Alfa-MOS Technology

AF1206

300KHz, 5A / 23V Step-Down Converter

General Description

AF1206 consists of step-down switching regulator with PWM control. These devices include a reference voltage source, oscillation circuit, error amplifier, internal PMOS and etc.

AF1206 provides low-ripple power, high efficiency, and excellent transient characteristics. The PWM control circuit is able to very the duty ratio linearly from 0 up to 100%. This converter also contains an error amplifier circuit as well as a soft-start circuit that prevents overshoot at startup. An enable function, an over current protect function and a short circuit protect function are built inside, and when OCP or SCP happens, the operation frequency will be reduced from 300KHz to 60KHz. Also, an internal compensation block is built in to minimum external component count.

With the addition of an internal P-channel Power MOS, a coil, capacitors, and a diode connected externally, these ICs can function as step-down switching regulators. They serve as ideal power supply units for portable devices when coupled with the SOP-8P mini-package, providing such outstanding features as low current consumption. Since this converter can accommodate an input voltage up to 23V, it is also suitable for the operation via an AC adapter.

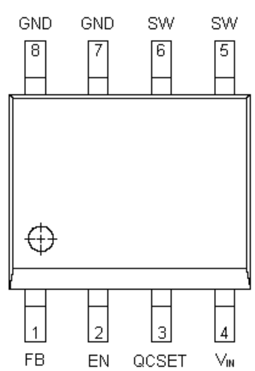
Features

- Input voltage: 4.2V to 23V.
- Output voltage: 0.8V to VIN.
- Duty ratio: 0% to 100% PWM control
- Oscillation frequency: 300KHz typ.
- Soft-start, Current limit, Enable function
- Thermal Shutdown function
- Built-in internal P-channel MOS
- SOP-8P Package.

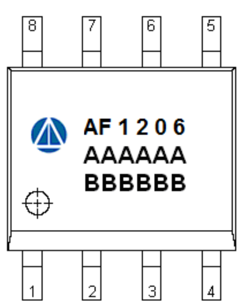
Application

- PC Motherboard
- LCD Monitor
- Graphic Card
- DVD-Video Player
- Telecom Equipment
- ADSL Modem
- Printer and other Peripheral Equipment
- Microprocessor core supply
- Networking power supply

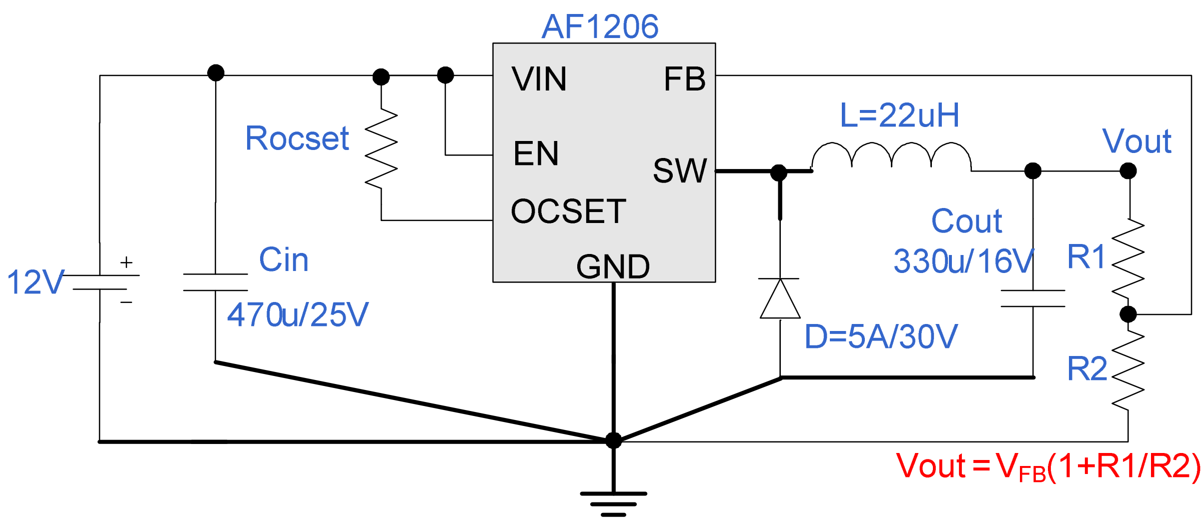
Pin Define (SOP-8P)



