

Description

The DIODES™ AP3968 / DIODES™ AP3969 / DIODES™ AP3970 consists of a primary side regulation controller and a high voltage transistor, and is specially designed for off-line power supplies within 12W output power. Typical applications include adapter for ADSL and auxiliary supplies.

The AP3968/69/70 operates at pulse frequency modulation (PFM), and provides accurate constant voltage, constant current (CV/CC) regulation without requiring an opto-coupler and secondary control circuitry. It has internal cable compensation function for tight constant voltage regulation.

The AP3968/69/70 solution has fewer component numbers, smaller size, and lower total cost.

The AP3968 is packaged in SO-7. The AP3969 is available in PDIP-7. The AP3970 is available in PDIP-7 and PDIP-8 packages.

Applications

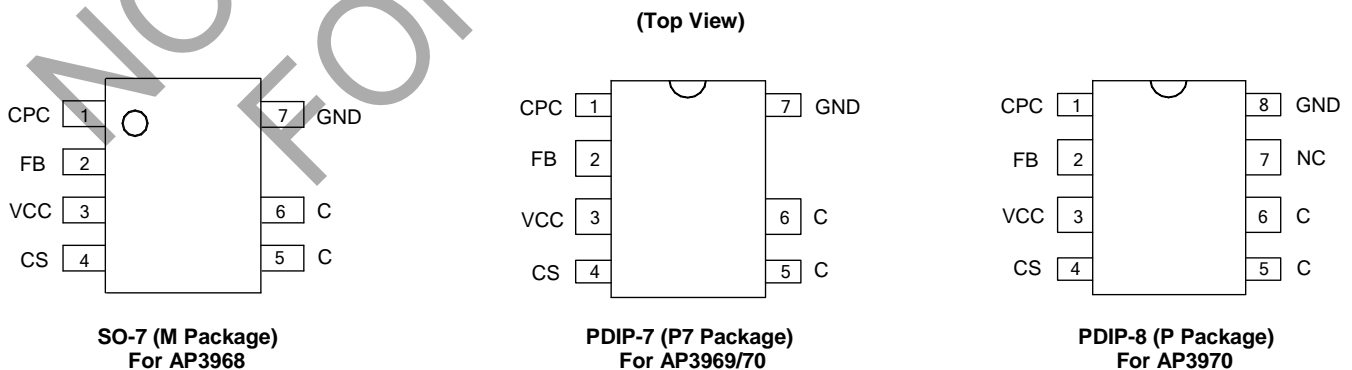
- Chargers
- Adapters
- Set top boxes
- Auxiliary supplies
- DVD
- LED drivers

- 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.

