VS6380 Series Low-dropout Regulators

1 Introduction

The VS6380 device is a very high voltage tolerant linear regulator that is able to withstand continuous DC or transient input voltages of up to 50V and has an internal thermal shutdown and Short-Circuit protection to protect the system during fault conditions.

In addition, the VS6380 device is ideal for generating a low-voltage supply from intermediate voltage rails in telecom and industrial applications; not only can it supply a well-regulated voltage rail, but it can also withstand and maintain regulation during very high and fast voltage transients. These features translate to simpler and more cost-effective electrical surge-protection circuitry for a wide range of applications, including PoE, bias supply, and LED lighting.

2 Available Packages

PARTNUMBER	PACKAGE
VS6380 Series	SOT-23-3L
	SOT-23-5L
	SOT-89-3L
	SOT-223

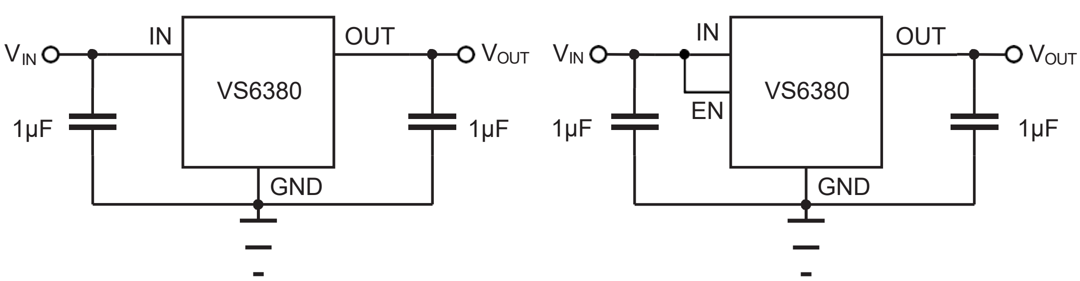
Note: For all available packages, please refer to the part *Orderable Information*.

3 Features

- Very High Maximum Input Voltage: 50V
- Wide Input Voltage Range: 3 to 50V
- Output Voltage Range: 1.2V~12V
- Output Tolerance: ±1%
- Low Quiescent Current: 2.7μA
- Quiescent Current at Shutdown: 0.1μA
- Maximum Output Current: 200mA
- CMOS Logic-Level-CompatibleEnable Pin
- Dropout Voltage: 480mV@50mA
- Complete Protection:
  Short circuit Protection, Thermal Shutdown
- Automatic Output Discharge at Shutdown
- Power Supply Rejection Ratio:
  88dB@1kHz, 76dB@10kHz
- Output Noise Voltage:
  20 x Vout μV_{RMS}(10Hz~100kHz)

4 Applications

- Microprocessors, Microcontrollers
  Powered by Industrial Busses with High Voltage Transients
- Industrial Automation
- Automotive
- Power over Ethernet (PoE)
- LED Lighting
- Bias Power Supplies



Typical Application Circuit

6 Specifications

6.1 Absolute Maximum Ratings

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

CHARACTERISTIC		SYMBOL	VALUE	UNIT
Input voltage range(2)		V_{IN}	-0.3 ~ 60	V
Output voltage range(2)		V_{OUT}	-0.3 ~ 12	V
Enable voltage range(2)		V_{EN}	-0.3 ~ 60	V
Work temperature		Top	-40 ~ +125	℃
Maximum power dissipation	VS6380 Series	$P_{D\ Max}$	Internally Limited(3)	W
Maximum junction temperature		T_J	150	℃
Storage temperature		T_{STG}	-40 ~ +150	℃
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.

6.2 Recommended Operating Conditions

PARAMETER	SYMBOL	MIN.	NOM.	MAX.	UNIT
Input voltage	V_{IN}	3	-	50	V
Operating junction temperature	T_J	-40	-	150	°C
Operating ambient temperature	T_A	-40	-	125	°C

6 Specifications

6.3 ESD Ratings

ESD RATINGS		SYMBOL	VALUE	UNIT
Electrostatic discharge[4]	Human body model	$V_{ESD\text{-}HBM}$	2500	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.

6.4 Thermal Information

THERMAL METRIC[5]	SYMBOL	VS6380 Series			UNIT
Junction-to-ambient thermal resistance	$R_{\Theta JA}$	**SOT-23**	**SOT-23-3L**	**SOT-89-3L**	°C/W
		357.2	261.1	160.6	
		SOT-23-5L	**SOT-223**	-	
		250.3	99.5		
Junction-to-case thermal resistance	$R_{\Theta JC}$	**SOT-23**	**SOT-23-3L**	**SOT-89-3L**	°C/W
		136.4	67.0	52.9	
		SOT-23-5L	**SOT-223**	-	
		65.4	19.6		
Reference maximum power dissipation for continuous operation	$P_{D\ Ref}$	**SOT-23**	**SOT-23-3L**	**SOT-89-3L**	W
		0.28	0.38	0.63	
		SOT-23-5L	**SOT-223**	-	
		0.40	1.00		

