

PRIMARY SIDE POWER SWITCHER FOR OFF-LINE SMPS

Description

The AP3968/69/70 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.

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)**

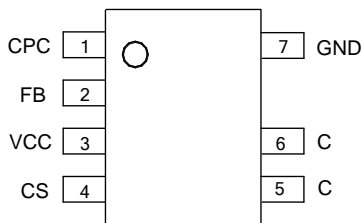
Applications

- Chargers
- Adapters
- Set Top Boxes
- Auxiliary Supplies
- DVD
- LED Driver

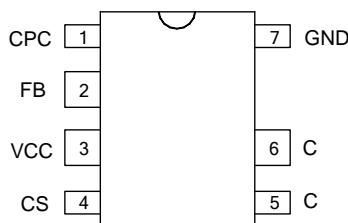
- Notes:
1. Typical continuous power in a non-ventilated enclosed adapter measured at +50°C ambient.
 2. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
 3. See http://www.diodes.com/quality/lead_free.html for more information about Diodes Incorporated's 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

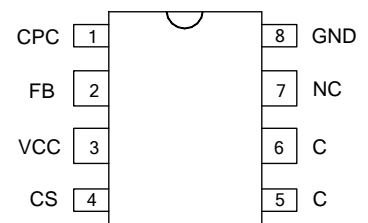
(Top View)



