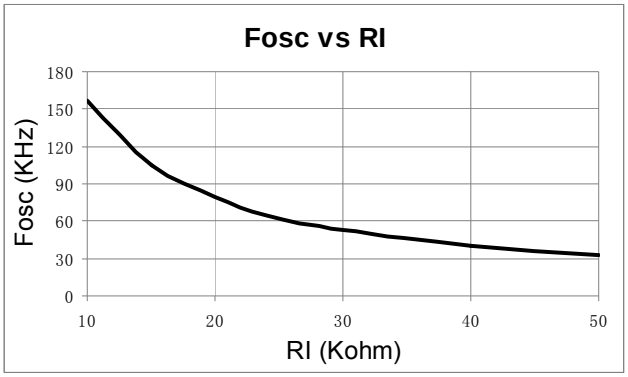


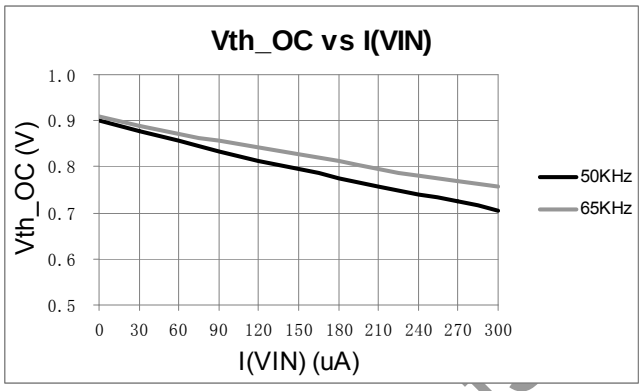












OPERATION DESCRIPTION

The COX3165 is a highly integrated current mode PWM controller for offline flyback converter applications. The versatile protection features and high performance make it a vey competitive for medium-to-large power converter applications.

● Start-up Current and Operating Current

The typical startup current of COX3165 is only about 5uA so that a high resistance startup resistor can be used to minimize power loss. For an AC/DC adapter with universal input range, a 2M Ohm, 1/8W startup resistor can be used to provide a fast startup and yet low power dissipation design solution.

The operating current has been reduced to 2.3mA. The low operating current enables a better efficiency and reduces the requirement of VDD hold up capacitance.

● Oscillator with "Hybrid Frequency Jittering"

Connect a resistor from RI pin to GND according to the equation below to program the normal switching frequency:

$$F_{OSC}(KHz) = \frac{1560}{RI(K\Omega)}$$

It can typically operate between 50kHz to 130kHz. To improve system EMI performance, COX3165 integrates proprietary "Hybrid Frequency Jittering" to operate the system with ±4% frequency jittering around setting frequency.

● Leading Edge Blanking (LEB)

Each time the power MOSFET is switched on, a turn-on spike occurs across the sensing resistor. The spike is caused by primary side capacitance and secondary side rectifier reverse recovery. To avoid premature termination of the switching pulse, an internal leading edge blanking circuit is built in. During this blanking period (250ns, typical), the PWM comparator is disabled and cannot switch off the gate driver. Thus, external RC filter with a small time constant is enough for current sensing.

● Built-in Slope Compensation

In the conventional application, the problem of the stability is a critical issue for current mode controlling, when it operates in higher than 50% of the duty-cycle. In COX3165, the slope compensation circuit is integrated by adding voltage ramp onto the current sense input voltage for PWM generation. This greatly improves the close loop stability at CCM and prevents the sub-harmonic oscillation and thus reduces the output ripple voltage.

● Constant Power Limiting

In flyback converter applications, the GATE drive delay can cause system OPP (Over Power Point) to change according to the AC line input voltage. In COX3165, a Proprietary "Constant Power Limiting" block is integrated to achieve constant max. output power capability over universal AC input range. Since the pin VIN is connected to the rectified input line voltage through the startup resistor, the current flowed into the VIN pin indicates the line voltage. Using the information of VIN pin current, the IC adjusts the cycle-by-cycle OCP threshold according to the following equation:

$$V_{TH\_OCP}(V) = 0.9 - 0.0278 \times RI \times I(VIN)$$

In this way, the system OPP variation can be compensated automatically.

● Soft Start

COX3165 features an internal 3ms (typical) soft start that slowly increases the threshold of cycle-by-cycle current limit comparator during startup sequence. It helps to prevent transformer saturation and reduce the stress on the secondary diode during startup. Every restart attempt is followed by a soft start activation.

