PRIMARY SIDE POWER SWITCHER FOR FLYBACK/NON-ISOLATED BUCK SMPS

Description

The DIODES™ AP3965/66/71 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 or non-isolated buck applications within 5W. Typical applications include adapter for ADSL, auxiliary supplies or open frame types for appliances.

The AP3965/66/71 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 AP3965/66/71 solution has fewer component numbers, smaller size, and lower total cost.

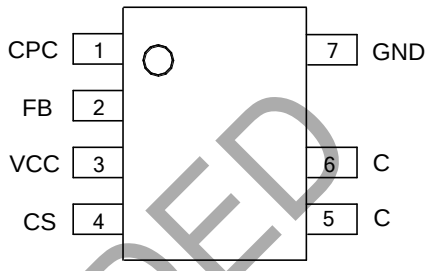
The AP3965 is packaged in SO-7. The AP3966/71 is available in PDIP-7.

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):
  - AP3965 for 5W Adapter and 3W Buck
  - AP3966 for 10W Adapter and 4.5W Buck
  - AP3971 for 12W Adapter and 5W Buck
- **Totally Lead-Free & Fully RoHS Compliant (Notes 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/**

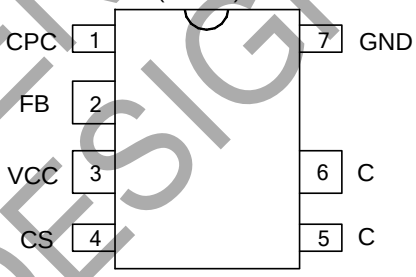
Pin Assignments

M Package
(SO-7)



For AP3965

P7 Package
(PDIP-7)



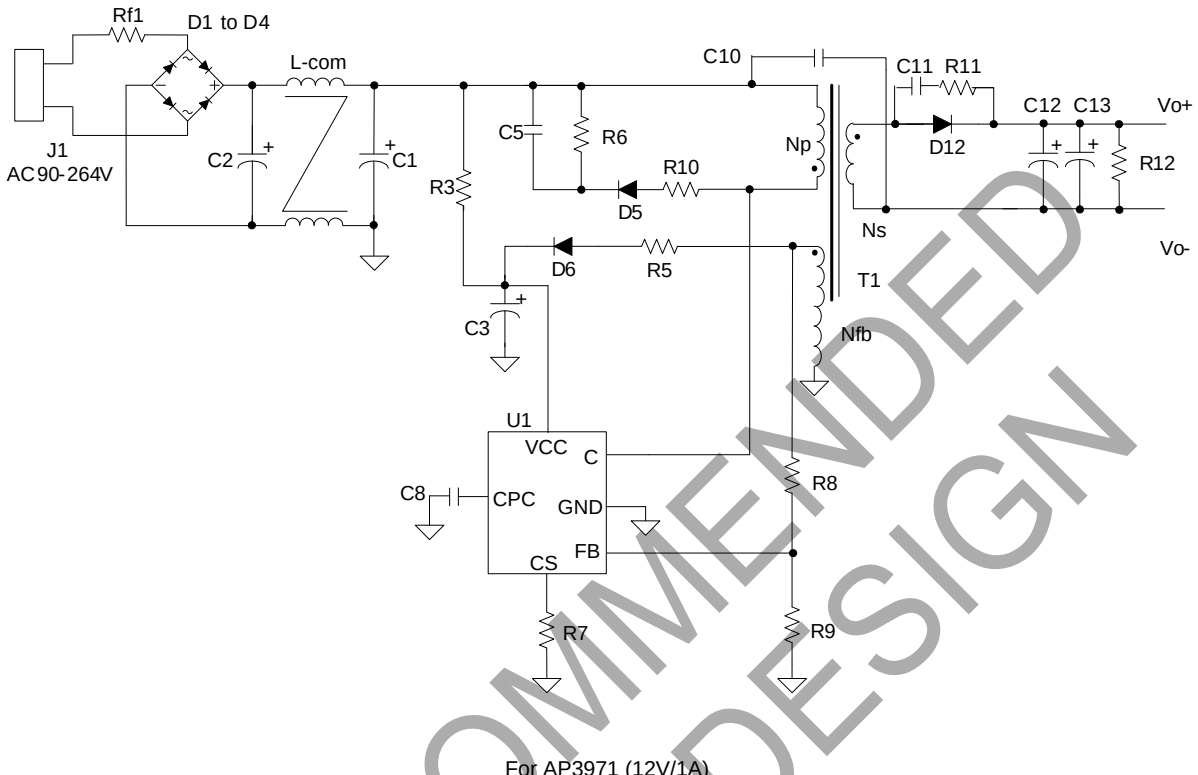
For AP3966/71

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) & 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



