TAIWAN SEMICONDUCTOR

TS2509
3A / 500KHz PWM Buck Converter

SOP-8

Pin Definition:
1. FB   8. Vss
2. EN   7. Vss
3. Comp   6. SW
4. Vcc   5. SW

General Description

TS2509 consists of step-down switching regulator with PWM control. These devise include a reference voltage source, oscillation circuit, error amplifier, internal PMOS and etc. TS2509 provides low-ripple power, high efficiency, and excellent transient characteristics. The PWM control circuit is able to the duty ratio linearly form 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 short circuit protect function are built inside, and when OCP or SCP happens, the operation frequency will be reduced. 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-8L 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: 3.6V~23V
- Output Voltage: 0.8V~Vcc
- Duty Ratio: 0%~100% PWM Control
- Oscillation Frequency: 500kHz typ.
- Soft-Start (SS), Current Limit (CL), Enable Function
- Thermal Shutdown Function
- Short Circuit Protect (SCP)
- External SW P-Channel MOSFET
- Low ESR output capacitor (MLCC application)

Ordering Information

Part No.	Package	Packing
TS2509CS RL	SOP-8	2.5Kpcs / 13" Reel

Application

- Simple High-efficiency Step down Regulator
- On-Card Switching Regulators

## Absolute Maximum Rating

Parameter	Symbol	Rating	Unit
VCC Pin Voltage	V_{CC}	V_{SS} - 0.3 to V_{SS} + 25	V
Feedback Pin Voltage	V_{FB}	V_{SS} - 0.3 to V_{CC}	V
ON/OFF Pin Voltage	V_{EN}	V_{SS} - 0.3 to V_{CC} + 0.3	V
Switch Pin Voltage	V_{SW}	V_{SS} - 0.3 to V_{CC} + 0.3	V
Power Dissipation	P_D	Internally limited	mW
Storage Temperature Range	$T_{ST G}$	-40 to +150	°C
Operating Temperature Range	T_{OP}	-20 to +125	°C
Operating Supply Voltage	V_{OP}	+3.6 to +23	V
Thermal Resistance from Junction to case	θ_{JC}	40	°C/W
Thermal Resistance from Junction to ambient	θ_{JA}	70	°C/W

Electrical Specifications (V$_{IN}$=12V, Ta=25°C unless otherwise noted)

Characteristics	Symbol	Conditions		Min	Typ	Max	Units
Feedback Voltage	V$_{FB}$	I$_{OUT}$ =0.1A		0.784	0.800	0.816	V
Quiescent Current	I$_q$	V$_{FB}$ =1.2V force driver off		--	3	5	mA
Feedback Bias Current	I$_{FB}$	I$_{OUT}$ =0.1A		--	0.1	0.5	uA
Shutdown Supply Current	I$_{SD}$	V$_{EN}$ =0V		--	2	10	uA
Current limit	I$_{SW}$			4	--	--	A
Line Regulation	ΔV$_{OUT}$/V$_{OUT}$	V$_{CC}$ = 5V~23V, I$_{OUT}$ =0.2A		--	0.6	1.2	%
Load Regulation	ΔV$_{OUT}$/V$_{OUT}$	I$_{OUT}$ = 0.1 to 3A		--	0.2	0.4	%
Oscillation Frequency	F$_{OSC}$	SW pin		400	500	600	KHz
EN Pin Logic input threshold voltage	V$_{SH}$	High (regulator ON)		2.0	--	--	V
	V$_{SL}$	Low (regulator OFF)		--	--	0.8	
EN Pin Input Current	I$_{SH}$	V$_{EN}$ =2.5V (ON)		--	20	--	uA
	I$_{SL}$	V$_{EN}$ =0.3V (OFF)		--	-10	--	uA
Soft-Start Time	T$_{SS}$			0.3	4	8	ms
Internal MOSFET	R$_{DSON}$	V$_{CC}$ = 5V, V$_{FB}$ =0V		--	90	140	mΩ
		V$_{CC}$ = 12V, V$_{FB}$ =0V		--	60	90	
Efficiency	E$_{FFI}$	V$_{OUT}$ = 5V	I$_{OUT}$ = 2A	--	91	--	%
			I$_{OUT}$ = 3A	--	90	--	
Thermal Shutdown Temp.	T$_{SD}$			--	125	--	℃

