

18V, 5.5A Synchronous Step-Down DC/DC Converter

Description

The FR9855B is a synchronous step-down DC/DC converter with fast constant on time (FCOT) mode control. The device provides 4.5V to 18V input voltage range and 5.5A continuous load current capability. Operation frequency depends on input and output voltage condition. At light load condition, the FR9855B can operate at power saving mode to support high efficiency and reduce power loss.

The FR9855B fault protection includes cycle-by-cycle current limit, short circuit protection, UVLO and thermal shutdown. The soft-start function prevents inrush current at turn-on. The FR9855B use fast constant on time control that provides fast transient response, the noise immunity and all kinds of very low ESR output capacitor for ensuring performance stabilization.

The FR9855B is offered in SOP-8 (Exposed Pad) and TDFN-10 (3mmx3mm) packages, which provides good thermal conductance.

Features

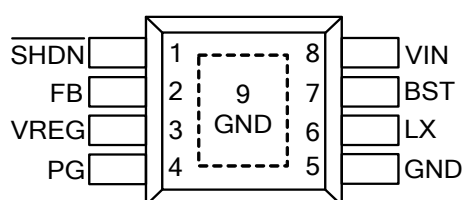
- Low $R_{DS(ON)}$ Integrated Power MOSFET (70mΩ/38mΩ)
- Wide Input Voltage Range: 4.5V to 18V
- Output Voltage Range: 0.6V to 8V
- 5.5A Output Current
- FCOT Mode Enables Fast Transient Response
- Pseudo 630kHz Frequency
- Power Good Function
- Input Under Voltage Lockout
- Internal 1ms Soft-Start
- Cycle-by-Cycle Current Limit
- Hiccup Short Circuit Protection
- Over Temperature Protection with Auto Recovery
- SOP-8 (Exposed Pad) and TDFN-10 (3mmx3mm) Packages

Applications

- STB (Set-Top-Box)
- LCD Display, TV
- Distributed Power System
- Networking, XDSL Modem

Pin Assignments

SP Package: SOP-8 (Exposed Pad)



DA Package: TDFN-10 (3mmx3mm)

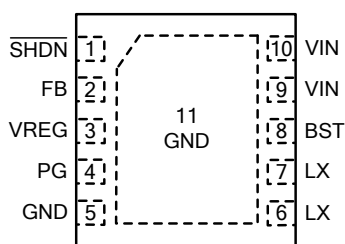


Figure 1. Pin Assignments of FR9855B

Ordering Information

FR9855B  Package Type
 SP: SOP-8 (Exposed Pad)
 DA: TDFN-10 (3mmx3mm)

Typical Application Circuit

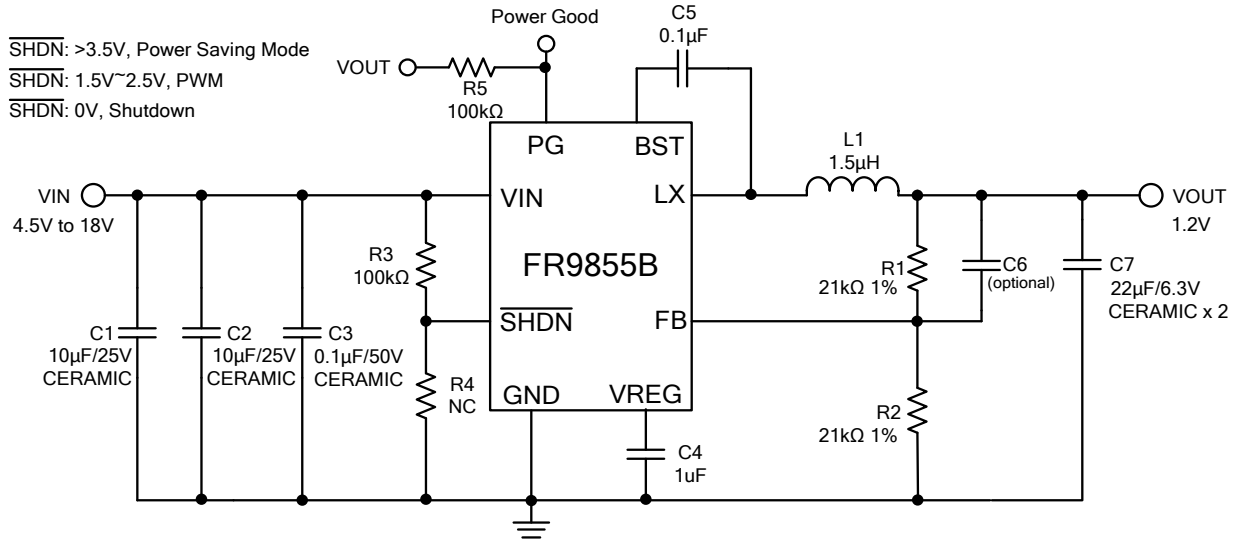


Figure 2. Application Circuit

$V_{IN}=12V$, the recommended BOM list is as below.

V _{OUT}	C1	R1	R2	C2	C6	L1	C7
1.05V	10µF MLCC x2	15.8kΩ	21kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
1.2V	10µF MLCC x2	21kΩ	21kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
1.8V	10µF MLCC x2	42kΩ	21kΩ	10µF MLCC	5pF~33pF	1.5µH	22µF MLCC x2
3.3V	10µF MLCC x2	95.3kΩ	21kΩ	10µF MLCC	5pF~33pF	2.2µH	22µF MLCC x2
5V	10µF MLCC x2	154kΩ	21kΩ	10µF MLCC	5pF~33pF	3.3µH	22µF MLCC x2

Table 1. Recommended Component Values

Functional Pin Description

Pin Name	Pin No. (SOP-8EP)	Pin No. (TDFN3x3-10)	Pin Function
SHDN	1	1	This pin includes enable the converter on/off, and select operation mode (The mode setting, please refer to the following page 11). Connect VIN with a 100kΩ resistor for self-startup and operate in power saving mode.
FB	2	2	Voltage feedback input pin. Connect FB and VOUT with a resistive voltage divider. This IC senses feedback voltage via FB and regulates it at 0.6V.
VREG	3	3	Internal regulator output. Connect a 1μF capacitor to GND to stabilize the internal regulator voltage.
PG	4	4	Open drain power good output.
GND	5	5	Ground pin.
LX	6	6,7	Power switching node. Connect an external inductor to this switching node.
BST	7	8	High side gate drive boost pin. A capacitor rating between 0.1μF~1μF must be connected from this pin to LX. It can boost the gate drive to fully turn on the internal high side NMOS.
VIN	8	9,10	Power supply input pin. Placed input capacitors as close as possible from VIN to GND to avoid noise influence.
Exposed Pad	9	11	Ground pin. The exposed pad must be soldered to a large PCB area and connected to GND for maximum power dissipation.

