NEW PRODUCT

AP3988/89/90

PRIMARY SIDE POWER SWITCHER FOR OFF-LINE SMPS

Description

The AP3988/89/90 is a performance enhanced power switcher for power supplies with better conversion efficiency, better voltage & current accuracy, and improved protection functions. Typical applications include charger, adapter for ADSL, home appliance power supply, LED lighting power supply and PC auxiliary power supplies. The controller regulates the output voltage and current in the primary side by piece-wise Pulse Frequency Modulation (p-PFM) in discontinuous conduction mode (DCM). The system operating frequency reduces linearly from heavy load to light load in each interval of the p-PFM, and enters constant current mode when the load current equals to the maximum system output current.

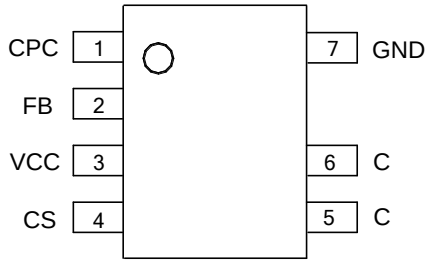
The AP3988/89/90 provides operating frequency dithering function to improve EMC performance of power supply. The AP3988/89/90 also has built-in fixed cable voltage drop compensation (5% of nominal system output voltage) and adjustable line voltage compensation.

The AP3988/89/90 solution has fewer component number, smaller size, and lower total cost.

The AP3988 is packaged in SO-7. The AP3989/90 is packaged in PDIP-7.

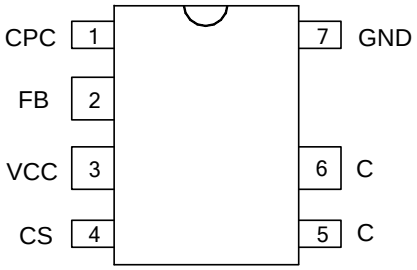
Pin Assignments

(Top View)



SO-7 (M Package) For AP3988

(Top View)



PDIP-7 (P7 Package) For AP3989/90

Features

- Primary Side Control for Eliminating Opto-coupler and Secondary CV/CC Control Circuitry
- Built-in NPN Transistor with 700V_{CBO}
- Low Start-up Current: 0.2μA (Typ.)
- Internal Output Cable Voltage Drop Compensation
- Hiccup Function to Improve Short Circuit Protection
- Better Over Voltage Protection
- Better Over Temperature Protection
- Low Total Cost Solution
- Output Power Range (Note 1):
  AP3988 for 5.5W Adapter
  AP3989 for 8W Adapter
  AP3990 for 12W Adapter
- **Totally Lead-free & Fully RoHS Compliant (Note 2 & 3)**
- **Halogen and Antimony Free. "Green" Device (Note 4)**

Applications

- Adapters
- Set Top Boxes
- Auxiliary Supplies
- Appliances

Notes:
1. Typical continuous power in a non-ventilated enclosed adapter measured at +50°C ambient.
2. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
3. 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.
4. 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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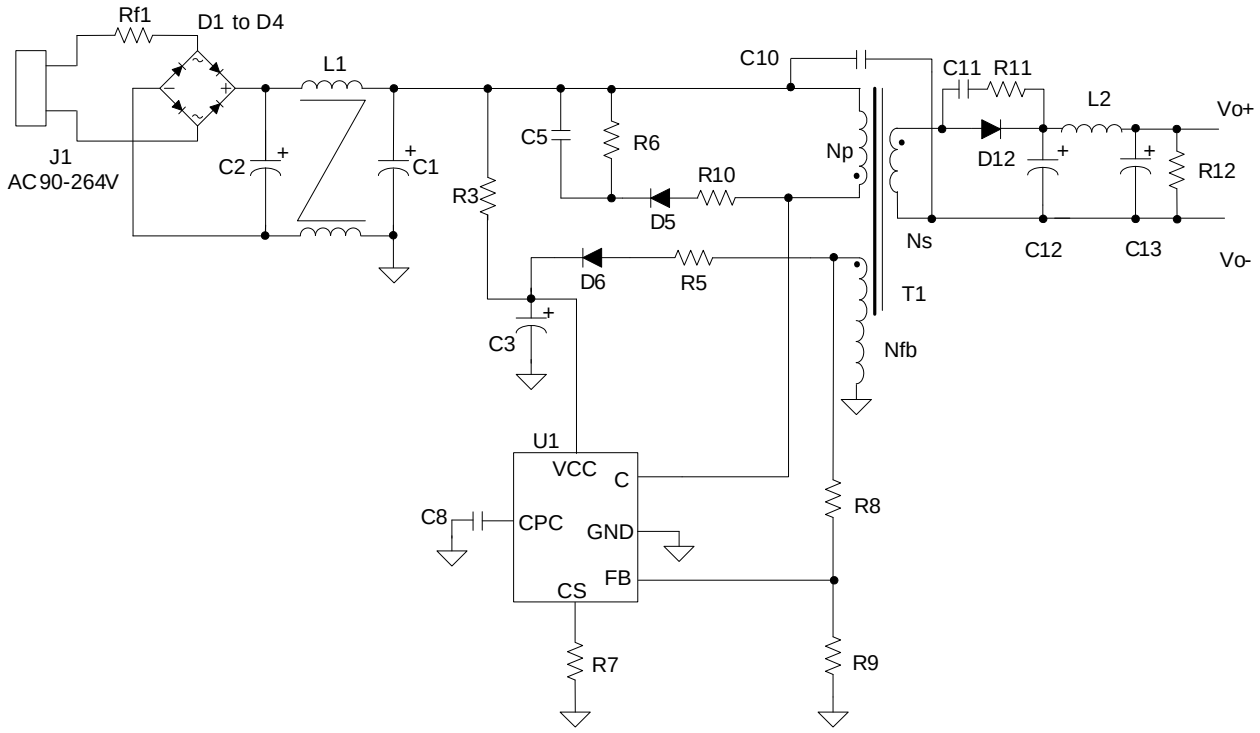
Typical Applications Circuit



