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.

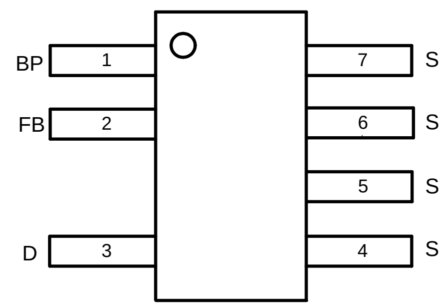
The AP3927D supports fixed frequency CCM mode with heavy load, and PFM (Pulse-Frequency Modulation) operation at light load. Since the peak current is very low for light-load operation, it ensures an excellent audible noise-free performance.

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.

Pin Assignments

(Top View)



SO-7 (Type B)

Features

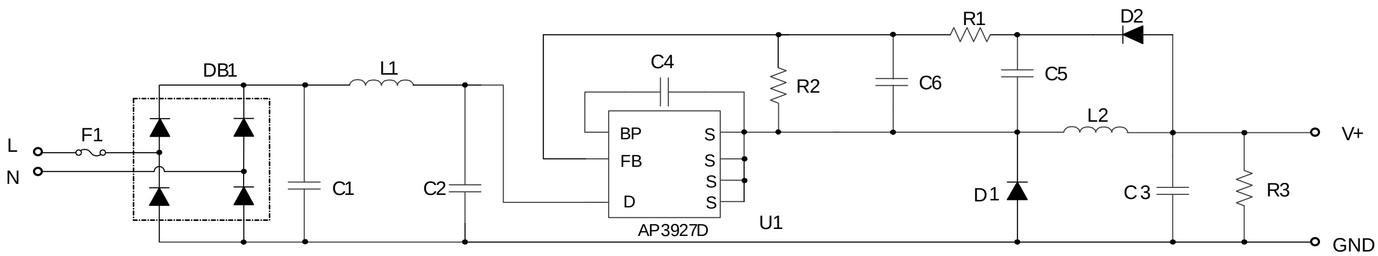
- Universal 85V_{AC} to 277V_{AC} Input Range
- Internal MOSFET of 700V
- Maximal Peak Current: 650mA Typical
- Typical Output Current: 360mA
- Improved Constant Voltage: ±5%
- Low No-Load Power Consumption
- No Audible Noise Solution
- Support Topology: Buck, Boost, Buck-Boost
- Frequency Dithering to Suppress EMI
- Various Protections
  - OTP (Overtemperature Protection)
  - OLP (Overload Protection)
  - SCP (Short-Circuit Protection)
- 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/**

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

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.