Block Diagram

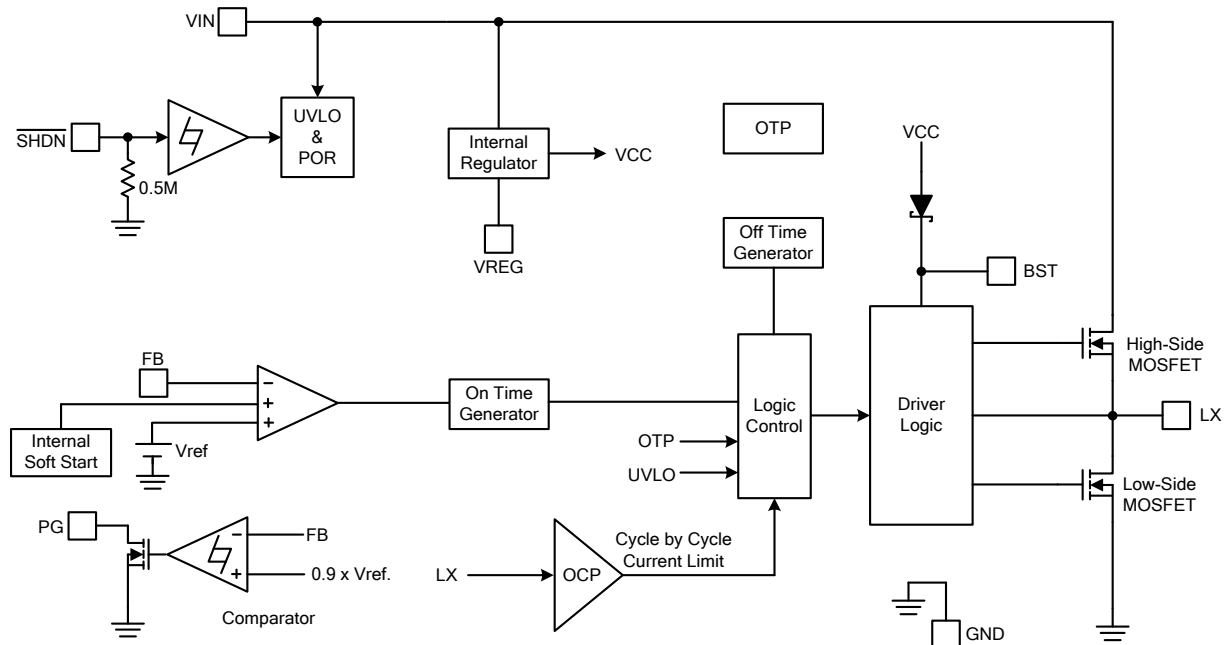


Figure 3. Block Diagram of FR9855B

Absolute Maximum Ratings ^(Note 1)

- Supply Voltage V_{IN} ----- -0.3V to +20V
- Enable Voltage $V_{\overline{SHDN}}$ ----- -0.3V to +20V
- LX Voltage V_{LX} ----- -0.3 to $V_{IN}+0.3V$
- Dynamic LX Voltage in 15ns Duration----- -5V to $V_{IN}+5V$
- BST Pin Voltage V_{BST} ----- -0.3V to $V_{LX}+6.5V$
- All Other Pins Voltage ----- -0.3V to +6V
- Maximum Junction Temperature (T_J) ----- +150°C
- Storage Temperature (T_S) ----- -65°C to +150°C
- Lead Temperature (Soldering, 10sec.) ----- +260°C
- Package Thermal Resistance, (θ_{JA}) ^(Note 2)
 - SOP-8 (Exposed Pad) ----- 60°C/W
 - TDFN-10 (3mmx3mm) ----- 65°C/W
- Package Thermal Resistance, (θ_{JC}) ^(Note 2)
 - SOP-8 (Exposed Pad) ----- 15°C/W
 - TDFN-10 (3mmx3mm) ----- 30°C/W

Note 1: Stresses beyond this listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

Note 2: θ_{JA} is measured at 25°C ambient with the component mounted on a high effective thermal conductivity 4-layer board of JEDEC-51-7. θ_{JC} is measured at the exposed pad. The thermal resistance greatly varies with layout, copper thickness, number of layers and PCB size.

Recommended Operating Conditions

- Supply Voltage V_{IN} ----- +4.5V to +18V
- Operation Temperature Range ----- -40°C to +85°C

Electrical Characteristics

($V_{IN}=12V$, $T_A=25^{\circ}C$, unless otherwise specified.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
V_{IN} Quiescent Current	I_{DDQ}	$V_{\overline{SHDN}}=5V$, $V_{FB}=1V$		0.6	1	mA
V_{IN} Shutdown Supply Current	I_{SD}	$V_{\overline{SHDN}}=0V$		1	10	μA
Feedback Voltage	V_{FB}	$4.5V \leq V_{IN} \leq 18V$	0.588	0.6	0.612	V
Feedback Input Current	I_{FB}	$V_{FB}=1V$		0.01	0.1	μA
High-Side MOSFET $R_{DS(ON)}$	$R_{DS(ON)}$			70		m Ω
Low-Side MOSFET $R_{DS(ON)}$	$R_{DS(ON)}$			38		m Ω
Current Limit ^(Note 3)	I_{LIMIT}			6.8		A
On Time ^(Note 3)	T_{ON}	$V_{IN}=12V$, $V_{OUT}=1.05V$		155		ns
Minimum Off Time	$T_{OFF(MIN)}$	$V_{FB}=0.6V$		250		ns
Input Supply Voltage UVLO Threshold	$V_{UVLO(Vth)}$	V_{IN} Rising		4.1		V
UVLO Threshold Hysteresis	$V_{UVLO(HYS)}$			0.35		V
Internal Soft Start Period	T_{SS}			1		ms
$\overline{SHDN}$ Input Low Voltage	$V_{\overline{SHDN}(L)}$				0.5	V
$\overline{SHDN}$ Input High Voltage	$V_{\overline{SHDN}(H)}$		1.5			V
REG Output Voltage	V_{REG}	$6V \leq V_{IN} \leq 18V$		4.1		V
REG Output Current	I_{REG}	$V_{REG}=4.1V$		10		mA
Power Good Threshold ^(Note 3)	V_{PG}	V_{FB} Rising		90		%
		V_{FB} Falling		85		
Power Good Sink Current	I_{PG}	$V_{PG}=0.5V$		4		mA
Thermal Shutdown Threshold ^(Note 3)	T_{SD}			160		$^{\circ}C$
Thermal Shutdown Hysteresis ^(Note 3)	T_{HYS}			30		$^{\circ}C$

Note 3: Not production tested.

Typical Performance Curves

$V_{IN}=12V$, $V_{OUT}=1.2V$, $C1=10\mu F \times 2$, $C7=22\mu F \times 2$, $L1=1.5\mu H$, $T_A=+25^\circ C$, unless otherwise noted. This is measured by using FR9855BSP.