For AP3990 (12V/1A)

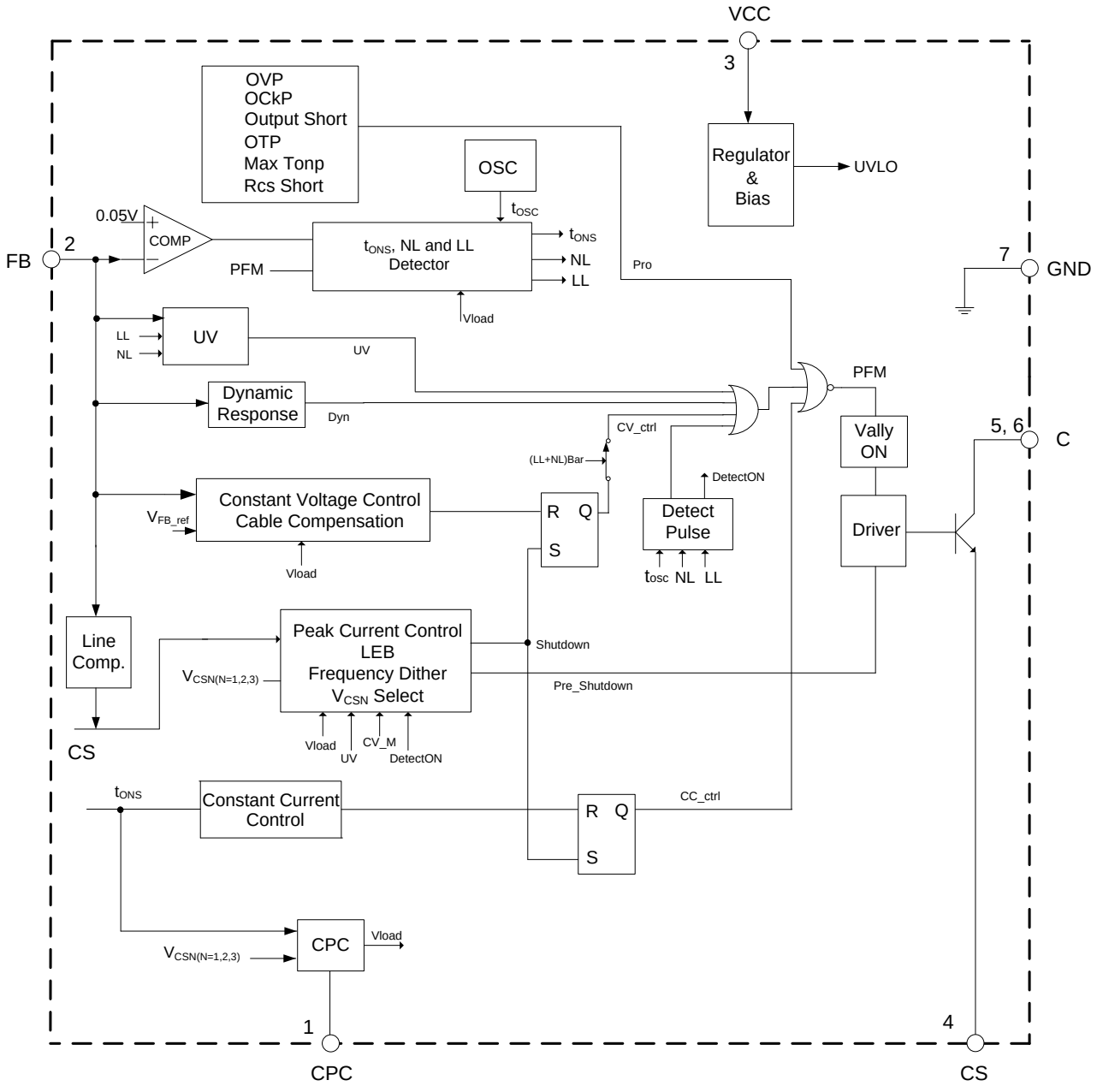
Item	Function	QTY	Item	Function	QTY
C1,C2	10µF/400V, electrolytic	2	U1	AP3990, PDIP-7	1
C3	4.7µF/50V, electrolytic	1	Rf1	2A/250V, fuse	1
C5	1nF/250V, ceramic	1	R3	3.3MΩ/0.25W	1
C8	0.1µF, 0805	1	R5	3.9Ω, 0805	1
C10	1nF/250V_{AC}, Y1 capacitor	1	R6	150kΩ, 0.25W	1
C11	1nF, 0805	1	R7	0.62Ω, 1206	1
C12, C13	470µF/16V	2	R8	31kΩ, 0805	1
D1 to D6	1N4007, rectifier diode	6	R9	13kΩ, 0805	1
D12	MBR3100, Schottky diode	1	R10	360Ω, 0805	1
L1	15mH, Common inductor, EE10	1	R11	27Ω, 0805	1
L2	10µH/1A, inductor, 0805	1	R12	1.2kΩ, 0805	1
–	–	–	T1	EE20 core, PC40, transformer	1

