

## Description

The AP3927D is a universal AC/DC offline regulator with low standby power, which is specially designed for IoT applications and home appliances with non-isolated buck solution or buck-boost solution.

The device integrates the controller and a 700V high-performance power MOSFET into one monolithic device. Coordinating with a single-winding inductor, it uses minimum external components and provides a low Bill Of Material (BOM) cost solution.

The AP3927D supports fixed frequency CCM mode with heavy load, and PFM (Pulse Frequency Modulation) operation at light load. Since the peak current is very low for light-load operation, it ensures an excellent audible noise-free performance.

The AP3927D has multiple protection features to enhance the system safety and reliability, which include overtemperature protection, undervoltage lockout function, output short protection, and overload protection.

The AP3927D is available in SO-7 (Type B) package.

## Features

- Universal 85VAC to 277VAC Input Range
- Internal MOSFET of 700V
- Maximal Peak Current: 650mA Typical
- Typical Output Current: 360mA
- Improved Constant Voltage:  $\pm 5\%$
- Low No-Load Power Consumption
- No Audible Noise Solution
- Support Topology: Buck, Boost, Buck-Boost
- Frequency Dithering to Suppress EMI
- Various Protections
  - OTP (Overtemperature Protection)
  - OLP (Overload Protection)
  - SCP (Short-Circuit Protection)
  - OVP (Overvoltage Protection)
- SO-7 (Type B) Package
- Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- Halogen and Antimony Free. "Green" Device (Note 3)**
- 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.**

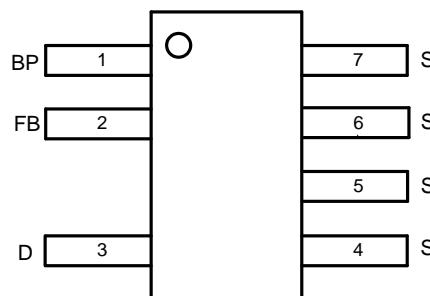
<https://www.diodes.com/quality/product-definitions/>

Notes:

1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. 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.
3. 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)

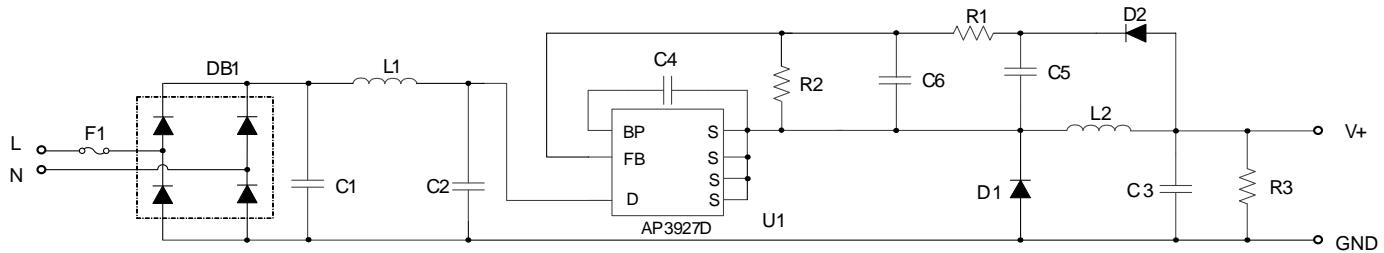


SO-7 (Type B)

## Applications

- IoT applications: smoke detectors, fire alarms
- Non-isolated home appliances: AC fans, rice cookers, shavers, milk machines, ceiling lights
- Industrial controls
- Standby and auxiliary power supply units