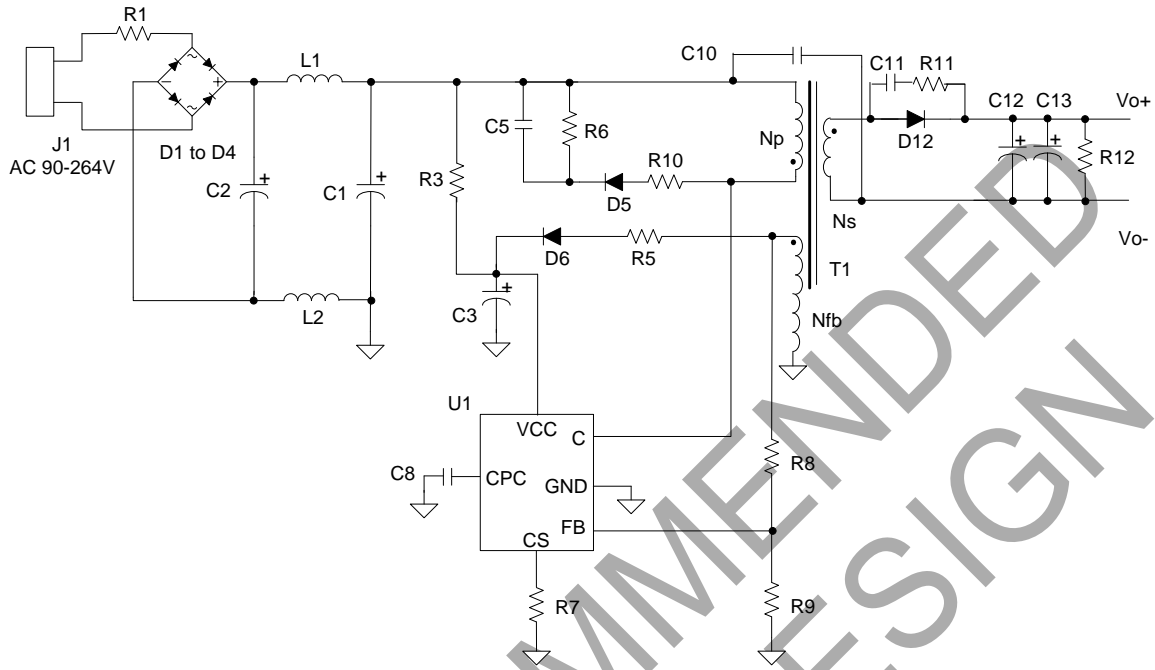
Features

- 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
- Random Frequency Modulation for Low EMI
- Short Circuit Protection
- Low Total Cost Solution
- Output Power Range (Note 1):
 - AP3968 for 5W Adapter
 - AP3969 for 7.5W Adapter
 - AP3970 for 12W Adapter
- **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/>**

Pin Assignments



Typical Applications Circuit



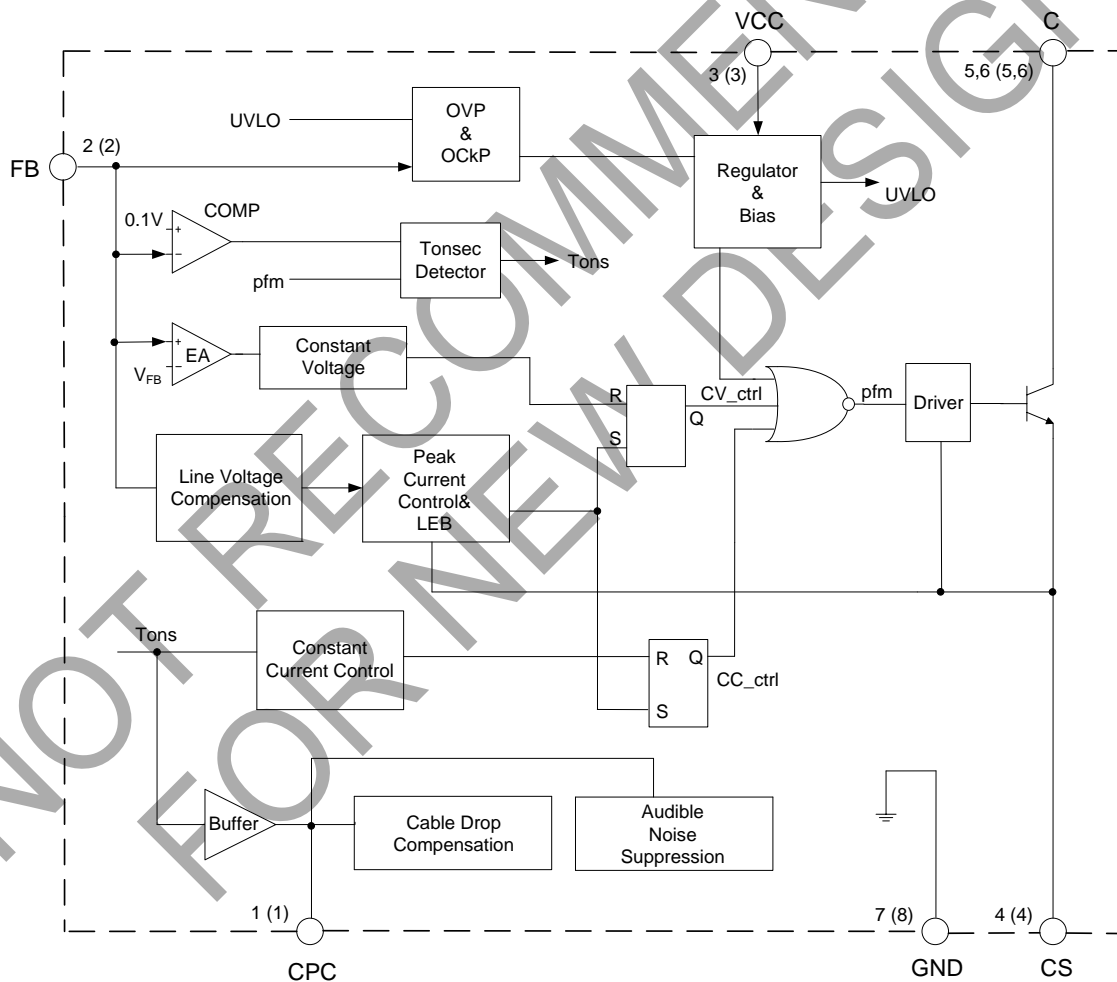
Typical Application of AP3969 (9V/800mA)

