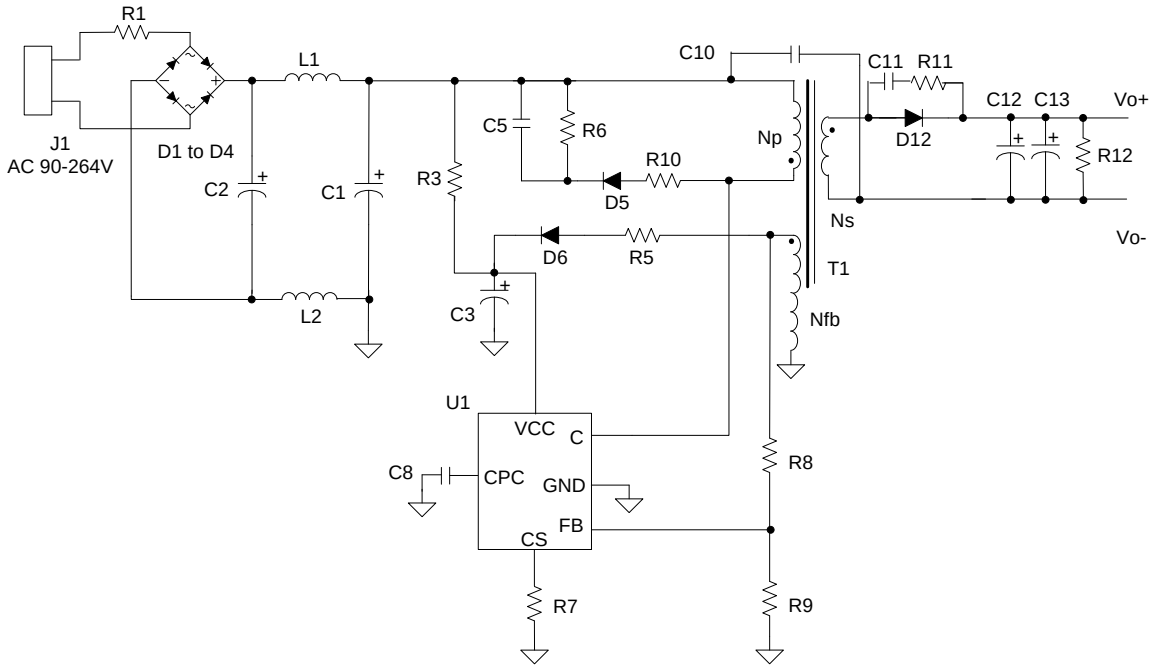
Typical Applications Circuit



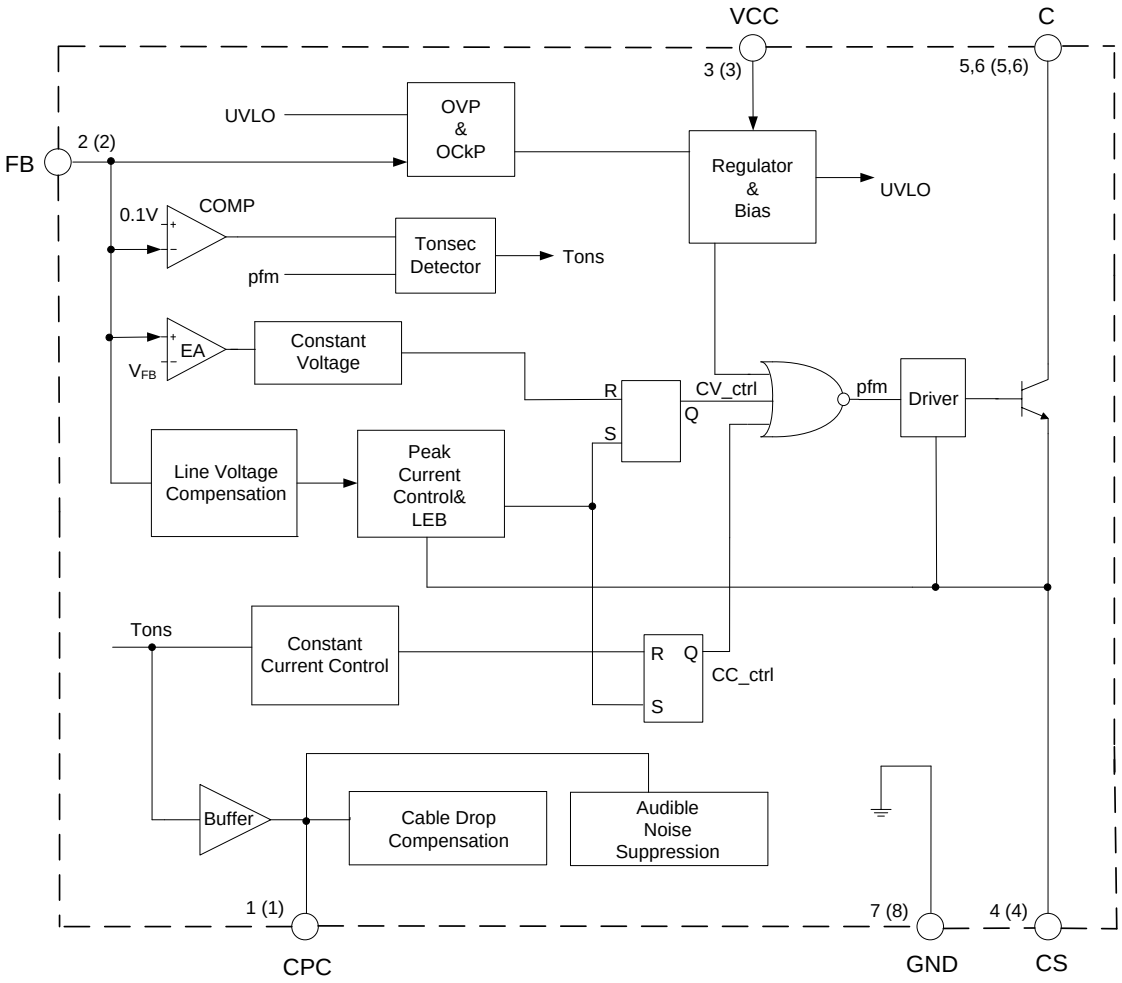
Typical Application of AP3969 (9V/800mA)

Item	Function	QTY	Item	Function	QTY
C1	10.0μF/400V, electrolytic	1	U1	AP3969	1
C2	4.7μF/400V, electrolytic	1	R1	11Ω, 2W	1
C3	3.3μF/50V, electrolytic	1	R3	3.3MΩ/0.25W	1
C5	1nF/1kV, ceramic	1	R5	3.9Ω, 0805	1
C8	0.01μF, 0805	1	R6	150kΩ, 1206	1
C10	1nF/250Vac, Y1 capacitor	1	R7	1Ω, 1206	1
C11	1nF, 0805	1	R8	20kΩ, 0805	1
C12, C13	470μF/16V	2	R9	13kΩ, 0805	1
D1 to D6	1N4007, rectifier diode	6	R10	360Ω, 0805	1
D12	MBR3100	1	R11	27Ω, 0805	1
L1	470μH, inductor	1	R12	1.2kΩ, 0805	1
L2	Bead, 0805	1	T1	EE16 core, PC40, transformer	1

Pin Descriptions

Pin Number		Pin Name	Function
SO-7/PDIP-7	PDIP-8		
1	1	CPC	This pin connects a capacitor to GND for output cable compensation
2	2	FB	The voltage feedback from auxiliary winding
3	3	VCC	This pin receives rectified voltage from the auxiliary winding of the transformer
4	4	CS	Current sense for primary side of transformer
5, 6	5, 6	C	This pin is connected with an internal power BJT's collector
–	7	NC	Not connected
7	8	GND	This pin is the signal reference ground

Functional Block Diagram



A(B)
A for SO-7/PDIP-7
B for PDIP-8

Absolute Maximum Ratings (Note 5)

Symbol	Parameter	Rating		Unit
V_{CC}	Supply Voltage	-0.3 to 22		V
V_{FB}	FB Input Voltage	-1 to 10		V
V_{CBO}	Collector-emitter Voltage	700		V
–	Collector DC Current	AP3968/69	1.5	A
		AP3970	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	AP3968	0.7	W
		AP3969	0.9	
		AP3970	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	–	22	V
T_{OP}	Operating Temperature Range	-40	+85	°C
$f_{(MAX)}$	Maximum Operating Frequency	–	60	kHz

