VS6216 Series Low-dropout Regulators

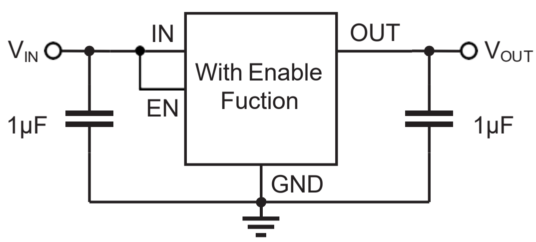
1 Introduction

The VS6216 Series is a linear regulator capable of supplying 500mA output current. Designed to meet the requirements of RF and analog circuits, the VS6216 Series provides low noise, high PSRR, low quiescent current and very good load / line transients. Using innovative design techniques,the VS6216 series offers an ultra-low noise performance without the addition of a noise bypass capacitor. The VS6216 Series can work with a 1μF input and 1μF output ceramic capacitor.

The VS6216 Series is available in DFNWB1×1-4L, SOT-23-5L,and CSPC0606-4 packages.

2 Applications

- Smartphones/tablets
- Digital cameras
- Image sensors
- Instrumentation
- VCO and RF modules



Typical Application Circuits

3 Features

- Low output voltage noise: 4.5μVRMS
- Power Supply Rejection Ratio:
  - 98dB@1kHz (Typ.)
  - 91dB@10kHz (Typ.)
  - 73dB@100kHz (Typ.)
- Input Voltage Range: 1.8V ~ 5.5V
- Fixed Output Voltage:
  - Available from 1.2V to 5.0V
- Output Voltage Tolerance: ±1%
- Output Current: up to 500mA
- Low Quiescent Current: 10μA (Typ.)
- Shutdown Current: 0.005μA (Typ.)
- Dropout Voltage:
  - 200mV@500mA (V_{OUT} = 2.8V,SOT-23-5L)
- Excellent Transient Response
- Integrated Fault Protection:
  - Inrush Current Limit
  - Output Current Limit
  - Thermal Shutdown
  - Short-Circuit Protection

4 Available Packages

PART NUMBER	PACKAGE
VS6216 Series	SOT-23-5L
	DFNWB1×1-4L
	CSPC0606-4

7 Specifications

7.1 Absolute Maximum Ratings

(T_A = 25°C, unless otherwise specified)(1)

CHARACTERISTIC			SYMBOL	VALUE	UNIT
Input voltage range(2)			V_{IN}	-0.3 ~ 6.5	V
Enable input voltage range(2)			V_{EN}	VSS-0.3 ~ VIN+0.3	
Output voltage range(2)			V_{OUT}	VSS-0.3 ~ VIN+0.3	
Maximum power dissipation	VS6216 series	DFNWB1×1-4L	$P_{D\ Max}$	Internally Limited(3)	W
		CSPC0606-4			
		SOT-23-5L			
Maximum junction temperature			$T_{J\ Max}$	150	°C
Storage temperature			T_{stg}	-40 ~ 150	°C
Soldering temperature & time			T_{solder}	260°C, 10s	-

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum rated conditions for extended periods may affect device reliability.
(2) All voltages are with respect to network ground terminal.
(3) Refer to *Thermal Information* for details.

7.2 Recommended Operating Conditions

PARAMETER	SYMBOL	MIN.	NOM.	MAX.	UNIT
Input voltage	V_{IN}	1.8	-	5.5	V
Operating junction temperature	T_J	-40	-	125	°C

7.3 ESD Ratings

ESD RATINGS		SYMBOL	VALUE	UNIT
Electrostatic discharge(4)	Human body model	$V_{ESD-HBM}$	2000	V

(4) ESD testing is conducted in accordance with the relevant specifications formulated by the Joint Electronic Equipment Engineering Commission (JEDEC). The human body model (HBM) electrostatic discharge test is based on the JS-001: 2017 test standard, using a 100pF capacitor and discharging to each pin of the device through a resistance of 1.5kΩ.

7 Specifications

7.4 Thermal Information

THERMAL METRIC(5)	SYMBOL	VS6216 Series		UNIT
Junction-to-ambient thermal resistance	$R_{\Theta JA}$	**SOT-23-5L**	**DFNWB1×1-4L**	°C/W
		250.0	220.0	
		CSPC0606-4	**-**	
		-	-	
Junction-to-case thermal resistance	$R_{\Theta JC}$	**SOT-23-5L**	**DFNWB1×1-4L**	°C/W
		65.0	115.0	
		CSPC0606-4	**-**	
		-	-	
Reference maximum power dissipation for continuous operation	$P_{D\ Ref}$	**SOT-23-5L**	**DFNWB1×1-4L**	W
		0.40	0.45	
		CSPC0606-4	**-**	
		-	-	

(5) Thermal metric is measured in still air with T_A = 25°C and installed on a 1 in^2 FR-4 board covered with 2 ounces of copper.

