36V, 5A, 130KHz Synchronous Step-Down DC/DC Converter for Charger Application

Description

The FR9838 is a dual-channel synchronous step-down DC/DC converter that provides wide 4.5V to 36V input voltage range and 5A load current capability. It is providing solutions for car charger, smart power strip and portable charger. The FR9838 operates in either CV (Constant Voltage) or CC (Constant Current) mode. The FR9838 can be applied to single output or dual output and provide a programmable CC threshold for current limitation. At light load condition, the FR9838 can operate at power saving mode to support high efficiency and reduce power loss.

The FR9838 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. This device uses current mode control scheme which provides fast transient response. Internal compensation function reduces external compensatory components and simplifies the design process. In shutdown mode, the supply current is about 1mA.

The FR9838 is offered in TDFN-10L (5mm x 6mm) package, which provides good thermal conductance.

Features

- Wide Input Voltage Range: 4.5V to 36V
- Adjustable Output Voltage Down to 0.8V
- 5A Output Current
- 130kHz Switching Frequency
- Dual Channel CC/CV Mode Control
- <1mA Shutdown Current
- Internal 3ms Soft-Start
- Internal Compensation Function
- Cycle-by-Cycle Current Limit
- Hiccup Short Circuit Protection
- Input Under Voltage Lockout
- Input Over Voltage Protection
- Cable Voltage Drop Compensation
- Over-Temperature Protection with Auto Recovery
- Output Voltage Thermal Regulation
- TDFN-10L (5mm x 6mm) Package

Applications

- Car Charger
- Portable Charger Application
- Smart Power Strip

Pin Assignments

DH Package (TDFN-10L 5mm x 6mm)