Typical Applications Circuit

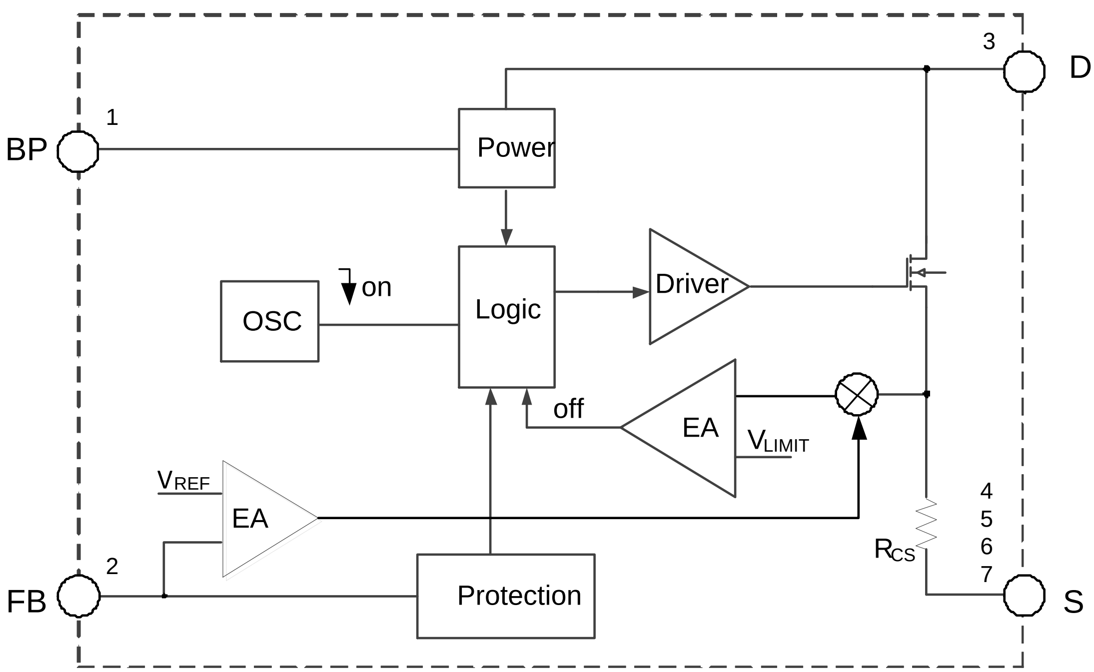


High-Side Buck-Direct Feedback

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_{DSS}	Drain Pin Voltage (Note 5)	-0.3 to 700	V
V_{BP}	Internally Generated Control Circuit Power Supply Voltage	-0.3 to 7.0	V
V_{FB}, V_S	FB Pin and S Pin Voltage	-0.3 to 7.0	V
P_D	Continuous Power Dissipation (T_A = +25°C)	1	W
T_J	Operating Junction Temperature	+150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
θ_{JA}	Thermal Resistance – SO-7 (Type B) Package (Junction to Ambient) (Note 6)	58	°C/W
θ_{JC}	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_{DS} in the aging condition.
6. Test condition: device mounted on FR-4 substrate PC board, 2oz copper, with 1inch^2 cooling area.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{BP}	Supply Voltage	4.85	5.55	V
V_{DSS}	Drain-Source Voltage (Note 6)	—	560	V
T_A	Ambient Temperature	-40	+125	°C

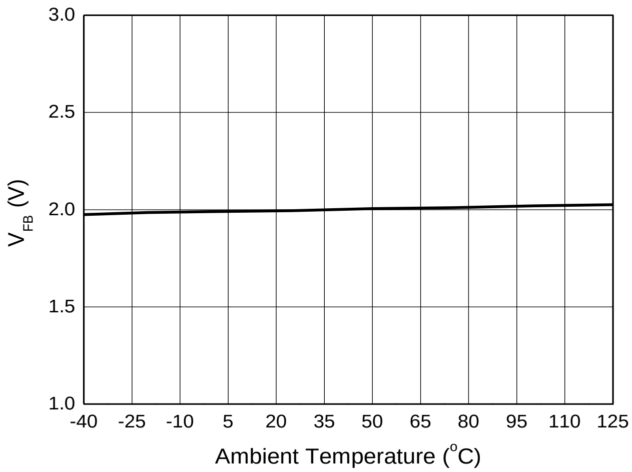
Electrical Characteristics (V_{BP} = 5.0V, -40°C < T_A < +125°C, unless otherwise specified.)

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

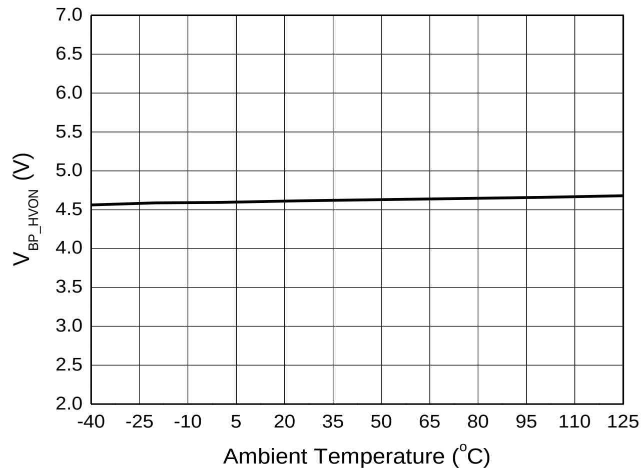
Notes: 7. The drain-source voltage is 80% of V_{DS} in the aging condition.
8. Guaranteed by design.