Thermal Impedance

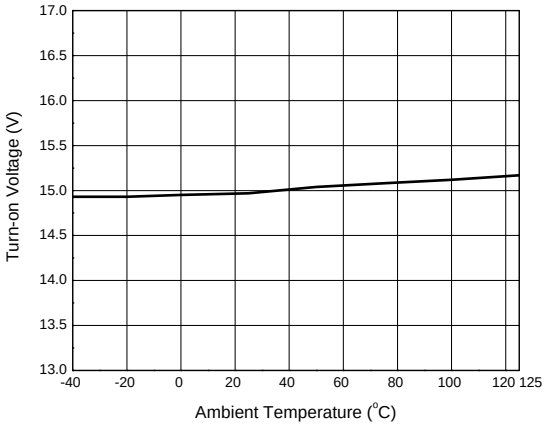
Symbol	Parameter	Value		Unit
θ_{JA}	Junction to Ambient	AP3968	100	°C/W
		AP3969	80	
		AP3970	65	
θ_{JC}	Junction to Case	AP3968	50	
		AP3969	40	
		AP3970	35	

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

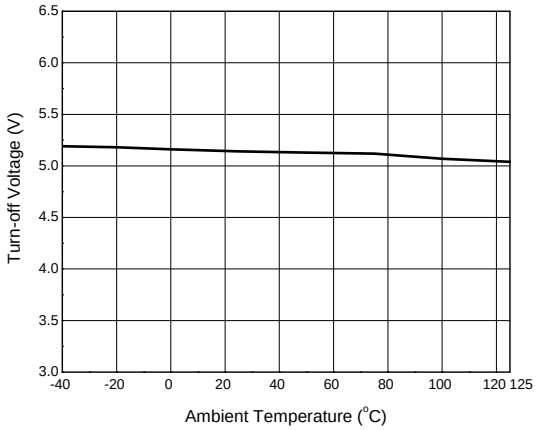
Symbol	Parameters	Conditions	Min	Typ	Max	Unit
UVLO SECTION						
V_{ON}	Turn-on Voltage	–	13	15	17	V
V_{OFF}	Turn-off Voltage	No drive Current	4.5	5.3	6.3	V
STANDBY CURRENT SECTION						
I_{ST}	Start-up Current	V_{CC}=V_{ON}-0.5V	–	0.2	0.6	μA
I_{CC}	Operating Current	–	320	435	550	
FEEDBACK INPUT SECTION						
V_{FB}	FB Threshold Voltage	–	4.23	4.3	4.37	V
I_{FB}	FB Pin Input Current	V_{FB}=4V	1.5	3.5	5.5	μA
POWER TRANSISTOR SECTION						
$V_{CE(SAT)}$	Collector-emitter Saturation Voltage	AP3968/69: I_C=0.5A AP3970: I_C=1A	–	–	0.3	V
h_{FE}	DC Current Gain	AP3968/69	14	17	–	–
		AP3970	17	26	–	–
I_{CEO}	Leakage Current	–	–	–	60	nA
OVER TEMPERATURE PROTECTION						
T_{SHDN}	Shutdown Temperature	–	+125	+160	–	°C
–	Temperature Hysteresis	–	–	+40	–	°C

