VS6022 Series Low-dropout Regulators

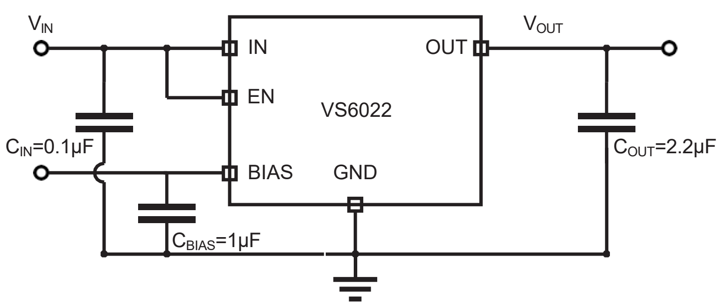
1 Introduction

The VS6022 series is a 500mA LDO equipped with NMOS pass transistor and a separate bias supply voltage (V_{BIAS}). The device provides very stable, accurate output voltage with low noise suitable for space constrained, noise sensitive applications. In order to optimize performance for battery operated portable applications, the VS6022 features low I_Q consumption. The output can be turned off by controlling the EN pin on the chip, and the power consumption after turning off is only below 0.1μA.

2 Available Packages

PARTNUMBER	PACKAGE
VS6022 Series	SOT-23-5L
	DFNWB1.2×1.2-4L
	DFNWB1.2×1.2-6L

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



Typical Application Circuit

3 Features

- Low BIAS Current:
  - Quiescent Current: 40μA (typ.)
  - Shutdown Current: 0.1μA (typ.)
- Input Voltage Range: V_{OUT}~5.5V
- BIAS Voltage Range: 2.5V~5.5V
- Fixed Output Voltage:
  - Available from 0.4V to 2.1V
- Output Tolerance: ±1%
- Output Current: up to 500mA
- Dropout Voltage: 150mV@500mA
- Output active discharge
- Enable Control
- Complete protection:
  - Thermal Shutdown
  - Current limiting protection

4 Applications

- Battery-powered Equipment
- Cellular and Smart Phones
- Digital Still and Video Cameras
- Laptop, Palmtops and PDA
- Portable Audio Video Equipment
- Radio Control System

7 Specifications

7.1 Absolute Maximum Ratings

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

<table>
<tr><th colspan="3">CHARACTERISTIC</th><th>SYMBOL</th><th>VALUE</th><th>UNIT</th></tr>
<tr><td colspan="3">Input voltage range[(2)]</td><td>V_{IN}</td><td>-0.3 ~ 6.0</td><td>V</td></tr>
<tr><td colspan="3">Output voltage range[(2)]</td><td>V_{OUT}</td><td>Vss-0.3 ~ VIN+0.3 ≤ 6</td><td>V</td></tr>
<tr><td colspan="3">Enable、BIAS input voltage range[(2)]</td><td>V_{EN}, V_{BIAS}</td><td>Vss-0.3 ~ VIN +0.3</td><td>V</td></tr>
<tr><td colspan="3">Work temperature</td><td>T_{OP}</td><td>-40 ~ +125</td><td>℃</td></tr>
<tr><td rowspan="3">Maximum power dissipation</td><td rowspan="3">VS6022 Series</td><td>DFNWB1.2×1.2-4L</td><td rowspan="3">$P_{D\ Max}$</td><td rowspan="3">Internally Limited[(3)]</td><td rowspan="3">W</td></tr>
<tr><td>DFNWB1.2×1.2-6L</td></tr>
<tr><td>SOT-23-5L</td></tr>
<tr><td colspan="3">Maximum junction temperature</td><td>T_J</td><td>150</td><td>℃</td></tr>
<tr><td colspan="3">Storage temperature</td><td>T_{STG}</td><td>-40 ~ +150</td><td>℃</td></tr>
<tr><td colspan="3">Soldering temperature & time</td><td>T_{solder}</td><td>260°C, 10s</td><td>-</td></tr>
</table>

(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}	V_{OUT}		5.5	V
BIAS Voltage Range	V_{BIAS}	2.5		5.5	V
Operating junction temperature	T_J	-40		125	°C

7 Specifications

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.