Marking Information



Typical Application Circuit



Pin Description

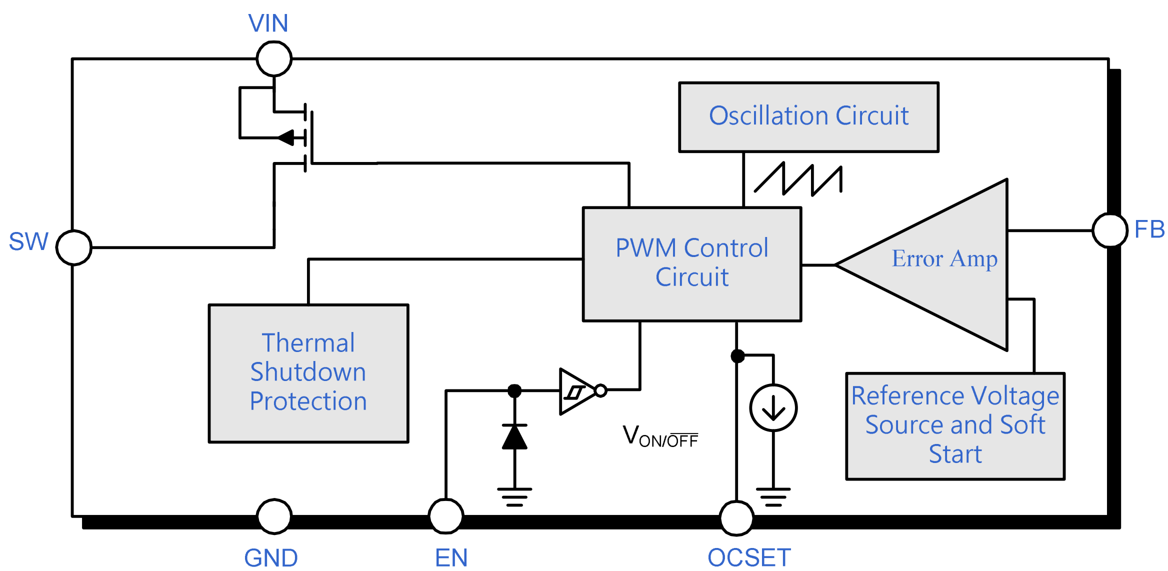
Pin	Symbol	Description
FB	1	Feedback pin.
EN	2	Enable / Disable pin H: Normal operation mode. (Step-down operation) L: Shutdown mode. (All circuits deactivated)
OCSET	3	Add an external resistor to set max output current.
VIN	4	IC power supply pin
SW	5、6	Switch Pin. Connect external inductor/diode here. Minimize trace area at this pin to reduce EMI.
GND	7、8	GND Pin

Ordering Information

Part Ordering No.	Part Marking	Package	Unit	Quantity
AF1206S8RG	AF1206	SOP-8P	Tape & Reel	2500 EA

※ A Lot code
※ B Date code
※ AF1206S8RG : 13" Tape & Reel ; Pb- Free ; Halogen- Free

Block Diagram



Absolute Maximum Ratings (T_A=25°C Unless otherwise noted)

The following ratings designate persistent limits beyond which damage to the device may occur.

Symbol	Parameter	Value	Unit
V_{IN} *1	V_{IN} Pin Voltage	V_{SS} - 0.3 to V_{SS} + 25	V
V_{FB}	Feedback Pin Voltage	V_{SS} - 0.3 to V_{CC}	V
$V_{ON/OFF}$ *1	ON/OFF Pin Voltage	V_{SS} - 0.3 to V_{IN} + 0.3	V
V_{OUTPUT}	Switch Pin Voltage	V_{SS} - 0.3 to V_{IN} + 0.3	V
P_D	Power Dissipation	Internally limited	mW
T_{OPR}	Operating Temperature Range	-20 to +125	°C
T_{STG}	Storage Temperature Range	-40 to +150	°C

Caution:

The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

Electrical Characteristics

(T_A=25℃, V_{CC}=12V, unless otherwise specified.)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Input Voltage		4.2		23	V
V_{FB}	Feedback Voltage	I_{OUT}=0.1A	0.784	0.8	0.832	V
I_{FB}	Feedback Bias Current	I_{OUT}=0.1A		0.1	0.5	µA
Isw	Switch Current		6		-	A
I_{GND}	Current Consumption During Power Off	$V_{ON/OFF}$=0V		1	10	µA
I_{OCSET}	OCSET Pin Bias Current		75	90	105	µA
$\Delta V_{OUT}/V_{OUT}$	Line Regulation	V_{IN}=5V~23V		1	2	%
$\Delta V_{OUT}/V_{OUT}$	Load Regulation	I_{OUT}=0.1 to 5A		0.2	0.5	%
f_{OSC}	Oscillation Frequency	Measure waveform at SW pin	240	300	360	KHz
f_{OSC1}	Frequency of Current Limit or Short Circuit Protect	Measure waveform at SW pin	30	60	90	KHz
V_{SH}	EN Pin Input Voltage	Evaluate oscillation at SW pin	2.0			V
V_{SL}		Evaluate oscillation stop at SW pin			0.8	
I_{SH}	EN Pin Input Leakage Current			20	-	µA
I_{SL}				-10	-	µA
T_{SS}	Soft-Start Time		0.3	2	5	ms
R_{DSON}	Internal MOSFET Rdson	V_{IN}=5V, V_{FB}=0V		45	65	mΩ
		V_{IN}=12V, V_{FB}=0V		35	55	
η	Efficiency	V_{IN}=12V, V_{OUT} = 5V		87		%

Application Information

PWM Control

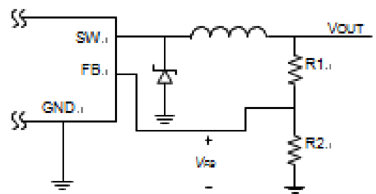
The AF1206 consists of DC/DC converters that employ a pulse-width modulation (PWM) system.

In converters of the AF1206, the pulse width varies in a range from 0 to 100%, according to the load current. The ripple voltage produced by the switching can easily be removed through a filter because the switching frequency remains constant. Therefore, these converters provide a low-ripple power over broad ranges of input voltage and load current.

Output Voltage Programming

AF1206 develops a band-gap between the feedback pin and ground pin. Therefore, the output voltage can be formed by R1 and R2. Use 1% metal film resistors for the lowest temperature coefficient and the best stability. Select lower resistor value to minimize noise pickup in the sensitive feedback pin, or higher resistor value to improve efficiency. The output voltage is given by the following formula:

$$V_{OUT} = V_{FB} \times (1 + R1 / R2) \text{ where } V_{FB} = 0.8V$$

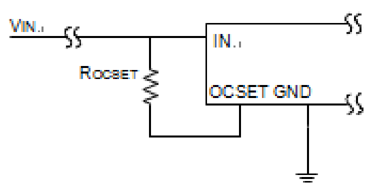


Short Circuit Protection

When the output is shorted to ground, the protection circuit will be triggered and force the oscillation frequency down to approximately 60KHz. The oscillation frequency will return to 300KHz once the output voltage or the feedback voltage rises above 0V.

Current Limit Setting

This device reserves OCSET pin to set the switching peak current. In general, the peak current must be 1.5 times of the continuous output current. It can be calculated as below:

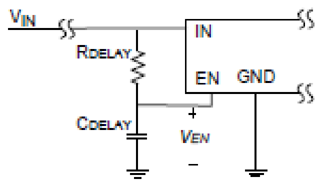


$$I_{CL} = (I_{OCSET} \times R_{OCSET}) / R_{DS(ON)}$$

Where ICL is the current limit, IOCSET is the OCSET bias current (90uA Typ.), and $R_{DS(ON)}$ is theON-resistance of the internal power MOSFET.

Delay Start-up

The following circuit uses the EN pin to provide a time delay between the input voltage is applied and the output voltage comes up. As the instant of the input voltage rises, the charging of capacitor C_{DELAY} pulls the EN pin low, keeping the device off. Once the capacitor voltage rises above the EN pin threshold voltage, the device will start to operate. The start-up delay time can be calculated by the following formula



$$V_{IN} \times (1 - e^{-T/(RxC)}) > V_{EN}$$

Where T is the start-up delay time, R is R_{DELAY}, C is C_{DELAY}, and V_{EN} is 2.0V.
This feature is useful in situations where the input power source is limited in the amount of current it can deliver. It allows the input voltage to rise to a higher voltage before the device starts operating.

Inductor Selection

The conduction mode of power stage depends on input voltage, output voltage, output current, and the value of the inductor. Select an inductor to maintain this device operating in continuous conduction mode (CCM). The minimum value of inductor can be determined by the following procedure.