$V_{OUT}=1.05V$

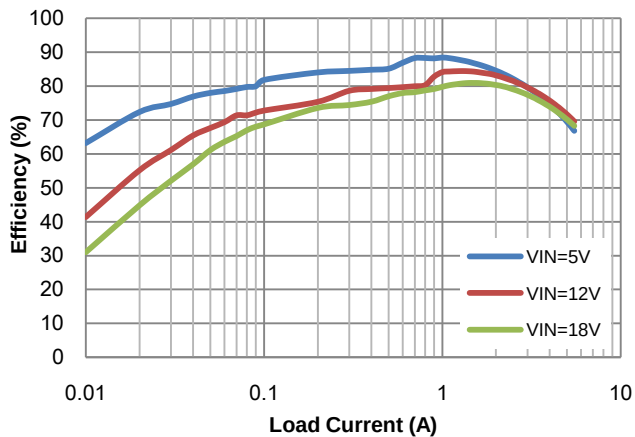


Figure 4. Efficiency vs. Load Current

$V_{OUT}=1.2V$

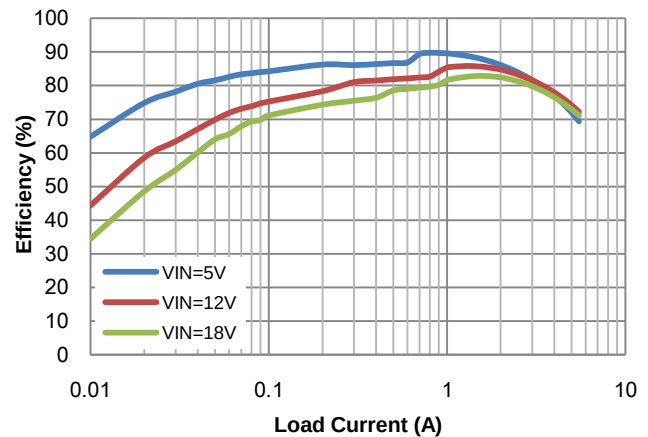


Figure 5. Efficiency vs. Load Current

$V_{OUT}=3.3V$

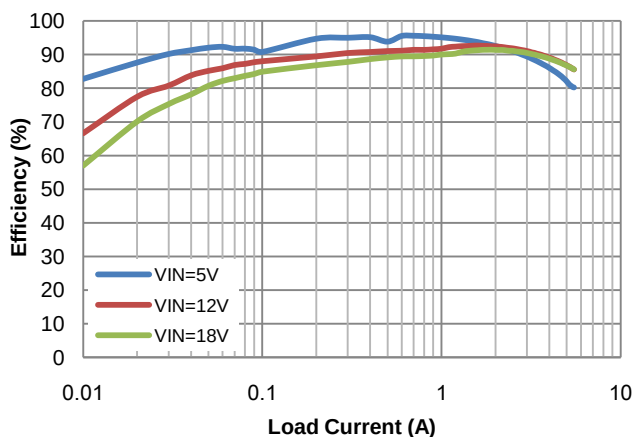


Figure 6. Efficiency vs. Load Current

$V_{OUT}=5V$

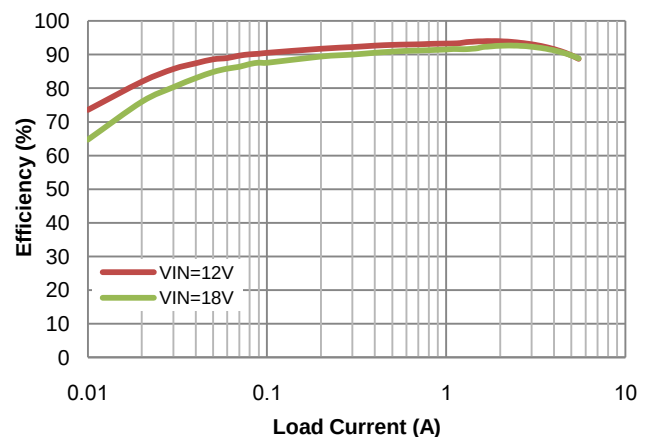


Figure 7. Efficiency vs. Load Current

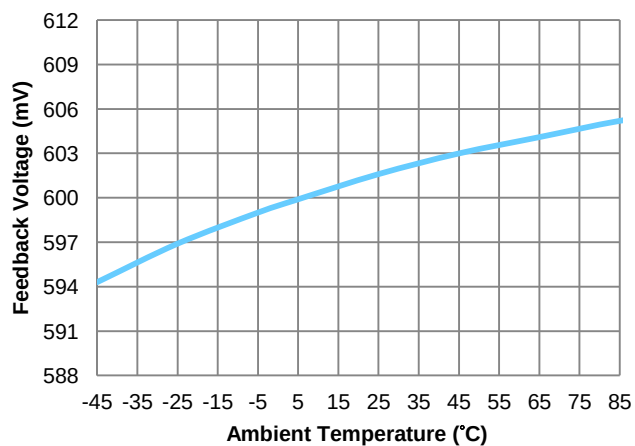


Figure 8. Feedback Voltage vs. Ambient Temperature

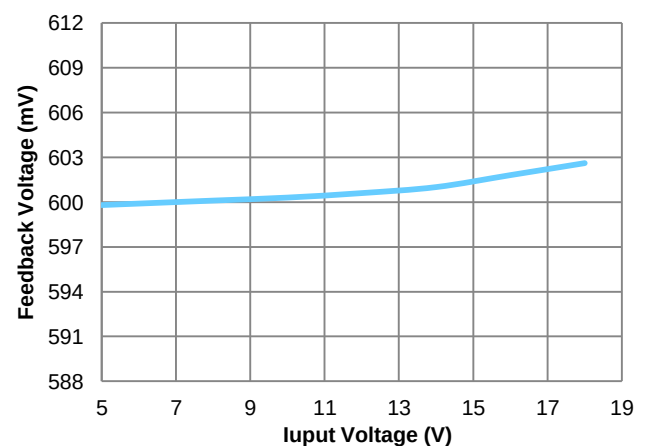


Figure 9. Feedback Voltage vs. Input Voltage

Typical Performance Curves (Continued)

$V_{IN}=12V$, $V_{OUT}=1.2V$, $C1=10\mu F \times 2$, $C7=22\mu F \times 2$, $L1=1.5\mu H$, $T_A=+25^\circ C$, unless otherwise noted. This is measured by using FR9855BSP.

