Dual Channel Charge Pump Controller

General Description

The RT9399 is a highly integrated step-up charge pump and inverting charge pump to generate positive and negative output voltage. The RT9399 is available in the XDFN-12SL 3x1.5 package to achieve optimized solution for PCB space.

Ordering Information

RT9399□□

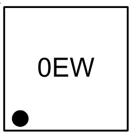
- Package Type
  QX : XDFN-12SL 3x1.5 (X-Type)
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Marking Information



0E : Product Code

W : Date Code

Features

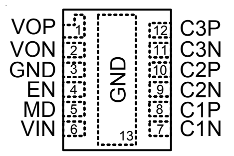
- **2.5V to 4.5V Supply Voltage Range**
- **Over 80% Average Efficiency of Battery Life**
- **Support up to 50mA Output Current**
- **Low 1μA Shutdown Current**
- **Internal Soft-Start Function**
- **Short Circuit Protection Function**
- **x2 Mode for Positive Voltage and x–1 Mode for Negative Voltage**
- **Low Input Noise and EMI**
- **Available in 12S-Lead XDFN Package**
- **RoHS Compliant and Halogen Free**

Applications

- Applications for Power Conversion

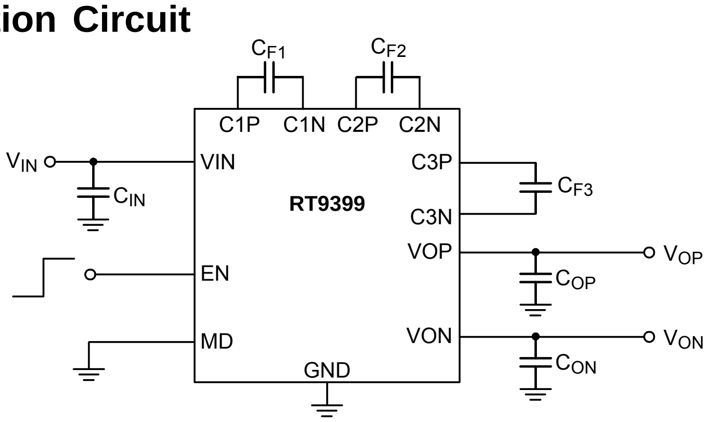
Pin Configuration

(TOP VIEW)



XDFN-12SL 3x1.5

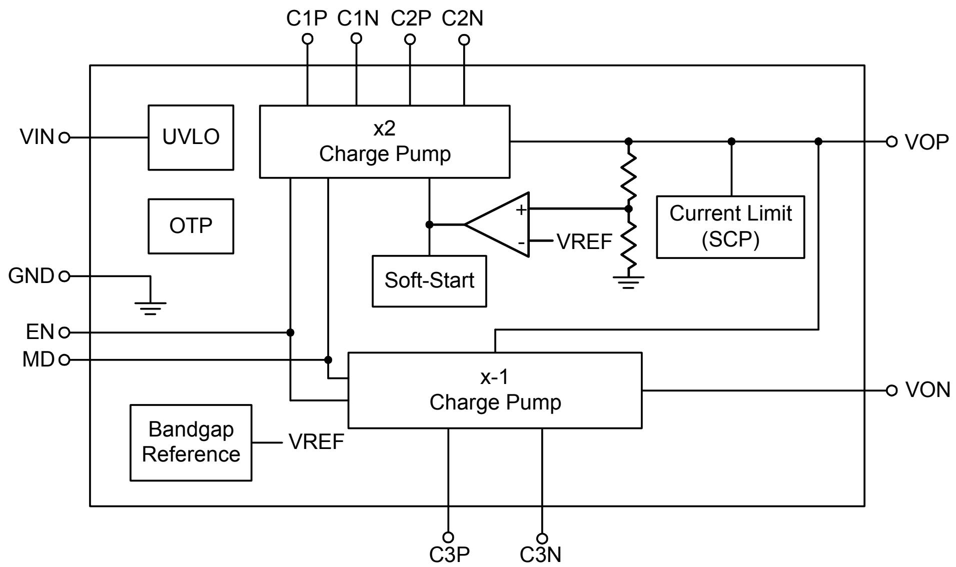
Simplified Application Circuit



Functional Pin Description

Pin No.	Pin Name	Pin Function
1	VOP	Positive terminal output.
2	VON	Negative terminal output.
3	GND	Ground.
4	EN	Charge pump enable.
5	MD	Charge pump mode selection. (Connect to GND for X2 mode)
6	VIN	Power input.
7	C1N	Fly capacitor 1 negative connection.
8	C1P	Fly capacitor 1 positive connection.
9	C2N	Fly capacitor 2 negative connection.
10	C2P	Fly capacitor 2 positive connection.
11	C3N	Fly capacitor 3 negative connection.
12	C3P	Fly capacitor 3 positive connection.
13 (Exposed Pad)	GND	Ground exposed paddle (Bottom). Connect to ground.

Functional Block Diagram



Operation

The RT9399 is a highly integrated step-up charge pump and inverting charge pump to generate positive and negative output voltages. It can support input voltage range from 2.5V to 4.5V and the output current up to 50mA. During start-up procedure, the RT9399 provides soft-start function to avoid inrush current. It also provides Over-Temperature Protection (OTP) and Short-Circuit Protection (SCP) mechanisms to prevent the device from damage with abnormal operations. When the EN voltage is logic low for more than 1ms, the IC will be shut down. In shutdown mode, the input supply current for the device is less than 1μA.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VIN ---------- –0.3V to 6V
- Output Voltage, VOP, VON ---------- –0.3V to 7V
- Other Pins ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  XDFN-12SL 3x1.5 ---------- 2.88W
- Package Thermal Resistance (Note 2)
  XDFN-12SL 3x1.5, θ_{JA} ---------- 34.7°C/W
  XDFN-12SL 3x1.5, θ_{JC} ---------- 11°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{IN} = 3.3V, C_{IN} = C_{OP} = C_{ON} = 4.7μF, C_{F1} = C_{F2} = C_{F3} = 1μF, Test in X2 mode, T_A = 25°C, unless otherwise specification)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Input Supply							
Input Voltage Range		V_{IN}		2.5	--	4.5	V
Under-Voltage Lockout Threshold Voltage		V_{UVLO}		1.9	2	2.1	V
Under-Voltage Lockout Hysteresis Voltage		V_{HYS}		--	100	--	mV
Switching Frequency		f_{SW}		--	1000	--	kHz
VIN Shutdown Current		I_{SHDN}	EN = MD = 0V	--	--	1	μA
General							
System Efficiency		η1	V_{IN} = 3.3V, I_{OP} = I_{ON} = 15mA	--	84	--	%
		η2	V_{IN} = 3.3V, I_{OP} = I_{ON} = 30mA	--	86	--	
		η3	V_{IN} = 3.3V, I_{OP} = I_{ON} = 50mA	--	85	--	
VOP Output Ripple		ΔV_{OP}	V_{IN} = 3.3V, I_{OP} = I_{ON} = 10mA (Note 5)	--	10	--	mV
VON Output Ripple		ΔV_{ON}	V_{IN} = 3.3V, I_{OP} = I_{ON} = 10mA (Note 5)	--	10	--	mV
Logic Interface							
EN/MD Input Voltage	Logic-High	V_{IH}	V_{IN} = 2.5V to 4.5V	1	--	--	V
	Logic-Low	V_{IL}	V_{IN} = 2.5V to 4.5V	--	--	0.4	