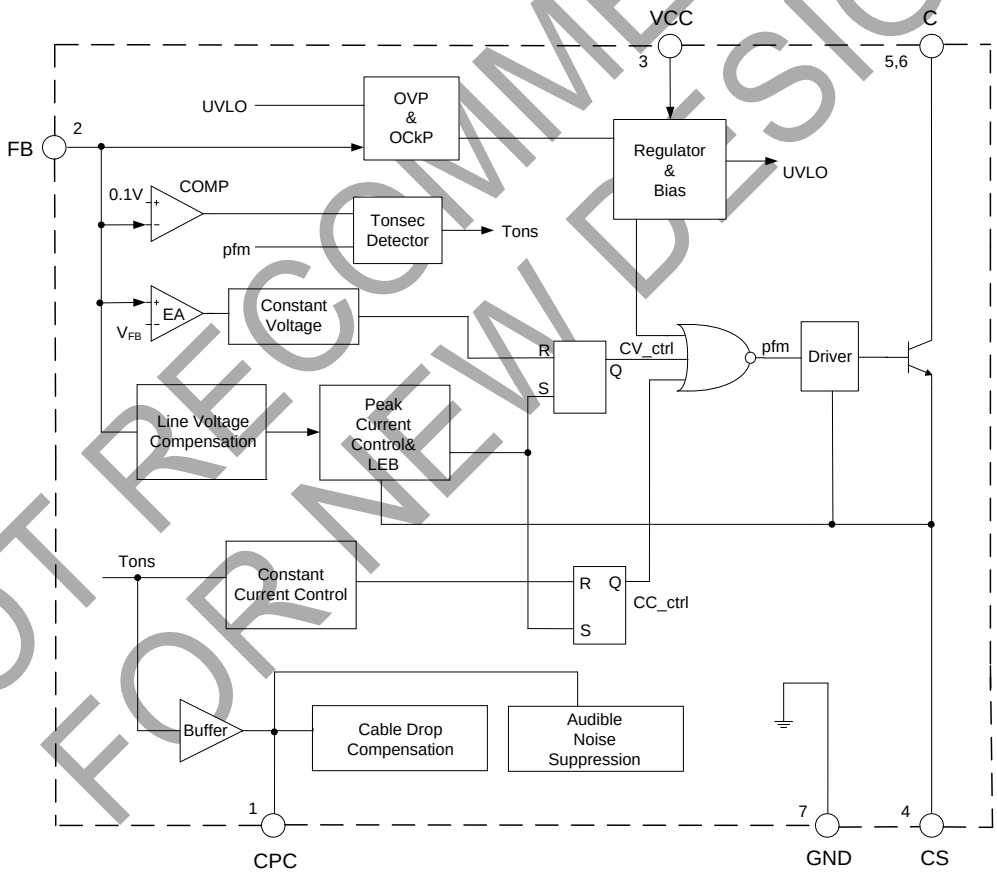
For AP3971 (12V/1A)

Item	Function	QTY	Item	Function	QTY
C1, C2	10μF/400V, electrolytic	2	U1	AP3971, 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
L-com	EE10, 15mH, Common inductor	1	R11	27Ω, 0805	1
T1	EE19 core, PC40, transformer	1	R12	1.2kΩ, 0805	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	C	This pin is connected with an internal power BJT's collector
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 +22		V
V_{FB}	FB Input Voltage	-1 to +10		V
V_{CBO}	Collector-Emitter Voltage	700		V
—	Collector DC Current	AP3965	1.5	A
		AP3966	3.2	
		AP3971	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	AP3965	0.9	W
		AP3966	1.4	
		AP3971	1.5	

