

GREEN MODE PWM CONTROLLER
AP3102/V/L
General Description

The AP3102/V/L series is a green-mode PWM controller with low start-up current. At normal operation, the switching frequency is externally programmable and trimmed to tight range, the frequency dithering technique is also equipped to improve the EMI performance. When the load is very low or zero, the IC enters green mode and skip mode to minimize switching loss. In skip mode, the PWM switching frequency is about 20kHz to avoid the audible noise and reduce the standby loss.

The AP3102/V/L series features a lot of functions such as the Leading-Edge Blanking (LEB) of the current sensing, internal slope compensation, line compensation, and several protection functions including cycle-by-cycle current limit (OCP), over voltage protection (VCC or line voltage), OTP, OLP and brownout protection.

The AP3102/V/L series provides 3 different versions with optional protection functions. AP3102 has external trigger latch shutdown only (VOVP and OLP are auto recoverable). AP3102V supports both VOVP and external latch shutdown. AP3102L provides latch shutdown control for VOVP, OLP and external trigger.

This IC is available in SOIC-8 and DIP-8 packages.

Features

- Bi-CMOS Process with Excellent Performance
- Very Low Start-up Current: 5 μ A typical
- Current Mode Control
- Non-audible-noise Green Mode Control
- Frequency Foldback for High Average Efficiency
- Internal Slope Compensation
- Programmable Brownout Protection
- Programmable Line Compensation
- Useful Pin Fault Protection:
 - SENSE Pin Floating
 - RI Pin Short to Ground
 - RI Pin Floating
- Smart Latch/Auto-recoverable Protection Option
- Comprehensive Protection Feature:
 - VCC Over Voltage Protection (VOVP)
 - Line Over Voltage Protection (LOVP)
 - Over Temperature Protection (OTP)
 - Over Load Protection (OLP)
- Internal Soft Start Function During Start-up
- 500mA Gate Output Current Capability

Applications

- Switching AC-DC Adapter
- LCD Monitor/TV Power
- Open Frame Switching Power Supply

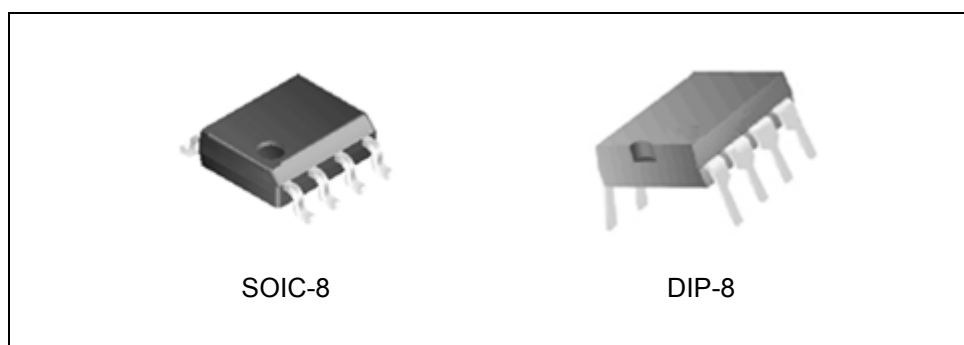


Figure 1. Package Types of AP3102/V/L

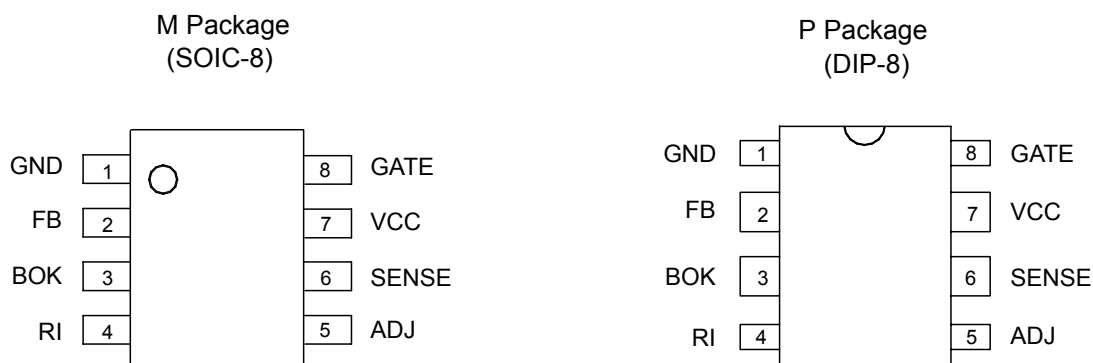
GREEN MODE PWM CONTROLLER
AP3102/V/L
Pin Configuration


Figure 2. Pin Configuration of AP3102/V/L (Top View)

Pin Description

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	BOK	Brownout Protection Pin. Connected to a resistor divider from the ground to bulk capacitor for setting the brownout level and line compensation. When the voltage of this pin is lower than 0.5V and lasts 35ms, the PWM signal will be off and system enters the auto recoverable protection mode (hiccup mode). Moreover this pin is also for the line OVP (trigger level is 4V) and line compensation (compensate the current sense for over load protection.)
4	RI	Set the bias current to determine the normal switching frequency
5	ADJ	To adjust the level of skip cycle. When its value is greater than 4.5V, the system will be latched
6	SENSE	Current sense
7	VCC	Supply voltage of driver and control circuits
8	GATE	Gate driver output