7 Specifications

7.5 Electrical Characteristics

VS6216 Series (V_{IN} = V_{OUT} +1V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		MIN.	TYP.(6)	MAX.	UNIT
Input voltage range	V_{IN}			1.8	-	5.5	V
DC output tolerance	-	T_J = 25°C, I_{OUT} = 10mA		-1	-	1	%
Output current	I_{OUT}	V_{IN} = V_{OUT}+1V		500	-	-	mA
Quiescent current	I_Q	V_{IN} = V_{OUT}+1V		-	10	20	μA
Dropout voltage	V_{DO}(7)	I_{OUT} = 500mA		-	200	-	mV
Load regulation	ΔV_{LOAD}	V_{IN} = V_{OUT} +1V, I_{OUT} = 1mA to 500mA		-	20	-	mV
Line regulation	LNR(8)	V_{IN} = V_{OUT} +1V to 5.5V, I_{OUT} = 1mA		-	0.02	-	%/V
Output current limit	I_{CL}	V_{OUT} = 90%$V_{OUT\ Normal}$		-	650	-	mA
Short current	I_{SC}	V_{OUT} = 0 V		-	90	-	mA
Shutdown current	I_{SHDN}	V_{EN} = 0V		-	0.005	1	μA
EN high level	V_{ENH}	Turn on with stable output voltage		1	-	-	V
EN low level	V_{ENL}	Trun off, V_{OUT} = 0V		-	-	0.4	V
EN pin current	I_{EN}	V_{EN} = 5V		-	0.04	0.5	μA
Output noise voltage	V_N(9)	f = 10Hz -100kHz , Vout = 2.8V	I_{OUT} = 1mA	-	5	-	μV_{RMS}
			I_{OUT} = 300mA	-	4.5	-	μV_{RMS}
Power supply rejection ratio	PSRR(9)	I_{OUT} = 10mA, V_{IN} = [V_{OUT} + 1] V + 0.5V_{PP} AC	f = 1kHz	-	98	-	dB
			f = 10kHz	-	91	-	
			f = 100kHz	-	73	-	
			f = 1MHz	-	60	-	
Thermal shutdown	T_{SD}	I_{OUT}=20mA		-	165	-	°C
Thermal shutdown hysteresis	ΔT_{SD}			-	20	-	°C
Active discharge resistance	R_{Dis}	V_{EN} < V_{ENL}		-	900	-	Ω
Turn on time	t_{ON}	From V_{EN} < V_{ENH} to V_{OUT}= 90%$V_{OUT\ Normal}$		-	750	-	μs
Load transient	ΔV_{OUT}(9)	V_{OUT} = 2.8V	I_{OUT} = 1 mA to 500 mA in 1 μs	-	24	-	mV
			I_{OUT} = 500 mA to 1 mA in 1 μs	-	20	-	

Note:

(6) Typical numbers are at 25°C and represent the most likely norm.

(7) Test the difference of output voltage and input voltage when input voltage is decreased gradually till output voltage equals to 98% of $V_{OUT\ Normal}$.

(8) The line regulation is calculated by the following formula:

$$\square\square\square = \frac{\Delta V_{OOUT}}{\square_{\square\square\square\square} \times \Delta V_{\square\square}}$$

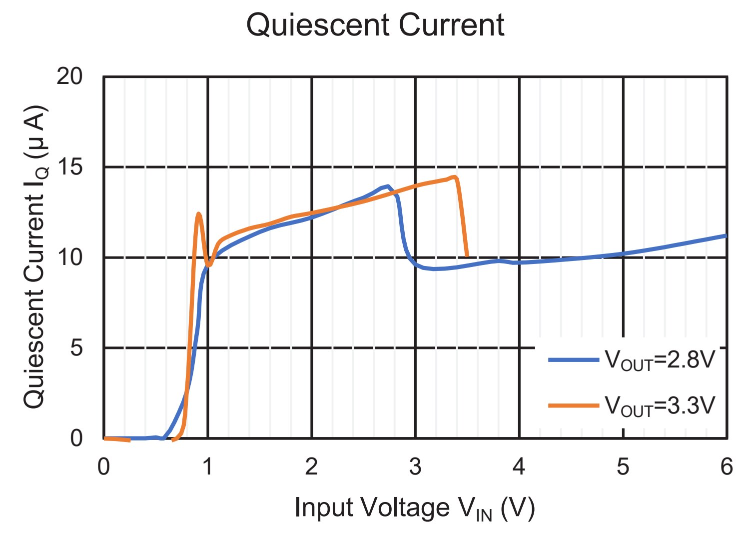
where, ΔV_{OUT} is the variation of the output voltage, ΔV_{IN} is the variation of the input voltage.

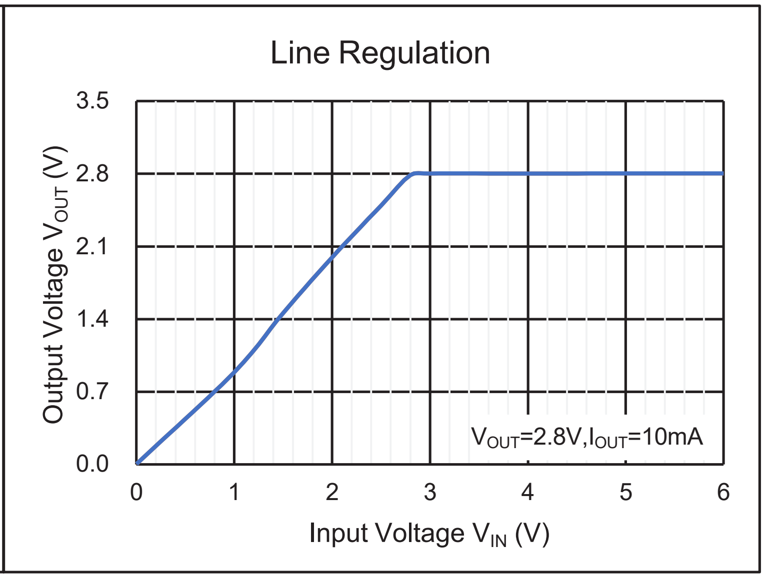
(9) Guaranteed by design, not subject to production testing.

