APSemi

APS1026

Dual Channel 1.5 MHz, 600mA Synchronous Step-Down DC-DC Converter

GENERAL DESCRIPTION

APS1026 is a dual channel high efficiency monolithic synchronous step down current mode DC-DC converter operating at 1.5MHz constant frequency. The device integrates a main switch and a synchronous rectifier for high efficiency without an external Schottky diode for each of the channels. The APS1026 can operate from a 2.5V to 5.5V input voltage and is ideal for powering portable equipment that runs from a single cell lithium-Ion (Li+) battery. It can supply 600mA output current for each channel and can also run at 100% duty cycle for low dropout operation, extending battery life in portable system.

User can select between idle mode or power saving mode via Mode/Sync input pin. Idle mode provides low ripple noise at light load while power saving Mode provides high efficiency at light load.

APPLICATIONS

- Portable Media Players
- Digital Still Cameras
- Cellular Telephones
- PDAs
- Wireless and DSL modems

FEATURES

- High Efficiency: Up to 95%
- 600mA Output Current at Vin=3.0V
- 1.5MHz Constant Frequency Operation
- Very Low Quiescent Current of 40uA
- No Schottky Diode Required
- Low $R_{DS(on)}$ Internal Switches: 0.35Ω
- 0.6V reference allows low Output Voltage
- Current Mode Operation for excellent line and load transient Response
- Short-Circuit & Thermal Fault Protection
- <1μA Shut Down Current
- Power-On Reset Output
- Externally Synchronizable Oscillator
- Small Thermally Enhanced MSOP-10 and DFN-10 Package

EVALUATION BOARD

Board Number	Dimensions (Inches)
EV1026EMJ (MSOP)	2.4"X x 2.4"Y x 0.5"X
EV1026EDJ (DFN)	2.4"X x 2.4"Y x 0.5"X

Typical Application

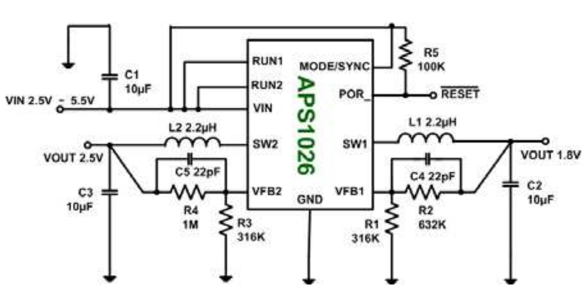

Figure 1. Basic Application Circuit

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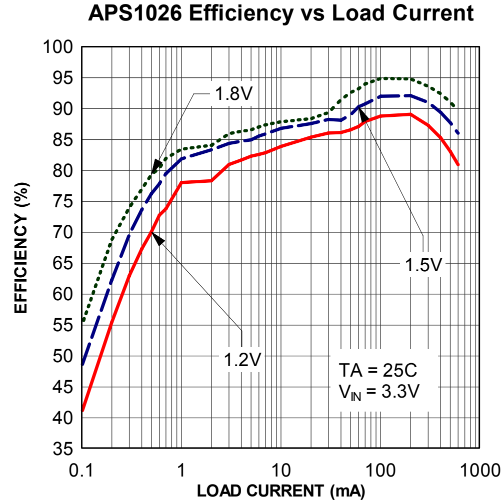
APS1026 Efficiency vs Load Current



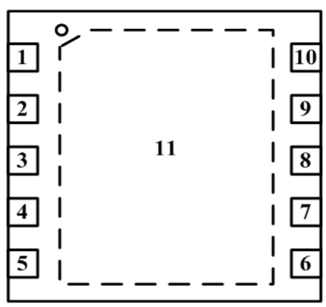
Absolute Maximum Rating (Note 1)

Input Supply Voltage .... -0.3V to +6V
RUN1, RUN2........................... -0.3V to V_{IN}+0.3V
VFB1, VFB2 Voltages .... -0.3V to V_{IN}+0.3V
SW1, SW2 Voltages................ -0.3V to V_{IN}+0.3V
$\overline{\text{POR}}$ Voltages .... -0.3V to V_{IN}+0.3V

Peak SW1, SW2 Sink & Source Current 1.5A
Operating Temperature Range... -40°C to +85°C
Junction Temperature (Note2) ....+125°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (Soldering, 10s).........+300°C

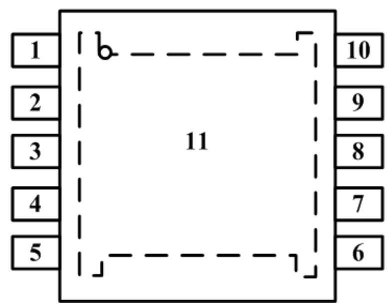
Package/Order Information

TOP VIEW



10-Lead (3mm X 3mm) Plastic DFN
Exposed Pad is PGND (Pin 11)
Must be connected to GND.

TOP VIEW



10-Lead Plastic MSOP
Exposed Pad is PGND (Pin 11)
Must be connected to GND.

Part Number	Top Mark	Temp Range	Part Number	Top Mark	Temp Range
APS1026EDJ	D2XY(Note4)	-45℃ to 85℃	APS1026EMJ	D1XY	-45℃ to 85℃

Thermal Resistance (Note 3):

Package	Θ_{JA}	Θ_{JC}
MSOP-10 (EXPOSE PAD)	45℃/W	10℃/W
DFN-10 (EXPOSE PAD)	45℃/W	10℃/W

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.
Note 2: T_J is calculated from the ambient temperature T_A and power dissipation P_D according to the following formula: $T_J = T_A + (P_D) \times \Theta_{JA}$.
Note 3: Thermal Resistance is specified with approximately 1 square of 1 oz copper.
Note 4: XY = Manufacturing Date Code. X = Year and Y = Week.