Block Diagram
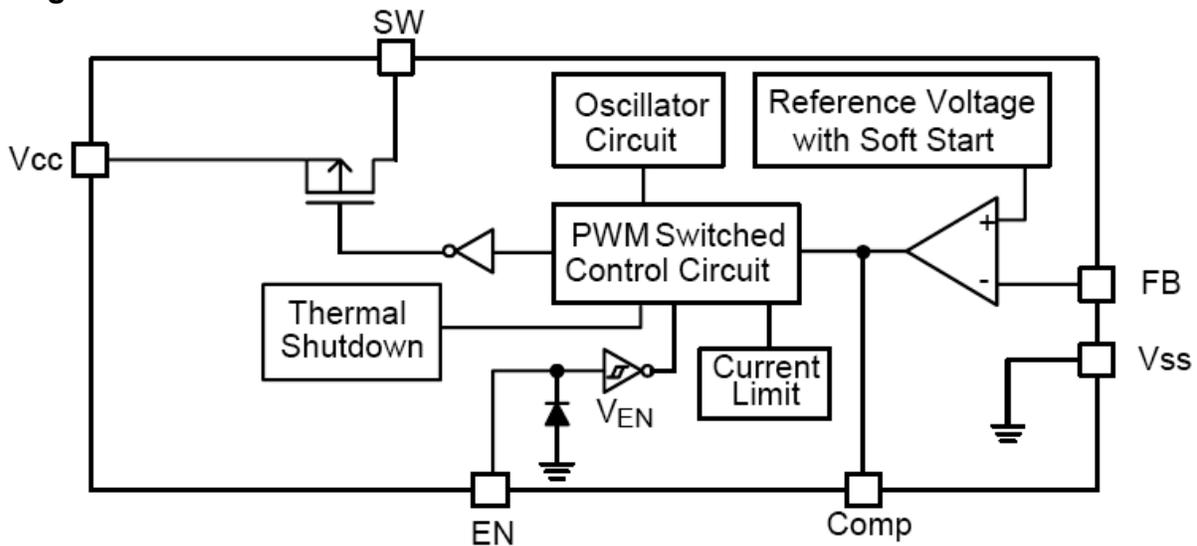
Pin Assignment

| Name	Description
FB	Feedback pin
EN	H: Normal operation (Step-down) L: Step-down operation stopped (All circuit deactivated)
Comp	Compensation pin
SW	Switch pin. Connect external inductor/diode here
Vcc	IC power supply pin
Vss	Gnd pin

Application Circuit

MLCC
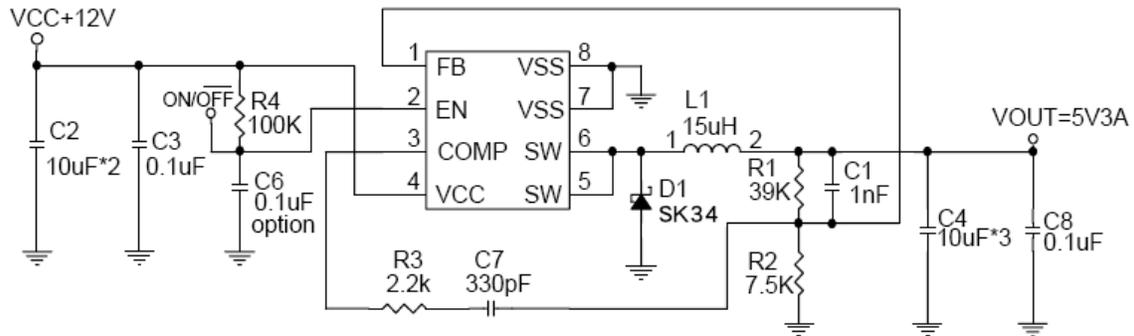
$$VOUT = VFB \times \left(1 + \frac{R1}{R2}\right)$$