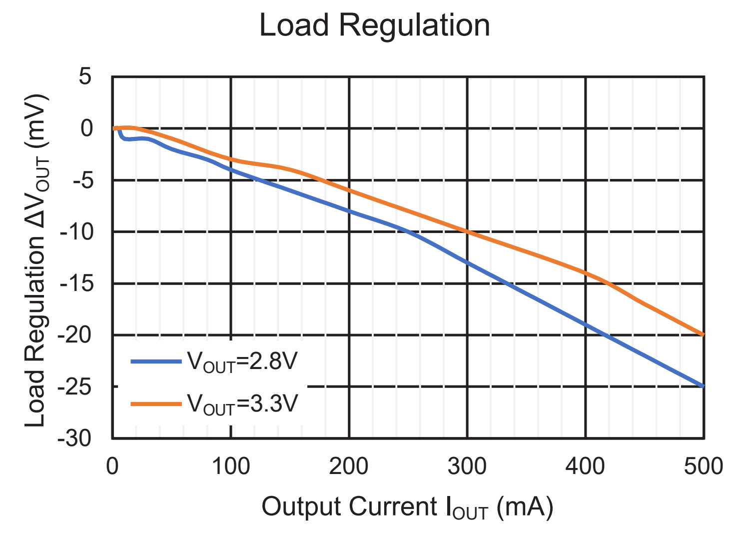
7 Specifications

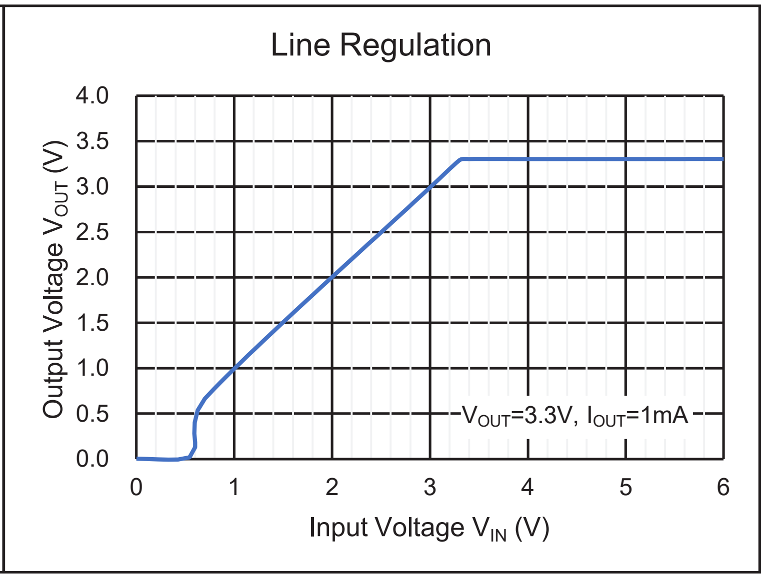
7.6 Typical Characteristics

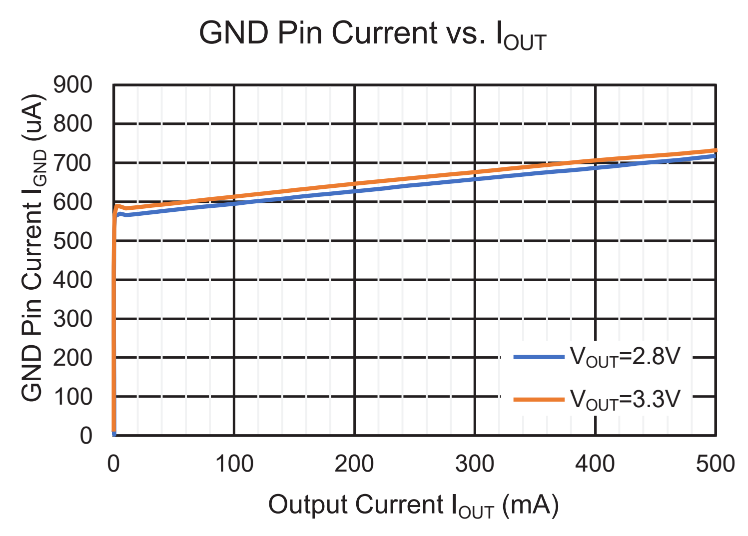
VS6216 Series (V_{IN}=V_{OUT}+1V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