Performance Characteristics

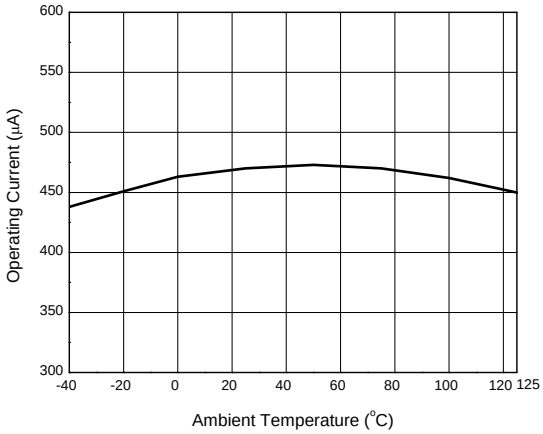
Turn-on Voltage vs. Ambient Temperature



Turn-off Voltage vs. Ambient Temperature



Operating Current vs. Ambient Temperature



Operation Description

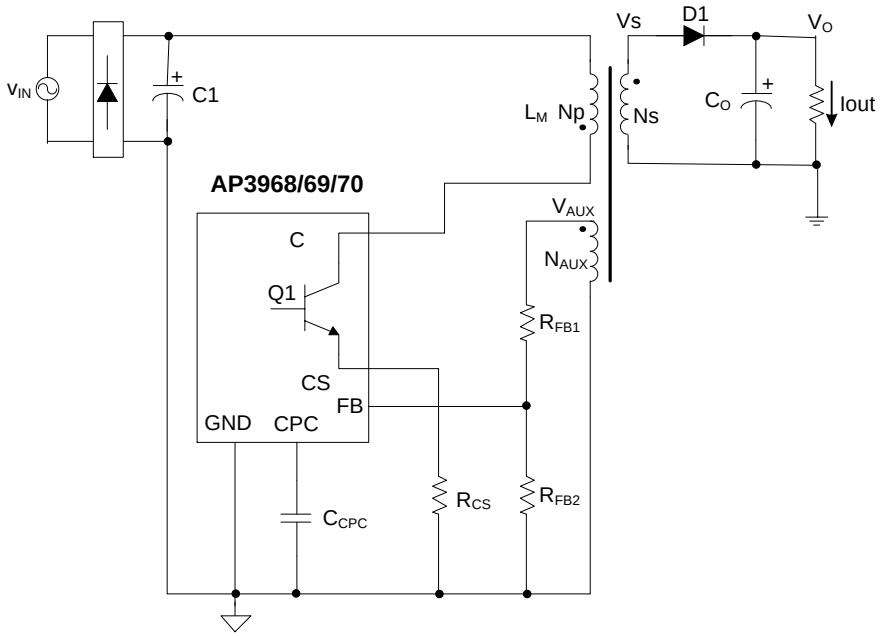


Figure 1. Simplified Flyback Converter Controlled by AP3968/69/70

Figure 1 illustrates a simplified flyback converter controlled by AP3968/69/70.

Constant Primary Peak Current

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

The current rises up linearly at a rate of:

$$\frac{dip(t)}{dt} = \frac{vg(t)}{L_M} \quad \text{.....(1)}$$

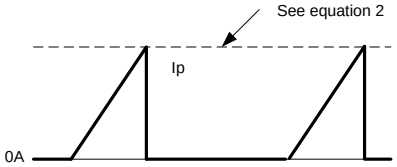


Figure 2. Primary Current Waveform

As illustrated in Figure 2, when the current Ip(t) rises up to Ipk, the switch Q1 turns off. The constant peak current is given by:

$$Ipk = \frac{Vcs}{Rcs} \quad \text{.....(2)}$$

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

$$Eg = \frac{1}{2} \cdot L_M \cdot Ipk^2 \quad \text{.....(3)}$$

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

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

Operation Description (Cont.)

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

Constant Voltage Operation

The AP3968/69/70 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:

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

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.

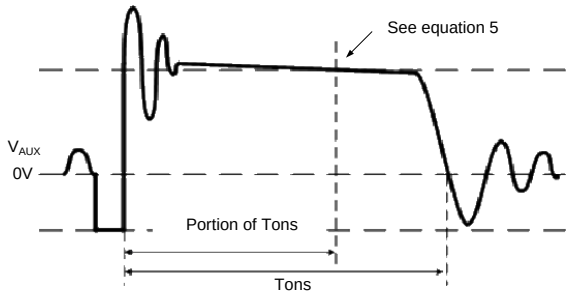


Figure 3. Auxiliary Voltage Waveform

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 Tons after D1 is turned on. The CV loop control function of AP3968/69/70 then generates a D1 off-time to regulate the output voltage.

Constant Current Operation

The AP3968/69/70 is designed to work in constant current (CC) mode. Figure 4 shows the secondary current waveforms.