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 (Note 6)

Symbol	Parameter	Value		Unit
θ_{JA}	Junction to Ambient	AP3965	80	°C/W
		AP3966	50	
		AP3971	45	
θ_{JC}	Junction to Case	AP3965	40	
		AP3966	26	
		AP3971	22	

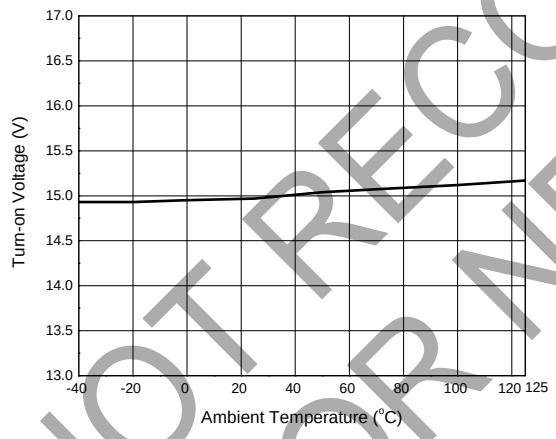
Note 6: When mounted a standard single-sided FR4 board with 300mm^2 Cu (at least 35µm thick) connected to all collectors and CS pins.

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

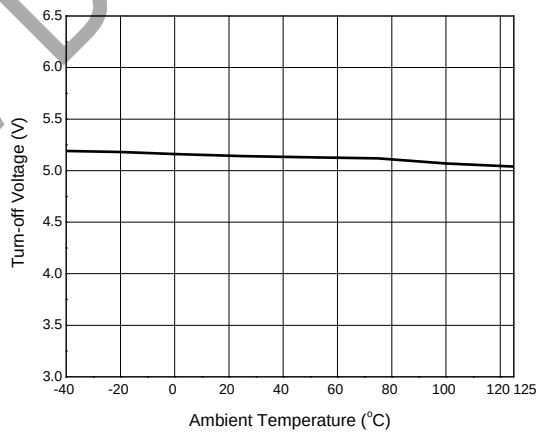
Symbol	Parameters	Conditions	Min	Typ	Max	Unit
UVLO Section						
V_{ON}	Turn-on Voltage	—	13	15	17	V
V_{OFF}	Turn-off Voltage	No drive current	4.5	5.3	6.3	V
Standby Current Section						
I_{ST}	Start-up Current	$V_{CC} = V_{ON} - 0.5V$	—	0.2	0.6	μA
I_{CC}	Operating Current	—	320	435	550	
Feedback Input Section						
I_{FB}	FB Input Current	V_{FB} = 4V	1.5	3.5	5.5	μA
V_{FB}	FB Threshold Voltage	—	4.324	4.4	4.476	V
Power Transistor Section						
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage	AP3965: I_C = 0.5A AP3966/71: I_C = 1A	—	—	0.3	V
h_{FE}	DC Current Gain	AP3965	14	17	—	—
		AP3966/71	17	26	—	
I_{CEO}	Leakage Current	—	—	—	60	nA
Over Temperature Protection						
T_{SHDN}	Shutdown Temperature	Surface temperature	+125	+160	—	°C
—	Temperature Hysteresis	—	—	+40	—	°C