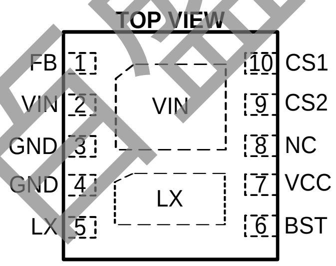


Figure 1. Pin Assignments of FR9838

Ordering Information

FR9838□

Package Type
DH: TDFN-10L 5mm x 6mm

Typical Application Circuit

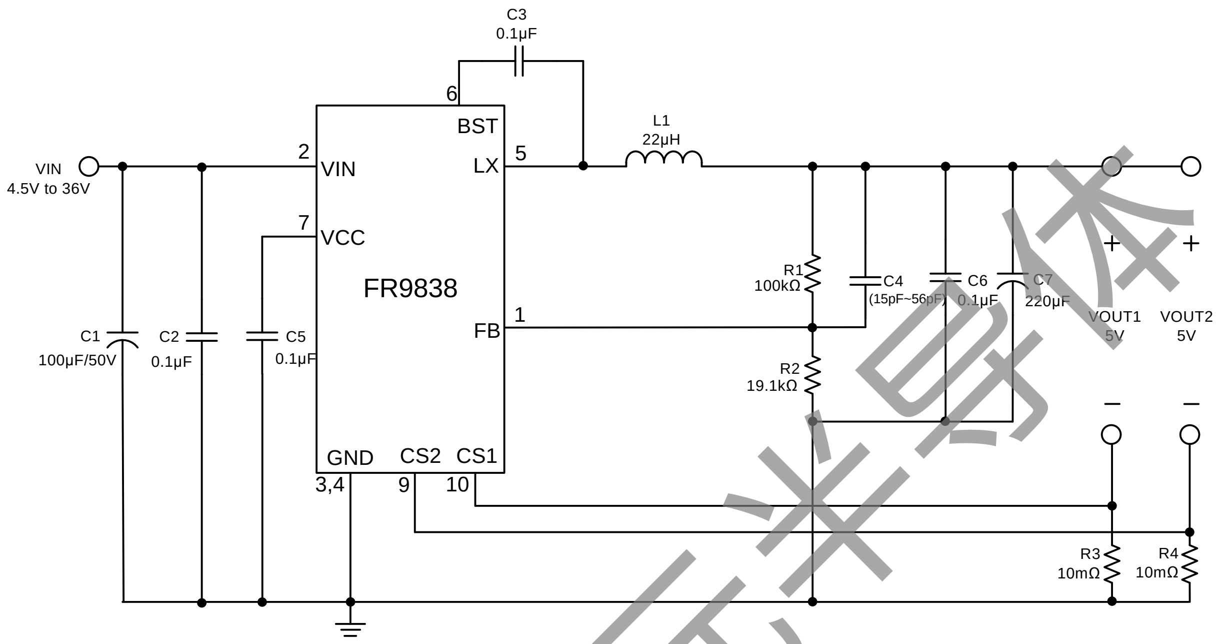


Figure 2. FR9838 Application Circuit

Functional Pin Description

Pin Name	Pin No.	Pin Function
FB	**1**	Voltage feedback input pin. Connect FB and VOUT with a resistive voltage divider. This IC senses feedback voltage via FB and regulates it at 0.8V.
VIN	**2**	Power supply input pin. Placed input capacitors as close as possible from VIN to GND to avoid noise influence.
GND	**3,4**	Ground pin.
LX	**5**	Power switching node. Connect an external inductor to this switching node.
BST	**6**	High side gate drive boost pin. A capacitance 100nF must be connected from this pin to LX. It can boost the gate drive to fully turn on the internal high side NMOS.
VCC	**7**	Internal regulator output. Connect a 0.1uF capacitor to GND to stabilize the internal regulator voltage.
NC	**8**	No contact.
CS2	**9**	Channel 2 current sense input pin.
CS1	**10**	Channel 1 current sense input pin.
VIN (Exposed Pad)	**-**	Power supply input pin. The exposed pad must be connected to VIN pin.
LX (Exposed Pad)	**-**	Power switching node. The exposed pad must be connected to LX pin.

Block Diagram

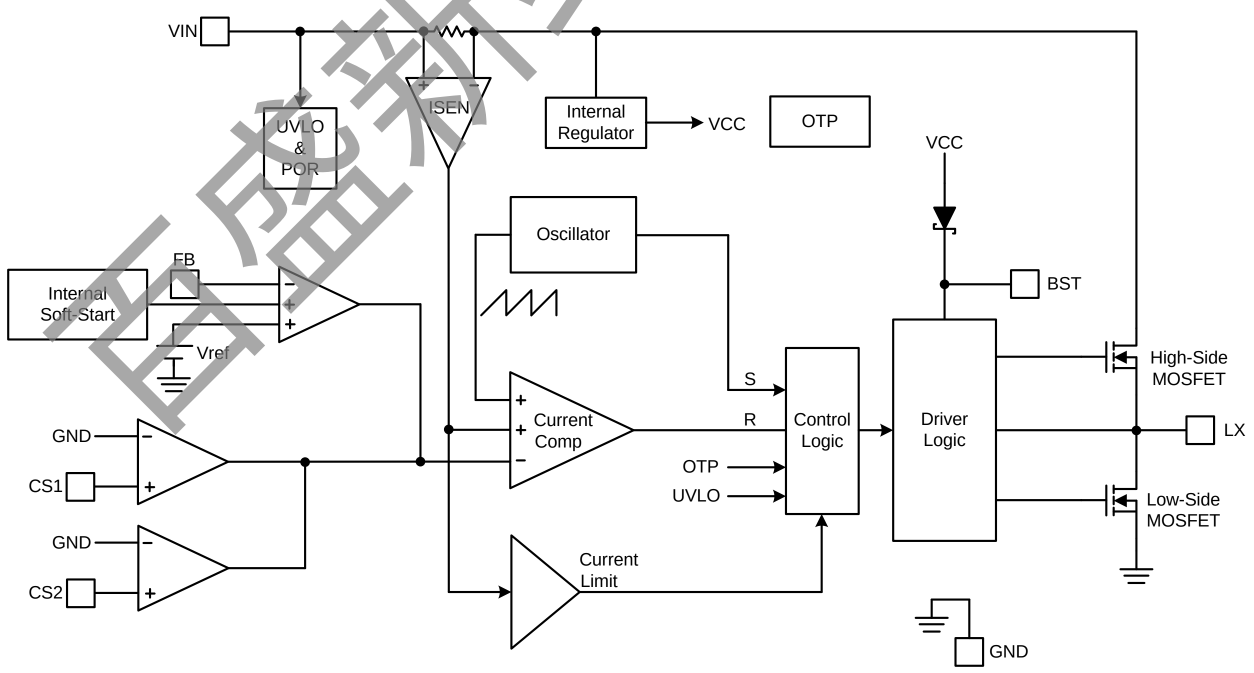


Figure 3. Block Diagram of FR9838

Absolute Maximum Ratings (Note 1)

- Supply Voltage V_{IN} ---------- -0.3V to +40V
- LX Voltage V_{LX} ---------- -0.3V to V_{IN} +0.3V
- BST Pin Voltage V_{BST} ---------- -0.3V to V_{LX} +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)
  - TDFN-10L (5mmx6mm) ---------- 37.7°C/W
- Package Thermal Resistance, (θ_{JC}) (Note 2)
  - TDFN-10L (5mmx6mm) ---------- 13°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 on 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 +36V
- Operation Temperature Range ---------- -40°C to +85°C