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
EN/MD Input Current	I_{EN}/I_{MD}	EN = MD = 4.5V	--	2.5	10	μA
EN/MD Low to Shutdown Delay	t_{SHDN}	EN = MD = high to low	2	--	--	ms
EN/MD Rising Time	t_R		1	--	100	ns
EN/MD Falling Time	t_F		1	--	100	ns
EN/MD High Pulse Width	t_{WH}		0.1	--	--	μs
EN/MD Low Pulse Width	t_{WL}		0.1	--	--	μs
Output Voltage						
Positive Output Voltage	V_{OP}	V_{IN} = 3.3V to 4.5V	--	6	--	V
Negative Output Voltage	V_{ON}	V_{IN} = 3.3V to 4.5V	--	–6	--	V
Maximum VOP Output Current	I_{OP_MAX}	V_{IN} = 3.3V to 4.5V	50	--	--	mA
Maximum VON Output Current	I_{ON_MAX}	V_{IN} = 3.3V to 4.5V	50	--	--	mA
Static Line Regulation 1	V_{OP_LNR1}	V_{IN} = 3.3V to 4.5V, I_{OP} = I_{ON} = 5mA	--	0.1	--	%
Static Line Regulation 2	V_{OP_LNR2}	V_{IN} = 3.3V to 4.5V, I_{OP} = I_{ON} = 10mA	--	0.1	--	%
Static Line Regulation 1	V_{ON_LNR1}	V_{IN} = 3.3V to 4.5V, I_{OP} = I_{ON} = 5mA	--	0.1	--	%
Static Line Regulation 2	V_{ON_LNR2}	V_{IN} = 3.3V to 4.5V, I_{OP} = I_{ON} = 10mA	--	0.1	--	%
Static Load Regulation 1	V_{OP_LDR1}	V_{IN} = 3.3V, I_{OP} = I_{ON} = 1mA to 30mA	--	0.5	--	%
Static Load Regulation 2	V_{ON_LDR2}	V_{IN} = 3.3V, I_{OP} = I_{ON} = 1mA to 30mA	--	5	--	%
Output Voltage Undershoot/Overshoot @ TDMA Noise Test	ΔV_{OPN_TDMA1}	I_{OP} = I_{ON} = 3mA to 15mA, 0.5V pulse signal apply to V_{IN} w/ 217Hz frequency (Note 5)	--	±40	--	mV
Protection						
Input Current Limit 1	I_{SCP1}	VOP short to GND	--	200	--	mA
VOP Soft-Start Time	t_{SSP}	No load	--	1	--	ms
VON Soft-Start Time	t_{SSN}	No load	--	1	--	ms
Soft-Start Inrush Current	I_{SS}	V_{IN} = 3.3V, load = 10mA (Note 5)	--	400	--	mA
Over-Temperature Protection	T_{OTP}	(Note 5)	--	140	--	°C
Over-Temperature Protection Hysteresis	T_{OTP_HYST}	(Note 5)	--	15	--	°C

Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard. θ_{JC} is measured at the exposed pad of the package.

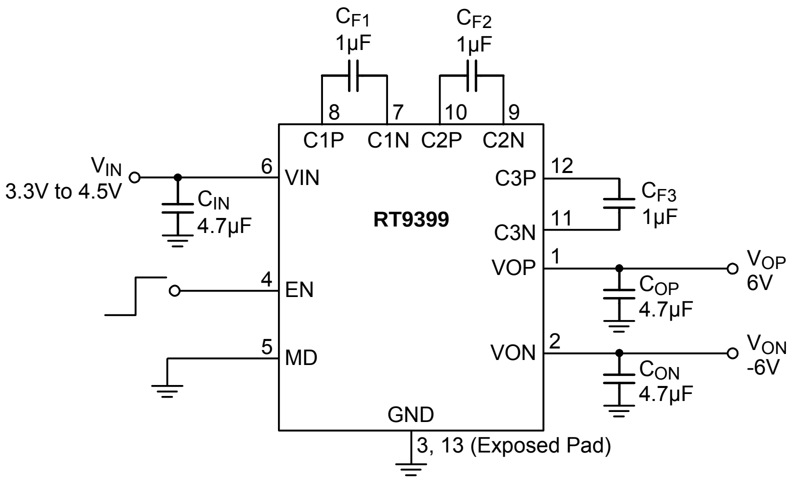
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