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

6 Specifications

6.5 Electrical Characteristics

VS6380 Series (V_{IN} = 5V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		MIN.	TYP.[6]	MAX.	UNIT
Input voltage	V_{IN}	T_A = 25°C		3	-	50	V
DC output tolerance	V_{OUT}	T_J = 25°C, I_{OUT} = 1mA		-1		+1	%
Available output voltage	-	-		1.2	-	12	V
Output current	I_{OUT}[7]	-		200	-	-	mA
Quiescent current	I_Q	I_{OUT}=0mA			2.7	5.0	uA
Line regulation	LNR[9]	V_{IN} = V_{OUT} +1V to 60V, I_{OUT}=5mA			0.0048		%/V
Load regulation	LDR	1mA≤I_{OUT}≤200mA			5		mV
Dropout voltage	V_{DO}[8]	I_{OUT} =50mA	V_{OUT}=3.3V		480		mV
Shutdown current	I_{SD}	V_{EN} ≤ 0.4V			0.11		μA
EN high	$V_{EN(H)}$	Turn on, stable output voltage		0.9			V
EN low	$V_{EN(L)}$	Turn off, output voltage is 0V				0.3	V
EN Pull down current	I_{EN}	V_{EN}= 5V			0.07	0.2	μA
Power supply rejection ratio	PSRR	I_{OUT}=10mA, V_{IN}=12V, V_{OUT}=3.3V	f=1kHz		88		dB
			f=10kHz		76		
			f=100kHz		55		
			f=1MHz		63		
Output noise voltage	V_N	I_{OUT} = 10mA, f = 10 to100kHz			20xVout		μV_{RMS}
Short Circuit current		V_{OUT} =0			45		mA
Thermal shutdown	T_{SD}			-	151	-	℃
Thermal shutdown hysteresis	ΔT_{SD}			-	20	-	℃
C_{OUT} auto-discharge resistance	R_{DIS}	V_{EN}<0.4			73		Ω
Load Transient		I_{OUT} = 1 mA to 150 mA in 1 us V_{OUT}=3.3V, V_{IN}=12V			-290		mV
		I_{OUT} = 150 mA to 1 mA in 1 us V_{OUT}=3.3V, V_{IN}=12V			+180		mV

Note:

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

(7) Maximum output current is affected by the PCB layout, metal trace width, number of layers, ambient temperature and other environmental factors. Thermal limitations of the system must be carefully considered.

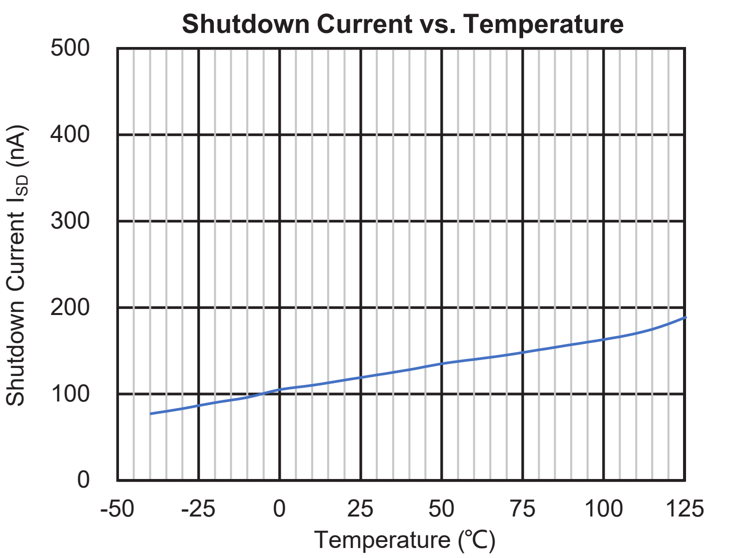
(8) The line regulation is calculated by the following formula: LNR=△V_{OUT}/(V_{OUT}×△V_{IN}) where, ΔV_{OUT} is the variation of the output voltage, ΔV_{IN} is the variation of the input voltage.

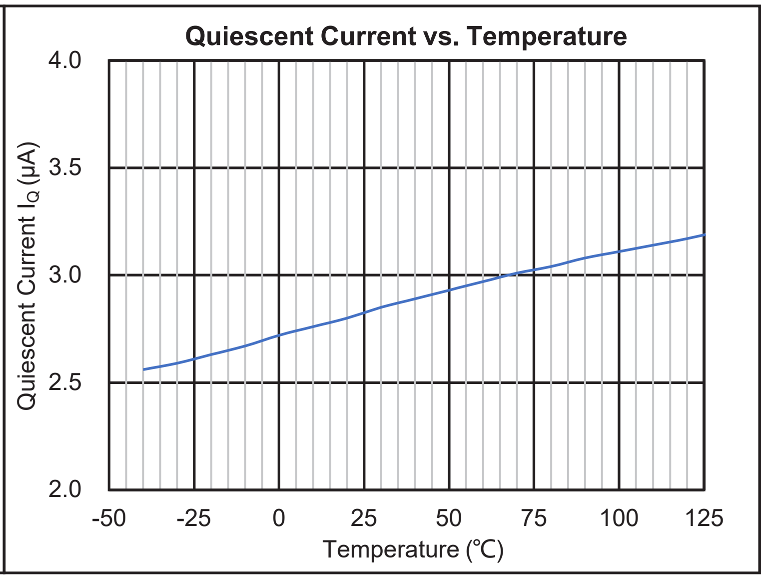
(9) Test the difference of output voltage and input voltage when input voltage is decreased gradually till output voltage equals to 98% of V_{OUT} Normal.

