Description

The AP3917B is a universal AC voltage input step-down power switcher, which is specially designed for home appliances and IoT applications, with non-isolated buck solution or offline flyback solution.

The device integrates a 650V high-performance Power MOSFET. Coordinating with a single-winding inductor, it uses fewer external components and provides a low Bill Of Material (BOM) cost solution.

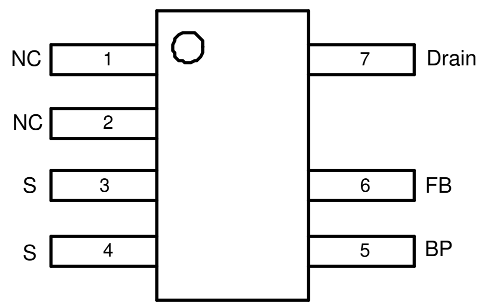
The AP3917B can achieve excellent regulation and high power efficiency. The peak current and switching frequency continuously reduce as the load decreases, thus receiving excellent efficiency performance at light load and improves the overall system efficiency.

The AP3917B has multiple protection features to enhance system safety and reliability. It has over-temperature protection, under-voltage lock function, output short protection, overload protection, and open-loop protection.

The AP3917B is available in the SO-7 package.

Pin Assignments

(Top View)



SO-7

Features

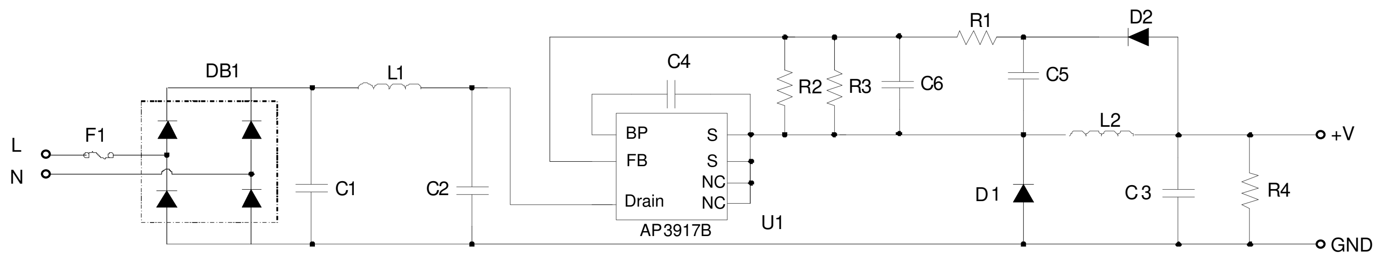
- Universal $85V_{AC}$ to $300V_{AC}$ Input Range
- Internal MOSFET of 650V
- Maximal Peak Current: 280mA Typical
- Improved Constant Voltage: ±5%
- Maximum 170mA Rated Output Current
- No Load Power Consumption: < 30mW with External Bias
- Frequency Modulation to Suppress EMI
- Various Protections: OTP (Over-Temperature Protection), OLP (Overload Protection), SCP (Short Circuit Protection)
- Fewer Components
- Low Audible Noise Solution
- SO-7 Package
- Moisture Sensitivity: MSL Level 3 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per M2003 JESD22-B102, Method 208 (e3)
- Weight: 0.077 grams (Approximate)
- **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-Q100/101/200, 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

- Non-Isolated Home Appliances: AC Fans, Rice Cookers, Shavers; Milk Machines
- IoT Applications
- Industrial Controls
- Standby and Auxiliary

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.