Electrical Characteristics

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

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
V_{IN} Input Supply Voltage	V_{IN}		4.5		36	V
Input Over Voltage Protection	V_{IN_OVP}			37.5		V
V_{IN} Under voltage Lockout Threshold	$V_{UVLO(on)}$	VIN Rising		4.15		V
	$V_{UVLO(off)}$	VIN Falling		3.75		V
Under Voltage Lockout Threshold Hysteresis	$V_{UVLO(HYS)}$			400		mV
V_{IN} Quiescent Current	I_{DDQ}	V_{FB}=1V		1		mA
CS1/CS2 Sense Voltage	V_{CS1}/V_{CS2}		33.5	36	38.5	mV
Feedback Voltage	V_{FB}	4.5V≦V_{IN}≦36V	0.788	0.8	0.812	V
Load Regulation					2	%
Internal Soft-Start Time	T_{ss}			3		ms
High-Side MOSFET R_{DS}(ON) (Note 3)	$R_{DS(ON)}$	VBST-LX = 5V		20		mΩ
Low-Side MOSFET R_{DS}(ON) (Note 3)	$R_{DS(ON)}$	LX-GND= 5V		20		mΩ
High-Side MOSFET Leakage Current (Note 3)	$I_{LX(leak)}$				10	μA
Oscillation Frequency	F_{OSC}	V_{IN}=12V		130		kHz
Maximum Duty Cycle	D_{MAX}			97		%
Minimum On Time (Note 3)	T_{ON}			150		ns
Minimum Off Time (Note 3)	T_{OFF}			192		ns
High Side Current Limit	I_{LIM}			10		A
Output Under-Voltage Trip Threshold				60		%
Output Under-Voltage Trip Threshold Hysteresis				10		%
Internal Soft-Start Period	T_{SS}			3		ms
Thermal Shutdown Threshold (Note 3)	T_{SD}			150		°C
Thermal Shutdown Hysteresis (Note 3)	$T_{SD(HYS)}$			50		°C
Cable Compensation		R1=100kΩ,R2=19.1kΩ,R4(R5)=10mΩ	90	100	110	mV/A

Note 3: Not production tested.

Typical Operating Characteristics

V_{IN}=12V,V_{OUT}=5V, T_A=25°C, unless otherwise specified.