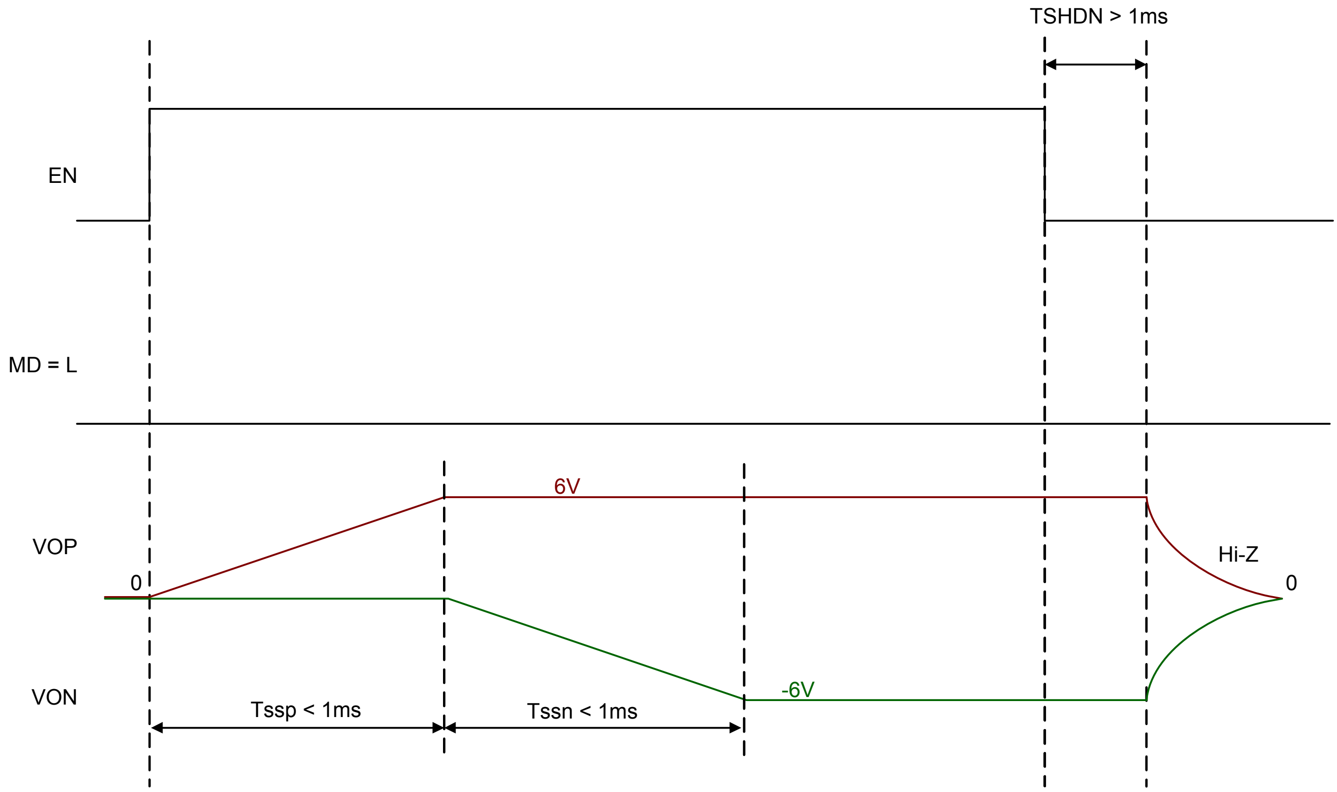
Note 5. Specifications are guaranteed by design.