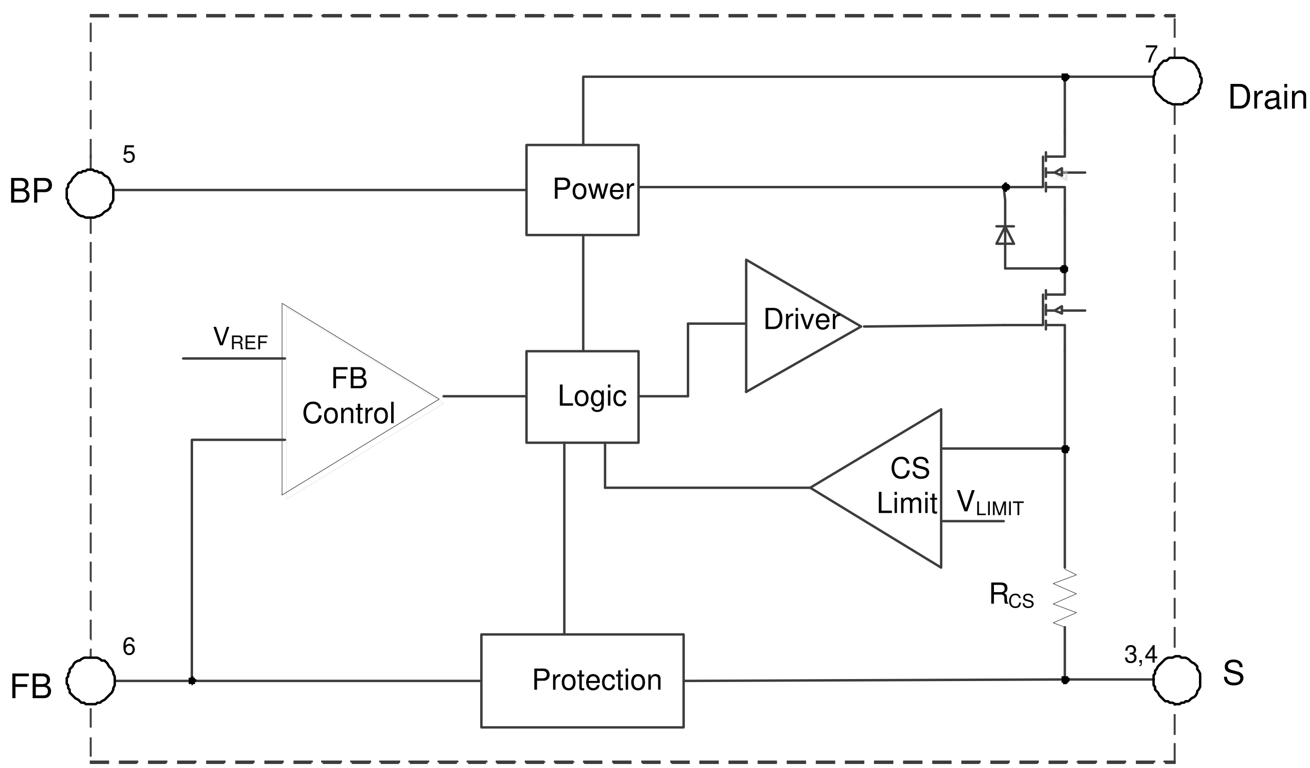
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1, 2	N/C	Not Connected Internally. Recommend to connect to Source for better heat dissipation.
3, 4	S	Internal Power MOSFET Source. Ground Reference for BP and FB Pins.
5	BP	Connection Point of External Bypass Capacitor for Internally Generated Control Circuit Power Supply.
6	FB	Regulator Feedback.
7	Drain	Internal Power MOSFET Drain. High-Voltage Current Source Input.

Functional Block Diagram



Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{DSS}	Drain Pin Voltage	-0.7 to 650	V
V_{BP}	Internally Generated Control Circuit Power Supply Voltage	8.9	V
V_{FB}, V_S	FB Pin and S Pin Voltage	-0.7 to 5.5	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 (Junction to Ambient)(Note 5)	95	°C/W
θ_{JC}	Thermal Resistance (Junction to Case)	13.5	°C/W
—	ESD (Human Body Model)	4000	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. 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	8.2	8.8	V
V_{DSS}	Drain-Source Voltage (Note 6)	—	520	V
T_A	Ambient Temperature	-40	+125	°C

Notes: 6. The drain-source voltage is 80% of V_{DS} in the aging condition.

