28V 2A 500KHz COT PSM Synchronous Step-Down Converter

Features

- Wide operating input voltage range: 4.5V to 28V
- Continuous output current: 2A
- COTPSM control mode with fast transient response
- Switching frequency: 500KHz
- Built-in OCP, OVP, OTP (thermal shutdown), and short circuit protection (hiccup mode)
- Light-load and efficient PFM mode
- Built-in soft start circuit
- Built-in low on-resistance power FET：100mΩ/50mΩ
- Adjustable output voltage options：0.6V/0.8V/0.765V
- Synchronous buck mode: No need for external Schottky diodes
- Integrated internal compensation circuit
- SOT23-6 packaging
- Operating temperature range：-40℃ to +85℃

Applications

- Automotive system
- Network terminal equipment
- Security surveillance camera
- Printer system
- Industrial power supply system
- Distributed power system

General Description

AD943XA-20CT0 is a high-frequency, synchronous rectification buck switching power converter with built-in low on-resistance power field-effect transistors. It can provide a continuous output current of 2A over a wide input voltage range and exhibits excellent load and line regulation. The COTPSM control operation features fast transient response and simple loop design, while ensuring strict output voltage regulation. This device requires only a few conventional external components and is housed in a space-saving SOT23-6 package.

Typical Application

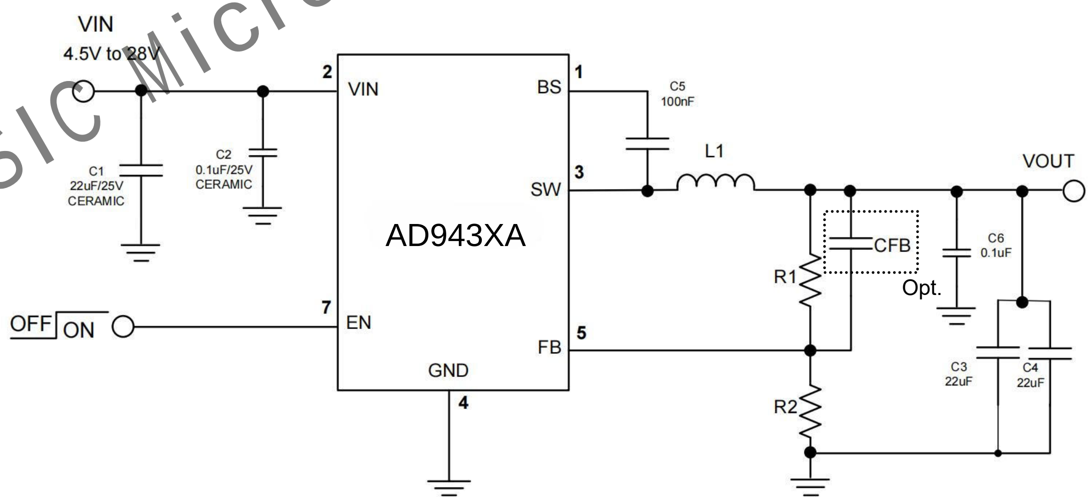
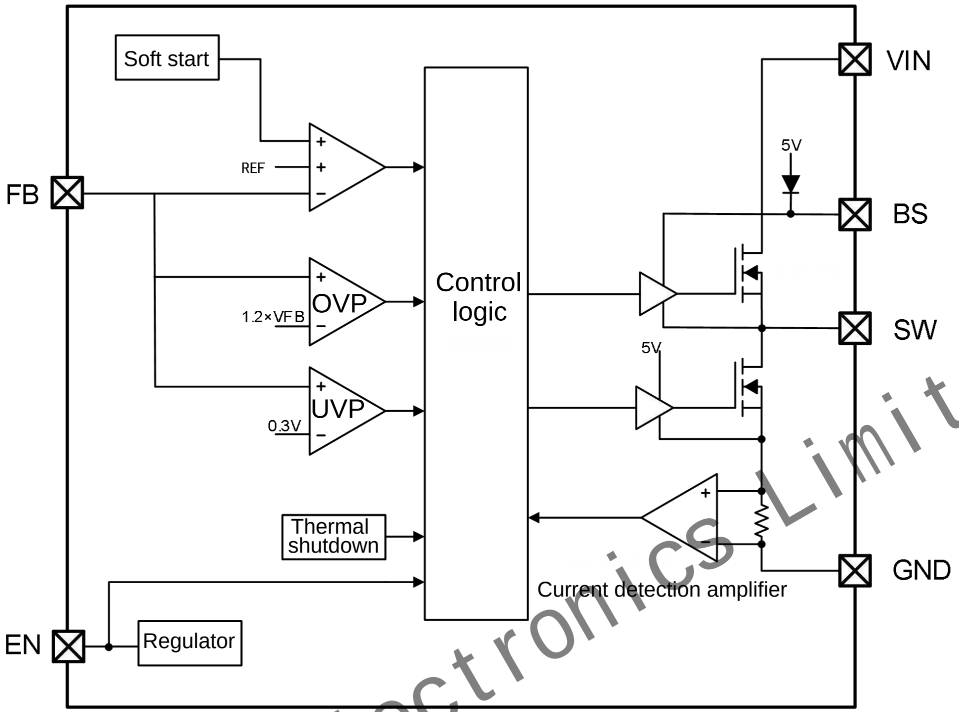


Figure 1. A typical circuit includes an input capacitor, an output capacitor, a feedback resistor, and an inductor

Block Diagram



Functional Description

Internal regulator

AD943XA is a COT step-down DC/DC converter that provides excellent transient response without requiring additional external compensation components. The device includes an internal low-resistance high-voltage power MOSFET, operating at frequencies up to 500KHz, ensuring a compact and efficient design as well as excellent AC and DC performance.