Electrical Characteristics (Note 5)

(V_{IN} =V_{RUN}= 3.6V, TA = 25°C, Test circuit of Figure 3, unless otherwise noted.)

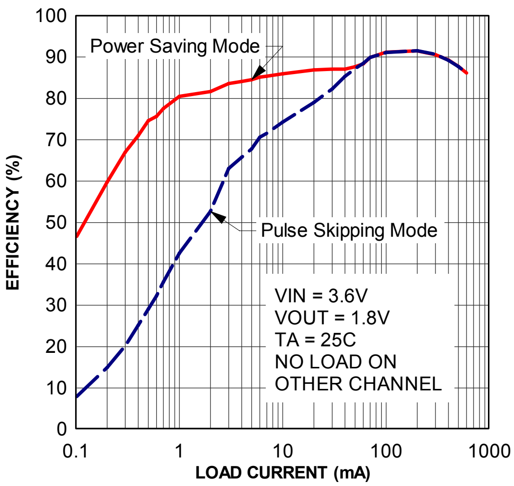
Parameter	Conditions	MIN	TYP	MAX	Unit
Input Voltage Range		2.5		5.5	V
Input DC Supply Current					
Active Mode	V_{FB1} = V_{FB2} = 0.5V, MODE = GND		500	800	µA
Sleep Mode	V_{FB1} = V_{FB2} = 0.63V, MODE = 3.6V		45	60	µA
Shutdown Mode	RUN = 0V, V_{IN} = 4.2V, MODE = 0V		0.3	2	µA
Regulated Feedback Voltage	T_A = +25°C, Channel 1 or 2	0.5880	0.6000	0.6120	V
	T_A= 0°C ≤ T_A ≤ 85°C, Channel 1 or 2	0.5865	0.6000	0.6135	V
	T_A= -40°C ≤ T_A ≤ 85°C, Channel 1 or 2	0.5850	0.6000	0.6150	V
Feedback Pin Input Current	V_{FB} = 0.65V			±30	nA
Reference Voltage Line Regulation	V_{IN} = 2.5V to 5.5V, V_{OUT} = V_{FB} (R2=0)		0.04	0.40	%/V
Output Voltage Line Regulation	V_{IN} = 2.5V to 5.5V, V_{OUT} = 1.8V, I_{OUT} = 10mA		0.24	0.40	%/V
Output Voltage Load Regulation	V_{IN} = 3.6V, , I_{OUT} = 0 to 600mA, Mode = 3.6V or 0V		0.0015		%/mA
Maximum Output Current	V_{IN} = 3.0V	600			mA
Oscillator Frequency	$V_{FB1/2}$ = 0.6V	1.2	1.5	1.8	MHz
$R_{DS(ON)}$ of P-CH MOSFET	V_{IN} = 3.6V, I_L = 100mA		0.35	0.45	Ω
$R_{DS(ON)}$ of N-CH MOSFET	V_{IN} = 3.6V, I_L = 100mA		0.28	0.45	Ω
Peak Inductor Current	V_{IN}=3V, V_{FB1} = V_{FB2}= 0V, SW1 or SW2		1.0		A
SW Leakage	V_{RUN} = 0V, V_{SW}= 0V or 5V, V_{IN} = 5V		±0.01	±1	µA
Output Over Voltage Lockout	$\Delta V_{OVLX} = V_{OVLX} - V_{FBX}$	20	50	80	mV
RUN Threshold	-40°C ≤ T_A ≤ 85°C	0.3	0.45	1.30	V
RUN Leakage Current			±0.1	±1	µA
Power-On Reset Threshold (POR)	V_{FBX} Ramping Up, MODE/SYN = 0V		8.5		%
	V_{FBX} Ramping Down, MODE/SYN = 0V		-8.5		%
	Power-On Reset Delay		175		mS
	Power-On Reset On-Resistance		100		Ω

Note 5: 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization.

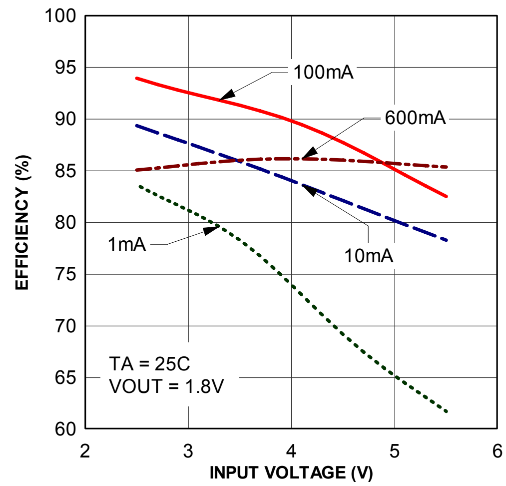
Typical Performance Characteristics

(Test Figure 1 above unless otherwise specified)