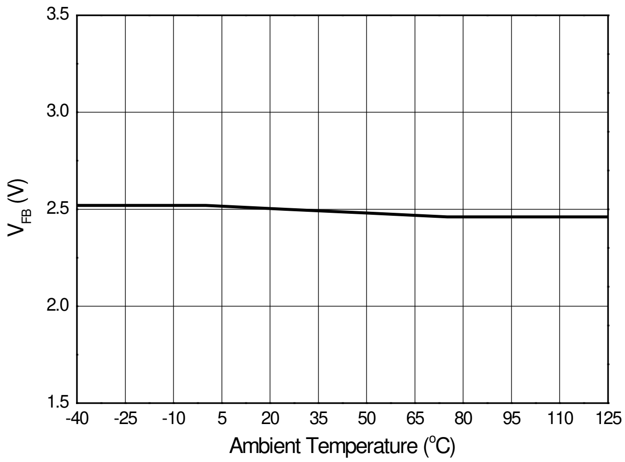
Electrical Characteristics (V_{BP} = 8.2V, -40°C <T_A<+125°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
HV Pin Startup Current Source						
I_{HV}	HV Supply Current	V_{BP} = 7V, V_{DRAIN} = 100V	—	3.5	—	mA
I_{LEAK}	Leakage Current of Drain Pin	V_{BP} = 8.7V, V_{DRAIN} = 400V, T_A = +25°C	—	10	12	µA
V_{BP} Voltage Management						
V_{BP_HVOFF}	V_{BP} Increasing Level at which HV Supply is OFF	—	8.1	8.5	8.8	V
V_{BP_HVON}	V_{BP} Decreasing Level at which HV Supply is ON	—	7.8	8.2	8.6	V
V_{BP_HYS}	V_{BP} Hysteresis (V_{BP_HVOFF} - V_{BP_HVON})	—	—	280	—	mV
V_{BP_UVLO}	V_{BP} Minimum Operating Voltage	T_A = +25°C	—	6.5	—	V
$V_{BP\_RESTART}$	V_{BP} Restart Voltage	—	—	4.5	—	V
I_{BP1}	V_{BP} Operating Current with MOSFET Switching	V_{BP} = 8.5V, f = 37kHz, D = 40%, T_A = +25°C	—	—	350	µA
I_{BP2}	V_{BP} Quiescent Current with No Switching	T_A = +25°C	—	110	200	µA
I_{BP_LATCH}	V_{BP} Latch Off-Current	V_{BP} = 8.8V, T_A = +25°C	—	26	—	µA
Internal MOSFET						
V_{DS}	Breakdown Voltage	T_A = +25°C (Note 7)	650	—	—	V
$R_{DS(ON)}$	ON Resistance	T_A = +25°C, I_D = 0.4A	—	—	16	Ω
Internal Current Sense						
I_{PK_MAX}	Maximum Peak Current	T_A = +25°C	230	280	330	mA
t_{LEB1}	Leading-Edge Blanking	T_A = +25°C	—	250	400	ns
I_{SCP}	Current Set Point for Short Circuit Protection	T_A = +25°C	320	390	460	mA
t_{LEB2}	Leading-Edge Blanking for Short Circuit Protection	T_A = +25°C	—	200	—	ns
Feedback Input (FB Pin)						
t_{MINOFF}	Minimum Off-Time	T_A = +25°C	12.5	17.5	22.5	µs
V_{FB}	MOSFET Feedback Switch-On Threshold	—	2.4	2.5	2.6	V
V_{FB_OLP}	Overload Protection Feedback Trigger Threshold	—	1.56	1.7	1.84	V
t_{OLP}	Overload Protection Delay Time	f = 36kHz	—	170	—	ms
V_{OLD}	Open-Loop Detection Voltage	T_A = +25°C	—	60	—	mV
t_{OLD}	Open-Loop Detection Blanking Time	f = 15kHz, T_A = +25°C	—	4.3	—	ms
Over-Temperature Protection						
T_{OTP}	Thermal Shutdown Threshold (Note 8)	—	+135	+150	+165	°C

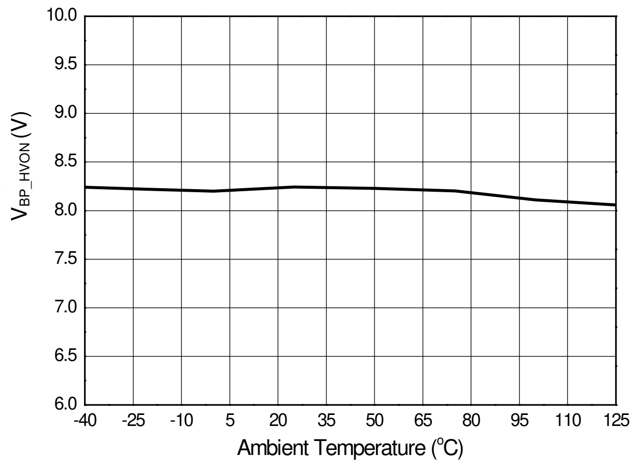
Notes: 7. The drain-source voltage is 80% of V_{DS} in the aging condition.
8. Guaranteed by design.