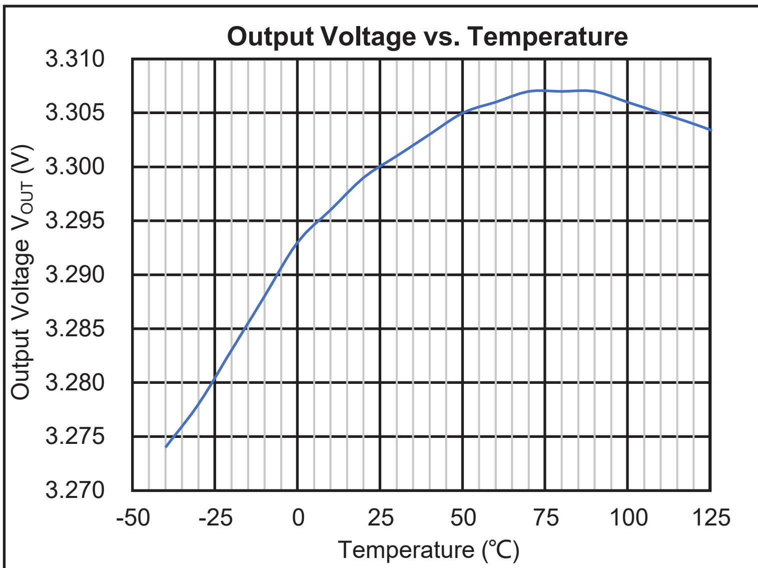
6 Specifications

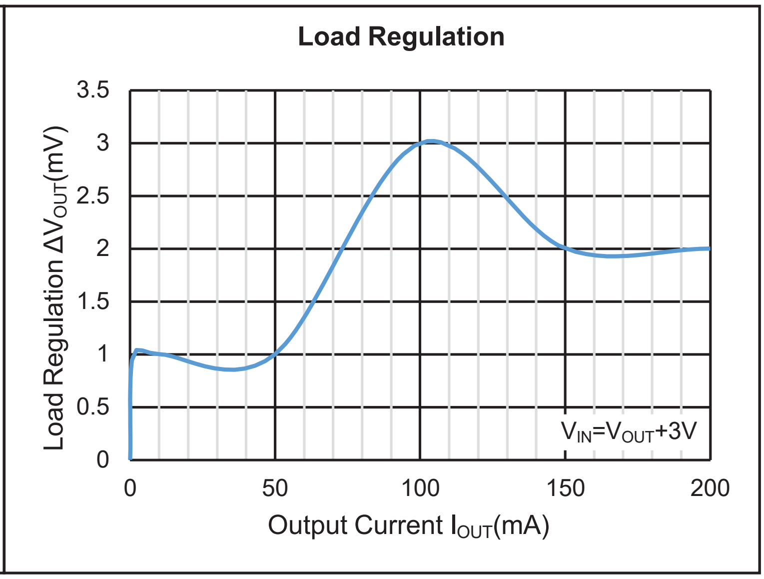
6.6 Typical Characteristics (continued)

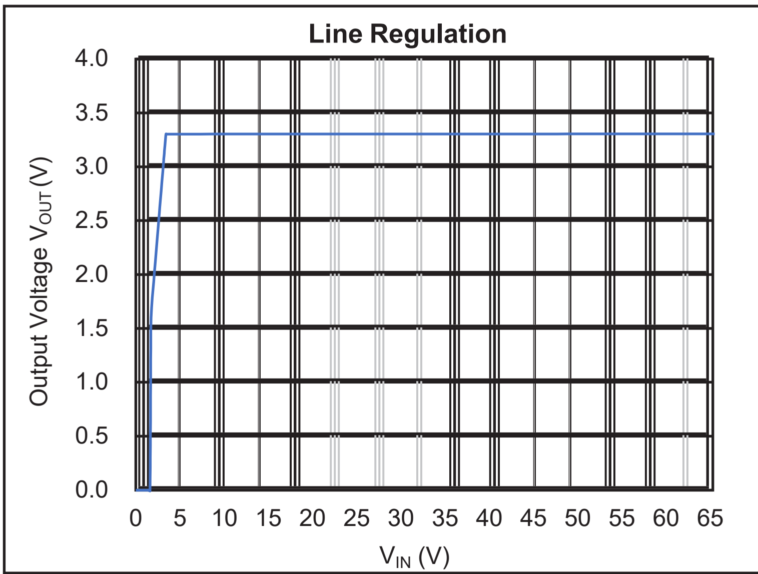
VS6380 Series, V_{OUT} = 3.3V (V_{IN} = 5V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

