



### Features

- Wide Input Voltage from 9V to 40V
- Up to 3A Output Current
- High Efficiency Up to 93%
- CC/CV control
- Internal Soft-Start
- Auto Recovery after Faults
- Output Load Voltage Drop Compensation
- Programmable Over Current Setting
- Over-Temperature Protection
- Thermal Enhanced ESOP8 Package
- ROHS Compliant

### Applications

- Car Charger
- Rechargeable Portable Device
- Automotive Industry

### General Description

The TX9523 is a monolithic, CC/CV step-down switch mode converter with a built-in high-side power MOSFET. It achieves 3A continuous output current over a wide input supply range with excellent load and line regulation. Current mode operation provides fast transient response and eases loop stabilization.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown.

The TX9523 is available in an SOP8-EP package provides a very compact system solution and good thermal conductance.

### Typical Application

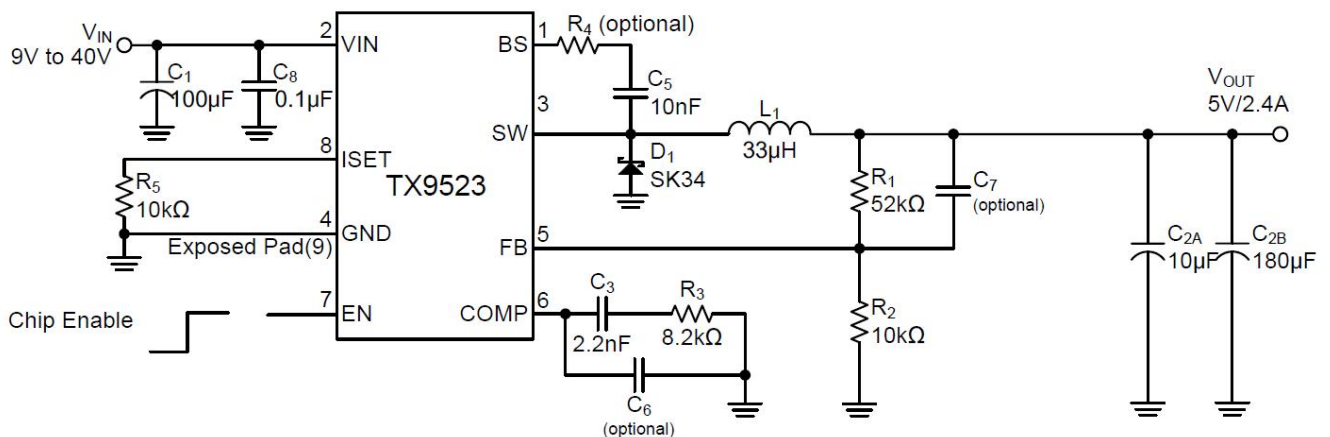


Figure 1 Typical Application Circuit

V <sub>OUT</sub> (V)	R <sub>1</sub> (kΩ)	R <sub>2</sub> (kΩ)	R <sub>3</sub> (kΩ)	C <sub>3</sub> (nF)	C <sub>6</sub>	L <sub>1</sub> (µH)	C <sub>2A</sub> (µF)	C <sub>2B</sub> (µF)
5	52	10	8.2	2.2	NA	47	10µF 6.3V/Ceramic	180 6.3V/30mΩ
5	52	10	8.2	2.2	NA	47	10µF 6.3V/Ceramic	470 6.3V/30mΩ