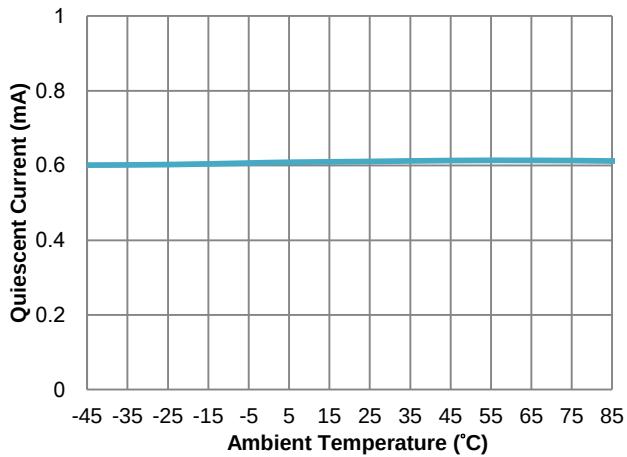


Figure 10. Quiescent Current vs. Ambient Temperature

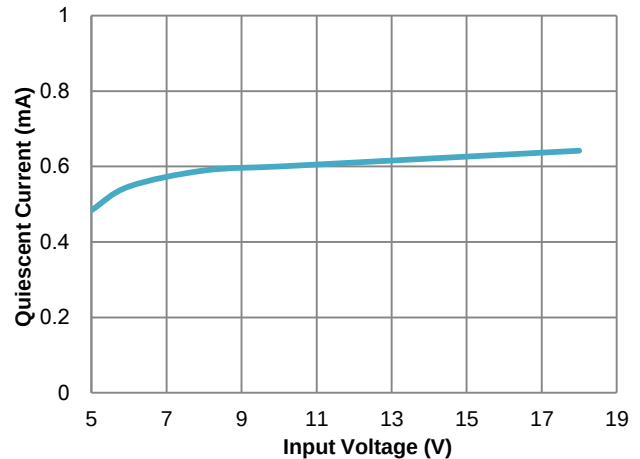


Figure 11. Quiescent Current vs. Input Voltage

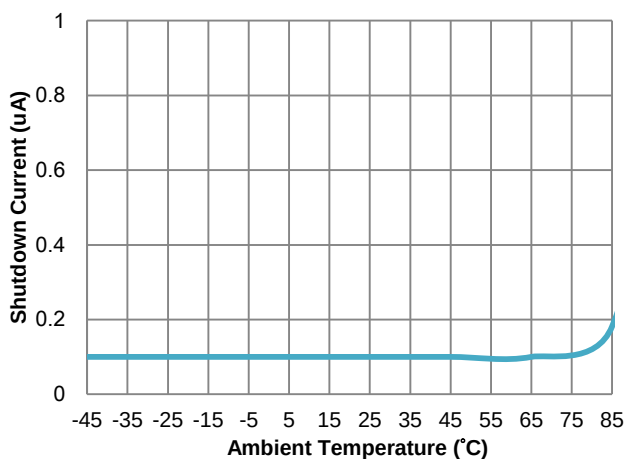


Figure 12. Shutdown Current vs. Ambient Temperature

$V_{IN}=12V$, $V_{SHDN}=2V$, $V_{OUT}=1V$, $L=1.5\mu H$

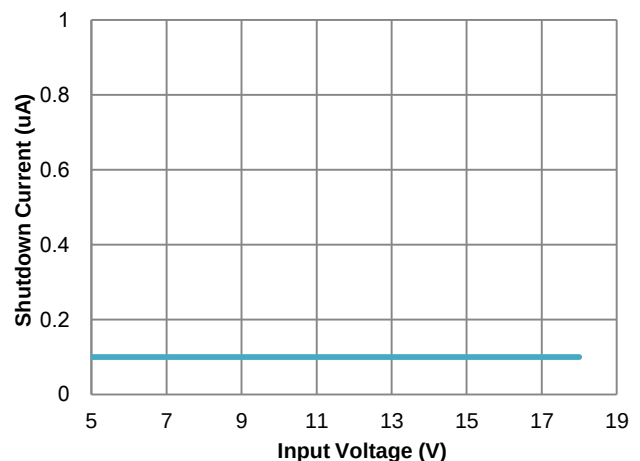


Figure 13. Shutdown Current vs. Input Voltage

$V_{IN}=12V$, $V_{SHDN}=2V$, $V_{OUT}=5V$, $L=3.3\mu H$

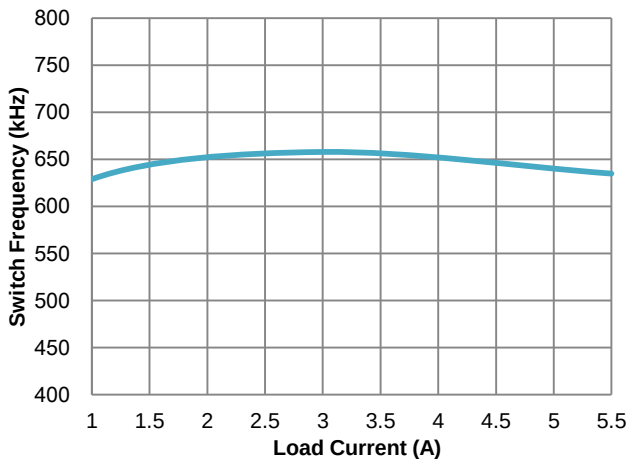


Figure 14. Switch Frequency vs. Load Current

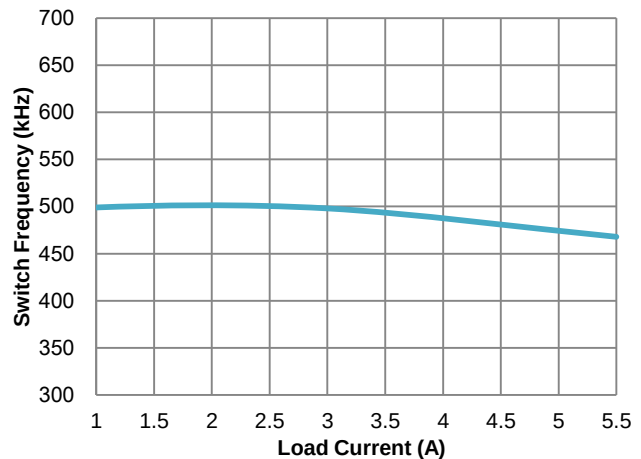
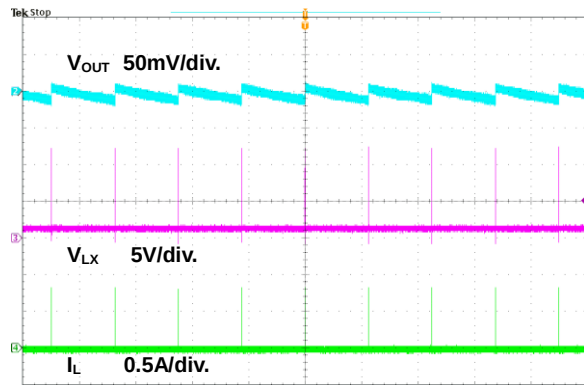


Figure 15. Switch Frequency vs. Load Current

Typical Performance Curves (Continued)

$V_{IN}=12V$, $V_{OUT}=1.2V$, $C1=10\mu F \times 2$, $C7=22\mu F \times 2$, $L1=1.5\mu H$, $T_A=+25^\circ C$, unless otherwise noted. This is measured by using FR9855BSP.

