KP1510

PWM Control 3A Step-Down Converter

■ General Description

The KP1510 consists of step-down switching regulator with PWM control . This device include a reference source, oscillation circuit,error amplifier, internal P-channel DMOS and etc.

KP1510 provides low-ripple power, high efficiency, and excellent transient characteristics. The PWM control circuit is able to vary the duty ratio linearly from 0 up to 100%. This converter also contains an error amplifier as well as a soft-start circuit that prevent a overshoot at startup. An enable function, over current protect function and a short circuit protect function are built inside, when OCP or SCP happens, the operation frequency will be reduced from 300KHz to 30KHz. Also, an internal compensation block is built in to minimum external component count.

With the addition of internal P-channel DMOS, a coil, capacitors, and a schottky diode connected externally, this IC serve as ideal power supply unit for portable when coupled with the SOP-8L mini-package, providing such outstanding features as low current consumption. Since this converter can accommodate an input voltage up to 24V, It is also ideal when operating via an AC adapter.

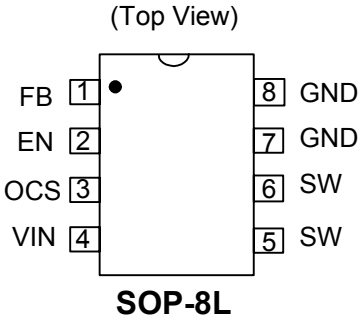
■ Features

- Input voltage:3.6V to 24V
- Adjustable output voltage range :0.8V to VCC
- Duty ratio:0% to 100% PWM control
- Oscillation frequency:320KHz typ.
- Soft-start, Current limit,Enable function
- Thermal Shutdown function
- Bulit-in internal 70mΩ P-channel DMOS
- Up to 95% Efficiency
- Output load current: 3A
- SOP-8L Pb-Free Package
- Low power standby mode

■ Applications

- Distributed Power Systems
- LCD Monitor
- DVD-Video Player
- Telecom Equipment
- ADSL Modem
- Printer and other Peripheral Equipment
- Battery Chargers
- Set-Top Boxes
- Cigarette Lighter Powered Devices

■ Pin Assignments



SOP-8L

■ Pin Descriptions

Pin#	Name	Description
1	FB	Feedback pin
2	EN	Power-off pin H: Normal operation L: Disable operation
3	OCS	Connects an external resistor to set maximum output current.
4	VIN	IC power supply pin.
5,6	SW	Switch Pin. Connect external inductor/schottky diode here.
7,8	GND	Ground Pin.

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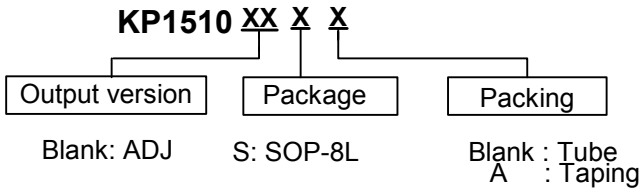
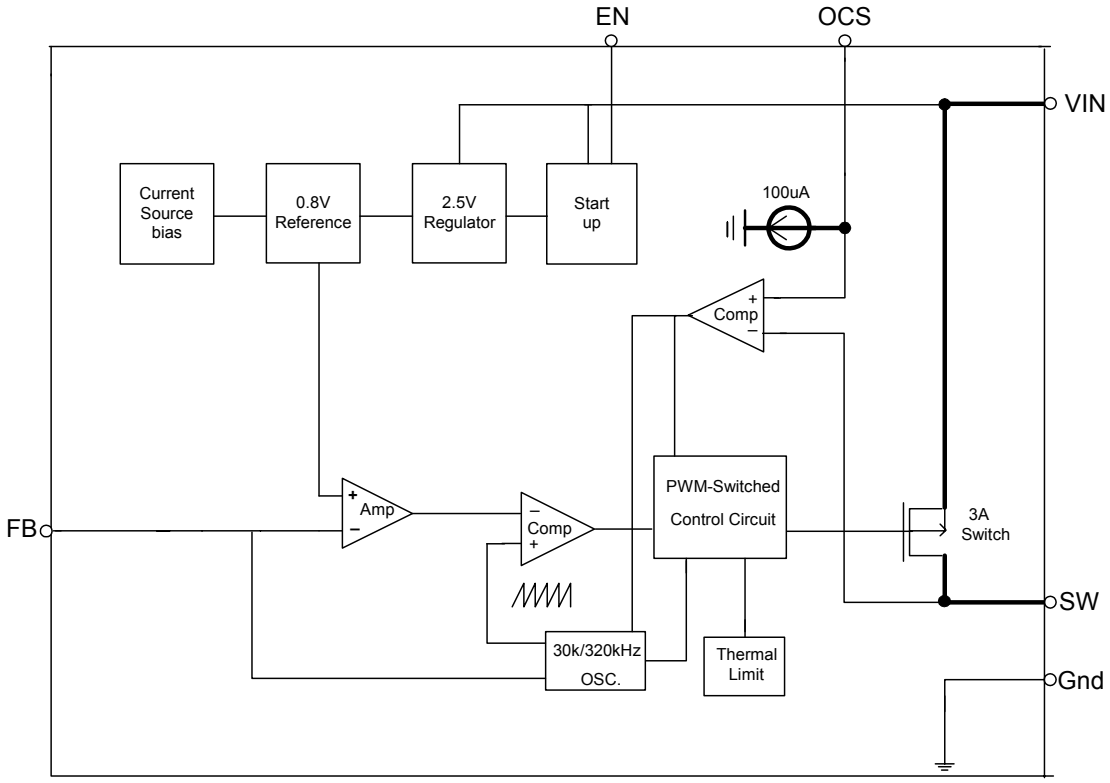
■ Order Information