GREEN MODE PWM CONTROLLER

AP3102/V/L

Functional Block Diagram

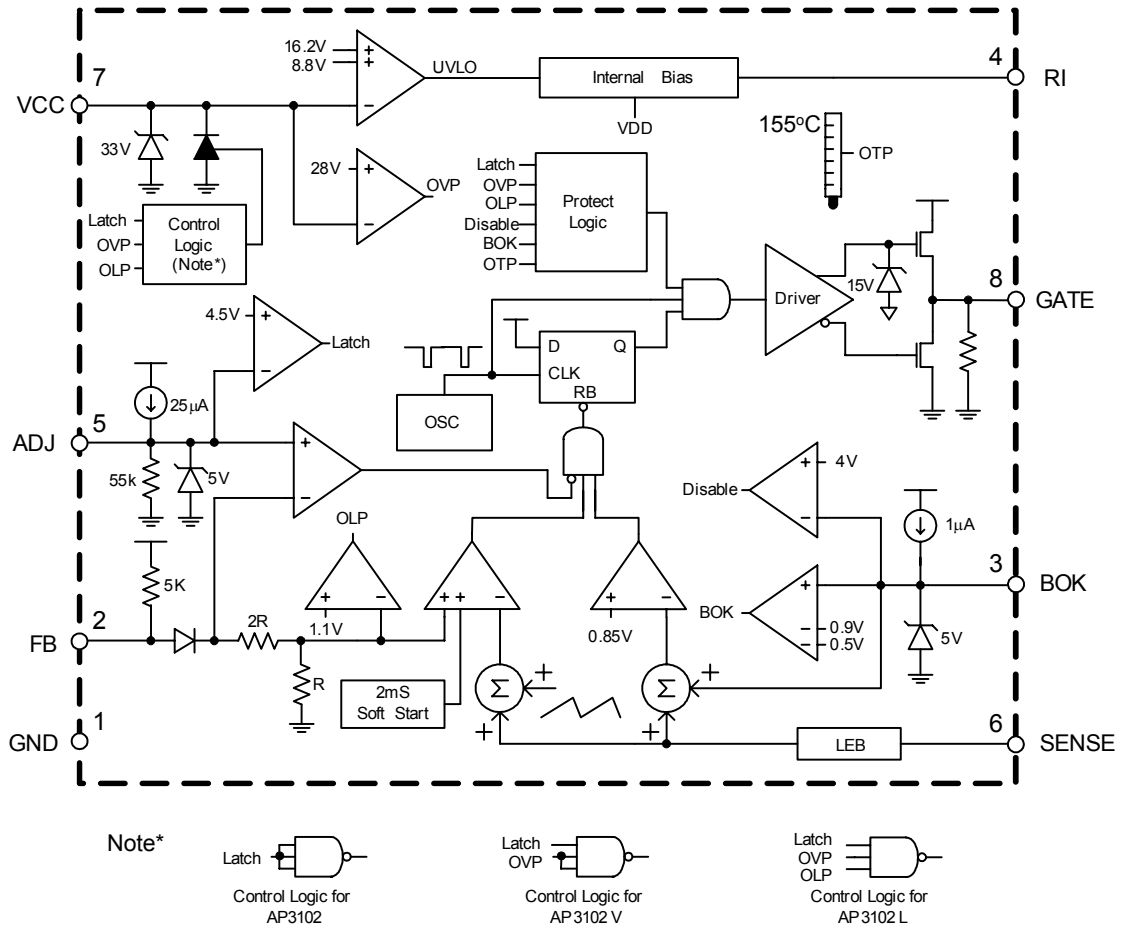


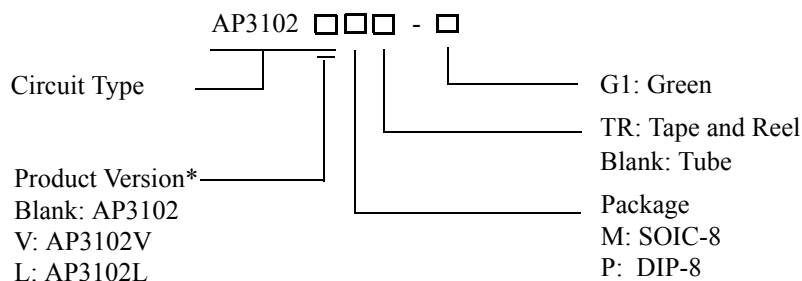
Figure 3. Functional Block Diagram of AP3102/V/L



GREEN MODE PWM CONTROLLER

AP3102/V/L

Ordering Information



Package	Temperature Range	Part Number	Marking ID	Packing Type
SOIC-8	-40 to 85°C	AP3102M-G1	3102M-G1	Tube
		AP3102MTR-G1	3102M-G1	Tape & Reel
		AP3102VM-G1	3102VM-G1	Tube
		AP3102VMTR-G1	3102VM-G1	Tape & Reel
		AP3102LM-G1	3102LM-G1	Tube
		AP3102LMTR-G1	3102LM-G1	Tape & Reel
DIP-8	-40 to 85°C	AP3102P-G1	AP3102P-G1	Tube
		AP3102VP-G1	AP3102VP-G1	Tube
		AP3102LP-G1	AP3102LP-G1	Tube

BCD Semiconductor's products, as designated with "G1" suffix in the part number, are RoHS compliant and Green.

*** Product Version Classification (with Different Protection Functions)**

Product Version	External Trigger by ADJ	VOVP	Output Short (OLP)
AP3102	Latch	Auto-Recoverable	Auto-Recoverable
AP3102V	Latch	Latch	Auto-Recoverable
AP3102L	Latch	Latch	Latch

**GREEN MODE PWM CONTROLLER****AP3102/V/L****Absolute Maximum Ratings (Note 1)**

Parameter	Symbol	Value		Unit
Power Supply Voltage	V_{CC}	30		V
Gate Output Current	I_O	500		mA
Input Voltage to FB, SENSE pin	V_{FB}, V_{SENSE}	-0.3 to 7		V
Input Voltage to RI, ADJ pin	V_{RI}, V_{ADJ}	-0.3 to 7		V
Thermal Resistance Junction to Ambient	θ_{JA}	DIP-8	83	°C/W
		SOIC-8	186	
Power Dissipation and Thermal Characteristic, SENSE at $T_A < 25^\circ\text{C}$	P_D	DIP-8	1359	mW
		SOIC-8	550	
Operating Junction Temperature	T_J	-40 to 150		°C
Storage Temperature Range	T_{STG}	150		°C
ESD (Human Body Model)		2500		V
ESD (Machine Model)		250		V