$VFB = 0.8V$; R1 suggest 10K ~ 50K

Compensation Capacitor Selection (MLCC)					
VIN	**VOUT**	**L1**	**R3**	**C7**	**C1**
7~23V	5.0/3.3/2.5V	15uH	2.2K	330pF	1nF
7~20V	1.8/1.5V	10uH	2K	330pF	1nF
9~20V	1.2V	10uH	2K	330pF	820pF
9~18V	1.1V	10uH	2K	560pF	820pF
9~18V	1.0V	10uH	2K	560pF	680pF
4~10V	3.3/2.5V	15uH	6.8K	330pF	1nF
4~10V	1.8/1.5/1.2/ 1.1/1.0V	10uH	4.7K	330pF	1nF

EL CAP
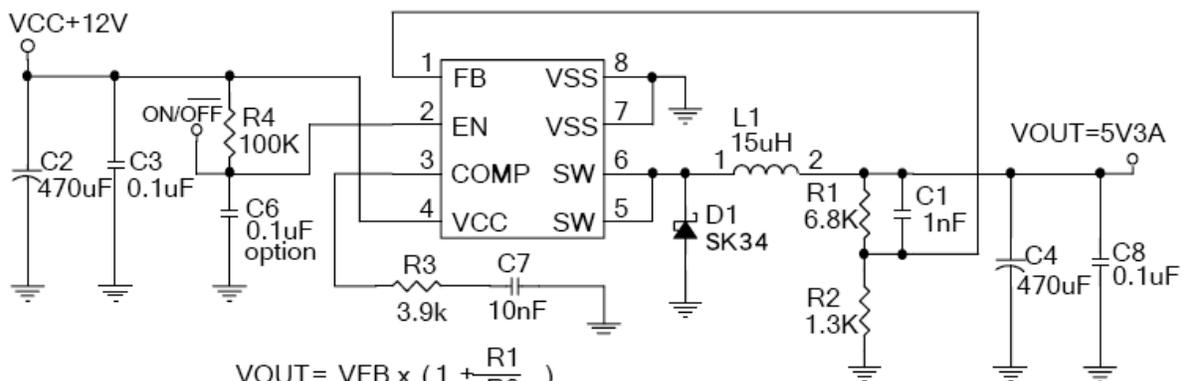
$$VOUT = VFB \times \left(1 + \frac{R1}{R2}\right)$$

$VFB = 0.8V$; R2 suggest 0.8K ~ 6.0K

Compensation Capacitor Selection (EL CAP)					
VIN	**VOUT**	**L1**	**R3**	**C7**	**C1**
7-20V	5.0/3.3/2.5/1.8V	Coil	3.9K	10nF	1nF
7-20V	1.8/1.5V	Coil	2K	10nF	1nF
5-7V	3.3/2.5/1.8/1.5/1.2V	Coil	2K	10nF	1nF
5-20V	3.3/2.5/1.8/1.5/1.2V	SMD	0.82K	10nF	1nF

Function Descriptions

PWM Control

The TS2509 consists of DC/DC converters that employ a pulse-width modulation (PWM) system. In converters of the TS2509, 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.

Setting the Output Voltage

Application circuit item shows the basic application circuit with TS2509 adjustable output version. The external resistor sets the output voltage according to the following equation:

$$VOUT = 0.8V \times \left(1 + \frac{R1}{R2}\right)$$

(EL CAP) Resistor select for output voltage setting

V_{OUT}	R2	R1
5V	1.3K	6.8K
3.3V	1.5K	4.7K
2.5V	2.2K	4.7K
1.8V	2K	2.5K
1.5V	2.2K	2K
1.2V	3K	1.5K
1V	10K	2.5K

(MLCC) Resistor select for output voltage setting

V_{OUT}	R2	R1
5V	7.5K	39K
3.3V	15K	47K
2.5V	22K	47K
1.8V	27K	33K
1.5V	30K	27K
1.2V	30K	15K
1V	56K	13K

Inductor Selection

For most designs, the operate with inductors of 10µH to 22µH. The inductor value can be derived from the following equation:

$$L = \frac{VOUT \times (VIN - VOUT)}{VIN \times \Delta IL \times Fosc}$$

L1 Recommend Value (V_{IN}=12V, I_{OUT}=3A)				
V_{OUT}	1.8V	2.5V	3.3V	5V
L1 Value	10~15uH	10~15uH	15~22uH	15~22uH