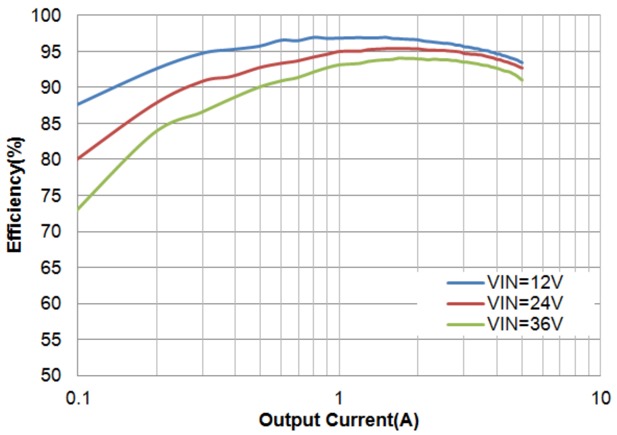


Figure 4. Efficiency vs. Output Current

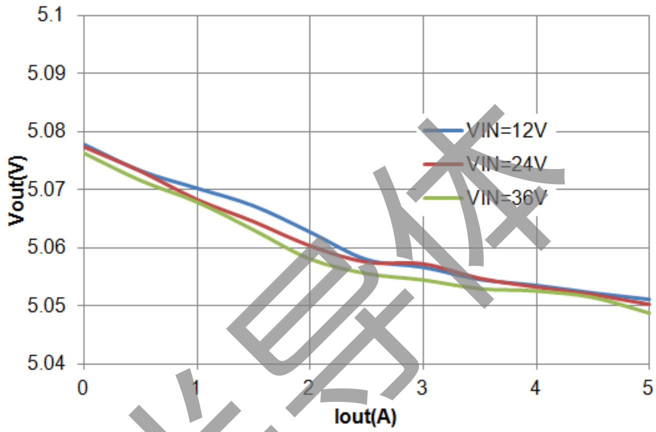


Figure 5. Output Voltage vs. Output Current

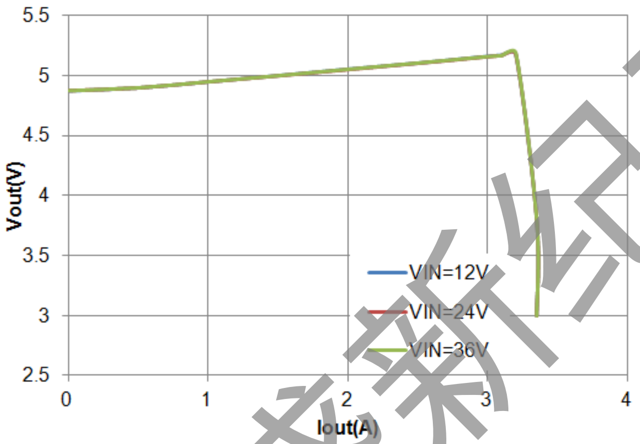


Figure 6. CS1 CC/CV Curve

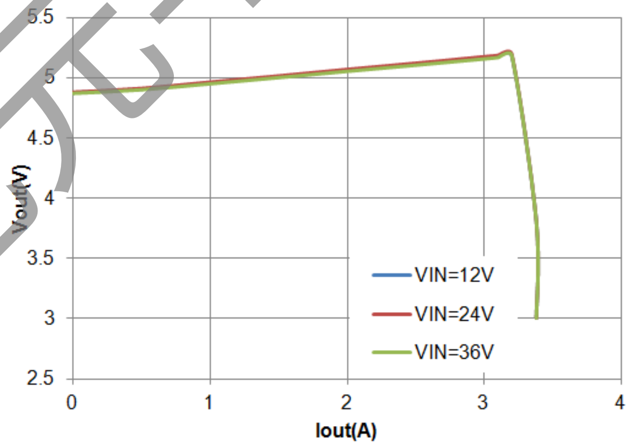


Figure 7. CS2 CC/CV Curve

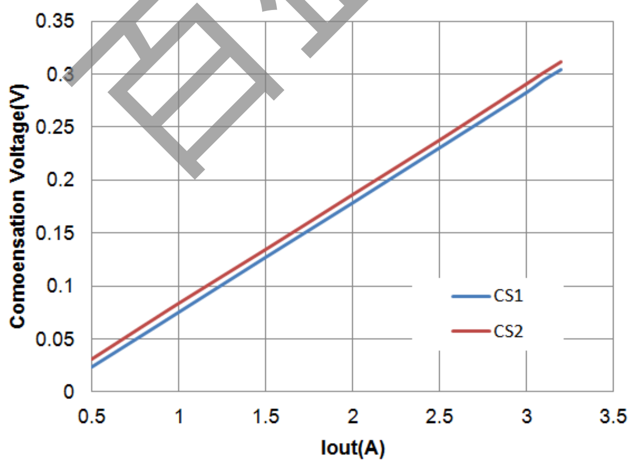


Figure 8. Cable Compensation

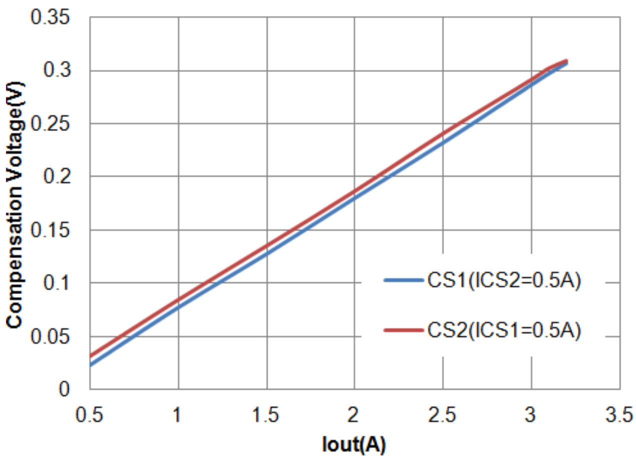
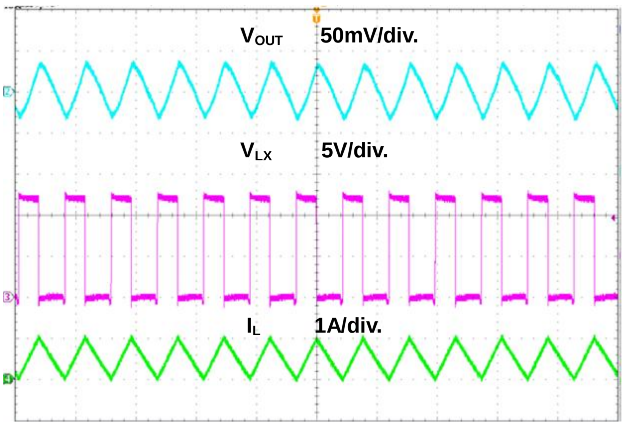


Figure 9. Cable Compensation

Typical Performance Curves (Continued)

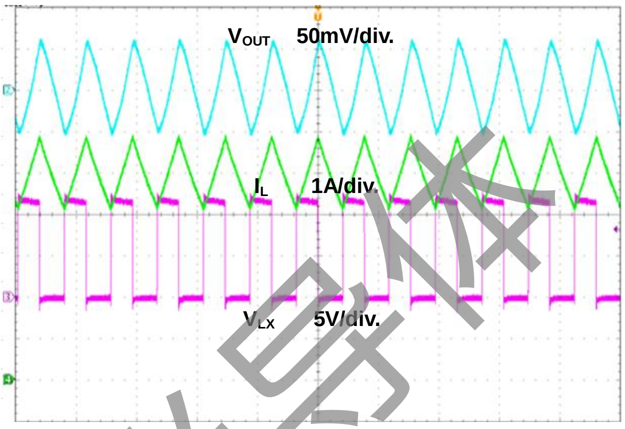
V_{IN}=12V, V_{OUT}=5V, T_A=25°C, unless otherwise noted.

