NEW PRODUCT

Description

The AP3301 is a peak-current control, Quasi-Resonant (QR) PWM controller which is optimized for high performance, low standby power and cost effective offline flyback converters.

At no load or light load, the IC will enter the burst mode to minimize standby power consumption. The minimum switching frequency (about 20kHz) is set to avoid the audible noise. At medium load, the IC will enter valley lock QR mode with frequency foldback to improve system efficiency and EMI performance. The maximum switching frequency (about 120kHz) is set to clamp the QR frequency to improve efficiency. At low line input & heavy load, when switching frequency decreases below 62KHz with output load increasing, the IC will enter CCM mode with fixed switching frequency of 62kHz to optimize low line power conversion efficiency. Furthermore, the frequency dithering function is built in to reduce EMI emission.

Internal slope compensation allows more stable peak-current mode control over wide range of input voltage and load conditions. Internal piecewise linear line compensation ensures constant output power limit over entire universal line voltage range.

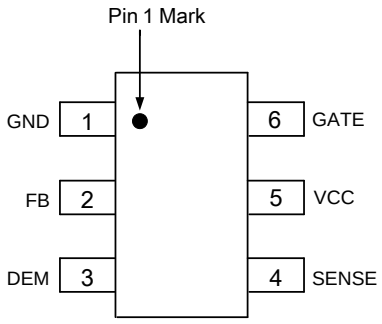
Comprehensive protection features are included, such as brown out protection, cycle-by-cycle current limit (OCP), VCC Over Voltage Protection (VOVP), Secondary-Side Output OVP (SOVP), internal OTP, Over Load Protection (OLP) and pins' fault protection.

Features

- Very Low Start-up Current
- Multi-Mode Control
- Quasi-Resonant Operation with Valley Lock
- Fixed Frequency CCM Operation at Low Line Heavy Load
- Non-Audible-Noise Quasi-Resonant Control
- Internal Slope Compensation
- Soft Start During Startup Process
- Frequency Fold Back for High Average Efficiency
- Secondary Winding Short Protection with FOCP
- Frequency dithering for Reducing EMI
- VCC Maintain Mode
- Useful Pin Fault Protection:
  SENSE Pin Floating
  FB/Opto-coupler Open/Short
- Comprehensive System Protection Feature:
  VCC Over Voltage Protection (VOVP)
  Over Load Protection (OLP)
- Brown Out Protection (BNO)
- Secondary Side OVP (SOVP)
- Mini Size Package of SOT26
- **Totally Lead-free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Pin Assignments

(Top View)



SOT26

Applications

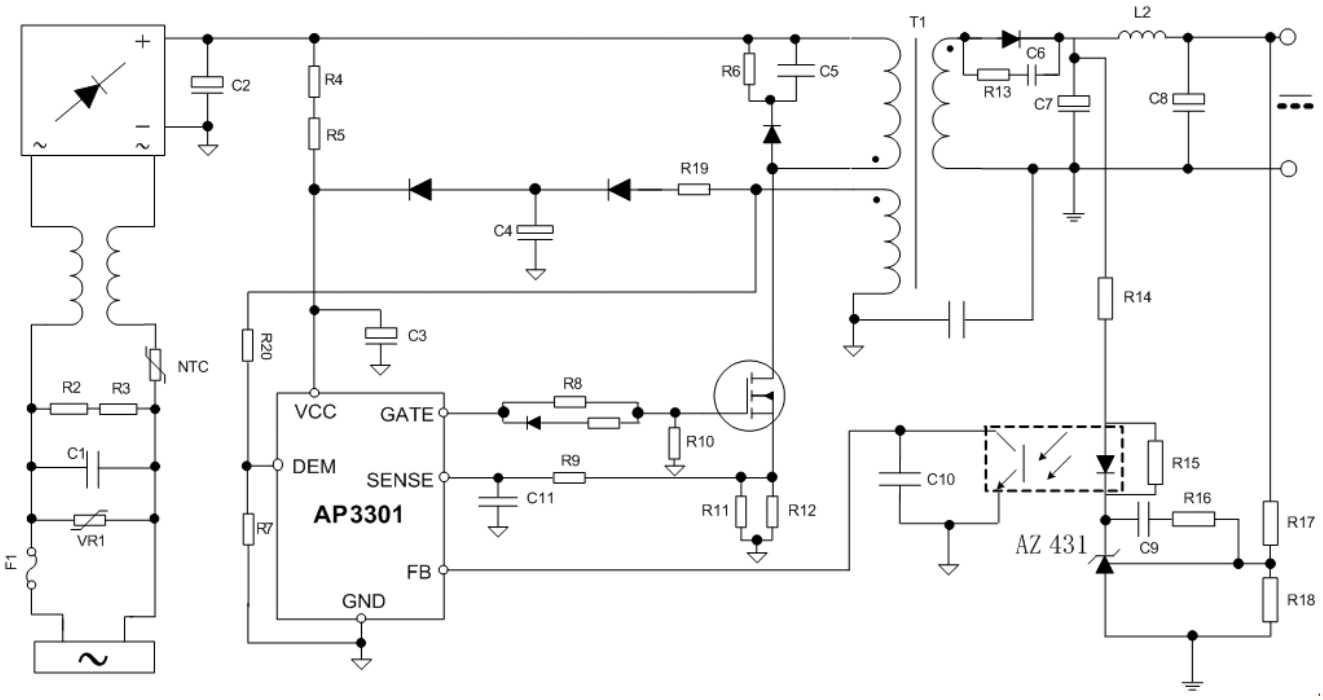
- Switching AC-DC Adapter/Charger
- ATX/BTX Auxiliary Power
- Set-Top Box (STB) Power Supply
- Open Frame Switching Power Supply