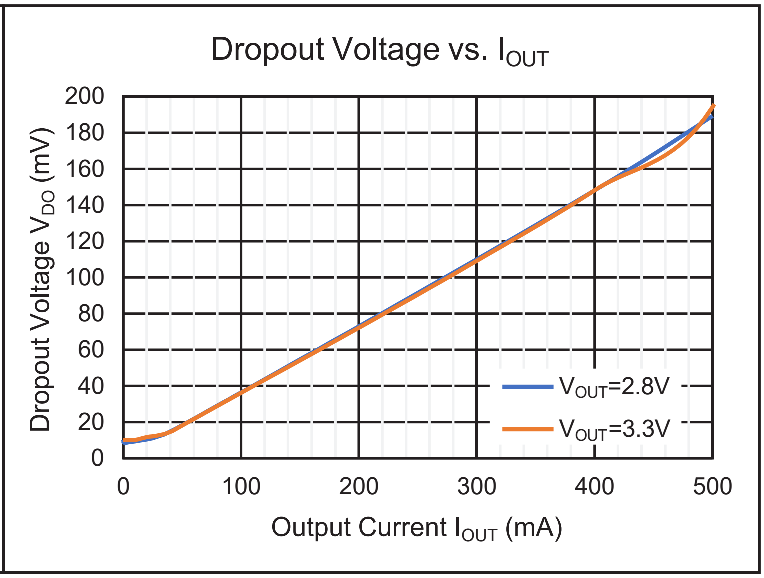








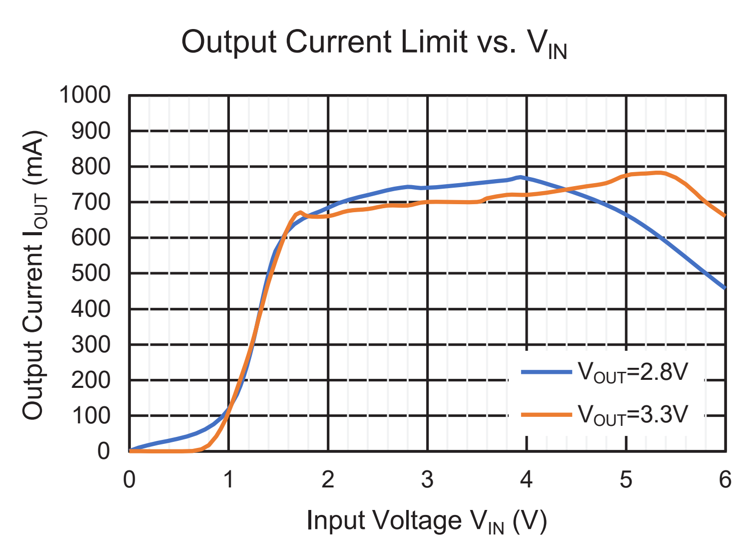


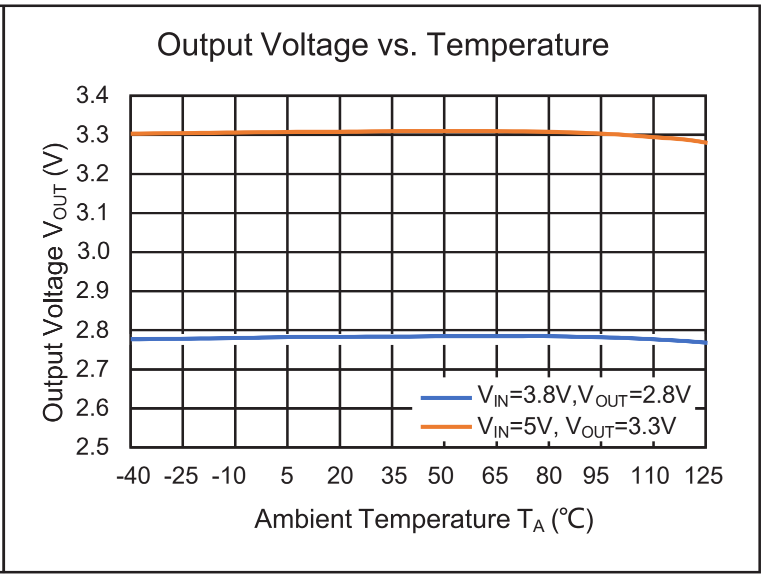


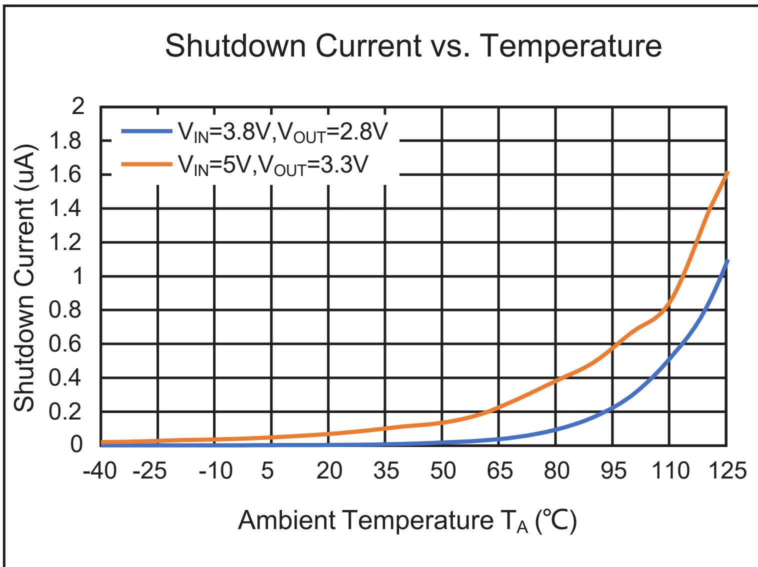
7 Specifications

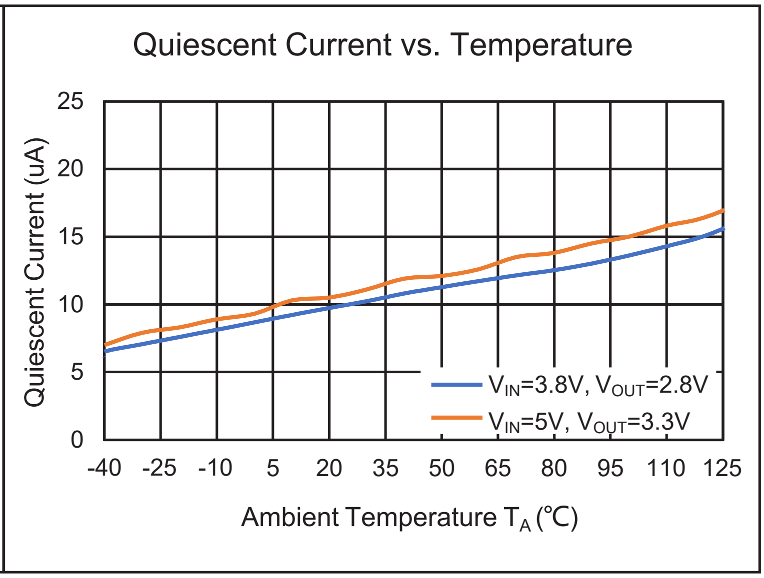
7.6 Typical Characteristics (continued)

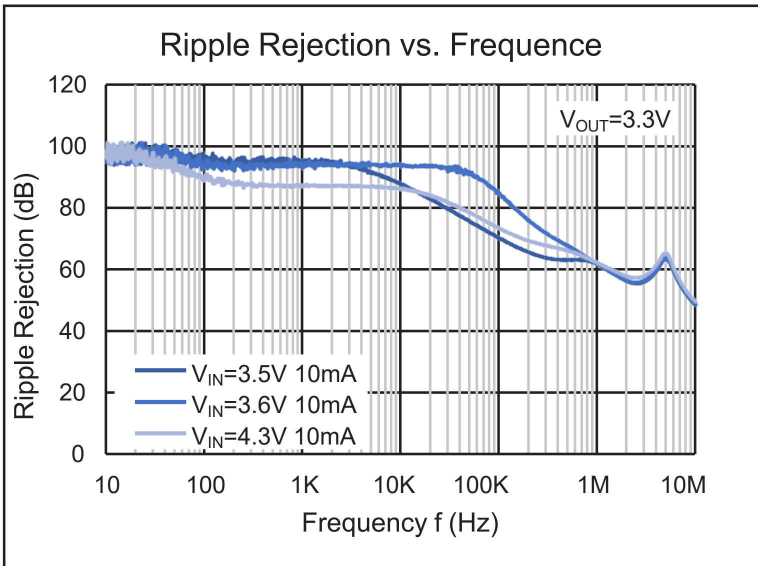
VS6216 Series(V_{IN}=V_{OUT}+1V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