I_{OUT}=0.5A



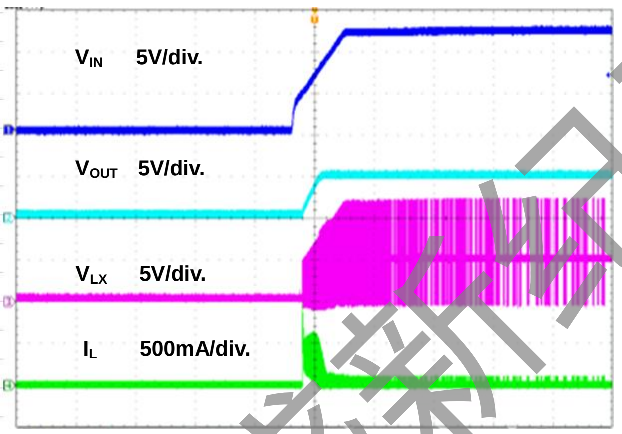
10us/div.
Figure 10. Steady State Waveform

I_{OUT}=5A



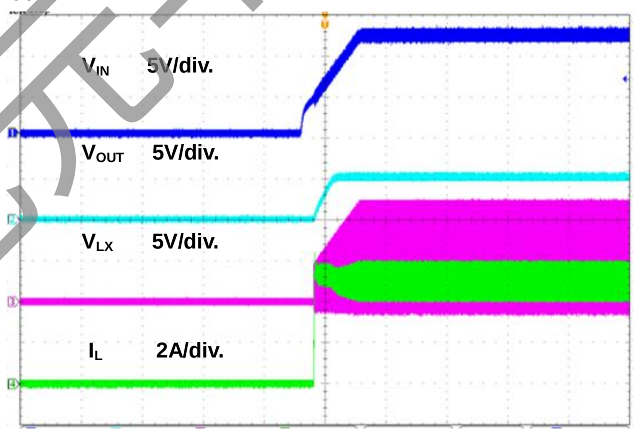
10us/div.
Figure 11. Steady State Waveform

I_{OUT}=0A



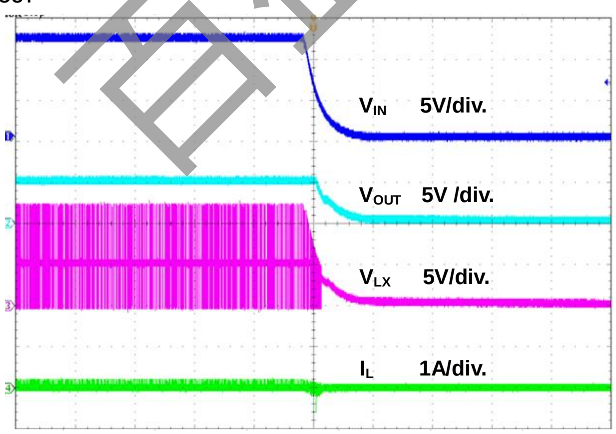
10ms/div.
Figure 12.Power On through VIN Waveform

I_{OUT}=5A



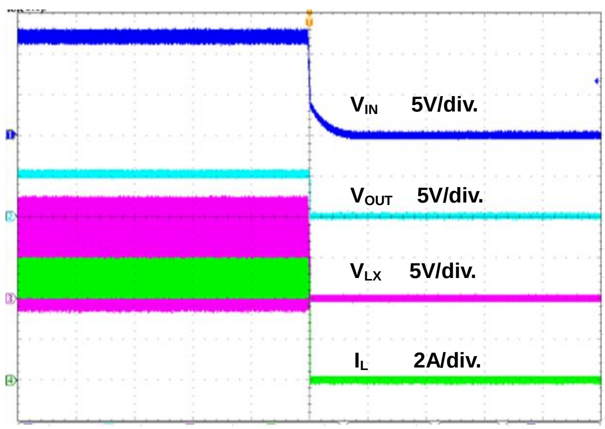
10ms/div.
Figure 13. Power On through VIN Waveform

I_{OUT}=0A



200ms/div.
Figure 14. Power Off through VIN Waveform

I_{OUT}=5A



200ms/div.
Figure 15. Power Off through VIN Waveform

Typical Performance Curves (Continued)

V_{IN}=12V, V_{OUT}=5V, T_A=25°C, unless otherwise noted.