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See http://www.diodes.com/quality/lead_free.html for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

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Typical Applications Circuit



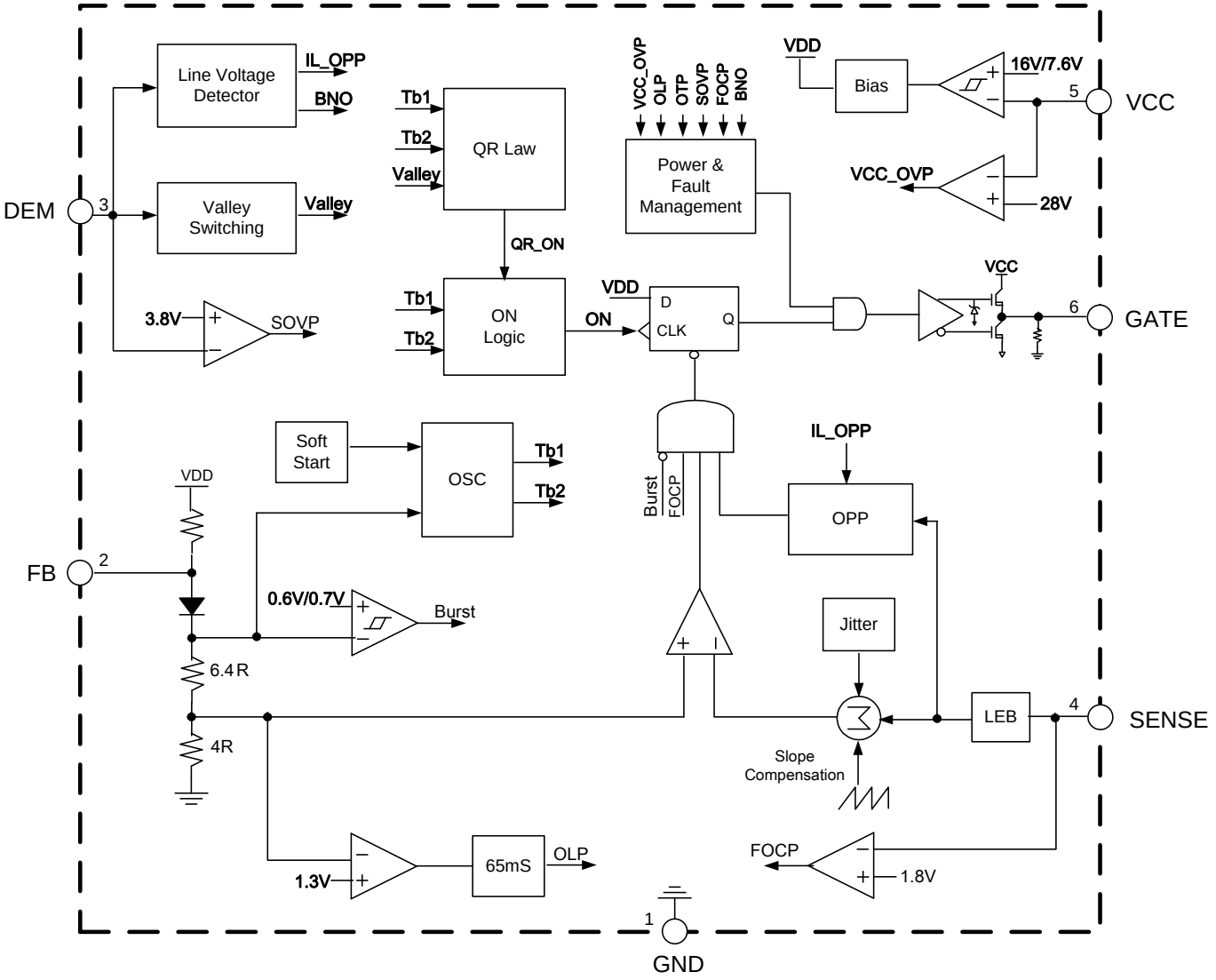
Pin Descriptions

Pin Number	Pin Name	Function
1	GND	Signal ground. Current return for driver and control circuits
2	FB	Feedback. Directly connected to the opto-coupler
3	DEM	Valley detection for QR control, AC line voltage detection for Brown-in/Brown-out trigger current and SOVP
4	SENSE	Current Sense
5	VCC	Supply voltage of driver and control circuits
6	GATE	Gate driver output

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Functional Block Diagram



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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Power Supply Voltage	30	V
I_O	Gate Output Current	350	mA
V_{FB}, V_{SENSE}, V_{DEM}	Input Voltage to FB, SENSE,DEM	-0.3 to 7	V
θ_{JA}	Thermal Resistance (Junction to Ambient)	250	°C/W
P_D	Power Dissipation at T_A < +25℃	500	mW
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature Range	+150	°C
–	ESD (Human Body Model)	3000	V
–	ESD (Machine Model)	200	V

Note 4: Stresses greater than 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 under "Recommended Operating Conditions" is not implied. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	10	25	V
T_A	Ambient Temperature	-40	+85	°C

