

## Description

The AP3983E is high frequency power switcher for power supplies with better conversion efficiency, better voltage & current accuracy, and improved protection functions. Typical applications include adapter for ADSL, home appliance power supply, LED lighting power supply and PC auxiliary power supplies. The AP3983E with built in MOSFET, 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 AP3983E provides operating frequency dithering function to improve EMC performance of power supply. The AP3983E also has built-in fixed cable voltage drop compensation and adjustable line voltage compensation.

The AP3983E solution has fewer component number, smaller size, and lower total cost.

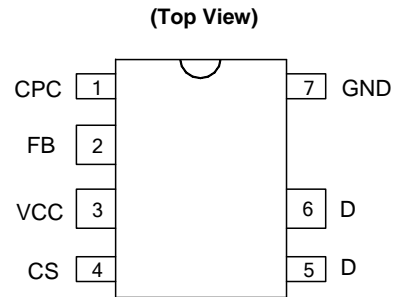
The AP3983E is packaged in PDIP-7.

## Features

- Primary Side Control for Eliminating Opto-coupler
- Valley Switching Turn on for Higher Efficiency and Better EMI Performance
- Better Transient Characteristics
- Built-in N Channel MOSFET with 700 BV<sub>DSS</sub>
- 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)
- AP3983E for 20W Adapter and 25W in Open Frame Design
- **Totally Lead-free & Fully RoHS Compliant (Note 2 & 3)**
- **Halogen and Antimony Free. "Green" Device (Note 4)**

- Note:
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](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.

## Pin Assignments

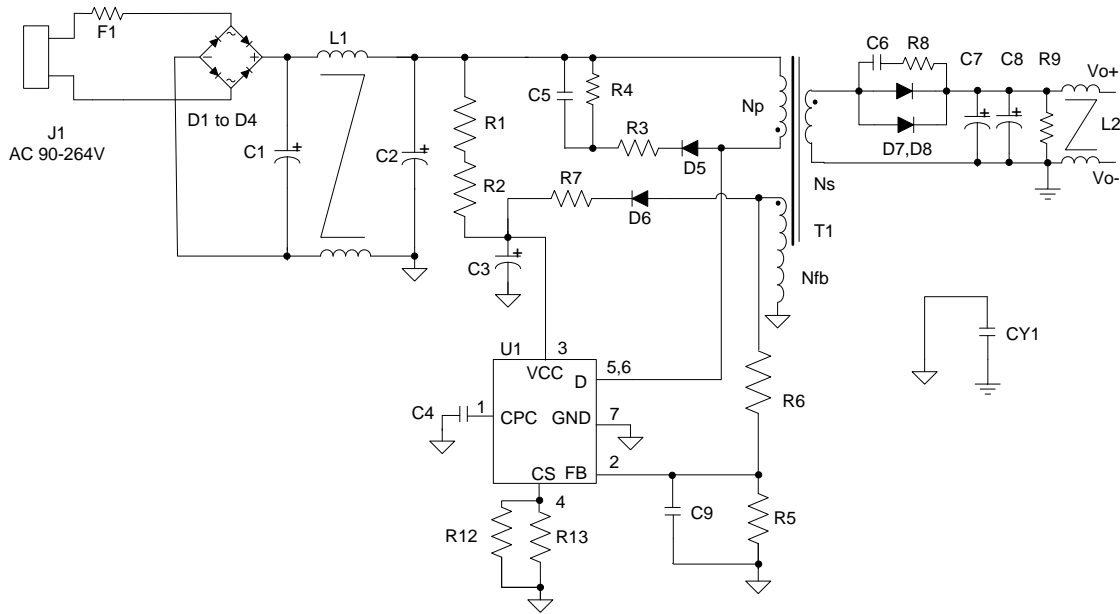


PDIP-7 For AP3983E

## Applications

- Adapters
- Set Top Boxes
- Auxiliary Supplies
- Appliances
- LED Driver

**Typical Applications Circuit**



For AP3983E (12V/1.5A)