7.4 Thermal Information

THERMAL METRIC[5]	SYMBOL	VS6022 Series			UNIT
Junction-to-ambient thermal resistance	$R_{\Theta JA}$	**DFNWB1.2×1.2-4L**	**DFNWB1.2×1.2-6L**	**SOT-23-5L**	°C/W
		169.5	-	249.5	
Junction-to-case thermal resistance	$R_{\Theta JC}$	**DFNWB1.2×1.2-4L**	**DFNWB1.2×1.2-6L**	**SOT-23-5L**	°C/W
		53.8	-	64.8	
Reference maximum power dissipation for continuous operation	$P_{D\ Ref}$	**DFNWB1.2×1.2-4L**	**DFNWB1.2×1.2-6L**	**SOT-23-5L**	W
		0.59	-	0.4	

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

7 Specifications

7.5 Electrical Characteristics

VS6022 Series (V_{IN}= $V_{OUT\ (NOM)}$ + 0.3V, V_{BIAS}=2.5V or V_{OUT}+1.5V which is greater, I_{OUT}=1mA, C_{IN} = 4.7μF, C_{OUT} = 10μF, T_A = 25°C, unless otherwise specified)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	MIN.	TYP.(6)	MAX.	UNIT
Input voltage	V_{IN}	T_A = 25°C	V_{OUT} + V_{DO}	-	5.5	V
BIAS voltage	V_{BIAS}	T_A = 25°C	(V_{OUT} + 1.5) ≥ 2.5	-	5.5	V
Under voltage Lock-out	V_{UVLO}	V_{BIAS} Rising hysteresis	-	1.7 0.2	-	V
DC output tolerance	V_{OUT}	$V_{OUT(NOM)}$+0.3V ≤ V_{IN} ≤ $V_{OUT(NOM)}$+1V, 2.5V or (V_{OUT}+1.6V), which is greater < V_{BIAS} < 5.5V,1mA < I_{OUT} < 500mA	-1	-	+1	%
Output current	I_{OUT}(7)	-	-	500	-	mA
Output current limit	I_{CL}	V_{OUT} = $V_{OUT\ (NOM)}$*90%	-	750	-	mA
VIN Line regulation	V_{IN} LNR(9)	$V_{OUT(NOM)}$ + 0.3V ≤ V_{IN} ≤ 5.0V	-	0.01	-	%/V
V_{BIAS} Line regulation	V_{BIAS} LNR(9)	2.5V or (V_{OUT} + 1.6V) which is better < V_{BIAS} < 5.5V	-	0.01	-	%/V
Load regulation	LDR	1mA ≤ I_{OUT} ≤ 500mA	-	4	-	mV
V_{IN} Dropout voltage	V_{DO}(8)	I_{OUT} = 500mA	-	150	300	mV
V_{BIAS} Dropout voltage	V_{DO}(8)	I_{OUT} = 500mA, V_{IN} = V_{BIAS}	-	1.1	-	V
BIAS Quiescent current	I_{BIASQ}	V_{BIAS} = 3.0V	-	40	70	μA
BIAS Shutdown current	I_{BIASSD}	V_{EN} ≤ 0.4V	-	0.1	1	μA
V_{IN} Shutdown current	I_{VINSD}	V_{EN} ≤ 0.4V	-	0.01	1	μA
EN high	$V_{EN(H)}$	Turn on, stable output voltage	1.2	-	-	V
EN low	$V_{EN(L)}$	Turn off, output voltage is 0	-	-	0.4	
EN Pull down current	I_{EN}	V_{EN} = 5.5V	-	0.06	1	μA
Output noise voltage	Noise	f = 10Hz - 100kHz, V_{IN} = V_{OUT} + 0.5V $V_{OUT(NOM)}$ = 0.8V, C_{OUT} = 10uF	-	33	-	μVrms
Power supply rejection ratio Fixed Output Voltage	PSRR （V_{IN}）	V_{IN} to V_{OUT}: PSRR, f = 1kHz, I_{OUT} = 10mA, V_{IN} ≥ V_{OUT}+0.5V,	-	70	-	dB
	PSRR （V_{BIAS}）	V_{BIAS} to V_{OUT}: PSRR, f = 1kHz, I_{OUT} = 10mA, V_{IN} ≥ V_{OUT} + 0.5V,	-	80	-	
Thermal shutdown	T_{SD}	-	-	160	-	°C
Thermal shutdown hysteresis	ΔT_{SD}	-	-	20	-	°C
C_{OUT} auto-discharge resistance	R_{DIS}	V_{EN} < 0.4	-	500	-	Ω
Turn-On Time	t_{ON}	From V_{EN} > $V_{EN(H)}$ to V_{OUT} = $V_{OUT(NOM)}$*90%, $V_{OUT(NOM)}$ = 1V,C_{OUT} = 10uF	-	100	-	μs

7 Specifications

7.5 Electrical Characteristics (continued)

Note:

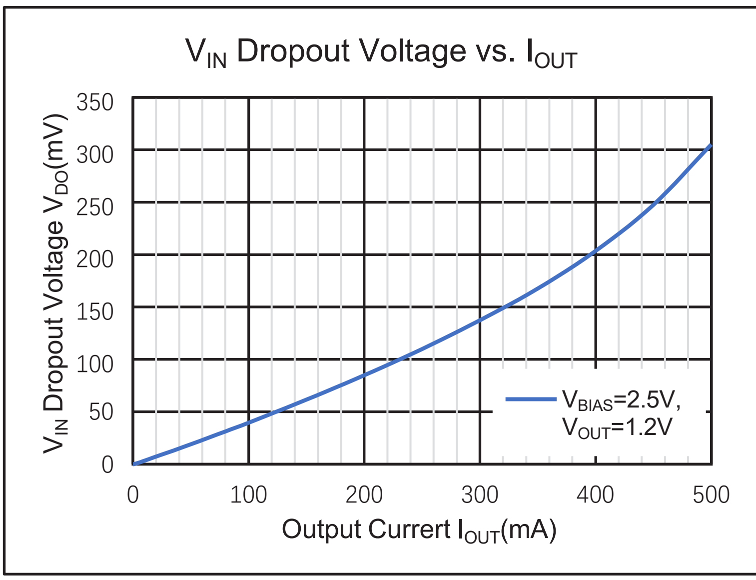
1. $V_{OUT\ (NOM)}$: nominal voltage;
2. For output voltages below 1.4 V, V_{BIAS} dropout voltage does not apply due to a minimum Bias operating voltage of 2.5 V.
3. (6) Typical numbers are at 25°C and represent the most likely norm.
4. (7) Maximum output current is affected by the PCB layout, metal trace width, number of layers, ambient temperature and other environmental factors. Thermal limitations of the system must be carefully considered.
5. (8) 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. (9) The line regulation is calculated by the following formula:

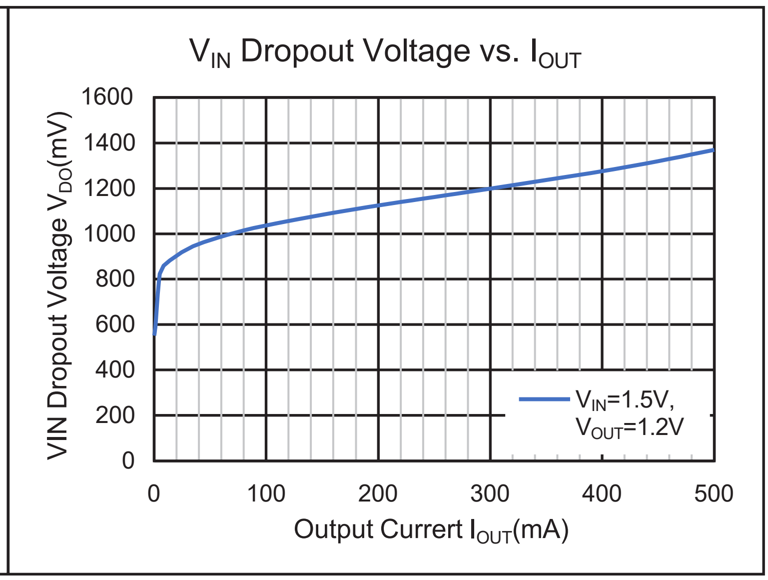
$$\square\square\square = \frac{\Delta V_{OOUT}}{\square_{\square\square\square\square} \times \Delta V_{\square\square}}$$

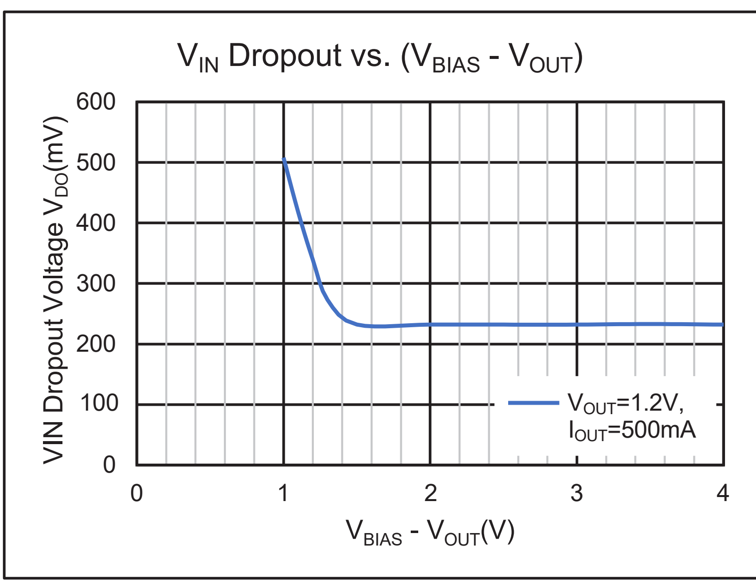
where , ΔV_{OUT} is the variation of the output voltage, ΔV_{IN} is the variation of the input voltage.