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Electrical Characteristics (@T_A = -40 to +85°C, V_{CC} =18V, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supply Voltage (VCC Pin)						
I_{ST}	Startup Current	–	–	1	5	μA
I_{CC}	Operating Supply Current	V_{FB}=4V, C_L=0nF (Note 5)	1.5	1.8	2	mA
$I_{CC-FAULT}$	Operating Current If Fault Occurs	V_{FB}=4V, V_{CS}=0V (Note 5)	0.15	0.3	0.45	mA
V_{ST}	Startup Voltage	–	14.5	15.8	16.5	V
V_M	V_{CC} Maintain	–	9.0	9.4	9.8	V
V_{UVLO}	Shutdown Voltage	–	7.1	7.6	8.1	V
V_{CC-OVP}	V_{CC} OVP	–	27	28.5	30	V
PWM Section/Oscillator Section						
$f_{OSC-CCM}$	CCM Oscillation Frequency	–	57	62	67	kHz
$f_{OSC-MAXC}$	Maximum Clamp Frequency	–	110	120	130	kHz
$f_{OSC-GREEN}$	Green Mode Frequency	–	18	–	25	kHz
$f_{OSC-JITTER}$	Frequency Dithering	CCM (Note 6)	–	±8	±12	%
Current Sense Section (SENSE Pin)						
V_{CS-MAX}	Maximum SENSE Voltage	I_{DEM_SOURCE}=150μA	0.8	0.88	0.96	V
$V_{TH-FOCP}$	FOCP Voltage	–	1.6	1.8	2.0	V
$t_{DELAY-FOCP}$	FOCP Debounce Time (Note 6)	–	–	6	–	Cycles
t_{LEB}	LEB Time of SENSE	–	150	250	350	ns
$t_{DELAY-CS}$	Delay to Output (Note 6)	–	–	150	–	ns
Feedback Input Section (FB Pin)						
K_{FB-CS}	The Ratio of Input Voltage to Current Sense Voltage	–	–	3	–	V/V
R_{FB}	Input Impedance	–	15	20	25	kΩ
$I_{FB-SOURCE}$	Source Current	V_{FB}=0V	0.15	0.25	0.35	mA
$V_{FB-GREEN}$	The Threshold Enter QR Mode	–	–	3	–	V
G_{QR}	QR Mode Frequency Modulation Slope Versus V_{FB}	–	–	140	–	kHz/V
V_{BURST}	Input Voltage for Zero Duty	–	1.35	1.55	1.75	V
V_{FB-OLP}	Over Load Protection	–	–	4.5	–	V
t_{ON-MAX}	Maximum On Time	–	11	13	16	μs
$t_{SOFT-ST}$	Soft-Start Time	–	–	5	–	ms
$t_{DELAY-OLP}$	Delay of Over Load Protection	–	–	70	–	ms

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Electrical Characteristics (Cont.) (@T_A=-40 to +85°C, V_{CC}=18V, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Output Section (GATE Pin)						
V_{GATE-L}	Output Low Level	I_O=20mA, V_{CC}=12V	–	–	1	V
V_{GATE-H}	Output High Level	I_O=20mA, V_{CC}=12V	8	–	–	V
$V_{GATE-CLP}$	Output Clamping Voltage	–	11	13	15	V
$t_{GATE-RISE}$	Rising Time (Note 6)	C_L=1nF, V_{CC}=13V	–	140	200	ns
$t_{GATE-FALL}$	Falling Time (Note 6)	C_L=1nF, V_{CC}=13V	–	50	100	ns
Demagnetization Section (DEM Pin)						
V_{TH-DEM}	De-Magnetization Voltage	–	–	75	–	mV
I_{BNI}	Brown In Reference	–	80	85	90	μA
I_{BNO}	Brown Out Reference	–	72	79	84	μA
$V_{TH-SOVP}$	SOVP Threshold	–	3.5	3.8	4.1	V
t_{SAMPLE}	Sample Delay Time (Note 6)	–	–	2.5	–	μs
Delay Time Section						
$t_{DELAY-BNO}$	Brown Out Debounce Time	–	–	50	–	ms
$t_{DELAY-LATCH}$	Delay of Lacth Protection (Note 6)	SOVP, V_{CC} OVP	–	6	–	Cycles
Internal OTP Section						
OTP	OTP Enter (Note 6)	–	–	+150	–	°C
T_{HYS}	OTP Exit (Note 6)	–	–	+125	–	°C

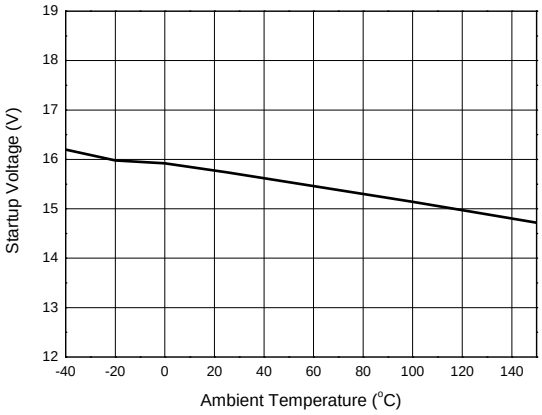
Notes: 5. Data measured in IC test mode.
6. Guaranteed by design.

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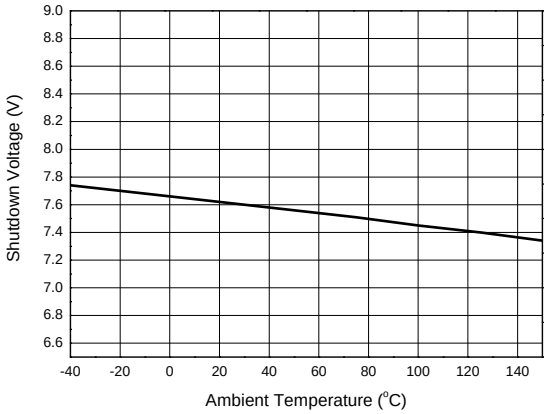
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Performance Characteristics