Performance Characteristics

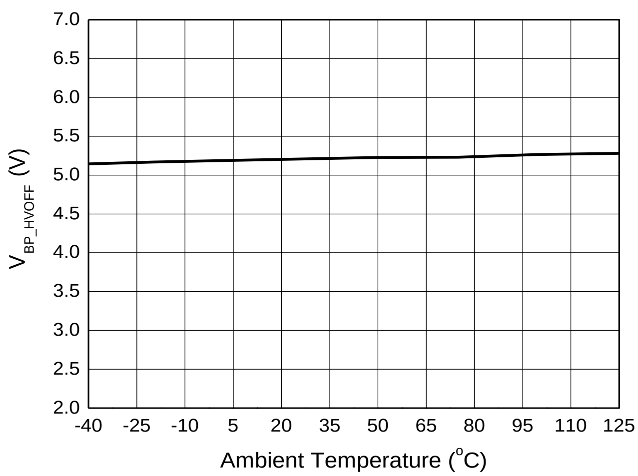
FB Voltage vs. Ambient Temperature



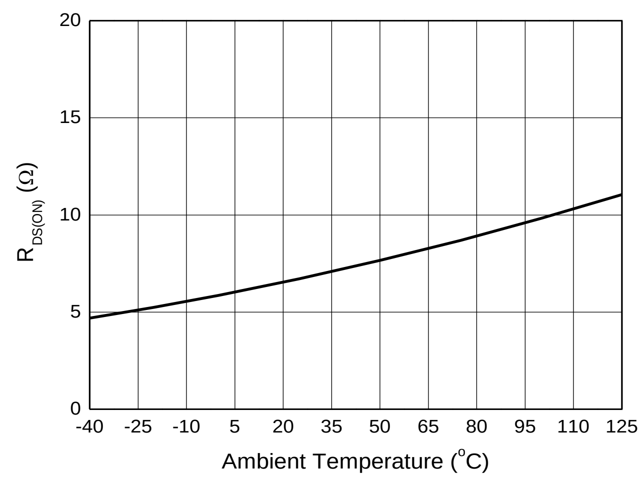
V_{BP_HVON} Voltage vs. Ambient Temperature



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 connected 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_{BP} 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_{BP}. When the BP voltage is charged to V_{BP_HVOFF}, the IC starts up, and the internal high-voltage regulator turns off. Along with the BP voltage slowly drops below V_{BP_HVON}, 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.

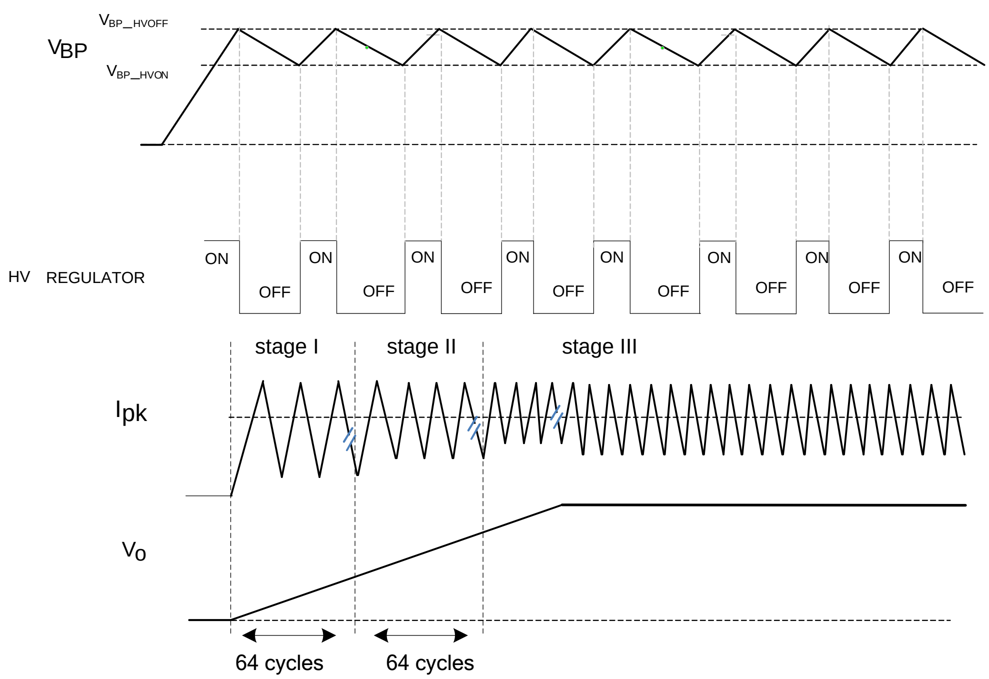


Figure 1. Startup and HV Regulator ON/OFF Control

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 is shown in Figure 2 as below.