Performance Characteristics

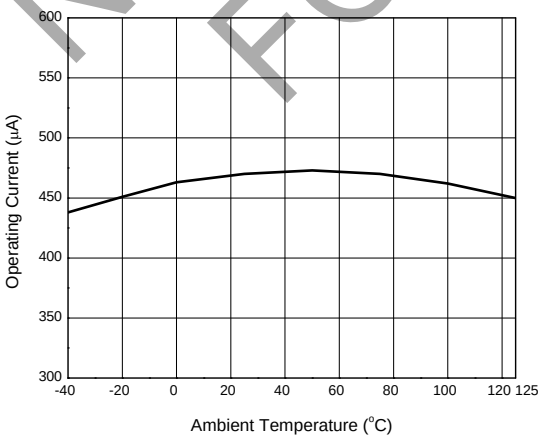
Turn-on Voltage vs. Ambient Temperature



Turn-off Voltage vs. Ambient Temperature



Operating Current vs. Ambient Temperature



Operation Description

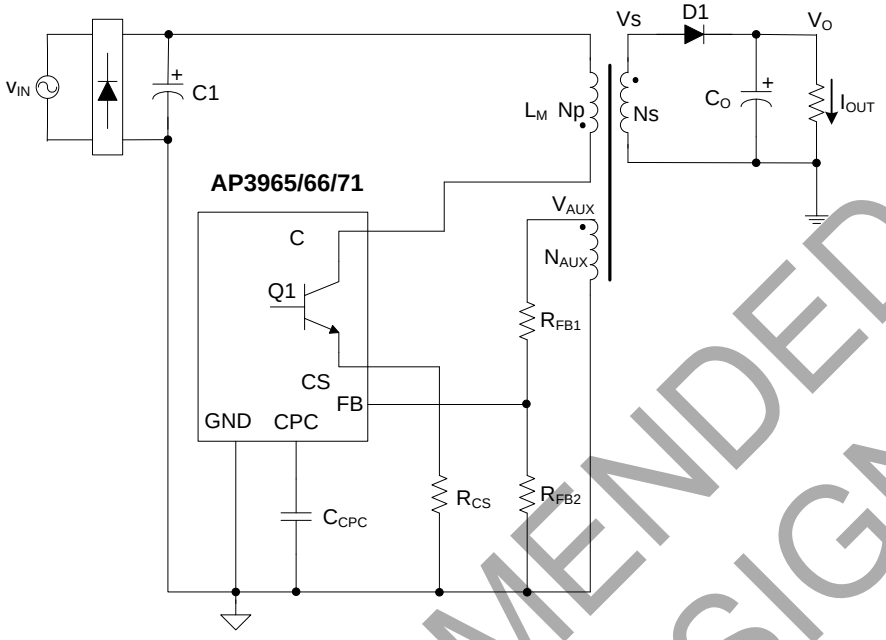


Figure 1 Simplified Flyback Converter Controlled by AP3965/66/71

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:

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

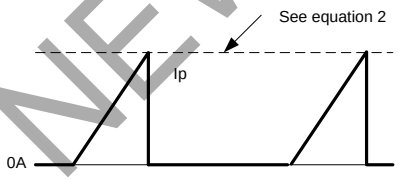


Figure 2 Primary Current Waveform

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:

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

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

Operation Description (continued)

Constant Voltage Operation

The AP3965/66/71 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.

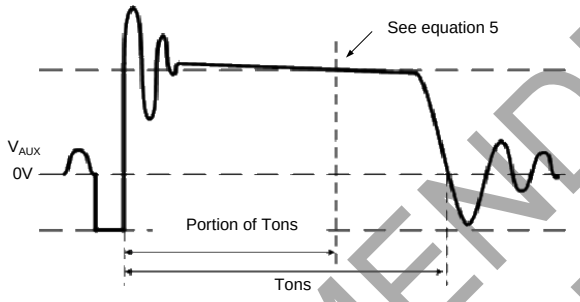


Figure 3. Auxiliary Voltage Waveform

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 AP3965/66/71 then generates a D1 off-time to regulate the output voltage.

Constant Current Operation

The AP3965/66/71 is designed to work in constant current (CC) mode. Figure 4 shows the secondary current waveforms.

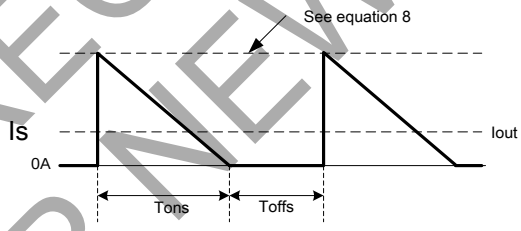


Figure 4. Secondary Current Waveform

In CC operation, the CC loop control function of AP3965/66/71 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

$$\frac{Tons}{Toffs} = \frac{4}{2} \quad \text{..... (6)}$$

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

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

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

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

Operation Description (continued)

Thus the output constant current is given by:

$$I_{OUT} = \frac{1}{3} \cdot \frac{N_P}{N_S} \cdot Ipk \quad \text{.....(9)}$$

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 AP3965/66/71 has shorter delay time from current sense terminal to output pulse than those IC solutions adopting external RC filter as LEB.