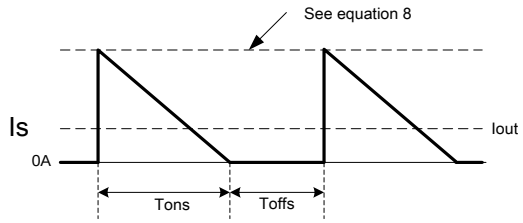


Figure 4. Secondary Current Waveform

In CC operation, the CC loop control function of AP3968/69/70 will keep a fixed proportion between D1 on-time Tons and D1 off-time Toffs by discharging or charging the built-in capacitance connected. This fixed proportion is

$$\frac{Tons}{Toffs} = \frac{4}{3} \quad \text{..... (6)}$$

The relation between the output constant-current and secondary peak current Ipks is given by:

$$Iout = \frac{1}{2} \cdot Ipks \cdot \frac{Tons}{Tons + Toffs} \quad \text{.....(7)}$$

Operation Description (Cont.)

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

$$Ipks = \frac{N_P}{N_S} \cdot Ipk \quad \text{.....(8)}$$

Thus the output constant current is given by:

$$Iout = \frac{2}{7} \cdot \frac{N_P}{N_S} \cdot Ipk \quad \text{.....(9)}$$

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 AP3968/69/70 has shorter delay time from current sense terminal to output pulse than those IC solutions adopting external RC filter as LEB.

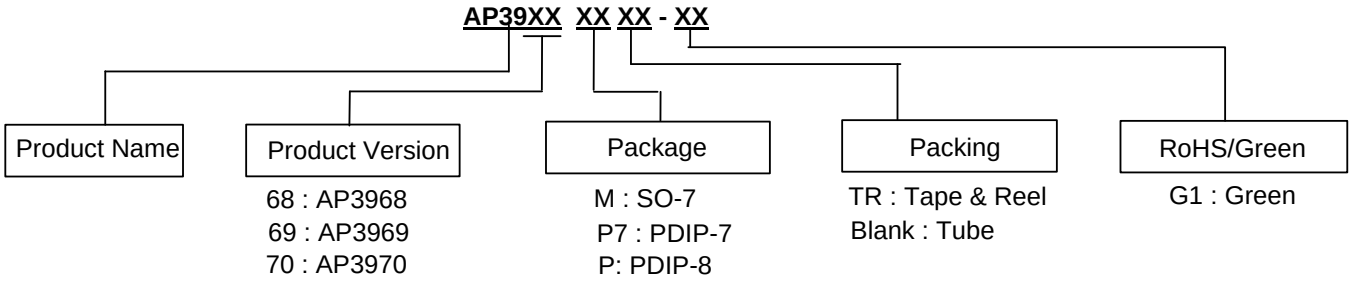
Built-in Cable Compensation

The AP3968/69/70 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 0.01µF external capacitor connected to the CPC pin is used to smooth voltage signal for cable compensation.

Over Temperature Protection

The AP3968/69/70 has internal thermal sensing circuit to shut down the PFM driver output when the die temperature reaches +160ºC typical. When the die temperature drops about 40ºC, the IC will recover automatically to normal operation.

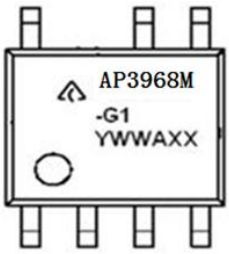
Ordering Information



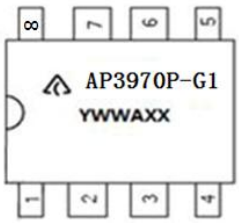
Diodes IC's Pb-free products with "G1" suffix in the part number, are RoHS compliant and green.

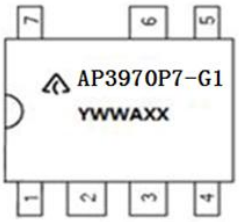
Package	Temperature Range	Part Number	Marking ID	Packing
SO-7	-40°C to +85°C	AP3968MTR-G1	AP3968M-G1	4000/Tape & Reel
PDIP-7		AP3969P7-G1	AP3969P7-G1	50/Tube
		AP3970P7-G1	AP3970P7-G1	50/Tube
PDIP-8		AP3970P-G1	AP3970P-G1	50/Tube

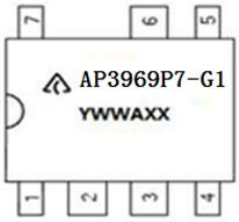
Marking Information



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.