Performance Characteristics

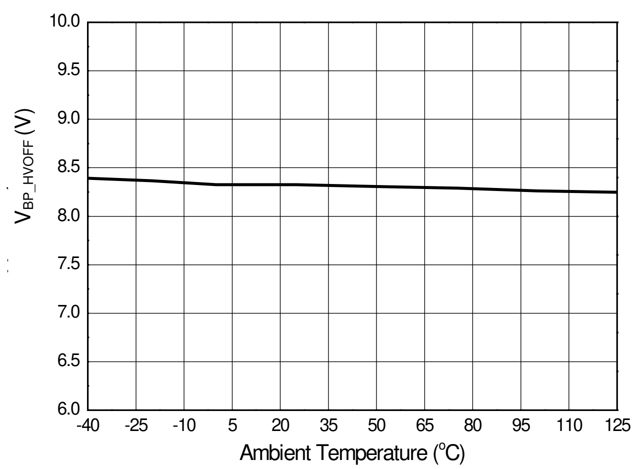
FB Voltage vs. Ambient Temperature



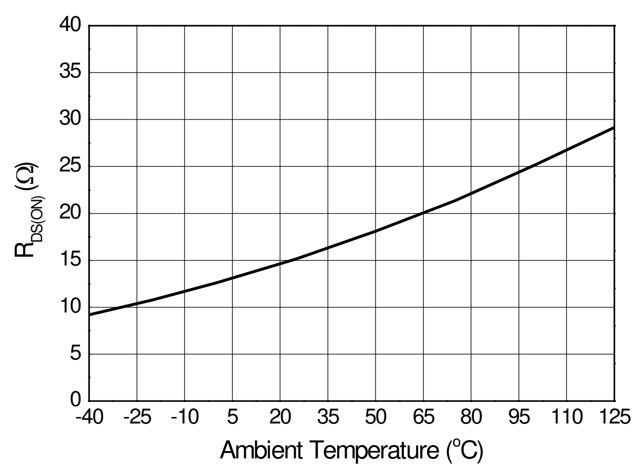
V_{BP_HVON} Voltage vs. Ambient Temperature



V_{BP_HVOFF} Voltage vs. Ambient Temperature



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



Performance Characteristics (continued)

Overall Introduction

The AP3917B is a universal AC input step-down power switcher. Peak current and switching frequency reduce as the load decreases, thus device receives excellent efficiency performance at light load and improving the overall system efficiency. Coordinating with an external single-winding inductor can achieve a low BOM cost solution.

V_{BP} Waveform and ON/OFF Control

The AP3917B control circuit power supply voltage V_{BP} is charged by the internal high-voltage regulator. When the BP voltage charges to V_{BP_HVOFF} (8.5V), the IC starts up, and the internal high-voltage regulator is turned off. When the BP voltage drops below V_{BP_HVON} (8.2V), the internal high-voltage regulator turns on again to charge the external BP capacitor.

When fault conditions happen, such as overload faults, short-circuit faults, over-temperature faults, and open-loop faults, the AP3917B stops switching. Afterwards, an internal current source I_{BP_LATCH} discharges the external BP capacitor. The internal high-voltage regulator will not turn on again until the voltage on the BP capacitor drops below $V_{BP\_RESTART}$ (4.5V). The restart time interval is proportional to the capacitance of external BP capacitor: the larger capacitance of the external BP capacitor, the longer the restart time.

The restart time after a fault is about

$$t_{RESTART} = C_{BP} \times \left(\frac{V_{BP\_FAULT} - V_{BP\_RESTART}}{I_{BP\_LATCH}} + \frac{V_{BP\_HVOFF} - V_{BP\_RESTART}}{I_{HV}}\right)$$

Where:

- V_{BP_FAULT} is actual voltage value of BP pin at the time of fault, which is between V_{BP_HVON} and V_{BP_HVOFF}

Figure 1 shows the typical waveform of V_{BP}.