Table 1 Recommended Component Selection



### System Block Diagram

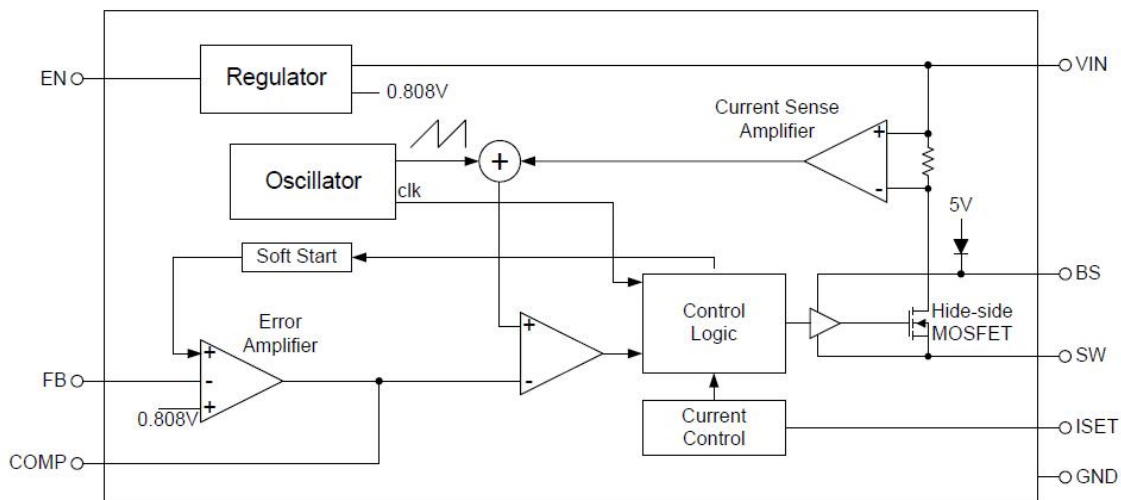


Figure 2 TX9523 Functional Block Diagram

### Function Description

The TX9523 is a constant frequency current mode step-down asynchronous DC/DC converter. It regulates input voltage from 9V to 40V, down to an output voltage as low as 1V, and can provide up to 3A of continuous load current.

#### Control Loop

During normal operation, the output voltage is sensed at FB pin through a resistive voltage divider and amplified through the error amplifier. The voltage of error amplifier output pin – COMP is compared to the switch current to controls the RS latch. At each cycle, the high side NMOS would be turned on when the oscillator sets the RS latch and would be turned off when current comparator resets the RS latch. When the load current increases, the FB pin voltage drops below 0.808V, it causes the COMP voltage increase until average inductor current arrive at new load current.

#### Input Under Voltage Lockout

When the TX9523 power on, the internal circuits are held inactive until VIN exceeds the input UVLO threshold voltage. And the regulator will be disabled when VIN below the input UVLO threshold voltage.

#### Over Current Protection

ISET pin is connected to a resistor to set output current limit value. At this point, the device will transition from regulating output voltage to regulating output current, and the output voltage will drop with increasing load.

The oscillator normally switches at 220kHz. However, if the FB voltage drops down, then the switching frequency decreases. Once the overload condition is removed, the frequency will return to normal.

#### Over Temperature Protection

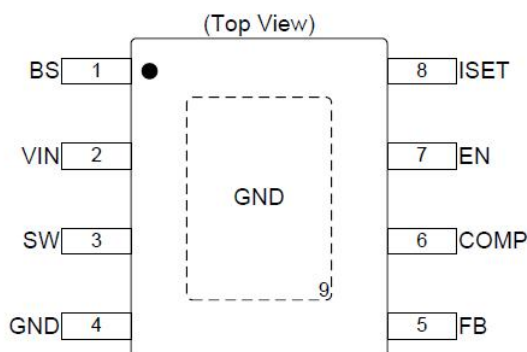
The TX9523 incorporates an over temperature protection circuit to protect itself from overheating. When the junction temperature exceeds the thermal shutdown threshold temperature, the regulator will be shutdown.

#### Compensation

The stability of the feedback circuit is controlled through COMP pin. The compensation value of the application circuit is optimized for particular requirements. If different conversions are requires, some of the components may need to be changes to ensure stability.