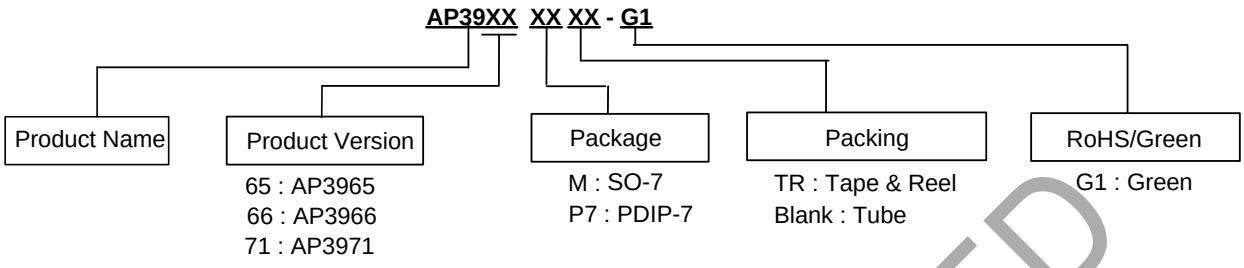
Built-in Cable Compensation

The AP3965/66/71 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 AP3965/66/71 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

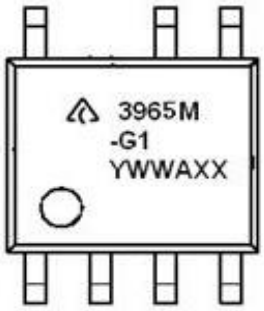


Diodes Incorporated's Pb-free products with "G1" suffix in the part number, are RoHS compliant and green.

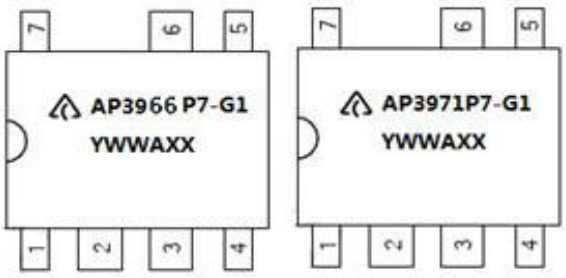
Part Number	Status	Package	Temperature Range	Marking ID	Packing	
					Qty.	Carrier
AP3965MTR-G1	NRND (Note 7)	SO-7	-40°C to +85°C	3965M-G1	4,000	Tape & Reel
AP3966P7-G1	NRND (Note 7)	PDIP-7		AP3966P7-G1	50	Tube
AP3971P7-G1 (Note 8)	Obsolete			AP3971P7-G1	50	Tube

Notes: 7. NRND = Not Recommended for New Design.
8. AP3971P7-G1 is obsolete and discontinued.

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.

