HIGH-FREQUENCY PRIMARY SIDE POWER SWITCHER FOR OFF-LINE SMPS

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.

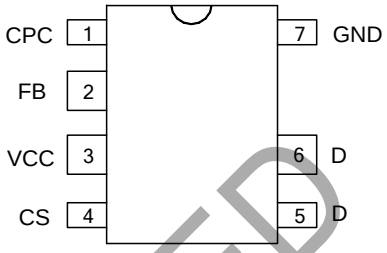
The AP3983E provides operating frequency dithering function to improve EMC performance of power supply. The AP3983E also has built-in fixed cable voltage drop compensation and adjustable line voltage compensation.

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

The AP3983E is packaged in PDIP-7.

Pin Assignments

(Top View)



PDIP-7 For AP3983E

Applications

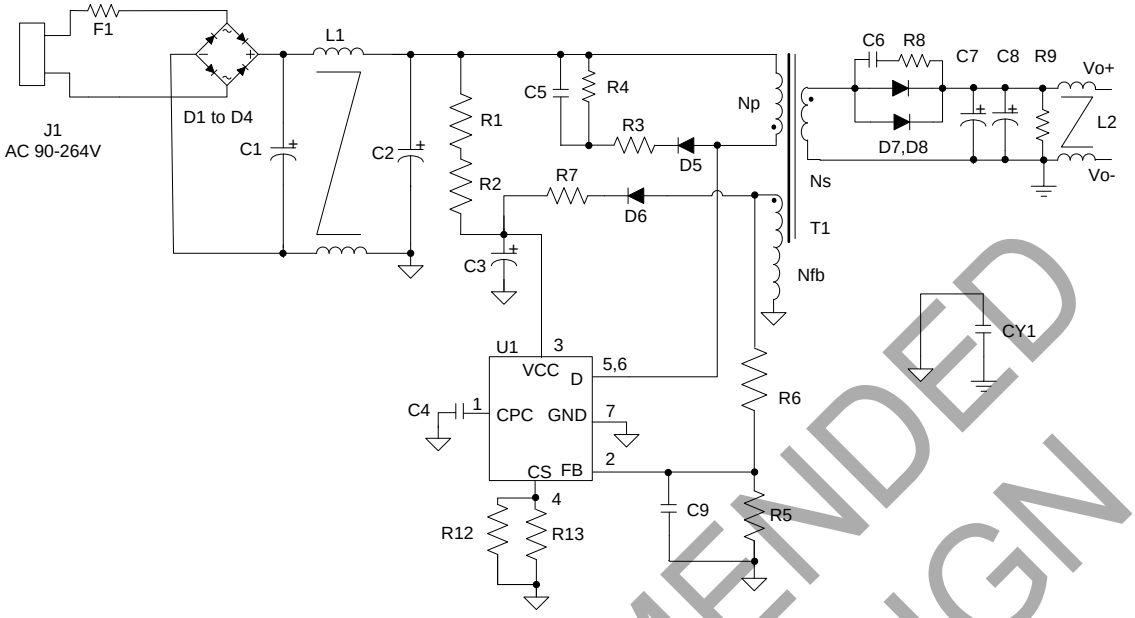
- Adapters
- Set-top boxes
- Auxiliary supplies
- Appliances
- LED drivers

Features

- Primary Side Control for Eliminating Optocoupler
- Valley Switching Turn On for Higher Efficiency and Better EMI Performance
- Better Transient Characteristics
- Built-in N-Channel MOSFET with 700 BV_{DSS}
- Low Startup Current: 0.2μA (typ)
- Internal Output Cable Voltage Drop Compensation
- Hiccup Function to Improve Short-Circuit Protection
- Better Overvoltage Protection
- Better Overtemperature 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)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

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) & 2015/863/EU (RoHS 3) compliant.
3. See https://www.diodes.com/quality/lead-free/ 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.