Undervoltage Lockout (UVLO)

Under Voltage Lockout (UVLO) prevents the chip from operating when the power supply voltage is insufficient. The UVLO protection function monitors the internal regulator voltage. When the voltage falls below the UVLO threshold voltage, the device will shut down. When the voltage rises above the UVLO threshold voltage, the device will be enabled again.

Thermal shutdown function

Thermal shutdown prevents the chip from operating at excessively high temperatures. When the silicon temperature exceeds 160°C, it shuts down the entire chip. When the temperature drops below its lower limit (typically 140°C), the chip is enabled again.

Built-in soft start function

Soft start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts up, the internal circuit generates a soft start voltage (SS) that rises from 0V to VFB. When it is lower than the internal reference (REF), SS overrides REF, so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control. The maximum SS time is internally set to 1.5ms.

Overcurrent protection function

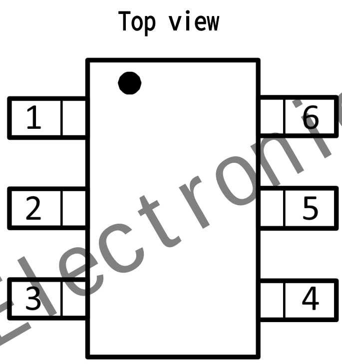
When the peak value of the inductor current exceeds the set current limit threshold, the AD943XA triggers cycle-by-cycle overcurrent protection. Simultaneously, the output voltage begins to drop until the feedback voltage (FB) falls below the undervoltage (UV) threshold. Once the undervoltage protection is triggered, the AD943XA enters hiccup mode and periodically attempts to restart the chip. This protection mode is particularly useful in cases where the output terminal is short-circuited to ground, as it significantly reduces the average short-circuit current, thereby mitigating overheating issues and protecting the voltage regulator. Once the overcurrent condition is resolved, the AD943XA exits hiccup mode and resumes normal operation.

Startup and shutdown

If both VIN and EN are higher than their respective turn-on thresholds, the chip will start up. Upon startup, the reference circuit block first operates to generate a stable reference voltage and current, and then the internal voltage regulator is enabled. The voltage regulator provides stable power supply to the remaining circuits.

There are four situations that can cause the chip to shut down: when the EN level is low, when the VIN voltage is either too low or too high, and due to overheating. During the shutdown process, the signal path will be blocked first to avoid triggering any faults. Subsequently, the compensation voltage (COMP voltage) and the internal power supply rail will be pulled down. However, the floating driver (FloatingDriver) is not affected by this shutdown command.

Pin Description



(SOT23-6)

PIN	NAME	FUNCTION
1	GND	Grounding pin.
2	SW	Switch pin
3	IN	Power input pin.
4	FB	Feedback pin, connected to the external resistor voltage divider point.
5	EN	Enable pin,pull high to turn on the chip.
6	BS	To bootstrap the pin, a capacitor needs a floating power supply.

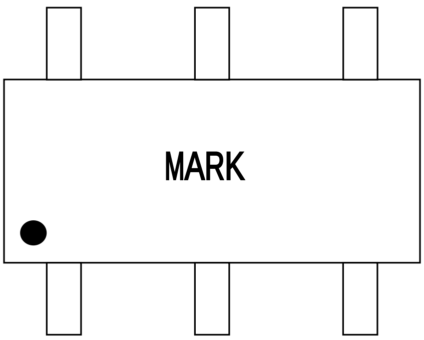
Package/order Information

AD94①②③-④⑤⑥⑦⑧

Num.	Unit	Function
①	3	Maximum withstand voltage 30V
②	6/7/8	FB voltage 6: 0.6V 7: 0.765V 8: 0.8V
③	A	On-load switching frequency A：500K
④⑤	20	Maximum continuous output current，20=2A
⑥⑦⑧	CT0	Package: SOT23-6 RoHS/lead-free

Mark	PN	Function	Package	Number
CAXXX	AD9436A-20CT0	AD9436A-20CT0 ,4.5-28V,Syn. Buck 2A, 500KHz, VFB=0.6V, SOT23-6	SOT23-6	3000 pcs/reel
CBXXX	AD9437A-20CT0	AD9437A-20CT0 ,4.5-28V,Syn. Buck 2A, 500KHz, VFB=0.765V,SOT23-6	SOT23-6	3000 pcs/reel
CDXXX	AD9438A-20CT0	AD9438A-20CT0 ,4.5-28V,Syn. Buck 2A, 500KHz, VFB=0.8V, SOT23-6	SOT23-6	3000 pcs/reel

Mark Information



SOT23-6
(TOP VIEW)

Top mark: CA/B/DXXX (Device code: CA/CB/CD, Chip batch number code: XXX).

Absolute Maximum Ratings (1) (2)

Vin,EN,SW pin voltage ....-0.3V ~ 32V

Operating temperature ....-40℃~ +150℃

FB,BS pin voltage...................................-0.3 ~ 6V

Pin soldering temperature(10s) ....+260℃

Power consumption(3) ....internal limit

Storage temperature................................-55℃~ 150℃

ESD(Human Body Model, HMB) 2KV

Thermal resistance ($R_{θJA}$) ....105 °C/W

Thermal resistance($R_{θJC}$)............................55 °C/W

(1):Exceeding these rated values may damage the equipment.

(2):The equipment cannot guarantee normal operation outside its working conditions.

(3):The maximum allowable power dissipation is a function of the maximum junction temperature (TJMAx), the thermal resistance from junction to ambient (RoJA), and the ambient temperature (TA). The maximum allowable power dissipation at any ambient temperature can be calculated using the following formula: Po(Ax) = (TJMAx - TA) RaA. Exceeding the maximum allowable power dissipation can lead to excessive chip temperature, causing the regulator to enter a thermal shutdown mode. An internal thermal shutdown circuit protects the device from permanent damage. Thermal shutdown is activated when the junction temperature reaches 160°C (typical value) and is released when the junction temperature drops to 140°C (typical value).

