VS6300E Series Low-dropout Regulators

1 Introduction

The VS6300Eseries is a group of low dropout voltage linear regulators manufactured using CMOS technology. It supports the input voltage range of 1.6V to 5.5V, and can also provide current up to 500mA under the condition of good heat dissipation.

The VS6300Eseries has ultra-lowquiescent current and low dropout voltage, which can provide large output current even when the input and output voltage difference is very small. In addition, the VS6300E series also features high power ripple rejection, ultralow output noise, and fast response speed. These features make the VS6300E series very suitable for application in battery-powered devices to extend battery life, such as RF applications or other systems that require a quiet voltage source.

The VS6300E series provides a adjustable voltage version from 0.8V to 5.0V， and the VS6300E series can use ceramic capacitors with smaller volumes than tantalum capacitors, which can minimize the size of printed circuit boards (PCBs).

The VS6300E series also has a built-in foldback current limiting and thermal shutdown function to help protect the regulator in the event of load short circuits or faults.

2 Applications

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

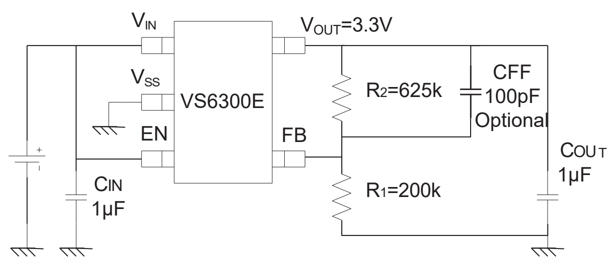
3 Features

- Input Voltage Range: 1.6V ~ 5.5V
- Adjustable Output Voltage: from 0.8V to 5.0V
- Output Tolerance: ±1%
- Output Current: up to 500mA
- Quiescent Current: 33μA (typ.)
- Dropout Voltage: 50mV@100mA
- Power Supply Rejection Ratio: 80dB@1kHz
- Output Noise Voltage: with C_{FF}=100pF
  20 × V_{OUT} μV_{RMS} (10Hz ~ 100kHz)
- Excellent Transient Response
- Anti-overshoot during Hot-swap
- Current Limit
- Fold-back Short-Circuit Protection
- Thermal shutdown protect

4 Available Packages

PART NUMBER	PACKAGE
VS6300E Series	SOT-23-5L

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



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 ~ 6.5	V
Output voltage range(2)			V_{OUT}	-0.3 ~ (V_{IN} + 0.3)	V
Enable voltage range(2)			V_{EN}	-0.3 ~ (V_{IN} + 0.3)	V
Work temperature			T_{OP}	-40 ~ +125	°C
Maximum power dissipation	VS6300E Series	SOT-23-5L	$P_{D\ Max}$	Internally Limited(3)	W
Maximum junction temperature			T_{Jmax}	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.

6.2 Recommend Operating Conditions

PARAMETER	SYMBOL	MIN.	NOM.	MAX.	UNIT
Input voltage	V_{IN}	1.6	-	5.5	V
Operating junction temperature	T_J	-40	-	125	°C
Operating ambient temperature	T_A	-40	-	85	°C

6.3 ESD Ratings

ESD RATINGS		SYMBOL	VALUE	UNIT
Electrostatic discharge(4)	Human body model	$V_{ESD\text{-}HBM}$	3000	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	VS6300E Series	UNIT
		SOT-23-5L	
Junction-to-ambient thermal resistance	$R_{\theta JA}$	249.5	°C/W
Junction-to-case thermal resistance	$R_{\theta JC}$	64.8	°C/W
Reference maximum power dissipation for continuous operation	$P_{D\ Ref}$	0.4	W

(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.