Item	Function	QTY	Item	Function	QTY
C1	10.0 μ F/400V, electrolytic	1	U1	AP3969	1
C2	4.7 μ F/400V, electrolytic	1	R1	11 Ω , 2W	1
C3	3.3 μ F/50V, electrolytic	1	R3	3.3M Ω /0.25W	1
C5	1nF/1kV, ceramic	1	R5	3.9 Ω , 0805	1
C8	0.01 μ F, 0805	1	R6	150k Ω , 1206	1
C10	1nF/250Vac, Y1 capacitor	1	R7	1 Ω , 1206	1
C11	1nF, 0805	1	R8	20k Ω , 0805	1
C12, C13	470 μ F/16V	2	R9	13k Ω , 0805	1
D1 to D6	1N4007, rectifier diode	6	R10	360 Ω , 0805	1
D12	MBR3100	1	R11	27 Ω , 0805	1
L1	470 μ H, inductor	1	R12	1.2k Ω , 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 _{CEO}	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* 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	–	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	

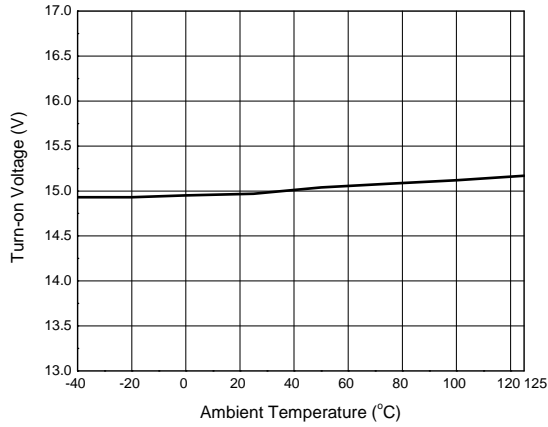
Electrical Characteristics (@V_{CC}=15V, T_J=+25°C, unless otherwise specified.)

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

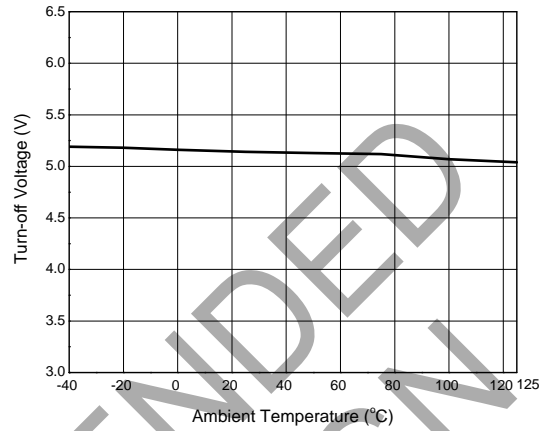
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Performance Characteristics