Note 1: 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

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



GREEN MODE PWM CONTROLLER

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Electrical Characteristics

V_{CC}=16V, T_A=25°C, unless otherwise specified.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage (VCC Pin)						
Start-up Current	I _{START-UP}	V _{CC} =14.8V		5	15	μA
Operating Supply Current	I _{CC}	V _{FB} =0V, C _L =1nF	1.5	2.5	3.5	mA
		V _{FB} =3V, C _L =1nF	2	3	4	
UVLO (on)			15.2	16.2	17.2	V
UVLO (off)			7.8	8.8	9.8	V
VCC OVP			27	28.5	30	V
VCC Clamp		I _{CC} =5mA			34	V
De-Latch VCC			4.5	6	7.5	V
PWM Section/Oscillator Section						
Maximum Duty Cycle			70	75	80	%
Minimum Duty Cycle				0		
Oscillation Frequency		R _{RI} =26kΩ	60	65	70	kHz
Frequency in Skip Mode		R _{RI} =26kΩ	22			kHz
Frequency Temperature Stability		-40°C to 85°C			5	%
Frequency Voltage Stability		V _{CC} =12V to 30V			3	%
Frequency Dithering				±6		%
Current Sense Section (SENSE Pin)						
Maximum SENSE Voltage	V _{CS}	V _{BOK} =0.95V	0.75	0.8	0.85	V
		V _{BOK} =2.76V	0.63	0.68	0.73	
LEB Time of SENSE		R _{RI} =26kΩ	150	250	350	ns
Delay to Output			50	150	250	ns
Soft-start Time		R _{RI} =26kΩ		2		ms
Feedback Input Section (FB Pin)						
The Ratio of Input Voltage to Current Sense Voltage			2.5	3	3.5	V/V
Input Impedance			3	4.5	6	kΩ
Source Current					-2	mA
Input Voltage for Zero Duty		V _{ADJ} =0V			1.2	V

**GREEN MODE PWM CONTROLLER****AP3102/V/L****Electrical Characteristics (Continued)** $V_{CC}=16V$, $T_A=25^{\circ}C$, unless otherwise specified.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Section (GATE Pin)						
Output Low Level		$I_O=50mA$, $V_{CC}=12V$			1	V
Output High Level		$I_O=50mA$, $V_{CC}=12V$	8.5			V
Output Clamping			13	15	17	V
Rising Time		$C_L=1nF$, $V_{CC}=13V$	150	250	350	ns
Falling Time		$C_L=1nF$, $V_{CC}=13V$	30	50	90	ns
Brownout Protection (BOK Pin)						
Brownout Turn-on			0.85	0.9	0.95	V
Brownout Turn-off			0.45	0.5	0.55	
Clamp Voltage on BOK		$I_{BOK}=1mA$	5.5	6.2	6.9	V
Line Compensation Ratio				0.055		
Line OVP Voltage			3.5	4	4.5	V
Skip Cycle Section (ADJ Pin)						
Source Current			10	25	45	μA
Latch Trigger Voltage			4.2	4.5	4.8	V
Clamp Voltage on ADJ			4	5	6	V
Input Impedance			35	50	65	$k\Omega$
Over-Temperature Protection Section						
Shutdown Temperature				155		$^{\circ}C$
Temperature Hysteresis				25		$^{\circ}C$
Delay Time Section						
Delay 1 of Protection		$R_{RI}=26k\Omega$, Output short and OLP, BOK pin trigger for turning off	25	35	45	ms
Delay 2 of Protection		$R_{RI}=26k\Omega$, ADJ, VCC OVP, Line OVP BOK pin trigger for turning on		25		μs



Typical Performance Characteristics

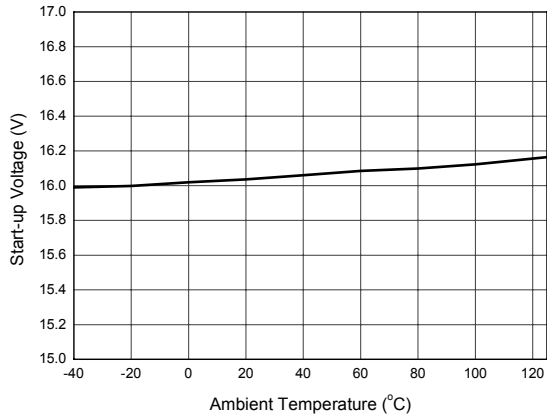


Figure 4. Start-up Voltage vs. Ambient Temperature

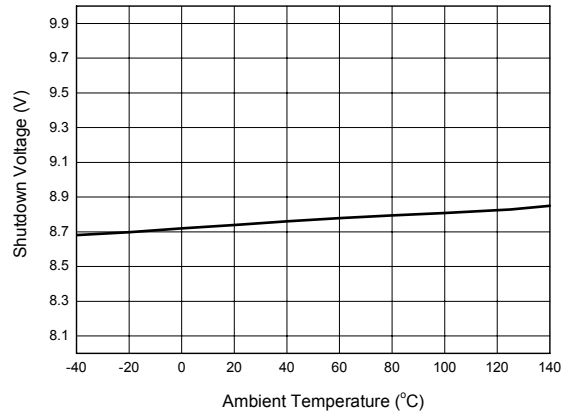


Figure 5. Shutdown Voltage vs. Ambient Temperature

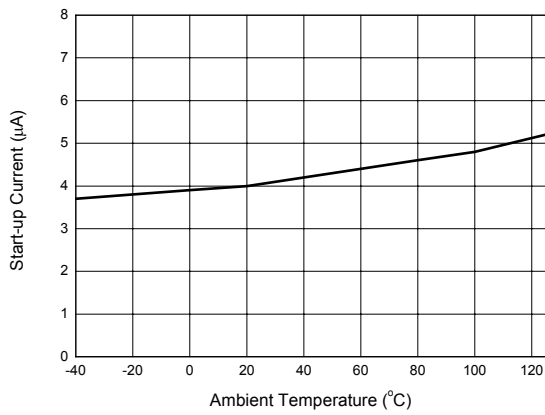


Figure 6. Start-up Current vs. Ambient Temperature

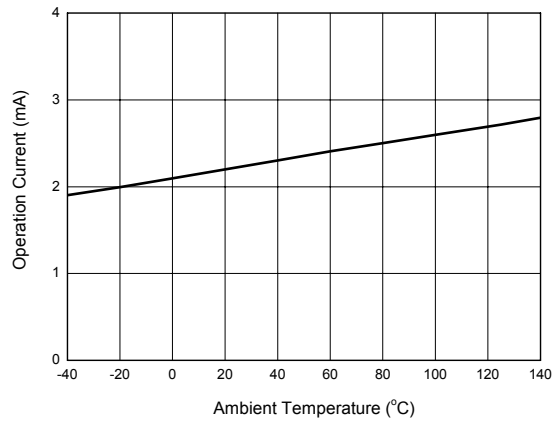


Figure 7. Operation Current vs. Ambient Temperature



Typical Performance Characteristics (Continued)