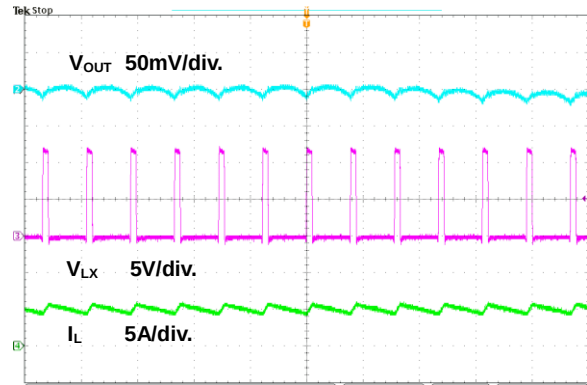
$I_{OUT}=0A$



10ms/div.

Figure 16. DC Ripple Waveform

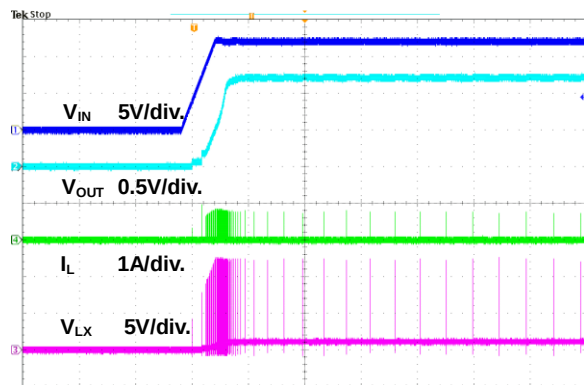
$I_{OUT}=5.5A$



2μs/div.

Figure 17. DC Ripple Waveform

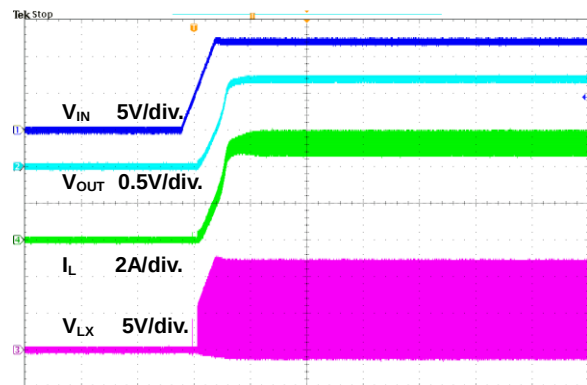
$I_{OUT}=0A$



20ms/div.

Figure 18. Startup Through Power Supply Waveform

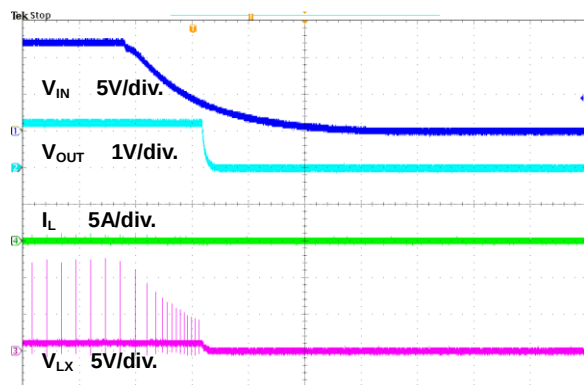
$I_{OUT}=5.5A$



20ms/div.

Figure 19. Startup Through Power Supply Waveform

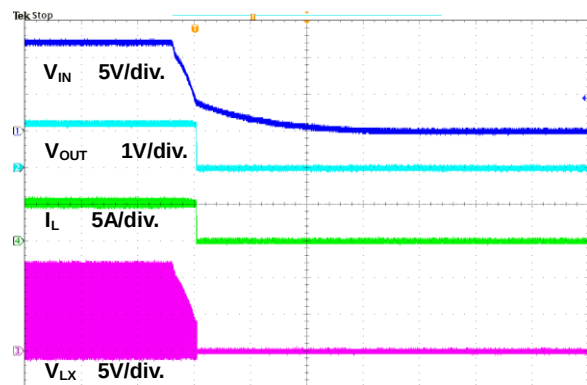
$I_{OUT}=0A$



40ms/div.

Figure 20. Shutdown Through Power Supply Waveform

$I_{OUT}=5.5A$



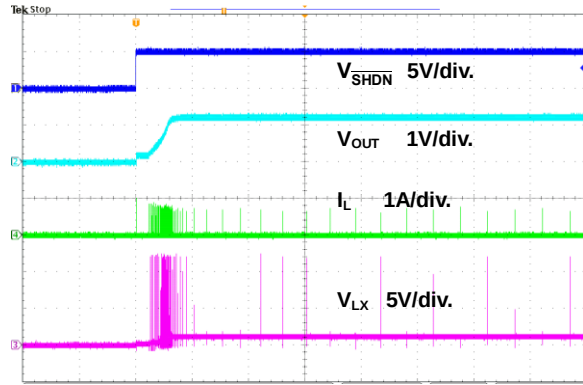
40ms/div.

Figure 21. Shutdown Through Power Supply Waveform

Typical Performance Curves (Continued)

$V_{IN}=12V$, $V_{OUT}=1.2V$, $C1=10\mu F \times 2$, $C7=22\mu F \times 2$, $L1=1.5\mu H$, $T_A=+25^\circ C$, unless otherwise noted. This is measured by using FR9855BSP.

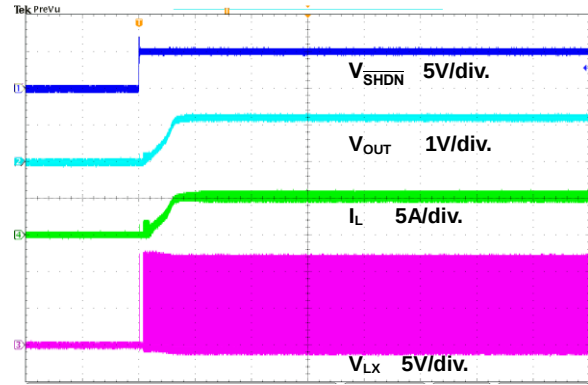
$I_{OUT}=0A$



20ms/div.