### Pin Configuration



### Pin Function Description

Pin NO.	Pin Name	Pin Description
1	BS	High Side Gate Drive Boost Input. A 22nF or greater capacitor must be connected from this pin to SW. It can boost the gate drive to fully turn on the internal high side NMOS.
2	VIN	Power Supply Input Pin. Drive 9V to 40V voltage to this pin to power on this chip. Connecting a bypass capacitor ( $\geq 22\mu\text{F} \times 2$ ) between VIN and GND to eliminate noise.
3	SW	Power Switching Output. It is the output pin that internal high side NMOS switching to supply power.
4	GND	Ground Pin.
5	FB	Voltage Feedback Input Pin. Connecting FB and VOUT with a resistive voltage divider. This IC senses feedback voltage via FB and regulate it at 0.808V.
6	COMP	Compensation Pin. This pin is used to compensate the regulation control loop. Connect a series RC network from COMP pin to GND.
7	EN	Enable Input Pin. This pin provides a digital control to turn the converter on or off. The pin could be floated for self-startup.
8	ISET	Output Current Setting Pin. Connect a resistor between ISET and GND pin to set output current.
9	GND	Exposed Pad. Connecting to Pin 4.



## Order Information

Part Number	Package	Shipment
TX9523	ESOP8	Tape & Reel / 4000

## Absolute Maximum Ratings <sup>(1)</sup>

Input Supply Voltage $V_{IN}$ .....	-0.3V ~ 42V	Maximum Junction Temperature .....	150°C
SW Voltage $V_{SW}$ .....	-0.3V(-5V for < 10ns) ~ 42V (44V for < 5ns)	Storage Temperature .....	-55°C ~ 150°C
Boost Voltage $V_{BS}$ .....	-0.3 ~ ( $V_{SW} + 6V$ )	Lead Temperature (Soldering 10sec) .....	260°C
All Other Pins Voltage .....	-0.3V ~ 6V	ESD Classification (HBM) .....	Class 2
		Power Dissipation ( $P_D$ ) @ $T_A = 25^\circ C$ .....	1.333W

## Recommended Operating Conditions <sup>(2)</sup>

Input Supply Voltage $V_{IN}$ .....	9V ~ 40V	Junction Temperature $T_J$ .....	-40°C~125°C
Ambient Temperature $T_A$ .....	-40°C~85°C		

## Thermal Characteristics

ESOP8, $\theta_{JA}$ .....	75°C/W	ESOP8, $\theta_{JC}$ .....	15°C/W
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Notes (1): Stresses exceed those ratings may damage the device.

Notes (2): If out of its operation conditions, the device is not guaranteed to function.



### Electrical Characteristics

V<sub>IN</sub>=12V, T<sub>A</sub>=25°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Supply Current</b>						
Quiescent Current (non-switching)	I <sub>Q</sub>	V <sub>EN</sub> = 3.0V, V <sub>FB</sub> = 1V	---	0.9	1.4	mA
Standby Supply Current (no loading)	---	V <sub>EN</sub> = 3.0V, V <sub>OUT</sub> = 5V	---	3	---	mA
Shutdown Current	---	V <sub>EN</sub> = 0V	---	75	115	uA
<b>Reference Voltage</b>						
Feedback Voltage	V <sub>FB</sub>	10V ≤ V <sub>IN</sub> ≤ 38V	792	808	824	mV
<b>Input UVLO</b>						
UVLO Threshold	---	V <sub>IN</sub> Rising	8	8.5	8.9	V
Hysteresis	---	V <sub>IN</sub> Falling	---	1.2	---	V
<b>Oscillator</b>						
Switching Frequency	f <sub>SW</sub>	V <sub>FB</sub> = 0.808V	170	220	270	kHz
Foldback Switching Frequency		V <sub>FB</sub> = 0V	---	30	---	kHz
Maximum Duty Cycle	D <sub>MAX</sub>	---	80	85	91	%
Minimum on time	T <sub>ON(MIN)</sub>	V <sub>FB</sub> = 0.7V	---	200	---	ns
<b>EN Logic Threshold</b>						
EN High-Level Input Voltage	V <sub>ENH</sub>	---	2	---	---	V
EN Low-Level Input Voltage	V <sub>ENL</sub>	---	---	---	0.4	V
EN Pull-up Current	---	---	---	4	---	uA
<b>MOSFET</b>						
High Side MOSFET On Resistance <sup>(3)</sup>	R <sub>DS(on)h</sub>	At 25°C	---	160	---	mΩ
High-Side MOSFET Leakage Current	---	V <sub>EN</sub> = 0V, V <sub>SW</sub> = 0V	---	---	10	uA
<b>Current Limit</b>						
Current Limit <sup>(3)</sup>	I <sub>LIM</sub>	L=30μH	---	4.5	---	A
<b>Error Amplifier</b>						
Error Amplifier Transconductance <sup>(3)</sup>	G <sub>EA</sub>	ΔI <sub>COMP</sub> = ±10μA	---	650	---	μA/V
Error Amplifier Voltage Gain <sup>(3)</sup>	A <sub>EA</sub>	---	---	4000	---	V/V
Current Sense Transconductance <sup>(3)</sup>	G <sub>CS</sub>	---	---	5.25	---	A/V
<b>Current Setting</b>						
ISET Voltage	---	---	---	1	---	V
ISET to I <sub>OUT</sub> Current Gain <sup>(3)</sup>	---	I <sub>OUT</sub> /I <sub>SET</sub> , R <sub>ISET</sub> =19.6kΩ	---	25000	---	A/A
Current Controller DC Accuracy <sup>(3)</sup>	---	R <sub>ISET</sub> =19.6kΩ V <sub>OUT</sub> =3.5V Open-Loop DC Test	---	1190	---	mA
<b>Thermal Shutdown</b>						
Thermal Shutdown threshold <sup>(3)</sup>	---	---	---	150	---	°C