Electrical Charcteristics (1) (2)

V_{IN}=12V, T_A=25°C, unless otherwise specified.

Parameter	Conditions	Min	Typ	Max	Unit
Input voltage range		4.5	---	28	V
Quiescent current	V_{EN}=3.0V	---	0.3	0.8	mA
Shutdown current	V_{EN} =0 or EN = GND	---	---	7	uA
Feedback voltage	AD9436A	0.585	0.600	0.615	V
	AD9437A	0.746	0.765	0.784	V
	AD9438A	0.780	0.800	0.820	V
High-side switch on-resistance	I_{SW}=100mA	---	100	---	mΩ
Low-side switch on-resistance	I_{SW}=-100mA	---	50	---	mΩ
Peak switch current limit		3.5	---	---	A
Overvoltage protection threshold		---	28.5	---	V
Switching frequency		---	500	---	KHz
Maximum duty cycle	Vin=12V,Vfb=0.5V	---	92	---	%
Minimum conduction time	Vin=28V,Vout=1.0V,Iout=1.0A	---	105	---	nS
EN turn-on voltage		1.4	---	---	V
EN shutdown voltage		---	---	0.5	V
Power supply undervoltage threshold voltage	Wake-up input voltage	---	3.8	4.2	V
	Power-off input voltage	3.0	3.4	---	V
	Power supply undervoltage threshold voltage hysteresis voltage	---	400	---	mV
Soft start time		---	1.5	---	ms
Thermal shutdown		---	160	---	℃
Thermal shutdown hysteresis temp.		---	20	---	℃

(1)：The on-resistance specification of power field-effect transistors is ensured by correlating with wafer-level measurement results.

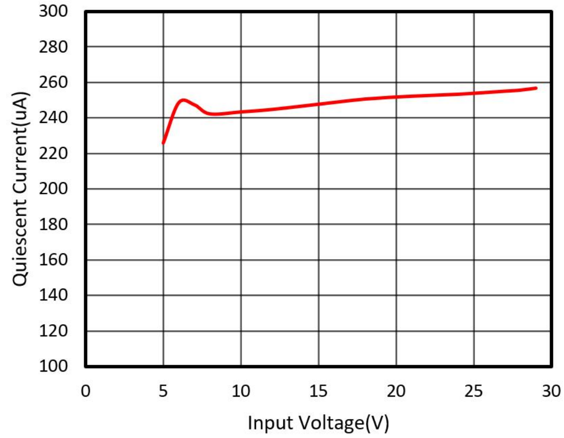
(2)：The thermal shutdown specification is ensured through design and characteristic analysis.

Typical Performance Characteristics (1) (2)

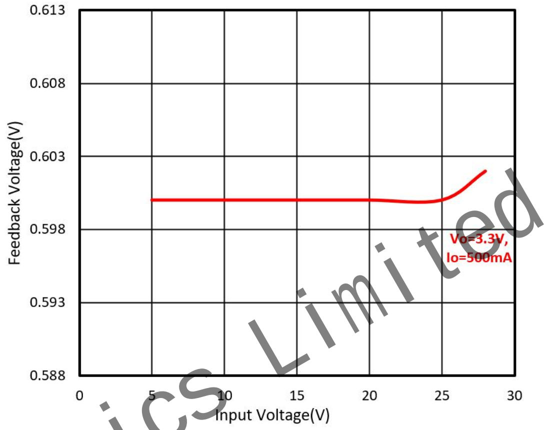
(1): The performance waveform is tested on the evaluation board.

(2): V_{IN} =12V, V_{OUT}=3.3V, T_A = +25ºC, unless otherwise specified.

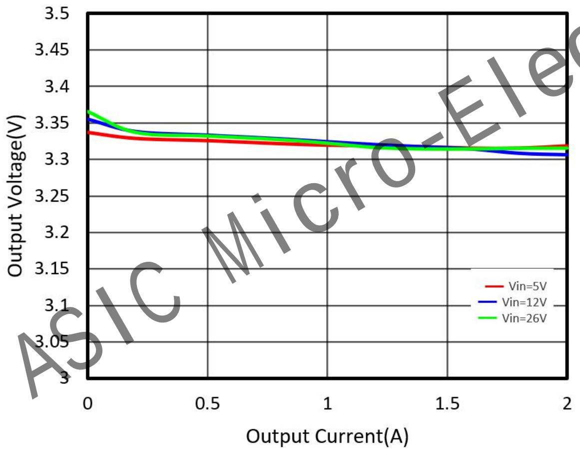
(1) Quiescent current and input voltage



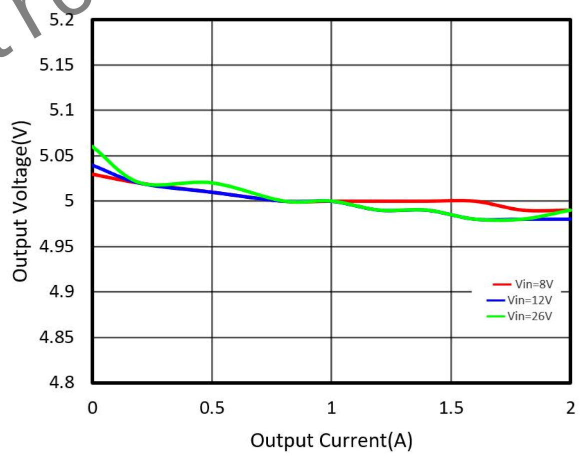
(2) Feedback voltage and input voltage



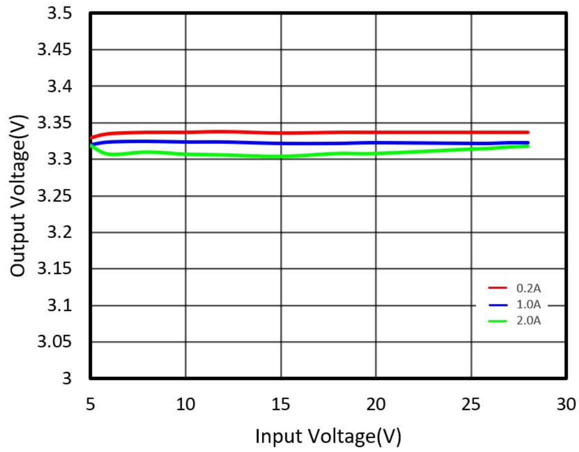
(3)Output voltage and load current (output voltage 3.3V)