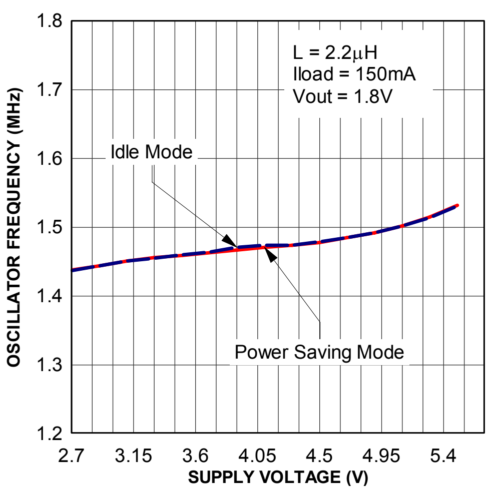
Efficiency vs Load Current



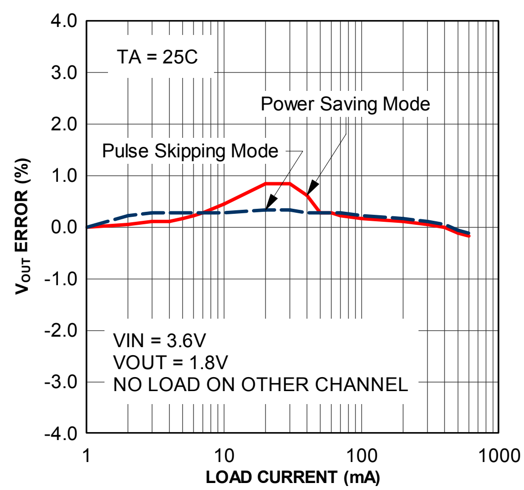
Efficiency vs Input Voltage



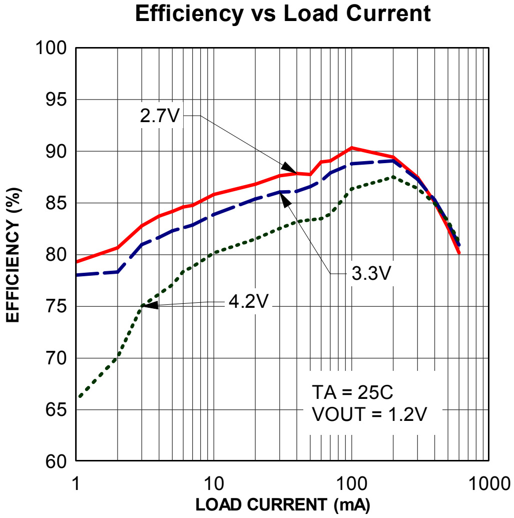
Oscillator Frequency vs Supply Voltage



Load Regulation

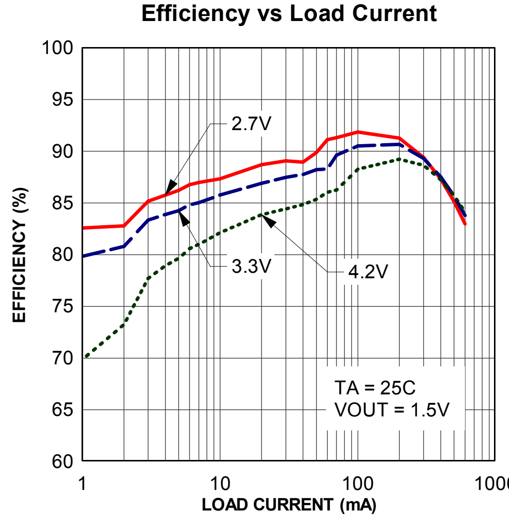


Power Saving Mode Operation
Efficiency vs Load Current



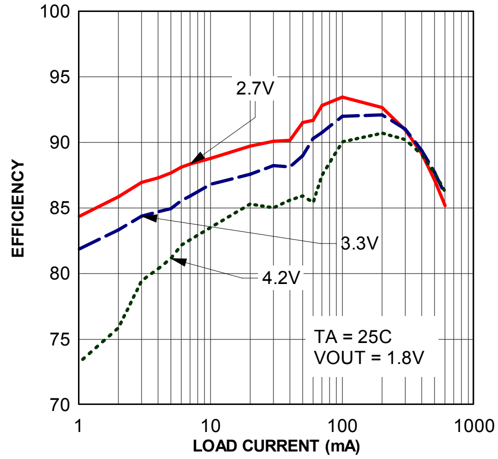
Note: No load on the other channel

Power Saving Mode Operation
Efficiency vs Load Current



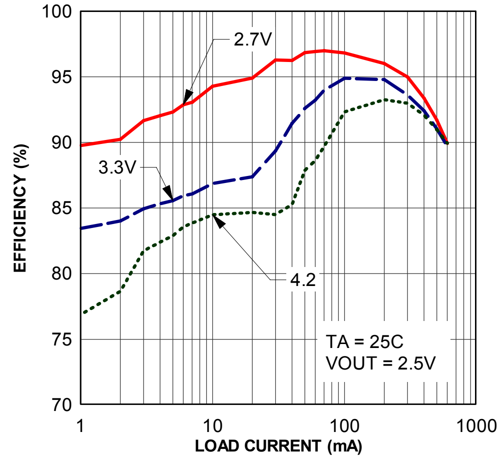
Note: No load on the other channel

Power Saving Mode Operation
Efficiency vs Load Current



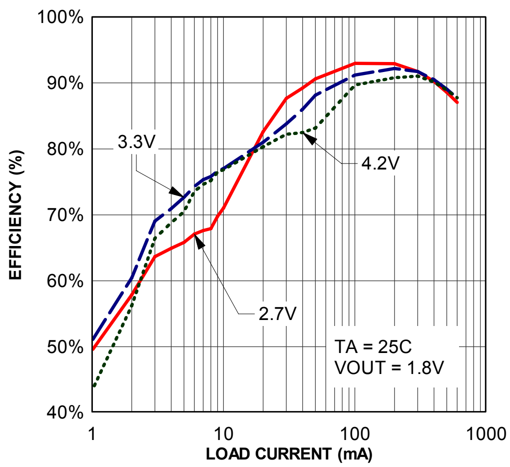
Note: No load on the other channel

Power Saving Mode Operation
Efficiency vs Load Current



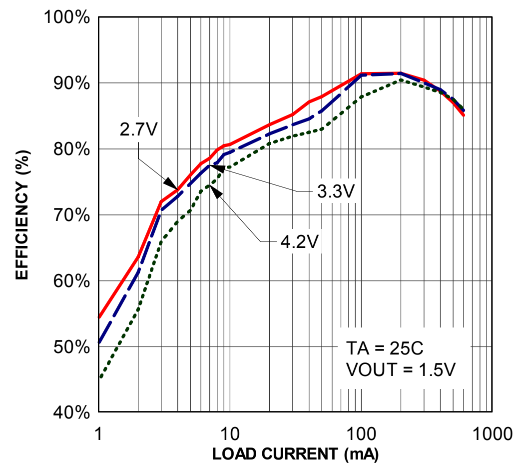
Note: No load on the other channel