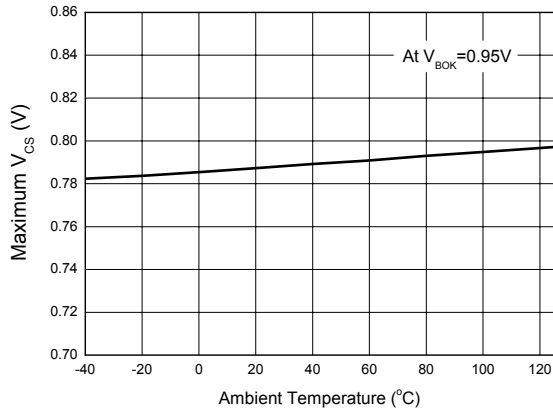


Figure 8. Maximum V_{CS} vs. Ambient Temperature

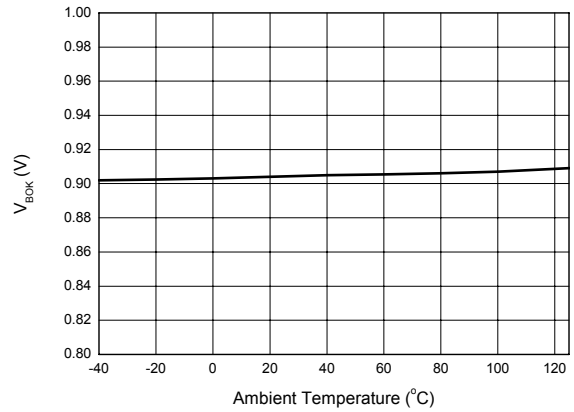


Figure 9. V_{BOK} vs. Ambient Temperature

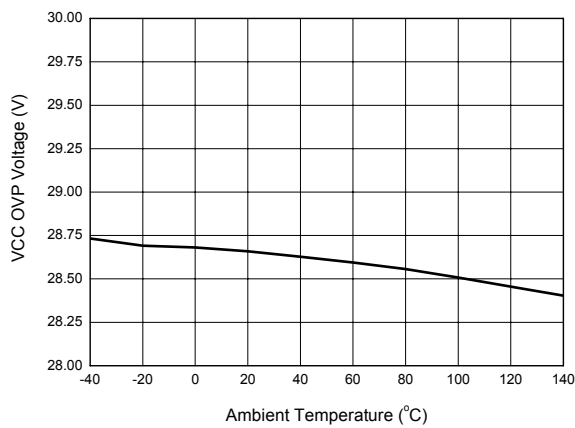


Figure 10. VCC OVP Voltage vs. Ambient Temperature

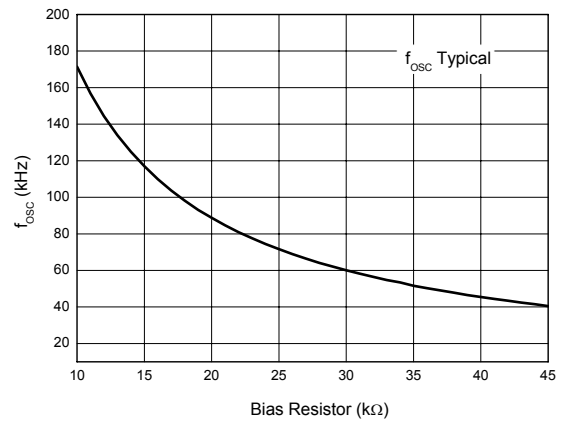


Figure 11. Oscillation Frequency vs. Bias Resistor



Typical Performance Characteristics (Continued)

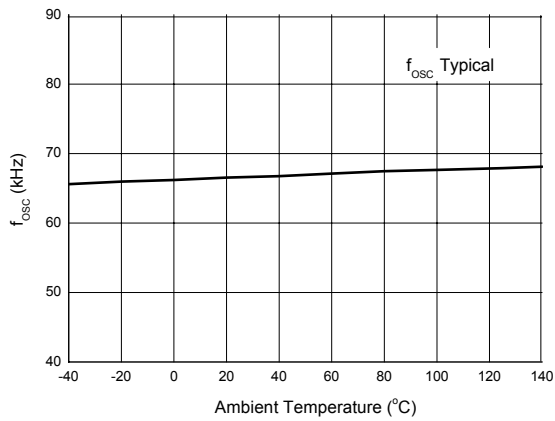


Figure 12. Oscillation Frequency vs. Ambient Temperature (R8=27kΩ)