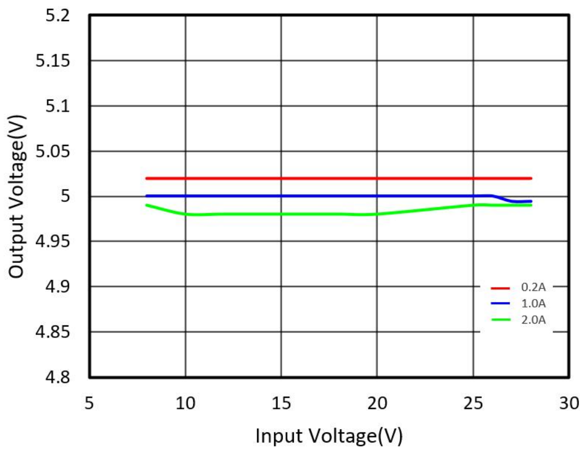
(4) Output voltage and load current (output voltage 5.0V)



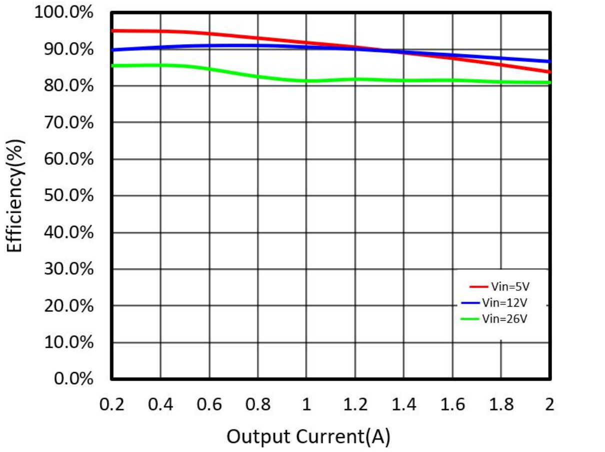
(5) Output voltage and input voltage (output voltage 3.3V)



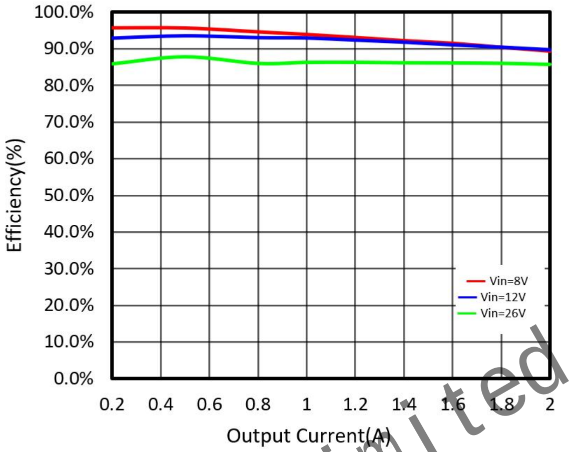
(6) Output voltage and input voltage (output voltage 5.0V)



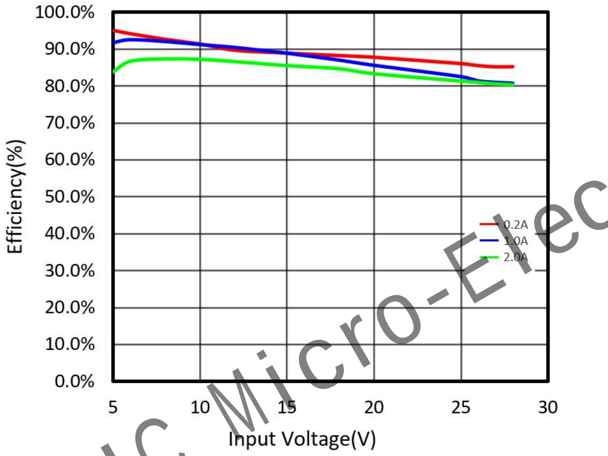
(7) Conversion efficiency and load current (output voltage 3.3V)



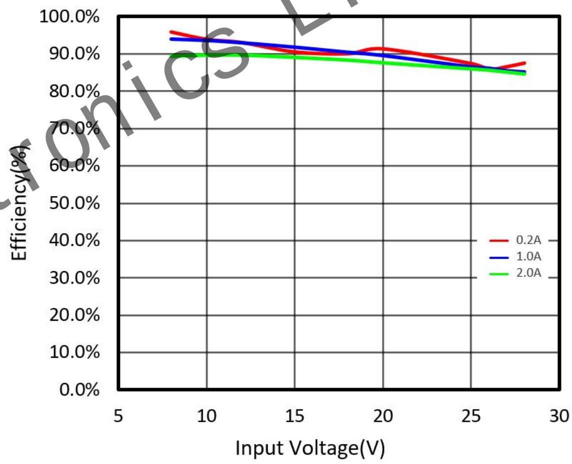
(8)Conversion efficiency and load current (output voltage 5.0V)