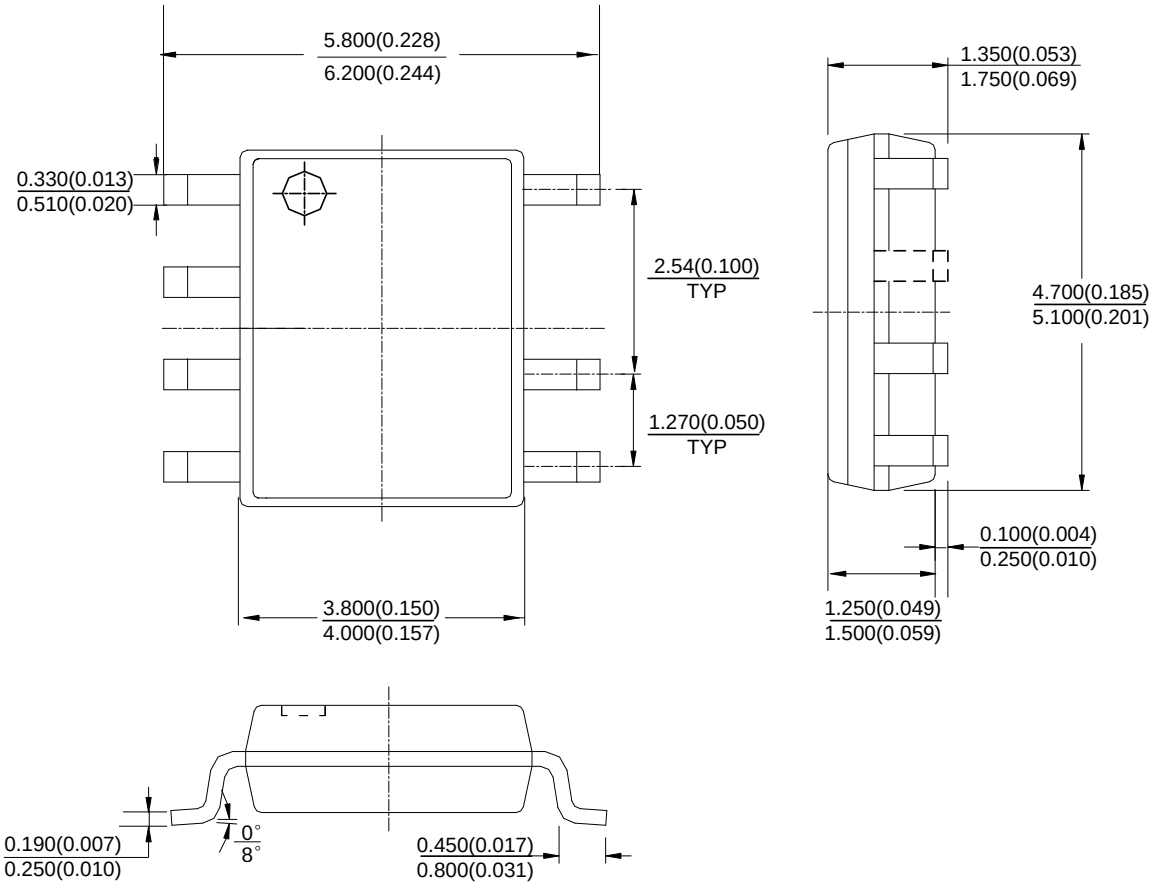




First Line: Logo and Marking ID
Second Line: Date Code
Y: Year
WW: Work Week of Molding
A: Assembly House Code
XX: 7th and 8th Digits of Batch No.