Idle Mode Operation
Efficiency vs Load Current



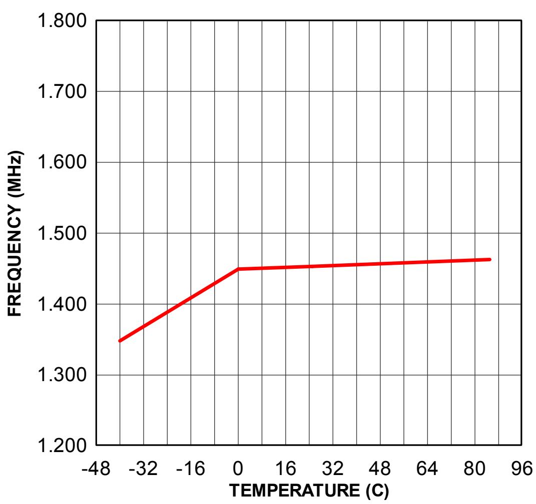
Note: No load on the other channel

Idle Mode Operation
Efficiency vs Load Current

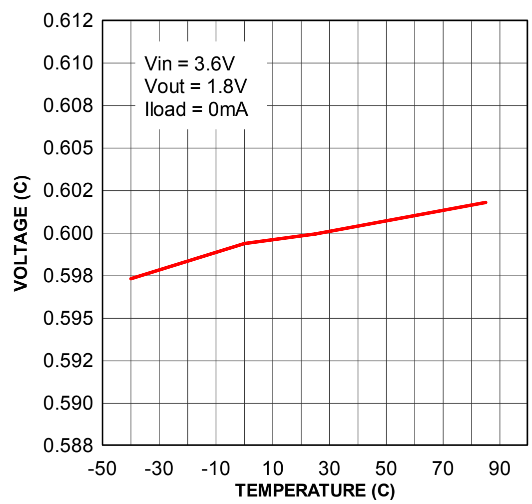


Note: No load on the other channel

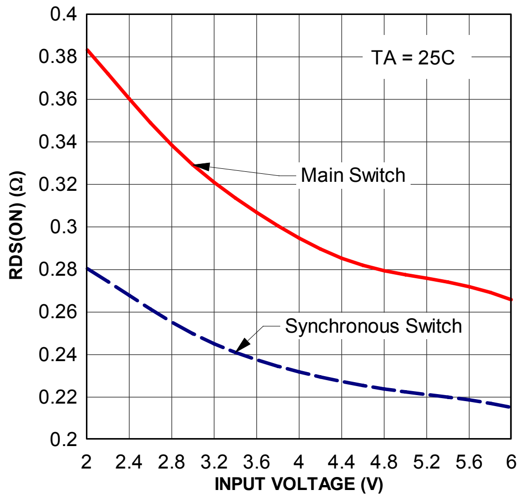
Oscillator Frequency vs Temperature



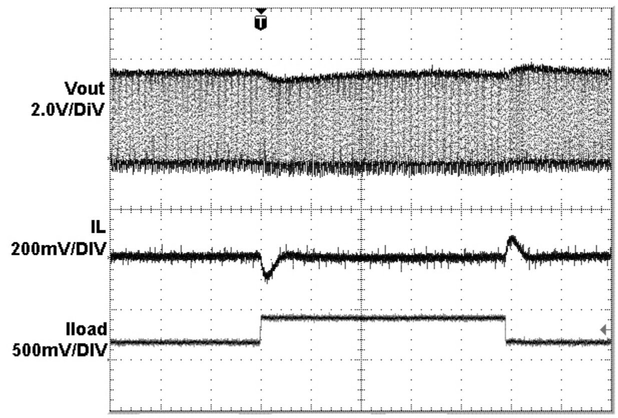
VFB vs Temperature



Rds(on) vs Input Voltage

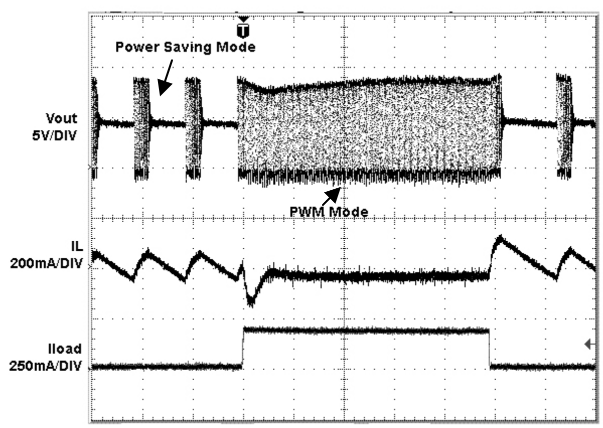


Load Transient Response PWM Mode Only



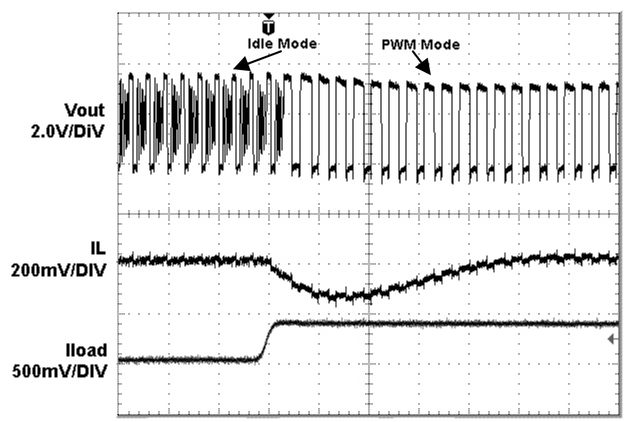
Iload = 180mA to 400mA, PWM Mode
L=2.2uH, Cin=10uF, Cout=10uF, Vin=3.6V, Vout=1.8V

Load Transient Response Power Saving Mode to PWM mode



Iload = 26mA to 400mA,
L=2.2uH, Cin=10uF, Cout=10uF, Vin=3.6V, Vout=1.8V

Load Transient Response Idle Mode to PWM mode



Iload = 26mA to 400mA, Idle Mode
L=2.2uH, Cin=10uF, Cout=10uF, Vin=3.6V, Vout=1.8V

Pin Description

PIN	NAME	FUNCTION & Description
1	VFB1	Channel 1 output feedback. It receives the feedback voltage from the external resistive divider across the output.
2	RUN1	Channel 1 Enable
3	VIN	Power Supply
4	SW1	Channel 1 power switch output
5	GND	Ground
6	MODE/SYNC	Combination Mode selection and Oscillator Synchronization. When MODE/SYNC = High, the circuit is in Idle mode operation; When MODE/SYNC = High, the circuit is in power saving mode operation.
7	SW2	Channel 2 power switch output.
8	POR	Power On Reset.
9	RUN2	Enable pin of Channel 2.
10	VFB2	Channel 2 output feedback. It receives the feedback voltage from the external resistive divider across the output.
11	EXPOSED PAD	Power Ground. It must be connect to ground properly.