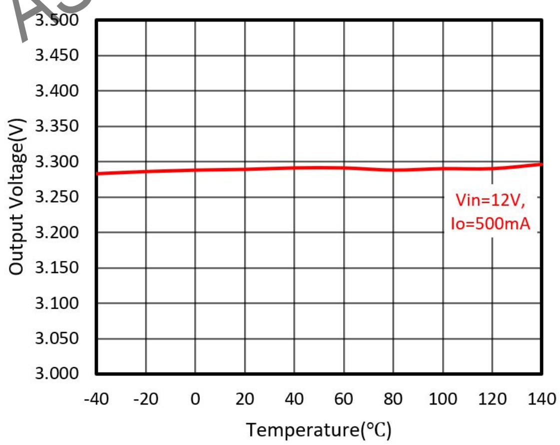
(9) Conversion efficiency and input voltage (output voltage 3.3V)



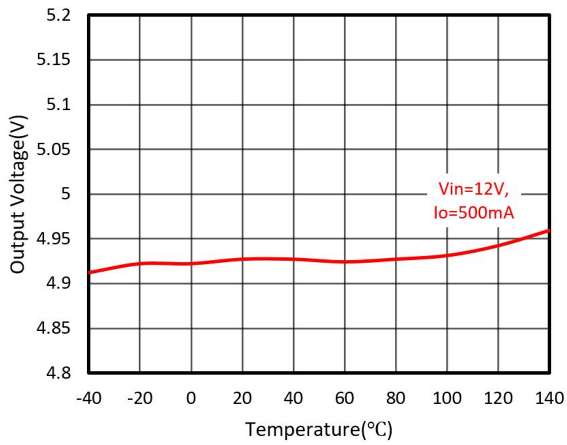
(10) Conversion efficiency versus input voltage (output voltage 5.0V)



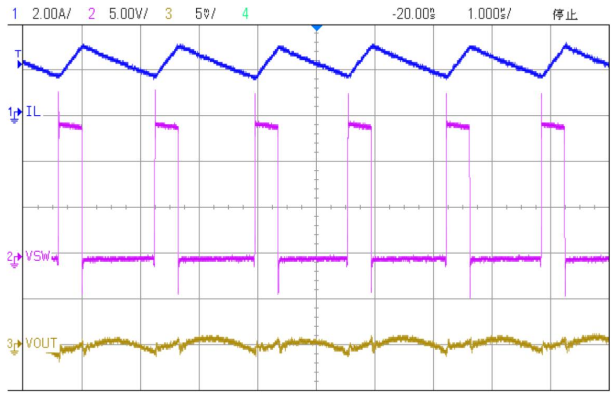
(11)Output voltage and temperature (output voltage 3.3V)



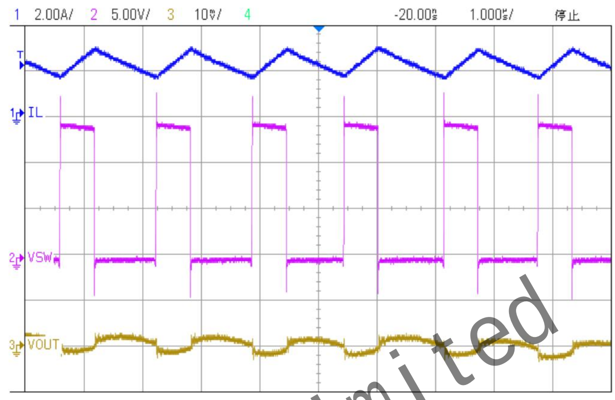
(12)Output voltage and temperature (output voltage 5.0V)



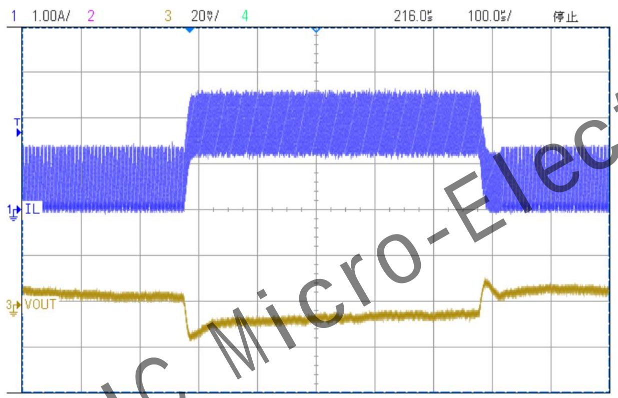
(13) Output ripple (Vin 15.0V, Vout 3.3V, load current 2A)



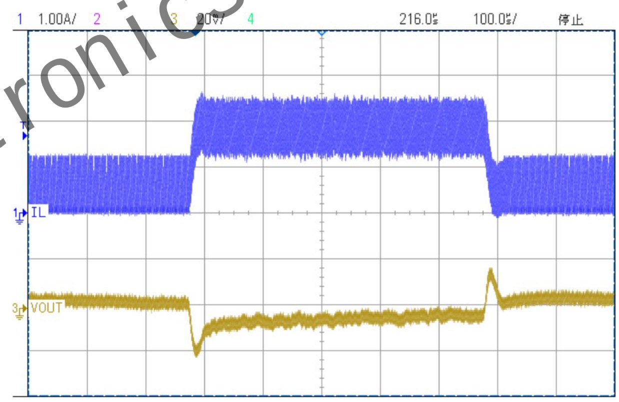
(14) Output ripple (Vin15.0V, Vout5.0V, load current 2A)