Notes:(3) Guaranteed by design.

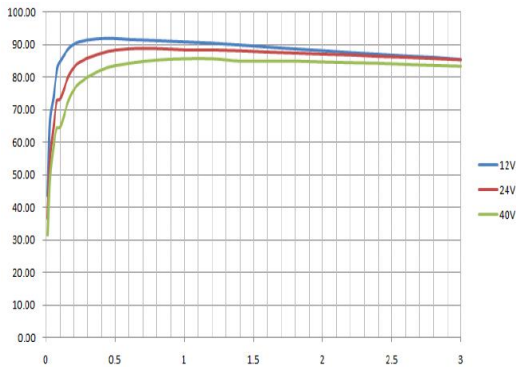


### Typical Operating Characteristics

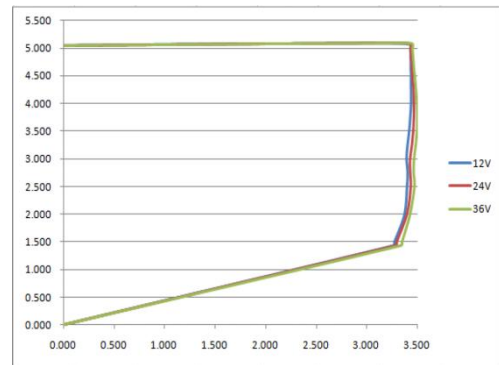
C1 = 100uF ,C2 = 10uF+180uF, L1 = 33uH,R5=8.2K, EN Pin Float, T<sub>A</sub> = +25°C, unless otherwise noted.