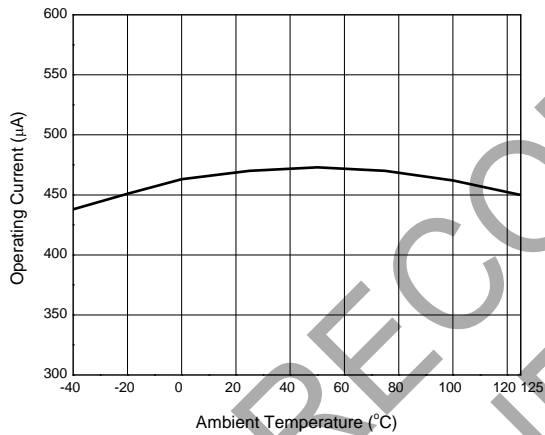
Turn-on Voltage vs. Ambient Temperature



Turn-off Voltage vs. Ambient Temperature



Operating Current vs. Ambient Temperature



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Operation Description

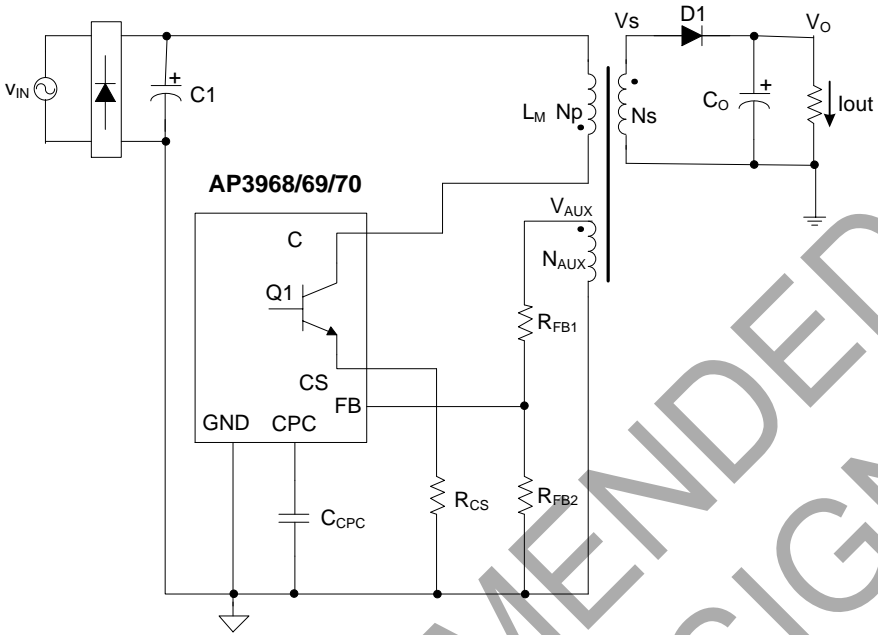


Figure 1. Simplified Flyback Converter Controlled by AP3968/69/70

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

Constant Primary Peak Current

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

The current rises up linearly at a rate of:

$$\frac{di_p(t)}{dt} = \frac{v_g(t)}{L_M} \dots\dots\dots(1)$$

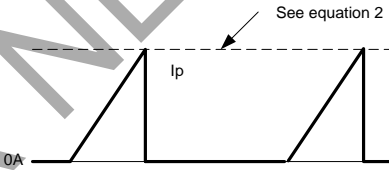


Figure 2. Primary Current Waveform

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:

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

Operation Description (continued)

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 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:

$$V_{AUX} = \frac{N_{AUX}}{N_s} \cdot (V_o + V_d) \dots\dots\dots(5)$$

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.

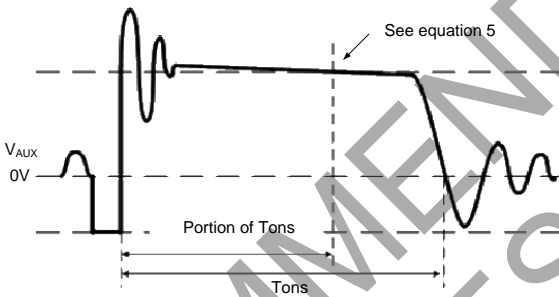


Figure 3. Auxiliary Voltage Waveform

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 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.