(1) Calculate the minimum duty ratio:

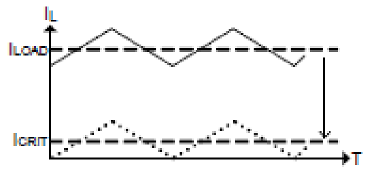
$$D_{(MIN)} = \frac{V_{OUT} + I_{LOAD} \times DCR + V_F}{V_{IN(MAX)} - I_{LOAD} \times R_{DS(ON)} + V_F} = \frac{T_{ON}}{T_S}$$

Where DCR is the DC resistance of the inductor, V_F is the forward voltage of the rectifier diode, and Ts is the switching period.

This formula can be simplified as below:

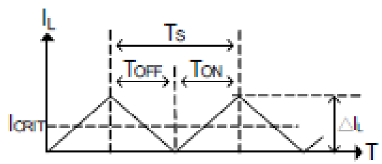
$$D_{(MIN)} = \frac{V_{OUT}}{V_{IN(MAX)}} = \frac{T_{ON}}{T_S} \quad ; \; 0 \le D \le 1$$

(2) Define a value of minimum current that is approximately 10%~30% of full load current to maintain continuous conduction mode, usually referred to as the critical current (I_{CRIT}).



$$I_{CRIT} = \delta \times I_{LOAD} \quad ; \quad \delta = 0.1 \sim 0.3$$

(3) Calculate the inductor ripple current (ΔI_L). In steady state conditions, the inductor ripple current increase, (ΔI_{L+}), during the ON time and the current decrease, (ΔI_{L-}), during the OFF time must be equal.



$$\Delta I_L = 2 \times I_{CRIT}$$

(4) Calculate the minimum value of inductor use maximum input voltage. That is the worst case condition because it gives the maximum ΔI_L.

$$L \geq \frac{[V_{IN(MAX)} - I_{LOAD} \times (R_{DS(ON)} + DCR) - V_{OUT}] \times D_{(MIN)}}{\Delta I_L \times fs}$$

This formula can be simplified to

$$L \geq \frac{(V_{IN(MAX)} - V_{OUT}) \times D_{(MIN)}}{\Delta I_L \times fs}$$

The higher inductance results in lower output ripple current and ripple voltage. But it requires larger physical size and price.

(5) Calculate the inductor peak current and choose a suitable inductor to prevent saturation.

$$I_{L(PEAK)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Coil inductors and surface mount inductors are all available. The surface mount inductors can reduce the board size but they are more expensive and its larger DC resistance results in more conduction loss. The power dissipation is due to the DC resistance can be calculated as below:

$$P_{D\_INDUCTOR} = I_{LOAD}^2 \times DCR$$

Rectifier Diode Selection

The rectifier diode provides a current path for the inductor current when the internal power MOSFET turns off. The best solution is Schottky diode, and some parameters about the diode must be take care as below:

(1) The forward current rating must be higher than the continuous output current.

(2) The reverse voltage rating must be higher than the maximum input voltage.

(3) The lower forward voltage will reduce the conduction loss.

(4) The faster reverse recovery time will reduce the switching loss, but it is very small compared to conduction loss.

(5) The power dissipation can be calculated by the forward voltage and output current for the time that the diode is conducting.

$$P_{D\_DIODE} = I_{LOAD} \times V_F \times (1 - D)$$

Output Capacitor Selection

The functions of the output capacitor are to store energy and maintain the output voltage. The low ESR (Equivalent Series Resistance) capacitors are preferred to reduce the output ripple voltage (V_{OUT}) and conduction loss. The output ripple voltage can be calculated as below:

$$\Delta V_{OUT} = \Delta I_L \times (ESR\_{COUT} + \frac{1}{8 \times fs \times C_{OUT}})$$

Choose suitable capacitors must define the expectative value of output ripple voltage first.

The ESR of the aluminum electrolytic or the tantalum capacitor is an important parameter to determine the output ripple voltage. But the manufacturers usually do not specify ESR in the specifications. Assuming the capacitance is enough results in the output ripple voltage that due to the capacitance can be ignored, the ESR should be limited to achieve the expectative output ripple voltage. The maximum ESR can be calculated as below:

$$ESR\_{COUT} \leq \frac{\Delta V_{OUT}}{\Delta I_L}$$

Choose the output capacitance by the average value of the RC product as below:

$$C_{OUT} \approx \frac{50 \sim 80 \times 10^{-6}}{ESR\_{COUT}}$$

If low ESR ceramic capacitor is used as output capacitor, the output ripple voltage due to the ESR can be ignored results in most of the output ripple voltage is due to the capacitance.