## Typical Applications Circuit

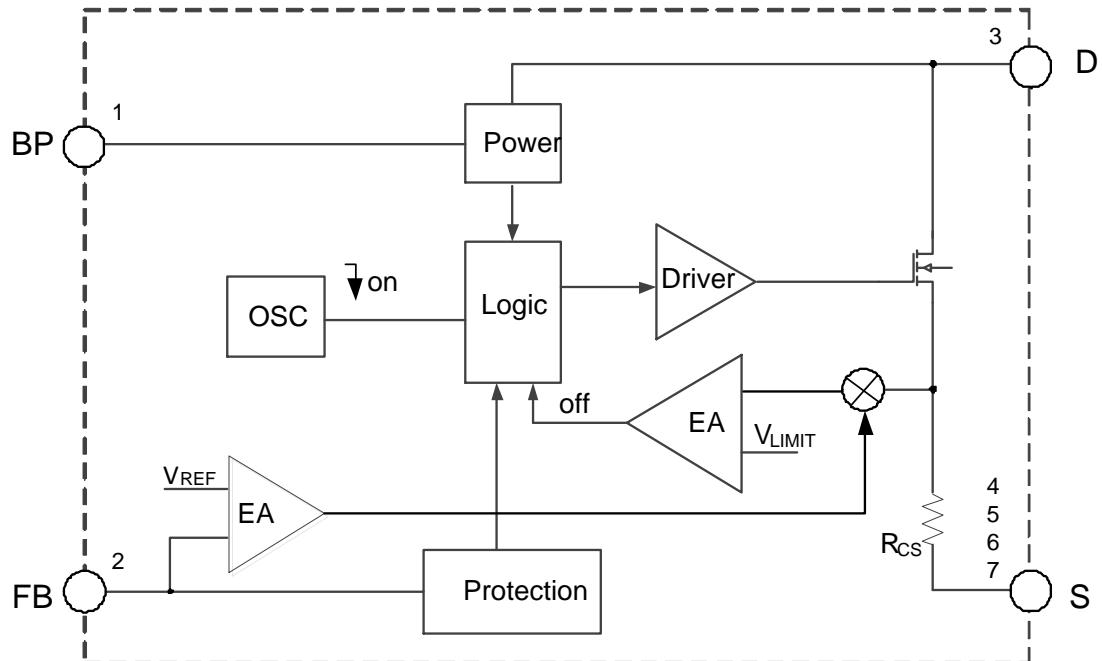


High-Side Buck-Direct Feedback

## Pin Descriptions

Pin Number	Pin Name	Function
1	BP	Connection Point of External Bypass Capacitor for Internally Generated Power Supply for Control Circuit.
2	FB	Regulator Feedback.
3	D	Internal Power MOSFET Drain. High-Voltage Current Source Input.
4, 5, 6, 7	S	Internal Power MOSFET Source. Ground Reference for BP and FB Pins.

## Functional Block Diagram



## Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V <sub>DSS</sub>	Drain Pin Voltage (Note 5)	-0.3 to 700	V
V <sub>BP</sub>	Internally Generated Control Circuit Power Supply Voltage	-0.3 to 7.0	V
V <sub>FB</sub> , V <sub>S</sub>	FB Pin and S Pin Voltage	-0.3 to 7.0	V
P <sub>D</sub>	Continuous Power Dissipation (T <sub>A</sub> = +25°C)	1	W
T <sub>J</sub>	Operating Junction Temperature	+150	°C
T <sub>STG</sub>	Storage Temperature	-65 to +150	°C
T <sub>LEAD</sub>	Lead Temperature (Soldering, 10s)	+300	°C
θ <sub>JA</sub>	Thermal Resistance – SO-7 (Type B) Package (Junction to Ambient) (Note 6)	58	°C/W
θ <sub>JC</sub>	Thermal Resistance – SO-7 (Type B) Package (Junction to Case) (Note 6)	6	°C/W
—	ESD (Human Body Model)	2000	V
—	ESD (Charge Device Model)	1000	V

Notes:

- 4. 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.
- 5. The drain-source voltage is 80% of V<sub>DS</sub> in the aging condition.
- 6. Test condition: device mounted on FR-4 substrate PC board, 2oz copper, with 1inch<sup>2</sup> cooling area.

## Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V <sub>BP</sub>	Supply Voltage	4.85	5.55	V
V <sub>DSS</sub>	Drain-Source Voltage (Note 6)	—	560	V
T <sub>A</sub>	Ambient Temperature	-40	+125	°C