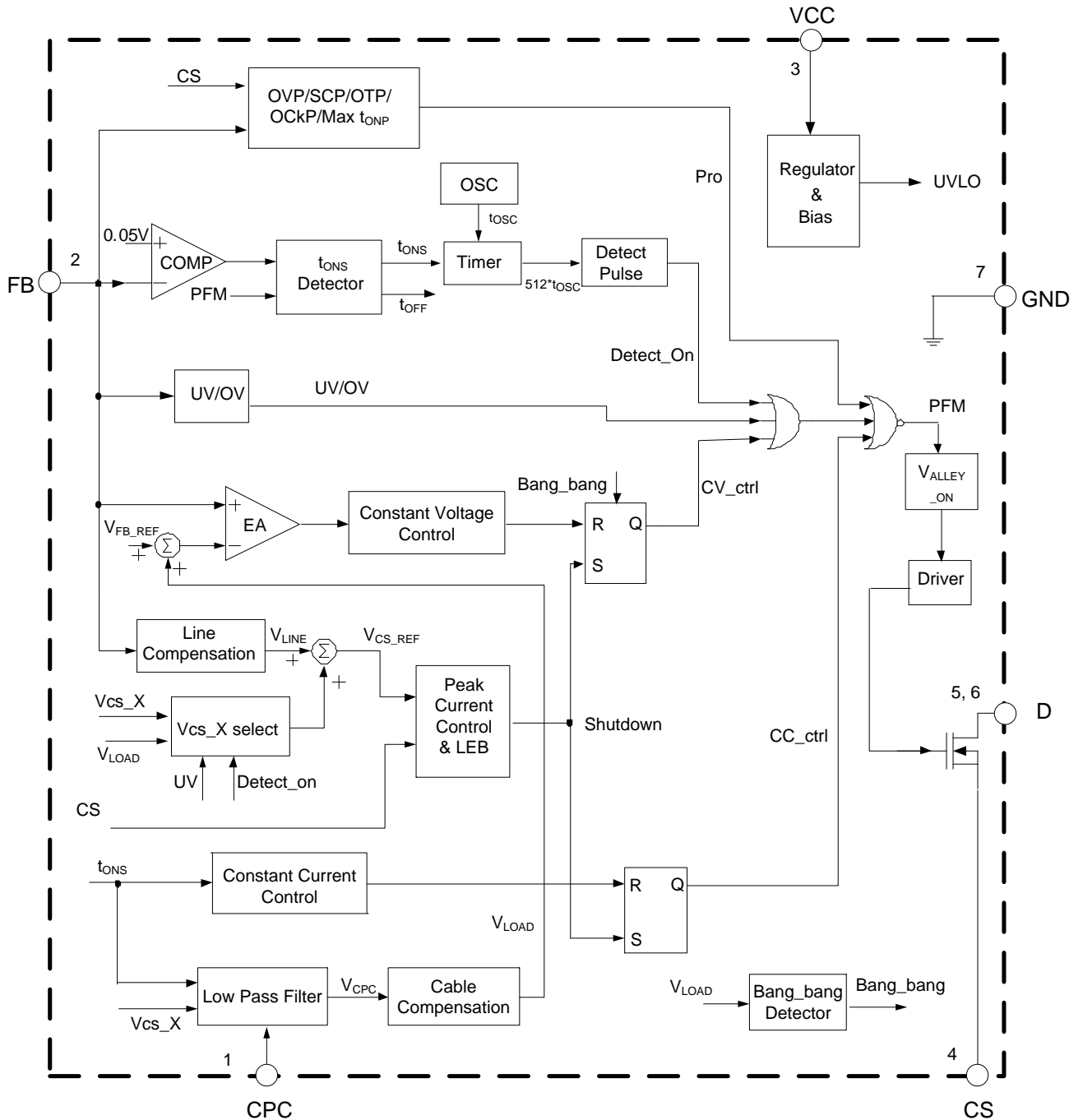
Item	Function	QTY	Item	Function	QTY
C1, C2	15 $\mu$ F/400V, electrolytic	2	U1	AP3983E, PDIP-7	1
C3	4.7 $\mu$ F/50V, electrolytic	1	R1, R2	2M $\Omega$ , 1206	2
C4	10nF, ceramic, 0805	1	R3	200 $\Omega$ , 1206	1
C5	1nF/250V, ceramic	1	R4	150k $\Omega$ , 1206	1
C6	1nF/100V, 0805	1	R5	22k $\Omega$ , 1%, 0805	1
C7, C8	1000 $\mu$ F/16V, electrolytic	2	R6	47k $\Omega$ , 1%, 0805	1
C9	10pF/16V, 0805	1	R7	2 $\Omega$ , 1206	1
CY1	1nF/250V <sub>AC</sub> , Y1 capacitor	1	R8	30 $\Omega$ , 1206	1
D1 to D6	1N4007, rectifier diode	6	R9	5.1k $\Omega$ , 1206	1
D7, D8	MBR3100, Schottky diode	2	R12	1.2 $\Omega$ , 1%, 1206	1
F1	2A/250V, fuse	1	R13	1.8 $\Omega$ , 1%, 1206	1
L1	30mH, Common inductor, EE9.8	1	T1	EE20 core, PC40, transformer	1
L2	250 $\mu$ H/2A, Common inductor	1	-	-	-