I_{OUT}=0.1A to 5A

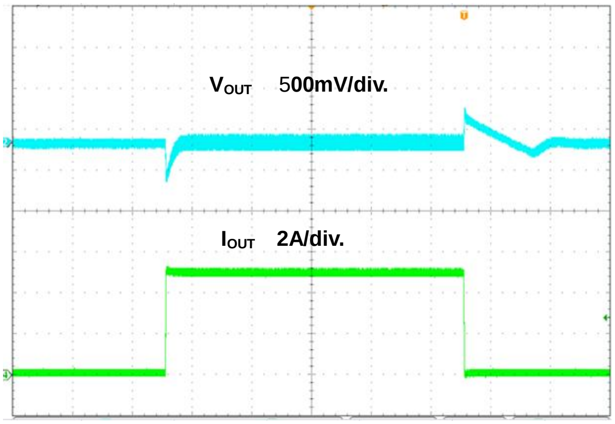


Figure 16. Load Transient Waveform

V_{OUT} Short to GND

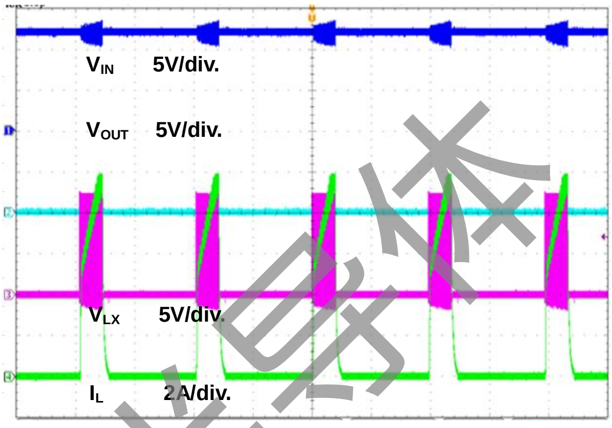


Figure 17. Short Circuit Protection

Function Description

The FR9838 is a high efficiency, internal compensation and synchronous step-down DC/DC converter with high-side (20mΩ, typ) and low side (20mΩ, typ) power switches, and provides 5A continuous load current. It regulates input voltage from 4.5V to 36V and down to an output voltage as low as 0.8V.

CC/CV mode control

The FR9838 operates in either CV mode or CC mode. The CV mode regulates the output voltage and CC mode regulates the output current. The device would switch from CV mode to CC mode for limiting the output current when output current reaches the CC threshold.

Internal Compensation Function

The stability of the feedback circuit is controlled by internal compensation circuits. This internal compensation function is optimized for most applications, and this function can reduce external R, C components.

Soft Start

The FR9838 employs internal soft start function to reduce input inrush current during start up. The typical value of internal soft start time is 3ms.

Input Under Voltage Lockout

When the FR9838 is power on, the internal circuits will be 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 hysteretic of the UVLO comparator is 400mV (typ).

Cable Voltage Drop Compensation

The FR9838 provides programmable cable voltage drop compensation using the impedance at the FB pin to compensate voltage drop across the charger's output cable. CS1 and CS2 choose the highest I_{OUT} be compensation. The cable compensation voltage can be expressed as

$$\Delta V_{OUT}=1.6\times R4\times I_{OUT}\times\left(1+\frac{R1}{R2}\right)$$

Over Current Protection

The FR9838 over current protection function is implemented by using cycle-by-cycle current limit architecture. The inductor current is monitored by measuring the high-side MOSFET series sense resistor voltage. When the load current increases, the inductor current will also increase. When the peak inductor current reaches the current limit threshold, the output voltage will start to drop. When the over current condition is removed, the output voltage will return to the regulated value.

Short Circuit Protection

The FR9838 provides short circuit protection function to prevent the device damaged from short condition. When the short condition occurs and the feedback voltage drops lower than 0.3V, hiccup mode will be triggered to prevent the FR9838 from overheating during the extended short condition. Once the short condition is removed, the FR9838 will end the hiccup mode and return to normal.

Over Temperature Protection

The FR9838 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 hysteretic of the over temperature protection is 50°C (typ).

Output Voltage Thermal Regulation

The FR9838 provides output voltage thermal regulation. When the junction temperature exceeds 130°C threshold temperature, the output voltage will drop. When the temperature continues to rise, the output voltage will continue to drop until the output is short circuited.

Input Over Voltage Protection

The FR9838 supports input over voltage protection. When input voltage exceeds the input over Voltage threshold, the regulator will be shutdown unless the input over voltage is removed. The hysteretic of the input OVP comparator is 2V (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 0.8V. Thus the output voltage equation is:

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

CC Current Setting

FR9838 channel 1 constant current value is set by the resistor R4 connected between the CS1 and GND pins. The channel 2 constant current value is set by the R5 connected between the CS2 and GND pins. In the CC mode, the voltage of CS pin will be regulated to 36mV. The CC current value is calculated as:

$$I_{cs1}=\frac{36mV}{R4}$$

$$I_{cs2}=\frac{36mV}{R5}$$

Input Capacitor Selection

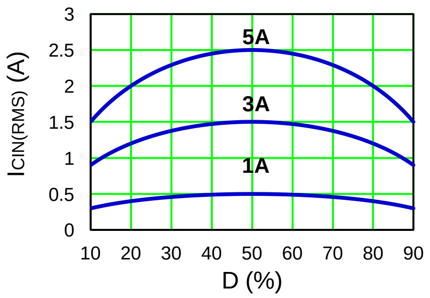
The use of the input capacitor is filtering the input voltage ripple and the MOSFETS switching spike voltage. Because the input current to the step-down converter is discontinuous, the input capacitor is required to supply the current to the converter to keep the DC input voltage. The capacitor voltage 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.