■ Block Diagram



■ Absolute Maximum Ratings

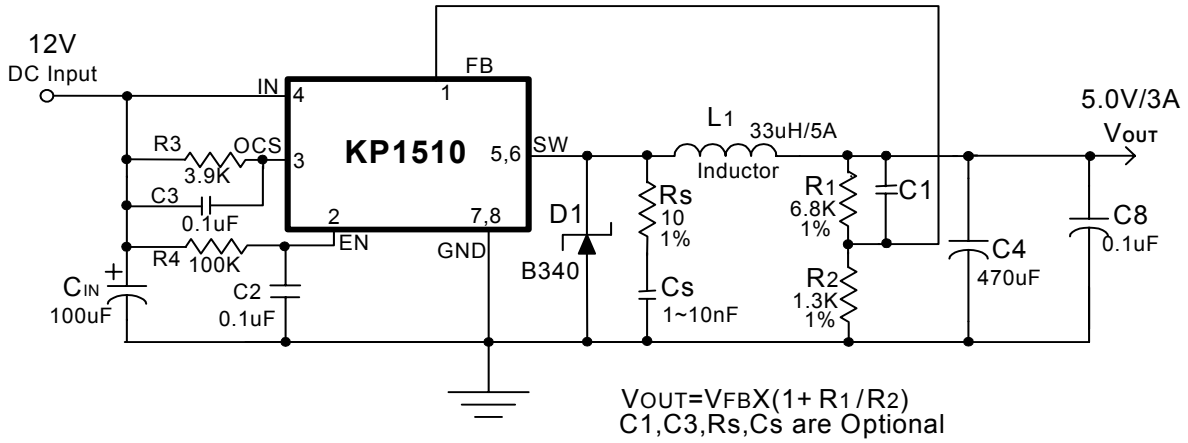
Symbol	Parameter	Rating	Unit
V_{CC}	Supply Voltage	+28	V
V_{EN}	Enable Pin input voltage	-0.3 to +VIN	V
V_{FB}	Feedback Pin voltage	-0.3 to +6	V
V_{OUT}	Output voltage to Ground	-1	V
P_D	Power dissipation	Internally limited	W
T_{ST}	Storage temperature	-65 to +150	°C
T_{OP}	Operating temperature	-20 to +125	°C
V_{OP}	Operating voltage	+3.6 to +24	V