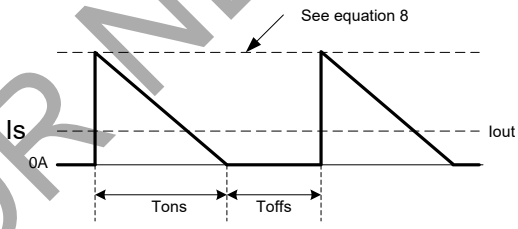


Figure 4. Secondary Current Waveform

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

$$\frac{T_{ons}}{T_{offs}} = \frac{4}{3} \dots\dots\dots(6)$$

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

$$I_{out} = \frac{1}{2} \cdot I_{pks} \cdot \frac{T_{ons}}{T_{ons} + T_{offs}} \dots\dots\dots(7)$$

Operation Description (continued)

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:

$$I_{out} = \frac{2}{7} \cdot \frac{N_p}{N_s} \cdot I_{pk} \dots\dots\dots(9)$$

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.

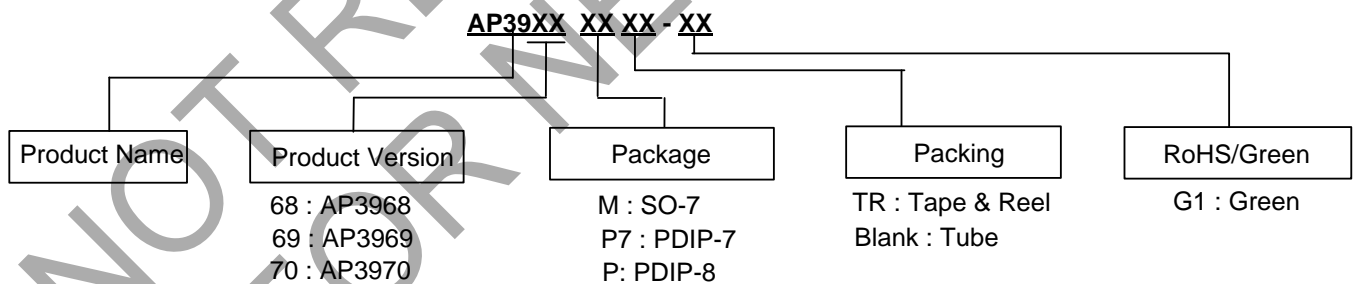
Built-in Cable Compensation

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

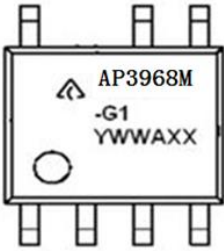
The AP3968/69/70 has internal thermal sensing circuit to shut down the PFM driver output when the die temperature reaches +160°C typical. When the die temperature drops about 40°C, the IC will recover automatically to normal operation.

Ordering Information

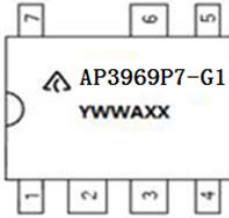
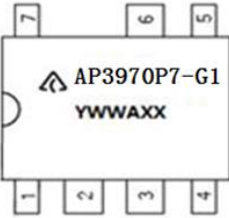
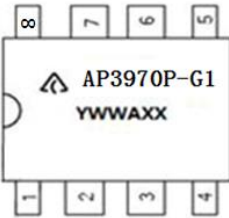


Package	Temperature Range	Part Number	Marking ID	Packing	
				Qty.	Carrier
SO-7	-40°C to +85°C	AP3968MTR-G1	AP3968M-G1	4000	Tape & Reel
PDIP-7		AP3969P7-G1	AP3969P7-G1	50	Tube
PDIP-8		AP3970P7-G1	AP3970P7-G1	50	Tube
		AP3970P-G1	AP3970P-G1	50	Tube

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.