Where is inductor Ripple Current. Large value inductors lower ripple current and small value inductors result in high ripple currents. Choose inductor ripple current approximately 15% of the maximum load current 3A, ΔIL=0.4A. 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 (3A+0.2A).

Input Capacitor Selection
(EL CAP)

This capacitor should be located close to the IC using short leads and the voltage rating should be approximately 1.5 times the maximum input voltage. The RMS current rating requirement for the input capacitor of a buck regulator is approximately 1⁄2 the DC load current. A low ESR input capacitor sized for maximum RMS current must be used. A 220µF low ESR capacitor for most applications is sufficient.

(MLCC)

A 22µF MLCC or two 10uF MLCC capacitors for most applications is sufficient.

Function Descriptions (Continue)

Output Capacitor Selection
(EL CAP)

The output capacitor is required to filter the output and provide regulator loop stability. The important capacitor parameters are; the 100KHz Equivalent Series Resistance (ESR), the RMS ripples current rating, voltage rating, and capacitance value. For the output capacitor, the ESR value is the most important parameter. The ESR can be calculated from the following formula.

$$V_{RIPPLE} = \Delta I_L \times ESR = 0.4A \times 110m\Omega = 44mV$$

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 the 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 330µF low ESR values < 110mΩ

(MLCC)

A 33µF MLCC or three 10uF MLCC capacitors for most applications is sufficient.

$R_{DS(ON)}$ Current Limiting

The current limit threshold is setting by the internal circuit.

V_{IN}	4.6V~6V	6V~10V	10V~23V
$I_{CL(MIN)}$	3A	3.8A	4.0A
$I_{OUT(MAX)}$	2.5A	3A	3A

Layout Guidance

When laying out the PC board, the following suggestions should be taken to ensure proper operation of the TS2509. These items are also illustrated graphically in below.

1. The power traces, including the PMOS Drain & Source trace, the Schottky and the C2 trace should be kept short, direct and wide to allow large current flow.
2. Connect the C5 to the V_{CC} & EN pins of the TS2509 as closely as possible to get good power filter effect.
3. Keep the switching node, away from the sensitive FB node.
4. Connect ground side of the C2 & D1 as closely as possible.
5. Connect PMOS Source and R3 as closely as possible.
6. Do not trace signal line under inductor.

Bypass C3 need closely from IC's Vcc

Signal ground must far way the power ground.

The heat sink copper of PCB area should be solder-painted without masked.