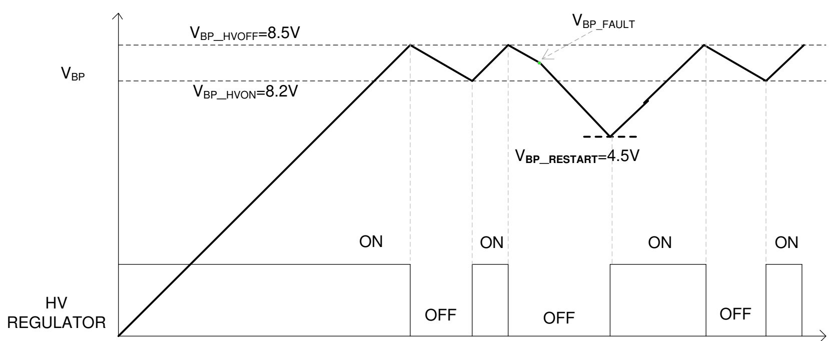


Figure 1. V_{BP} Waveform and HV Regulator ON/OFF Status

Auxiliary V_{BP} Supply

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. A standby power of less than 30mW can be achieved, especially in a no-load condition.

Figure 2 shows the low standby power circuit with the auxiliary V_{BP} supply.

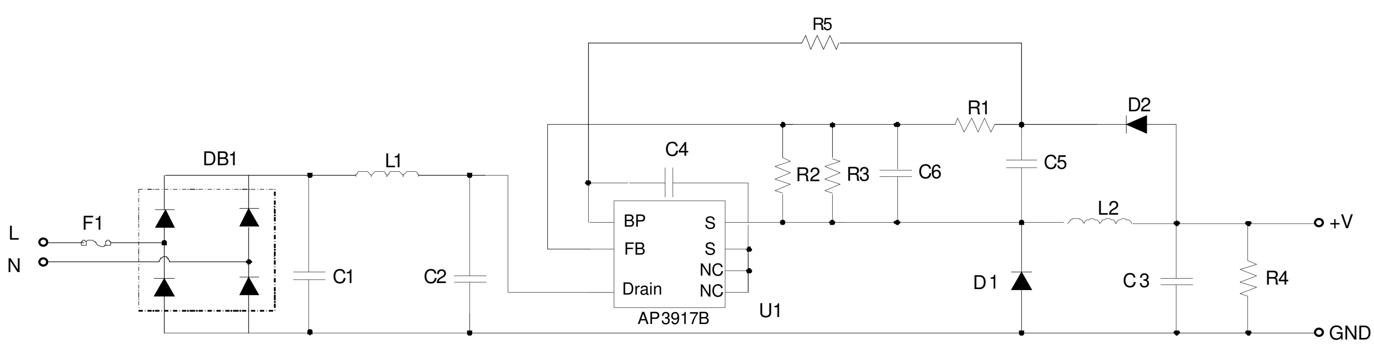


Figure 2. Low Standby Power Circuit with Auxiliary V_{BP} Supply

Performance Characteristics (continued)

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

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

Constant Voltage Operation

The AP3917B can be used in a buck circuit, as shown in the typical application circuit. In the beginning of each cycle, the internal integrated MOSFET turns ON when the FB voltages fall below the reference voltage V_{FB} (2.5V). The FB voltage derives from the sampling capacitor voltage, which can reflect output voltage.

The ON period time is determined by the inductor current variable value Δ_{IL}, (Δ_{IL} 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 status.

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 D2 and D1 respectively. In this stage, the sampling capacitor voltage reflects the output voltage.

The output voltage can be regulated by sampling the FB voltage. In the MOSFET OFF time, the inductor current decreases linearly from peak current. When the inductor current falls below the output current, the FB voltage begins to decrease with the sampling capacitor voltage decreasing. Once the FB voltage is detected below the reference voltage V_{FB} (2.5V), a new switching cycle starts.

The regulated output voltage can be described as the following equation:

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

Figures 3(a) and 3(b) show the operation diagram under DCM and CCM.