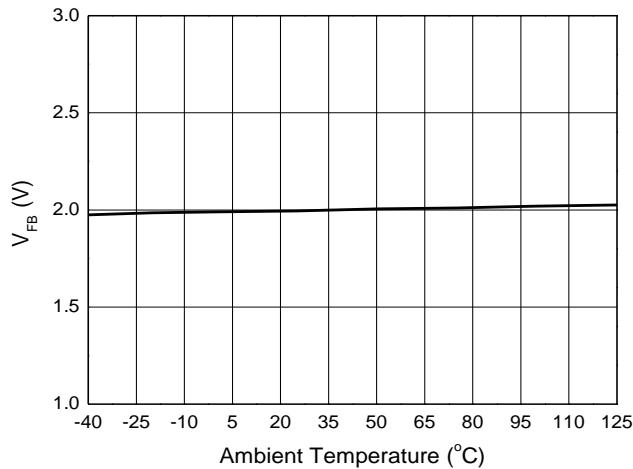
Electrical Characteristics (V<sub>BP</sub> = 5.0V, -40°C < T<sub>A</sub> < +125°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>HV Startup Current Source</b>						
I <sub>HV</sub>	HV Supply Current	V <sub>BP</sub> = 4.5 V	0.5	1.18	—	mA
I <sub>LEAK</sub>	Leakage Current of Drain	V <sub>BP</sub> = 5.5V V <sub>DRAIN</sub> = 400V T <sub>A</sub> = +25°C	—	5	12.3	μA
<b>V<sub>BP</sub> Voltage Management</b>						
V <sub>BP_HVON</sub>	V <sub>BP</sub> Decreasing Level at which HV Supply is ON	—	4.25	4.6	4.95	V
V <sub>BP_HVOFF</sub>	V <sub>BP</sub> Increasing Level at which HV Supply is OFF	—	4.85	5.2	5.55	V
V <sub>BP_HYS</sub>	Bypass Pin Hysteresis	—	—	600	—	mV
V <sub>BP_UVLO</sub>	V <sub>BP</sub> Minimum Operating Voltage	T <sub>A</sub> = +25°C	3.15	3.5	—	V
I <sub>BP1</sub>	V <sub>BP</sub> Operating Current with MOSFET Switching (Full Load)	V <sub>BP</sub> = 5V D = 67%, T <sub>A</sub> = +25°C	—	410	580	μA
I <sub>BP2</sub>	V <sub>BP</sub> Quiescent Current (No Load)	T <sub>A</sub> = +25°C	—	245	354	μA
<b>Internal MOSFET</b>						
V <sub>DSS</sub>	Breakdown Voltage	T <sub>A</sub> = +25°C (Note 7)	700	—	—	V
R <sub>DS(ON)</sub>	ON Resistance	T <sub>A</sub> = +25°C, I <sub>D</sub> = 45mA	—	7	—	Ω
I <sub>DSS</sub>	OFF-State Drain Leakage Current	T <sub>A</sub> = +25°C, V <sub>DS</sub> = 560V V <sub>BP</sub> = 5V	—	—	100	μA
<b>Internal Current Sense</b>						
t <sub>LEB1</sub>	Leading-Edge Blanking (Note 8)	T <sub>A</sub> = +25°C	—	250	—	ns
I <sub>PK_LIMIT</sub>	Standard Current Limit	T <sub>A</sub> = +25°C	590	650	—	mA
t <sub>LEB2</sub>	Leading-Edge Blanking for Short-Circuit Protection (Note 8)	T <sub>A</sub> = +25°C	—	200	—	ns
I <sub>SCP_TH</sub>	SCP Threshold	—	—	1.25 x I <sub>PK_LIMIT</sub>	—	mA
<b>Feedback Input (FB Pin)</b>						
V <sub>FB</sub>	Feedback Pin Reference Voltage	V <sub>BP</sub> = 5.0V to 5.5V T <sub>A</sub> = +25°C	1.9	2	2.1	V
f <sub>osc</sub>	Output Frequency	T <sub>A</sub> = +25°C	28	33	39	kHz
D <sub>MAX</sub>	Maximum Duty Cycle	—	60	68	76	%
V <sub>FB_OLP</sub>	Feedback Threshold for OLP	—	—	1.4	—	V
t <sub>OLP</sub>	OLP Delay Time	—	—	200	—	ms
V <sub>OLD</sub>	Open-Loop Detection Voltage	T <sub>A</sub> = +25°C	—	100	—	mV
<b>Overtemperature Protection</b>						
T <sub>OTP</sub>	Thermal Shutdown Threshold (Note 8)	—	+135	+150	+165	°C
T <sub>OTP_HYS</sub>	Thermal Shutdown Hysteresis (Note 8)	—	—	+50	—	°C

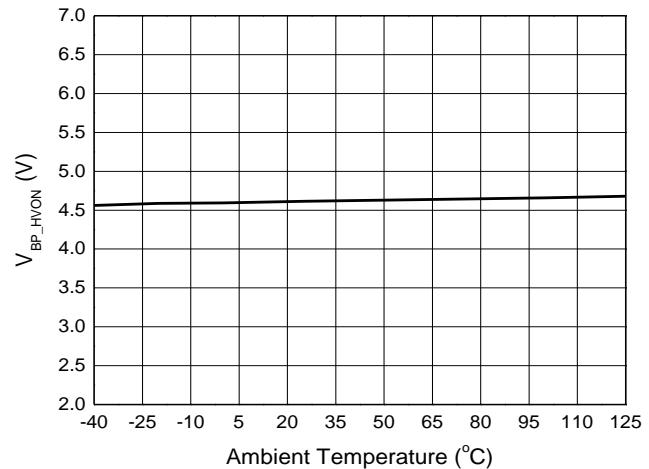
Notes: 7. The drain-source voltage is 80% of V<sub>DS</sub> in the aging condition.  
8. Guaranteed by design.