TAIWAN SEMICONDUCTOR

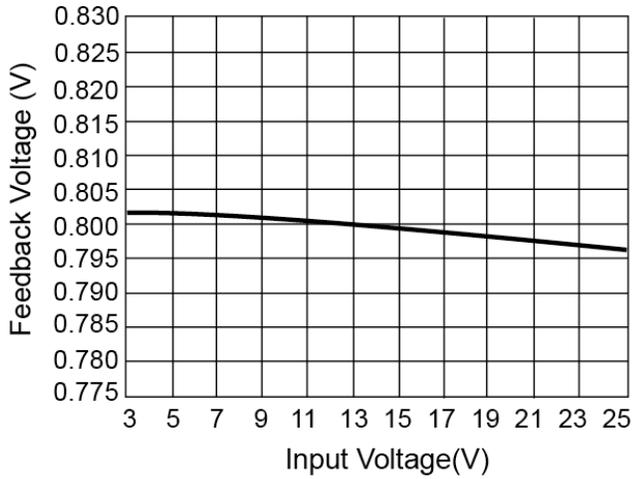**RoHS COMPLIANCE**
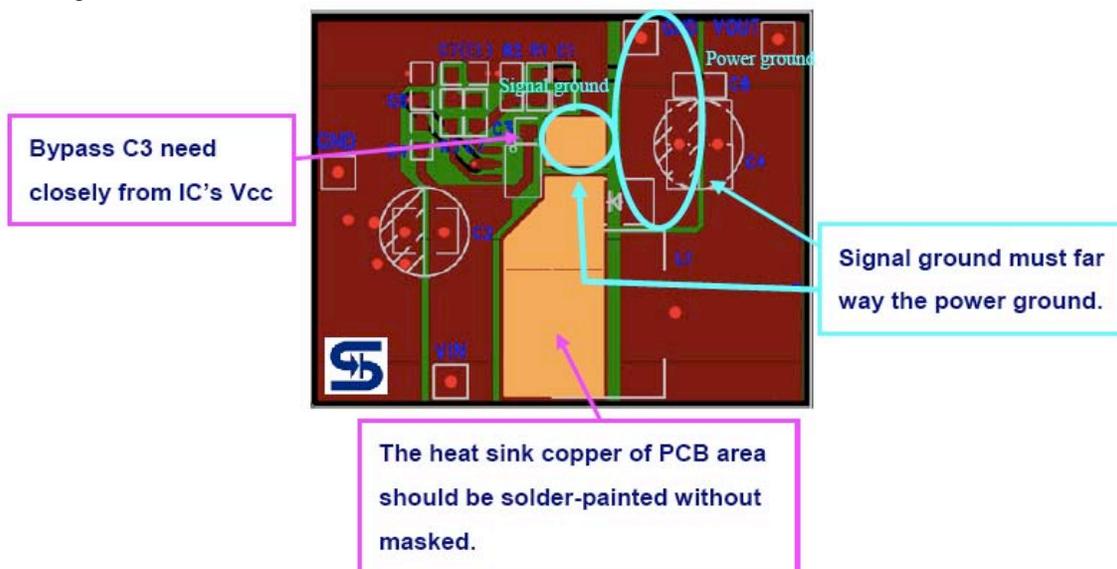
Electrical Characteristics Curve
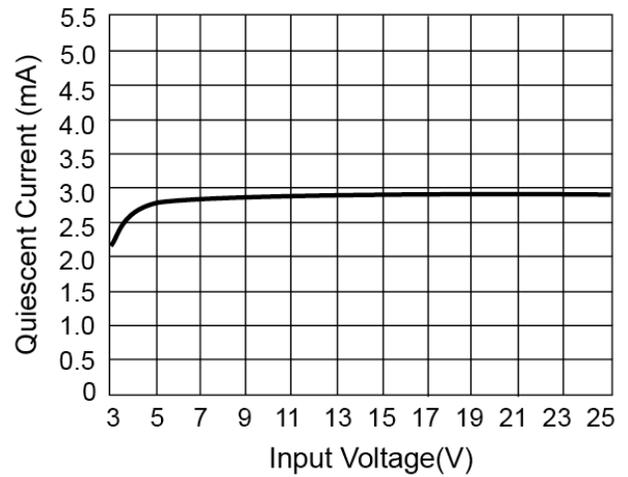
Figure 1. Feedback Voltage vs. Input Voltage
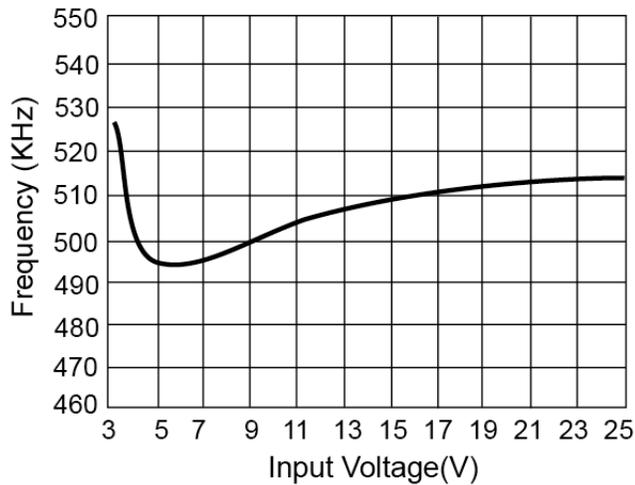
Figure 2.Quiescent Current vs. Input Voltage
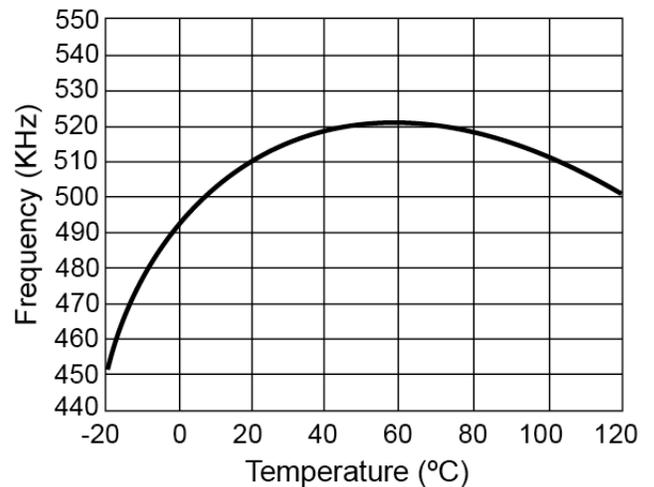
Figure 3. Frequency vs. Input Voltage