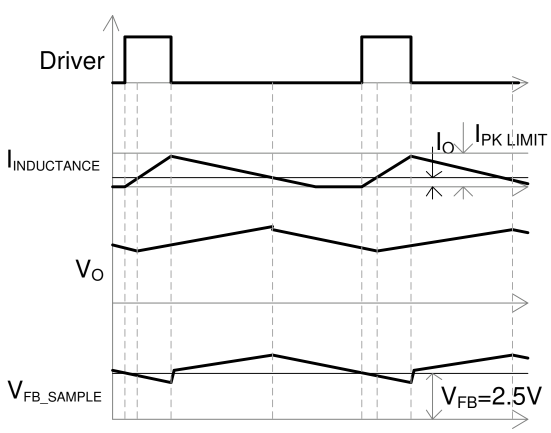


Figure 3(a). DCM

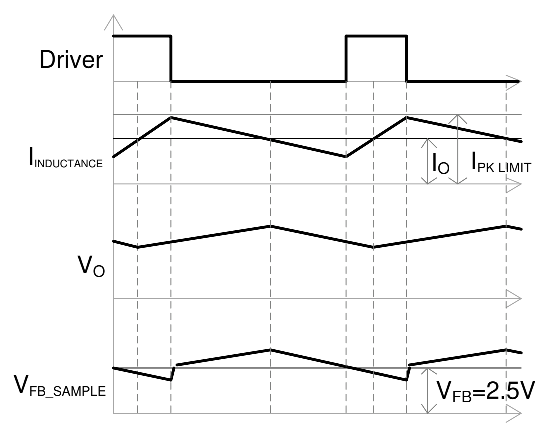


Figure 3(b).CCM

Startup Control

A three-stage control method is designed for soft start function in startup process. During these stages, the OFF time reduces from 70µs to 35µs in stage I, then from 35µs to 17.5µs (t_{MINOFF}) in stage II. Every stage has 128 switching cycles (see Figure 4), but once the output voltage reaches the rated value, the startup process ends no matter what stage it is, then AP3917B enters normal operation mode.

Performance Characteristics (continued)

Figure 4 describes the driver time sequence.

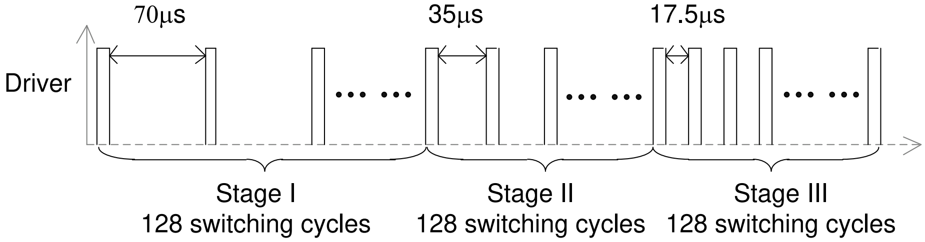


Figure 4. Driver Time Sequence in Startup Process

Operation Frequency and Peak Current Characteristics

In order to achieve excellent efficiency performance at light load and improve the overall system efficiency, AP3917B utilizes an optimized frequency curve as is shown in Figure 5. By means of increasing MOSFET off time, switching frequency continuously decreases as the load decrease, which is optimized for better light-load efficiency. The peak current also decreases with the load decreases, which may avoid the audio noise when the frequency enters into audio frequency range.

The switching-frequency equation is as follows:

$$f_s = \left(\frac{V_{IN} - V_O}{V_{IN}}\right) \cdot \frac{V_O}{2 \cdot L \cdot (I_{PK} - I_O)}, \quad \text{for} \quad \text{CCM}$$

$$f_s = \left(\frac{V_{IN} - V_O}{V_{IN}}\right) \cdot \frac{2 \cdot V_O \cdot I_O}{L \cdot I_{PK}^2}, \quad \text{for} \quad \text{DCM}$$