Typical Applications Circuit



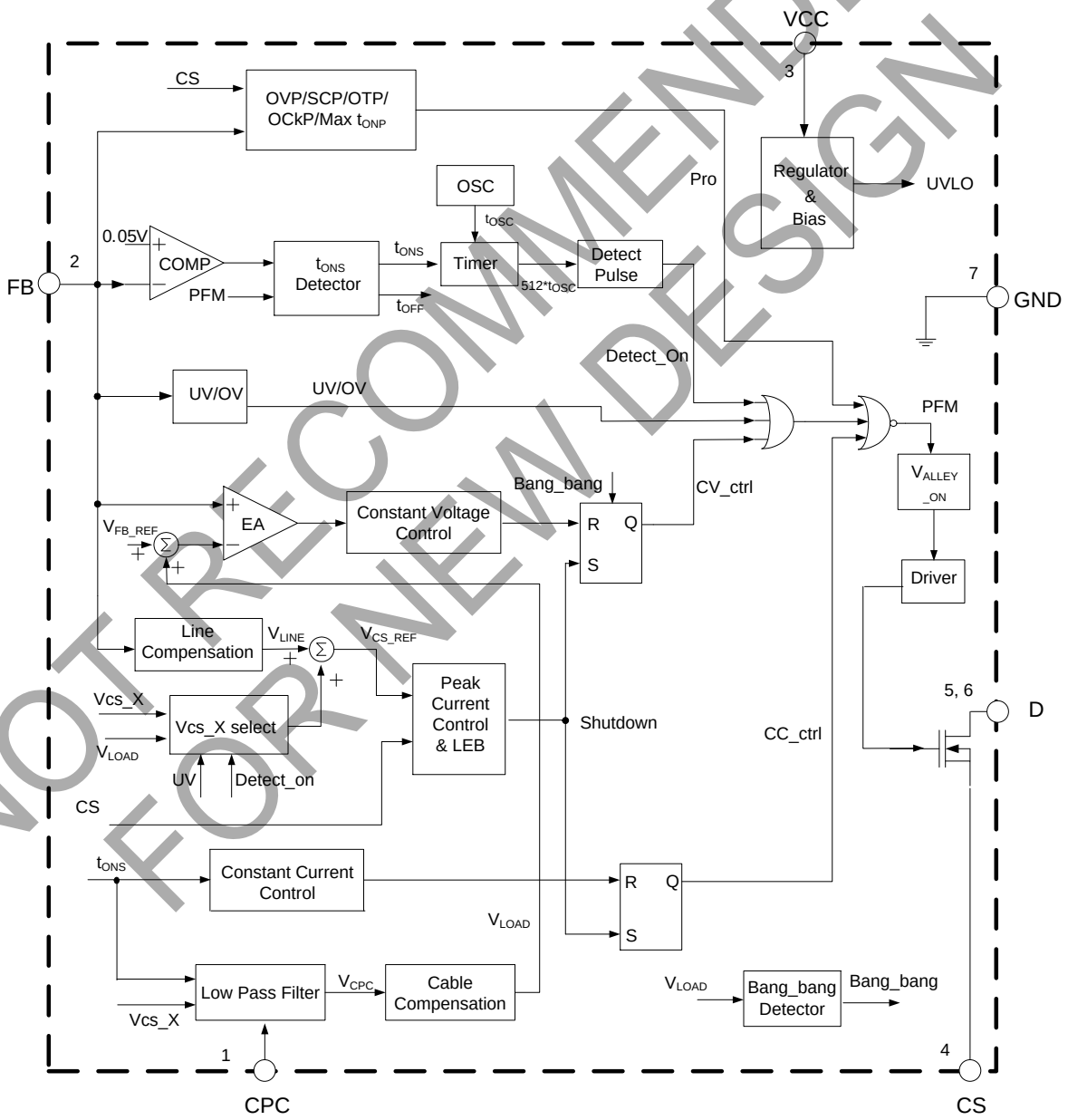
For AP3983E (12V/1.5A)

Item	Function	Qty.	Item	Function	Qty.
C1, C2	15µF/400V, electrolytic	2	U1	AP3983E, PDIP-7	1
C3	4.7µF/50V, electrolytic	1	R1, R2	2MΩ, 1206	2
C4	10nF, ceramic, 0805	1	R3	200Ω, 1206	1
C5	1nF/250V, ceramic	1	R4	150kΩ, 1206	1
C6	1nF/100V, 0805	1	R5	22kΩ, 1%, 0805	1
C7, C8	1000µF/16V, electrolytic	2	R6	47kΩ, 1%, 0805	1
C9	10pF/16V, 0805	1	R7	2Ω, 1206	1
CY1	1nF/250V_{AC}, Y1 capacitor	1	R8	30Ω, 1206	1
D1 to D6	1N4007, rectifier diode	6	R9	5.1kΩ, 1206	1
D7, D8	MBR3100, Schottky diode	2	R12	1.2Ω, 1%, 1206	1
F1	2A/250V, fuse	1	R13	1.8Ω, 1%, 1206	1
L1	30mH, Common inductor, EE9.8	1	T1	EE20 core, PC40, transformer	1
L2	250µH/2A, Common inductor	1	—	—	—

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



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 Pins	-0.3 to 7	V
V_{FB}	FB Input Voltage	-0.3 to 8	V
BV_{DSS}	Drain Voltage (T_J = +25°C)	700	V
I_D	Drain Continuous Current (T_J = +25°C)	5	A
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10 sec)	+260	°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* can 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 can affect device reliability.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	—	25	V
T_{OP}	Operating Temperature Range	-40	+105	°C
$f_{S(MAX)}$	Maximum Operating Frequency	—	80	kHz