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

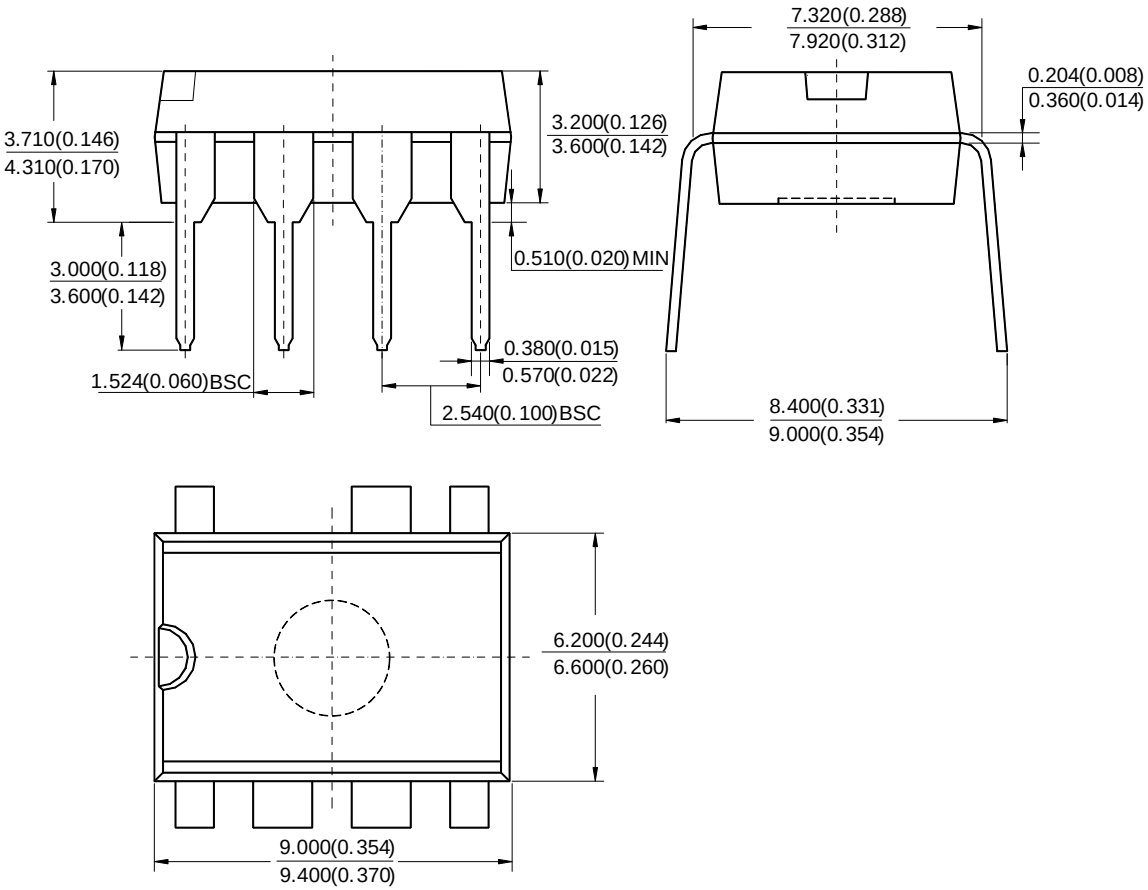
(1) Package Type: SO-7



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

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

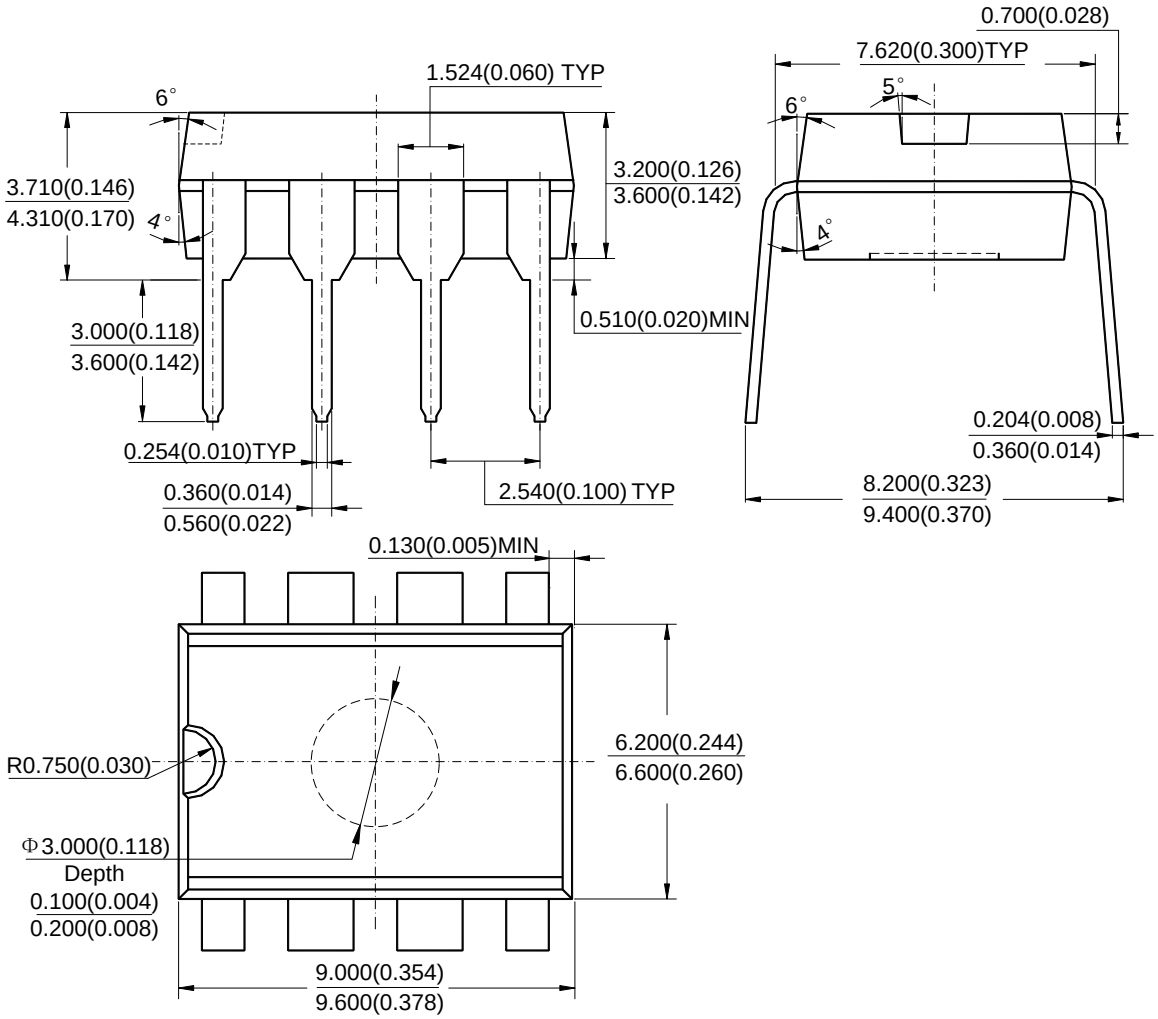
(2) Package Type: PDIP-7