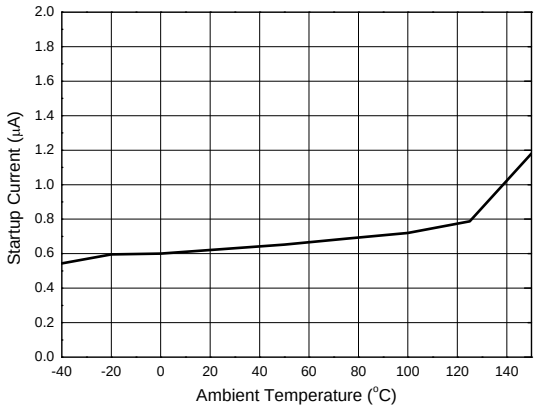
Startup Voltage vs. Ambient Temperature



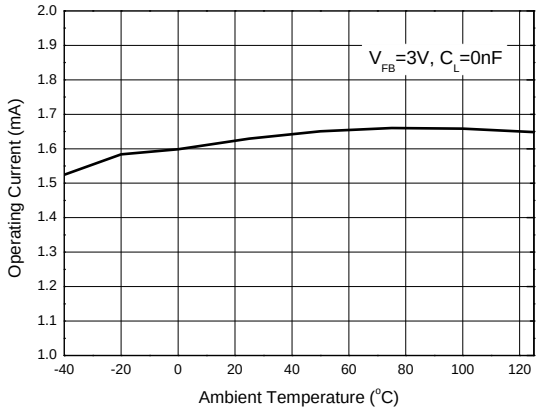
Shutdown Voltage vs. Ambient Temperature



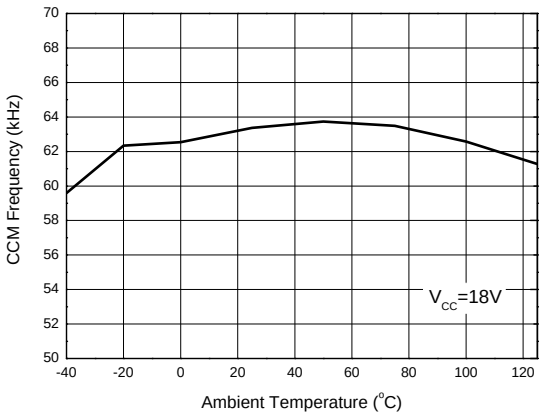
Startup Current vs. Ambient Temperature



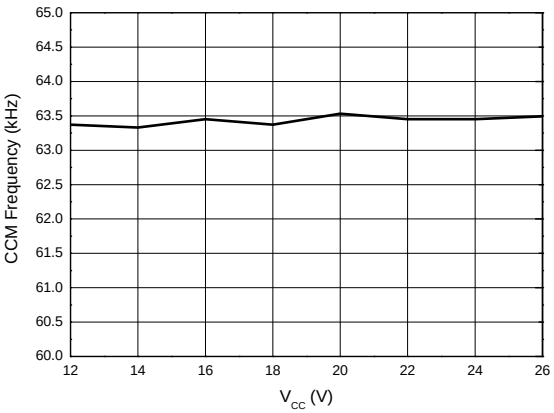
Operating Current vs. Ambient Temperature



CCM Frequency vs. Ambient Temperature



CCM Frequency vs. V_{CC}

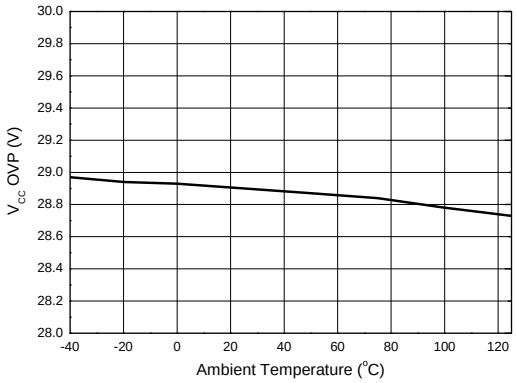


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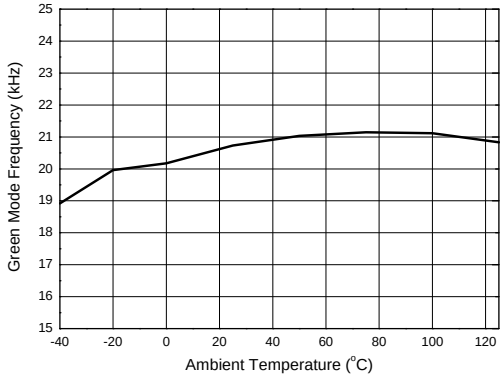
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Performance Characteristics (Cont.)

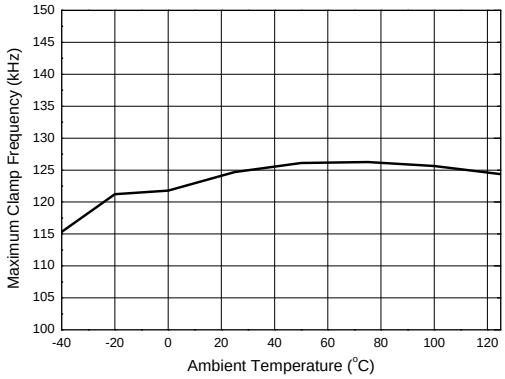
V_{CC} OVP vs. Ambient Temperature



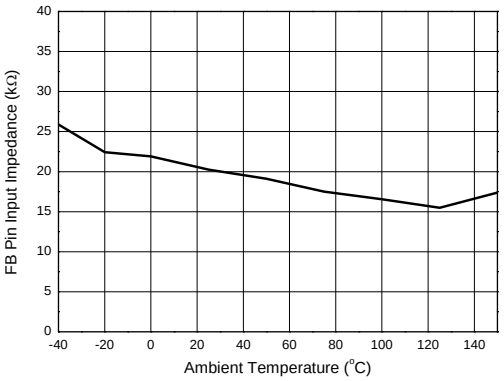
Green Mode Frequency vs. Ambient Temperature