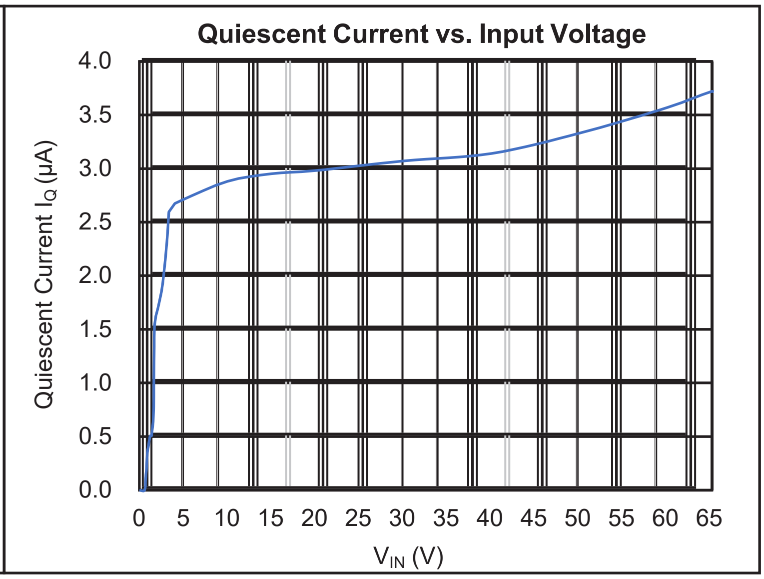








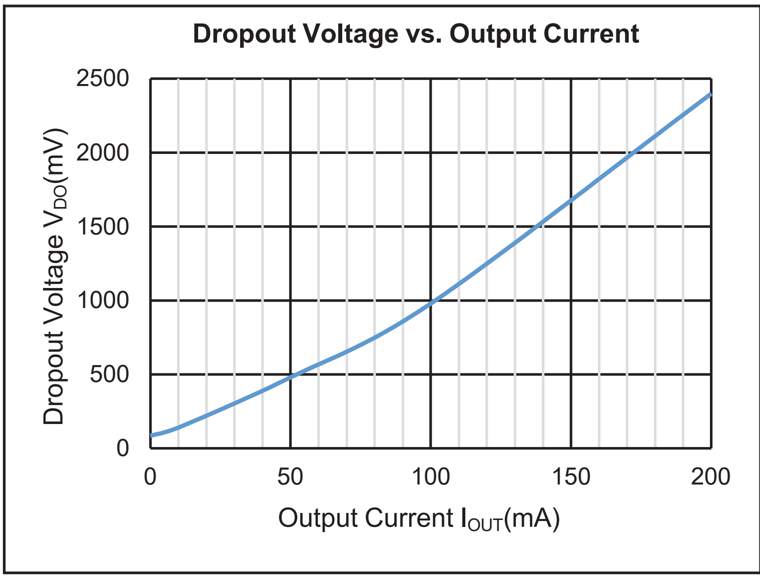


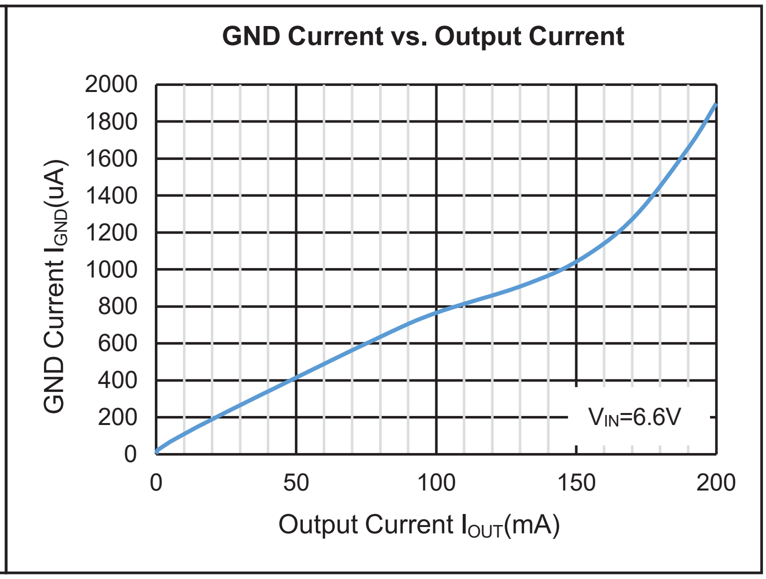


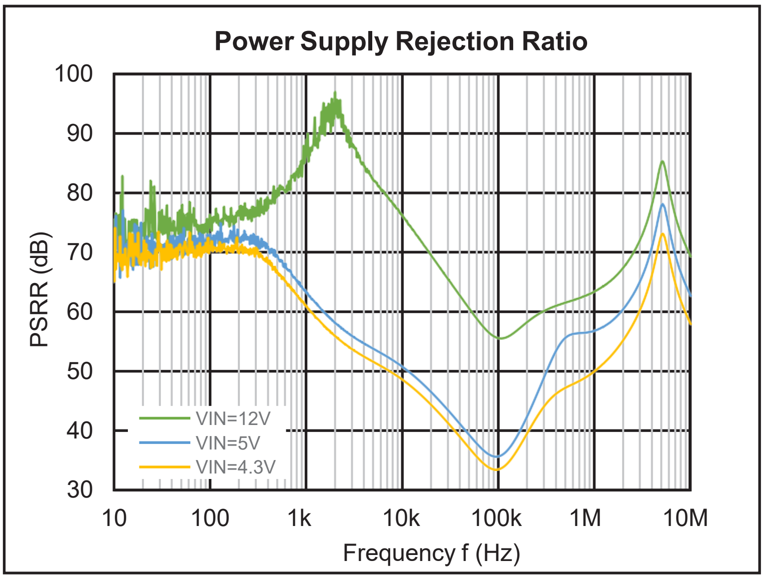
6 Specifications

6.6 Typical Characteristics (continued)

VS6380 Series, V_{OUT} = 3.3V (V_{IN} = 5V, C_{IN} = 1µF, C_{OUT} = 1µF, T_A = 25°C, unless otherwise specified)