■ Electrical Characteristics

Unless otherwise specified, V_{IN}=12V Ta=25 °C

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{FB}	Feedback Voltage		0.784	0.8	0.816	V
F_{OSC}	oscillator frequency after regulation	Measure waveform at SW pin	260	320	400	Khz
F_{OSC1}	Oscillator frequency of short circuit or current limit	Measure waveform at SW pin		30		Khz
V_{IN}	Input voltage		3.6		24	V
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	EN Pin High		20		uA
I_{SL}		EN Pin Low		-10		
I_{SW}	Switch Current	Rocs = 3.9KΩ, V_{IN}=12V	3.6	4.5	5.5	A
I_Q	Quiescent Current	V_{FB}=12 force driver off		5	10	mA
I_{STBY}	Standby Quiescent Current	V_{EN}=0V V_{IN} =12V		10		uA
$\triangle V_{OUT}/V_{OUT}$	Line regulation	V_{IN} =3.6V to 23V , I_{LOAD}=200mA		1	2	%
$\triangle V_{OUT}/V_{OUT}$	Load regulation	I_{LOAD}=100mA to 2A		0.2	0.5	%
I_{OCS}	OCS pin bias current		80	100	120	uA
T_{SS}	Soft-Start time		0.3	2	4	ms
R_{DSON}	Internal MOS R_{DSON}	V_{IN} =5V ,V_{FB}=0V		100	150	mΩ
		V_{IN} =12V , V_{FB}=0V		70	100	
EFFI	Efficiency	V_{IN}=12V V_{OUT}=5V I_{OUT}=2A		92		%
Ts	Over temperature shutdown threshold	Tj increasing (Measured from GND pin)		150		°C
		Tj decreasing (Measured from GND pin)		100		

■ Application Circuit



VCC=12V , IMAX=2A , ILIMIT=3.0A				VCC=12V , IMAX=3A, ILIMIT=4.0A			
VOUT	2.5V	3.3V	5V	VOUT	2.5V	3.3V	5V
L1	15uH	18uH	22uH	L1	22uH	27uH	33uH
R2/ R1	2.2K/4.7K	1.5K/4.7K	1.3K/6.8K	R1/ R2	2.2K/4.7K	1.5K/4.7K	1.3K/6.8K
Rocs	3.3K			Rocs	4.3K		

■ Detailed Description

The KP1510 is a voltage-mode step down regulator with integrated high side PMOS switch , It operates from 3.6V to 24V input range and supplies up to 3A of Load current. The duty cycle can be adjusted from 0% to 100% allowing a wide range of output range. Features include enable control,fixed internal soft-start, adjustable current limit, thermal shutdown, short circuit protection.

The KP1510 is available in SO-8L package.

Enable and Soft Start

The KP1510 include internal soft start feature to limit inrush current and ensure the output voltage ramp up smoothly to regulation voltage. A soft start function could be enhanced by external capacitor C3 when higher current limit is selected . The output voltage is ramped to regulation voltage more slowly because C3 and R3 create an RC time constant forcing current limit to activate at lower current at start-up.

The EN pin of the KP1510 is active high. Connect the EN pin to VIN if enable function is not used. Connect it to ground will disable the KP1510. Open the EN pin is inhibited.

Steady-State Operation

Under steady-state condition, the converter operates in fixed frequency and Continuous-Conduction Mode(CCM).

The KP1510 integrates an internal P-MOSFET as the high-side switch. Inductor current is sensed by the voltage drop across the drain to source of the high side power MOSFET. The output voltage is divided down by external voltage divider at FB pin. The difference of the FB pin voltage and constant voltage

reference is amplified by the error amplifier and internal compensation network to produce a error voltage. Then, the error voltage is compared against the ramp oscillator voltage, if the ramp voltage is less than error voltage, the internal high side switch is on. The inductor current flows from the input through the inductor to the output. When the ramp voltage exceeds the error voltage, The high side switch is off. The inductor current is freewheeling through the external Schottky diode to output.

The KP1510 uses a P-Channel MOSFET as the high switch. It saves the bootstrap capacitor normally seen in a circuit which is using an NMOS switch.

Switching Frequency

The KP1510 switching frequency is fixed after regulation, The typical value of frequency is 320KHz. When Current limit or the short circuit protection is triggered and the frequency equals to 1/12 of normal switching frequency. The inductor average current is greatly reduced because of the lower frequency.

Output Voltage Programming

Output voltage can be set by feeding back the output to the FB pin with a resistor divider network. In the application circuit, The resistor divider network include R_1 and R_2. Usually, a design is started by picking a fixed R_2 value and calculating the required R_1 with equation below.

$$V_O = 0.8 \times (R_1 + R_2) / R_2$$

Some standard value of R_1 and R_2 for most commonly used output voltage are listed below.

Vo (V)	R_1 (KΩ)	R_2 (KΩ)	L_1 Minumum
0.8V	0	open	8.2uH
1.0V	1.0	4	8.2uH
1.2V	1.5	3	10uH
1.5V	2.0	2.2	10uH
1.8V	2.5	2	15uH
2.5V	4.7	2.2	15uH
3.3V	4.7	1.5	18uH
5.0V	6.8	1.3	22uH

Since the switch duty cycle can be as high as 100%, the maximum output voltage can be set as high as the input voltage minus the voltage drop on upper PMOS and inductor.