Typical Application Circuit

X2 Mode Application

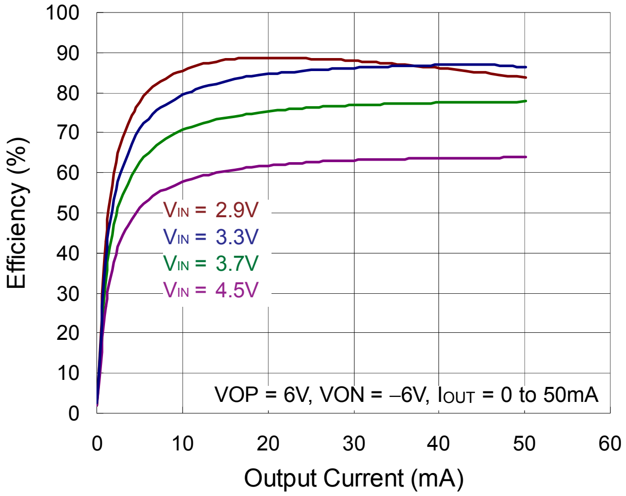


Timing Diagram

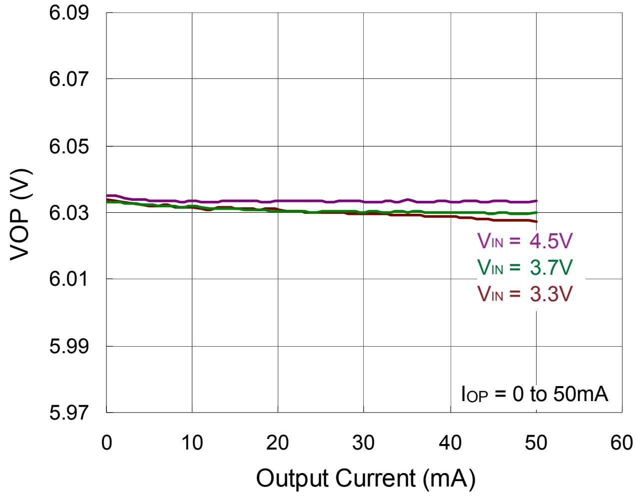


Typical Operating Characteristics

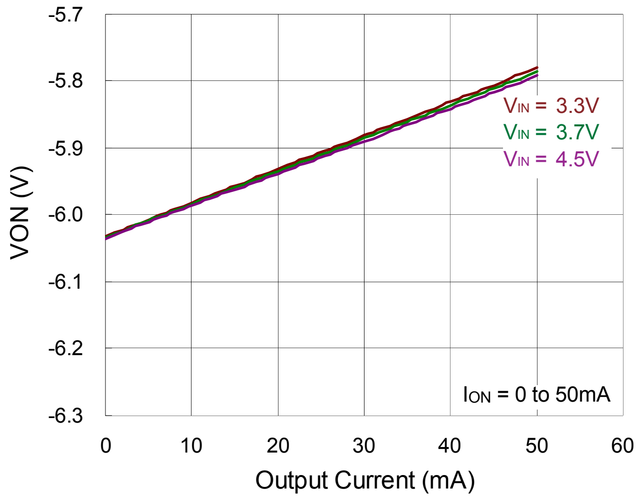
Efficiency vs. Output Current



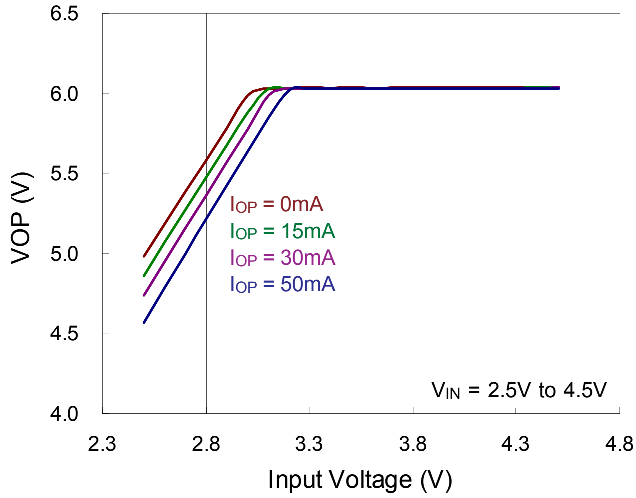
VOP vs. Output Current



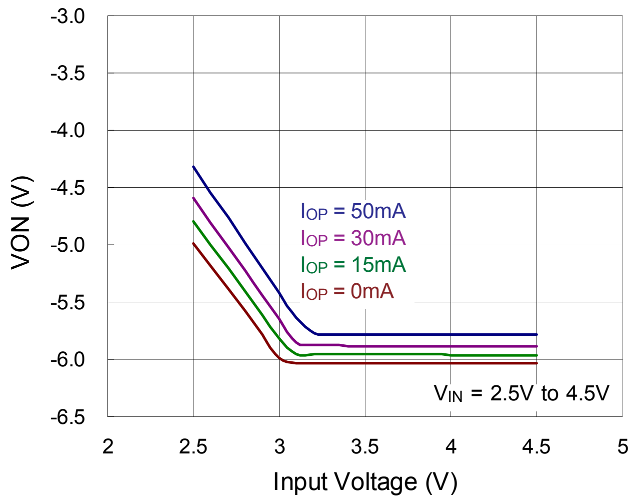
VON vs. Output Current



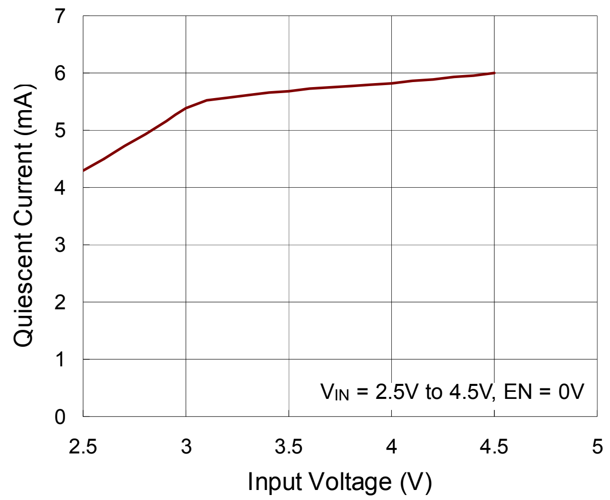
VOP vs. Input Voltage



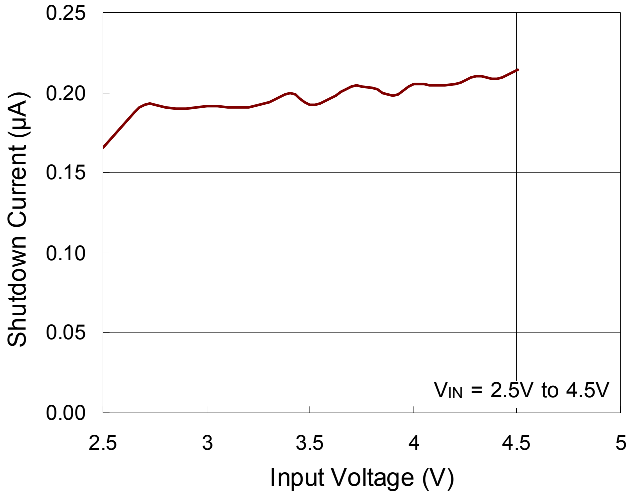
VON vs. Input Voltage



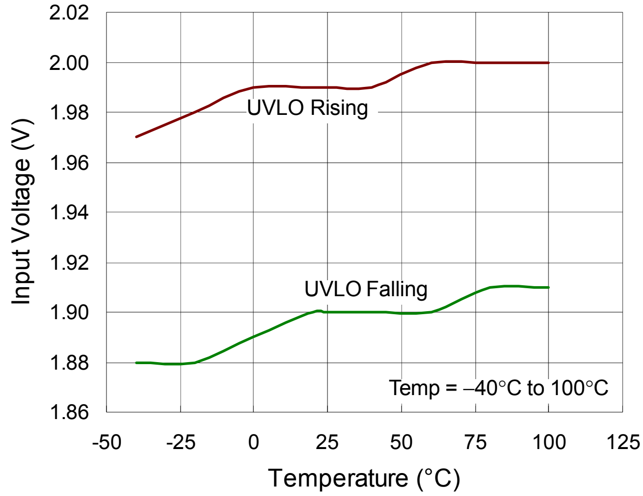
Quiescent Current vs Input Voltage



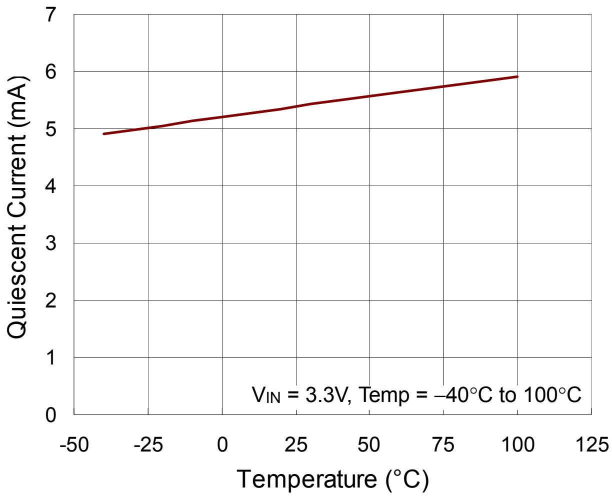
Shutdown Current vs. Input Voltage