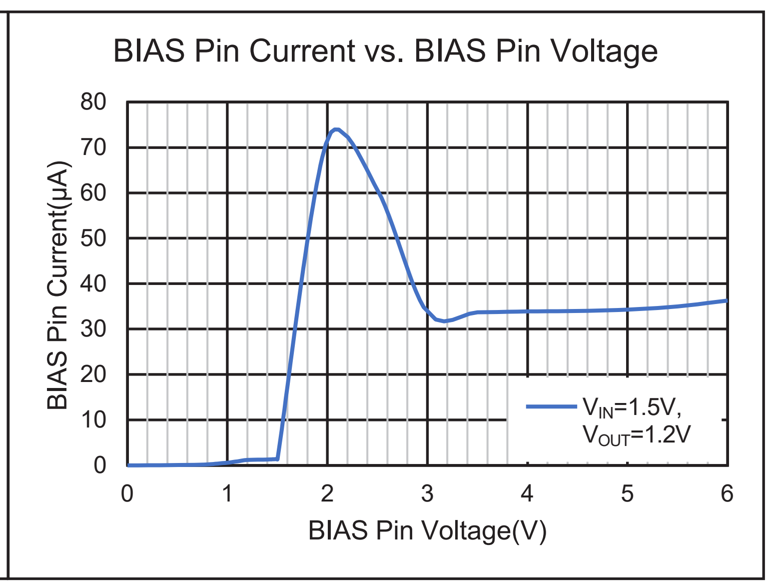
7.6 Typical Characteristics

VS6022 Series ($V_{IN} = V_{OUT\ (NOM)} + 0.3V$, $V_{BIAS} = 2.5V$ or $V_{OUT} + 1.5V$ which is better, $I_{OUT} = 1mA$, $C_{IN} = 1\mu F$, $C_{OUT} = 2.2\mu F$, $T_A = 25°C$, unless otherwise specified)







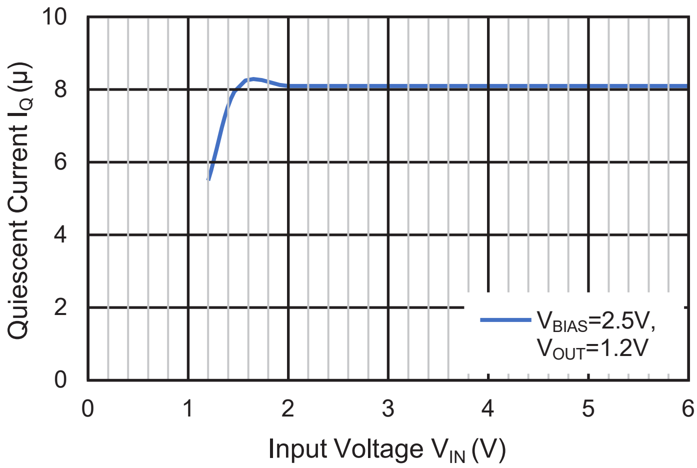


7 Specifications

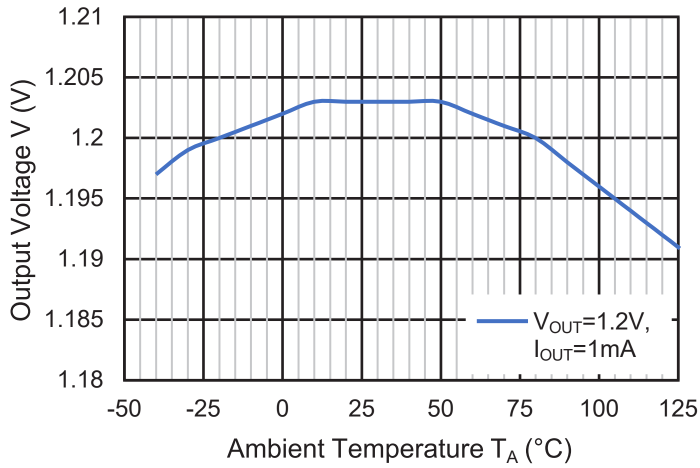
7.6 Typical Characteristics (continued)

VS6022 Series (V_{IN} = $V_{OUT\ (NOM)}$ + 0.3V, V_{BIAS} = 2.5V or V_{OUT} + 1.5V which is better, I_{OUT} = 1mA, C_{IN} = 1μF, C_{OUT} = 2.2μF, T_A = 25°C, unless otherwise specified)