NEW PRODUCT

Pin Descriptions

Pin Number	Pin Name	Function
1	CPC	This pin connects a capacitor to GND for output cable compensation
2	FB	The voltage feedback from auxiliary winding
3	VCC	This pin receives rectified voltage from the auxiliary winding of the transformer
4	CS	Current sense for primary side of transformer
5, 6	C	This pin is connected with an internal power BJT's collector
7	GND	This pin is the signal reference ground

Functional Block Diagram



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Absolute Maximum Ratings (Note 5)

Symbol	Parameter	Rating		Unit
V_{CC}	Supply Voltage	-0.3 to 30		V
V_{CS}, V_{CPC}	Voltage on CS, CPC Pin	-0.3 to 7		V
V_{FB}	FB Input Voltage	-0.3 to 8		V
V_{CBO}	Collector-emitter Voltage	700		V
I_{CDC}	Collector DC Current	AP3988/89	1.5	A
		AP3990	4	
T_J	Operating Junction Temperature	+150		°C
T_{STG}	Storage Temperature	-65 to +150		°C
T_{LEAD}	Lead Temperature (Soldering, 10 sec)	+300		°C
–	ESD (Machine Model)	200		V
–	ESD (Human Body Model)	2000		V
P_D	Total Power Dissipation	AP3988	0.7	W
		AP3989	0.9	
		AP3990	1.1	

Note 5: 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	–	25	V
T_{OP}	Operating Temperature Range	-40	+85	°C
$f_{S(MAX)}$	Maximum Operating Frequency	–	60	kHz

Thermal Impedance (Note 6)

Symbol	Parameter	Value		Unit
θ_{JA}	Junction to Ambient	AP3988	100	°C/W
		AP3989	80	
		AP3990	65	
θ_{JC}	Junction to Case	AP3988	50	
		AP3989	40	
		AP3990	35	

Note 6: When mounted a standard single-sided FR4 board with 300mm^2 Cu (at least 35µm thick) connected to all collectors and CS pins.