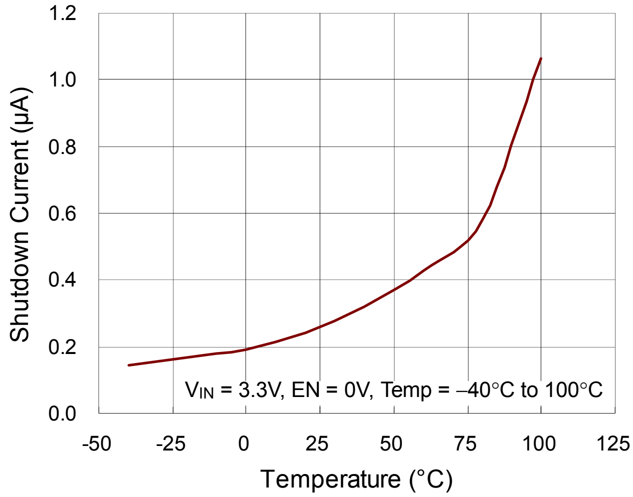
Input Voltage vs. Temperature



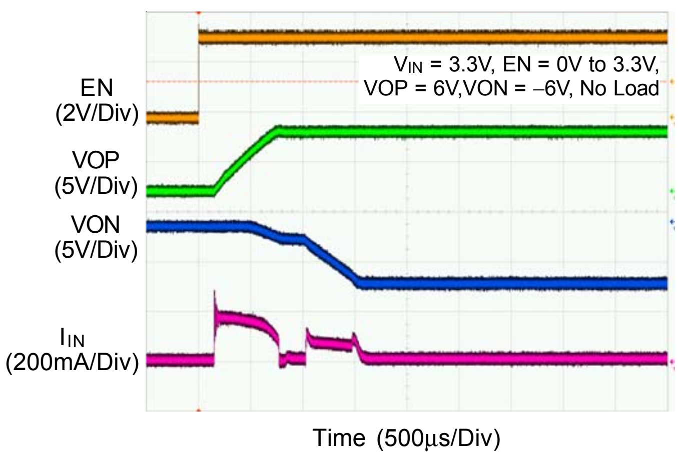
Quiescent Current vs. Temperature



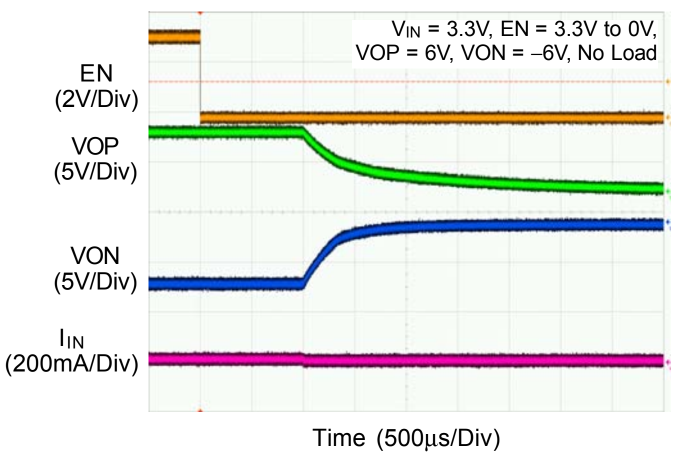
Shutdown Current vs. Temperature



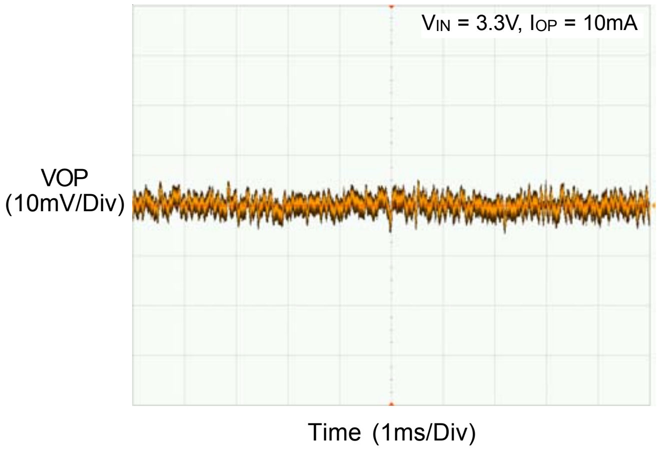
Power On



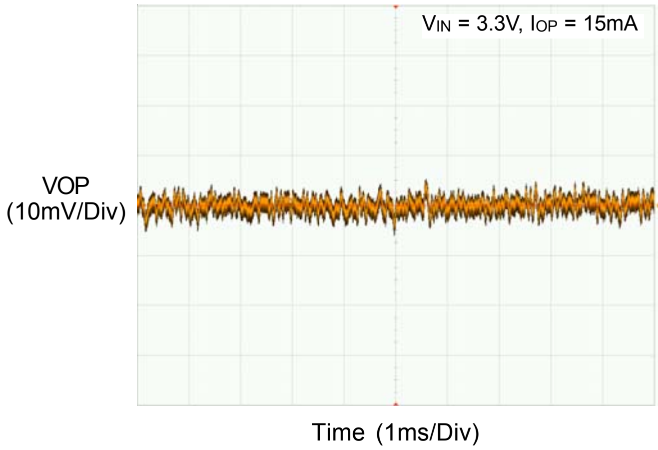
Power Off



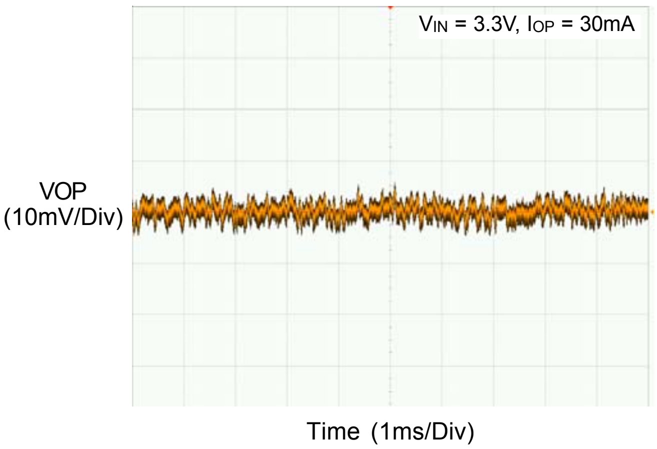
VOP Ripple Voltage



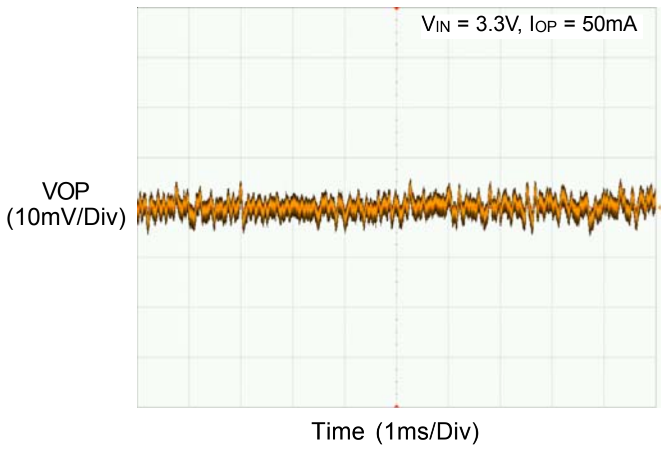
VOP Ripple Voltage



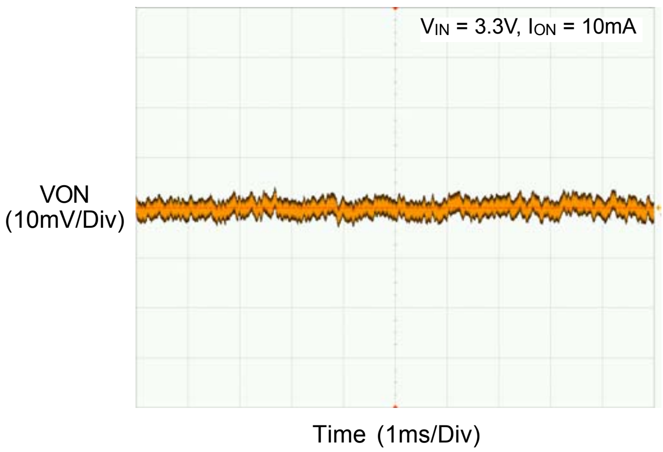
VOP Ripple Voltage



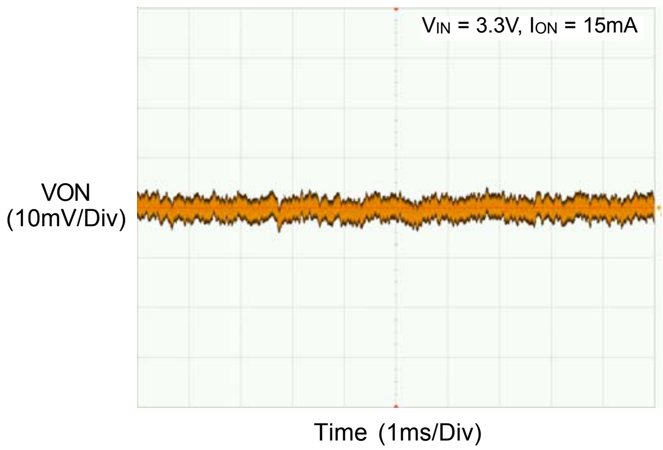
VOP Ripple Voltage



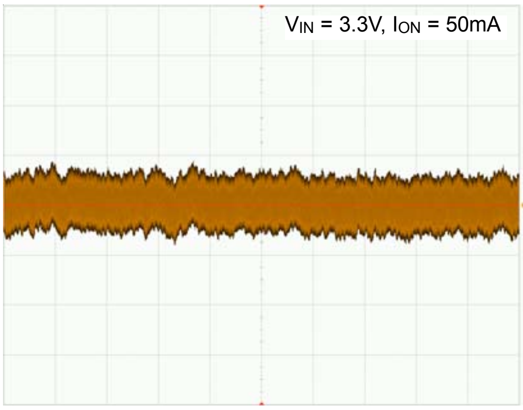
VON Ripple Voltage



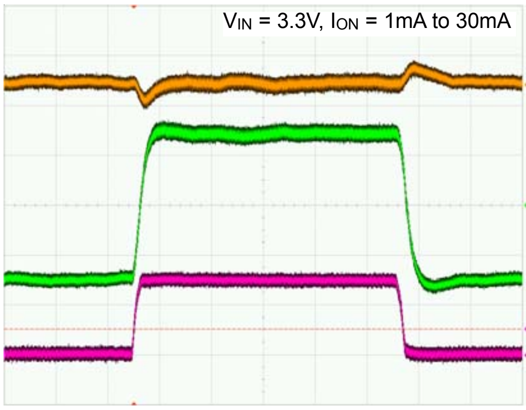