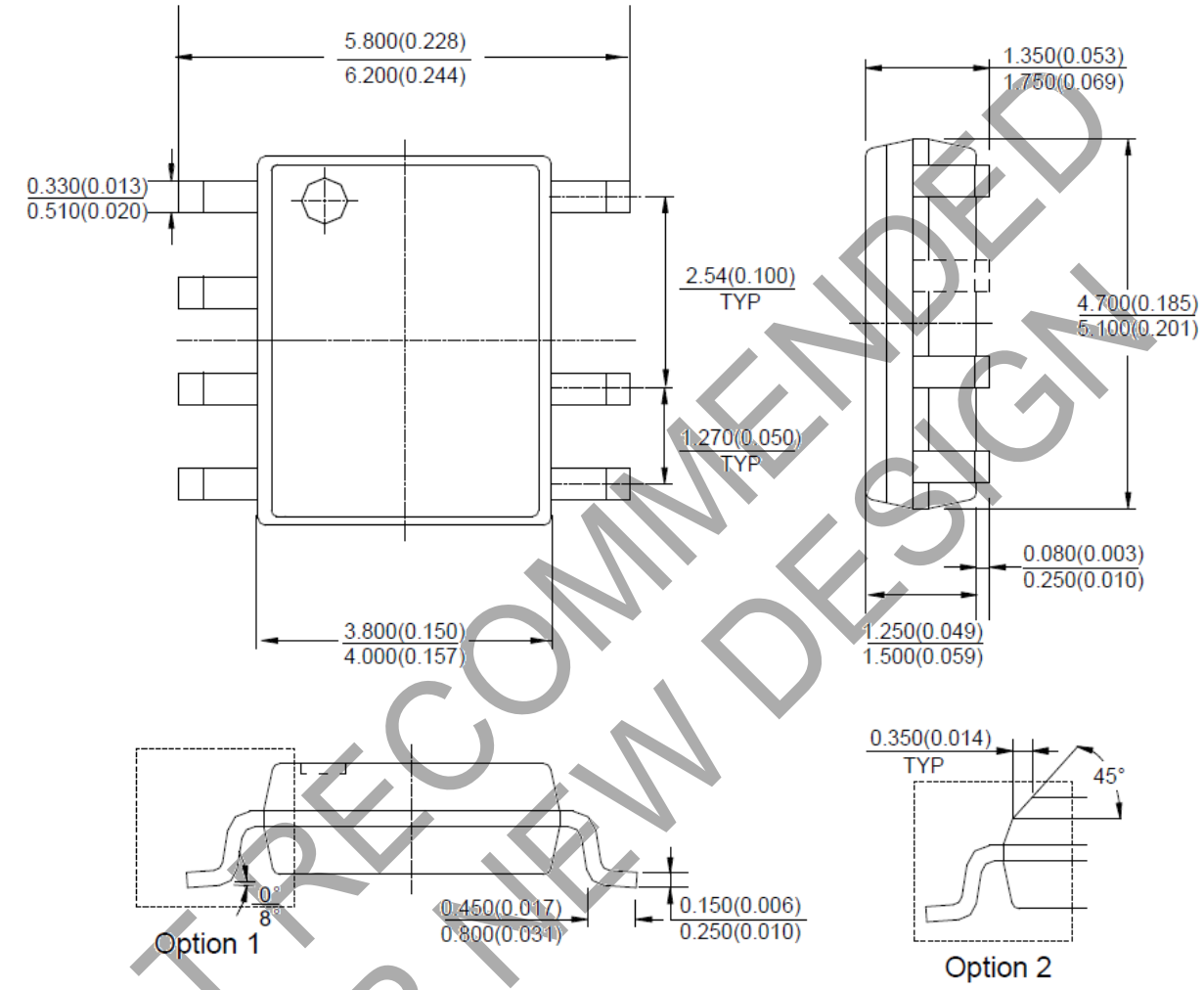


First Line: Logo and Marking ID
Second Line: Date Code
Y: Year
WW: Work Week of Molding
A: Assembly House Code
XX: 7th and 8th Digits of Batch No.