● Green Mode Operation

Since the main power dissipation at light/zero load in a switching mode power supply is from the switching loss which is proportional to the PWM switching frequency. To fulfill green mode requirement, it is necessary to reduce the switching cycles under such conditions either by skipping some switching pulses or by reducing the switching frequency.

Smooth Frequency Foldback

In COX3165, a Proprietary "Smooth Frequency Foldback" block is integrated to foldback the PWM switching frequency when the loading is light. Compared to the other frequency reduction implementations, Coxsemi's proprietary "Smooth frequency foldback" block can reduce the PWM frequency smoothly without audible noise.

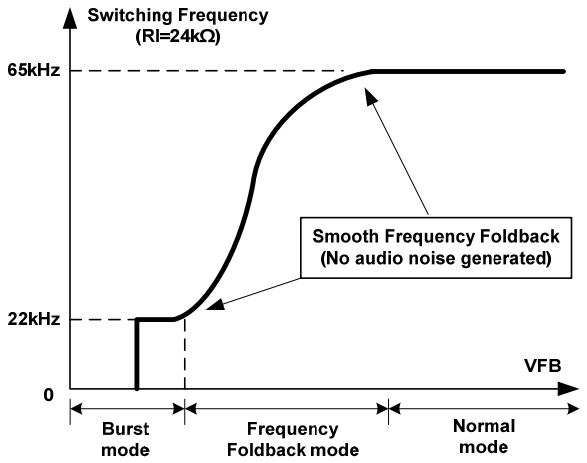


Fig.1

Burst Mode Control

When the loading is very small, the system enters into burst mode. When VFB drops below Vskip, COX3165 will stop switching and output voltage starts to drop, which causes the VFB to rise. Once VFB rises above Vskip, switching resumes. Burst mode control alternately enables and disables switching, thereby reducing switching loss in standby mode.

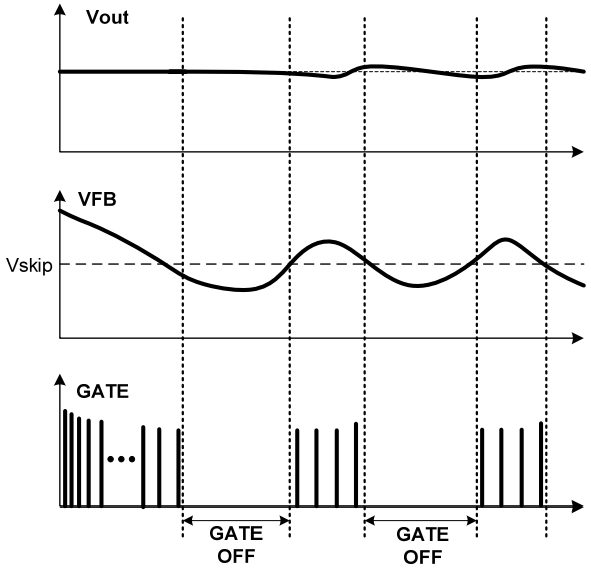


Fig.2

- **Gate Drive**

The output stage of COX3165 is a fast totem-pole gate driver with 800mA capability. Cross conduction has been avoided to minimize heat dissipation, increase efficiency, and enhance reliability. An internal 18V clamp is added for MOSFET gate protection at higher than expected VDD input. A soft driving waveform is implemented to minimize EMI.

- **Protections**

COX3165 provides many protections that can protect system from being damaged and enhance the system reliability. All the protections are listed as below:

Over Temperature Protection (OTP)

A NTC resistor in series with a regular resistor should be connected between RT and GND for temperature sensing and protection. NTC resistor value becomes lower when the ambient temperature rises. With the fixed internal 70uA current source (RI=24K Ohm) flowing through the resistors, the voltage at RT pin becomes lower at high temperature. The internal OTP circuit is triggered and shuts down the MOSFET when the sensed input voltage is lower than 1.065V. OTP protection is hysteresis type and will be released if RT pin voltage is higher than 1.165V.

VDD OVP (Over Voltage Protection)

VDD OVP (Over Voltage Protection) is implemented in COX3165 and it is a protection of hysteresis type.