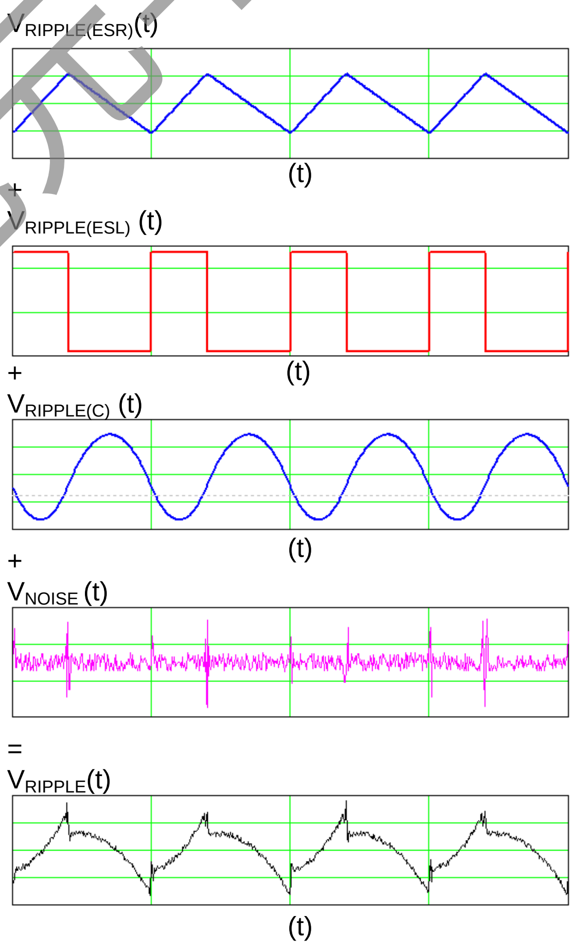
A low ESR capacitor is required to keep the noise minimum. Ceramic capacitors are better, but tantalum or low ESR electrolytic capacitors may also suffice. When using tantalum or electrolytic capacitors, a 0.1μF ceramic capacitor should be placed as close to the IC as possible.

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)

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

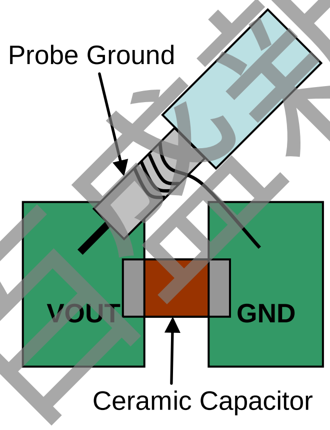
$$V_{RIPPLE(ESL)}=\frac{ESL}{L}\times V_{IN}$$

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

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.



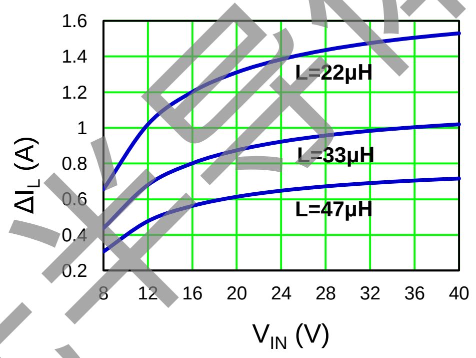
Inductor Selection

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:

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

The following diagram is an example to graphically represent ΔI_L equation.



V_{OUT}=5V, F_{OSC}=130kHz

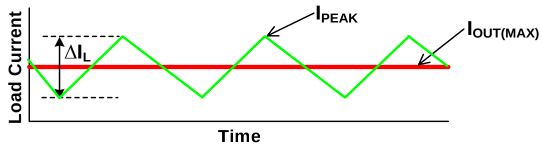
A good compromise value between size and efficiency is to set the peak-to-peak inductor ripple current ΔI_L equal to 30% of the maximum load current. But setting the peak-to-peak inductor ripple current ΔI_L between 20%~50% of the maximum load current is also acceptable. Then the inductance can be calculated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

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

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

To guarantee sufficient output current, peak inductor current must be lower than the FR9838 high-side MOSFET current limit. The peak inductor current is shown as below:

$$I_{PEAK}=I_{OUT(MAX)}+\frac{\Delta I_L}{2}$$



Application Information (Continued)

PCB Layout Recommendation

The proper PCB layout and component placement are critical for all switch mode power supplies. The noise-sensitive feedback and compensation circuitry are isolated from the high-frequency switching nodes. The careful attention should be taken to the high-frequency and high current loops. Use wide and short traces for the main current paths. Here are some suggestions to the layout of FR9838 design.