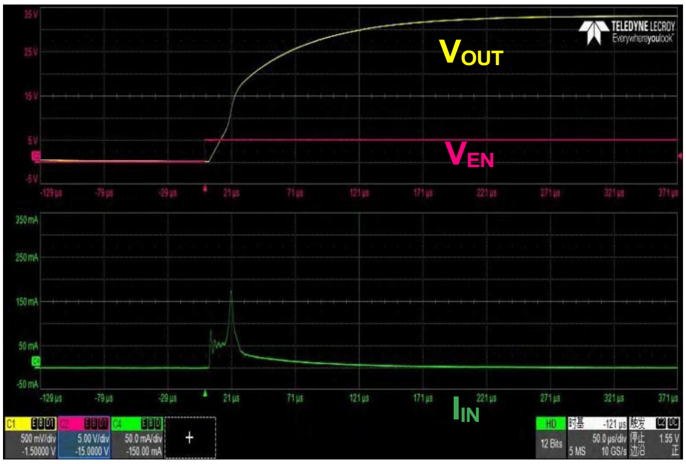


6 Specifications

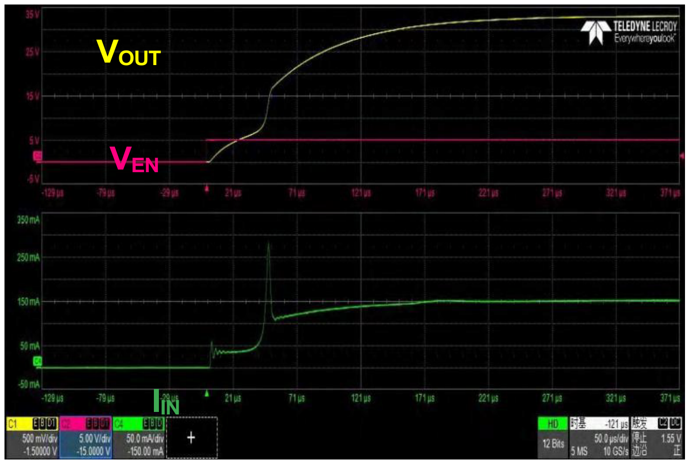
6.6 Typical Characteristics

VS6380 Series, V_{OUT} = 3.3V (C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

EN High (V_{IN} = 12V, V_{EN} = 0 ~5V, I_{OUT} = 0mA)

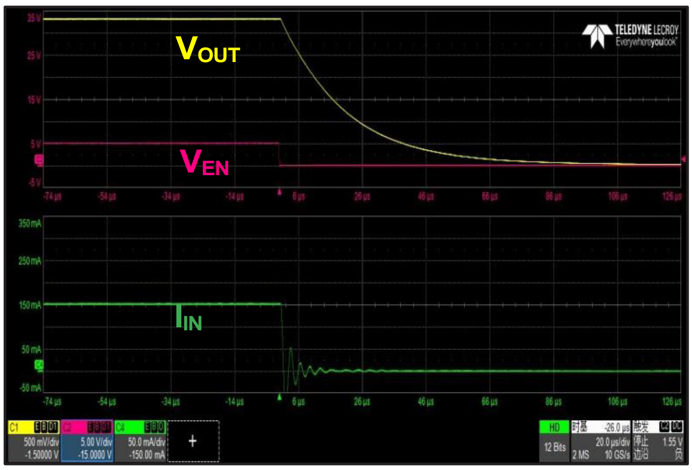


EN High (V_{IN} = 12V, V_{EN} = 0 ~5V, I_{OUT} =150mA)