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**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	D	This pin is connected with an internal power MOSFET's drain
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
$BV_{DSS}$	Drain Voltage ( $T_J = +25^{\circ}C$ )	700	V
$I_D$	Drain Continuous Current ( $T_J = +25^{\circ}C$ )	5	A
$T_J$	Operating Junction Temperature	-40 to +150	$^{\circ}C$
$T_{STG}$	Storage Temperature	-65 to +150	$^{\circ}C$
$T_{LEAD}$	Lead Temperature (Soldering, 10 sec)	+260	$^{\circ}C$
–	ESD (Machine Model)	200	V
–	ESD (Human Body Model)	2000	V
$P_D$	Total Power Dissipation	1.8	W

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	+105	$^{\circ}C$
$f_{S(MAX)}$	Maximum Operating Frequency	–	80	kHz

## Thermal Impedance (Note 6)

Symbol	Parameter	Value	Unit
$\theta_{JA}$	Junction to Ambient	40	$^{\circ}C/W$
$\theta_{JC}$	Junction to Case	20	

Note 6: When mounted a standard single-sided FR-4 board with  $300mm^2$  Cu (at least  $35\mu m$  thick) connected to all collectors and CS pins.

**Electrical Characteristics** (@V<sub>CC</sub> = 15V, T<sub>J</sub> = +25°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>STARTUP AND UVLO SECTION</b>						
V <sub>TH_ST</sub>	Turn-on Voltage	–	13	15.5	18	V
V <sub>OPR(MIN)</sub>	Turn-off Voltage	–	6	6.8	7.6	V
<b>STANDBY CURRENT SECTION</b>						
I <sub>ST</sub>	Turn-on Current	V <sub>CC</sub> = V <sub>TH_ST</sub> -1V before startup	0	0.2	0.6	μA
I <sub>CC_OPR</sub>	Operating Current	Static current @ no load	350	500	650	
<b>OPERATING FREQUENCY SECTION (5% LOAD TO FULL LOAD)</b>						
f <sub>S(MAX)</sub>	Operating Frequency in Full Load Condition	–	–	65	80	kHz
Δf/f	Frequency Dithering	5% to 100% of full load range	4	7	10	%
<b>OPERATING FREQUENCY SECTION (NO LOAD TO 5% OF I<sub>OUT(MAX)</sub>)</b>						
f <sub>S(MIN)</sub>	Output Voltage Detection Frequency	–	1.8	2	2.2	kHz
<b>CURRENT SENSE SECTION</b>						
V <sub>CS_H</sub>	Peak Current Sense Voltage in Heavy Load	30% to 100% of full load	828	900	972	mV
ΔV <sub>CS</sub> /V <sub>CS</sub>	V <sub>CS</sub> Modulation for Frequency Dithering	–	–	2.5	–	%