NEW PRODUCT

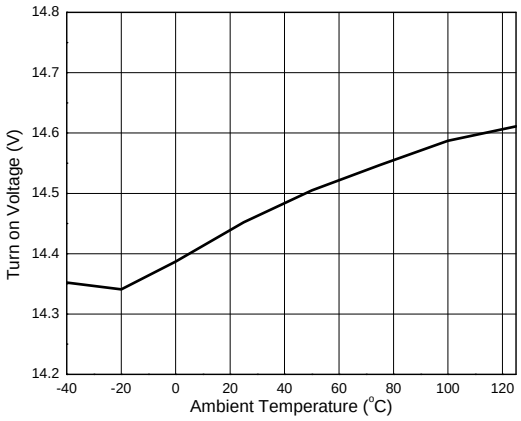
Electrical Characteristics (@V_{CC}=15V, T_J=+25°C, unless otherwise specified.)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
STARTUP AND UVLO SECTION						
V_{TH_ST}	Turn-on Voltage	–	13	15	17	V
$V_{OPR(MIN)}$	Turn-off Voltage	–	5.2	5.8	6.4	V
STANDBY CURRENT SECTION						
I_{ST}	Turn-on Current	V_{CC}=V_{TH_ST}-1V before startup	0	0.2	0.6	μA
I_{CC_OPR}	Operating Current	Static current @ no load	550	650	750	
OPERATING FREQUENCY SECTION (5% LOAD TO FULL LOAD)						
$f_{S(MAX)}$	Operating Frequency in Full Load Condition	–	–	–	60	kHz
Δf/f	Frequency Dithering	5% to 100% of full load range	4.5	5	5.5	%
OPERATING FREQUENCY SECTION (NO LOAD TO 5% OF $I_{OUT(MAX)}$)						
$f_{S(MIN)}$	Output Voltage Detection Frequency	–	1.8	2	2.2	kHz
CURRENT SENSE SECTION						
V_{CS_H}	Peak Current Sense Voltage in Heavy Load	40% to 100% of full load	874	910	946	mV
V_{CS_M}	Peak Current Sense Voltage in Middle Load	18% to 40% of full load	581	605	630	mV
V_{CS_L}	Peak Current Sense Voltage in Light Load	5% to 18% of full load	390	405	425	mV
V_{CS_EL}	Peak Current Sense Voltage in Extra-Light Load	0% to 5% of full load	216	225	234	mV
$ΔV_{CS}/V_{CS}$	V_{CS} Modulation for Frequency Dithering	–	–	2.5	–	%
t_{MOD}	V_{CS} Modulation Period	–	14.4	16	17.6	ms
R_{LINE}	Built-in Line Compensation Resistor	–	260	330	400	Ω
t_{LEB}	Leading Edge Blanking	@ V_{CS_H} and V_{CS_M}	410	500	575	ns
		@ V_{CS_EL}	155	200	245	ns
CONSTANT VOLTAGE SECTION						
V_{FB}	Equivalent Feedback Voltage @ Light Load	Closed loop test of V_{OUT}	3.94	4.00	4.06	V
I_{FB}	FB Pin Input Current	V_{FB}=4V	3.36	4.20	5.04	μA
V_{CABLE}/V_{OUT}	Cable Compensation Ratio	($V_{FB@FULLLOAD}$-V_{FB})/V_{FB}	5.65	6.00	6.40	%
CONSTANT CURRENT SECTION						
t_{ONS}/t_{SW}	Secondary Winding Conduction Duty	V_{FB}=2V	–	4/7	–	–
POWER TRANSISTOR SECTION						
$V_{CE(SAT)}$	Collector-emitter Saturation Voltage	AP3988/89: I_C=0.5A AP3990: I_C=1A	–	–	0.3	V
h_{FE}	DC Current Gain	AP3988/89	14	17	–	–
		AP3990	17	26	–	–
I_{CEO}	Leakage Current	–	–	–	60	μA
PROTECTION FUNCTION SECTION						
$V_{FB(OVP)}$	Over Voltage Protection	–	–	7.5	–	V
$V_{FB(SCP)}$	Short Circuit Protection	V_{FB} @ Hiccup	1.4	1.5	1.6	V
T_{OTP}	Shutdown Temperature	–	+125	+160	–	°C
T_{HYS}	Temperature Hysteresis	–	–	+40	–	°C
–	Driver Protection Voltage	–	4	5	6	V