**SO-7 (M Package)
For AP3968**

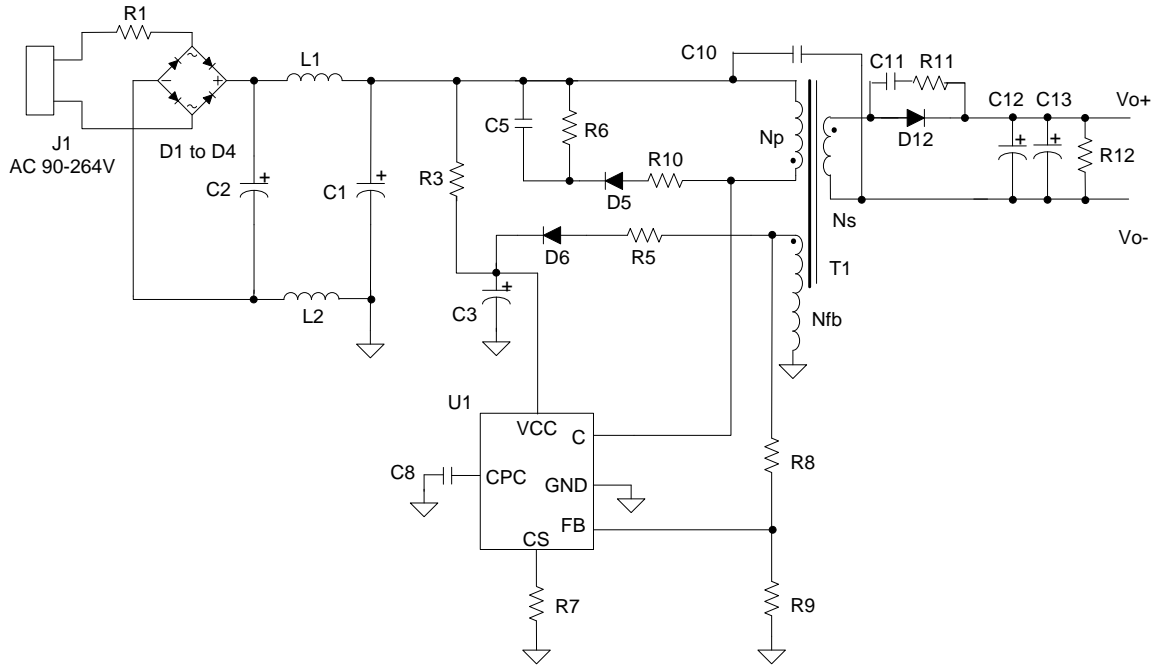


**PDIP-7 (P7 Package)
For AP3969/70**



**PDIP-8 (P Package)
For AP3970**

Typical Applications Circuit



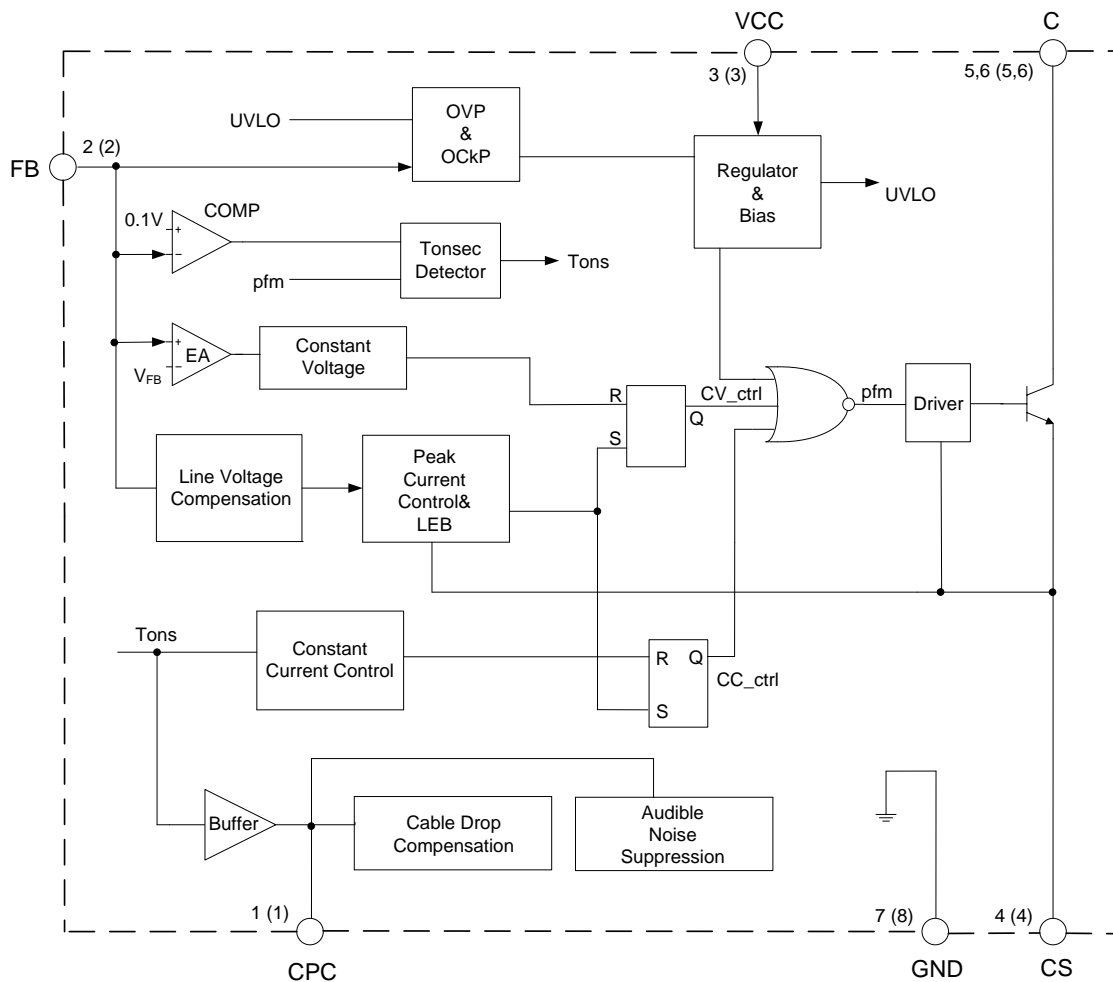
Typical Application of AP3969 (9V/800mA)

| 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 _{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