Auto Recovery Mode Protection

As shown in Fig.3, once a fault condition is detected, PWM switching will stop. This will cause VDD to fall because no power is delivered form the auxiliary winding. When VDD falls to UVLO(OFF) (typical 10.5V), the protection is reset and the operating current reduces to the startup current, which causes VDD to rise, as shown in Fig.3. The system begins switching when VDD reaches to UVLO(ON) (typical 16.5V). However, if the fault still exists, the system will experience the above mentioned process. If the fault has gone, the system resumes normal operation. In this manner, the auto restart can alternatively enable and disable the switching until the fault condition is disappeared.

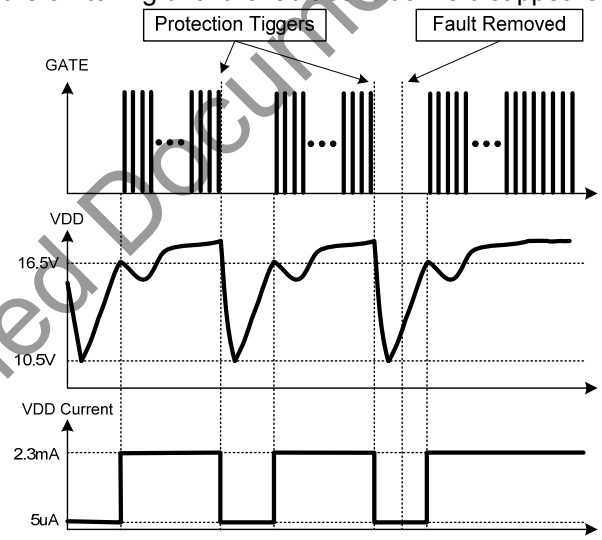


Fig.3

Over Load Protection (OLP)

When over load occurs, a fault is detected. If this fault is present for more than 82ms (typical), the protection will be triggered, the IC will experience an auto-recovery mode protection as mentioned above. The 82ms delay time is to prevent the false trigger from the power-on and turn-off transient

All Pins Floating and RI Pin Short-to-GND Protection

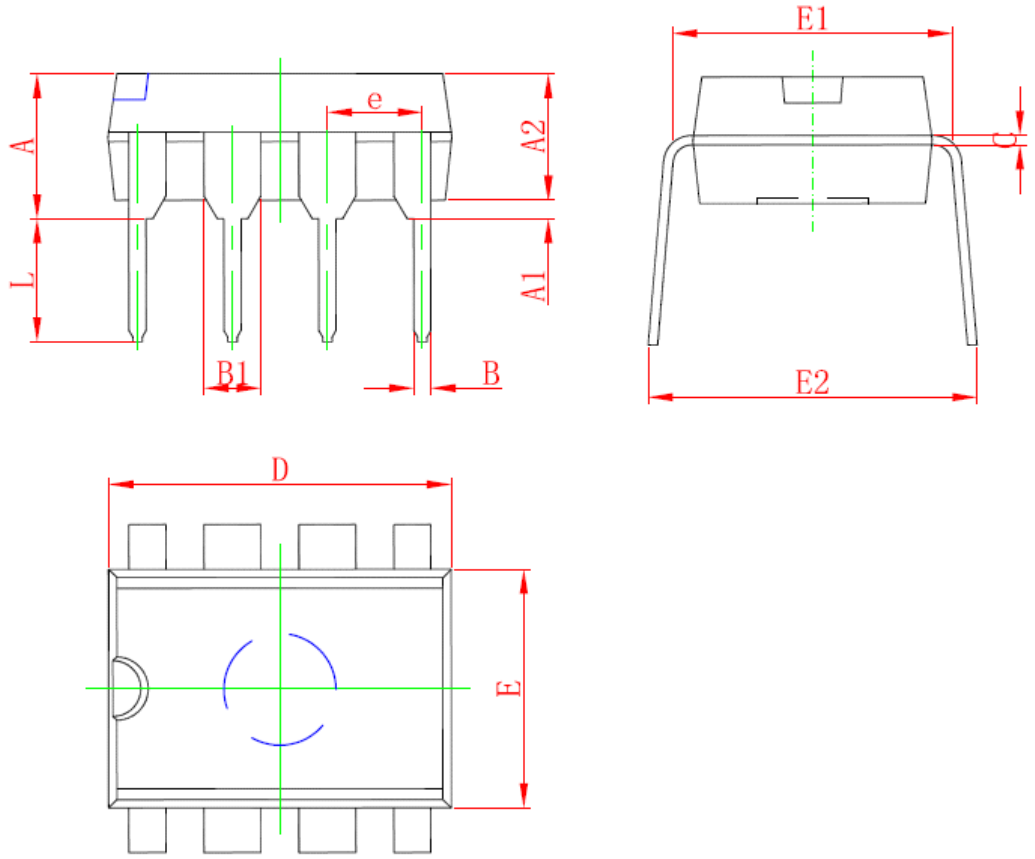
In COX3165, if pin floating situation occurs, the IC will cause no damage to the system. If CS and RI pin floating or RI pin short-to-GND occurs, the protection is triggered immediately and the system will experience the process of auto-recovery mode protection.