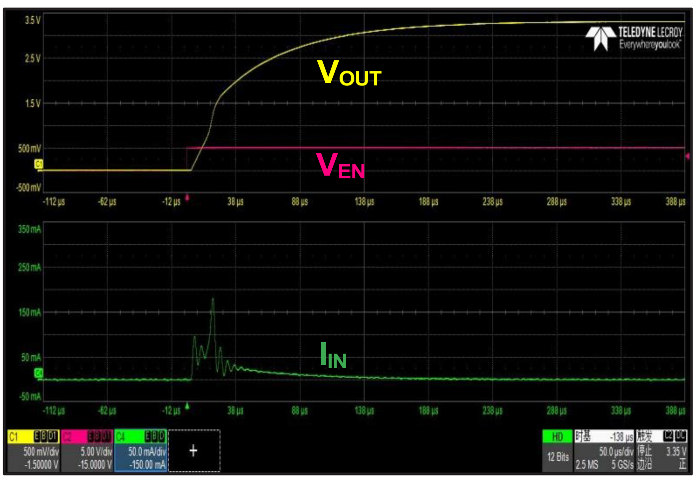


EN Low (V_{IN} = 12V, V_{EN} = 0 ~5V, I_{OUT} =0mA)

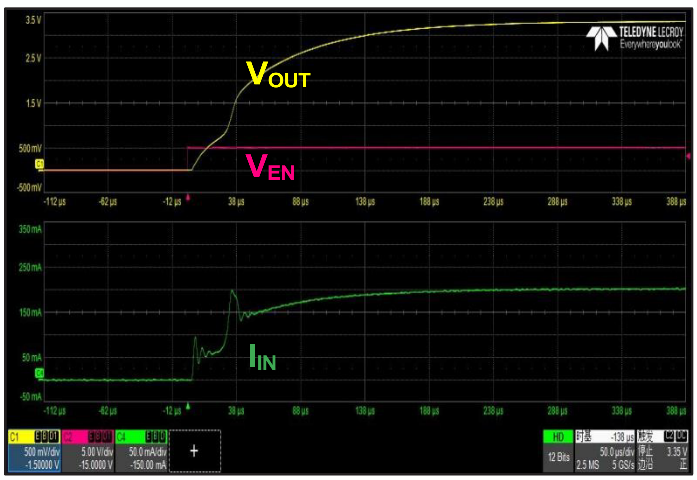
EN Low (V_{IN} = 12V, V_{EN} = 0 ~5V, I_{OUT} = 150mA)



EN High (V_{IN} = 8V, V_{EN} = 0 ~5V, I_{OUT} =0mA)



EN High (V_{IN} = 8V, VEN = 0 ~5V, I_{OUT} =200mA)



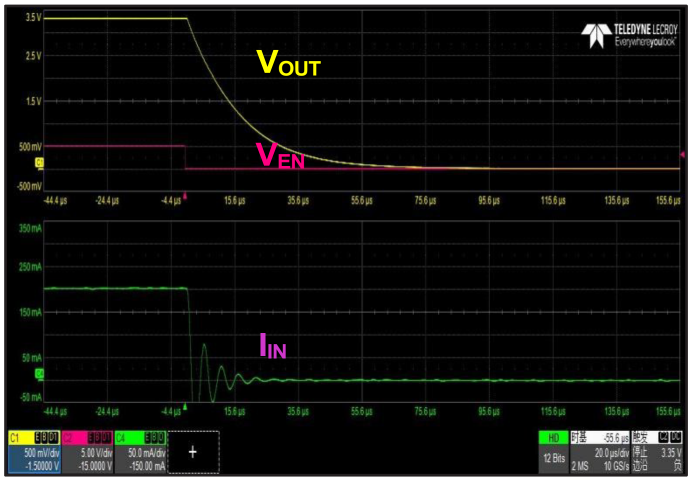
6 Specifications

6.6 Typical Characteristics (continued)

VS6380 Series, VOUT = 3.3V (CIN = 1μF, COUT = 1μF, TA = 25°C, unless otherwise specified)

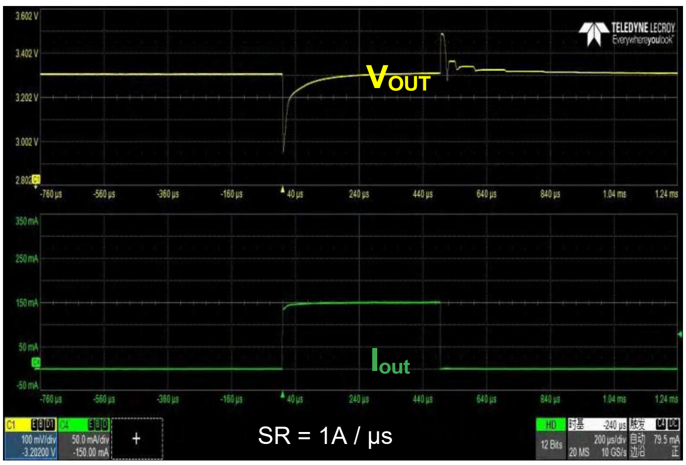
EN low (V_{IN} = 8V, V_{EN} = 0 ~5V, I_{OUT} = 0mA)