Functional Block Diagram

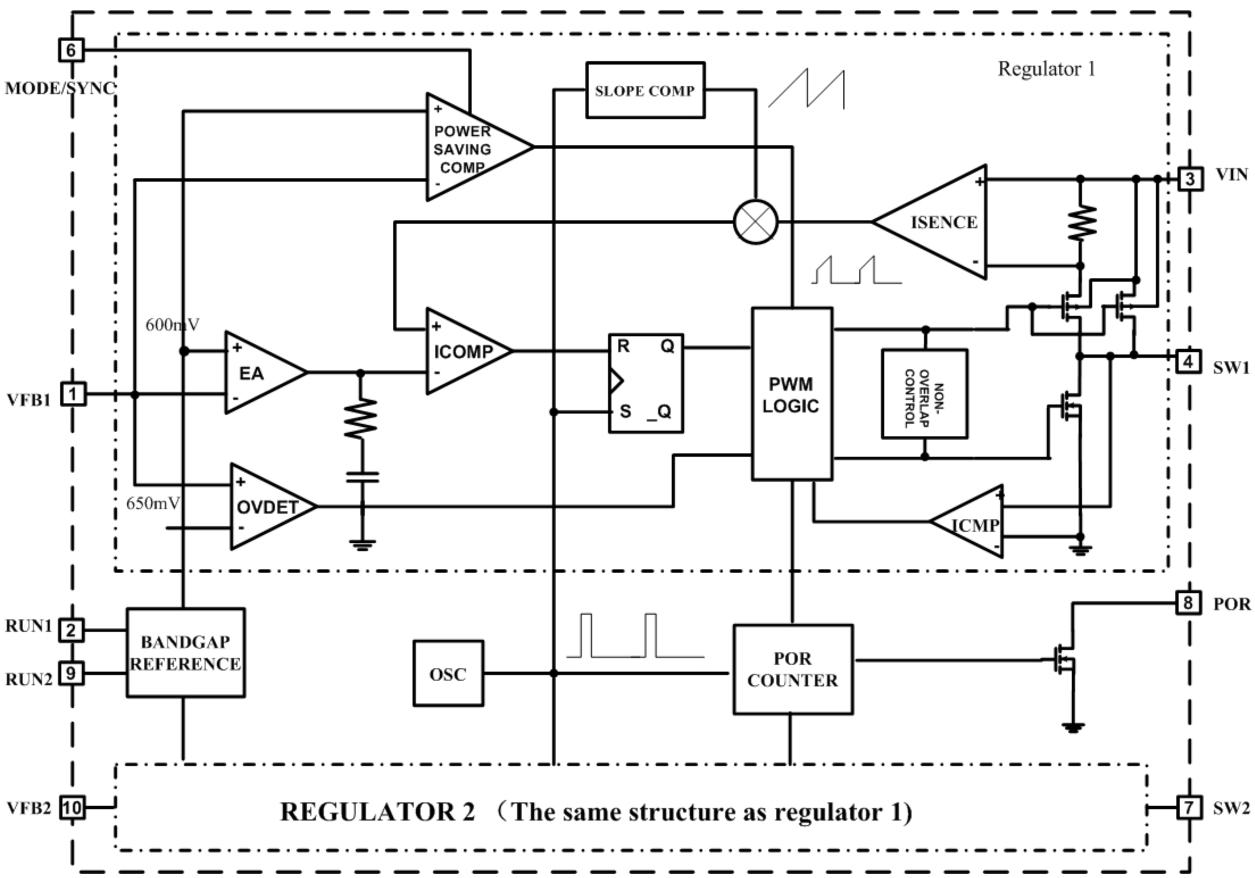


Figure 2. APS1026 Block Diagram

Operation

The APS1026 is a monolithic switching mode Step-Down DC-DC converter. It utilizes internal MOSEFETs to achieve high efficiency and can generate very low output voltage by using internal reference at 0.6V. It operates at a fixed switching frequency, and uses the slope compensated current mode architecture. This Step-Down DC-DC Converter supplies 600mA output current at VIN = 3V with input voltage range from 2.5V to 5.5V. With the mode selection pin, users may select the Power Saving Mode, optimizing efficiency at light load (Mode=Vin) or the Idle Mode, optimizing ripple at light load (Mode=GND).

Current Mode PWM Control

Slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for excellent load and line responses and protection of the internal main switch (P-Ch MOSFET) and synchronous rectifier (N-CH MOSFET). During normal operation, the internal P-Ch MOSFET is turned on for a certain time to ramp the inductor current at each rising edge of the internal oscillator, and switched off when the peak inductor current is above the error voltage. The current comparator, $I_{COMP,}$ limits the peak inductor current. When the main switch is off, the synchronous rectifier will be turned on immediately and stay on until either the inductor current starts to reverse, as indicated by the current reversal comparator, I_{ZERO}, or the beginning of the next clock cycle. The OVDET comparator controls output transient overshoots by turning the main switch off and keeping it off until the fault is no longer present.

Idle Operation

Two modes, the power saving mode and idle mode, are available to control the operation of the APS1026 at low currents. Both modes automatically switch from continuous operation to the selected mode when the load current is low.

The APS1026 may be selected to enter Idle operation (Mode=Vin) at light load. In the pulsing skipping mode, the inductor current may reach zero or reverse on each pulse. The PWM control loop will automatically skip pulses to maintain output regulation. The bottom MOSFET is turned off by the current reversal comparator, $I_{ZERO,}$ and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator.

Power Saving Operation

The APS1026 may be selected to enter Power Saving Mode (Mode=GND) at light load. In power saving mode at light load, a control circuit puts most of the circuit into sleep in order to reduce quiescent current and improve efficiency at light load. When the output voltage drops to certain threshold, the control circuit turns back on the oscillator and the PWM control loop, boosting output backup. When an upper threshold is reached, the control circuit again puts most of circuit into sleep, reducing quiescent current. While the power saving mode improves light load efficiency, however, with the turning on and off, the noise or ripple voltage is larger than that in the pulse skiing mode.

Dropout Operation

When the input voltage decreases toward the value of the output voltage, the APS1026 allows the main switch to remain on for more than one switching cycle and increases the duty cycle until it reaches 100%. The duty cycle D of a step-down converter is defined as:

$$D = T_{ON} \times f_{OSC} \times 100\% \approx \frac{V_{OUT}}{V_{IN}} \times 100\%$$

Where T_{ON} is the main switch on time and f_{OSC} is the oscillator frequency.

The output voltage then is the input voltage minus the voltage drop across the main switch and the inductor. At low input supply voltage, the $R_{DS(ON)}$ of the P-Channel MOSFET increases, and the efficiency of the converter decreases. Caution must be exercised to ensure the heat dissipated not to exceed the maximum junction temperature of the IC.

Maximum Load Current

The APS1026 will operate with input supply voltage as low as 2.5V, however, the maximum load current decreases at lower input due to large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely the current limit increases as the duty cycle decreases.

Layout Guidance

When laying out the PC board, the following suggestions should be taken to ensure proper operation of the APS1026. These items are also illustrated graphically in Figure 3 and 4.

1. The power traces, including the GND trace, the SW trace and the VIN trace should be kept short, direct and wide.
2. The VFB pin should be connected directly to the feedback resistor. The resistive divider R1/R2 must be connected between the (+) plate of COUT and ground.
3. Connect the (+) plate of CIN to the VIN pin as closely as possible. This capacitor provides the AC current to internal power MOSFET.
4. Keep the switching node, SW, away from the sensitive VFB node.
5. Keep the (-) plates of CIN and COUT as close as possible.