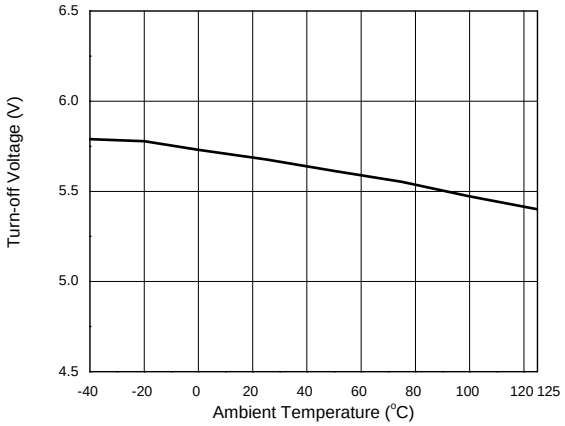
NEW PRODUCT

Performance Characteristics

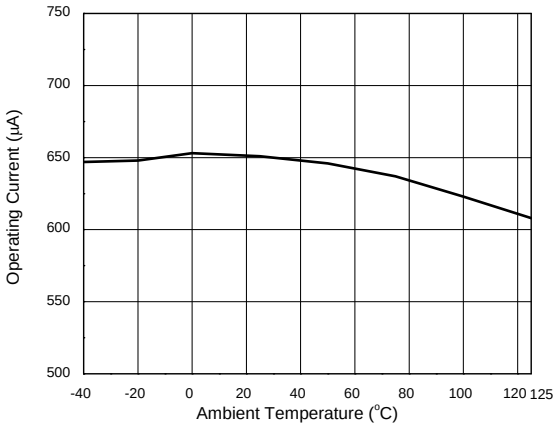
Turn-on Voltage vs. Ambient Temperature



Turn-off Voltage vs. Ambient Temperature



Operating Current vs. Ambient Temperature



Operation Description

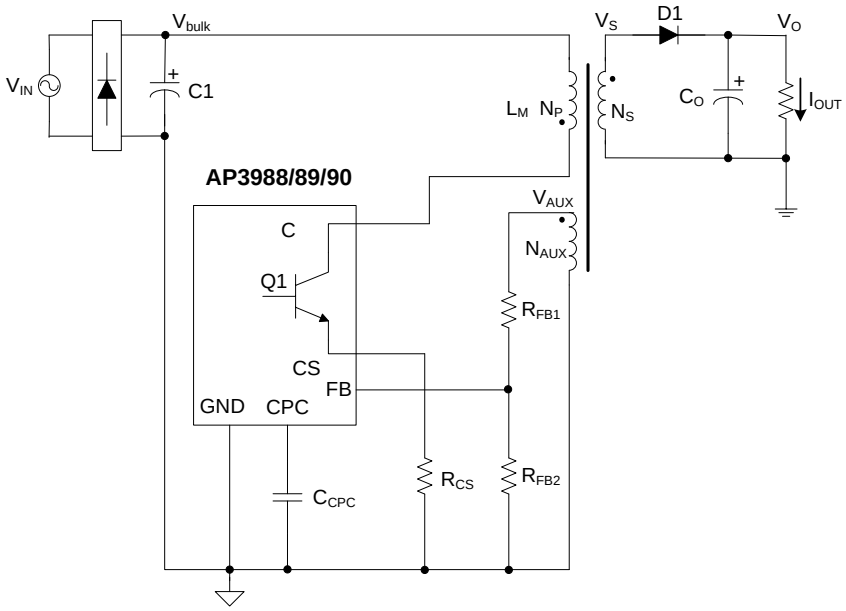


Figure 1. Simplified Flyback Converter Controlled by AP3988/89/90

NEW PRODUCT

Operation Description (Cont.)

Constant Primary Peak Current

The primary $i_p(t)$ current is sensed by a current sense resistor R_{CS} as shown in Figure 1.

The current rises up linearly at a rate of:

$$\frac{di_p(t)}{dt} = \frac{V_{bulk}(t)}{L_M} \quad \text{..... (1)}$$

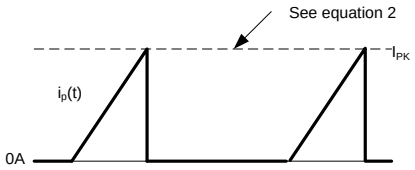


Figure 2. Primary Current Waveform

As illustrated in Figure 2, when the current $i_p(t)$ rises up to I_{PK}, the switch Q1 turns off. The constant peak current is given by:

$$I_{PK} = \frac{V_{CS}}{R_{CS}} \quad \text{.....(2)}$$

The energy stored in the magnetizing inductance L_M each cycle is therefore:

$$E_g = \frac{1}{2} \cdot L_M \cdot I_{PK}^{\ 2} \quad \text{.....(3)}$$

So the power transferring from input to output is given by:

$$P = \frac{1}{2} \cdot L_M \cdot I_{PK}^{\ 2} \cdot f_{SW} \quad \text{.....(4)}$$

Where f_{SW} is the switching frequency. When the peak current I_{PK} is constant, the output power depends on the switching frequency f_{SW}.

Constant Voltage Operation

The AP3988/89/90 captures the auxiliary winding feedback voltage at FB pin and operates in constant-voltage (CV) mode to regulate the output voltage. Assuming the secondary winding is master, the auxiliary winding is slave during the D1 on-time. The auxiliary voltage is given by:

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_O + V_d) \quad \text{.....(5)}$$

Where V_d is the diode forward drop voltage, N_{AUX} is the turns of auxiliary winding, and N_S is the turns of secondary winding.

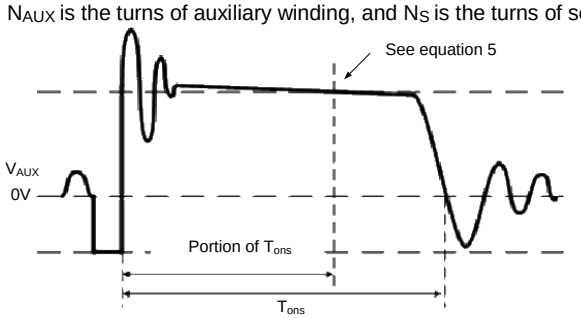


Figure 3. Auxiliary Voltage Waveform

The output voltage is different from the secondary voltage in a diode forward drop voltage V_d which depends on the current. If the secondary voltage is always detected at a constant secondary current, the difference between the output voltage and the secondary voltage will be a fixed V_d. The voltage detection point is portion of T_{ons} after D1 is turned on. The CV loop control function of AP3988/89/90 then generates a D1 off-time to regulate the output voltage.

NEW PRODUCT

Operation Description (Cont.)

Constant Current Operation

The AP3988/89/90 is designed to work in constant current (CC) mode. Figure 4 shows the secondary current waveforms.