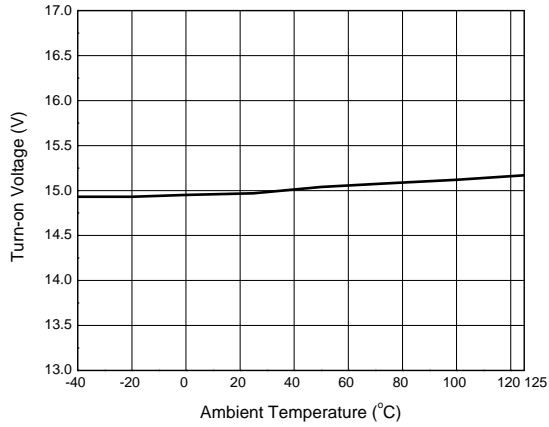
| Symbol | Parameter | Value | | Unit |
|-----------------|---------------------|--------|-----|------|
| θ _{JA} | Junction to Ambient | AP3968 | 100 | °C/W |
| | | AP3969 | 80 | |
| | | AP3970 | 65 | |
| θ _{JC} | Junction to Case | AP3968 | 50 | |
| | | AP3969 | 40 | |
| | | AP3970 | 35 | |

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

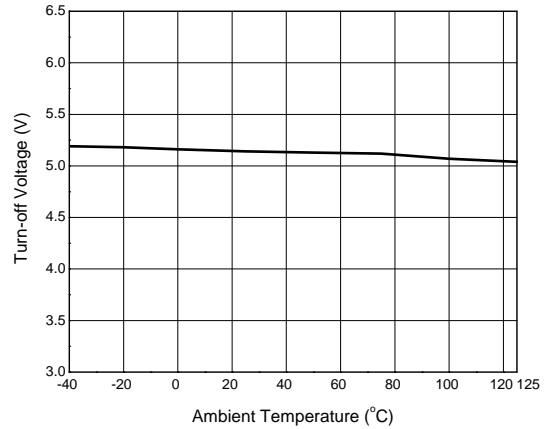
| Symbol | Parameters | Conditions | Min | Typ | Max | Unit |
|------------------------------------|--------------------------------------|---|------|------|------|-------------|
| UVLO SECTION | | | | | | |
| V_{ON} | Turn-on Voltage | – | 13 | 15 | 17 | V |
| V_{OFF} | Turn-off Voltage | No drive Current | 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 | – | $^{\circ}C$ |
| – | Temperature Hysteresis | – | – | +40 | – | $^{\circ}C$ |