Protection Features

The KP1510 has multiple protection features to prevent system circuit damage under abnormal conditions.

Over Current Protection (OCP)

Over current protection is implemented by sensing the voltage drop across the drain to source of the high side power MOSFET. The $R_{DS}ON$ of power MOSFET is between 60mΩ and 80 mΩ depending on input voltage and junction temperature. The drain to source voltage is then compared to a voltage level representing the over current threshold limit. The current limit threshold is set by external resistor connected between OCS pin and VIN. The stable current flow from VIN through resistor into OCS pin is about 100uA. When the load current reach the current limit threshold, the cycle by cycle current limit circuit turn off the high side switch immediately to terminate the current duty cycle. The inductor current stop rising. When cycle by cycle current limit circuit is triggered, the output voltage drops as the duty cycle decreasing and the frequency reduces to 1/12 of normal switching frequency.

Short Circuit Protection (SCP)

The KP1510 has internal short circuit protection to protect itself from catastrophic failure under output short circuit condition. The FB pin voltage is proportional to the output voltage. Whenever the short circuit protection circuit is triggered. As a result, the frequency drop to 1/12 of normal switching frequency. In short circuit protection mode, the inductor is greatly reduced.

Thermal Protection (OCP)

The internal temperature sensor monitors the junction temperature. It shut down the internal control circuit and high side PMOS if the junction temperature exceeds 150 °C. The regulator will restart automatically under the control of soft-start circuit when junction temperature decreases to 100 °C.

Under Voltage Lockout (UVLO)

The under voltage lockout circuit of the KP1510 assures that the high-side MOSFET driver outputs remain in the off state whenever the supply voltage drops below 3.3V. Normal operation resumes once VIN rises above 3.5V.

$R_{DS(ON)}$ Current Limiting

The current limit threshold is setting by the external resistor connecting from VIN supply to OCS pin. The internal 100uA sink current crossing the external resistor sets the voltage at the OCS pin. The power loss of the external resistor is less than the power loss of MOSFET, an over-current condition is triggered.

$$I_{LOAD} \times R_{DS(ON)} = I_{OCS} \times R_{OCS}$$

See above formula for setting the current limit value.

Inductor Selection

For most designs, that operates with inductor of 15uH to 33uH. The inductor value can be derived from the following equation.

$$\Delta I_L = \frac{V_O}{f \times L} \times (1 - \frac{V_O}{V_{IN}})$$

The peak inductor current is:

$$I_{Lpeak} = I_0 + \frac{\Delta I_L}{2}$$

High inductance give low inductor ripple current. Choose inductor ripple current approximately 15%of the maximum load current 3A, ΔI_L=0.4A , The DC current rating of the inductor should be at least equal to current limit plus half the ripple current to prevent core saturation (3A+0.2A).

Output capacitor Selection

The output capacitor must have a higher rated voltage specification than the maximum desired output voltage including ripple. De-rating needs to be considered for long term reliability.

Output ripple voltage specification is another important factor for selecting the output capacitor. In a buck converter circuit, output ripple voltage is determined by inductor value , switching frequency ,output capacitor value and ESR. It can be calculated by the equation below:

$$\Delta V_0 = \Delta I_L \times (ESR_{CO} + \frac{1}{8 \times f \times C_O})$$

where Co is the output capacitor value and ESRco is the Equivalent Series Resistor of output capacitor.

When low ESR ceramic capacitor is used as output capacitor, the impedance of the capacitor at the switching frequency dominates. Output ripple is mainly caused by capacitor value and inductor ripple current. The output ripple voltage calculation can be simplified to:

$$\Delta V_O = \Delta I_L \times \frac{1}{8 \times f \times C_O}$$

If the impedance of ESR at switching frequency dominates, the output ripple voltage is mainly decided by capacitor ESR and inductor ripple current. The output ripple voltage calculation can be further simplified to:

$$\Delta V_O = \Delta I_L \times ESR_{CO}$$

For lower output ripple voltage across the entire operating temperature range , X5R or X7R dielectric type of ceramic , or other low ESR tantalum are recommended to be used as output capacitor.