Thermal Impedance (Note 6)

Symbol	Parameter	Value	Unit
θ_{JA}	Junction to Ambient	40	°C/W
θ_{JC}	Junction to Case	20	

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

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

Symbol	Parameter	Condition	Min	Typ	Max	Unit
STARTUP AND UVLO SECTION						
V_{TH_ST}	Turn-on Voltage	—	13	15.5	18	V
$V_{OPR(MIN)}$	Turn-off Voltage	—	6	6.8	7.6	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	350	500	650	
OPERATING FREQUENCY SECTION (5% LOAD TO FULL LOAD)						
$f_{S(MAX)}$	Operating Frequency in Full Load Condition	—	—	65	80	kHz
Δf/f	Frequency Dithering	5% to 100% of full load range	4	7	10	%
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	30% to 100% of full load	828	900	972	mV
$\Delta V_{CS}/V_{CS}$	V_{CS} Modulation for Frequency Dithering	—	—	2.5	—	%
t_{MOD}	V_{CS} Modulation Period	—	—	250	—	μs
R_{LINE}	Built-in Line Compensation Resistor	—	200	230	260	Ω
t_{LEB}	Leading Edge Blanking	@ V_{CS_H} and V_{CS_M}	410	500	575	ns
		@ V_{CS_EL}	220	250	288	ns
CONSTANT VOLTAGE SECTION						
V_{FB}	Equivalent Feedback Voltage @ Light Load	Closed loop test of V_{OUT}	3.89	3.95	4.01	V
R_{FB}	FB Pin Input Resistance	—	560	700	840	kΩ
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	—	4/8	—	—
POWER MOSFET SECTION						
BV_{DSS}	Drain-Source Breakdown Voltage	—	700	—	—	V
$R_{DS(ON)}$	On-State Resistor	—	—	—	1.4	Ω
PROTECTION FUNCTION SECTION						
$V_{FB(OVP)}$	Overvoltage 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

Operation Description

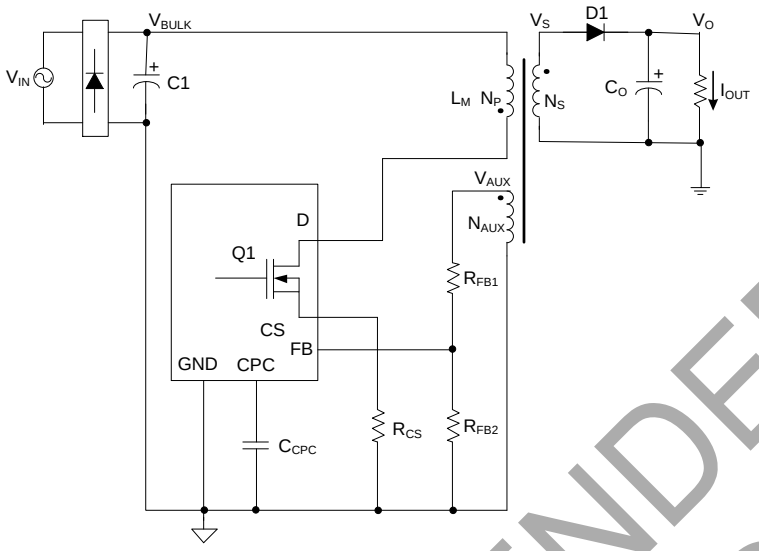


Figure 1. Simplified Flyback Converter Controlled by AP3983E

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:

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

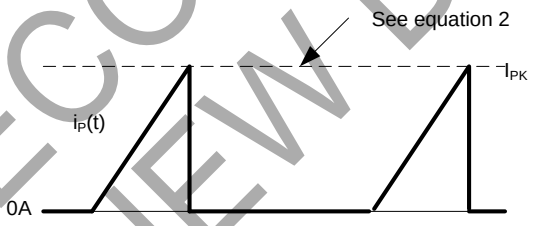


Figure 2. Primary Current Waveform

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:

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

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

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

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

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

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}.

Operation Description (continued)

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:

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

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.

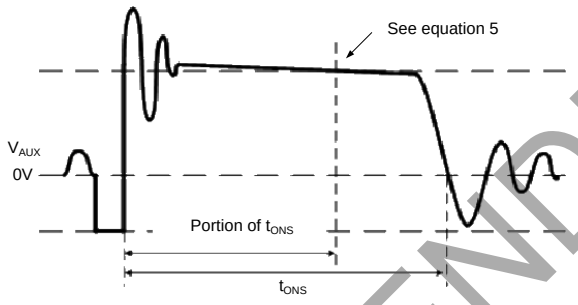


Figure 3. Auxiliary Voltage Waveform

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 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.