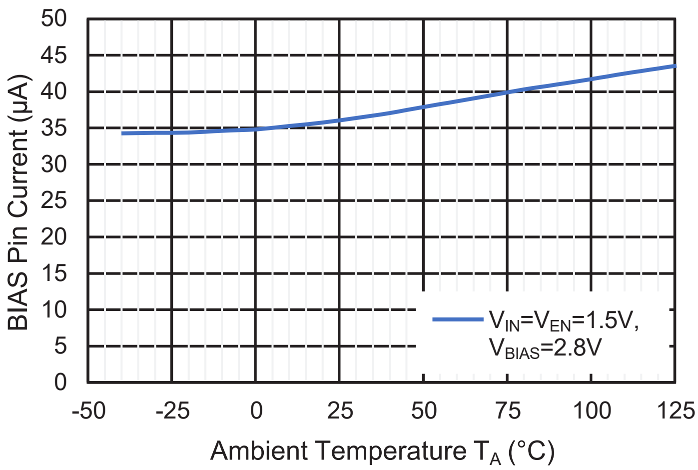
V_{IN} Quiescent Current



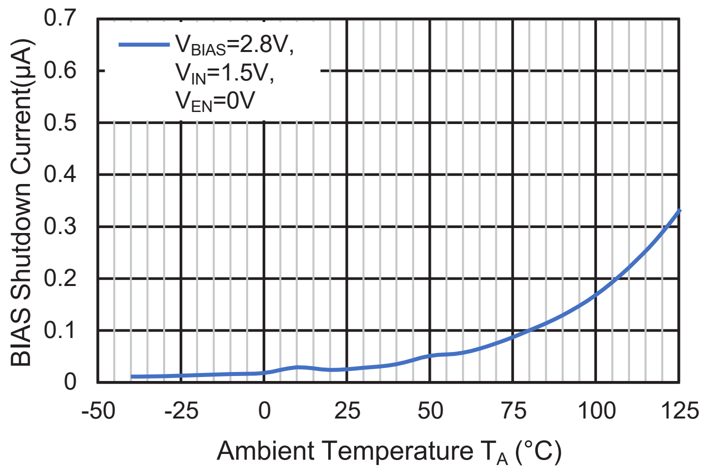
Output Voltage vs. Temperature



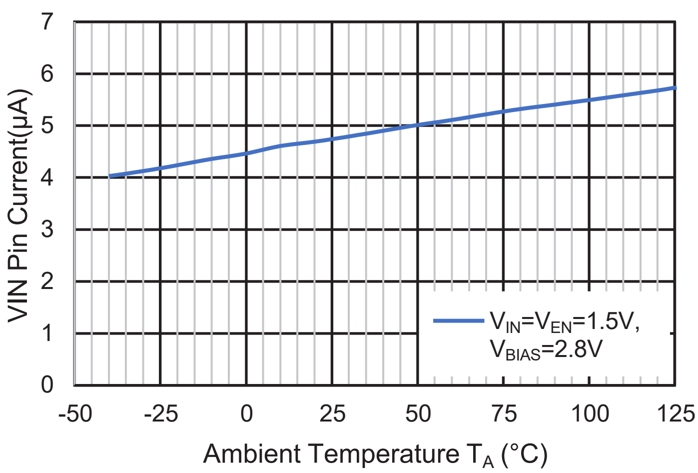
BIAS Pin Current vs. Temperature



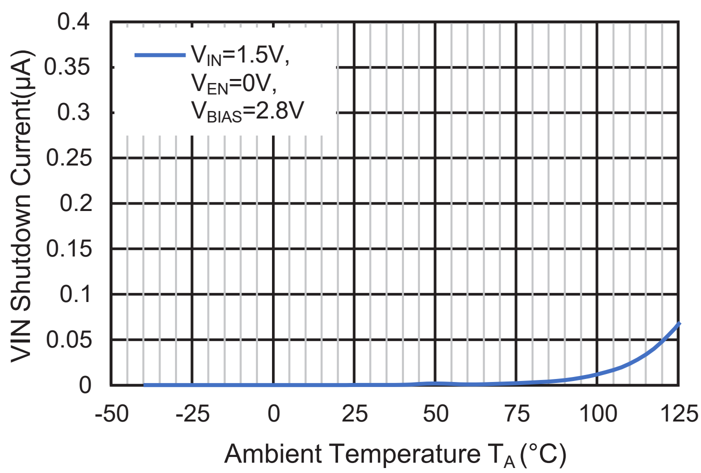
BIAS Shutdown Current vs. Temperature



V_{IN} Pin Current vs. Temperature



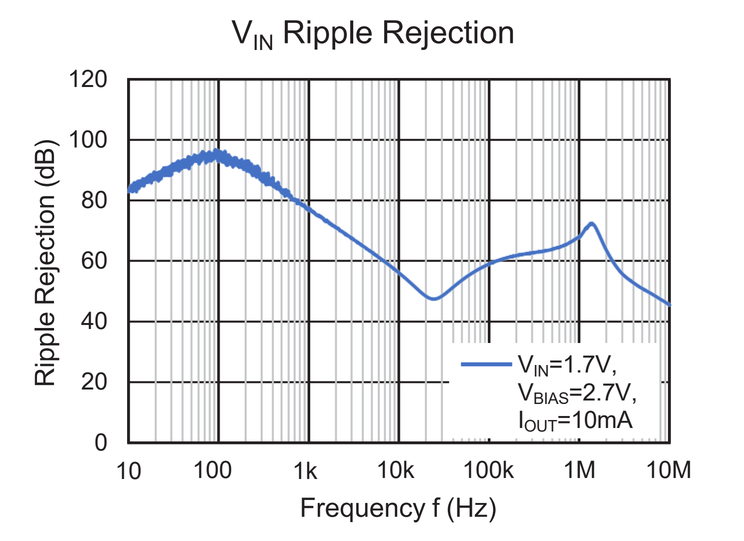
V_{IN} Shutdown Current vs. Temperature

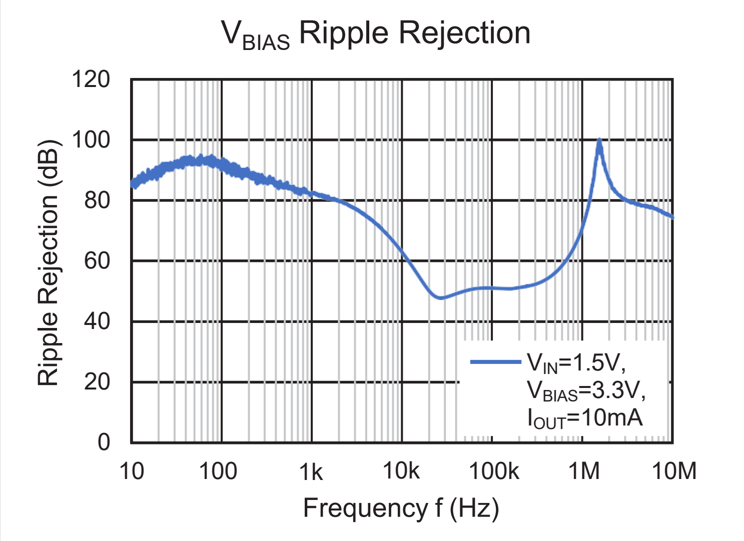


7 Specifications

7.6 Typical Characteristics (continued)