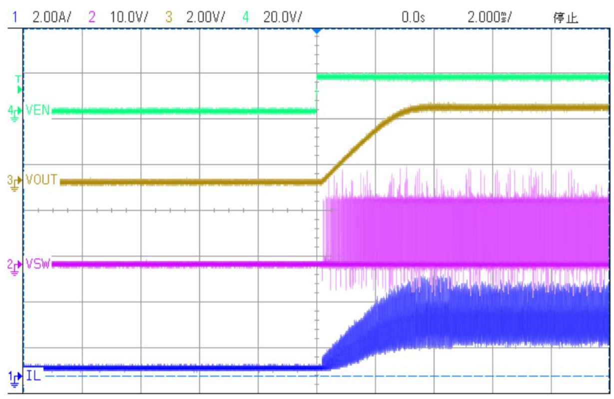
(15) Load transient (Vin15.0V, Vout3.3V, load current 0.5→1.8A)



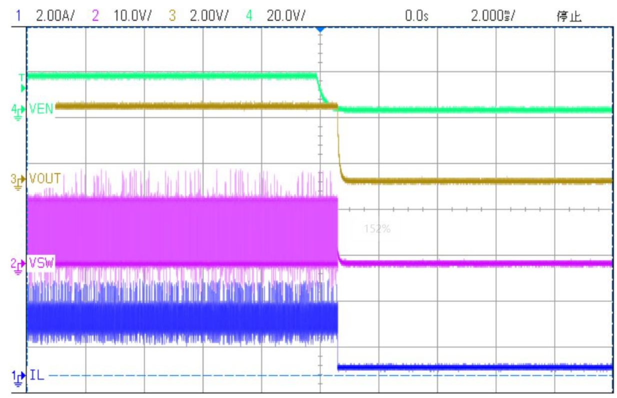
(16)Load transient (Vin15.0V, Vout5.0V, load current 0.5→1.8A)



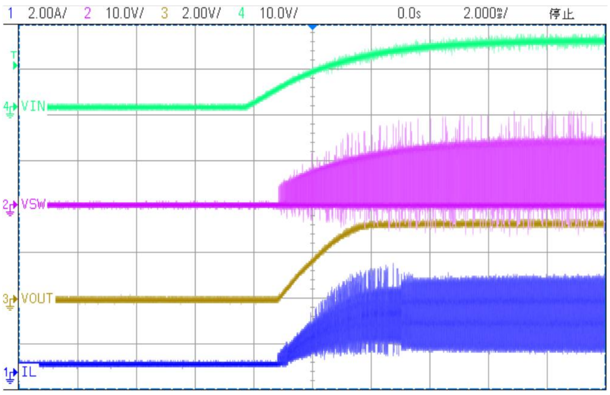
(17) En startup (Vin 15.0V, Vout 3.3V, load current 2A)



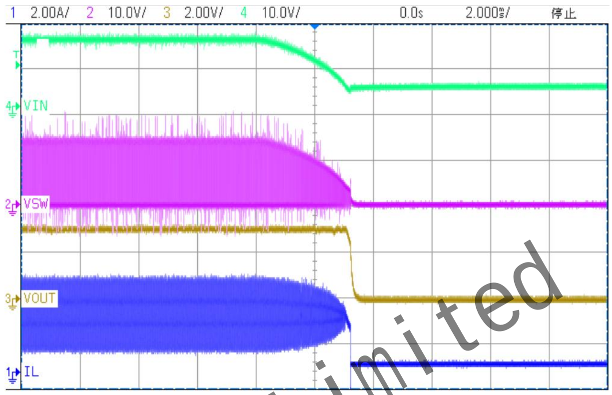
(18) EN is turned off (Vin 15.0V, Vout 3.3V, load current 2A)



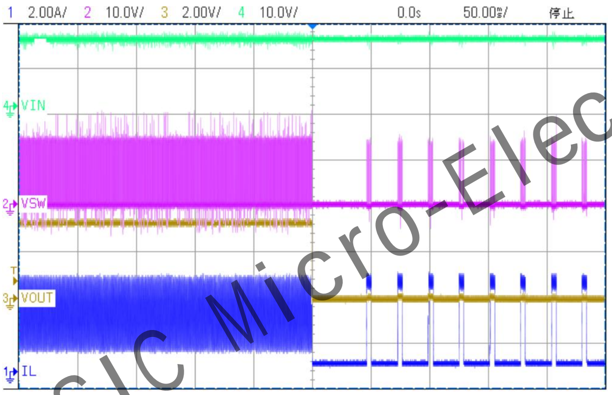
(19) Power on (Vin15.0V, Vout3.3V, load current 2A)



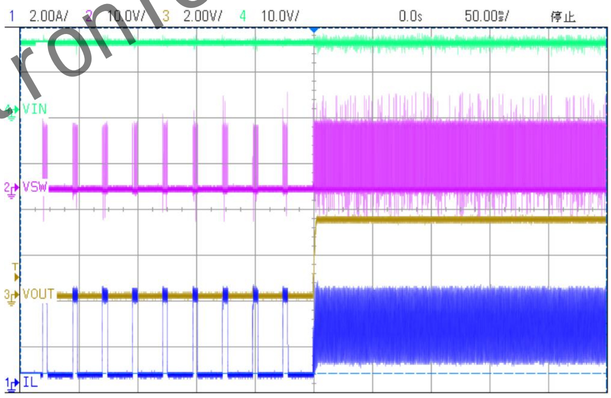
(20) Power off (Vin15.0V, Vout3.3V, load current 2A)



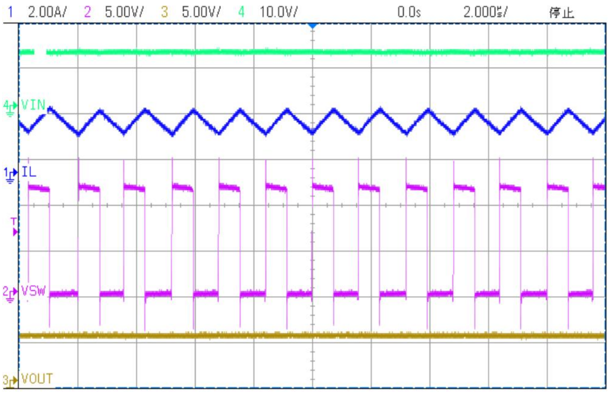
(21) Output short circuit (Vin15.0V, Vout3.3V, load current 2A)