Figure 22. Startup Through $\overline{SHDN}$ Waveform

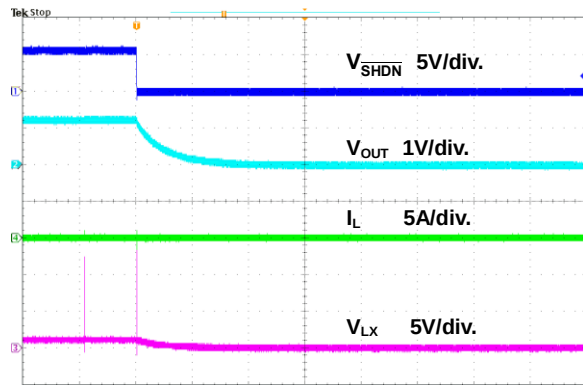
$I_{OUT}=5.5A$



20ms/div.

Figure 23. Startup Through $\overline{SHDN}$ Waveform

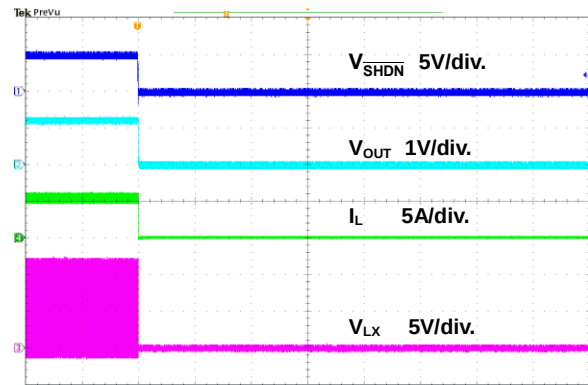
$I_{OUT}=0A$



4ms/div.

Figure 24. Shutdown Through $\overline{SHDN}$ Waveform

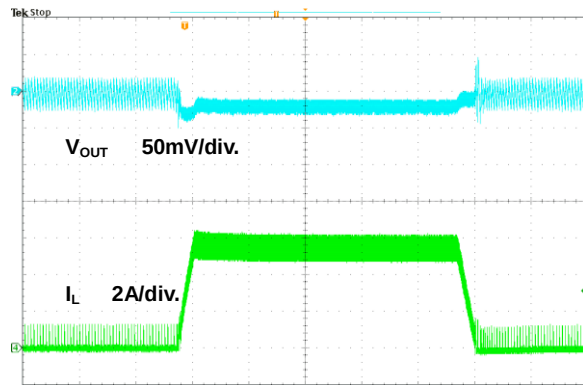
$I_{OUT}=5.5A$



4ms/div.

Figure 25. Shutdown Through $\overline{SHDN}$ Waveform

$I_{OUT}=0.1A \sim 5.5A$



200µs/div.

Figure 26. Load Transient Waveform

Function Description

The FR9855B is a synchronous step-down DC/DC converter with fast constant on time (FCOT) mode control. It has integrated high-side (70mΩ, typ) and low-side (38mΩ, typ) power switches, and provides 5.5A continuous load current. It regulates input voltage from 4.5V to 18V, and down to an output voltage as low as 0.6V. Using FCOT control scheme provides fast transient response, which can minimize the component size without additional external compensation network.

Enable/Mode

The FR9855B $\overline{\text{SHDN}}$ pin includes enable and mode function. Enable function provides digital control to turn on/off the converter. When the voltage of $\overline{\text{SHDN}}$ exceeds the threshold voltage, the converter starts the soft start function. If the $\overline{\text{SHDN}}$ pin voltage is below than the shutdown threshold voltage, the converter will turn into the shutdown mode and the shutdown current will be smaller than 1μA. The mode function can be selected in PWM or power saving mode. The mode setting can refer to following table.

$\overline{\text{SHDN}}$	Mode
>3.5V	Power Saving Mode
1.5V~2.5V	PWM
0V	Shutdown

For auto start-up operation, connect $\overline{\text{SHDN}}$ to VIN through a 100kΩ resistor, and the converter can automatically enter power saving mode.

Soft Start

The FR9855B employs internal soft start function to reduce input inrush current during start up. The typical value of internal soft start time is 1ms.

Power Good Signal Output (PG)

PG pin is an open-drain output and requires a pull up resistor. PG is actively held low in soft-start, standby and shutdown. It is released when the output voltage rises above 90% of nominal regulation point.

Input Under Voltage Lockout

When the FR9855B is power on, the internal circuits are held inactive until V_{IN} voltage exceeds the input UVLO threshold voltage. And the regulator will be disabled when V_{IN} is below the input UVLO threshold voltage. The hysteric of the UVLO comparator is 350mV (typ).

Over Current Protection

The FR9855B over current protection function is implemented using cycle-by-cycle current limit architecture. The inductor current is monitored by Low-side MOSFET. When the load current increases, the inductor current also increases. When the valley inductor current reaches the current limit threshold, the output voltage starts to drop. When the over current condition is removed, the output voltage returns to the regulated value.

Short Circuit Protection

The FR9855B provides short circuit protection function to prevent the device damage from short condition. When the short condition occurs and the feedback voltage drops lower than 0.33V, the oscillator frequency will be reduced naturally and hiccup mode will be triggered to prevent the inductor current increasing beyond the current limit. Once the short condition is removed, the frequency will return to normal.

Over Temperature Protection

The FR9855B 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. And the hysteric of the over temperature protection is 30°C (typ).

Application 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 0.6V. Thus the output voltage equation is:

$$V_{OUT} = 0.6V \times \left(1 + \frac{R1}{R2}\right)$$

Table 2 lists recommended values of R1 and R2 for most used output voltage.

Table 2 Recommended Resistance Values

V_{OUT}	R1	R2
5V	154k Ω	21k Ω
3.3V	95.3k Ω	21k Ω
1.8V	42k Ω	21k Ω
1.2V	21k Ω	21k Ω
1.05V	15.8k Ω	21k Ω

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

Input Capacitor Selection

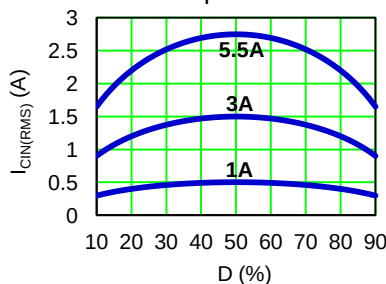
The use of the input capacitor is filtering the input voltage ripple and the MOSFETS switching spike voltage. Because the input current to the step-down converter is discontinuous, the input capacitor is required to supply the current to the converter to keep the DC input voltage. The capacitor voltage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

$$I_{CIN(RMS)} = I_{OUT} \times \sqrt{D \times (1-D)}$$

$$D = \frac{V_{OUT}}{V_{IN}}$$

Where D is the duty cycle of the power MOSFET.

This function reaches the maximum value at $D=0.5$ and the equivalent RMS current is equal to $I_{OUT}/2$. The following diagram is the graphical representation of above equation.