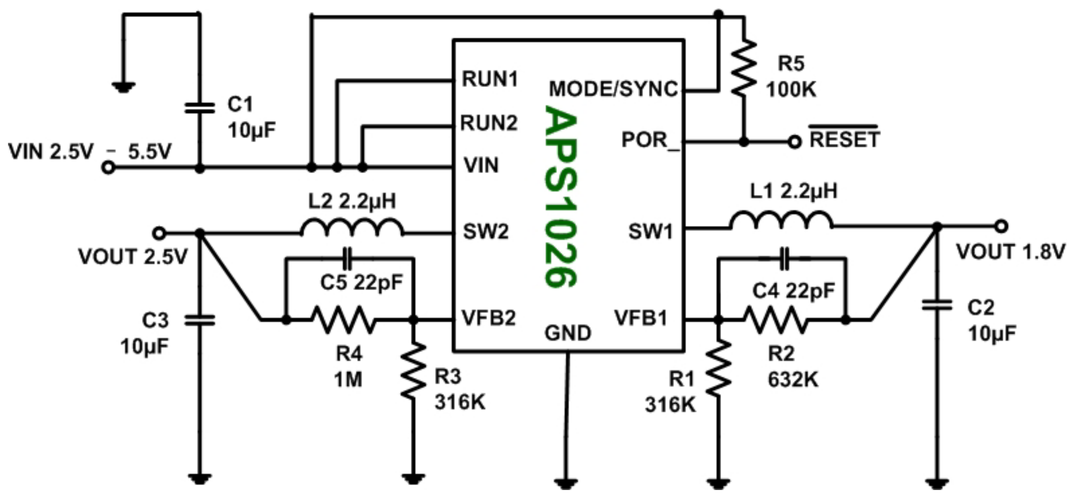


Figure 3. APS1026 Typical Application Circuit

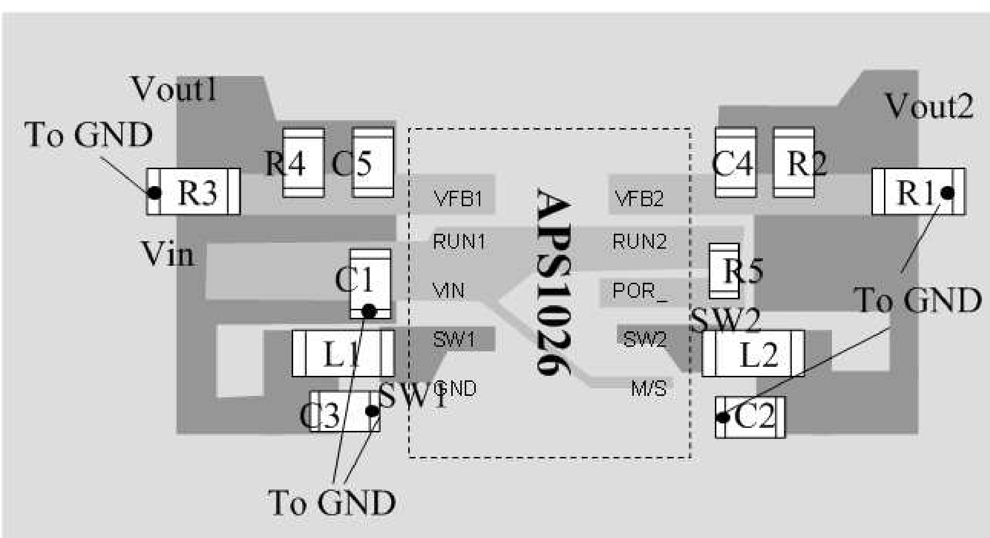


Figure 4. APS1026 Typical Application Circuit Layout

APPLICATIONS INFORMATION

Setting the Output Voltage

Figure 3 above shows the basic application circuit for the APS1026. The external resistor sets the output voltage according to the following equation:

$$V_{OUT} = 0.6V\left(1 + \frac{R2}{R1}\right)$$

Table 1 – Resistor select for output voltage setting

V_{OUT}	R1(R3)	R2(R4)
1.2V	316k	316k
1.5V	316k	474k
1.8V	316k	632k
2.5V	316k	1001k

Inductor Selection

For most designs, the APS1026 operates with inductors of 1µH to 4.7µH. Low inductance values are physically smaller but require faster switching, which results in some efficiency loss. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where ΔI_L is inductor Ripple Current. Large value inductors lower ripple current and small value inductors result in high ripple currents. Choose inductor ripple current approximately 35% of the maximum load current 600mA, or ΔI_L=210mA.

For output voltages above 2.0V, when light-load efficiency is important, the minimum recommended inductor is 2.2µH. For optimum voltage-positioning load transients, choose an inductor with DC series resistance in the 50mΩ to 150mΩ range. For higher efficiency at heavy loads (above 200mA), or minimal load regulation (but some transient overshoot), the resistance should be kept below 100mΩ. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation (600mA+105mA). Table 1 lists some typical surface mount inductors that meet target applications for the APS1026.

Part #	L (µH)	Max DCR (mΩ)	Rated D.C. Current (A)	Size WxLxH (mm)
Sumida CR43	1.4 2.2 3.3 4.7	56.2 71.2 86.2 108.7	2.52 1.75 1.44 1.15	4.5x4.0x3.5
Sumida CDRH4D18	1.5 2.2 3.3 4.7	75 110 162	1.32 1.04 0.84	4.7x4.7x2.0
Toko D312C	1.5 2.2 3.3 4.7	120 140 180 240	1.29 1.14 0.98 0.79	3.6x3.6x1.2

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency shall be less than input source impedance to prevent high frequency switching current passing to the input. A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 4.7µF ceramic capacitor for most applications is sufficient.

Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. The output capacitor must have low impedance at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current. The output ripple V_{OUT} is determined by:

Package Description

MSOP-10

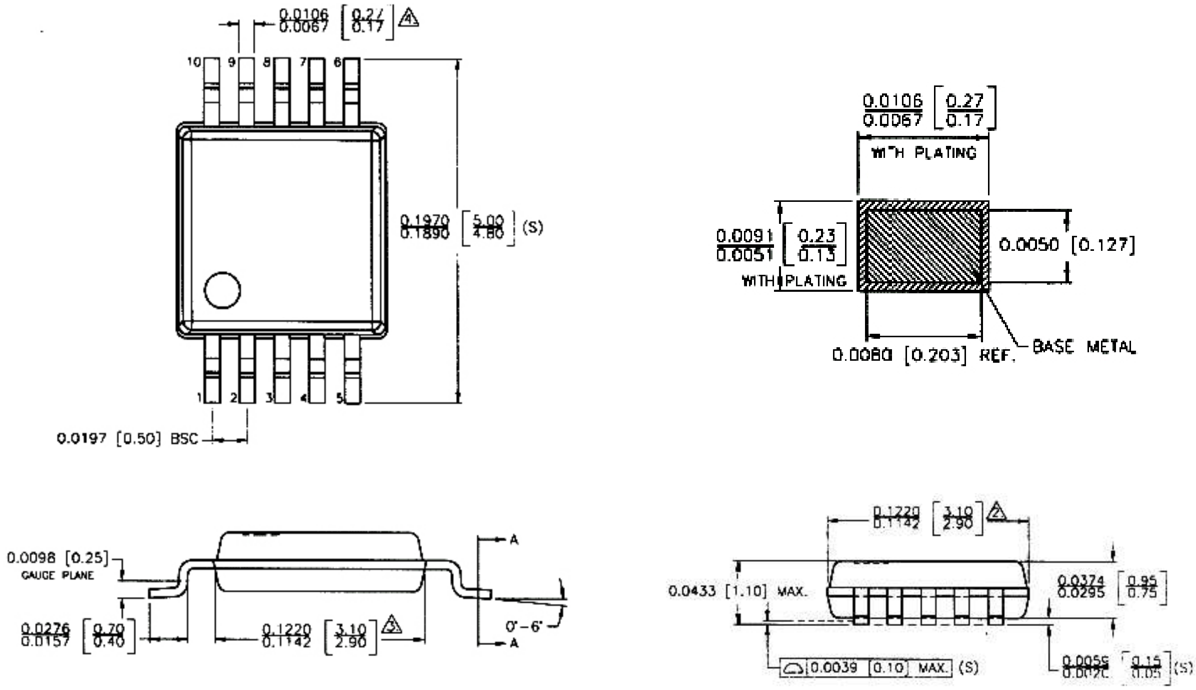
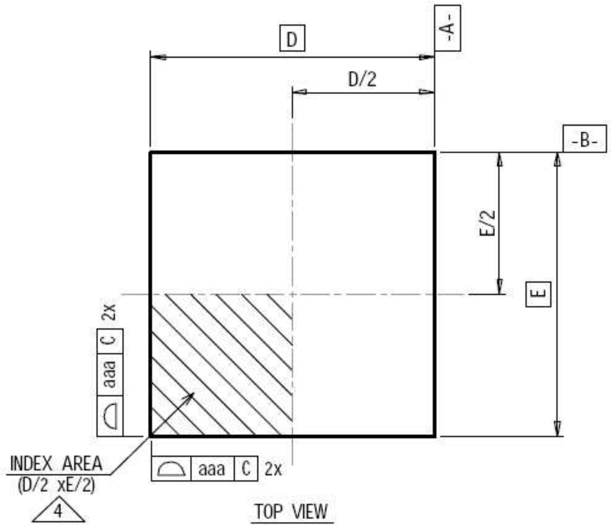


Figure 5 Package Dimensions of 10-lead Plastic MSOP

DFN-10

Dimension: mm



A	0.75
A1	0.02
A3	0.20 ref
aaa	0.15
bbb	0.10
ccc	0.10
ddd	0.05
eee	0.08
ggg	0.10
D BSC	3.00
E BSC	3.00
D2	2.20-2.70
E2	1.40-1.75
L	0.40
N	10
ND	5

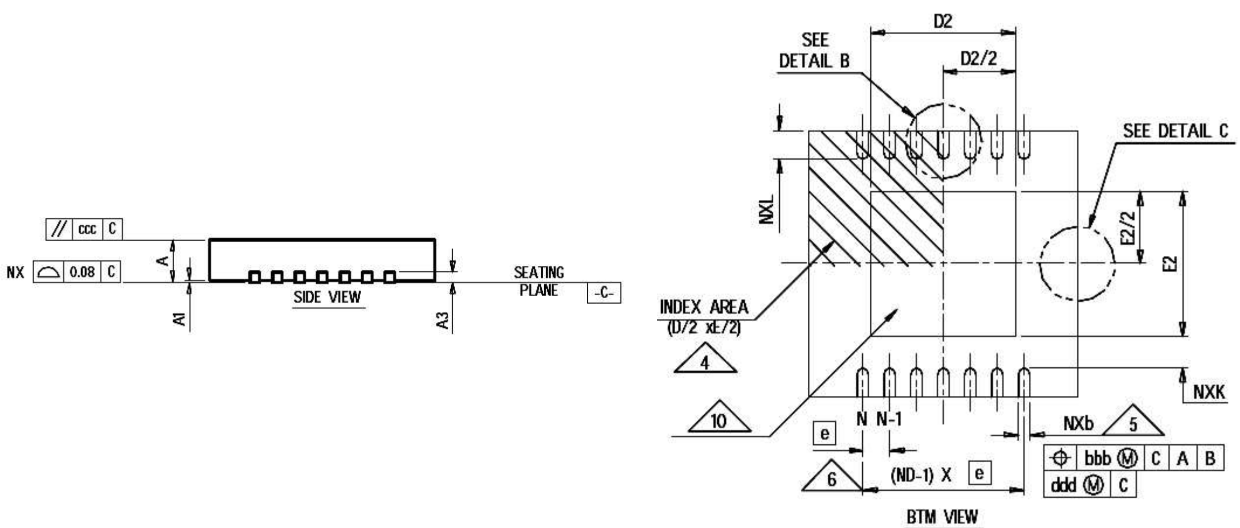


Figure 6 Package Dimensions of 10-lead Plastic DFN (3mmX3mm)

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