t <sub>MOD</sub>	V <sub>CS</sub> Modulation Period	–	–	250	–	μs
R <sub>LINE</sub>	Built-in Line Compensation Resistor	–	200	230	260	Ω
t <sub>LEB</sub>	Leading Edge Blanking	@ V <sub>CS_H</sub> and V <sub>CS_M</sub>	410	500	575	ns
		@ V <sub>CS_EL</sub>	220	250	288	ns
<b>CONSTANT VOLTAGE SECTION</b>						
V <sub>FB</sub>	Equivalent Feedback Voltage @ Light Load	Closed loop test of V <sub>OUT</sub>	3.89	3.95	4.01	V
R <sub>FB</sub>	FB Pin Input Resistance	–	560	700	840	kΩ
V <sub>CABLE</sub> /V <sub>OUT</sub>	Cable Compensation Ratio	(V <sub>FB@FULLLOAD</sub> -V <sub>FB</sub> )/V <sub>FB</sub>	5.65	6.00	6.40	%
<b>CONSTANT CURRENT SECTION</b>						
t <sub>ONS</sub> /t <sub>SW</sub>	Secondary Winding Conduction Duty	V <sub>FB</sub> = 2V	–	4/8	–	–
<b>POWER MOSFET SECTION</b>						
BV <sub>DSS</sub>	Drain-Source Breakdown Voltage	–	700	–	–	V
R <sub>DS(ON)</sub>	On State Resistor	–	–	–	1.4	Ω
<b>PROTECTION FUNCTION SECTION</b>						
V <sub>FB(OVP)</sub>	Over Voltage Protection	–	–	7.5	–	V
V <sub>FB(SCP)</sub>	Short Circuit Protection	V <sub>FB</sub> @ Hiccup	1.4	1.5	1.6	V
T <sub>OTP</sub>	Shutdown Temperature	–	+125	+160	–	°C
T <sub>HYS</sub>	Temperature Hysteresis	–	–	+40	–	°C

**Operation Description**

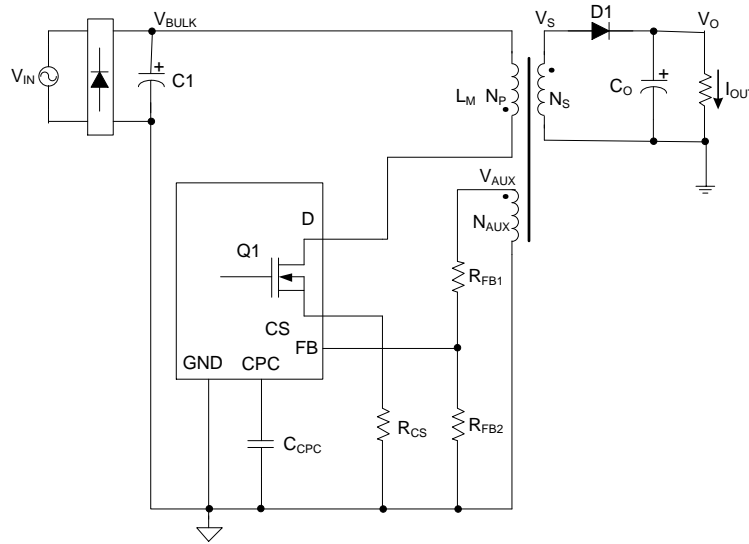


Figure 1. Simplified Flyback Converter Controlled by AP3983E

**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:

$$\frac{di_P(t)}{dt} = \frac{V_{BULK}(t)}{L_M} \dots\dots\dots (1)$$

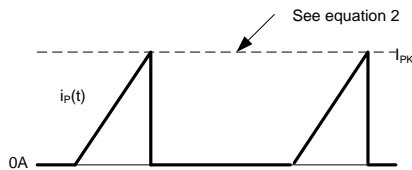


Figure 2. Primary Current Waveform

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:

$$I_{PK} = \frac{V_{CS}}{R_{CS}} \dots\dots\dots (2)$$

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

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

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

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

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 AP3983E 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:

**Operation Description (Cont.)**

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_0 + V_D) \dots \dots \dots (5)$$

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.