6 Specifications

6.5 Electrical Characteristics

VS6300E 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	V_{IN}	T_A = 25°C		1.6	-	5.5	V
DC output tolerance	V_{OUT}	T_J = 25°C, I_{OUT} = 1mA		-1	-	+1	%
		T_J = -40°C to 125°C, I_{OUT} = 1mA		-2	-	+2	%
Output current	I_{OUT}[7]	-		500	-	-	mA
Feedback Voltage	V_{FB}	T_J = 25°C, I_{OUT} = 1mA		0.792	0.8	0.808	V
Quiescent current	I_Q	I_{OUT} = 0mA, V_{OUT} = FB		15	33	66	μA
Line regulation	LNR[8]	V_{IN} = V_{OUT} + 1V to 5.5V, I_{OUT} = 10mA		-	0.01	-	%/V
Load regulation	LDR	I_{OUT} = 1 to 100mA		-	0.5	2	mV
		I_{OUT} = 1 to 500mA		-	2	10	
Dropout voltage	V_{DO}[9]	I_{OUT} = 500mA	0.8V ≤ V_{OUT} < 1.0V	-	1000	1500	mV
			1.0V ≤ V_{OUT} < 1.2V	-	800	1200	
			1.2V ≤ V_{OUT} < 1.8V	-	500	750	
			1.8V ≤ V_{OUT} < 2.5V	-	400	600	
			2.5V ≤ V_{OUT} < 3.3V	-	250	450	
			3.3V ≤ V_{OUT} < 5V	-	200	300	
Shutdown current	I_{VINSD}	V_{EN} ≤ 0.4V		-	0.03	0.2	μA
EN high	$V_{EN(H)}$	Turn on, stable output voltage		0.7	-	-	V
EN low	$V_{EN(L)}$	Turn off, output voltage is 0V		-	-	0.09	
EN Pull down current	I_{EN}	V_{EN} = 5V		-	0.07	0.2	μA
Power supply rejection ratio	PSRR	I_{OUT} = 10mA, V_{OUT} = 3.3V, V_{IN} = 5V, C_{FF} = 100pF	f = 1kHz	-	80	-	dB
			f = 10kHz	-	68	-	
			f = 100kHz	-	64	-	
			f = 1MHz	-	62	-	
Output noise voltage	V_N	I_{OUT} = 10mA, f = 10 to 100kHz	C_{FF} = 0pF	-	33 x V_{OUT}	-	$μV_{RMS}$
			C_{FF} = 100pF	-	20 x V_{OUT}	-	
Short Circuit current	I_{SC}	V_{OUT} =0V		-	55	-	mA

Note: Production test at +25°C .Specifications over the temperature range are guaranteed by design and characterization.

6 Specifications

6.5 Electrical Characteristics(continue)

VS6300E 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
Output current Ilimit	I_{Limit}	V_{OUT} = 90% * $V_{OUT(NOM)}$	-	650	-	mA
Thermal shutdown	T_{SD}	-	-	150	-	°C
Thermal shutdown hysteresis	ΔT_{SD}		-	20	-	°C
C_{OUT} auto-discharge resistance	R_{DIS}	V_{EN} < 0.4V	-	600	-	Ω
Load Transient	-	I_{OUT} = 1 mA to 500 mA in 1us, V_{OUT} = 3.3V, V_{IN} = 4.3V	-	50	-	mV
	-	I_{OUT} = 500 mA to 1 mA in 1us, V_{OUT} = 3.3V, V_{IN}=4.3V	-	50	-	

Note :

Production test at + 25°C.Specifications over the temperature range are guaranteed by design and characterization.

$V_{OUT\ (NOM)}$: nominal voltage;

(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.

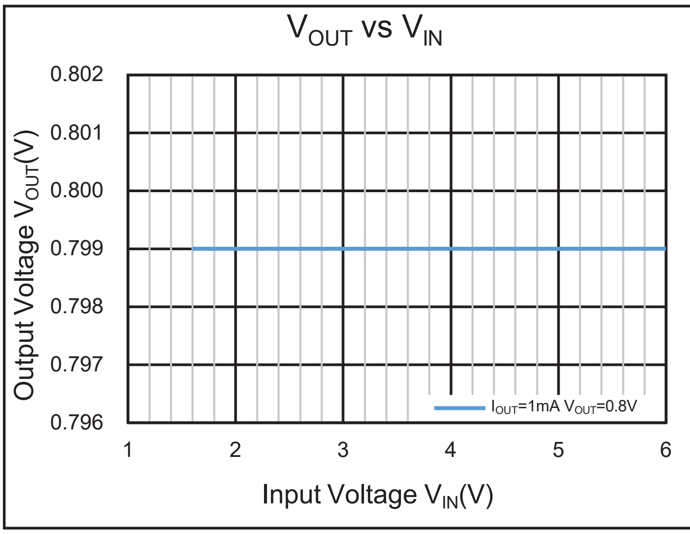
(8) The line regulation is calculated by the following formula: LNR = ΔV_{OUT} / (V_{OUT} × ΔV_{IN}) where, ΔV_{OUT} is the variation of the output voltage, ΔV_{IN} is the variation of the input voltage.

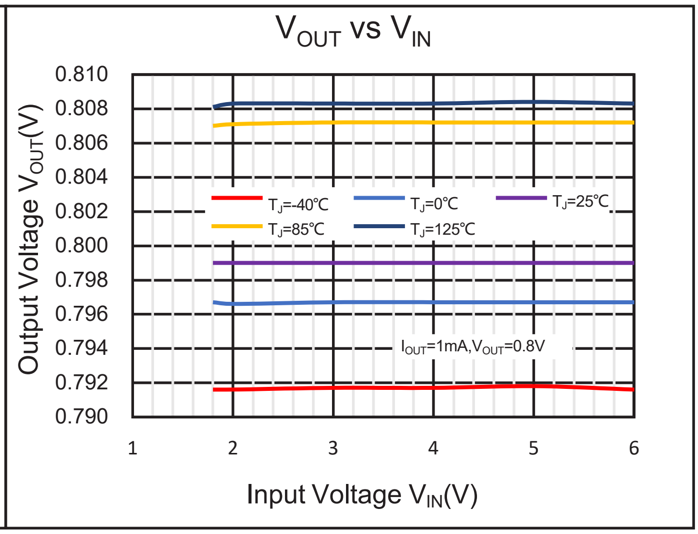
(9) Test the difference of output voltage and input voltage when input voltage is decreased gradually till output voltage equals to 98% of V_{OUT} Normal.