## Performance Characteristics

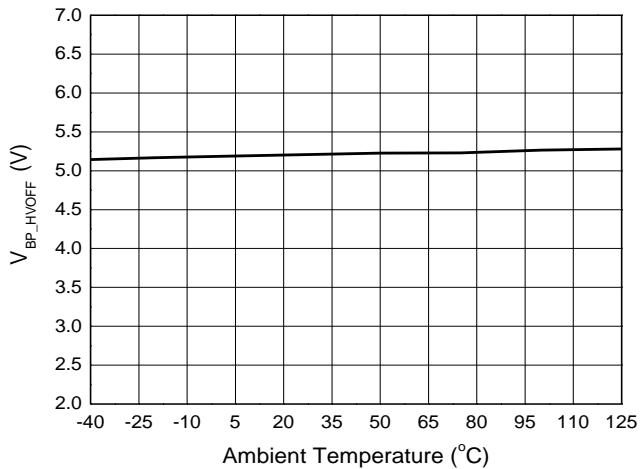
**FB Voltage vs. Ambient Temperature**



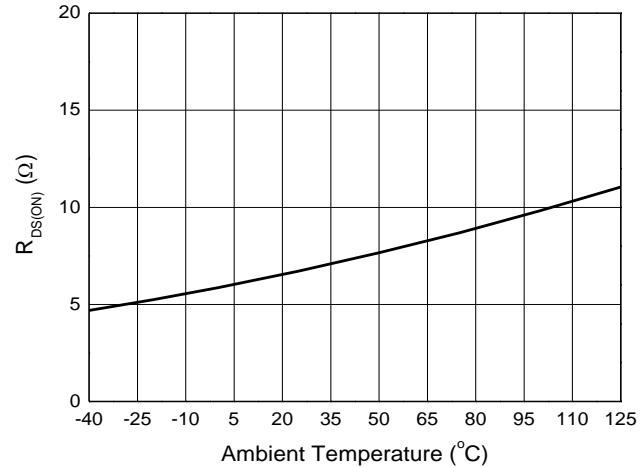
**$V_{BP\_HVON}$  Voltage vs. Ambient Temperature**



**$V_{BP\_HVOFF}$  Voltage vs. Ambient Temperature**



**$R_{DS(ON)}$  vs. Ambient Temperature**



## Operation Description

### Overall Introduction

The AP3927D is a universal offline regulator, which integrates a 700V high-voltage power MOSFET into one monolithic device. The feedback voltage signal derives from a resistor-divided network, which connects to output through rectifier diodes. The device is suitable for non-isolated AC-to-DC low buck and buck-boost configuration with level shifted direct feedback. Coordinating with an external single-winding inductor can achieve a low BOM cost solution.

### Startup Control and V<sub>BP</sub> Supply

To ensure a safe startup, a three-stage frequency control method is designed for AP3927D soft-start control. The initial switching frequency will keep 0.25 times maximum fixed frequency in stage I, sequentially shift to 0.5 times maximum fixed frequency in stage II. Finally, it rises to the maximum fixed frequency in stage III. Both stage I and stage II include 64 switching cycles.

The internal high-voltage regulator provides charging current for V<sub>BP</sub>. When the BP voltage is charged to V<sub>BP\_HVOFF</sub>, the IC starts up, and the internal high-voltage regulator turns off. Along with the BP voltage slowly drops below V<sub>BP\_HVON</sub>, the internal high-voltage regulator turns on again to charge the external BP capacitor.

Figure 1 shows the typical waveform of startup and HV regulator ON/OFF control.