Therefore, the minimum output capacitance can be calculated as below:

$$C_{OUT(MIN)} \geq \frac{\Delta I_L}{8 \times fs \times \Delta V_{OUT}}$$

The prerequisites for using low ESR output ceramic capacitors are Duty Cycle > 0.275 and feed-forward capacitor must be used to stabilize the control loop.

The capacitors' ESR and ripple current result in power dissipation that will increase the internal temperature. Usually, the capacitors' manufacturers specify ripple current ratings and should not be exceeded to prevent excessive temperature shorten the life time. Choose a smaller inductor causes higher ripple current which maybe result in the capacitor overstress. The RMS ripple current flowing through the output capacitor and power dissipation can be calculated as below:

$$I_{RMS\_COUT} = \frac{\Delta I_L}{\sqrt{12}} = \Delta I_L \times 0.289$$

$$P_{D\_COUT} = (I_{RMS\_COUT})^2 \times ESR\_COUT$$

The capacitor's ESL (Equivalent Series Inductance) maybe causes ringing in the low MHz region.
Choose low ESL capacitors, limiting lead length of PCB and capacitor, and parallel connecting several smaller capacitors to replace with a larger one will reduce the ringing phenomenon.

Input Capacitor Selection

The input capacitor is required to supply current to the regulator and maintain the DC input voltage. Low ESR capacitors are preferred those provide the better performance and the less ripple voltage.

The input capacitors need an adequate RMS current rating. It can be calculated by following formula and should not be exceeded.

$$I_{RMS\_CIN} = I_{LOAD(MAX)} \times \sqrt{D \times (1 - D)}$$

This formula has a maximum at $V_{IN}=2V_{OUT}$. That is the worst case and the above formula can be simplified to:

$$I_{RMS\_CIN} = \frac{I_{LOAD(MAX)}}{2}$$

Therefore, choose a suitable capacitor at input whose ripple current rating must greater than half of the maximum load current.

The input ripple voltage (ΔV_{IN}) mainly depends on the input capacitor's ESR and its capacitance.
Assuming the input current of the regulator is constant, the required input capacitance for a given input ripple voltage can be calculated as below:

$$C_{IN} = \frac{I_{LOAD(MAX)} \times D \times (1 - D)}{f_S \times (\Delta V_{IN} - I_{LOAD(MAX)} \times ESR\__{CIN})}$$

If using aluminum electrolytic or tantalum input capacitors, parallel connecting 0.1uF bypass capacitor as close to the regulator as possible. If using ceramic capacitor, make sure the capacitance is enough to prevent the excessive input ripple current.

The power dissipation of input capacitor causes a small conduction loss can be calculated as below:

$$P_{D}\__{CIN} = (I_{RMS}\__{CIN})^2 \times ESR\__{CIN}$$

Layout Considerations

PC board layout is very important, especially for switching regulators of high frequencies and large peak currents. A good layout minimizes EMI on the feedback path and provides best efficiency. The following layout guides should be used to ensure proper operation of this device.

(1) The power charge path that consists of the IN trace, the SW trace, the external inductor and the GND trace should be kept wide and as short as possible.

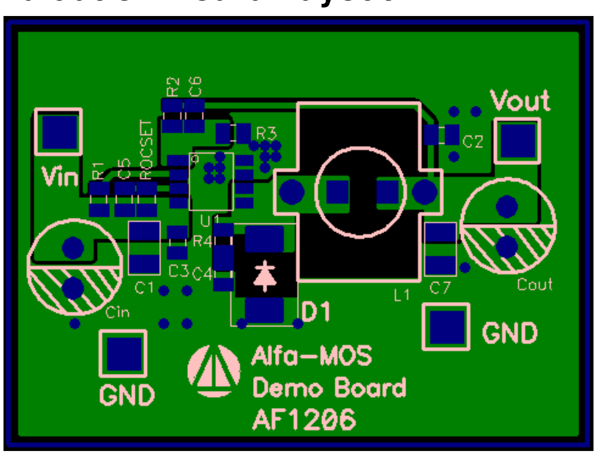
(2) The power discharge path that consists of the SW trace, the external inductor, the rectifier diode and the GND trace should be kept wide and as short as possible.