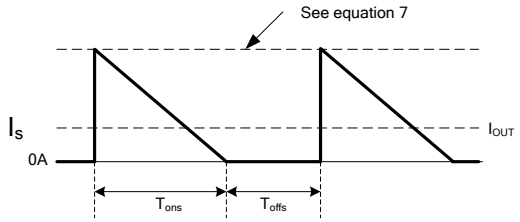


Figure 4. Secondary Current Waveform

In CC operation, the CC loop control function of AP3988/89/90 will keep a fixed proportion between D1 on-time T_{ons} and D1 off-time T_{offs} by discharging or charging the built-in capacitance connected. This fixed proportion is

$$\frac{T_{ons}}{T_{offs}} = \frac{4}{3} \quad \text{.....(6)}$$

The relation between the output constant-current and secondary peak current I_{PKS} is given by:

$$I_{OUT} = \frac{1}{2} \cdot I_{PKS} \cdot \frac{T_{ons}}{T_{ons} + T_{offs}} \quad \text{.....(7)}$$

At the instant of D1 turn-on, the primary current transfers to the secondary at an amplitude of:

$$I_{PKS} = \frac{N_P}{N_S} \cdot I_{PK} \quad \text{.....(8)}$$

Thus the output constant current is given by:

$$I_{OUT} = \frac{2}{7} \cdot \frac{N_P}{N_S} \cdot I_{PK} \quad \text{.....(9)}$$

Leading Edge Blanking (LEB)

When the power switch is turned on, a turn-on spike on the output pulse rising edge will occur on the sense-resistor. To avoid false termination of the switching pulse, a typical 500ns leading edge blanking is built in. During this blanking period, the current sense comparator is disabled and the gate driver cannot be switched off.

The built-in LEB in AP3988/89/90 has shorter delay time from current sense terminal to output pulse than those IC solutions adopting external RC filter as LEB.

Built-in Cable Compensation

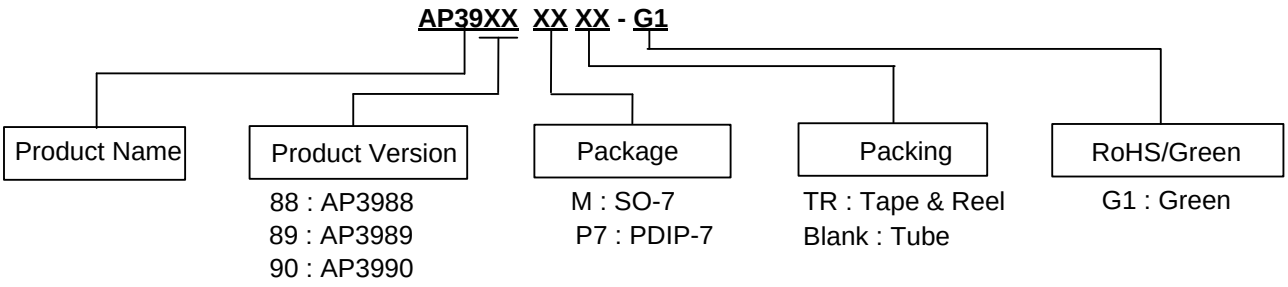
The AP3988/89/90 has built-in fixed voltage of 0.35V typical to compensate the drop of output cable when the load is changed from zero to full load. A typical 10nF external capacitor connected to the CPC pin is used to smooth voltage signal for cable compensation.

Over Temperature Protection

The AP3988/89/90 has internal thermal sensing circuit to shut down the PFM driver output when the die temperature reaches 160°C typical. When the die temperature drops about 40°C, the IC will recover automatically to normal operation.

NEW PRODUCT

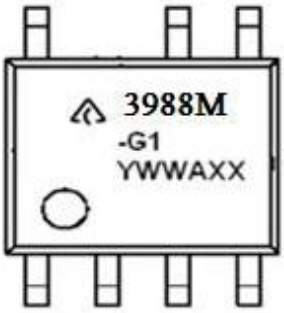
Ordering Information



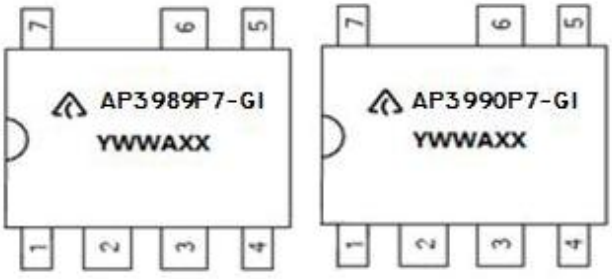
Diodes IC's Pb-free products with "G1" suffix in the part number, are RoHS compliant and green.

Package	Temperature Range	Part Number	Marking ID	Packing
SO-7	-40°C to +85°C	AP3988MTR-G1	3988M-G1	4000/Tape & Reel
PDIP-7		AP3989P7-G1	AP3989P7-G1	50/Tube
		AP3990P7-G1	AP3990P7-G1	50/Tube

Marking Information



First and Second Lines: Logo and Marking ID
Third Line: Date Code
Y: Year
WW: Work Week of Molding
A: Assembly House Code
XX: 7th and 8th Digits of Batch No.