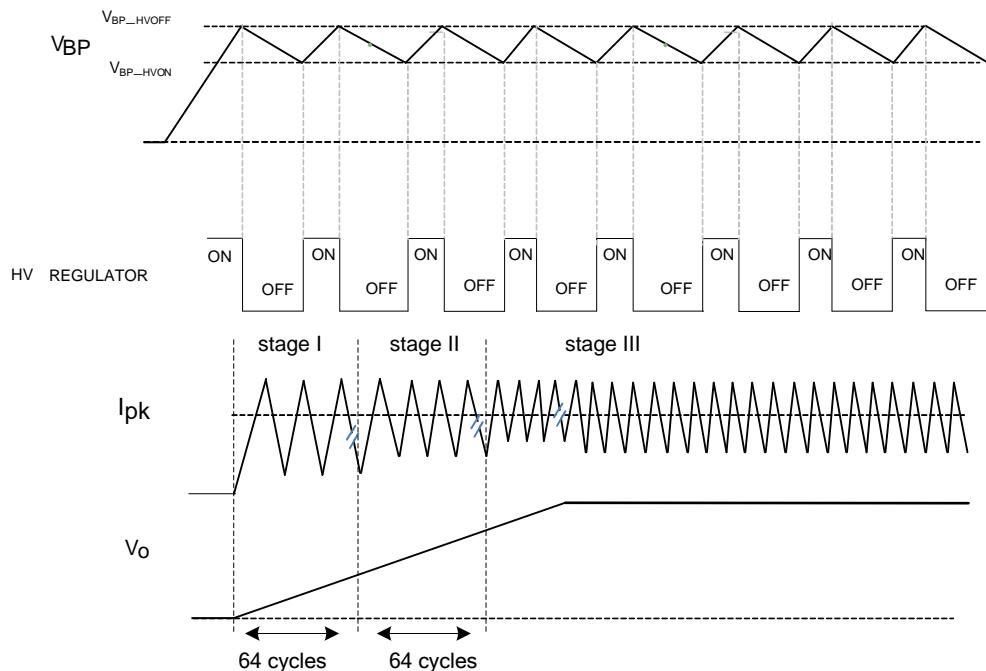


Figure 1. Startup and HV Regulator ON/OFF Control

### Operation Frequency and Peak Current Characteristics

The power system operates with 33kHz fixed frequency mode in heavy load. When the load current decreases, the switching frequency will keep 33kHz and the inductor peak current will follow the output current to go lower. Due to most of load range operating at a relative high frequency, so the audible noise-free performance is excellent. Once the peak current drops to the minimum peak current limit  $I_{PK\_MIN}$ , it will keep a constant value, and AP3927D operates in PFM (pulse frequency modulation) mode to improve the system efficiency at light load. Since the peak current is small at no-load condition, it still has no audible noise risk even if the operating frequency drops to 1kHz below. What's more, both the small peak current and low switching frequency is helpful to reduce the standby power consumption.

The switching frequency and peak current curves are shown in Figure 2 as below.

## Operation Description (continued)

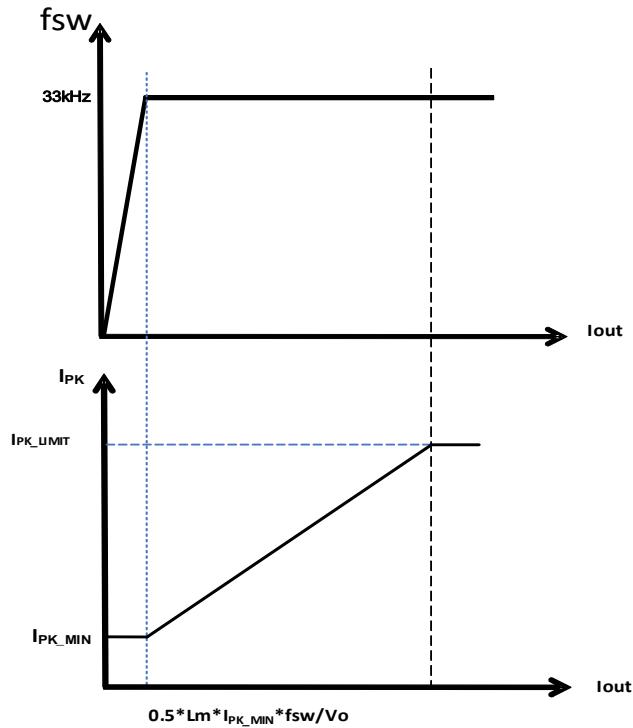


Figure 2. Switching Frequency and Peak Current vs. Output Current

## Constant Voltage Operation

The AP3927D usually uses in buck topology as shown in the typical application circuit. Figure 3 shows the operation diagram under CCM condition. At the beginning of each cycle, the integrated MOSFET turns on by falling edge of the internal oscillator clock signal (CLK), the inductor current  $I_{INDUCTANCE}$  will begin to rise, and the converter delivers power to the load. A current sensing is located between the source of the power MOSFET and the S pin to detect inductor peak current. Unlike low-side buck topology, the  $V_o$  feedback voltage is derived from the sampling capacitor (C5) voltage in high-side buck topology. It is fed back to input of amplifier to generate the amplifier output level, which mixed with  $R_{CS}$  sensing voltage to compare with internal  $V_{LIMIT}$  threshold to decide the shut-off moment of converter.

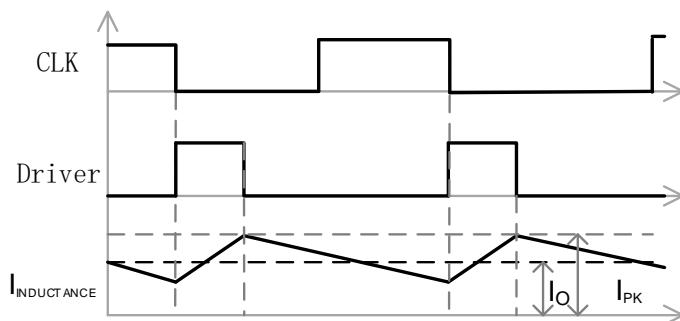


Figure 3. CCM Operation Diagram

## Operation Description (continued)

The ON period time (PWM duty cycle) is determined by the inductor current variable value  $\Delta I_L$ , ( $\Delta I_L$  is the gap of the peak-current limitation value  $I_{PK}$  and the initial inductor current value  $I_{INI}$ ), the inductance value, and the input voltage. The ON time calculation is as follows:

$$t_{ON} = L \cdot \frac{\Delta I_L}{V_{IN\_DC}} = L \cdot \frac{I_{PK} - I_{INI}}{V_{IN\_DC}}$$

Where  $I_{INI}$  is zero in DCM condition.