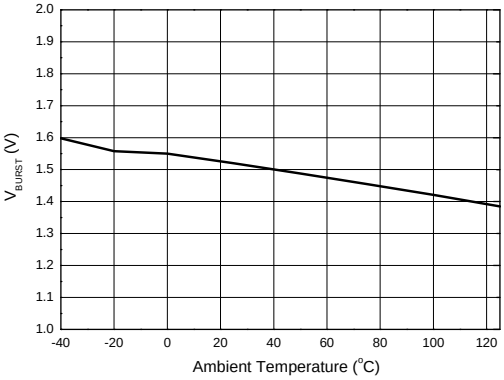
Maximum Clamp Frequency vs. Ambient Temperature



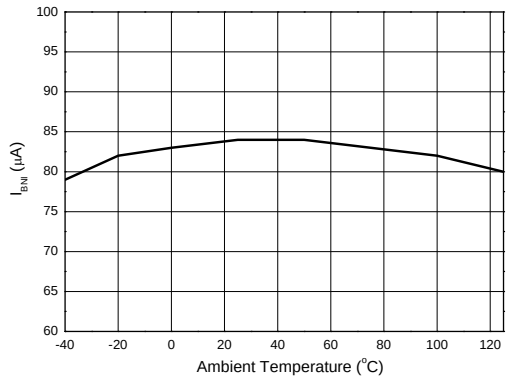
FB Pin Input Impedance vs. Ambient Temperature



V_{BURST} vs. Ambient Temperature



I_{BNI} vs. Ambient Temperature

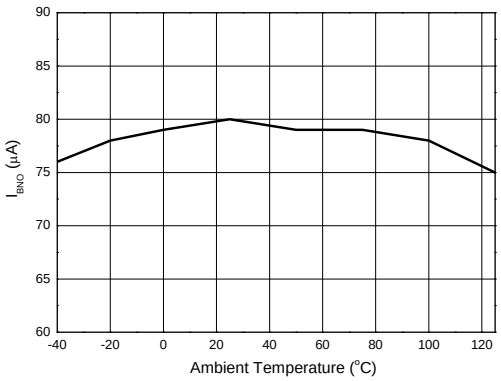


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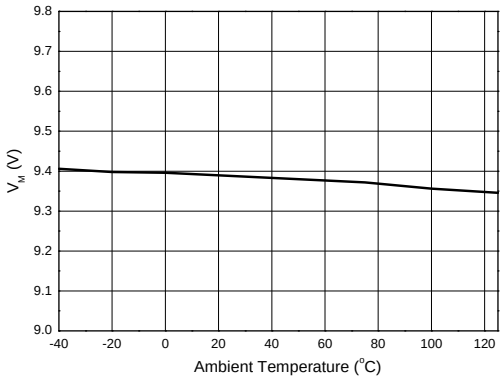
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Performance Characteristics (Cont.)

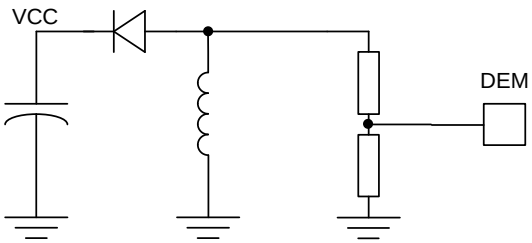
I_{BNO} vs. Ambient Temperature



V_M vs. Ambient Temperature



PIN3 Utilization for BNO/SOVP/OCP COMP



SOVP/IBNI/IBNO

Operation Description

The AP3301 realizes Multi-Mode Operation including Burst mode, QR mode and CCM mode, which is specifically designed for off-line AC-DC power supply used in LCD monitor, notebook adapter and battery charger applications. At medium load, the IC will enter valley lock QR mode with frequency foldback to improve system efficiency and EMI performance. It offers a cost effective solution with a versatile protection function.

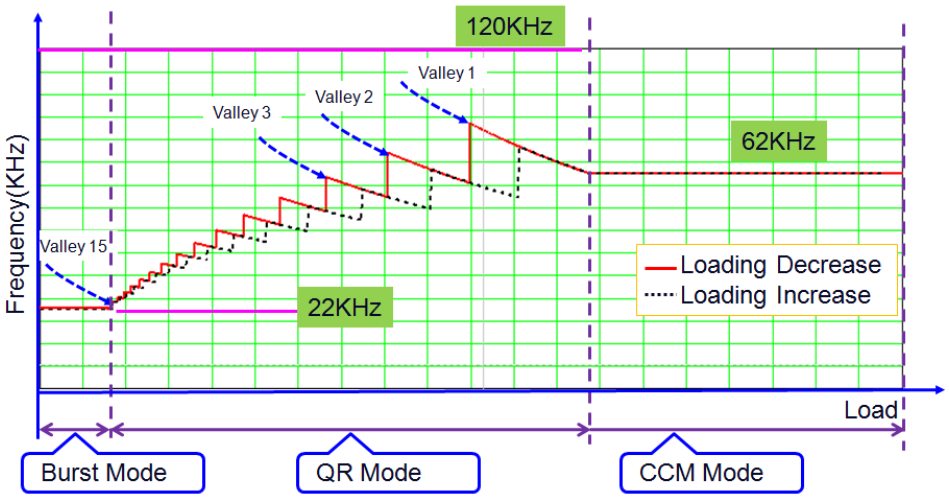


Figure 1

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Operation Description (Cont.)