Performance Characteristics

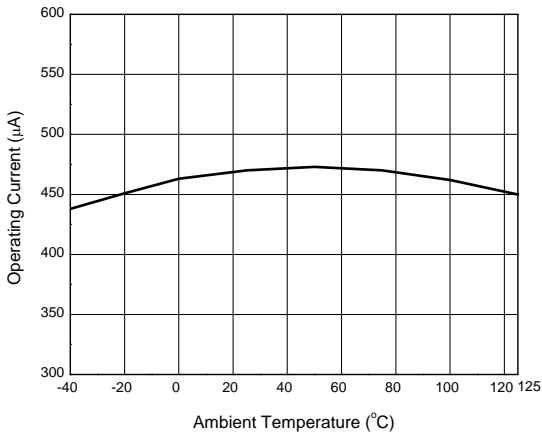
Turn-on Voltage vs. Ambient Temperature



Turn-off Voltage vs. Ambient Temperature



Operating Current vs. Ambient Temperature



Operation Description

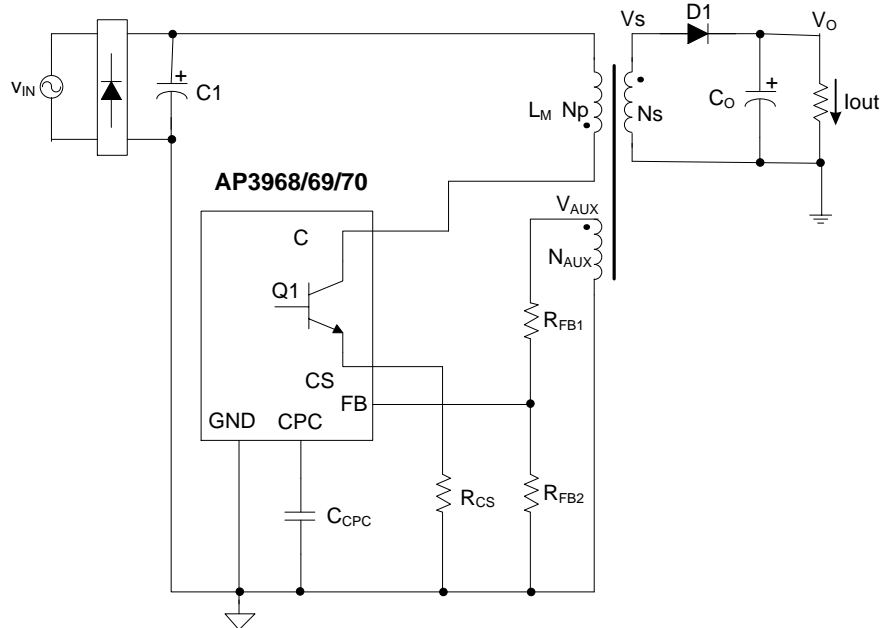


Figure 1. Simplified Flyback Converter Controlled by AP3968/69/70

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

Constant Primary Peak Current

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

The current rises up linearly at a rate of:

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

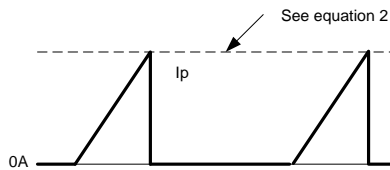


Figure 2. Primary Current Waveform

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 (Cont.)

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.

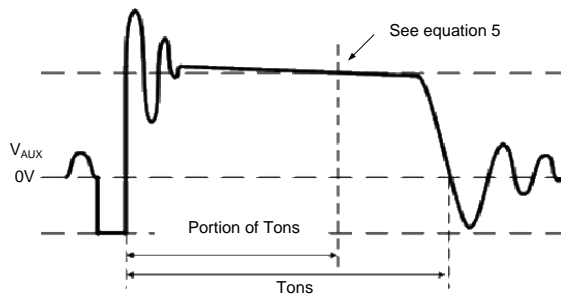


Figure 3. Auxiliary Voltage Waveform

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.

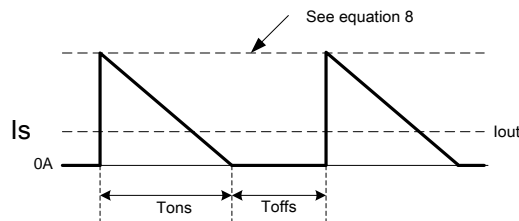


Figure 4. Secondary Current Waveform

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 (Cont.)

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.

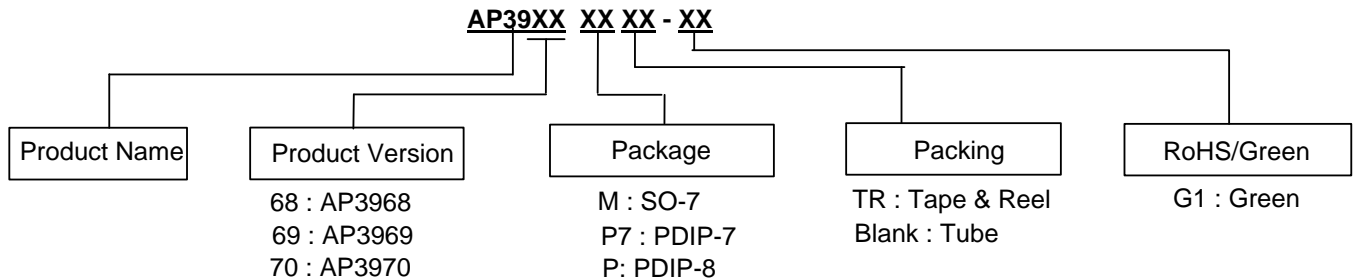
Built-in Cable Compensation

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.