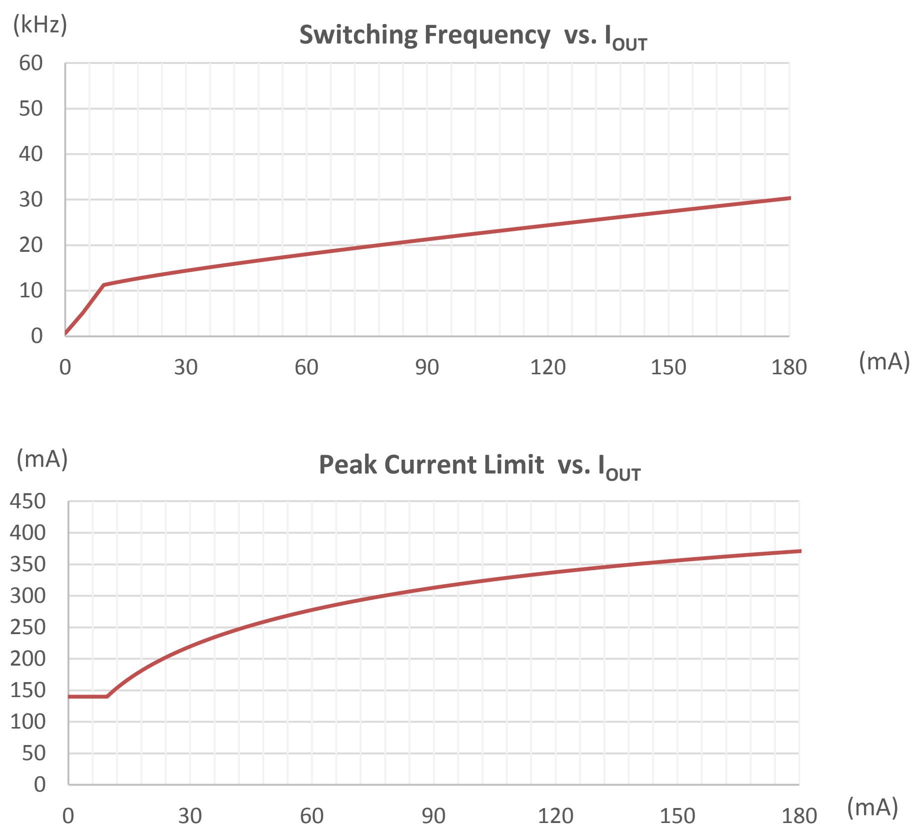


Figure 5. Frequency and Peak Current Limit Characteristic (Vo=12V, L1=1mH)

Performance Characteristics (continued)

Overload Protection (OLP)

With the increase of the load, the peak current and switching frequency increase. When the load continues to increase, peak current reaches its maximum limitation, and the OFF time is at its minimum, the output voltage and FB voltage will decrease. When the FB voltage drops below OLP threshold V_{FB_OLP} (1.7V), the internal overload timer will start to count. Once the overload duration lasts more than the OLP delay time t_{OLP} (170ms), OLP occurs.

The OLP's time delay setting should avoid triggering the OLP when the system starts up or enters a load transition phase. Therefore, it is required that the system startup time must be less than t_{OLP}. The 170ms time delay of t_{OLP} is calculated under the condition of 36kHz operating frequency. Different operating frequencies correspond to different time delays. The time delay calculation under different operating frequencies (f_S) is as follows:

$$t_{DELAY} \approx 170ms \times (\frac{36kHz}{f_S})$$

Short-Circuit Protection (SCP)

The AP3917B shuts down when the peak current exceeds short-circuit threshold I_{SCP} (390mA), and the AP3917B resumes operation when the fault is removed.

Over-Temperature Protection (OTP)

The AP3917B integrates an internal over-temperature protection function. The AP3917B shuts down when the inner junction temperature exceeds thermal shutdown threshold T_{OTP} (+150°C). After exceeding the threshold, the BP voltage begins to drop. When the BP voltage drops to $V_{BP\_RESTART}$ (4.5V), the internal high-voltage regulator turns on to charge the external BP capacitor.

Open-Loop Detection

When the FB voltage drops below open-loop detection threshold voltage V_{OLD} (60mV), the AP3917B stops working, and begins a restart cycle. The open-loop detection is blanked for 64 switching cycles during startup process.

Overshoot Improvement

In general, there is no capacitor between FB pin and S pin. But in some cases where strict overshoot is required, we recommend a ceramic capacitor C6 (390pF to 1nF) in Figure 6.

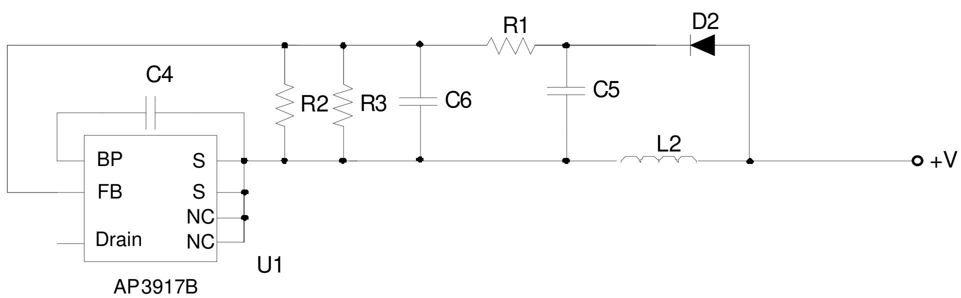
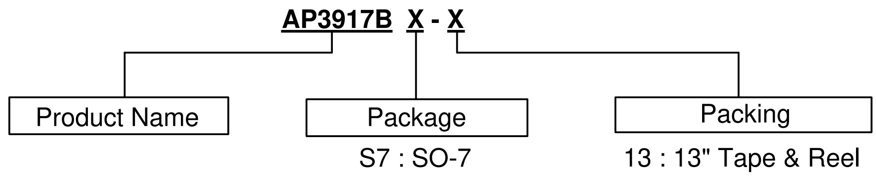