VON Ripple Voltage



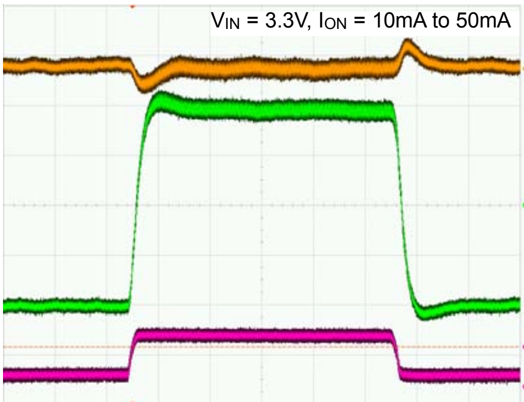
VON Ripple Voltage



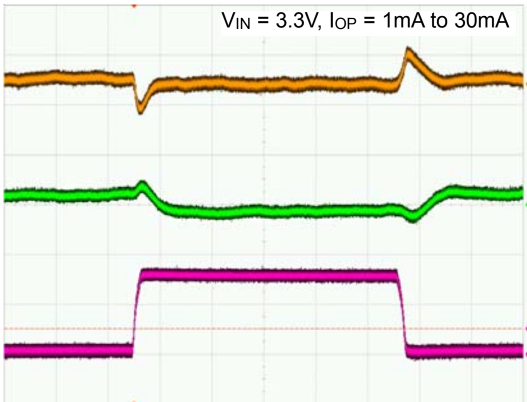
Load Transient Response



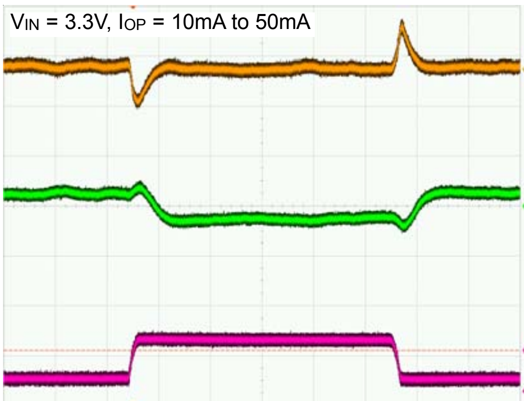
Load Transient Response



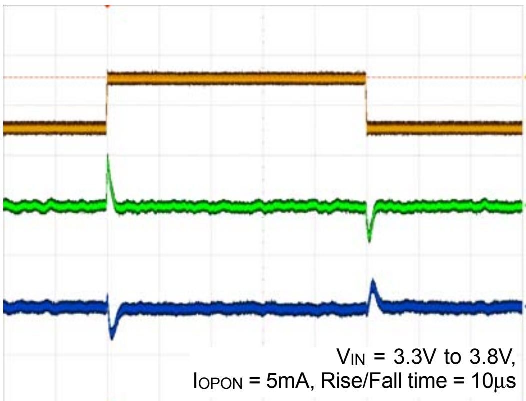
Load Transient Response



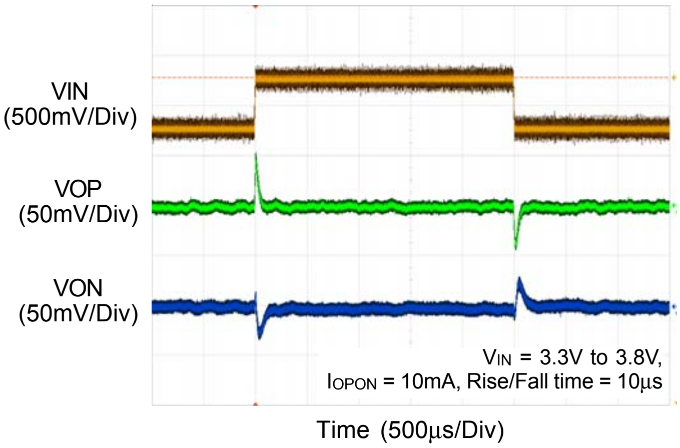
Load Transient Response



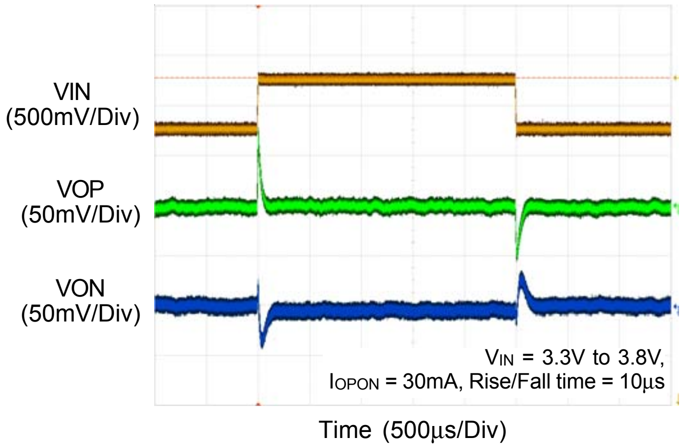
Line Transient Response



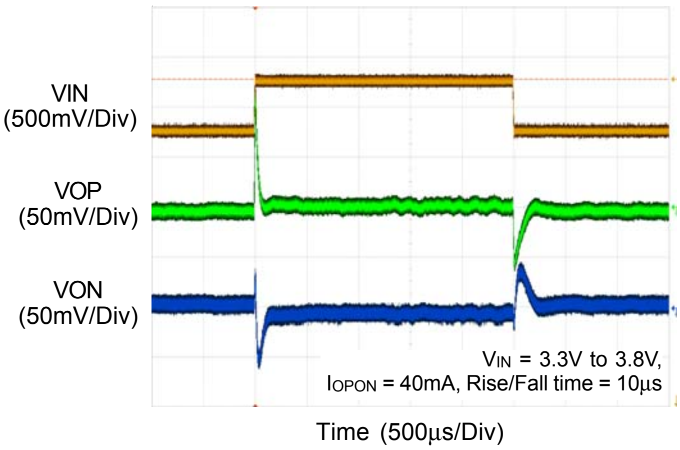
Line Transient Response



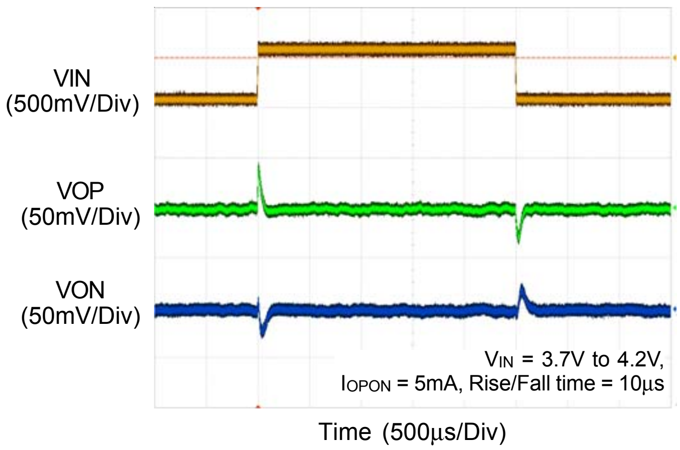
Line Transient Response



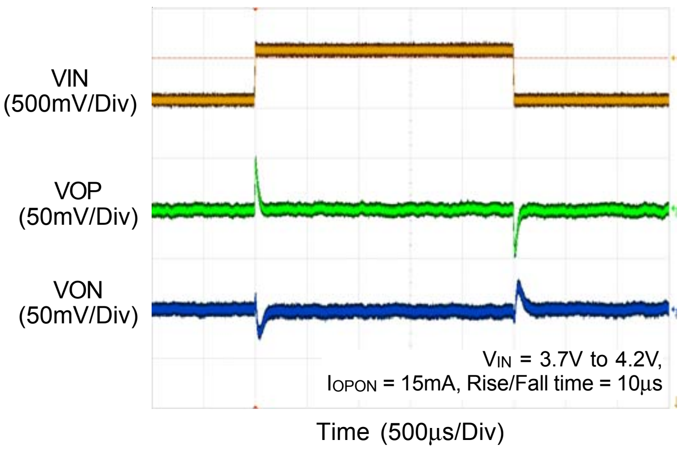
Line Transient Response



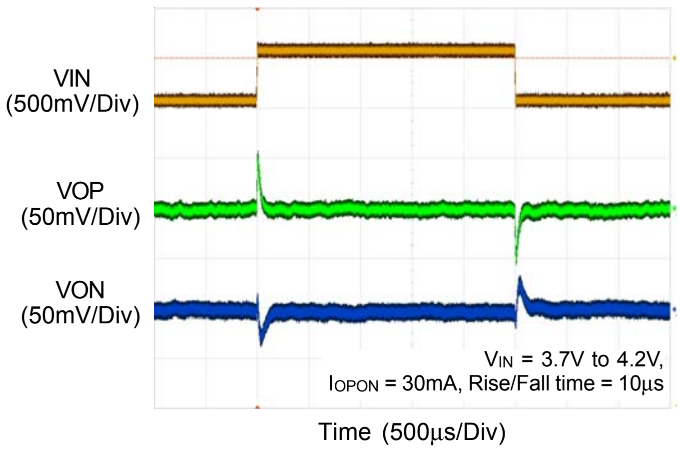
Line Transient Response