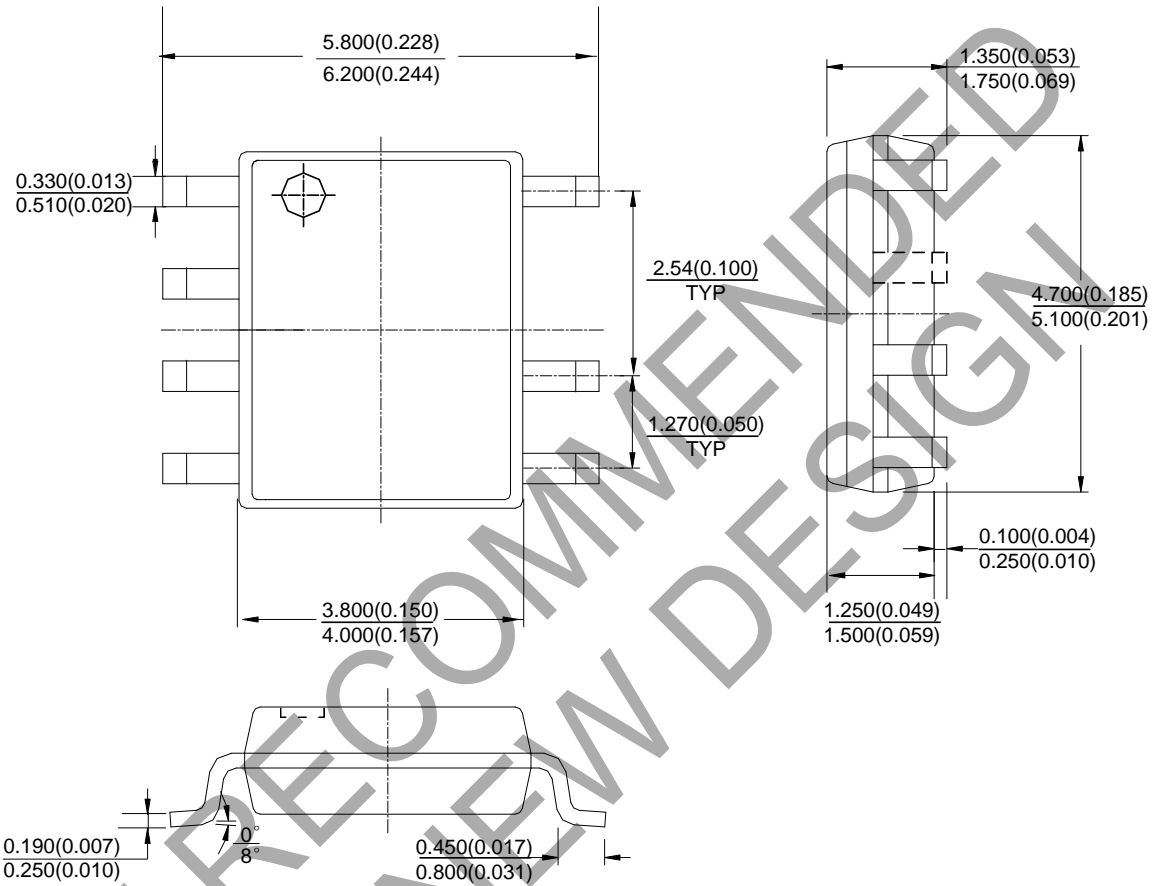
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Package Outline Dimensions (All dimensions in mm(inch).)