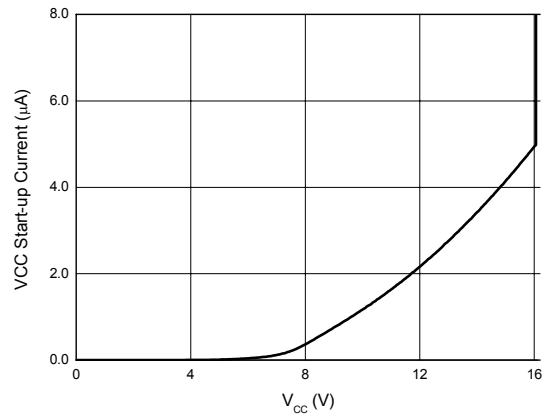


Figure 13. VCC Start-up Current vs. VCC Voltage

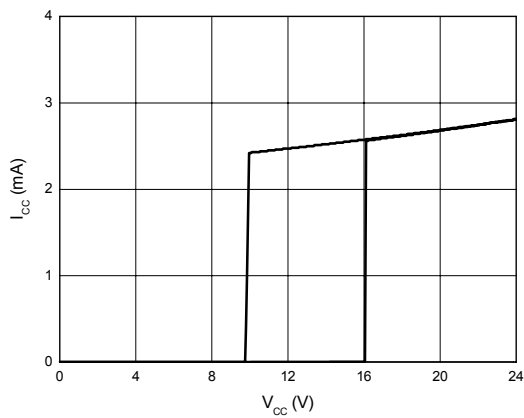


Figure 14. Operation Current vs. VCC Voltage

**GREEN MODE PWM CONTROLLER****AP3102/V/L****Operation Description**

The AP3102/V/L is specifically designed for off-line AC-DC power supply used in LCD monitor, notebook adapter and battery charger applications. It offers a cost effective solution with versatile protection functions for system designer.

Start-up Current and UVLO

The start-up current of AP3102/V/L is optimized to realize ultra low current (5 μ A 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 AP3102/V/L to detect the voltage on the VCC pin. It ensures AP3102/V/L to draw adequate energy from hold-up capacitor during power on. The turn-on threshold is 16V and the turn-off threshold is 10V.

Oscillator

The oscillation frequency is programmed by the value of resistor R8, connected from pin RI to ground. The resistor will make a constant current source to determine the oscillation frequency by charging and discharging an internal capacitor.

The oscillation frequency can be expressed as:

$$f \approx \frac{1720}{R8(k\Omega)} (kHz)$$

The recommended oscillation frequency is 40 to 130 kHz from the EMI consideration.

Current Sense Comparator and PWM Latch

AP3102/V/L operates as a current mode controller; the output switch conduction is initiated by every oscillator cycle and 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:

$$I_{PK} = (V_{FB} - 0.9) / 3R_S$$

Abnormal operating conditions occur when the power supply output is overloaded or the output voltage sensing is lost. Under these conditions, the current sense comparator threshold will be internally clamped to a value related to the value of V_{BOK} . As V_{BOK} value is proportional to the input line voltage, the constant over load protection can be achieved by compensating the delay time effect from the input line. The maximum peak switch current is:

$$I_{PK(MAX)} = (0.85 - 0.055 \times V_{BOK}) / R_S$$

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 250ns 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 can not be switched off. A resistor is usually connected to the current sense pin to avoid the PCB trace interference and it also can adjust the inductor peak current tinely by the resistance. Of course, adding a RC filter to CS pin is better to attenuate any unexpected noise.

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

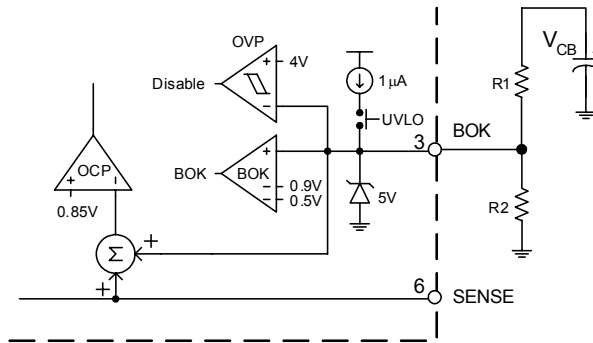
This pin is normally connected to the opt-coupler and always paralleled with a capacitor for loop compensation. When the voltage at this pin is great than 4.2V (such as output short to ground or the opt-coupler is broken) and lasts for about 35ms, the IC will enter the protection mode. For AP3102, the system will enter hiccup mode to wait the VCC decreasing to low UVLO level, then the IC will try to restart until the failure removed. For AP3102V, the IC will be latched unless unplugging the AC socket. Moreover, if the

GREEN MODE PWM CONTROLLER
AP3102/V/L
Operation Description (Continued)

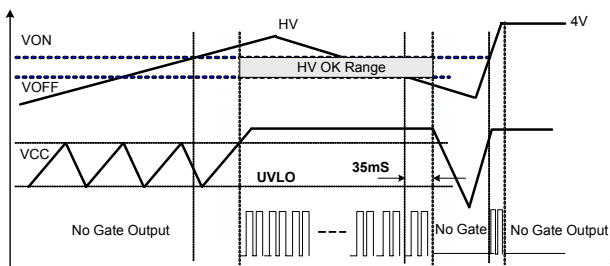
voltage is less than 0.7V, the IC will stop the drive pulse immediately. Therefore, this feature can be used for short circuit protection, which makes the system immune from catastrophic failure.

Brown-out and BOK Pin

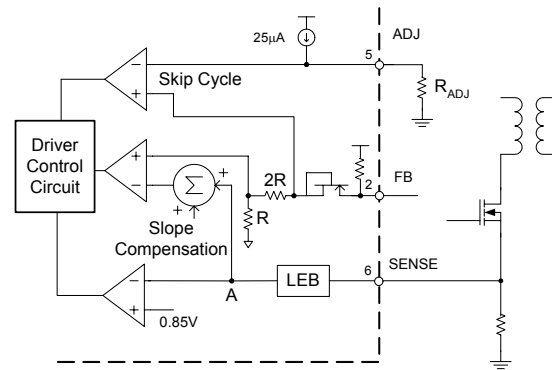
The switching converter normally has a suitable input range thus make the switching component operate under the safe operation condition. Too low or too high input will bring large heat shock or voltage spike on the switching device. Brown-out and line OVP function will avoid the supply to be worked in the unwanted condition such as below minimum and over maximum line voltage. The internal BOK connection is shown as the figure below:



From the figure, it is seen that the BOK is connected to the OCP comparator and used as feedforward to the V_{CS_MAX} (Refer to current sense comparator description). The V_{BOK} range for enable IC is 0.9 to 3.0V and disable range is under 0.5V or over than 4V. When V_{BOK} is over than 4V (line OVP) or under 0.5V (brown-out trigger), the IC enters the auto-recoverable protection. The ratio of R1/R2 is used to adjust the line voltage divider value.