Multi-Mode Operation

The switching frequency curve in Figure 1 shows three operation modes.

- Burst Mode
  At no load and light load, the system will operate at burst mode. In burst mode, the switching frequency is fixed at about 22kHz to avoid audible noise. When the FB voltage is lower than 1.55V, the controller will not provide driving signal and the FB voltage will rise above 1.65V, then the driving signal will resume. By this control strategy, the system will eliminate a bunch of pulses and the power loss is reduced.

- QR Mode
  QR is the abbreviation of Quasi-Resonant which means that the power MOSFET is forced to turn on at valleys of V_{DS}. With QR control, the switching power loss will be reduced by lower voltage stress of MOSFET. The V_{DS} valley is detected by DEM pin through the voltage divider network of R_{DEM} and R_{SOVP}, once the divided voltage is less than 75mV during turning off internal of MOSFET, the counter in AP3301 will count it as one valley. At light load and medium load, the system will enter QR mode. As the load changes, the trend of the switching frequency in QR mode is modulated by AP3301 and following the internal arithmetic it is increased or decreased. In general when the turning-on valley changes, the frequency will jump to a new value, this frequency jump transits quickly and the turning-on valley changes between two neighboring valleys back and forth, this unstable condition introduces unacceptable audible noise. In benefit of Diodes proprietary "Valley Lock" technology, the turning on valley is locked and will not switch iteratively when the load is changed. Meanwhile, the frequency dithering function is built in to reduce EMI emission. As Figure 2 shows, switching frequencies between the power increase and power decrease line are a little different because of the inherent characteristic of valley-lock QR control, and it will result in a tiny difference in efficiency. When the load increases, the switching frequency is also increased, a frequency of 120kHz is set to clamp the maximum operating frequency, if this 120kHz is touched, the system will operate in normal DCM mode, and will return to QR if the load continues to increase.

- CCM Mode
  With the load increases, if the switching frequency decreases below 62kHz in valley1 mode, CCM mode is implemented to achieve high efficiency. Usually at low line voltage, the system will enter CCM mode at heavy load, while high line voltage the system may still operate at QR mode with 1st or 2nd valley on.

Start-up Current and UVLO

The start-up current of AP3301 is optimized to realize ultra low current (1μA typical) so that VCC capacitor can be charged more quickly. The direct benefit of low start-up current is the availability of using large start-up resistor, which minimizes the resistor power loss for high voltage AC input.

An UVLO comparator is included in AP3301 to detect the voltage on VCC pin. It ensures that AP3301 can draw adequate energy from hold-up capacitor during power-on. The turn-on threshold is 15.8V and the turn-off threshold is 7.6V.

Current Sense Comparator and PWM Latch

The AP3301 operates as a current mode controller, the output switch conduction is initiated by every oscillator cycle and is terminated when the peak inductor current reaches the threshold level established by the FB pin. The inductor current signal is converted to a voltage signal by inserting a reference sense resistor R_S. The inductor current under normal operating conditions is controlled by the voltage at FB pin. The relation between peak inductor current (I_{PK}) and V_{FB} is:

$$I_{PK} = (V_{FB} - 1.0) / 3R_S$$

Moreover, FOCP with 1.8V threshold is only about $t_{DELAY\text{-}FOCP}$ delay, which can avoid some catastrophic damages such as secondary rectifier short test. Few drive cycles can alleviate the destruction range and get better protection.

Leading-edge Blanking

A narrow spike on the leading edge of the current waveform can usually be observed when the power MOSFET is turned on. A t_{LEB} time leading-edge blank is built-in to prevent the false-triggering caused by the turn-on spike. During this period, the current limit comparator is disabled and the gate driver cannot be switched off.

At the time of turning off the MOSFET, a negative undershoot (maybe larger than -0.3V) can occur on the SENSE pin. So it is strongly recommended to add a small RC filter or at least connect a resistor "R" on this pin to protect the IC (Shown as Figure 2).

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Operation Description (Cont.)

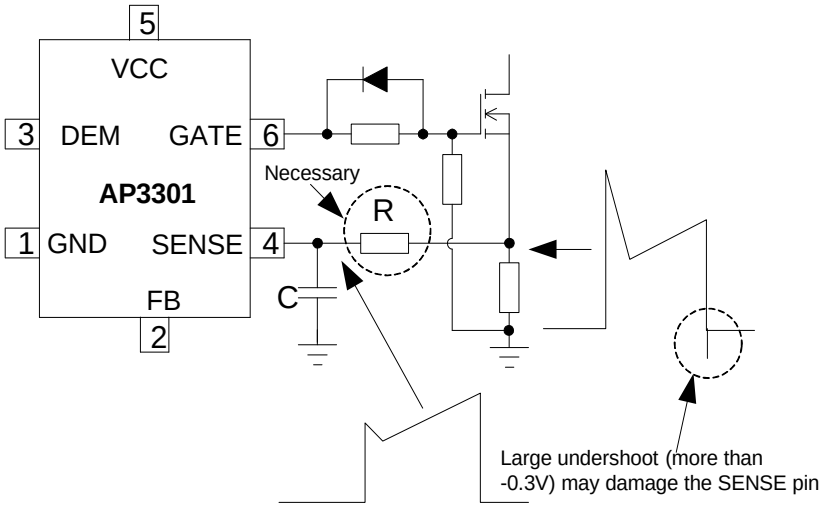


Figure 2

Built-in Slope Compensation

It is well known that a continuous current mode SMPS may become unstable when the duty cycle exceeds 50%. The built-in slope compensation can improve the stability, so there is no need for design engineer to spend much time on that.