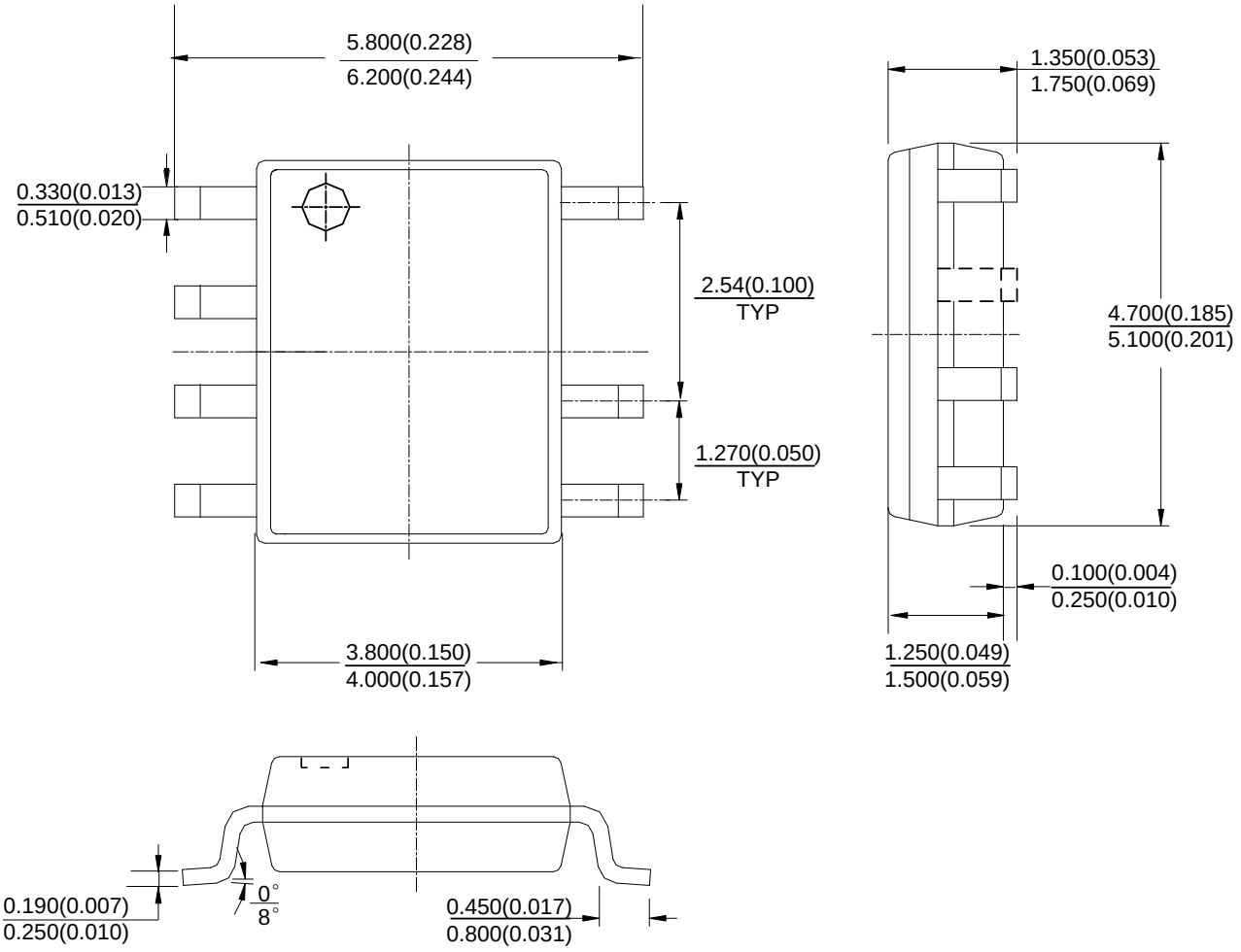


First Line: Logo and Marking ID
Second Line: Date Code
Y: Year
WW: Work Week of Molding
A: Assembly House Code
XX: 7th and 8th Digits of Batch No.