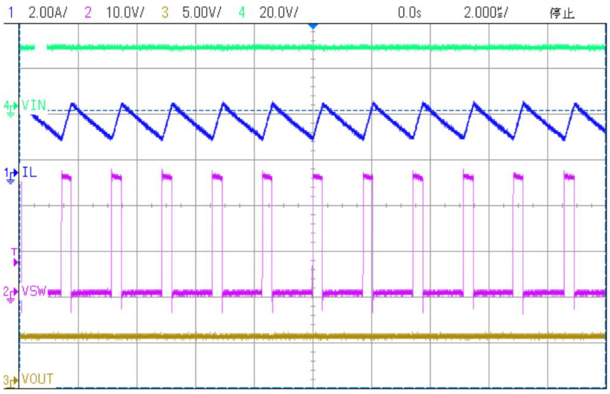
(22) Short circuit output recovery (Vin15.0V, Vout3.3V, load current 2A)



(23) Steady state output (Vin12.0V, Vout5.0V, load current 2A)



(24) Steady state output (Vin26.0V, Vout5.0V, load current 2A)



Applications Information

Output Voltage Setting

AD943XA requires an input capacitor, an output capacitor, and an inductor. These components are crucial for the performance of the device. The AD943XA has a built-in compensation circuit, which enables stable operation without the need for external components. The output voltage can be programmed through a resistive voltage divider. The calculation formula for output voltage is as follows:

$$V_{OUT} = V_{FB} \times \frac{R1 + R2}{R2}$$

The following table shows the recommended values for external components when VFB=0.6V.

VOUT(V)	R1(KΩ)	R2(KΩ)	L1(μH)	C5(nF)	C1/C3/C4(μF)	C2/C6(μF)
1.0	6.6	10	2.2	100	22	0.1
1.2	10	10	2.2	100	22	0.1
1.5	15	10	2.2	100	22	0.1
1.8	20	10	2.2	100	22	0.1
2.5	31.7	10	2.2	100	22	0.1
3.3	45	10	3.3	100	22	0.1
5.0	73.3	10	4.7	100	22	0.1
12	190	10	10	100	22	0.1

All external components are recommended values, and the final value depends on the application test results.

Inductor Selection

The recommended inductance values have been provided in the application circuit diagram. It is necessary to ensure that the magnetic core of the inductor will not saturate under any foreseeable operating conditions. When checking the saturation current ratings provided by different manufacturers, special attention should be paid to the fact that the inductor should have sufficient ratings to handle the maximum peak current of the inductor. The rated saturation current is usually given at 25 ° C, so the manufacturer should be requested for the rated value at the highest ambient temperature of the application. The inductance value can be calculated using the following formula:

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

ΔI_L is the inductor ripple current. Choose an inductor ripple current of approximately 30% to 40% of the maximum load current. The maximum peak current of the inductor can be estimated as:

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

Under light load conditions below 100mA, it is recommended to use larger inductors to improve efficiency. Larger inductors can generate smaller ripple currents and voltages, but their physical size is also larger, with lower saturation currents and higher linear impedances. Therefore, the choice of inductance should be balanced based on specific applications.

Input Capacitor Selection

The input current of a buck converter is discontinuous, therefore a capacitor is required to provide AC current to the buck converter while maintaining DC input voltage. For better performance, it is recommended to use ceramic capacitors and place them as close to VIN as possible. In addition, it is recommended to use a 0.1uF input capacitor to filter out high-frequency interference. It is recommended to choose capacitors with X5R and X7R ceramic dielectrics, as they have good stability under temperature changes. The input capacitor must also have a ripple current rating greater than the maximum input ripple current of the converter. The input ripple current can be estimated by the following formula:

$$I_{CIN} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

According to the above formula, it can be concluded that the input ripple current reaches its maximum value at VIN=2Vout . For simplicity, choose an input capacitor with an RMS current rating greater than half of the maximum load current. That is, $I_{CIN} = \frac{I_{OUT}}{2}$. The input capacitance value determines the input voltage ripple of the converter. If there is a requirement for input voltage ripple in the system, an input capacitor that meets the specifications should be selected. The input voltage ripple can be estimated using the following formula:

$$\Delta V_{IN} = \frac{I_{OUT}}{F_{OSC} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Similarly, when VIN=2VOUT, the input voltage ripple reaches its maximum value。 $\Delta V_{IN} = \frac{1}{4} \times \frac{I_{OUT}}{F_{OSC} \times C_{IN}}$

Output Capacitor Selection

The output capacitor is designed to maintain the DC output voltage. The output voltage ripple can be estimated using the following formula:

$$\Delta V_{OUT} = \frac{V_{OUT}}{F_{OSC} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times F_{OSC} \times C_{OUT}}\right)$$

There are some differences among different types of capacitors. In the application of ceramic capacitors, the impedance at switching frequency is mainly determined by the capacitance value. The output voltage ripple is mainly caused by capacitors. For simplicity, the output voltage ripple can be estimated using the following formula:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times F_{OSC}{}^{2} \times L \times C_{OUT}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

A larger output capacitance can achieve better load transient response, but the limitation of maximum output capacitance should also be considered in design applications. If the output capacitance value is too high, the output voltage will not reach the design value during the soft start process and will not be able to be stably adjusted. The maximum output capacitance value (CouT MAx) can be roughly limited by the following formula:

$$C_{OUT\_MAX} = \left(I_{LIM\_AVG} - I_{OUT}\right) \times T_{SS}/V_{OUT}$$

Among them, I_{LIM_AVG} is the average starting current during the soft start period, and Tss is the soft start time.