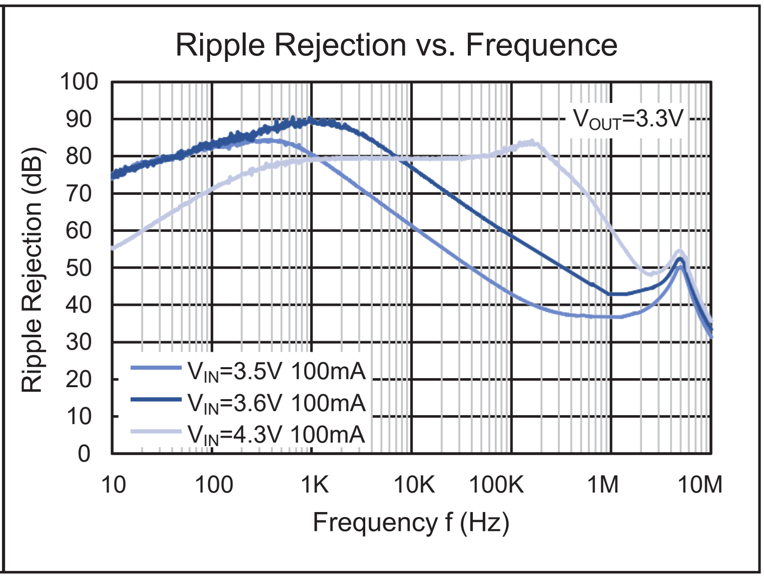










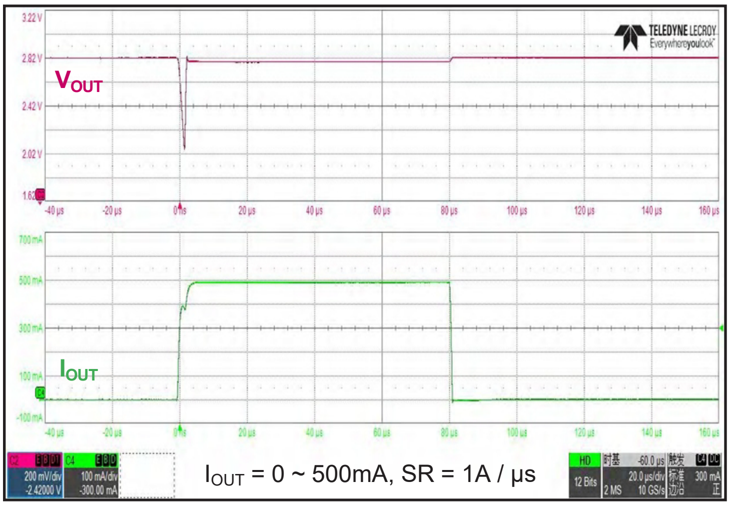


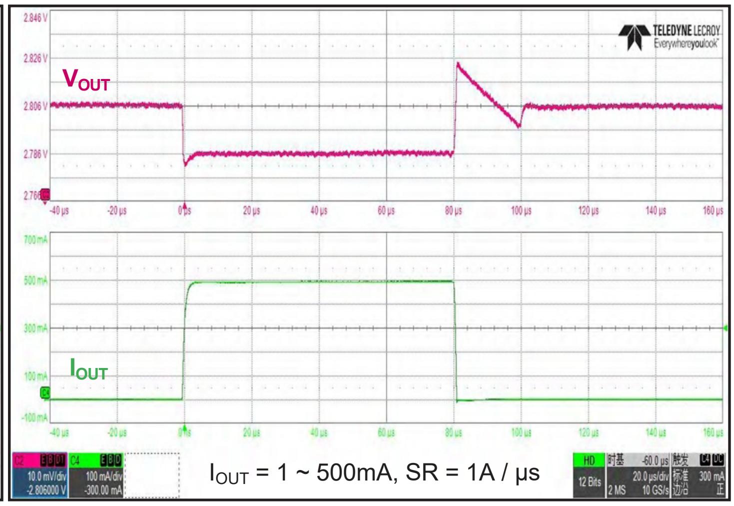
7 Specifications

7.6 Typical Characteristics (continued)

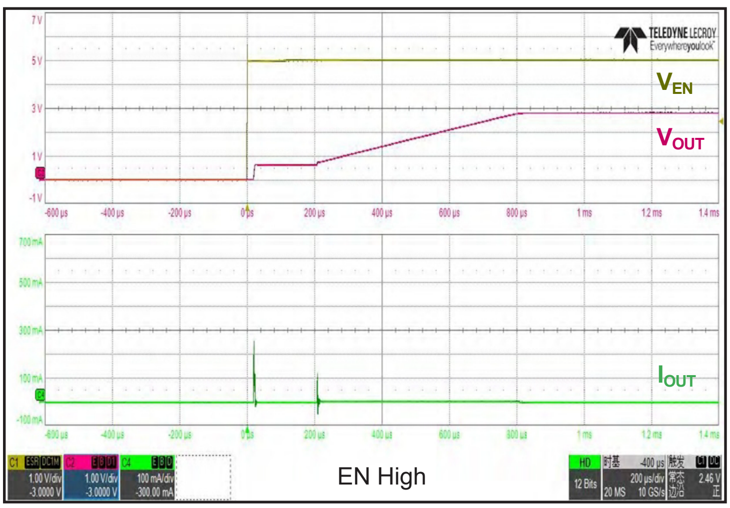
VS6216 Series (C_{IN} = 1µF, C_{OUT} = 1µF, T_A = 25°C, unless otherwise specified)