When the inductor current reaches peak-current limitation, the internal MOSFET will turn off. The inductor current charges the sampling capacitor (C5) and the output capacitor (C3) via the freewheeling diodes D1 and D2 respectively.

The regulated output voltage describes as the following equation:

$$V_o = V_{FB} \times \left( \frac{R_1 + R_2}{R_2} \right)$$

### Auxiliary V<sub>BP</sub> Supply for Low Standby Power

If the output voltage is higher than the voltage of  $V_{BP\_HVON}$ , an auxiliary V<sub>BP</sub> supply can be implemented to reduce overall power consumption by connecting a resistor (R5) between C4 and C5, which can eliminate power consumption due to VCC capacitor charging from MOSFET's drain polarity. A standby power of less than 20mW can be achieved in no-load condition.

Figure 4 shows the low standby power circuit with the auxiliary V<sub>BP</sub> supply.

The output voltage is not directly sensed in high-side buck. It is sampled and estimated by D2, C5, R1, and R2 feedback loop. Output voltage-sampling capacitor C5 stores output voltage information but not updated in real time. Only when MOSFET turns off can the C5 capacitor achieve the latest output voltage information. Especially, when system operates at no-load condition, the buck converter keeps a low switching frequency, and the feedback loop runs with its own time constant, which is not conducive to output voltage regulation. In order to improve the voltage regulation at no load, the high-side buck topology needs to connect a pre-load resistor R3 at the output terminal to prevent output voltage from going too high.

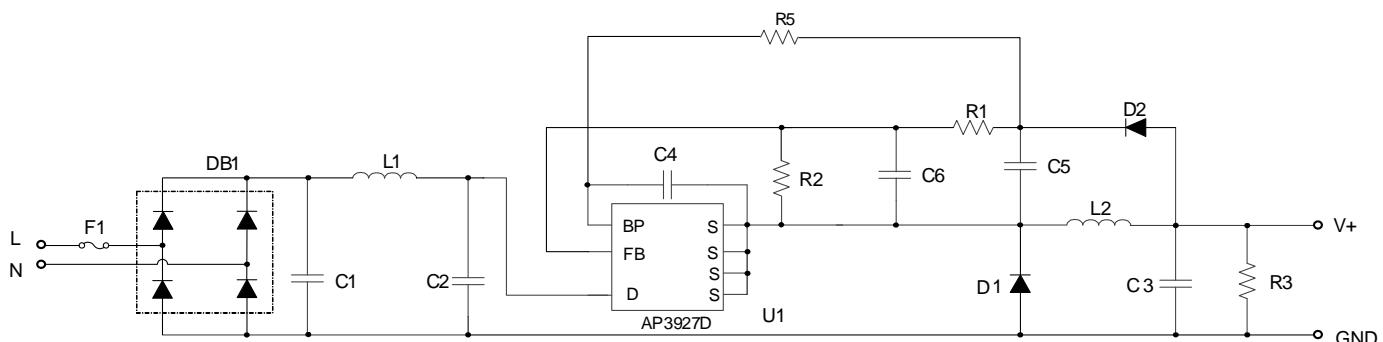


Figure 4: Low Standby Power Circuit with Auxiliary V<sub>BP</sub> Supply

The value of R5 can be estimated by the following equation:

$$R5 = \frac{V_o - V_{BP\_HVON}}{I_{BP2}}$$

## Operation Description (continued)

### Overload Protection (OLP) and Short-Circuit Protection (SCP)

The current limit circuit senses the current flowing through power MOSFET. As the load continues to increase, the inductor peak current will go up. When the peak current reaches the maximum limitation, the MOSFET gate-driving signal is disabled, and the output voltage begins to decrease. Once the output divided-voltage ( $V_{FB}$ ) drops below 1.4V OLP threshold, an internal overload protection timer starts to count. After lasting for 200ms delay time, the device will enter restart status with a 2.8s hiccup time and 200ms switching hold time. This OLP design mechanism can effectively reduce the system power losses and prevent IC from overheating. Figure 5 shows the overload protection time consequence.

To output short-circuit fault,  $V_{FB}$  drops to 1.4V below during a short time, and OLP also will be triggered. The device remains hiccup mode until the shorted issue is removed. To prevent peak current from being unable to be fully reset and rising too high in the output-shorted condition, a frequency reduction method is included to increase inductor demagnetization time. When inductor current increases to  $1.25 \times I_{PK\_LIMIT}$ , the switching frequency will be compulsory to drop to  $1/4 \times f_{osc}$ , thus the inductor can discharge energy sufficiently during the MOSFET off time, and the MOSFET current can keep at a safe level.