ADJ Pin and Green Mode Operation

Low standby loss is the main requirement for AC-DC off line power supply. The AP3102/V/L has a green mode operation to improve the light load or no load efficiency. When the load power becomes low and V_{FB} decreases to the threshold value, the IC will enter the green mode which means the switching frequency will decrease with the load decrease. And when the load power becomes more lower, the IC will operate at the skip mode to reduce switching loss, core loss and other high frequency loss due to blanking the driver. In skipping mode, the high frequency pulses is about 25kHz for the best standby performance.



The V_{ADJ} threshold is adjustable by changing the external resistor connected from pin ADJ to the ground. Adjusting the V_{ADJ} voltage can optimize the standby power and audible noise for most applications.

Another function of ADJ pin is to use it as the latch trigger input. When the voltage at this pin is over than 4.5V, the system will be latched by limiting the V_{CC} to a lower voltage. If the IC is started from bulk capacitor through resistor, the system will be latched until the bulk voltage decreases to a very low value just like unplugged the AC input. Then, the IC latch current can't be maintained and latch will be released (see description below). This function can be used as system OTP and other protection..

System Protection and Pin Fault Protection

AP3102/V/L provides versatile system and pin fault

GREEN MODE PWM CONTROLLER
AP3102/V/L
Operation Description (Continued)

protections. The OCP comparator realizes the cycle-by-cycle current limiting (OCP). Cooperating with BOK compensation from the input line voltage, the IC realizes the constant over load protection (OLP). VCC over voltage protection can be applied as the primary OVP or opt-coupler broken protection. The AP3102/V/L also has pin fault connection protection including

floating and short connection. The floating pin protection include the RI, SENSE, FB, etc; the short pin protection includes the RI pin short protection. When these pins are floated or RI pin is shorted to ground, PWM switching will be disabled, thus protect the power system. Figure 15 shows the relative timing sequences of system protections.