Cycle-by-Cycle Current Limiting

It is a basic protection and can be implemented easily in current mode PWM controller. The threshold of cycle-by-cycle current comparator is get from “Constant Power Limiting” block, which is mentioned above.

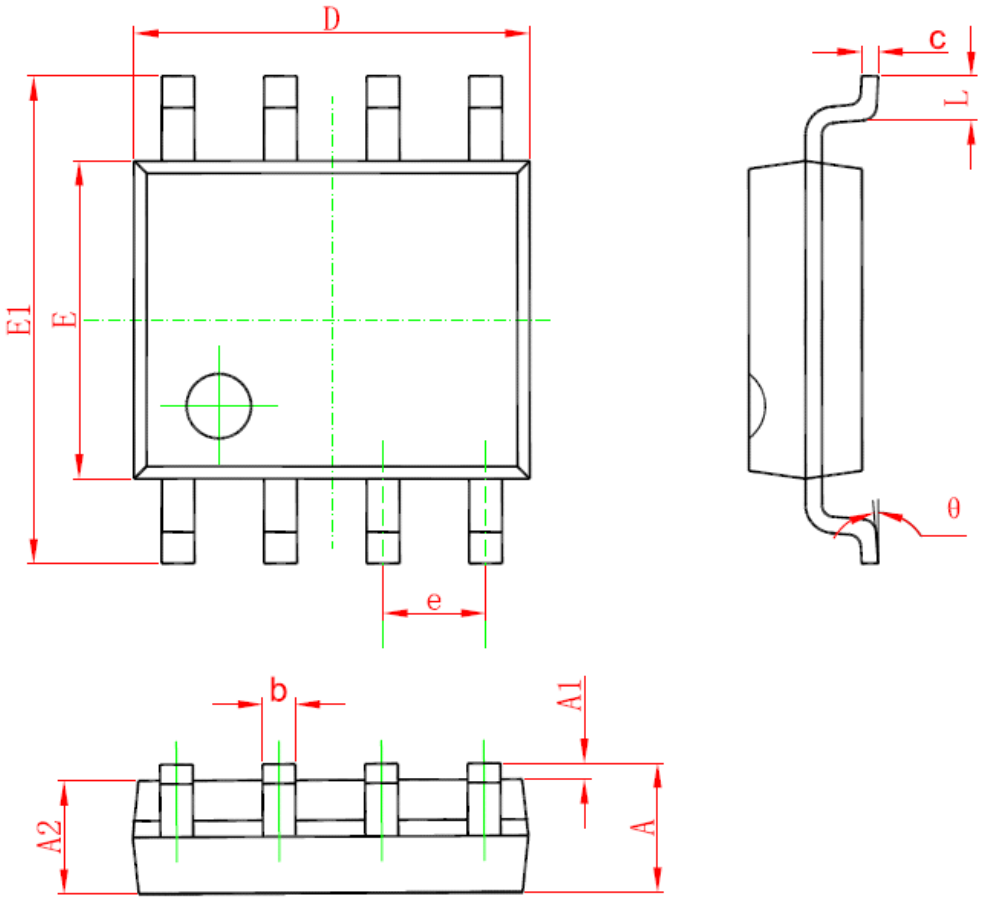
PACKAGE MECHANICAL DATA

DIP8 PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	3.710	5.334	0.146	0.210
A1	0.381		0.015	
A2	3.175	3.600	0.125	0.142
B	0.350	0.650	0.014	0.026
B1	1.524 (BSC)		0.06 (BSC)	
C	0.200	0.360	0.008	0.014
D	9.000	10.160	0.354	0.400
E	6.200	6.600	0.244	0.260
E1	7.320	7.920	0.288	0.312
e	2.540 (BSC)		0.1 (BSC)	
L	2.921	3.810	0.115	0.150
E2	8.200	9.525	0.323	0.375

SOP8 PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.150	0.185	0.203
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270 (BSC)		0.05 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

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