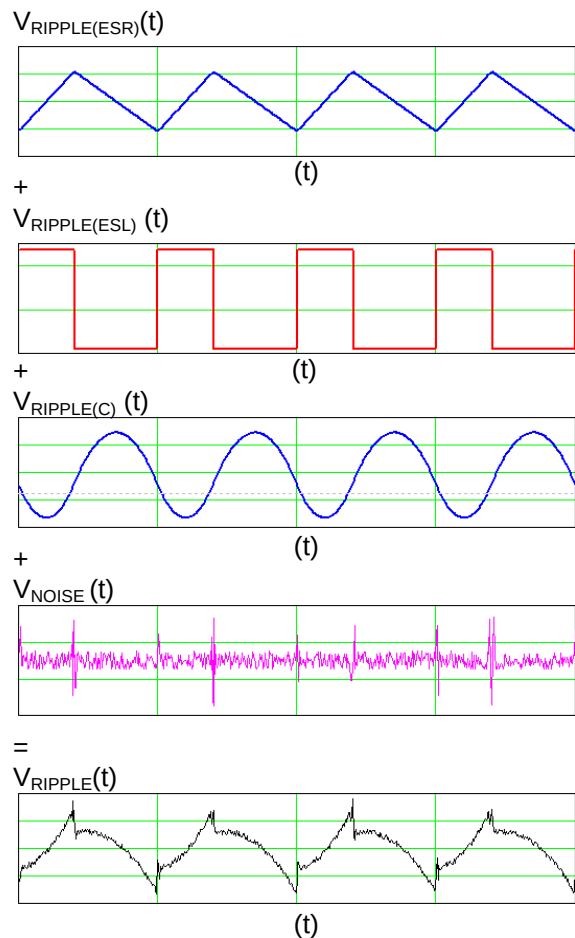
A low ESR capacitor is required to keep the noise minimum. Ceramic capacitors are better, but tantalum or low ESR electrolytic capacitors may also suffice. When using tantalum or electrolytic capacitors, a 0.1 μ F ceramic capacitor should be placed as close to the IC as possible.

Output Capacitor Selection

The output capacitor is used to keep the DC output voltage and supply the load transient current. When operating in constant current mode, the output ripple is determined by four components:

$$V_{RIPPLE}(t) = V_{RIPPLE(C)}(t) + V_{RIPPLE(ESR)}(t) + V_{RIPPLE(ESL)}(t) + V_{NOISE}(t)$$

The following figures show the form of the ripple contributions.



Application Information (Continued)

$$V_{\text{RIPPLE(ESR)}} = \frac{V_{\text{OUT}}}{F_{\text{OSC}} \times L} \times \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right) \times \text{ESR}$$

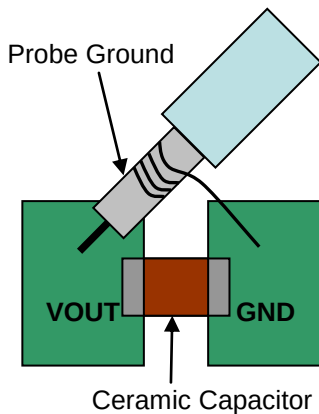
$$V_{\text{RIPPLE(ESL)}} = \frac{\text{ESL}}{L} \times V_{\text{IN}}$$

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

Where F_{OSC} is the switching frequency, L is the inductance value, V_{IN} is the input voltage, ESR is the equivalent series resistance value of the output capacitor, ESL is the equivalent series inductance value of the output capacitor and the C_{OUT} is the output capacitor.

Low ESR capacitors are preferred to use. Ceramic, tantalum or low ESR electrolytic capacitors can be used depending on the output ripple requirement. When using the ceramic capacitors, the ESL component is usually negligible.

It is important to use the proper method to eliminate high frequency noise when measuring the output ripple. The figure shows how to locate the probe across the capacitor when measuring output ripple. Removing the scope probe plastic jacket in order to expose the ground at the tip of the probe. It gives a very short connection from the probe ground to the capacitor and eliminating noise.



Inductor Selection

The output inductor is used for storing energy and filtering output ripple current. 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 result in lower output ripple voltage. The ΔI_L is inductor peak-to-peak ripple current:

$$\Delta I_L = \frac{V_{\text{OUT}}}{F_{\text{OSC}} \times L} \times \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right)$$

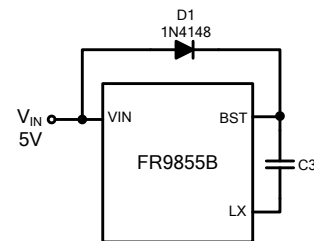
A good compromise value between size and efficiency is to set the peak-to-peak inductor ripple current ΔI_L equal to 30% of the maximum load current. But setting the peak-to-peak inductor ripple current ΔI_L between 20%~50% of the maximum load current is also acceptable. Then the inductance can be calculated with the following equation:

$$\Delta I_L = 0.3 \times I_{\text{OUT(MAX)}}$$

$$L = \frac{(V_{\text{IN}} - V_{\text{OUT}}) \times V_{\text{OUT}}}{V_{\text{IN}} \times F_{\text{OSC}} \times \Delta I_L}$$

External Diode Selection

For 5V input applications, it is recommended to add an external boost diode. This helps improving the efficiency. The boost diode can be a low cost one such as 1N4148.



REG Capacitor Selection

Connect a 1uF ceramic capacitor between the REG and GND. This helps stabilize the internal regulator voltage.

Application Information (Continued)

PCB Layout Recommendation

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

1. Place the input capacitors and output capacitors as close to the device as possible. Trace to these capacitors should be as short and wide as possible to minimize parasitic inductance and resistance.
2. Place feedback resistors close to the FB pin.
3. Keep the sensitive signal (FB) away from the switching signal (LX).
4. 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 connecting to the exposed pad should be maximized to improve thermal performance.
5. Multi-layer PCB design is recommended.