Operation Description (continued)

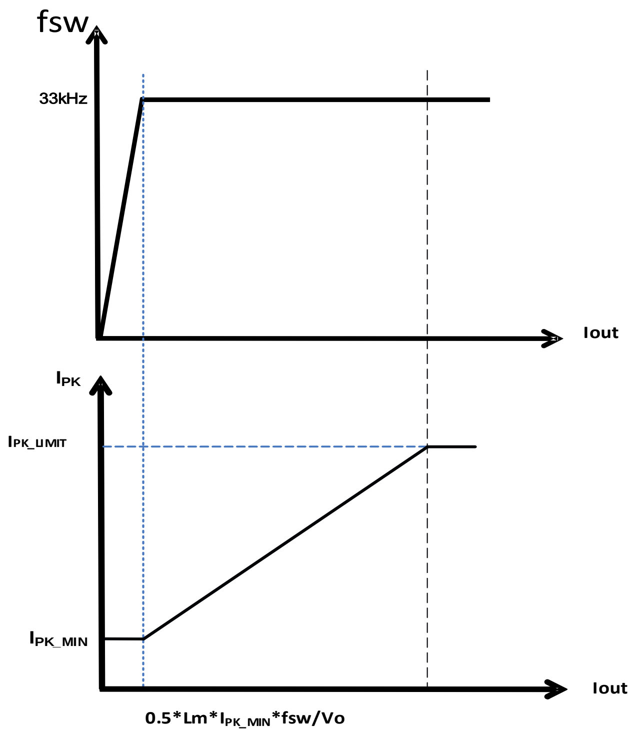


Figure 2. Switching Frequency and Peak Current vs. Output Current

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.

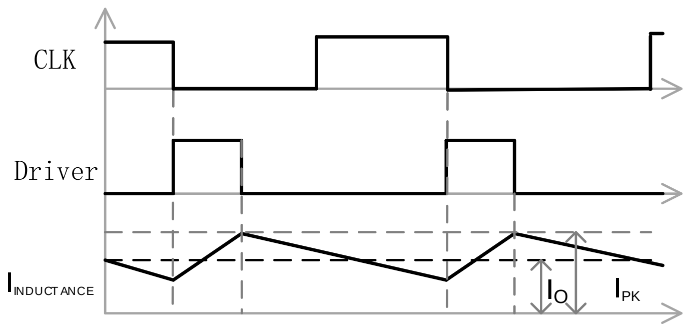


Figure 3. CCM Operation Diagram

Operation Description (continued)

The ON period time (PWM duty cycle) is determined by the inductor current variable value ΔI_L, (ΔI_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:

$$V_O = V_{FB} \times (\frac{R_1 + R_2}{R_2})$$

Auxiliary V_{BP} Supply for Low Standby Power

If the output voltage is higher than the voltage of V_{BP_HVON}, an auxiliary V_{BP} 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_{BP} 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.