#### Efficiency Test

V<sub>out</sub>=5V

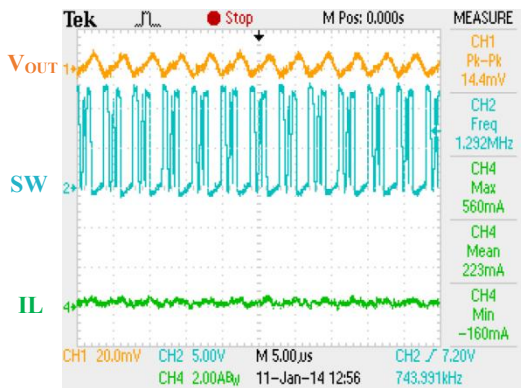


#### CC/CV Curve



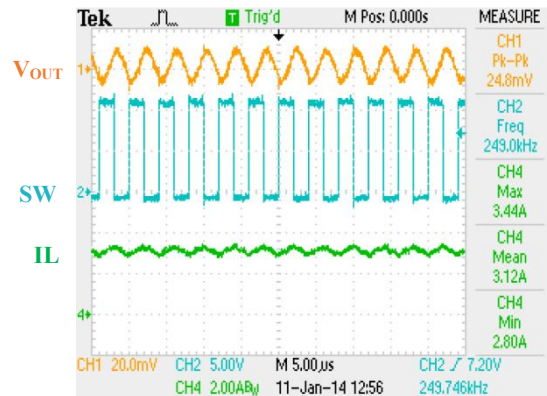
#### Steady State

V<sub>in</sub>=12V, V<sub>out</sub>=5V, I<sub>out</sub>=0A



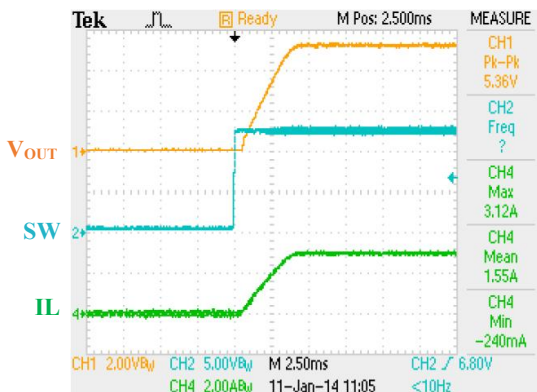
#### Steady State

V<sub>in</sub>=12V, V<sub>out</sub>=5V, I<sub>out</sub>=3A



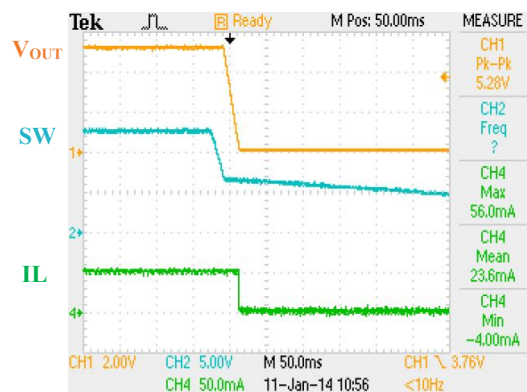
#### Power On

V<sub>in</sub>=12V, V<sub>out</sub>=5V, I<sub>out</sub>=2.4A



#### Shut Down

V<sub>in</sub>=12V, V<sub>out</sub>=5V, I<sub>out</sub>=0.05A





## Applications Information

### Output Voltage Setting

The output voltage  $V_{OUT}$  is set using a resistive divider from the output to FB. The FB pin regulated voltage is 0.808V. Thus the output voltage is:

$$V_{OUT} = 0.808 * (1 + \frac{R1}{R2}) V$$

Table2 lists recommended values of R1 and R2 for most used output voltage:

$V_{OUT}$	R1	R2
5V	52K	10K
3.3V	30.9K	10K

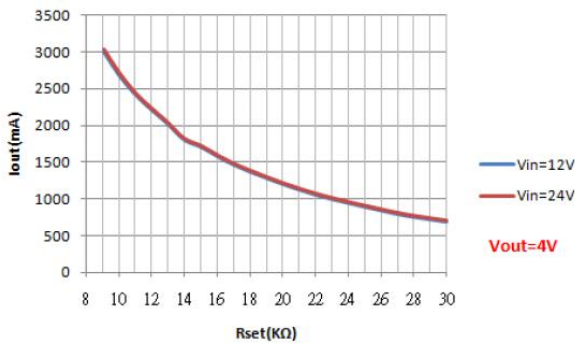
Table2 Recommended Resistance Values

Place resistors R1 and R2 close to FB pin to prevent stray pickup.

### Current Limit Setting

TX9523 current limit value is set by a resistor connected between the ISET pin and GND. The output current is linearly proportional to the current flowing out of the ISET pin. The voltage at ISET is roughly 1V and the current gain from ISET to output is roughly 25000 (25mA/1μA).