Figure 4. Frequency vs. Temperature

Figure 5. Feedback Voltage vs. Temperature
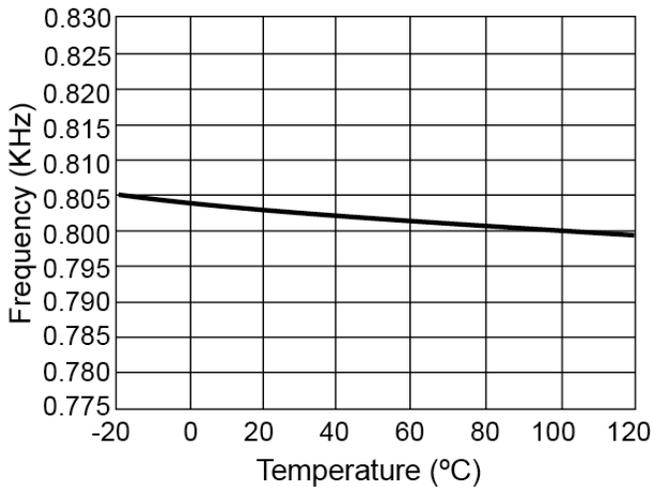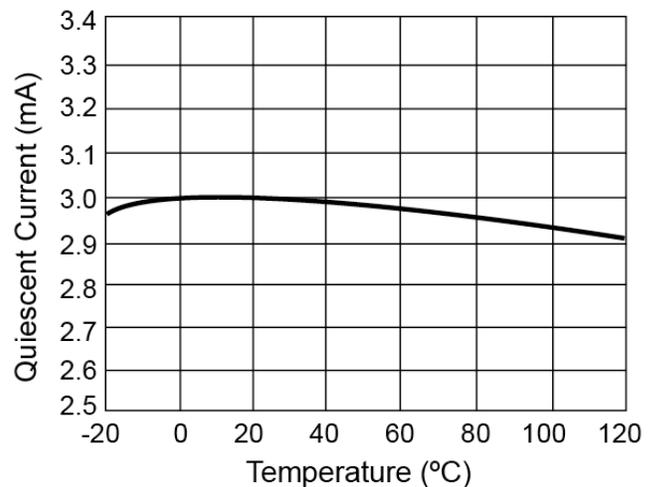
Figure 6. Quiescent Current vs. Temperature
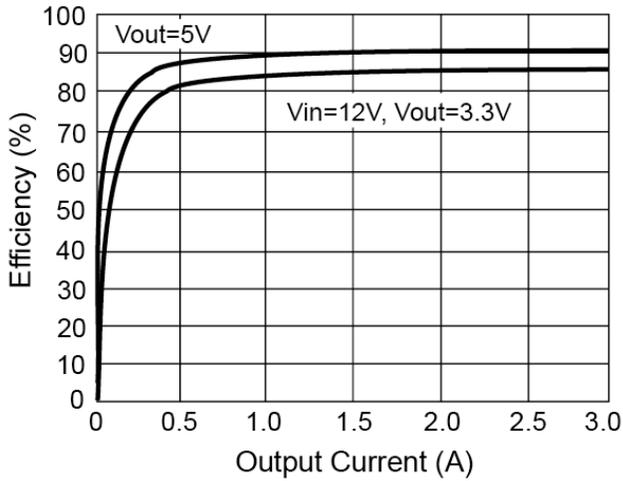
Version: A09