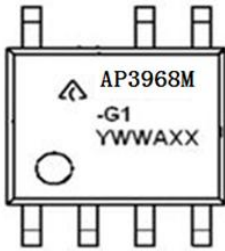
Ordering Information



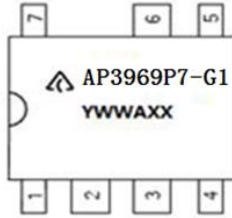
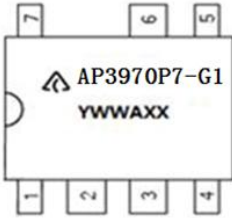
Diodes IC's Pb-free products with "G1" suffix in the part number, are RoHS compliant and green.

| 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 |
| | | AP3970P-G1 | AP3970P-G1 | 50/Tube |

Marking Information



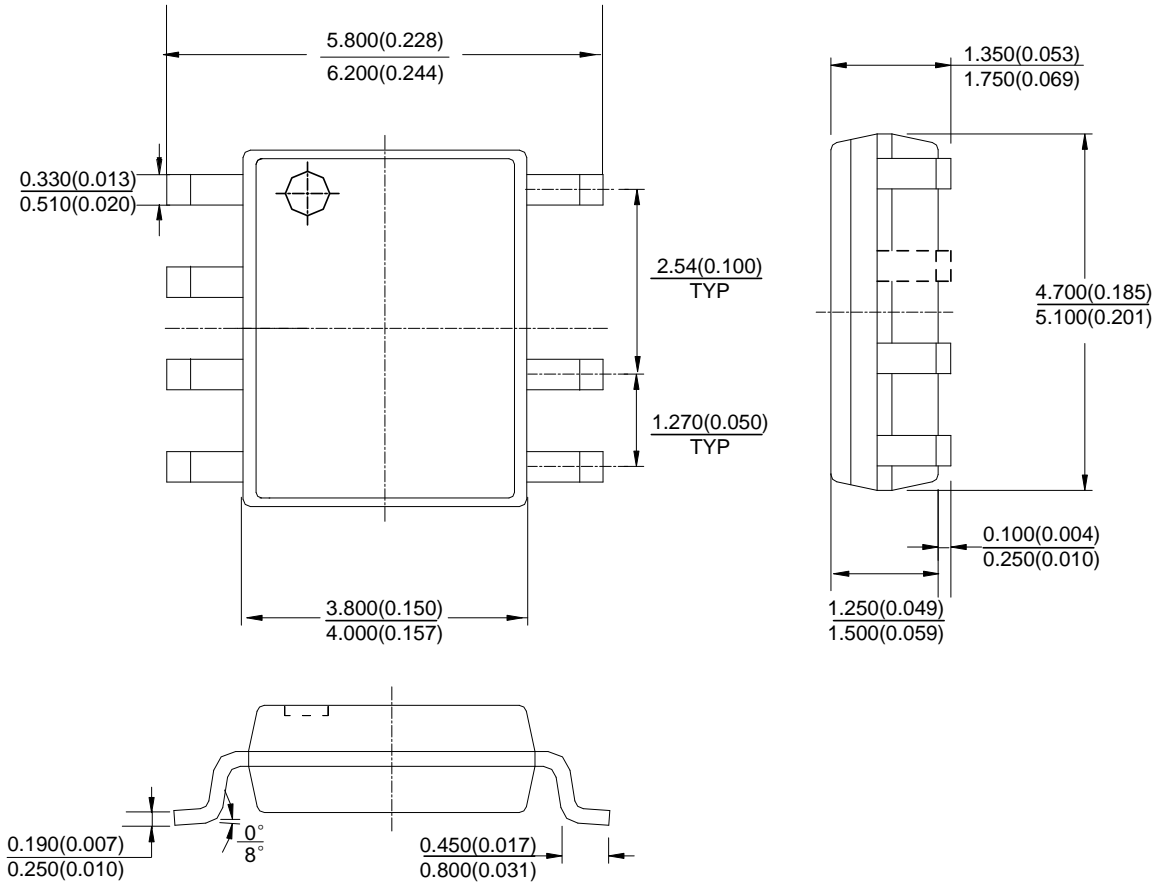
First and Second Lines: Logo and Marking ID
 Third Line: Date Code
 Y: Year
 WW: Work Week of Molding
 A: Assembly House Code
 XX: 7th and 8th Digits of Batch No.



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).)