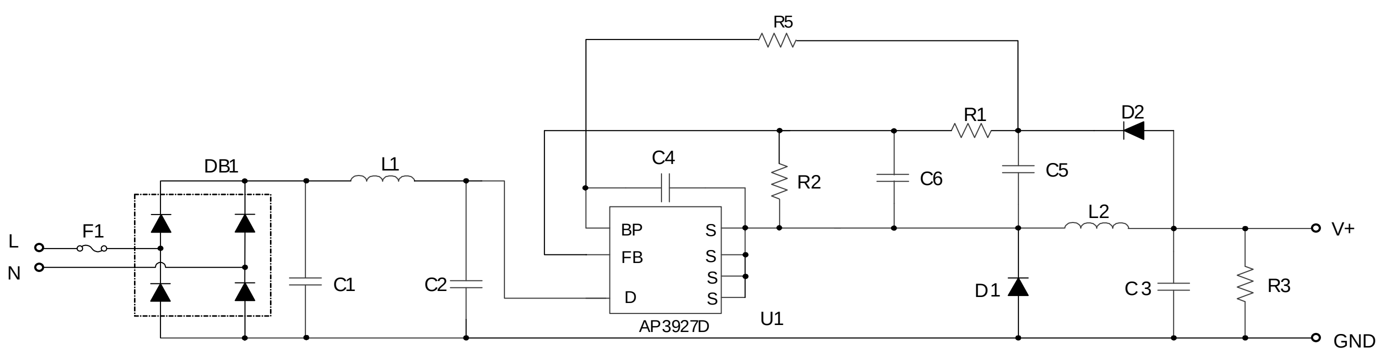


Figure 4. Low Standby Power Circuit with Auxiliary V_{BP} Supply

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 x I_{PK_LIMIT}, the switching frequency will be compulsory to drop to 1/4 x f_{OSC}, thus the inductor can discharge energy sufficiently during the MOSFET off time, and the MOSFET current can keep at a safe level.

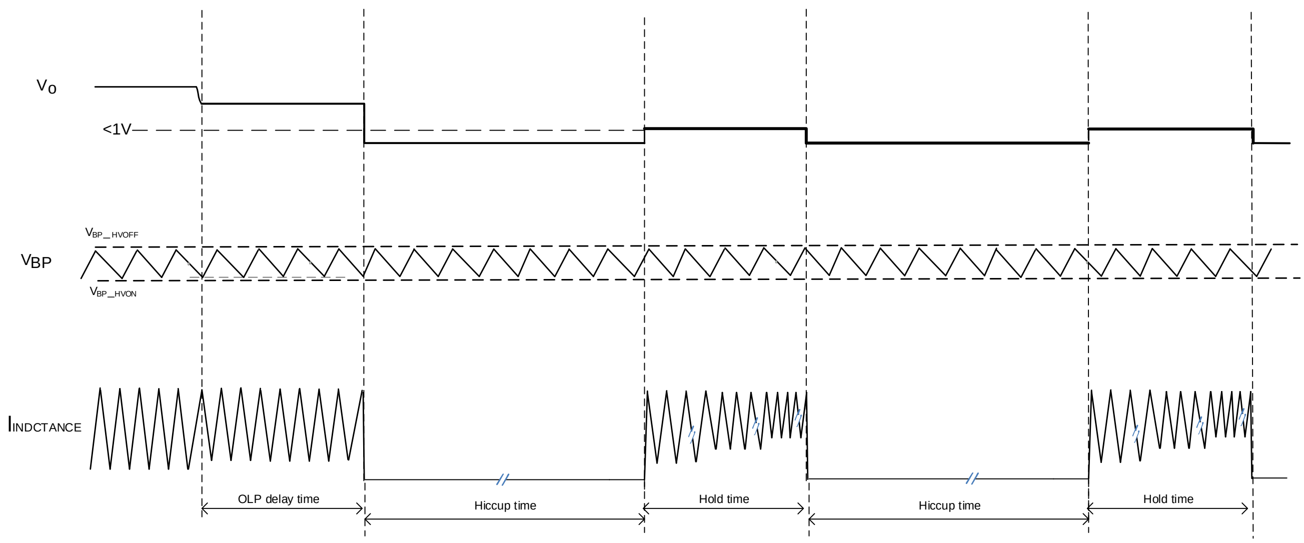


Figure 5. Overload Protection

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.

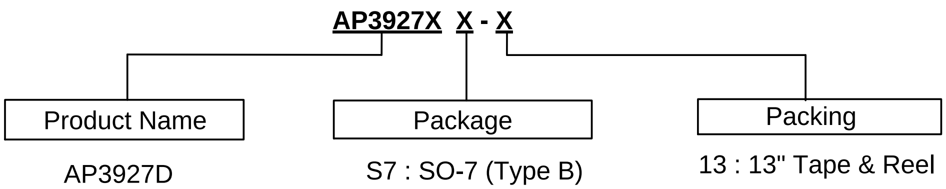
Overtemperature Protection (OTP)

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.