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

(1) Package Type: SO-7

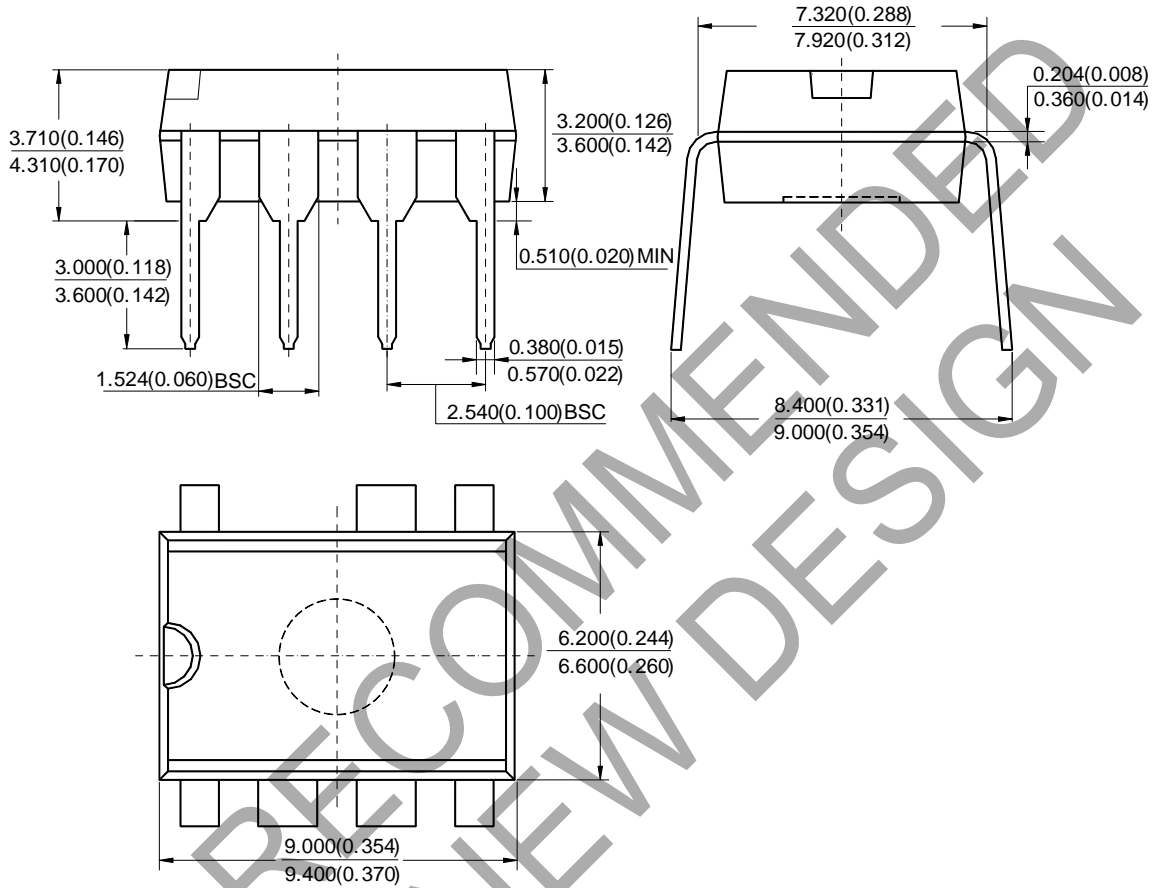


Note: Eject hole, oriented hole and mold mark is optional.