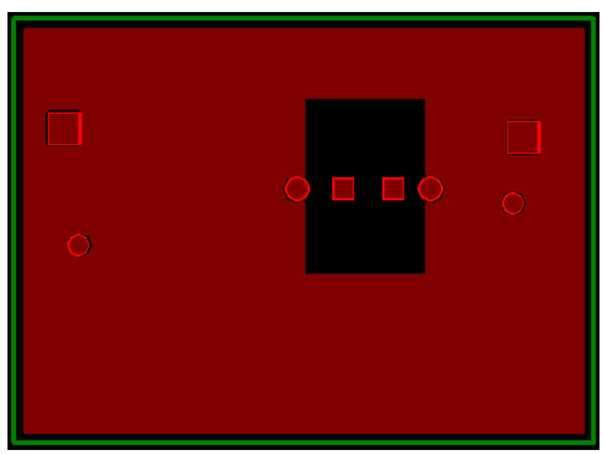
(3) The feedback path of voltage divider should be close to the FB pin and keep noisy traces away; also keep them separate using grounded copper.

(4) The input capacitors should be close to the regulator and rectifier diode.

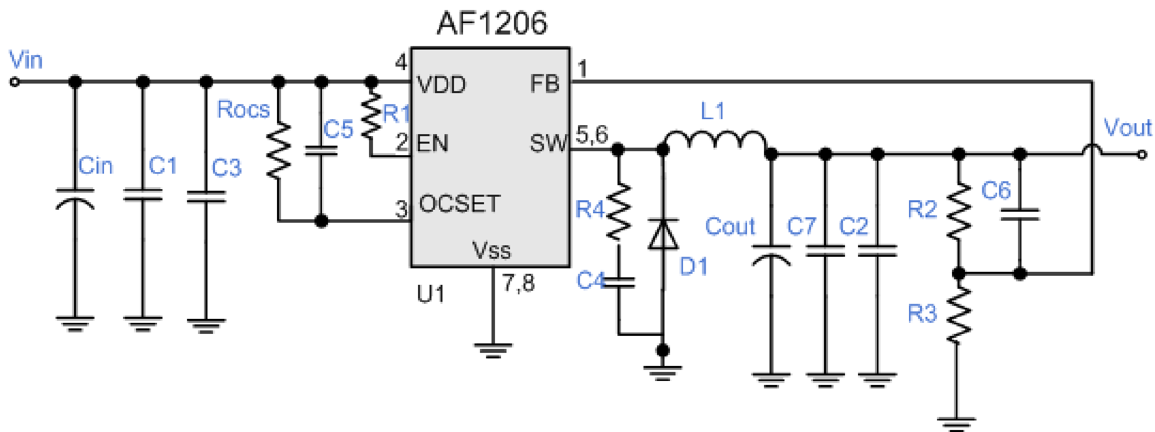
(5) The output capacitors should be close to the load.