To determine the proper resistor for a desired current please refer to below:



### Current Limit Line Compensation

When operating at current limit mode, the current limit increase slightly with input voltage. For wide input voltage application, a resistor  $R_C$  is added to compensate line change and keep output high current limit accuracy, as shown in Figure 3.

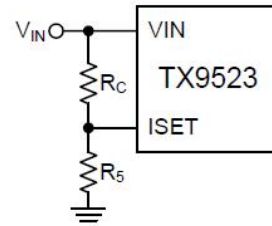


Figure 3 Input Line Compensation

### Input Capacitor Selection

The use of the input capacitor is controlling the input voltage ripple and the MOSFETS switching spike voltage. Because the input current to the step-down converter is discontinuous, the input capacitor is required to supply the current to the converter to keep the DC input voltage. The capacitor voltage rating should be 1.25 times to 1.5 times greater than the maximum input voltage. The input capacitor ripple current RMS value is calculated as:

$$I_{IIN(RMS)} = I_{OUT} * \sqrt{D * (1 - D)}$$

Where D is the duty cycle and the value is  $V_{OUT} / V_{IN}$ . A low ESR capacitor is required to keep the noise minimum. Ceramic capacitors are better, but tantalum or low ESR electrolytic capacitors may also suffice. When tantalum or electrolytic capacitors is used, a 0.1μF ceramic capacitor should be placed as close to the IC as pos

### Output Capacitor Selection

The output capacitor is used to keep the DC output voltage and supply the load transient current. Low ESR capacitors are preferred. Ceramic, tantalum or low ESR electrolytic capacitors can be used, depends on the output ripple requirement. Add a 100μF or 470μF low ESR electrolytic capacitor when operated in high input voltage range ( $V_{IN} > 20V$ ). It can improve the device's stability. The output ripple voltage  $\Delta V_{OUT}$  is described as:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s * L} * (1 - \frac{V_{OUT}}{V_{IN}}) * (R_{ESR} + \frac{1}{8 * f_s * C_2})$$

Where  $f_s$  is the switching frequency, L is the inductance value,  $V_{IN}$  is the input voltage,  $V_{OUT}$  is the output



voltage, RESR is the equivalent series resistance value of the output capacitor, and the C2 is the output capacitor. When using the ceramic capacitors, the RESR can be ignored and the output ripple voltage  $\Delta V_{OUT}$  is shown as:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 * f_s^2 * L * C2} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

When using tantalum or electrolytic capacitors, typically 90% of the output voltage ripple is contributed by the ESR of output capacitors. the output ripple voltage  $\Delta V_{OUT}$  can be estimated as:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * RESR$$

The characteristics of the output capacitor also affect the stability of the regulation system. The TX9523 can be optimized for a wide range of capacitance and ESR values

### Inductor

The output inductor is used for store energy and filter output ripple current. A large value inductor will result in less ripple current and lower output ripple voltage. But the trade-off condition often happens between maximum energy storage and the physical size of the inductor. The first consideration for selecting the output inductor is to make sure that the inductance is large enough to keep the converter in the continuous current mode. That will lower ripple current and results in lower output ripple voltage. A good rule for determining the inductance is set the peak-to-peak inductor ripple current  $\Delta I$  almost equal to 30% of the maximum load current. Then the minimum inductance can be calculated with the following equation:

$$L \geq \frac{V_{OUT}}{f_s * \Delta I} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

$$\Delta I = 0.3 * I_{LOAD(MAX)}$$

Where  $V_{IN}$  is the input voltage,  $f_s$  is the switching frequency,  $\Delta I$  is the peak-to-peak inductor ripple current and  $I_{LOAD(MAX)}$  is the maximum load current. Choose an inductor that will cause the peak inductor current satisfying the equation:

$$I_{LP} = I_{LOAD(MAX)} + \frac{V_{OUT}}{2 * f_s * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \leq LIMIT$$

Where  $I_{LIMIT}$  is the high-side MOSFET current limit value.