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

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

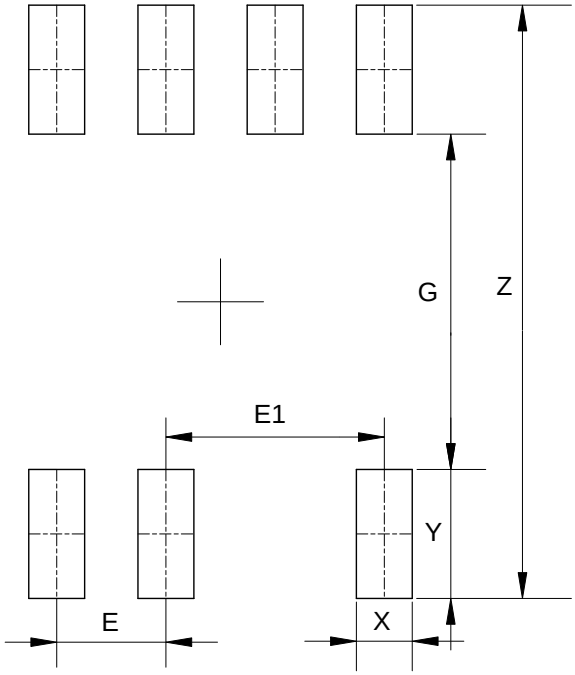
(3) Package Type: PDIP-8



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

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

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