EN Low (V_{IN} = 8V, V_{EN} = 0 ~5V, I_{OUT} = 200mA)

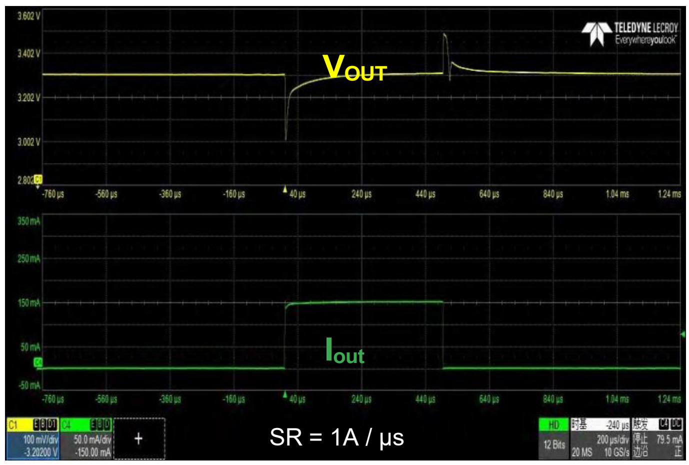


Load Transient (VEN = VIN)

V_{IN} =12V I_{OUT} = 0mA-150mA



V_{IN} =12V I_{OUT} = 1mA-150mA



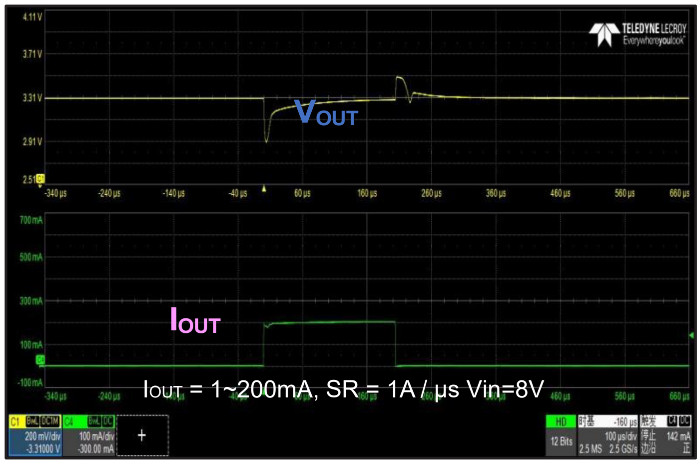
6 Specifications

6.6 Typical Characteristics (continued)

VS6380 Series, VOUT = 3.3V (CIN = 1μF, COUT = 1μF, TA = 25°C, unless otherwise specified)