### Rectifier Diode

During the transition between switching MOSFETs, a Schottky diode should be connected between SW pin and GND pin. The Schottky diode must have current rating higher than the maximum

### Compensation Components

The system stability and transient response are controlled through the COMP pin. Selecting the appropriate compensation value by the following procedure:

1. Calculate the R3 value with the following equation:

$$R3 < \frac{2\pi * C2 * f_s * V_{OUT}}{10 * GEA * GCS * V_{FB}}$$

where GEA is the error amplifier transconductance, and GCS is the current sense transconductance.

2. Calculate the C3 value with the following equation:

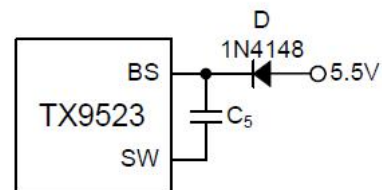
$$C3 > \frac{4 * 10}{2\pi * R3 * f_s}$$

3. If the C2 ESR zero is less than half of the switching frequency, use C6 to cancel the ESR zero:

$$C6 = \frac{C2 * RESR}{R3}$$

### External Boost Diode Selection

For duty cycle larger than 65% applications, it is recommended that an external boost diode be added. This helps improve the efficiency. The boost diode can be a low cost one such as 1N4148.





### PCB Layout Recommendation:

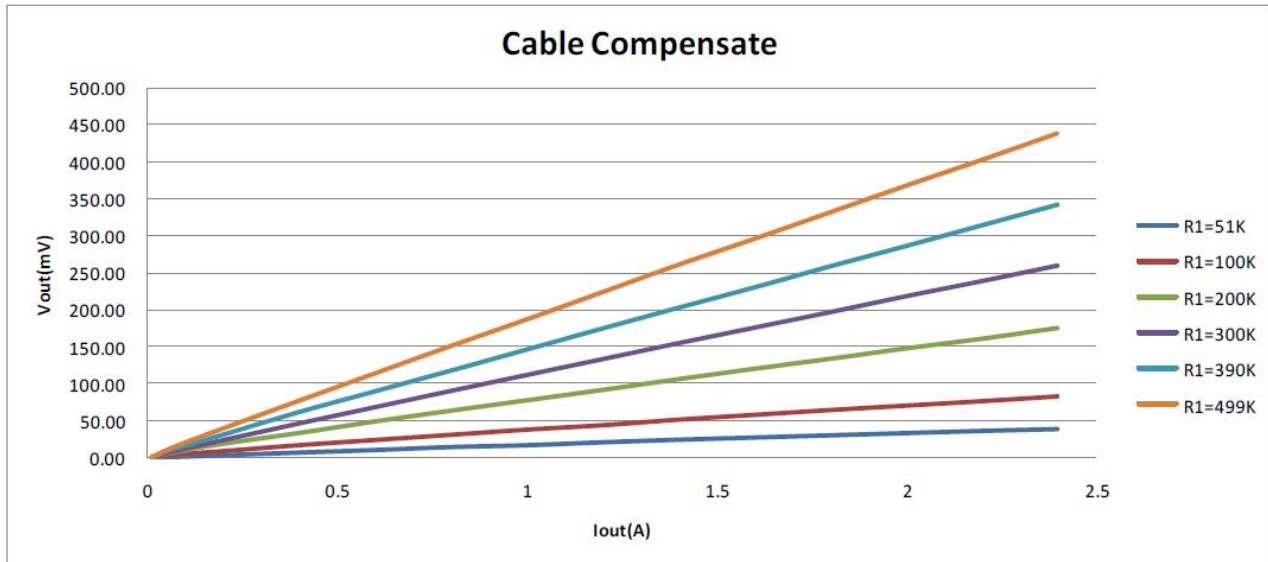
The device's performance and stability is dramatically affected by PCB layout. It is recommended to follow these general guidelines show bellow:

1. Keep the traces of the main current paths as short and wide as possible to minimize parasitic inductance and resistance.
2. Place VIN bypass capacitor (CIN) close to the device pins (VIN and GND). The loop area formed by CIN and VIN/GND pins must be minimized.
3. Place feedback resistors close to the FB pin. Connect feedback network behind the output capacitors.
4. Place compensation components close to the COMP pin.