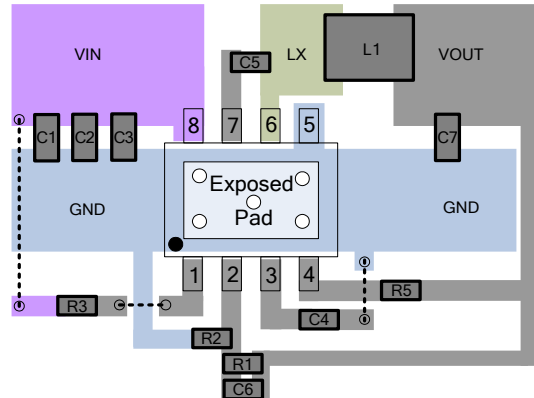


Figure 27. Recommended PCB Layout Diagram for SP Package

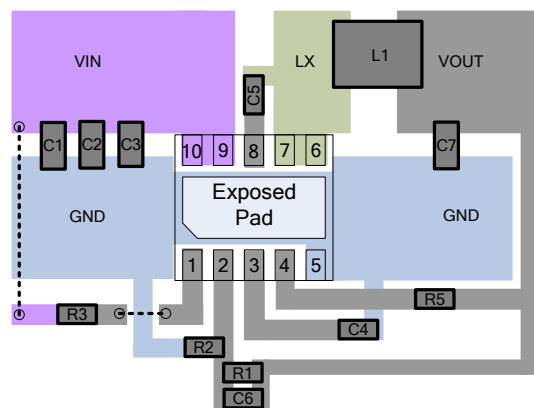
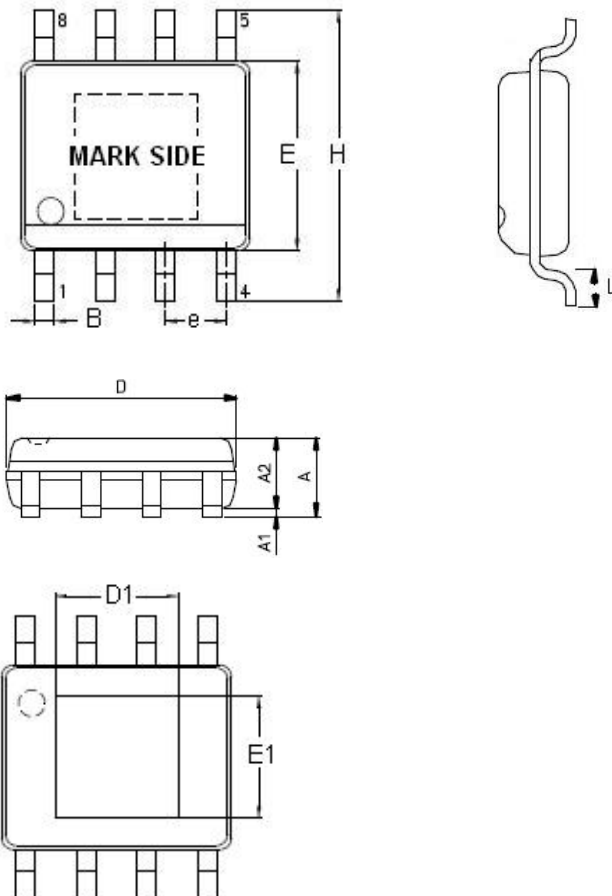


Figure 28. Recommended PCB Layout Diagram for DA Package

Outline Information

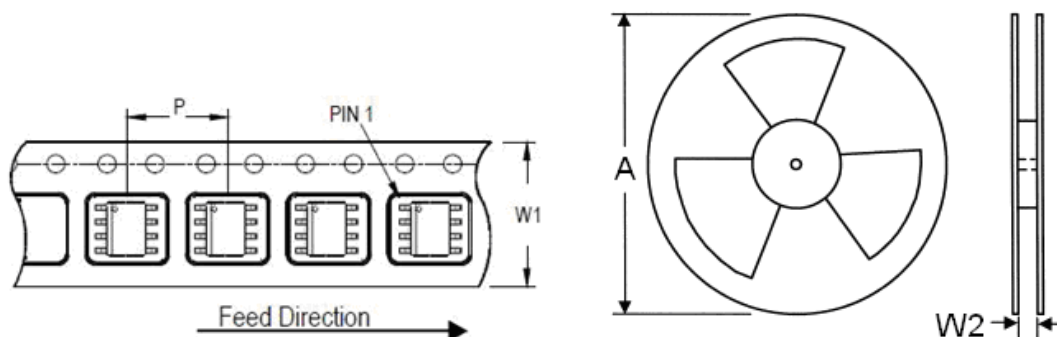
SOP-8 (Exposed Pad) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	1.25	1.70
A1	0.00	0.15
A2	1.25	1.55
B	0.31	0.51
D	4.80	5.00
D1	3.04	3.50
E	3.80	4.00
E1	2.15	2.41
e	1.20	1.34
H	5.80	6.20
L	0.40	1.27

Note: Followed From JEDEC MO-012-E.

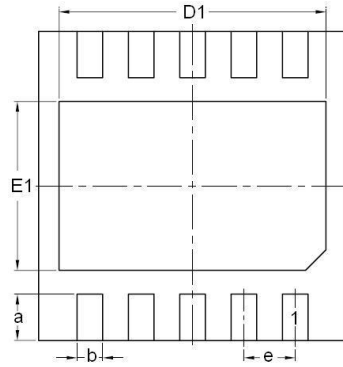
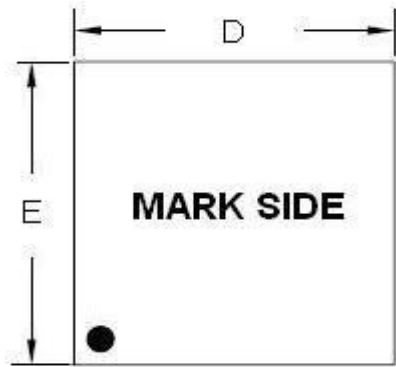
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	2,500

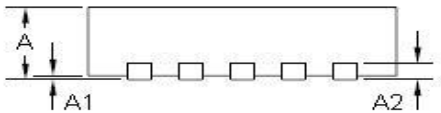
Outline Information (Continued)

TDFN-10 3mmx3mm (pitch 0.5 mm) Package (Unit: mm)

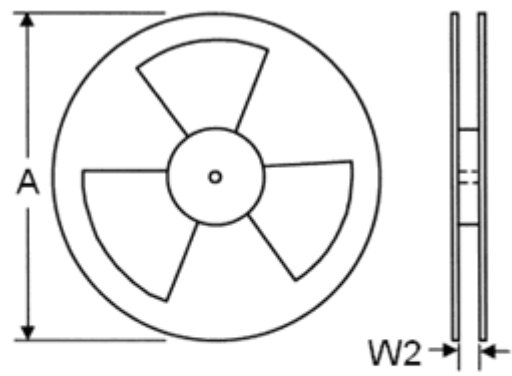
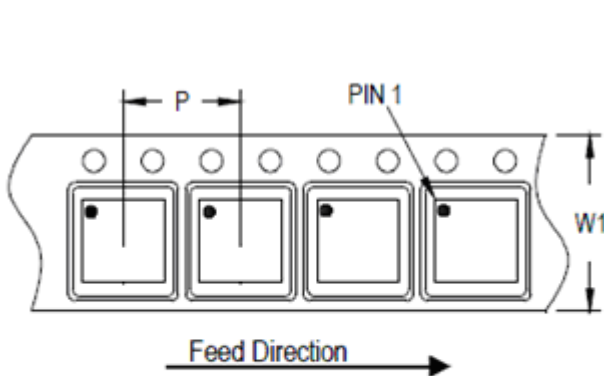


SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.18	0.25
D	2.95	3.05
E	2.95	3.05
a	0.30	0.50
b	0.18	0.30
e	0.45	0.55
D1	2.20	2.70
E1	1.40	1.75

Note: Followed From JEDEC MO-229F.



Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	3,000

Life Support Policy

Fitipower's products are not authorized for use as critical components in life support devices or other medical systems.