FB Pin and Short Circuit Protection

This pin is normally connected to the opto-coupler and always paralleled with a capacitor for loop compensation. When the voltage at this pin is greater than V_{FB-OLP} and lasts for about $t_{DELAY-OLP}$, the IC will enter the protection mode. For AP3301, the system will enter hiccup mode to wait the V_{CC} decreasing to low UVLO level, then the IC will try to restart until the failure removed. And when this voltage is less than 1.55V, the IC will stop the drive pulse immediately. Therefore, this feature can be used for short circuit protection, which makes the system immune from damage. Normally, output short makes the V_{FB} value to the maximum because the opto-coupler is cut off.

When V_{CC} decreases to a setting threshold, the V_{CC} maintain comparator will output some drive signal to make the system switch and provide a proper energy to VCC pin. The V_{CC} maintain function will cooperate with the PWM and burst mode loop which can make the output voltage variation be within the regulation. This mode is very useful for reducing startup resistor loss and achieving a better standby performance with a low value VCC capacitor. The V_{CC} is not easy to touch the shutdown threshold during the startup process and step load. This will also simplify the system design. The minimum VCC voltage is suggested to be designed a little higher than V_{CC} maintain threshold thus can achieve the best balance between the standby and step load performance.

Brown-in/Brown-out

During turning-on interval of primary power MOSFET, the DEM pin is clamped to GND, the current flows through R_{DEM} and pin DEM reflecting the rectified value of AC line voltage as showed as Figure 3, this current multiplies with R_{BNO} represents the sample voltage of AC line voltage, take the peak value of the sample voltage to compare with the internal fixed threshold.

When the AC source is on, the IC will send several drive signals to confirm that the DEM pin current is higher than I_{BNI} during primary MOSFET turning on time, then AP3301 starts to provide drive signal, and if the current decreases below I_{BNO} for about 50ms, AP3301 enters brown out protection and no drive pulse output, a new startup will not begin until the sampled signal is lower than I_{BNI} again and V_{CC} is higher than V_{UVLO} threshold.

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Operation Description (Cont.)

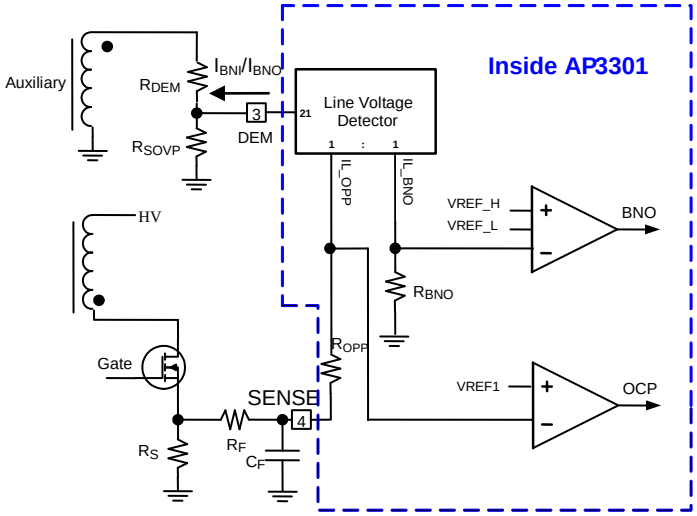


Figure 3

SOVP Protection Function

For some applications, the system requires the output over voltage protection function. The DEM pin compares the divided voltage from the VCC winding with the inner threshold, when the voltage between R_{DEM} and R_{SOVP} is higher than $V_{TH\text{-}SOVP}$ during primary power MOSFET turning off duration, AP3301 will trigger SOVP function and the system will enter the latch protection mode. Since the value of VCC winding's waveform reflects the output voltage precisely, the Secondary Output Voltage Protection (SOVP) can be achieved by this function.

Other System Protection and Pin Fault Protection

The AP3301 provides versatile system and pin fault protections. The OCP comparator realizes the cycle-by-cycle current limiting (OCP). In universal input line voltage, the IC realizes the constant over load protection (OLP). VCC over voltage protection can be applied as the primary OVP or opto-coupler broken protection. The AP3301 also has pin fault connection protection including floating and short connection. The floating pin protection includes the SENSE, FB, etc. The short pin protection includes the DEM pin short protection. When these pins are floated or DEM pin is shorted to ground, PWM switching will be disabled, thus protecting the power system.

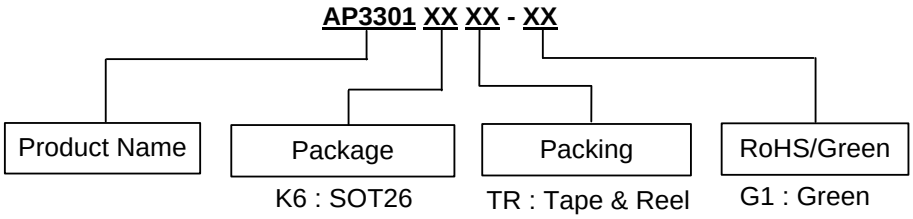
Internal OTP Protection Function

The AP3301 integrates an internal temperature sensor. It has a trigger window of entering OTP mode at +150°C and exiting at +125°C. The internal OTP protection mode is auto-recovery mode.