VS6022 Series (V_{IN} = $V_{OUT\ (NOM)}$ + 0.3V, V_{BIAS} = 2.5V or V_{OUT} + 1.5V which is better, I_{OUT} = 1mA, C_{IN} = 1μF, C_{OUT} = 2.2μF, T_A = 25°C, unless otherwise specified)



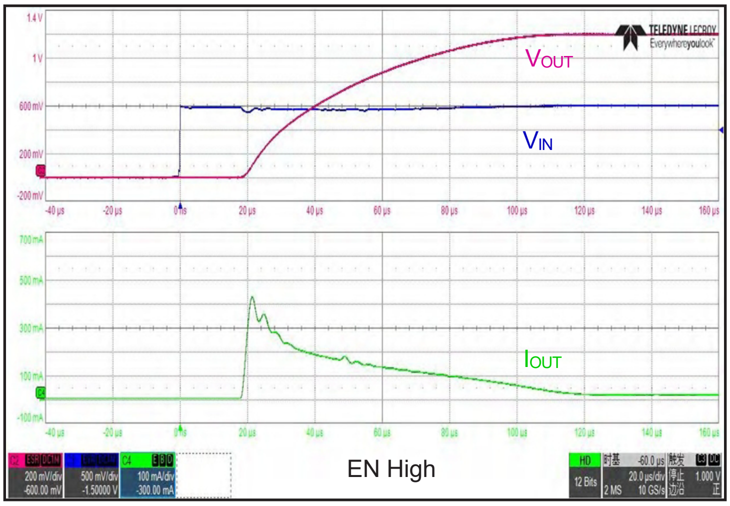


7 Specifications

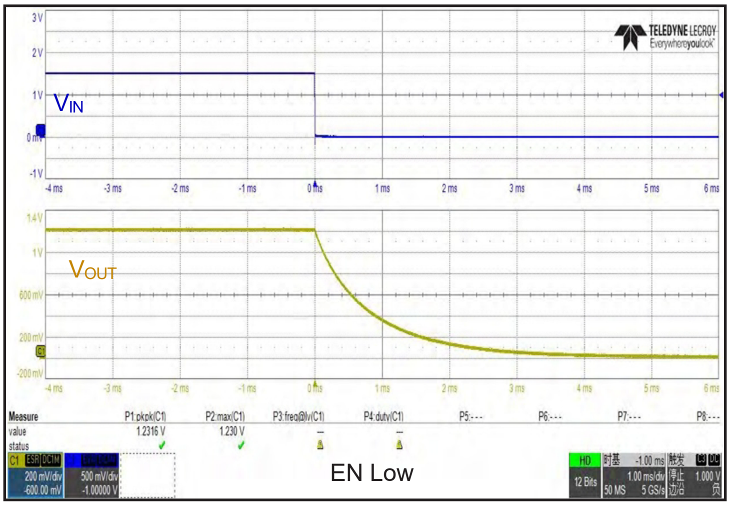
7.6 Typical Characteristics (continued)

VS6022 Series (V_{IN} = $V_{OUT\,(NOM)}$ + 0.3V, V_{BIAS} = 2.5V or V_{OUT} + 1.5V which is better, I_{OUT} = 1mA, C_{IN} = 1μF, C_{OUT} = 2.2μF, T_A = 25°C, unless otherwise specified)