Figure 6. Overshoot Improvement

Leading-Edge Blanking

A narrow spike on the leading edge of the current waveform can usually be observed when the power MOSFET is turned on. Normally, the leading-edge blanking time t_{LEB1} is built in to prevent the false-triggering caused by the turn-on spike. But in the case of short circuit, the leading-edge blanking time is t_{LEB2}. During this period, the current limit comparator is disabled, and the gate driver cannot be switched off.

Ordering Information

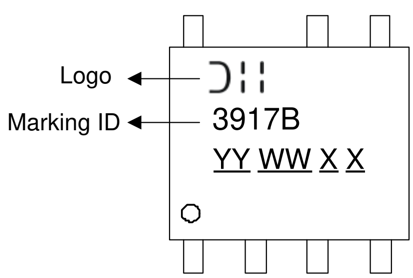


Package	Part Number	Marking ID	13"Tape and Reel	
			Quantity	Part Number Suffix
SO-7	AP3917BS7-13	3917B	4000/Tape and Reel	-13

Marking Information

Package Type: SO-7

(Top View)

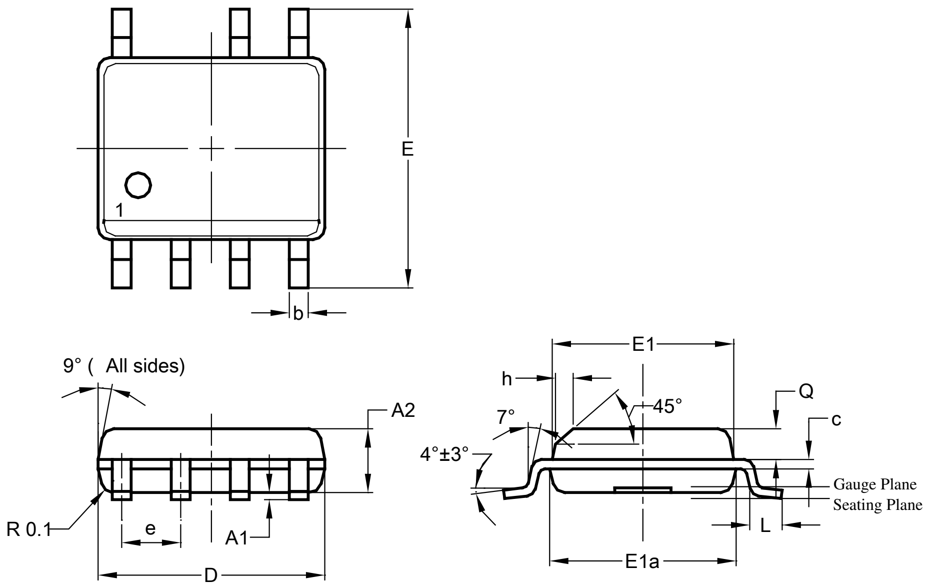


YY : Year : 19, 20, 21 ~
WW : Week : 01~52; 52 represents 52 and 53 week
X X : Internal Code

Package Outline Dimensions

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

SO-7

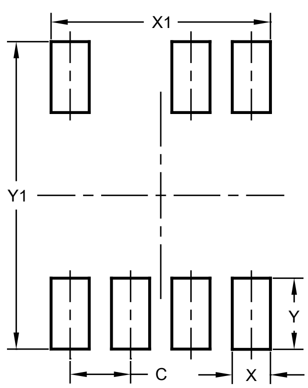


SO-7			
Dim	**Min**	**Max**	**Typ**
A2	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E1a	3.85	3.95	3.90
e	—	—	1.27
h	—	—	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

Suggested Pad Layout

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

SO-7



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