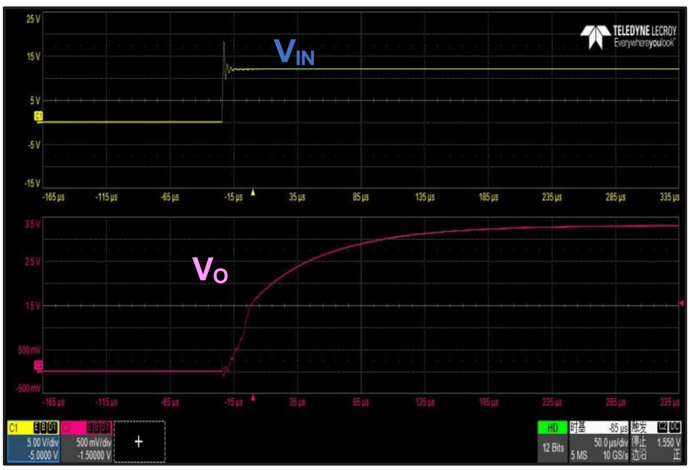
VIN=8V Io=0mA-200mA

VIN=8V Io=1mA-200mA

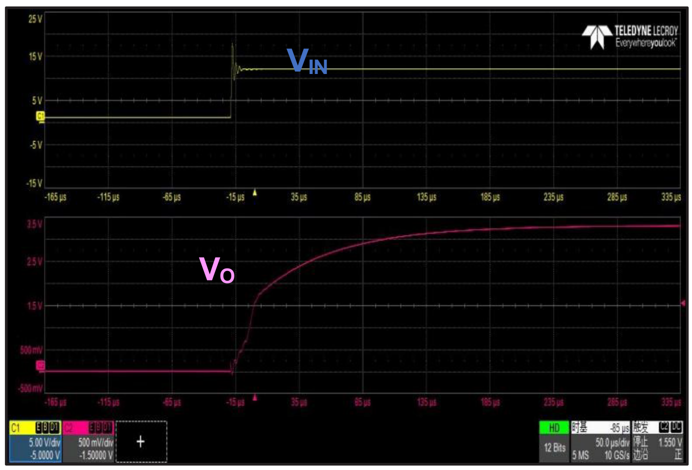


Hot pulg-in

VIN=12V Io=0mA



VIN=12V Io=1mA



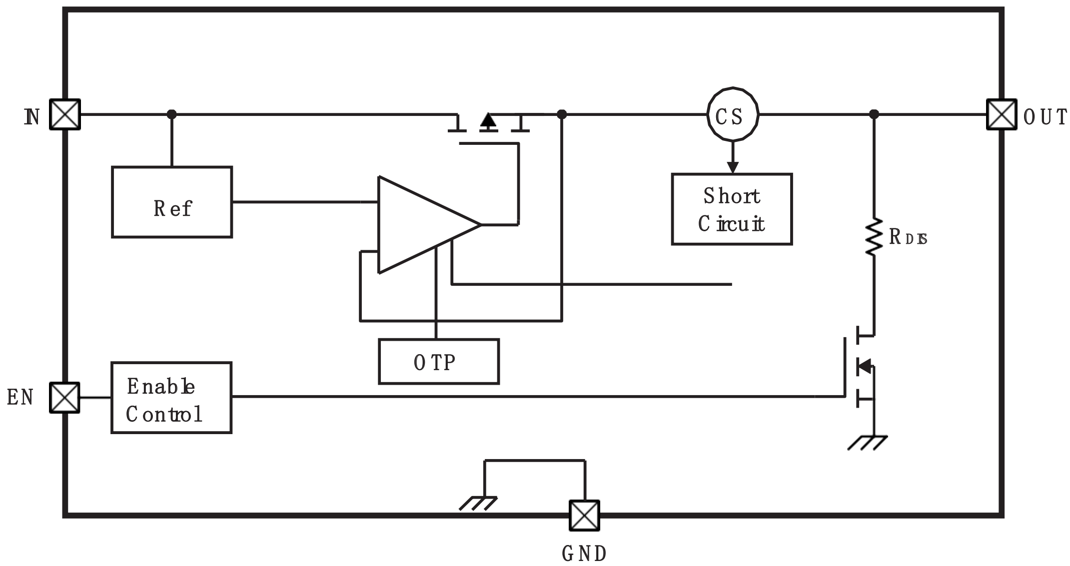
7 Detailed Description

7.1 Description

The VS6380 device belongs to a new generation of linear regulators that use a BiCMOS process technology to achieve very high maximum input and output voltages. This process not only allows the VS6380 device to maintain regulation during very fast high-voltage transients up to 50V, but it also allows the VS6380 device to regulate from a continuous high-voltage input rail.

The output can be turned off by controlling the EN pin on the chip, and the power consumption after turning off is only below 0.12μA.

7.2 Function Block Diagram



7.3 Feature Description

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).

Input and Output Capacitors

For the VS6380 series, it is recommended to use 1μF input C_{IN} and output C_{OUT} ceramic capacitors. It is recommended to use a 1μF capacitor at the input & Output pin of the device separately, and the position of the capacitor should be as close to the device pin as possible. 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 VS6380 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.

7 Detailed Description

7.3 Feature Description (continued)

Enable Operation

The enable pin will turn the regulator on or off. The threshold limits are covered in the electrical characteristics table in this data sheet. If the enable function is not to be used then the pin should be connected to V_{IN}.

Short-Circuit protection

The internal Foldback Current Limitation circuitry allows the device to supply the full nominal current but protects the device against Short. Foldback is a current-limiting feature that reduces the output current as the output voltage decreases in the event of an overcurrent condition. When VOUT has decreased to 0 V, the current is limited to an internally set constant value. When a fault condition causing overcurrent disappears, an LDO automatically recovers from overcurrent protection, returning the output voltage to the normal level.

Thermal Protection

Internal thermal shutdown (TSD) circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When TSD activated, the regulator output turns off. When cooling down under the low temperature threshold, device output is activated again. This TSD feature is provided to prevent failures from accidental overheating. Activation of the thermal protection circuit indicates excessive power dissipation or inadequate heatsinking. For reliable operation, junction temperature should be limited to +151°C maximum.

8 Application and Implementation

8.1 Application Information

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.

Operation in Dropout Mode

The VS6380 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.

Recommended Continuous Operating Areas

As an LDO, the working area of VS6380 series is limited by dropout voltage, output current, junction temperature and input voltage under continuous working condition. The recommended areas for continuous operation are shown in Figure 8-1:

A. The LDO input and output voltage difference V_{IN} - V_{OUT} must meet the dropout voltage V_{DO} conditions. See *Dropout Voltage* for more details.
B. Rated output current range I_{Rated}.
C. The actual junction temperature T_J of LDO shall not exceed the rated junction temperature. The product of voltage difference and current at both ends of LDO is power consumption, which determines the actual working junction temperature of LDO, so the curve is not linear.

In addition, the working area of VS6380 series is limited by the rated $V_{IN\ MIN}$ and $V_{IN\ MAX}$.