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

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

(2) Package Type: PDIP-7



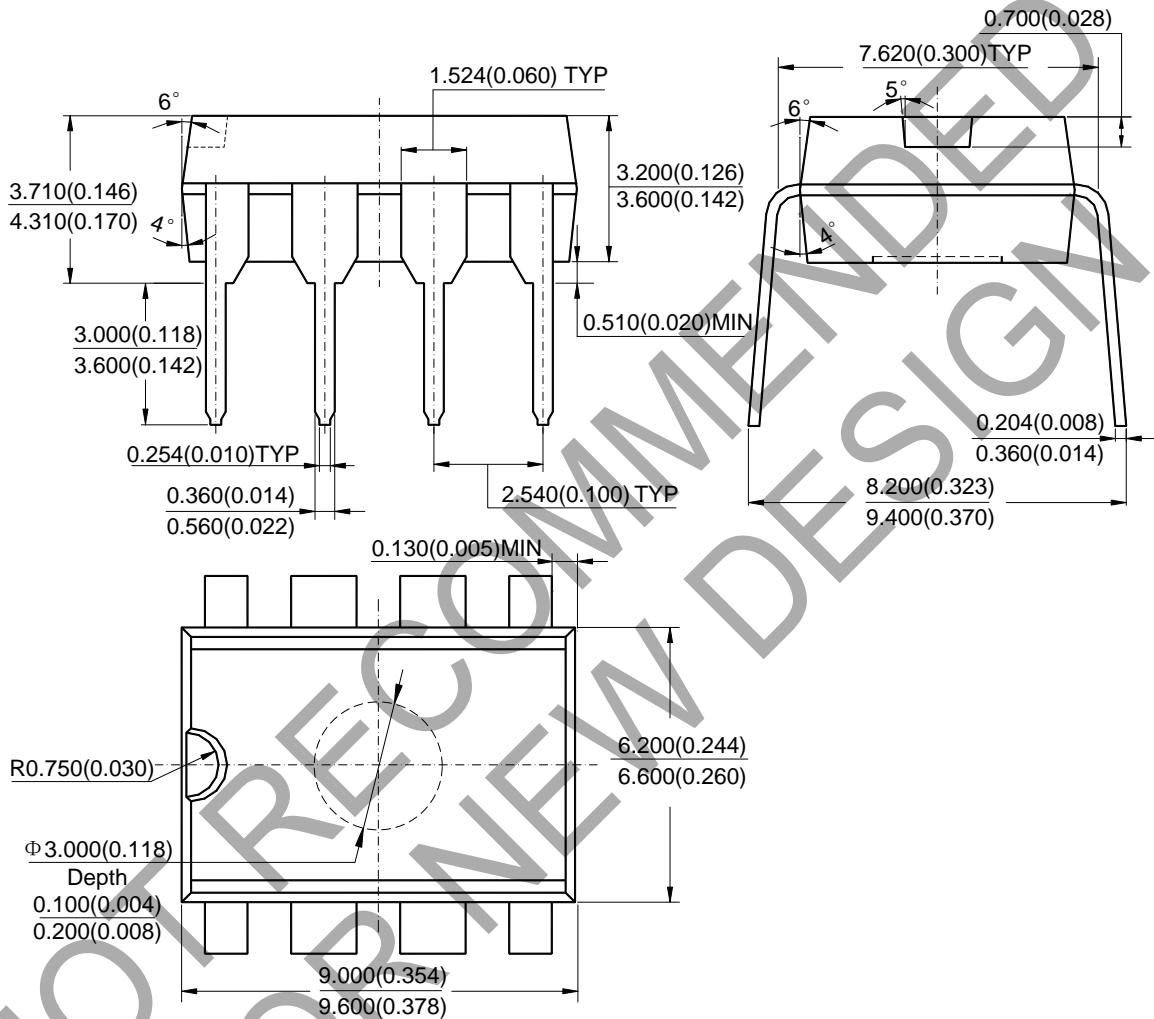
Note: Eject hole, oriented hole and mold mark is optional

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

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

(3) Package Type: PDIP-8

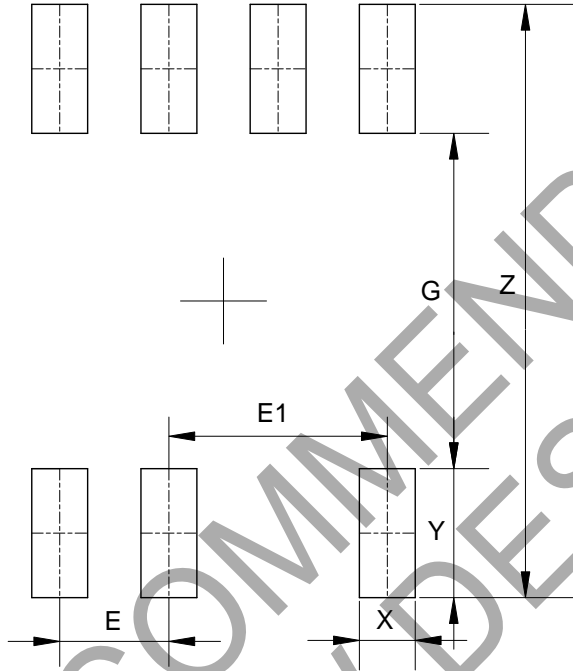


Note: Eject hole, oriented hole and mold mark is optional.

Suggested Pad Layout

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

(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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