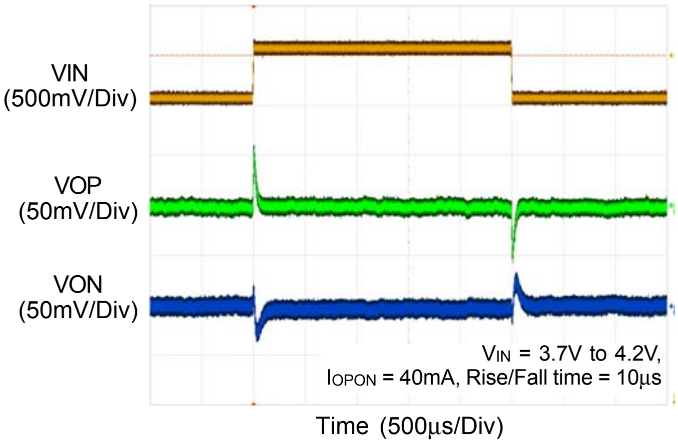
Line Transient Response



Line Transient Response



Line Transient Response



Application Information

The RT9399 is a highly integrated step-up charge pump and inverting charge pump to generate positive and negative output voltages for TFT-LCD bias. It can support input voltage range from 2.5V to 4.5V and the output current up to 50mA. Positive and negative output voltages are fixed ±6V.

Under-Voltage Lockout

To prevent abnormal operation of the IC in low voltage condition, an under-voltage lockout is included which shuts down the device when input voltage is lower than 1.9V. All functions will be turned off in this state.