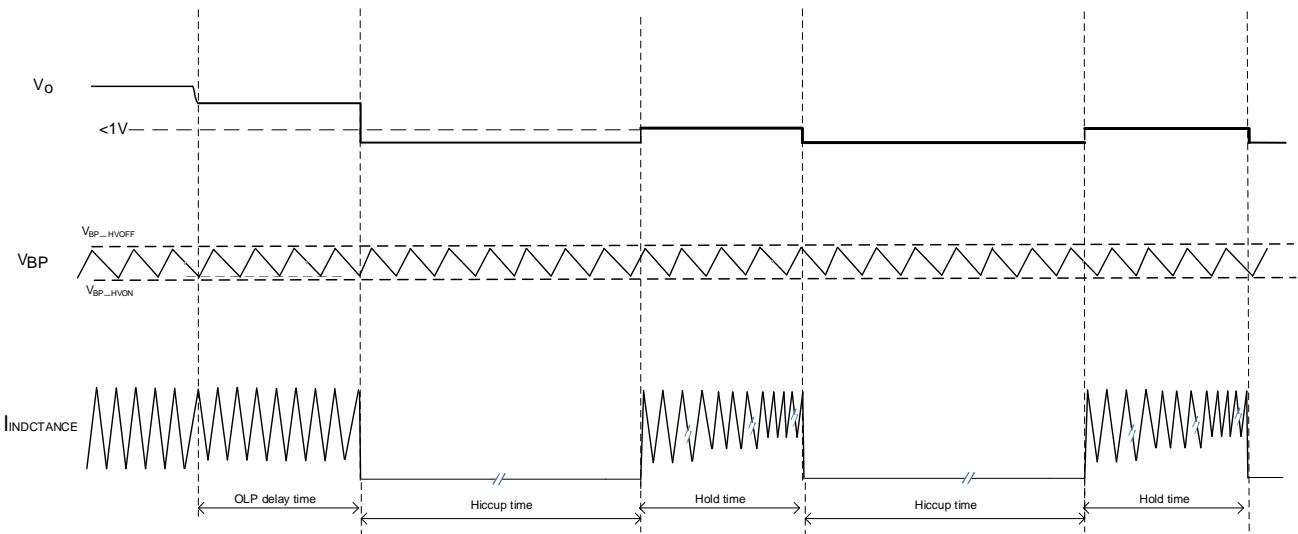


Figure 5. Overload Protection

### Open-Loop Detection

To prevent FB pin or its divided resistor from being open and arousing output voltage dramatic elevation in some occasional condition, the AP3927D integrates open-loop detection function. When the fault occurs and the FB voltage drops below open-loop detection threshold voltage  $V_{OLD}$  (100mV), the AP3927D will stop switching and begin restart cycles. During startup period, the open-loop detection will blank for 64 switching cycles to prevent false triggering.

### Overtemperature Protection (OTP)

The AP3927D integrates an internal overtemperature protection function. If the junction temperature rises above thermal shutdown threshold  $T_{OTP}$  (+150°C), the overtemperature protection is triggered, and the controller enters restart mode. Once the junction temperature falls by  $T_{OTP\_HYS}$  hysteresis voltage below  $T_{OTP}$ , the protection will be removed, and the device will resume operation.

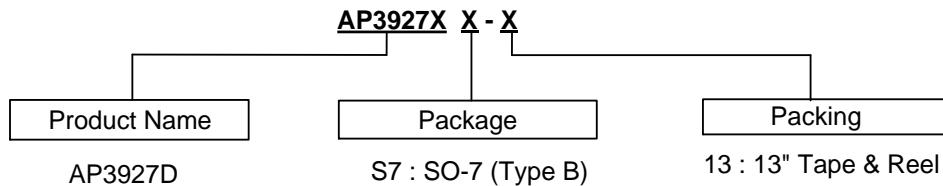
### Leading-Edge Blanking

A narrow spike on the leading edge of the current waveform can be observed when the power MOSFET is turned on. It is introduced by parasitic capacitance and reverse recovery of the freewheeling diode. Normally, the leading-edge blanking time  $t_{LEB1}$  is built-in to prevent premature switching pulse termination caused by the turn-on spike. In the case of short circuit, a relatively short  $t_{LEB2}$  leading-edge blanking time is more conducive to suppress inductor current amplitude. During this blanking period, the internal current limit comparator is disabled, and MOSFET keeps turn-on.

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## Ordering Information

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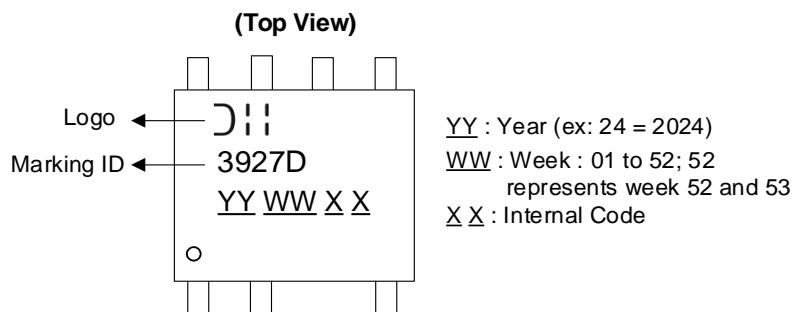