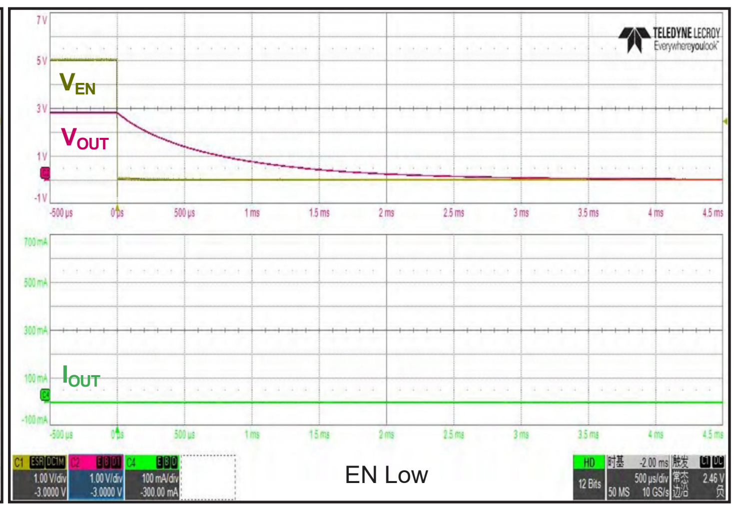
Load Transient (V_{IN} = 3.8V, V_{OUT} = 2.8V, V_{EN} = V_{IN})



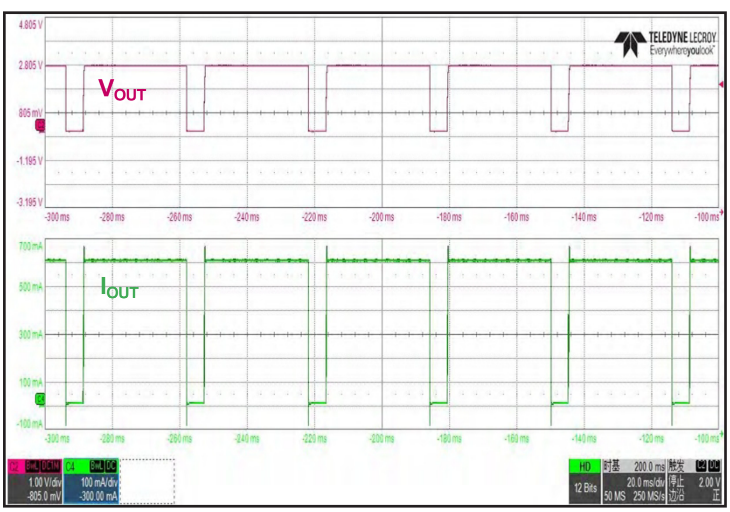


EN High and EN Low(V_{IN} = 3.8V, V_{OUT} = 2.8V, V_{EN} = 0~3.8V)

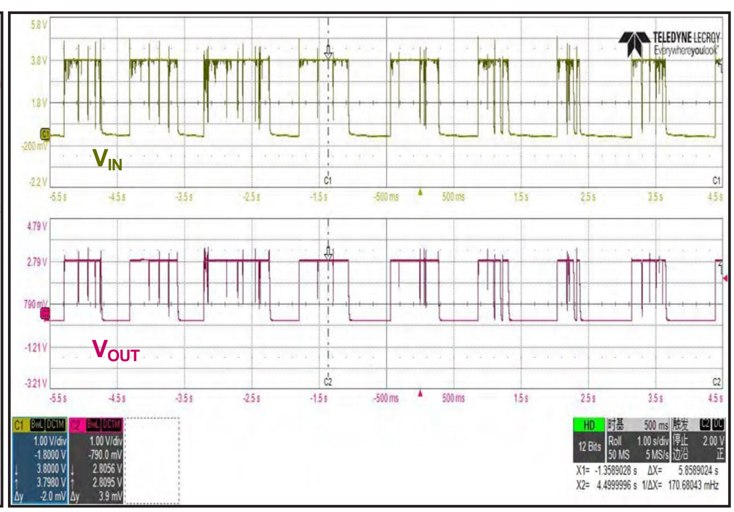




Thermal Shutdown (V_{IN} = 5.2V, I_{OUT} = 600mA)



Continuous Power-up Response

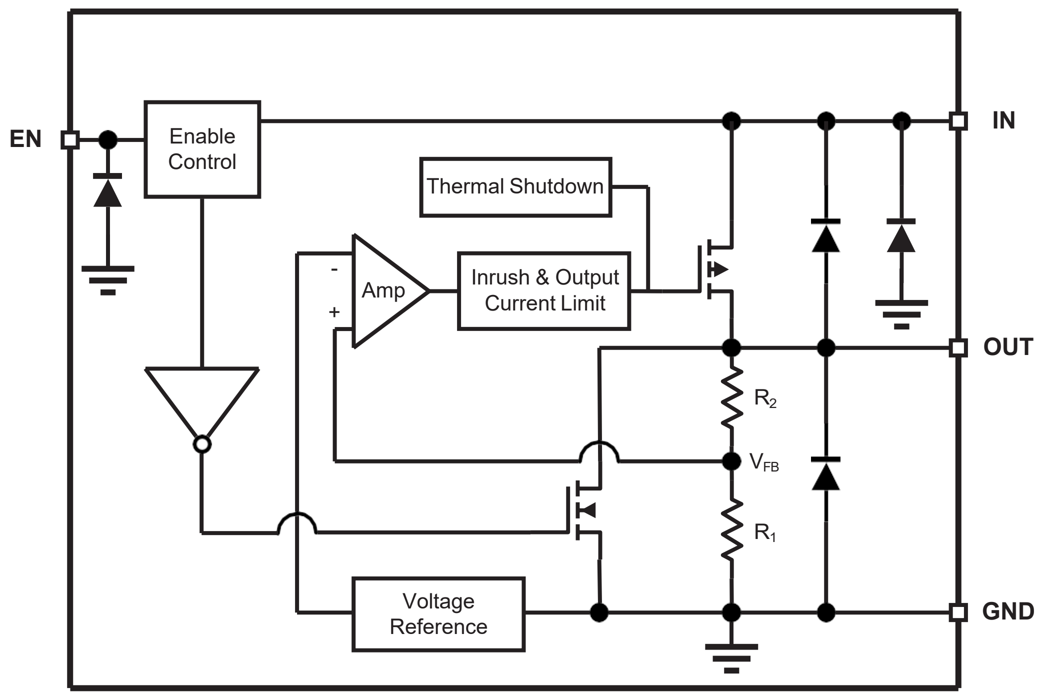


8 Detailed Description

8.1 Description

The VS6216 Series is a linear regulator capable of supplying 500mA output current. The VS6216 Series provides low noise, high PSRR, low quiescent current and very good load / line transients. The VS6216 series has low I_Q performance and is internally integrated with current limiting, short-circuit protection and thermal shutdown protection.