NEW PRODUCT

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

(1) Package Type: SO-7

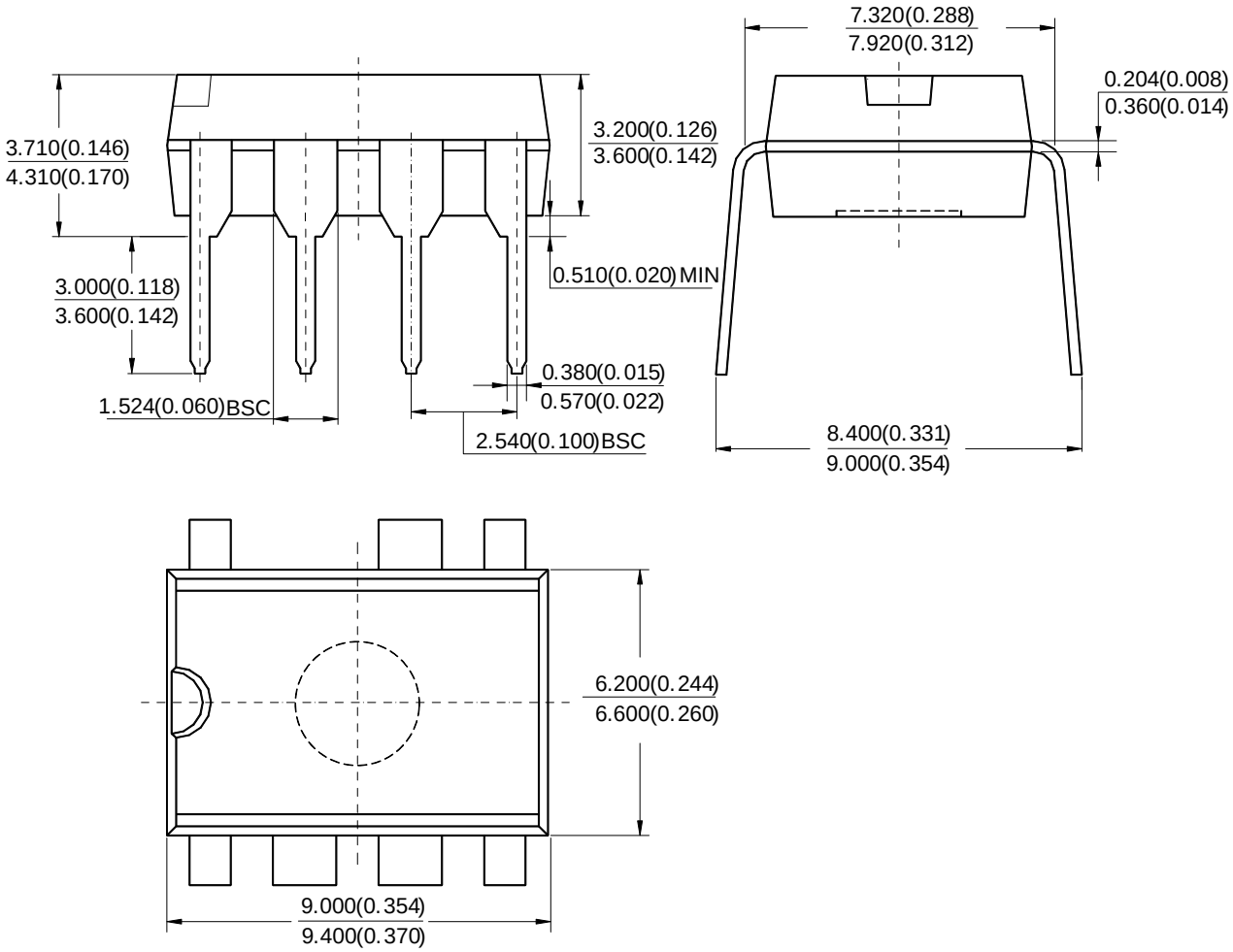


Note: Eject hole, oriented hole and mold mark is optional.

NEW PRODUCT

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

(2) Package Type: PDIP-7

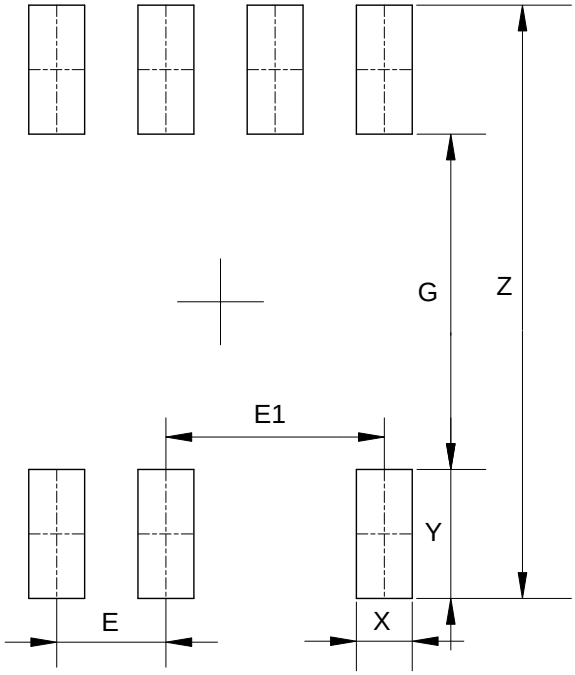


Note: Eject hole, oriented hole and mold mark is optional

NEW PRODUCT

Suggested Pad Layout

(1) Package Type: SO-7



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (mm)/(inch)	E1 (mm)/(inch)
Value	6.900/0.272	3.900/0.154	0.650/0.026	1.500/0.059	1.270/0.050	2.540/0.100

NEW PRODUCT

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2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

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