EN Response (V_{OUT} = 1.2V, V_{IN} = 1.5V, V_{BIAS}=2.8V, V_{EN} = 0 ~ 2.2V, I_{OUT} = 10mA)

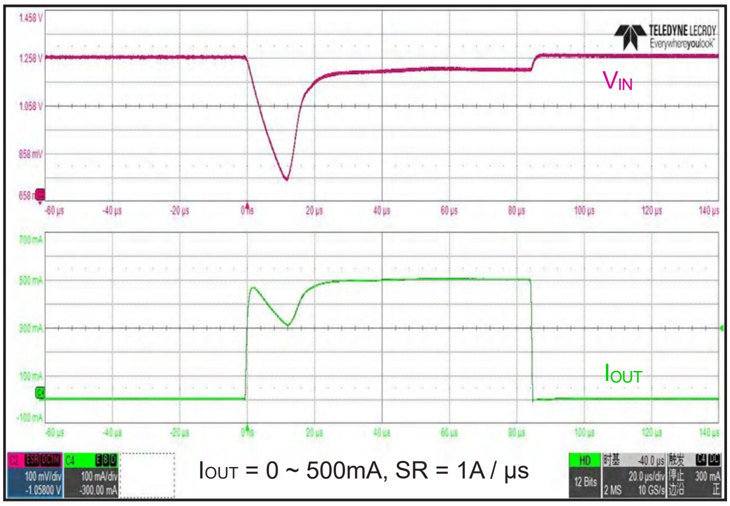


EN High

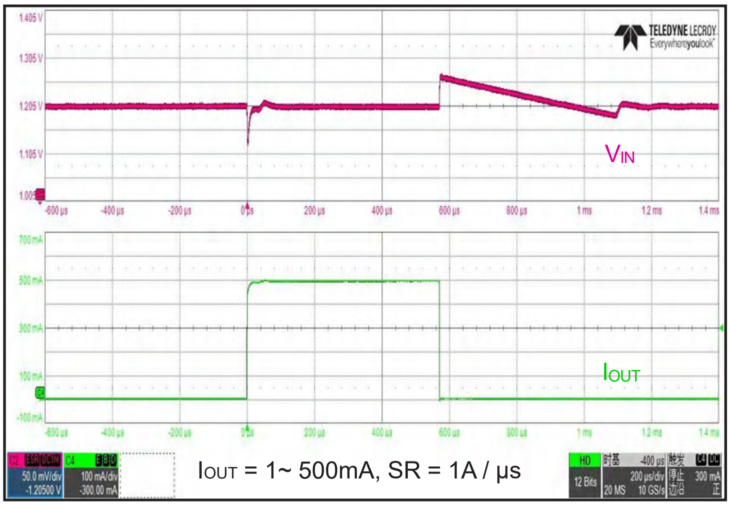


EN Low

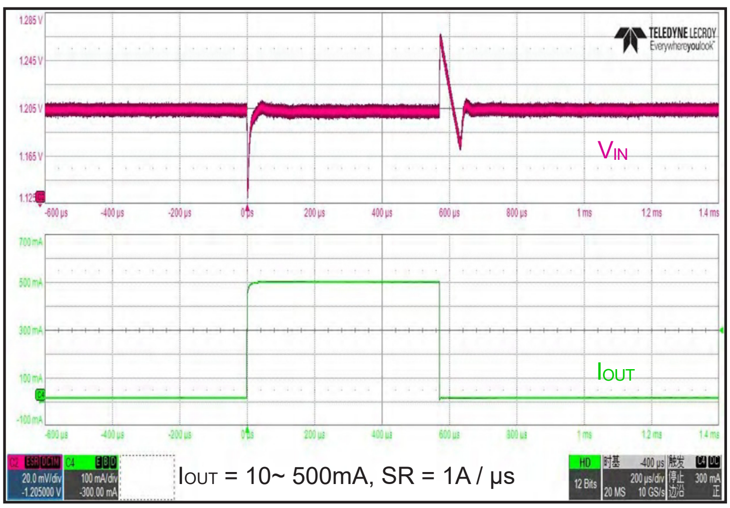
Load Response (V_{OUT} = 1.2V, V_{IN} = V_{EN} = 1.5V, V_{BIAS} = 2.8V)