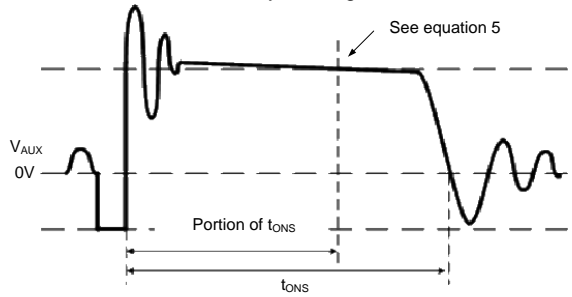


Figure 3. Auxiliary Voltage Waveform

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 AP3983E then generates a D1 off-time to regulate the output voltage.

**Constant Current Operation**

The AP3983E is designed to work in constant current (CC) mode. Figure 4 shows the secondary current waveforms.

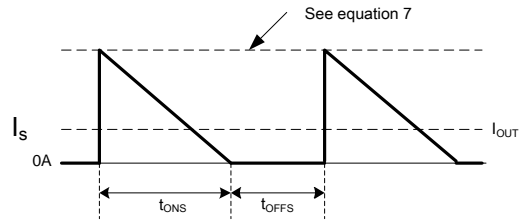


Figure 4. Secondary Current Waveform

In CC operation, the CC loop control function of AP3983E 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

$$\frac{t_{ONS}}{t_{OFFS}} = \frac{4}{4} \dots \dots \dots (6)$$

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

$$I_{OUT} = \frac{1}{2} \cdot I_{PKS} \cdot \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} \dots \dots \dots (7)$$

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

$$I_{PKS} = \frac{N_P}{N_S} \cdot I_{PK} \dots \dots \dots (8)$$

Thus the output constant current is given by:

$$I_{OUT} = \frac{1}{4} \cdot \frac{N_P}{N_S} \cdot I_{PK} \dots \dots \dots (9)$$

## Operation Description (Cont.)

### 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 AP3983E has shorter delay time from current sense terminal to output pulse than those IC solutions adopting external RC filter as LEB.

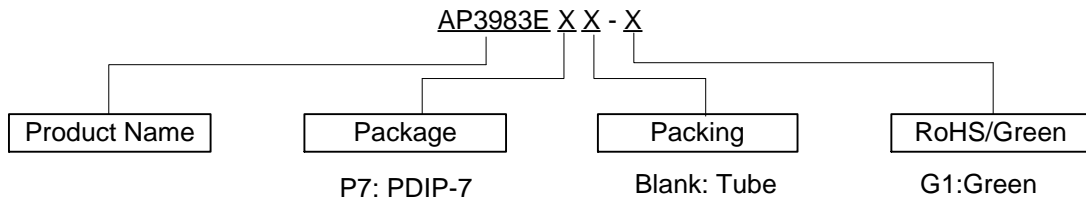
### Built-in Cable Compensation

The AP3983E has built-in fixed voltage of 0.3V 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 AP3983E 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.