8.2 Functional Block Diagram



The internal feedback resistors R_1 and R_2 form a voltage divider circuit to compare the V_{FB} input error amplifier with the reference voltage. The internal regulator tube (PMOS) will control its conduction degree through the grid voltage provided by the error amplifier output, which will make the output voltage V_{OUT} not affected by temperature changes or input voltage changes to a certain extent, thus maintaining the stability of the device output voltage.

8 Detailed Description

8.3 Feature Description

Power Supply Input

When the input voltage is lower than the rated range of the data sheet, the device will lose the regulation function of stabilizing the output voltage, that is, it is unable to maintain the output voltage within the rated range. At this time, compared with normal operation, the quiescent current of the device may exceed the rated range, and the transient response performance may be seriously degraded.

When the input voltage is higher than the rated range of the data sheet, the device may cause irreversible damage or failure due to exceeding the maximum rated range of electrical stress.

For the rated input voltage of the device, see *Recommended Operating Conditions* and *Dropout Voltage*.

Output Current

When the circuit design is appropriate, the VS6216 series can reach the maximum load capacity of up to 500mA. According to the power dissipation of the package and the effective connection thermal resistance with the environment, selecting the appropriate package for the circuit design can make the device emit more heat energy.

Output Current Limit & Short Circuit Protection

The VS6216 series has an internal current limiting circuit, which can protect the device by limiting the load current value in case of instantaneous high load current. When the current limiting is triggered, the output voltage is not regulated. If the out pin of the regulator is short circuited, the internal current limiting circuit will be triggered. The current limiting state will continue until the load current drops to the normal range.

When the load current of the device is large, the device will generate more heat due to the increase of power consumption, which may cause the device to turn off its output due to the internal thermal shutdown protection before the current limit is triggered. After the device cools down, the internal thermal shutdown circuit turns the device back on. If the fault condition continues, the device cycles between current limit and thermal shutdown.

In order to ensure the normal operation of current limit, the inductance of input and load shall be minimized. Continuous operation under current limit is not recommended.

Thermal Shutdown

The VS6216 series has thermal shutdown protection mechanism. When the junction temperature T_J of the internal main channel MOSFET exceeds the thermal shutdown threshold temperature T_{SD}, thermal shutdown will be triggered. At this time, the output will be turned off to prevent catastrophic damage to the chip due to accidental heating. When the T_J drops to a certain range of thermal shutdown threshold temperature ΔT_{SD}, the thermal shutdown will be released and the device will return to the normal output. The temperature threshold of device triggering thermal shutdown T_{SD} and temperature range to be lowered to released from thermal shutdown ΔT_{SD} can be found in the *Electrical Characteristics*.

To ensure reliable operation, please limit the junction temperature to the specified range of *Recommended Operating Conditions* in the data sheet. Applications that exceed the recommended temperature range may cause the device to exceed its operating specifications.

Although the internal protection circuit of the device is designed to prevent overall thermal conditions, it is not intended to replace proper power dissipation. Running the device continuously until thermal shutdown or higher than the recommended operating T_J will reduce long-term reliability.

8 Detailed Description

8.3 Feature Description (continued)

Dropout Voltage

Dropout voltage V_{DO} refers to the minimum voltage difference between input and output V_{IN} - V_{OUT} to make the device output voltage reach the rated range at rated current. When the dropout voltage condition required by the device is reached, the internal MOSFET will be fully turned on, at this time, the MOSFET is equivalent to a switch for regulation.

The V_{DO} increases with the increase of load current. Since V_{IN} - V_{OUT} must be no less than the V_{DO}, the V_{DO} indirectly specifies the minimum input voltage of devices under different load current conditions. If the V_{IN} - V_{OUT} is less than the V_{DO}, the performance of the device may deteriorate (see *Operation in Dropout Mode* for details).

Enable Control

The enable pin of the device EN is active at high level. When the voltage of the EN is greater than the EN logic high voltage $V_{EN\ H}$, the device will be enabled and maintain the normal output. When the voltage of the EN is lower than the EN logic low voltage $V_{EN\ L}$, the internal circuit of the device will be disabled and the output will be turned off, the device will be in the standby mode until EN is turned to high level again. The $V_{EN\ H}$ and $V_{EN\ L}$ can be found in the *Electrical Characteristics*.

Normal startup waveform and startup slope rate control can be ensured when the device starts from any low voltage lower than $V_{EN\ L}$, but the discharge time of output capacitor must be taken into account. EN can be float, when the EN is floating, it will be pulled down to ground internally. If EN is not required to control the output voltage independently, it's recommend to connect EN to IN.

Auto-discharge Function

The device with enable control has an auto-discharge circuit. When the enable control is turned off, the device will be disabled. An internally integrated pull-down MOSFET (see *Functional Block Diagram*) will connect a resistor $R_{Discharge}$ to the ground to release the charge in the output capacitor, thus closing the entire device circuit. The value of $R_{Discharge}$ can be found in the *Electrical Characteristics*. The discharge time of the output capacitor after the device is disabled is determined by the output capacitance C_{OUT} and load resistance R_L in parallel with the $R_{Discharge}$. The time constant τ can be calculated by the following formula:

$$\tau \quad \times R_{Discharaae} \ (R_L = 0) \neq$$

$$\tau = C \times = (C \frac{R_L \times R_{Discharaae}}{R_L + R_{Discharaae}}) \ (R_L \quad 0)$$