I_{OUT} = 0 ~ 500mA, SR = 1A / μs



I_{OUT} = 1~ 500mA, SR = 1A / μs



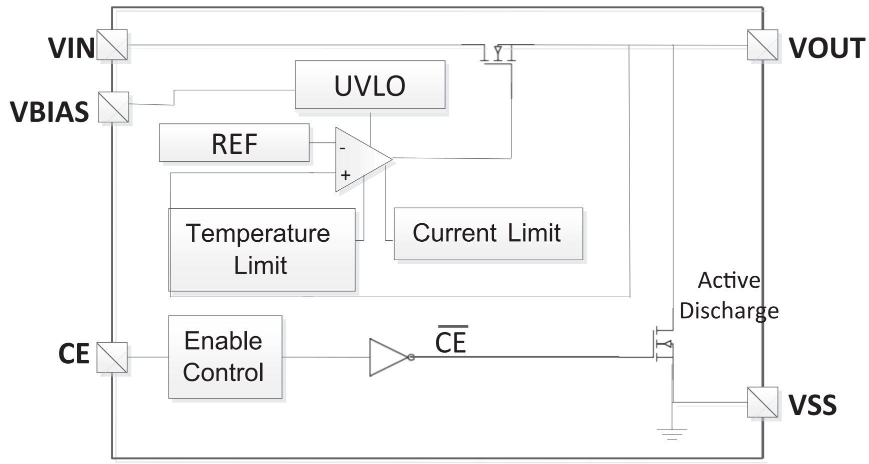
I_{OUT} = 10~ 500mA, SR = 1A / μs

8 Detailed Description

8.1 Description

The VS6022 series is dual−rail very low dropout voltage regulator is using NMOS pass transistor for output voltage regulation from V_{IN} voltage. All the low current internal control circuitry is powered from the V_{BIAS} voltage. The use of an NMOS pass transistor offers several advantages in applications. Unlike PMOS topology devices, the output capacitor has reduced impact on loop stability. V_{IN} to V_{OUT} operating voltage difference can be very low compared with standard PMOS regulators in very low V_{IN} applications. The VS6022 offers smooth monotonic start-up. The controlled voltage rising limits the inrush current. The Enable (EN) input is equipped with internal hysteresis. VS6022 Voltage linear regulator Fixed version is available.

8.2 Function Block Diagram



8 Detailed Description

8.3 Description

Dropout Voltage

Because of two power supply inputs V_{IN} and V_{BIAS} and one V_{OUT} regulator output, there are two Dropout voltages specified. The first, the V_{IN} Dropout voltage is the voltage difference (V_{IN} – V_{OUT}) when V_{OUT} starts to decrease by percent specified in the Electrical Characteristics table. V_{BIAS} is high enough; specific value is published in the Electrical Characteristics table. The second, V_{BIAS} dropout voltage is the voltage difference (V_{BIAS} – V_{OUT}) when V_{IN} and V_{BIAS} pins are joined together and V_{OUT} starts to decrease.

Input and Output Capacitors

The device is designed to be stable for ceramic output capacitors with Effective capacitance in the range from 2.2uF to 10uF. The device is also stable with multiple capacitors in parallel, having the total effective capacitance in the specified range. In applications where no low input supplies impedance available (PCB inductance in V_{IN} and/or V_{BIAS} inputs as example), the recommended C_{IN} = 4.7μF and C_{BIAS} =10μf or greater. Ceramic capacitors are recommended. For the best performance all the capacitors should be connected to the VS6022 respective pins directly in the device PCB copper layer, not through vias having not negligible impedance. When using small ceramic capacitor, their capacitance is not constant but varies with applied DC biasing voltage, temperature and tolerance. The effective capacitance can be much lower than their nominal capacitance value, most importantly in negative temperatures and higher LDO output voltages. That is why the recommended Output capacitor capacitance value is specified as Effective value in the specific application conditions.

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} or V_{BIAS}.

Current Limitation

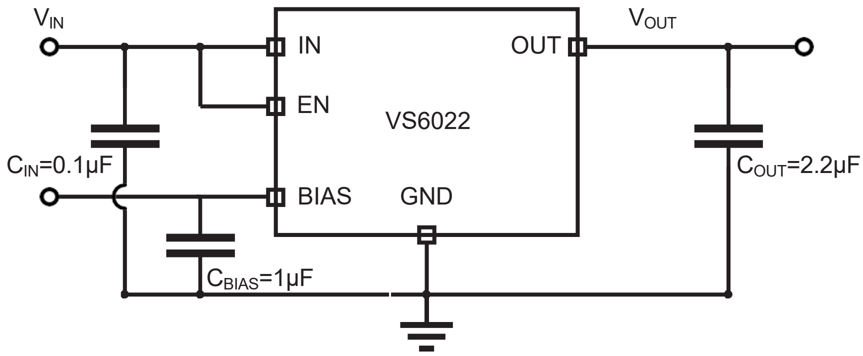
The internal Current Limitation circuitry allows the device to supply the full nominal current and surges but protects the device against Current Overload or Short.

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 +125°C maximum.

9 Application and Implementation

9.1 Typical Application Circuits



9.2 Application Information

Selection of Bypass Capacitances

For the VS6022 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 VS6022 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 VS6022 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

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 VS6022 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.

Operation in Dropout Mode

The VS6022 series is internally integrated with an N-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.