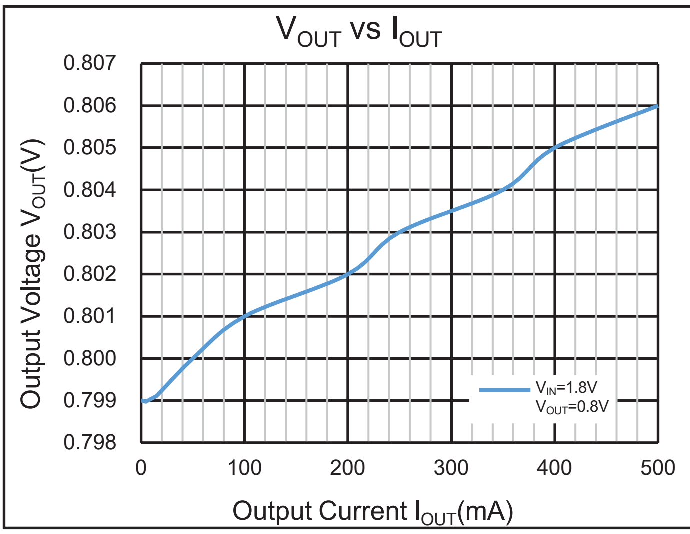
6 Specifications

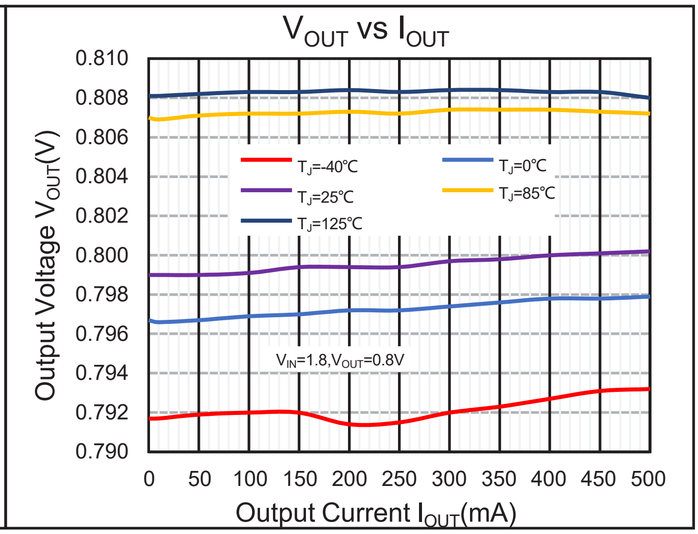
6.6 Typical Characteristics

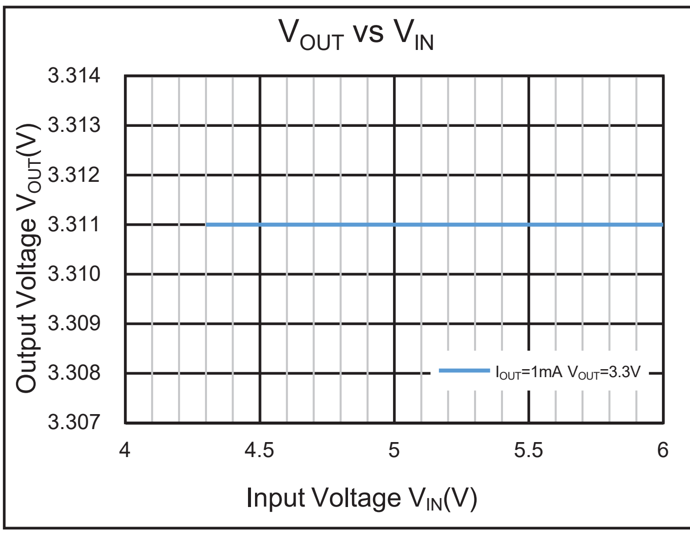
VS6300E Series,V_{OUT}=0.8V (V_{IN}= 4.3V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