Evaluation Board Layout





Evaluation Board Schematic



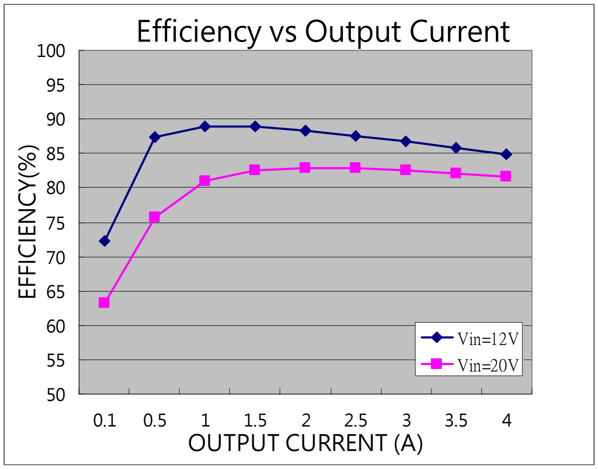
Bill of Materials

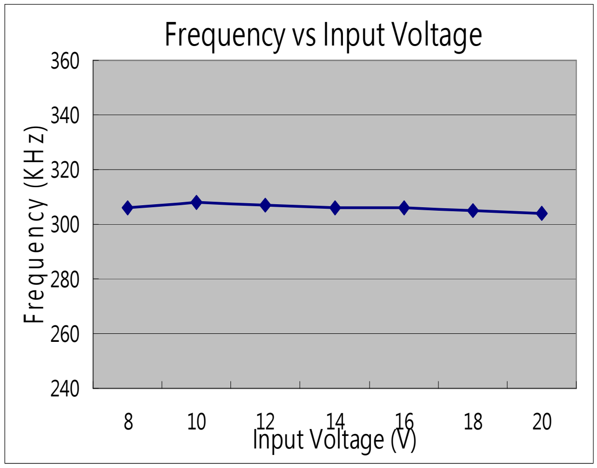
VIN=12V , V_{OUT}=5V, I_{OUT}=4A

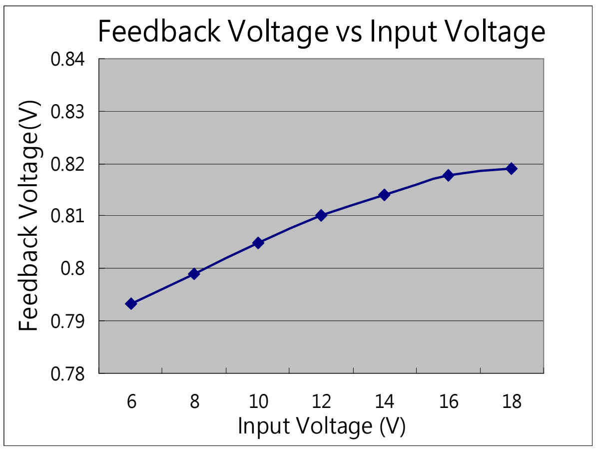
Item	Descriptions
U1	AF1206S8RG
Cin,Cout	Low ESR Electrolytic Cap. 330uF/25V
C1,C7	Chip Cap. 4.7uF/25V
C2,C3	Chip Cap. 1uF/25V
C4,C5	NC
C6	SMD Cap. 1nF/50V
R1	Chip Resistor 1kΩ 5%
R2	Chip Resistor 6.8kΩ 1%
R3	Chip Resistor 1.3kΩ 1%
R4	NC
Rocset	Chip Resistor 3.6kΩ 5%
L1	Choke 22uH, 5A
D1	Schottky Diode 40V/5A ;SMC package

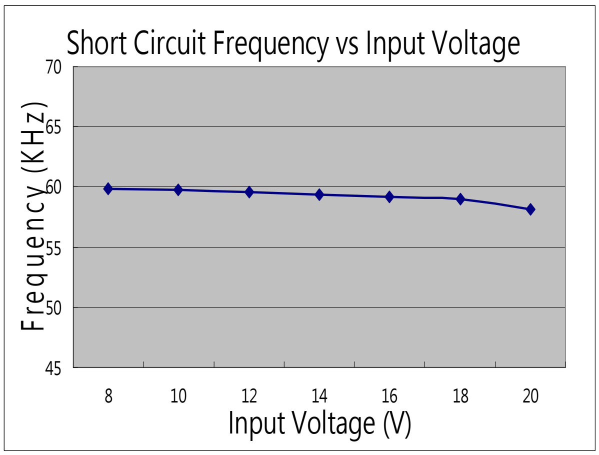
Typical Characteristics

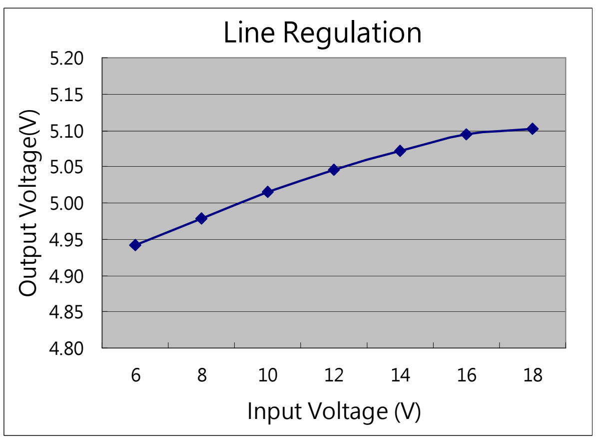
V_{IN}=12V , V_{OUT}=5V, Ta=25℃, Unless otherwise noted.