Soft-Start

The RT9399 provides an internal soft-start feature to avoid high inrush current during start-up. An internal current source charges a capacitor to build the soft-start ramp voltage. The reference voltage will track the ramp voltage during soft-start interval. The typical soft-start time is 1ms.

Over-Temperature Protection (OTP)

The RT9399 equips an over-temperature protection circuitry to prevent overheating due to excessive power dissipation. The OTP will shut down IC when junction temperature exceeds 140°C. Once the junction temperature cools down by approximately 15°C, IC will resume normal operation automatically. To maintain continuous operation, the maximum junction temperature should be prevented from rising above 125°C.

Short-Circuit Protection (SCP)

The RT9399 has an advanced short-circuit protection mechanism which prevents the device from damage by unexpected applications. When the output V_{OP} becomes shorted to ground, the device will limit the input current to maximum 200mA.

Shutdown Delay

When the EN voltage is logic low for more than 1ms, the IC will be shut down with an internal fast discharge resistor. In shutdown mode, the input supply current for the device is less than 1μA.

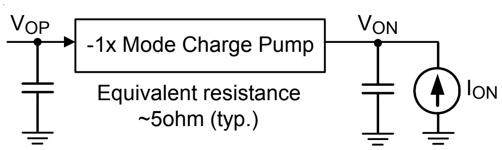
Headroom Voltage of V_{ON}

Due to the negative voltage V_{ON} is supplied from the positive voltage V_{OP}.

There is a voltage drop on the negative charge pump (-1x Mode) which equivalent resistance is about 5Ω (typ.). The headroom voltage can be calculated depending on output load I_{ON} as below equation.

$$V_{ON} = -V_{OP} + I_{ON} \times Req$$

$$\text{Headroom} = V_{OP} + V_{ON} = I_{ON} \times Req$$



Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula :

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a XDFN-12SL 3x1.5, the thermal resistance, θ_{JA}, is 34.7°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below :

$P_{D(MAX)}$ = (125°C − 25°C) / (34.7°C/W) = 2.88W for a XDFN-12SL 3x1.5 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curves in Figure 1 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

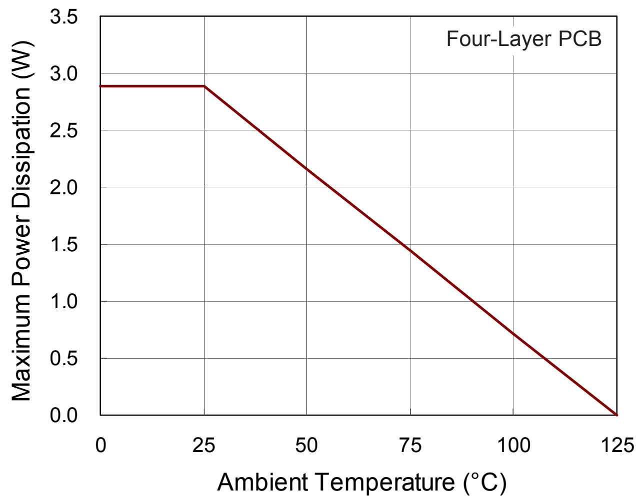


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Consideration

For the best performance of the RT9399, the following PCB layout guidelines should be strictly followed.

- The traces should be wide and short especially for the high current output loop.
- The input and output bypass capacitors should be placed as close to the IC as possible and connected to the round plane of the PCB.
- Connect the exposed pad to a strong ground plane for maximum thermal dissipation.

Layout Consideration

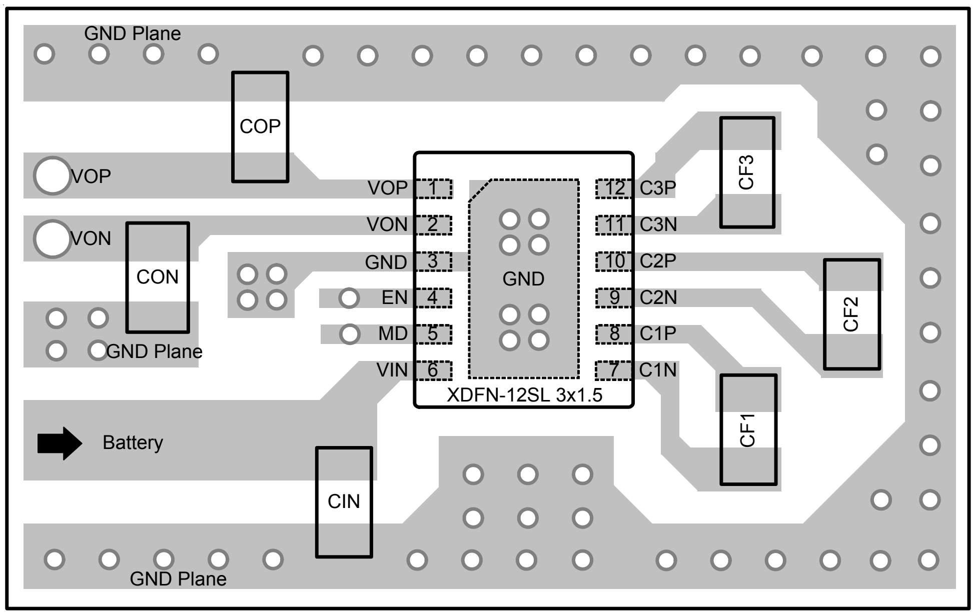
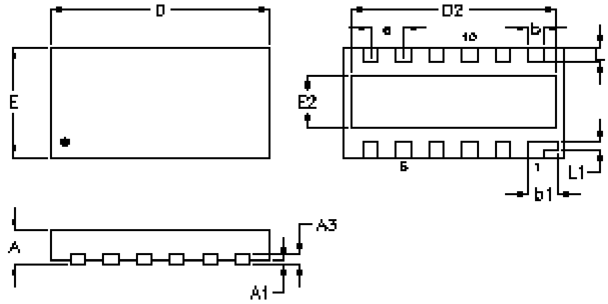


Figure 2. PCB Layout Guide

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.400	0.500	0.016	0.020
A1	0.000	0.050	0.000	0.002
A3	0.100	0.175	0.004	0.007
b	0.150	0.250	0.006	0.010
b1	0.350	0.450	0.014	0.018
D	2.900	3.100	0.114	0.122
D2	2.750	2.850	0.108	0.112
E	1.400	1.600	0.055	0.063
E2	0.650	0.750	0.026	0.030
e	0.450		0.018	
L	0.150	0.250	0.006	0.010
L1	0.050	0.150	0.002	0.006

X-Type 12SL DFN 3x1.5 Package

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