5. Keep the sensitive signal (FB, COMP, ISET) away from the switching signal (SW).
6. Connect all analog grounds to a common node and then connect the common node to the power ground behind the output capacitors.
7. The exposed pad of the package should be soldered to an equivalent area of metal on the PCB. This area should connect to the GND plane and have multiple via connections to the back of the PCB as well as connections to intermediate PCB layers. The GND plane area connects to the exposed pad should be maximized to improve thermal performance.
8. Multi-layer PCB design is recommended

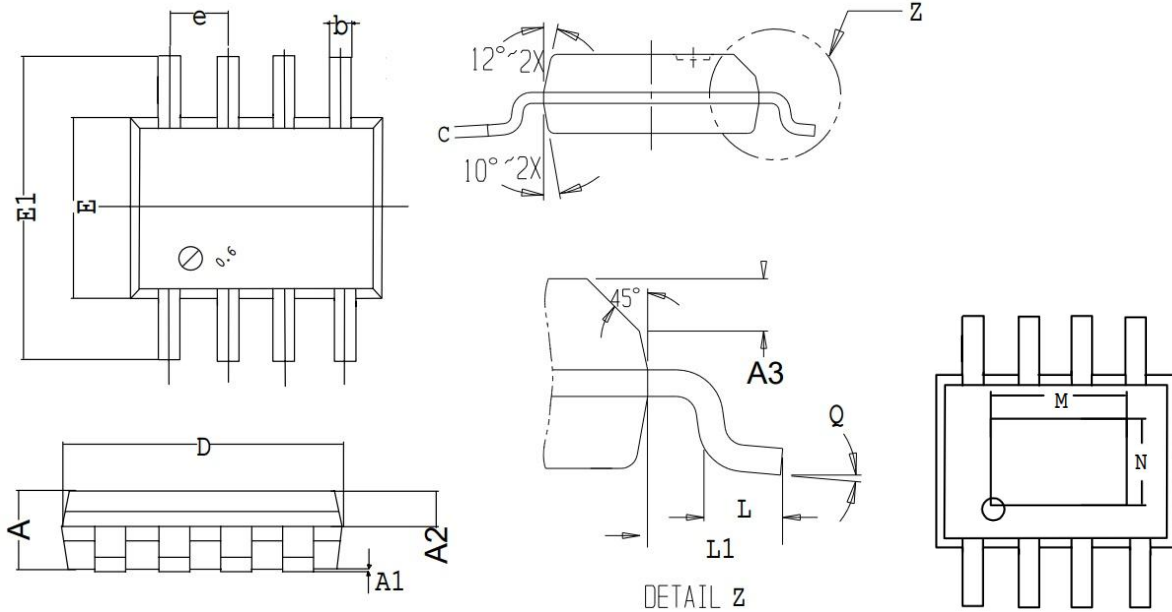
### Stability Compensation

R1 is the high side resistor of voltage divider. In the case of high R1 used, the frequency compensation needs to be adjusted correspondingly. As show in Figure 1, adding a capacitor(C7) in parallel with R1 or increasing the compensation capacitance(C3、C6) at COMP pin helps the system stability.





**ESOP8 PACKAGE INFORMATION**



COMMON DIMENSIONS UNITS MEASURE=MILLIMETER			
SYMBOL	MIN	MID	MAX
A	1.35	1.45	1.55
A1	0.00	0.05	0.10
A2	0.65	0.70	0.75
A3	0.35	0.40	0.45
b	0.35	0.40	0.45
c	0.18	0.20	0.22
D	4.70	4.90	5.10
e	-	1.27TYP	-
E1	5.80	6.10	6.20
E	3.80	3.90	4.00
L	0.40	0.60	0.80
Q	0°	/	8°
M	3.10	3.20	3.30
N	2.20	2.30	2.40
L1	1.05REF		



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