## Ordering Information



Package	Temperature Range	Part Number	Marking ID	Packing
PDIP-7	-40°C to +105°C	AP3983EP7-G1	AP3983EP7-G1	50/Tube

## Marking Information

(Top View)

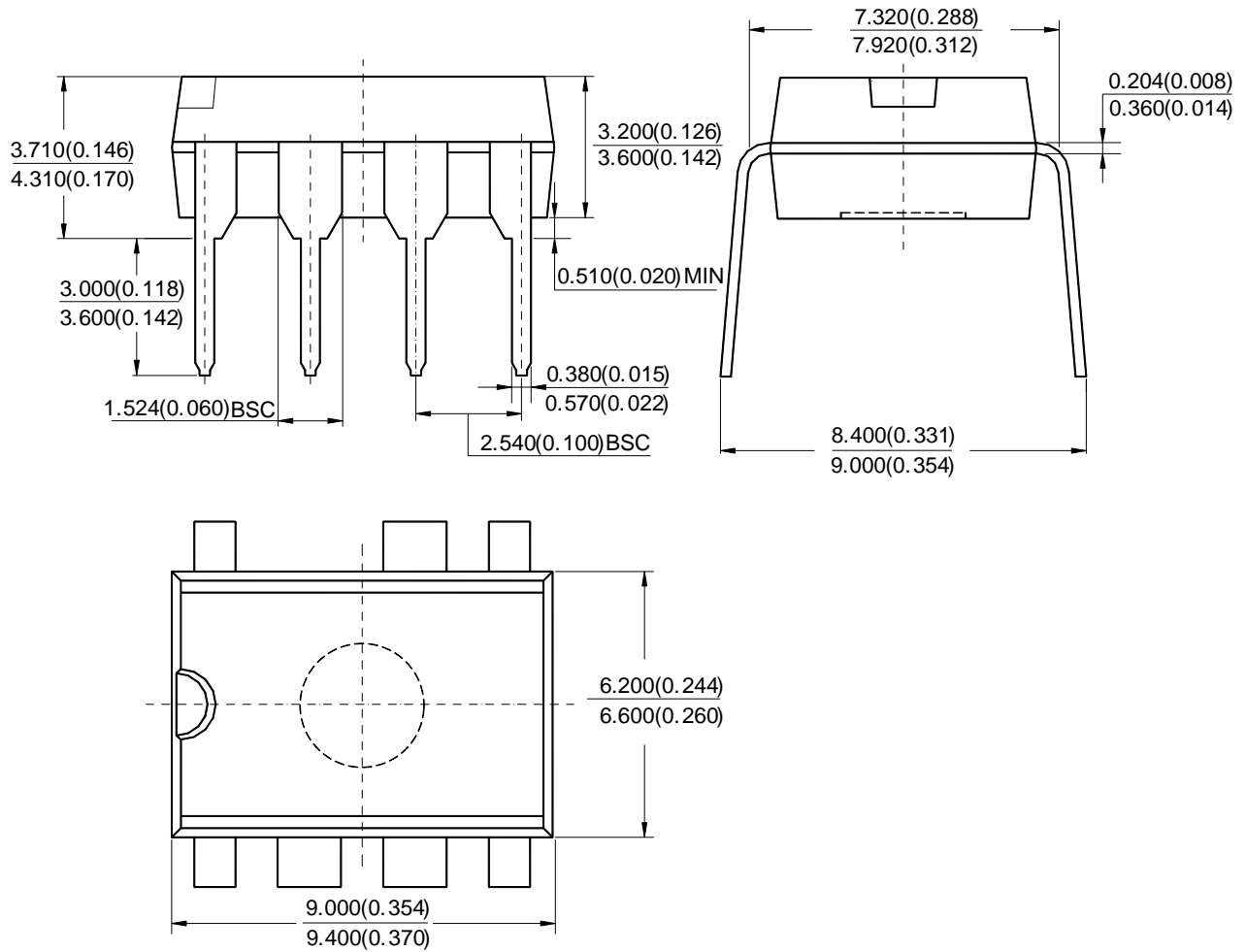


First Line: Logo and Marking ID  
 Second Line: Date Code  
 Y: Year  
 WW: Work Week of Molding  
 A: Assembly House Code  
 XX: 7<sup>th</sup> and 8<sup>th</sup> Digits of Batch No.



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

(1) Package Type: PDIP-7



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

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