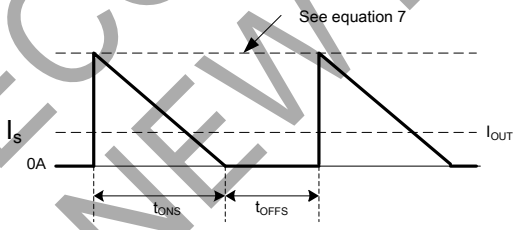


Figure 4. Secondary Current Waveform

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

$$\frac{t_{ONS}}{t_{OFFS}} = \frac{4}{4} \quad \text{.....(6)}$$

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:

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

Operation Description (continued)

Thus the output constant current is given by:

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

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 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.

Overtemperature 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

AP3983E X X - X

Product Name	Package	Packing	RoHS/Green
	P7: PDIP-7	Blank: Tube	G1:Green

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

Marking Information

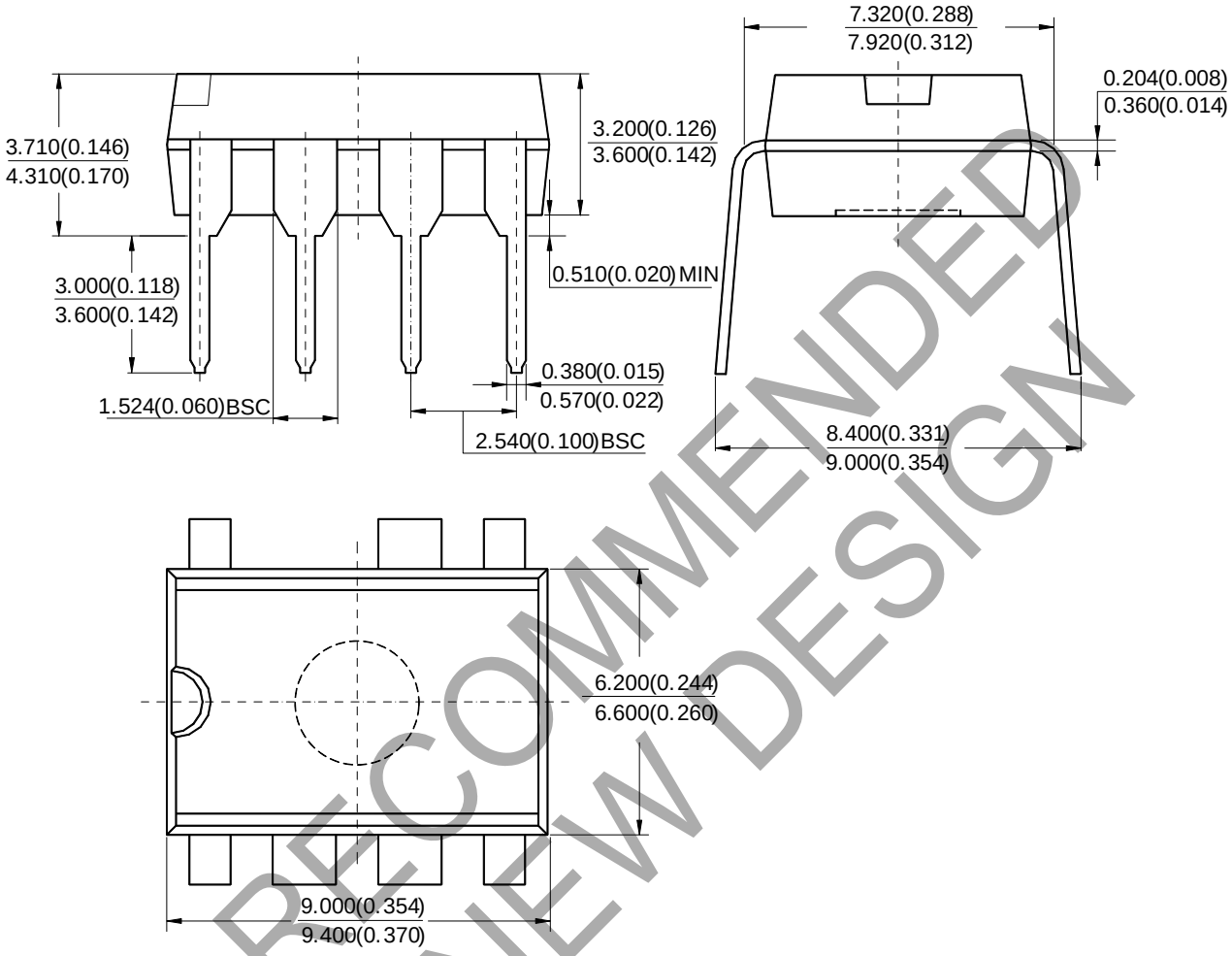
(Top View)

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

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

Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package Type: PDIP-7



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

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