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 equal amount of metal area on the PCB.
5. The VIN and LX plane area connecting to the exposed pad should be maximized, and use multiple vias to connect to the intermediate PCB power plane.
6. The GND plane area and connecting vias should be maximized to improve thermal performance.
7. Multi-layer PCB design is recommended.

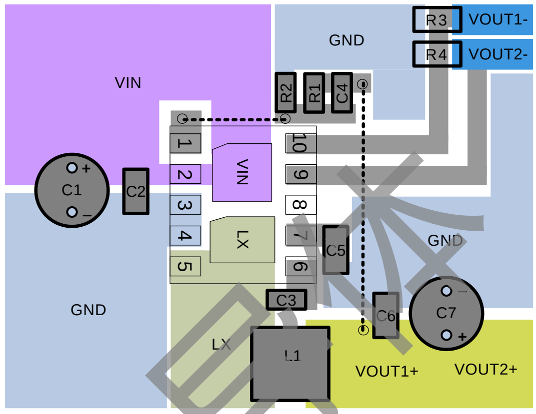
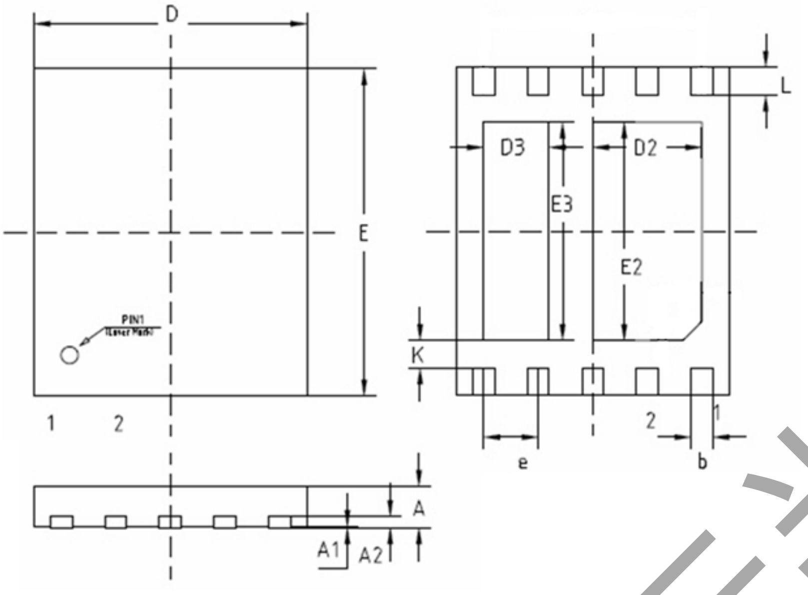


Figure 18. Recommended PCB Layout Diagram

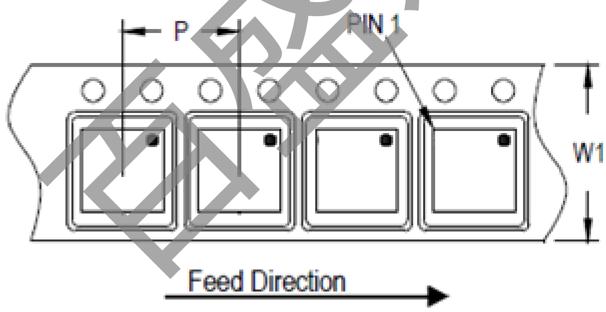
Outline Information

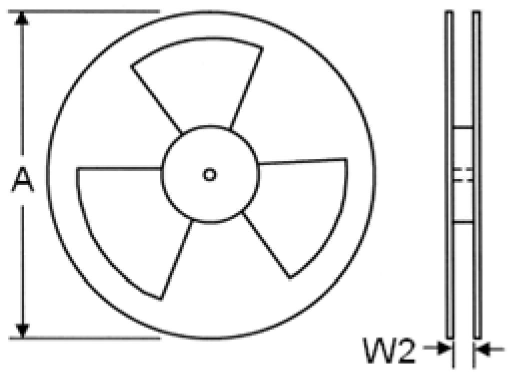
TDFN- 10L 6mm x 5mm (pitch 1.00 mm)   Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.203 REF	
D	4.90	5.10
E	5.90	6.10
b	0.35	0.45
K	0.45 MIN	
L	0.45	0.55
e	1.00 BSC	
D2	1.90	2.10
E2	3.90	4.10
D3	1.10	1.30
E3	3.90	4.10

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.