An aluminum electrolytic capacitor's ESR value is related to the capacitance and its voltage rating. In most case , higher voltage electrolytic capacitors have lower ESR values. Most of time, capacitors with much higher voltage ratings may be needed to provide the low ESR values required for low output ripple voltage. It is recommended to replace this low ESR capacitor by using a 470u low ESR values<50 mΩ.

Thermal management and PCB layout Consideration
The thermal performance of the KP1510 is strongly affected by the PCB layout. The size of the heatsink depends on the input voltage, the output voltage, the load current and the ambient temperature.

In the KP1510 buck regulator circuit, the major power dissipating component are the KP1510,The Schottky diode and output inductor. The total power dissipation of converter circuit can be measured by input power minus output power.

$$P_{total\_loss} = V_{IN} * I_{IN} – V_O * I_O$$

The power dissipation in Schottky diode can be approximated as: (D: PWM Duty cycle)

$$P_{diode\_loss} = I_O * (1 – D) * V_{FW\_Schottky}$$

The power dissipation of inductor can be approximated as:

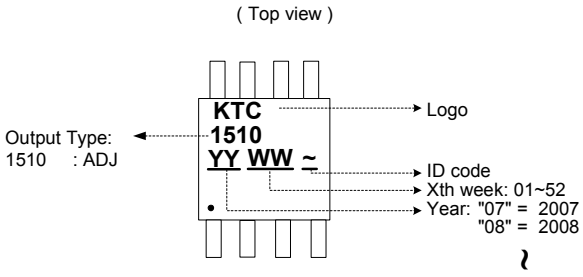
$$P_{inductor\_loss} = I_O^2 * R_{inductor}$$

The actual junction temperature can be calculated with power dissipation in the KP1510 and thermal impedence from junction to ambient. (Θ_{JA} = 65 °C / W)

$$T_{junction} = (P_{total\_loss} – P_{diode\_loss} – P_{inductor\_loss}) * \Theta_{JA}$$

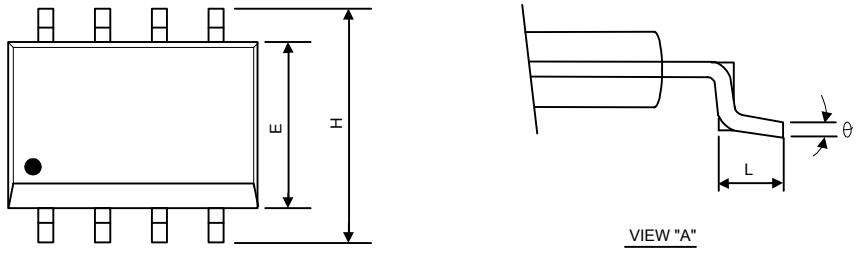
The maximum junction temperature of KP1510 is 150 °C, which limits the maximum load current capability.
The two SW pin are connected to internal MOSFET drain. They are low resistance thermal conductor path and most noisy switching node. Connected a copper plane to SW pin to help thermal dissipation. The copper plane should not be too larger otherwise switching noise may be coupled to other part of circuit in PCB.

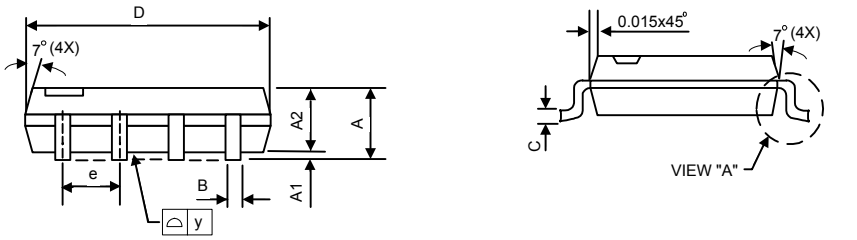
■ Marking Information



■ Package Information

Package Type: SOP-8L





Symbol	Dimensions In Millimeters			Dimensions In Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	1.40	1.60	1.75	0.055	0.063	0.069
A1	0.10	–	0.25	0.040	–	0.100
A2	1.30	1.45	1.50	0.051	0.057	0.059
B	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.010
D	4.80	4.85	5.05	0.189	0.191	0.199
E	3.80	3.91	4.00	0.150	0.154	0.157
e	–	1.27	–	–	0.050	–
H	5.79	5.99	6.20	0.228	0.236	0.244
L	0.38	0.71	1.27	0.015	0.028	0.050
y	–	–	0.10	–	–	0.004
θ	0^O	–	8^O	0^O	–	8^O