Part Number	Part Number Suffix	Package	Marking ID	Packing	
				Qty.	Carrier
AP3927DS7-13	-13	SO-7 (Type B)	3927D	4000	Tape and Reel

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## Marking Information

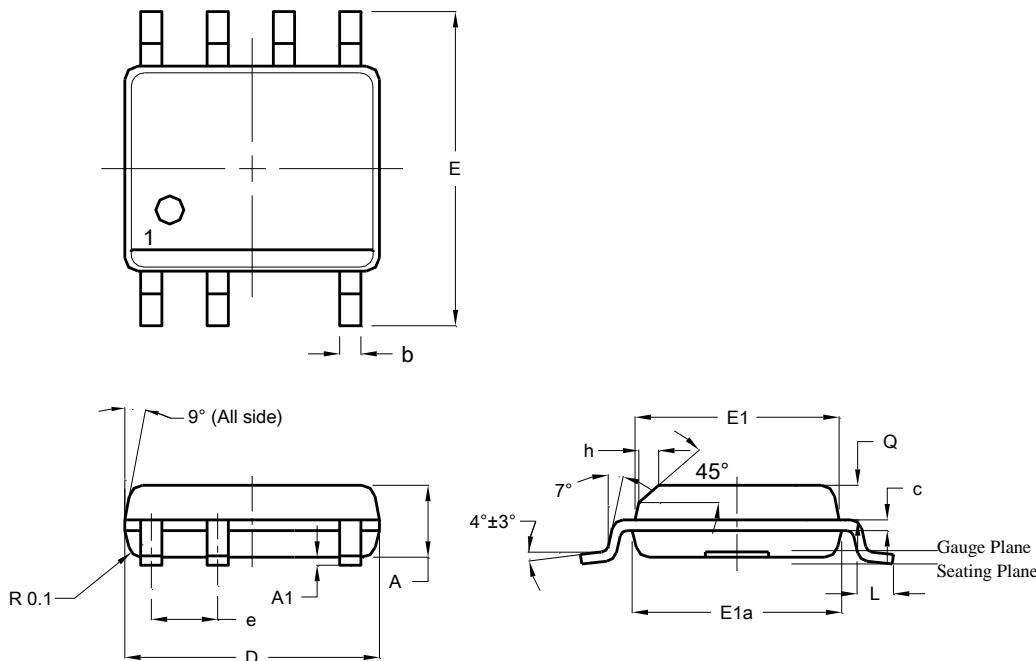
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## Package Outline Dimensions

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

SO-7 (Type B)

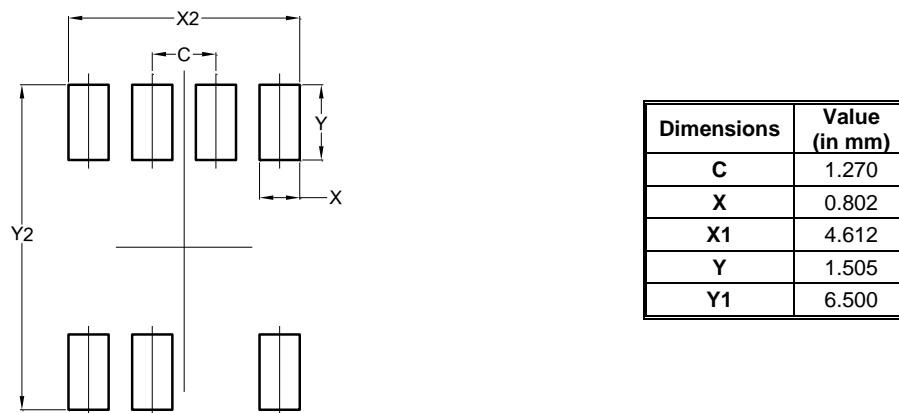


SO-7 (Type B)			
Dim	Min	Max	Typ
<b>A</b>	1.40	1.50	1.45
<b>A1</b>	0.08	0.25	0.15
<b>b</b>	0.30	0.50	0.40
<b>c</b>	0.15	0.25	0.20
<b>D</b>	4.85	4.95	4.90
<b>E</b>	5.90	6.10	6.00
<b>E1</b>	3.80	3.90	3.85
<b>E1a</b>	3.85	3.95	3.90
<b>e</b>	-	-	1.27
<b>h</b>	-	-	0.35
<b>L</b>	0.62	0.82	0.72
<b>Q</b>	0.60	0.70	0.65
All Dimensions in mm			

## Suggested Pad Layout

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

SO-7 (Type B)



## Mechanical Data

- Moisture Sensitivity: Level 3 per J-STD-020
- Terminals: Matte Tin Plated Leads, Solderable per M2003 JESD22-B102, Method 208 **(E3)**
- Weight: 0.077 grams (Approximate)

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