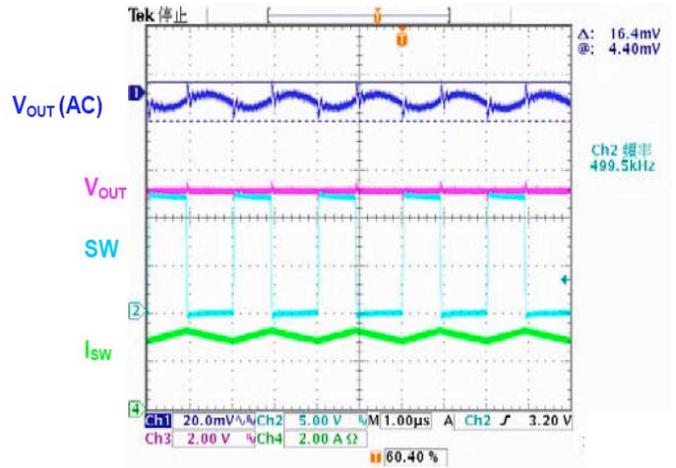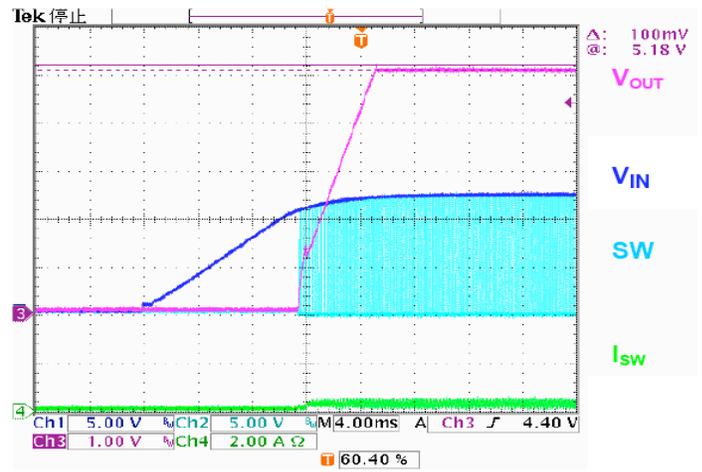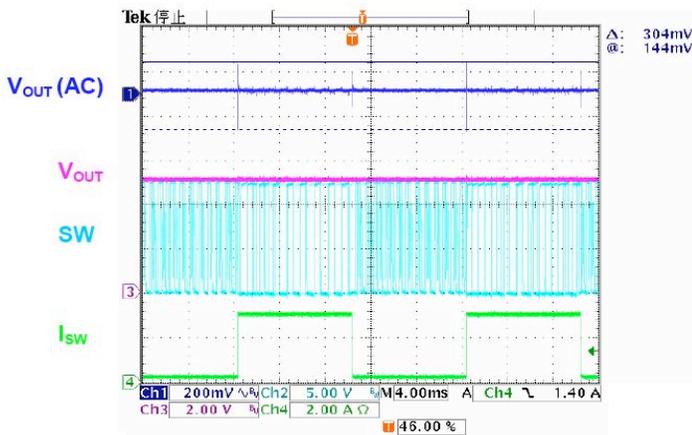## Electrical Characteristics Curve