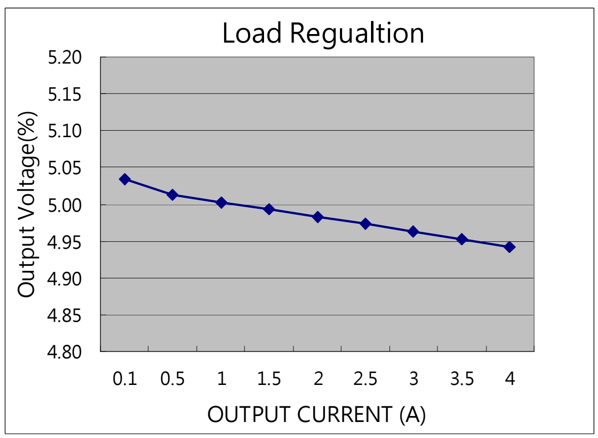








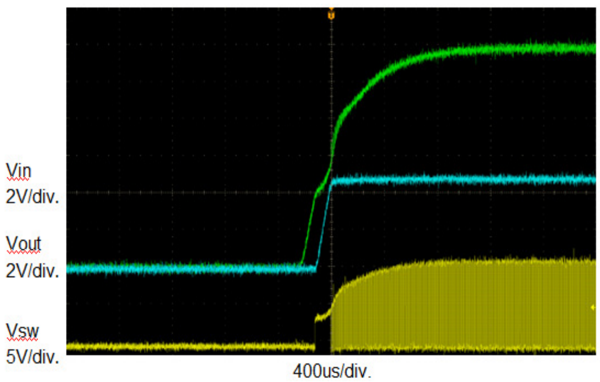




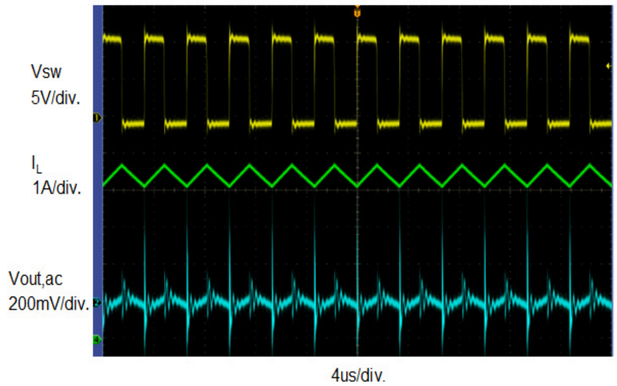
Typical Characteristics

V_{IN}=12V , V_{OUT}=5V, Ta=25℃, Unless otherwise noted.

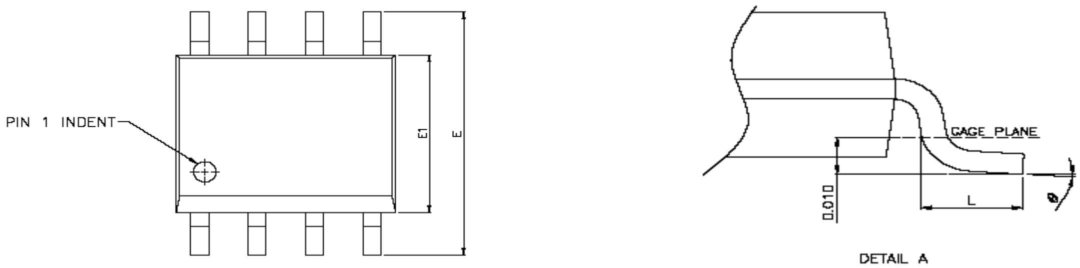
Power on test wave
(Vin=12V, V_{OUT}=5V,I_{OUT}=4A)

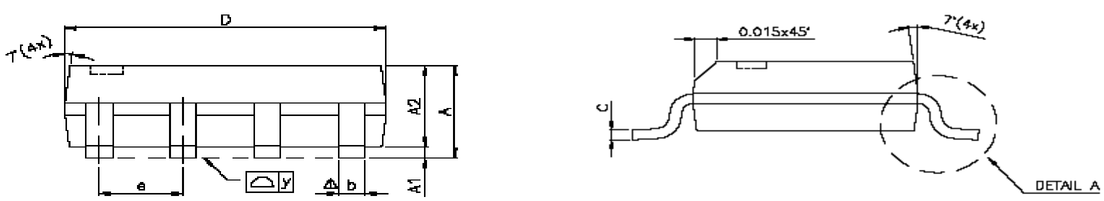


Output Voltage Ripple
(Vin=12V, V_{OUT}=5V,I_{OUT}=4A)



Package Information (SOP-8P)





SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.47	1.60	1.73	0.058	0.063	0.068
A1	0.10	——	0.25	0.004	——	0.010
A2	——	1.45	——	——	0.057	——
b	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.0098
D	4.80	4.85	4.95	0.189	0.191	0.195
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e	——	1.27	——	——	0.050	——
L	0.38	0.71	1.27	0.015	0.028	0.050
△2 y	——	——	0.076	——	——	0.003
θ	0°	——	8°	0°	——	8°

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