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

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

SO-7



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

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

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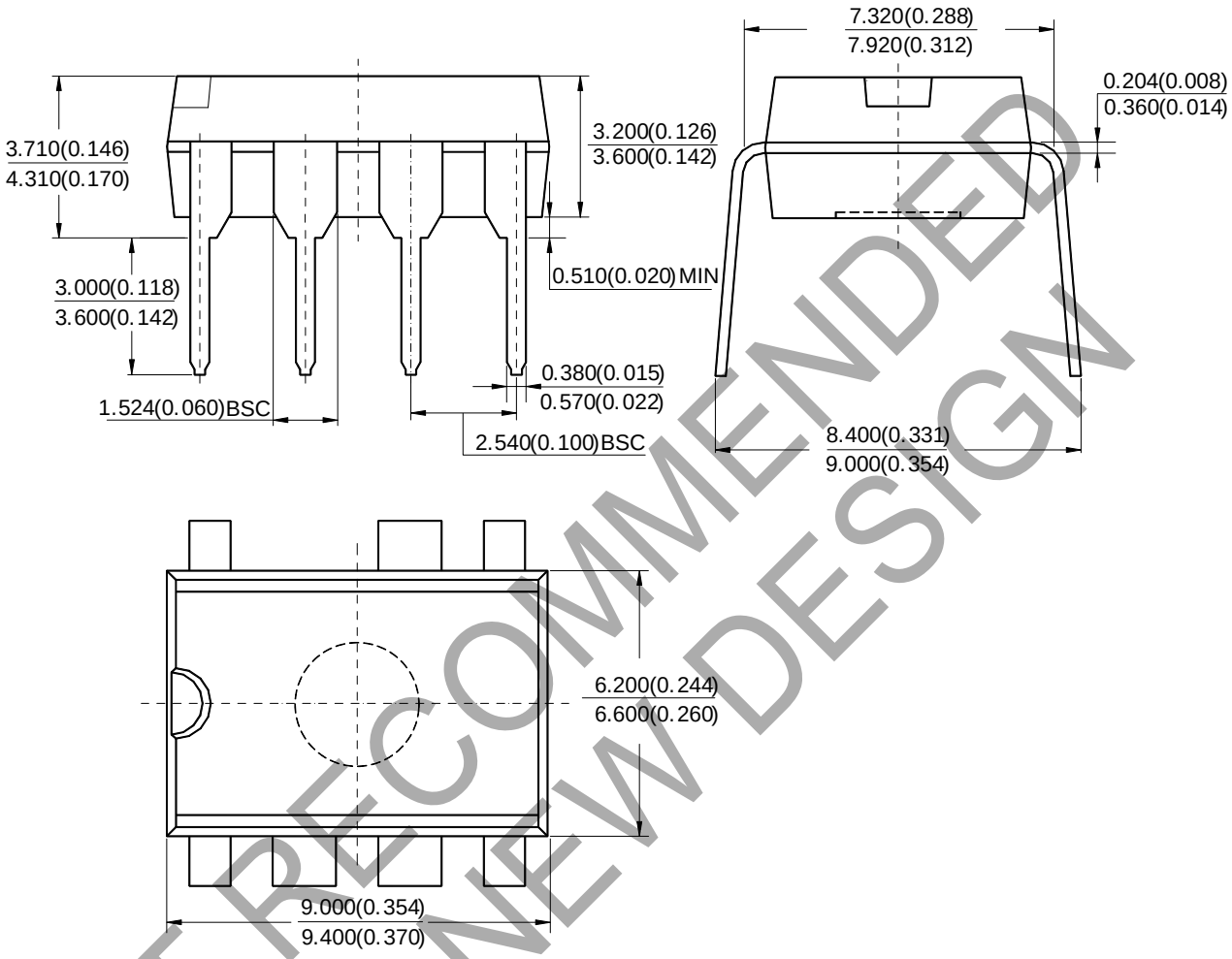
PDIP-7



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

Suggested Pad Layout

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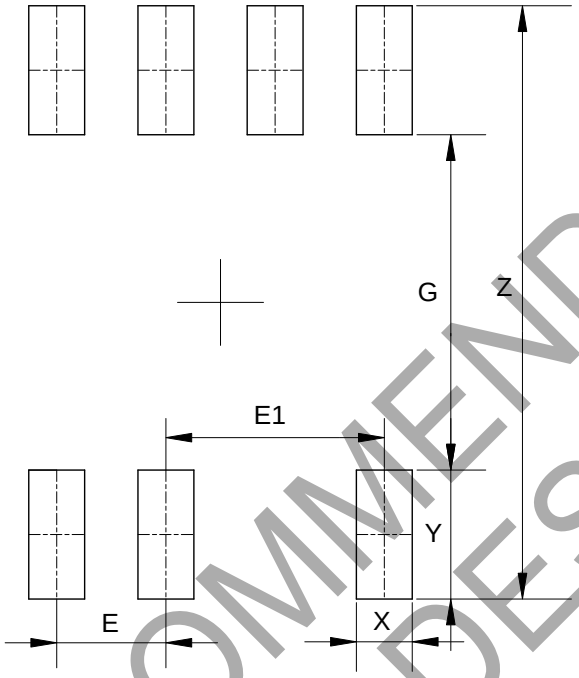
SO-7



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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