On the other hand, special attention should be paid when selecting these components. The DC bias of capacitors may cause their capacitance value to be lower than the minimum value given in the recommended capacitance specification table. The actual capacitance value of ceramic capacitors will vary with temperature. The operating temperature range of X7R capacitors is -55 ° C to+125 ° C, with a capacitance value variation range of only ± 15%. X5R capacitors have a similar temperature variation range, but their operating temperature range is -55 ° C to+85 ° C. Many ceramic capacitors larger than 1uF use Z5U or Y5V temperature characteristics, and their capacitance values decrease by more than 50% as the temperature changes from 25 ° C to 85 ° C. Therefore, in applications with large temperature fluctuations, it is recommended to use X5R or X7R capacitors instead of Z5U or Y5V capacitors.

Feedforward capacitor (C_{FB})

The AD943XA already integrates loop compensation internally, so adding a feedforward capacitor (C_{FB}) is optional. Specifically, for certain specific application scenarios, if necessary, consideration can be given to whether to add feedforward capacitors based on the situation.

The purpose of using feedforward capacitors (C_{FB}) in feedback networks is to improve transient response or increase phase margin. When optimizing feedforward capacitors, the first step is to determine the crossover frequency. The cross frequency (or converter bandwidth) can be determined by using a network analyzer. If the cross frequency is obtained without identifying the feedforward capacitor, the value of the feedforward capacitor (C_{FB}) can be calculated using the following formula:

$$C_{FB} = \frac{1}{2\pi \times F_{CROSS}} \times \sqrt{\frac{1}{R1} \times \left(\frac{1}{R1} + \frac{1}{R2}\right)}$$

In the formula, F_{CROSS} is the crossover frequency.

To reduce transient ripple, the value of the feedforward capacitor can be increased to push the crossover frequency towards a higher frequency range. Although this can improve transient response, it also reduces phase margin and leads to more ringing. On the other hand, if a higher phase margin is required, the value of the feedforward capacitor can be reduced to push the crossover frequency towards a lower frequency range.

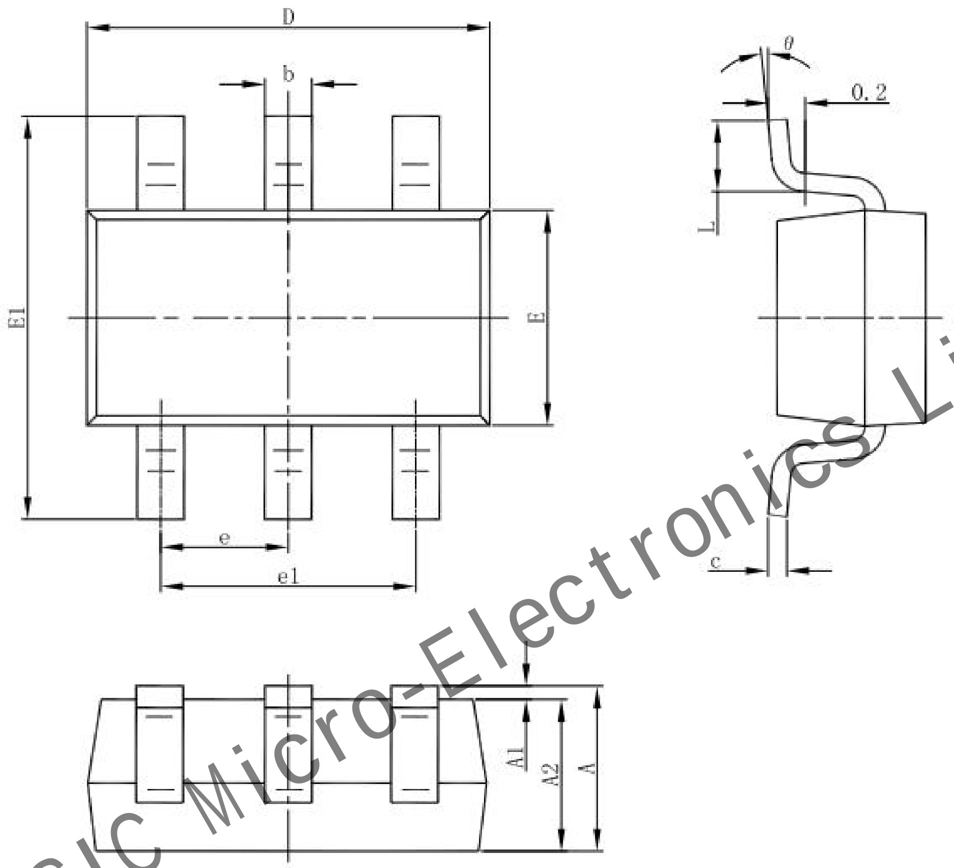
PCB Layout Guide

PCB layout is crucial for achieving stable operation. It is strongly recommended to replicate the layout of the evaluation board (EVB) for optimal performance. If changes are required, please follow the following guidelines:

1. Keep the switch current path as short as possible and minimize the loop area formed by the input capacitor, high side MOSFET, and low side MOSFET.
2. The bypass ceramic capacitor should be placed as close as possible to the Vin pin.
3. Ensure that all feedback connections are as short and direct as possible. Place the feedback resistor and compensation component as close as possible to the chip.
4. The VOUT and SW pins should be kept away from sensitive analog areas, such as the FB pin.
5. Connect the IN, SW, and especially GND pins to large-area copper foil to help dissipate heat, improve the thermal performance and long-term reliability of the chip.

Package Description

SOT23-6 Outline Dimensions



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
C	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(	BSC)	0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°