Figure 7. Efficiency

Figure 8.Output Ripple (V$_{IN}$=12V, V$_{OUT}$=5V, I$_{OUT}$=3A)
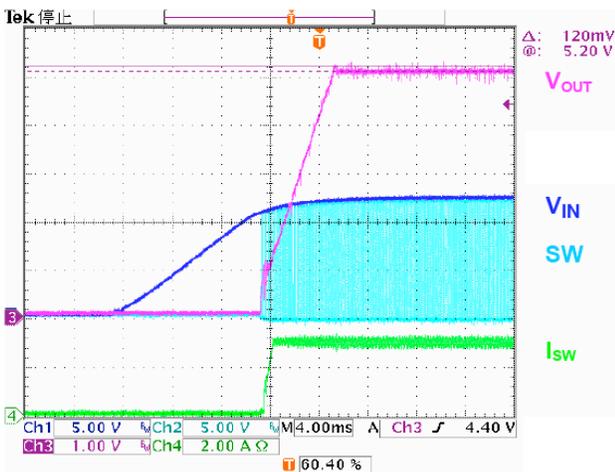
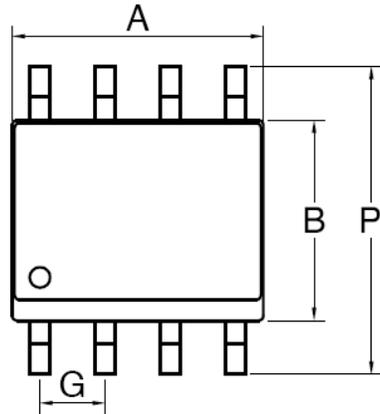(V$_{IN}$=12V, V$_{OUT}$=5V, I$_{OUT}$=3A)
Figure 9.Power On test Wave

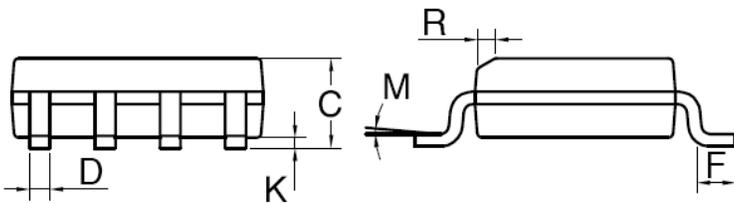(V$_{IN}$=12V, V$_{OUT}$=5V, I$_{OUT}$=0.2A)
Figure 10.Power On test Wave

(V$_{IN}$=12V, V$_{OUT}$=5V, I$_{OUT}$=0.1~3A)
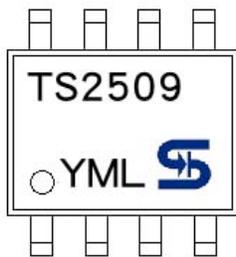**Figure 11. Load Transient Response**

SOP-8 Mechanical Drawing

SOP-8 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX.
A	4.80	5.00	0.189	0.196
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27BSC		0.05BSC	
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

Marking Diagram

Y = Year Code

M = Month Code
   (**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep,
   J=Oct, **K**=Nov, **L**=Dec)

L = Lot Code

Notice

Specifications of the products displayed herein are subject to change without notice. TSC or anyone on its behalf, assumes no responsibility or liability for any errors or inaccuracies.

Information contained herein is intended to provide a product description only. No license, express or implied, to any intellectual property rights is granted by this document. Except as provided in TSC's terms and conditions of sale for such products, TSC assumes no liability whatsoever, and disclaims any express or implied warranty, relating to sale and/or use of TSC products including liability or warranties relating to fitness for a particular purpose, merchantability, or infringement of any patent, copyright, or other intellectual property right.

The products shown herein are not designed for use in medical, life-saving, or life-sustaining applications. Customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify TSC for any damages resulting from such improper use or sale.