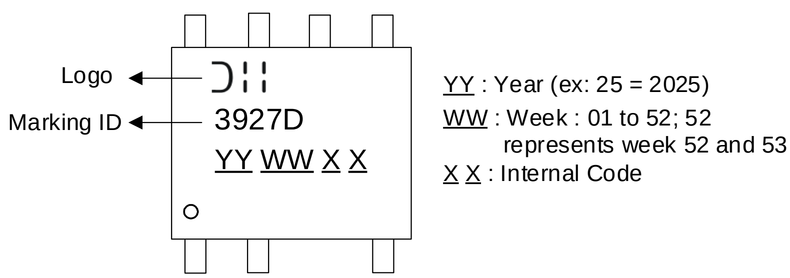
Ordering Information



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

Marking Information

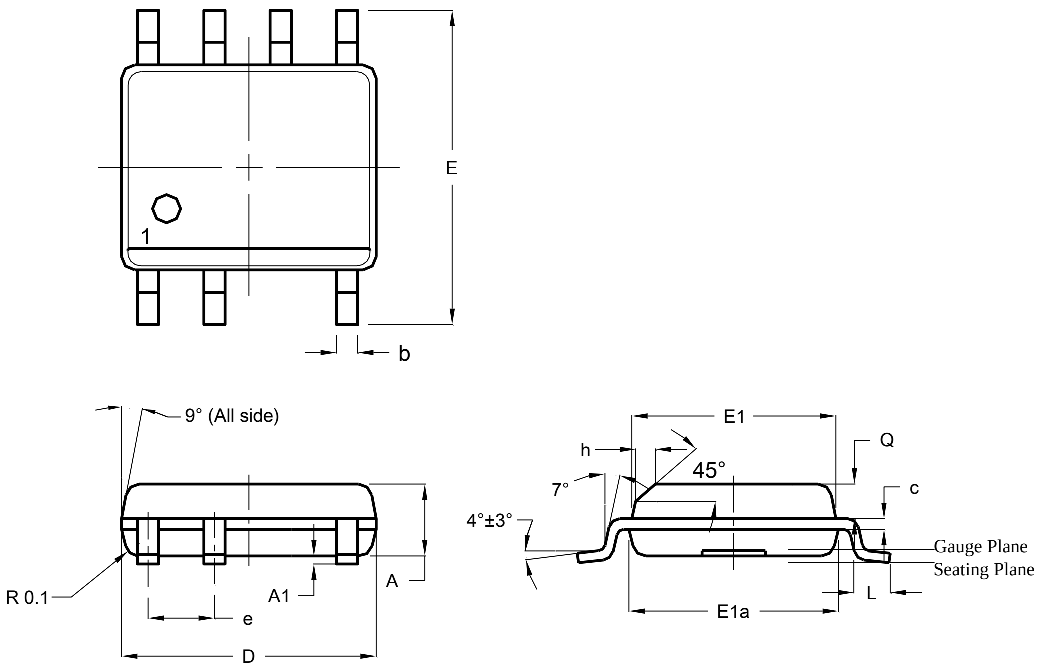
(Top View)



Package Outline Dimensions

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

SO-7 (Type B)

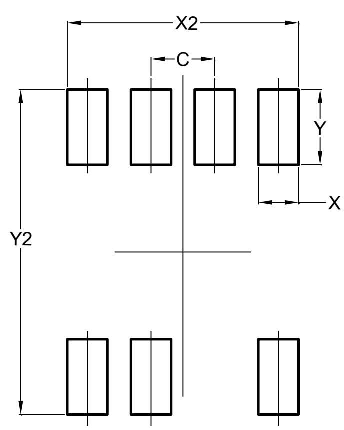


SO-7 (Type B)			
Dim	**Min**	**Max**	**Typ**
A	1.40	1.50	1.45
A1	0.08	0.25	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E1a	3.85	3.95	3.90
e	-	-	1.27
h	-	-	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

Suggested Pad Layout

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

SO-7 (Type B)



Dimensions	Value (in mm)
C	1.270
X	0.802
X1	4.612
Y	1.505
Y1	6.500

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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