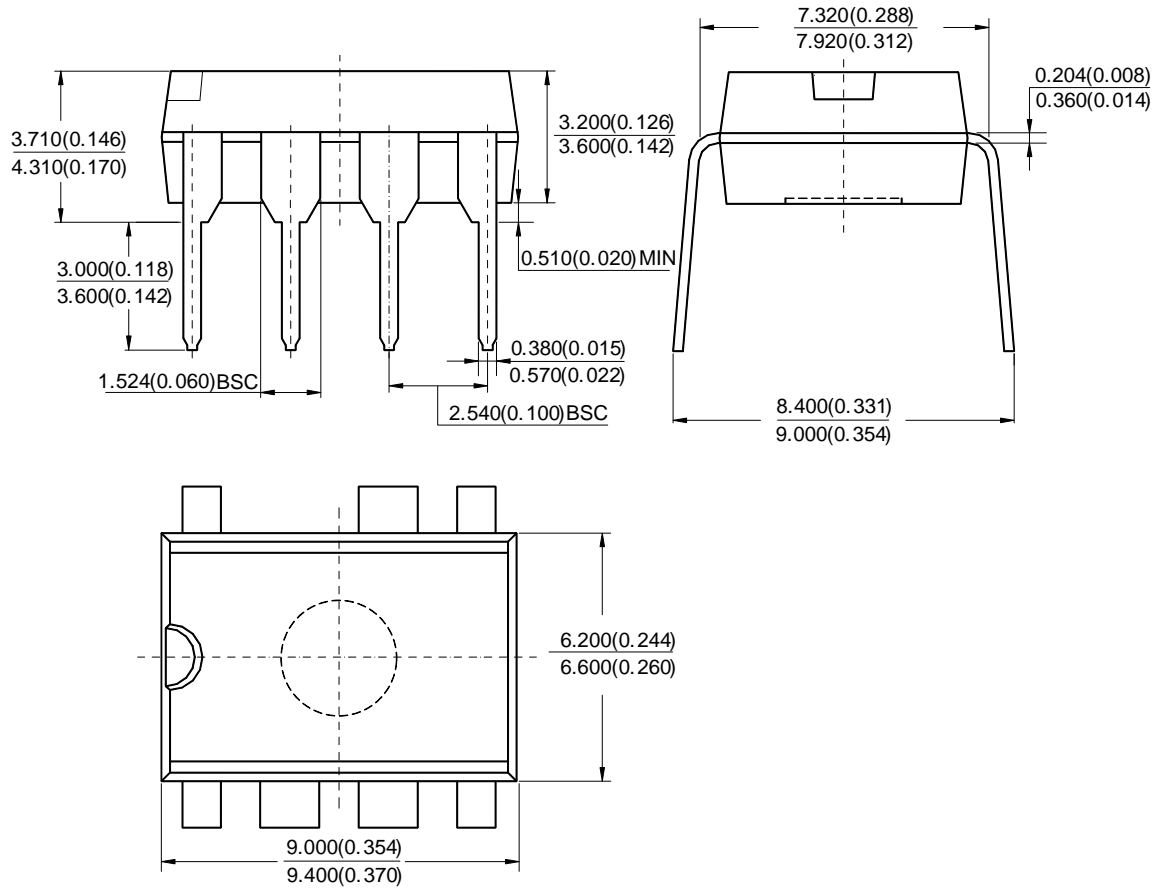
(1) Package Type: SO-7



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

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

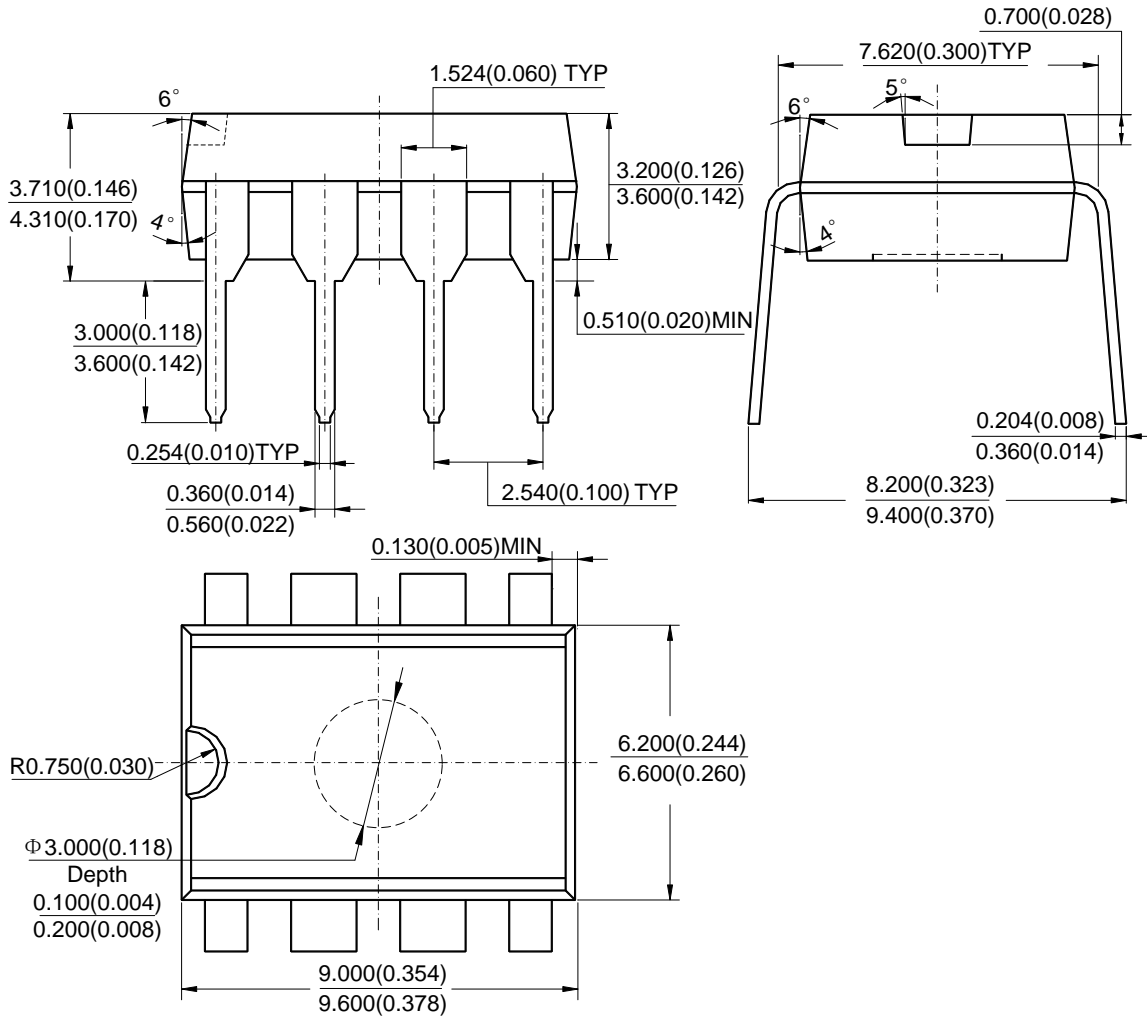
(2) Package Type: PDIP-7