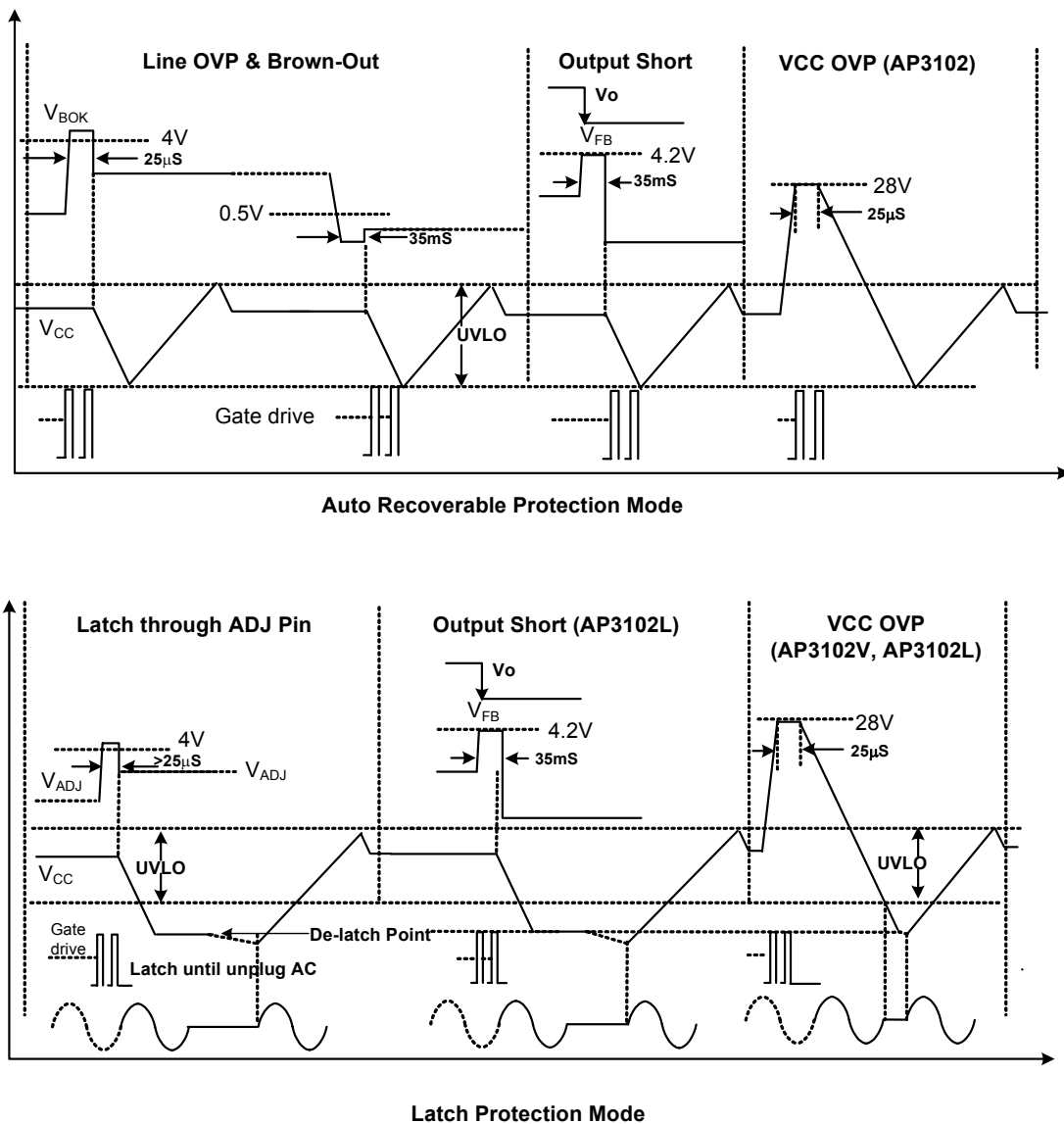


Figure 15. Typical Timing Sequences of AP3102/V/L Protections

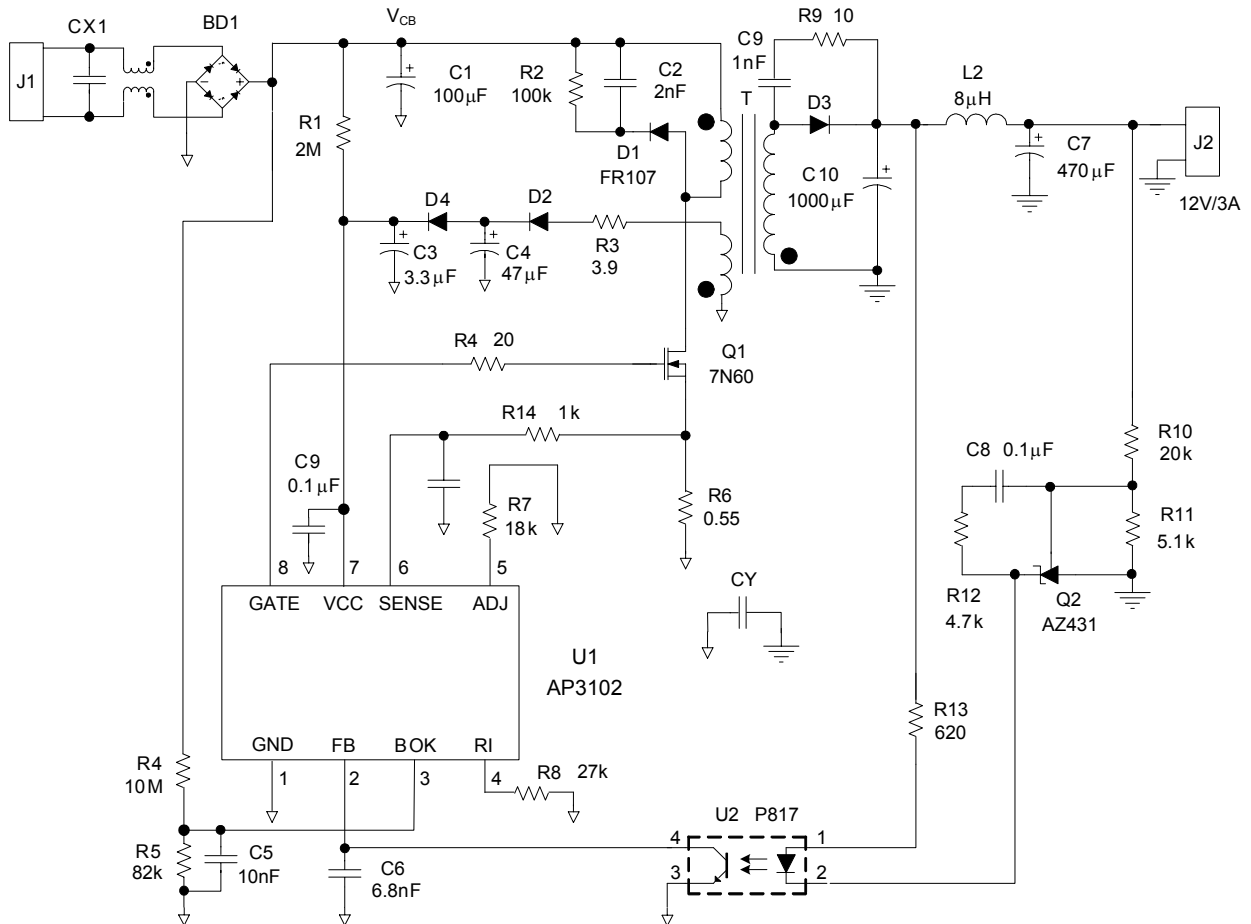
GREEN MODE PWM CONTROLLER
AP3102/V/L
Typical Application