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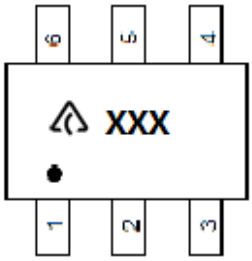
Ordering Information



Package	Part Number	Marking ID	Packing
SOT26	AP3301K6TR-G1	GTC	3000/Tape & Reel

Marking Information

(Top View)



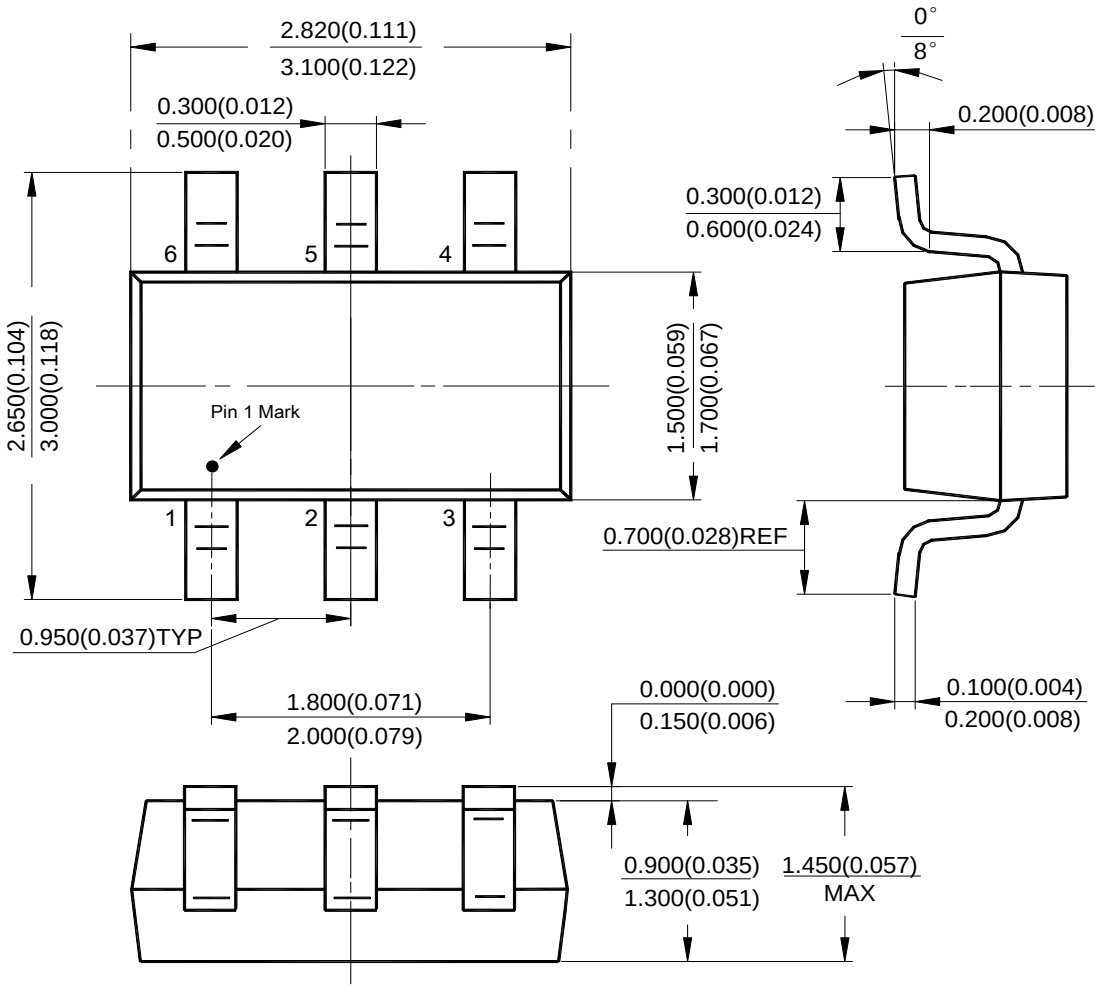
: Logo
XXX: Marking ID (See Ordering Information)

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NEW PRODUCT

Package Outline Dimensions (All dimensions in mm(inch).)

(1) Package Type: SOT26

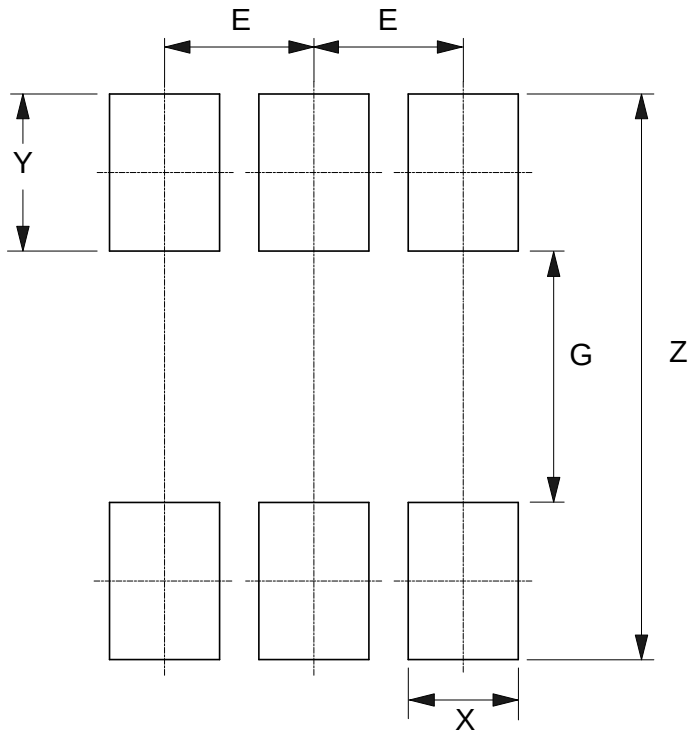


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NEW PRODUCT

Suggested Pad Layout

(1) Package Type: SOT26



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (mm)/(inch)
Value	3.600/0.142	1.600/0.063	0.700/0.028	1.000/0.039	0.950/0.037

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NEW PRODUCT

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