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

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

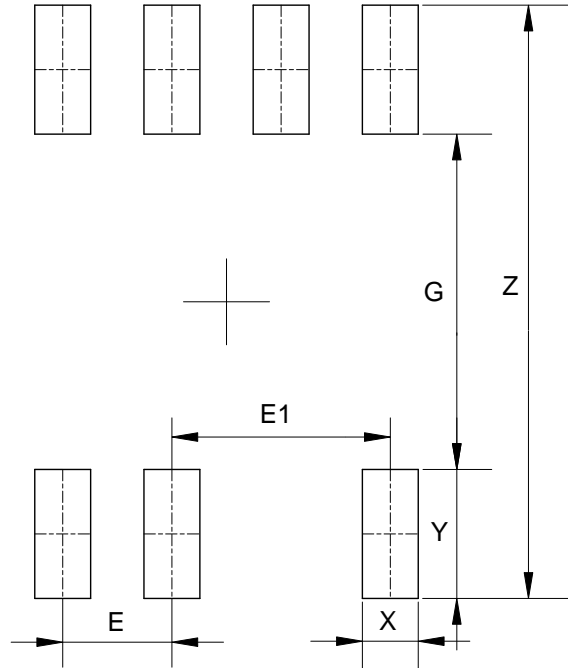
(3) Package Type: PDIP-8



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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