Figure 16. Typical Application Circuit Using AP3102

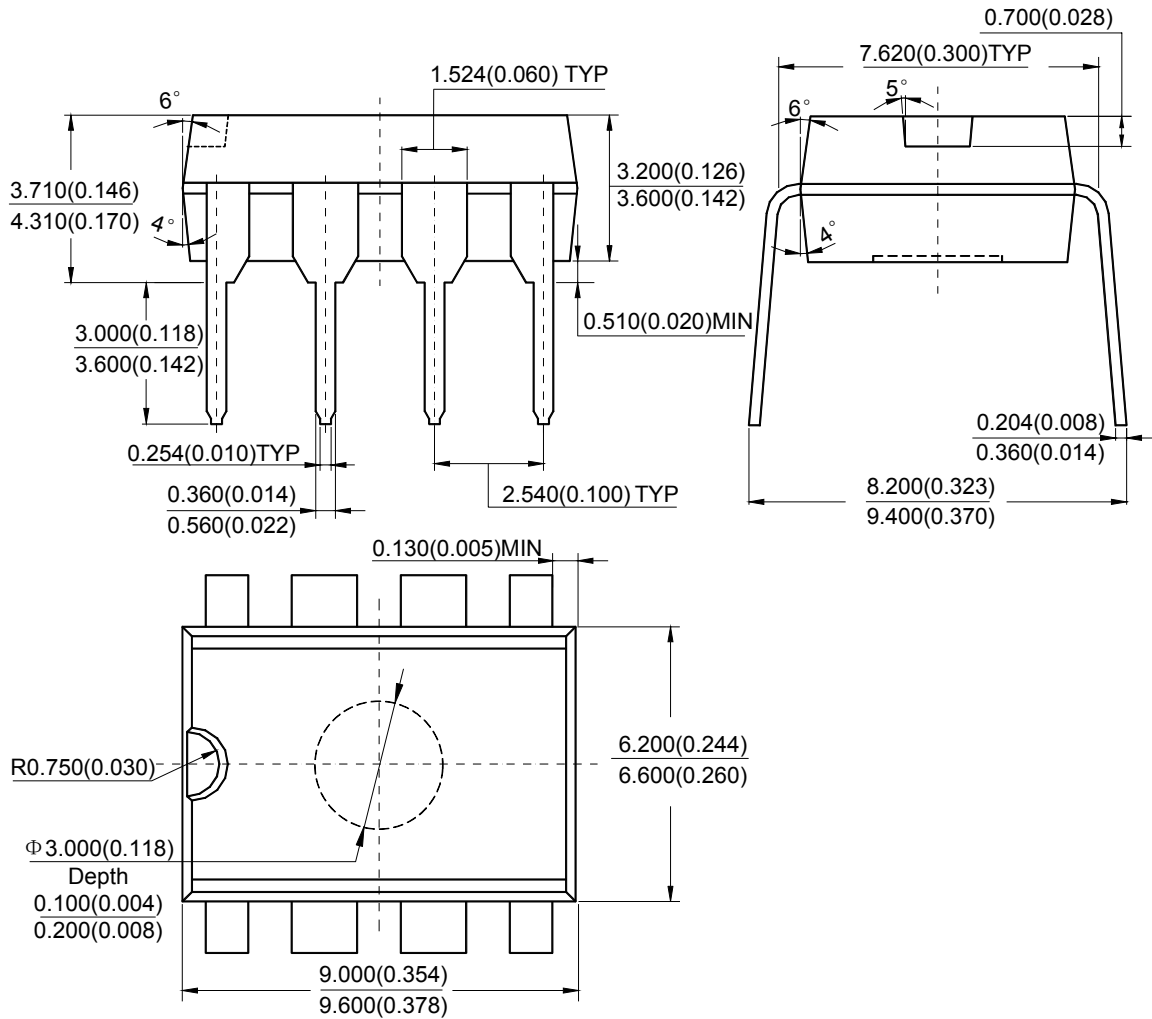
GREEN MODE PWM CONTROLLER

AP3102/V/L

Mechanical Dimensions

DIP-8

Unit: mm(inch)



Note: Eject hole, oriented hole and mold mark is optional.



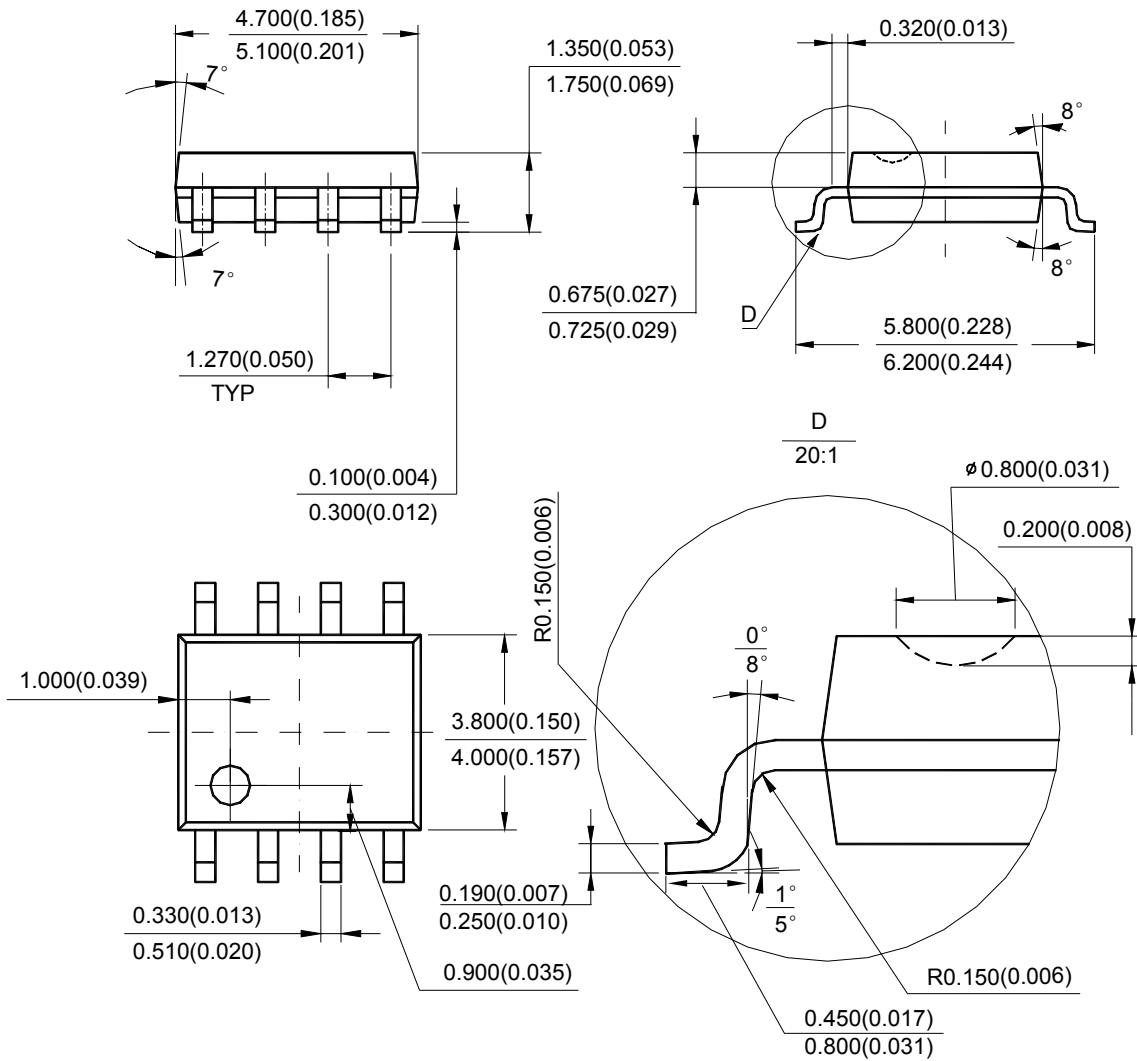
GREEN MODE PWM CONTROLLER

AP3102/V/L

Mechanical Dimensions (Continued)

SOIC-8

Unit: mm(inch)



Note: Eject hole, oriented hole and mold mark is optional.



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