The output voltage after discharging through pull-down MOSFET can be calculated by the following formula:

$$V \quad V_{OOUT} \quad ee^{-\frac{t}{\tau}}$$

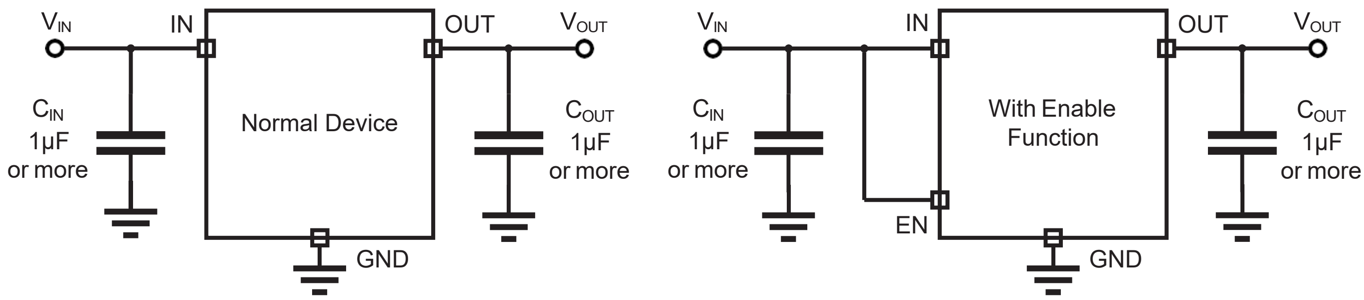
$$t == \tau \times \ln(\times \frac{\square}{\square})$$

Where, V is the output voltage after discharge, V_{OUT} is the output voltage, t is the discharge time, τ is the discharge time constant.

Do not rely on the active discharge circuit to release a large amount of output capacitance after the input power supply crashes, because the reverse current can flow from the output to the input. This reverse current may damage the device. The limiting reverse current shall not exceed 5% of the rated current of the device.

9 Application and Implementation

9.1 Typical Application Circuits



9.2 Application Information

Selection of Bypass Capacitances

For the VS6216 series, it is recommended to use 1μF input (C_{IN}) and output (C_{OUT}) ceramic capacitors.

Type of Capacitors:

Since any leakage of the capacitor will increase the quiescent power consumption of the whole circuit, attention should be paid to selecting capacitors with low leakage. When designing the circuit of portable equipment including VS6216 series, due to the shortage of tantalum capacitors, it is a good choice to use small size, low equivalent series resistance (ESR) and high RMS current capacity multilayer ceramic capacitors (MLCC) in the DC to DC voltage conversion. The designer must choose the appropriate capacitor type for circuit design: X7R- Ceramic capacitors of X5R- and COG- rated dielectric materials can provide relatively good capacitance stability within the temperature range, Y5V- type capacitors are not recommended because of large changes in capacitance values. However, no matter which type of ceramic capacitor is selected, the effective capacitance may vary with the operating voltage and temperature. The designer must consider the influence of the change of the effective value of capacitance according to the circuit design and application conditions.

Input Capacitors C_{IN}:

It is recommended to use a 1μF capacitor at the input pin of the device, and the position of the input capacitor should be as close to the device input pin as possible.

For the VS6216 series, the input capacitor is not necessary to maintain the output stability, but it can offset the reactive input source and improve the transient response, input ripple and PSRR performance of the device. It should be noted that although many types of capacitors can be used for input bypass, using ceramic capacitors for input filtering may cause problems. Due to the self resonance and high Q characteristics of some types of ceramic capacitors, under certain starting conditions, applying voltage steps to ceramic capacitors may lead to large current surges (such as directly connecting the input pin of LDO to the power supply), which may cause some energy stored in the parasitic inductance of the power lead. When the stored energy is transferred from these inductors to ceramic capacitors, large voltage spikes may occur in the circuit. These voltage spikes are easily twice the step amplitude of the input voltage, and are likely to bring potential risks to the normal operation and reliability of the device. Therefore, the selection of ceramic capacitors as input capacitors must be careful. Adding 3Ω resistors and X5R- type ceramic capacitors will minimize voltage transients during startup. A higher value capacitor may be necessary if large, fast rise-time load or line transients are anticipated or if the device is located several inches from the input power source.

9 Application and Implementation

9.2 Application Information (continued)

Selection of Bypass Capacitances (continued)

Output Capacitors C_{OUT}:
Recommended 1μF output ceramic capacitor to keep the device output stable, and the capacitor position should be as close to the device pin as possible.
For VS6216 series, the device needs an output capacitor to achieve loop stability. As with any regulator, a larger output capacitance reduces the peaks during a load transient but slows down the response time of the device. The proper capacitor can help to obtain better dynamic performance.

Transient Response

Transient response refers to the change of system output from initial state to stable state under the action of typical signal input. For LDO, the designer should pay attention to the possible impact of linear transient response and load transient response on the system: linear transient response refers to the transient response of output to change when the input voltage changes, while load transient response refers to the transient response of output to change when the output current changes. The specific phenomenon is that the output voltage of the device will have a short spike, especially when the input voltage or output current changes greatly in a short time. This change is not only related to the performance of the chip itself, but also related to the change of output current, change rate and output capacitance:

1. When the output current increases, the output voltage of the device will decrease to a certain extent, and the larger output current will provide a higher current discharge path for the output capacitor, which will affect the peak value generated by the transient spike and reduce the peak value;
2. The output current or input voltage changes relatively slowly, and the output change of the device is relatively small, affecting the spike caused by the change;
3. The use of large input and output capacitors can reduce the spike caused by transient response to a certain extent to improve the transient performance, but large output capacitors can also affect the response time of devices.

For the selection of bypass capacitance value, refer to the *Section of Bypass Capacitances* selection.

Operation in Dropout Mode

The VS6216 series is internally integrated with a P-MOSFET to achieve low dropout voltage. The voltage difference between the input and the output V_{IN} - V_{OUT} of the device must not be lower than the corresponding dropout voltage V_{DO} to ensure that the output voltage tolerance is within the rated range of the data sheet. The dropout voltage will increase with the increase of load current. When the V_{IN} - V_{OUT} is less than the V_{DO}, the P-MOSFET inside the device is in a linear state, the resistance from the input pin to the output pin is equal to the resistance from the drain to the source of the P-MOSFET, and the device functions like a resistor. When operating in this state, the response time of the error amplifier inside the device will be limited, which will seriously degrade the transient performance of the device, when the external circuit has a transient change, the deviation of the output voltage will become larger than the normal operating state. In addition, the PSRR and noise performance of the device will be worse than that under normal operating conditions.