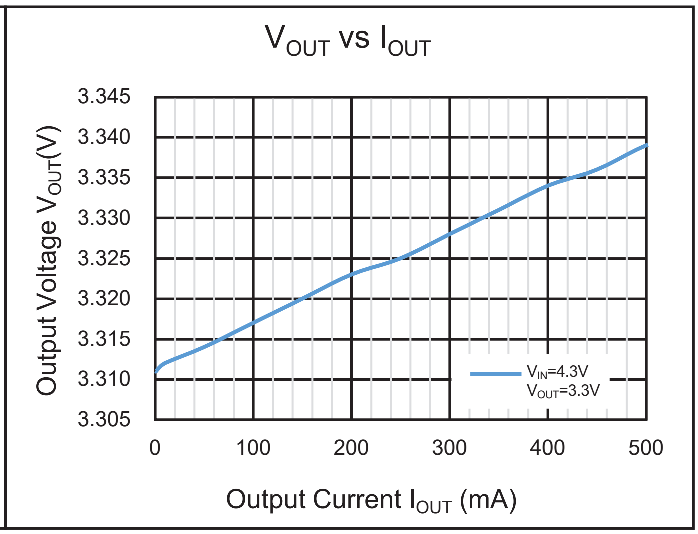








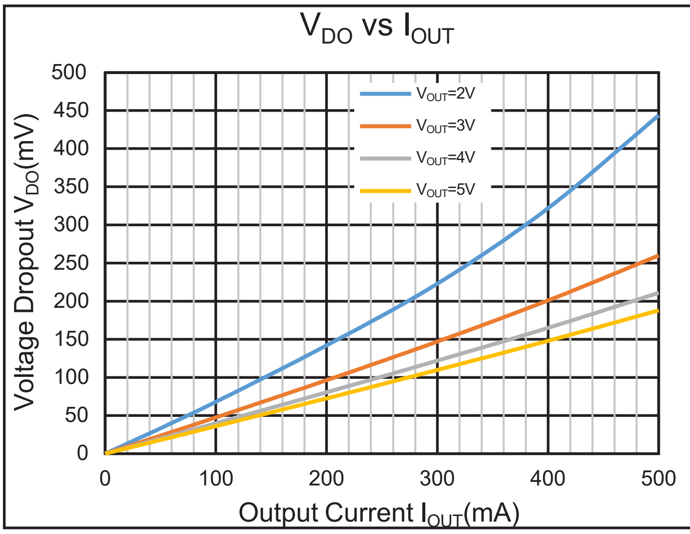


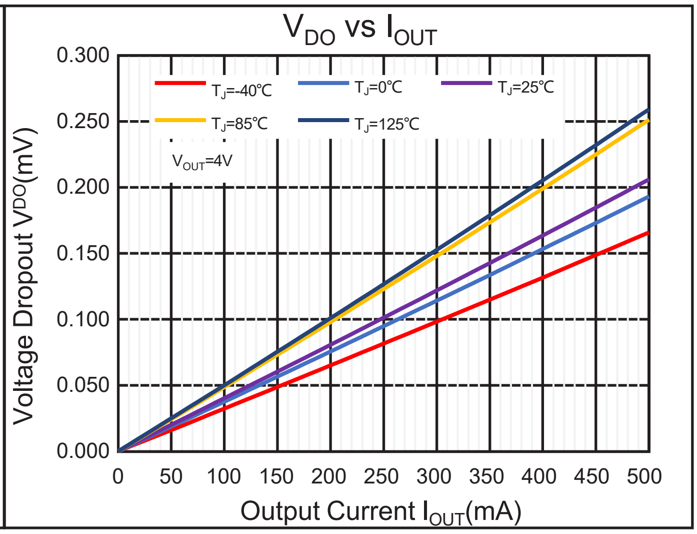


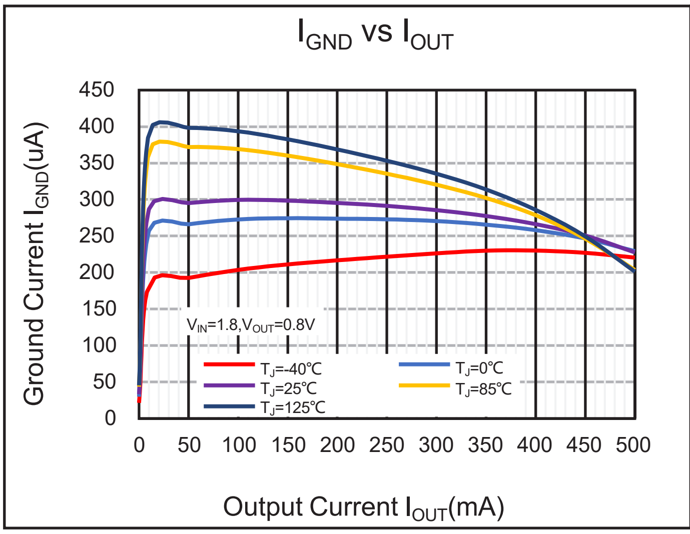
6 Specifications

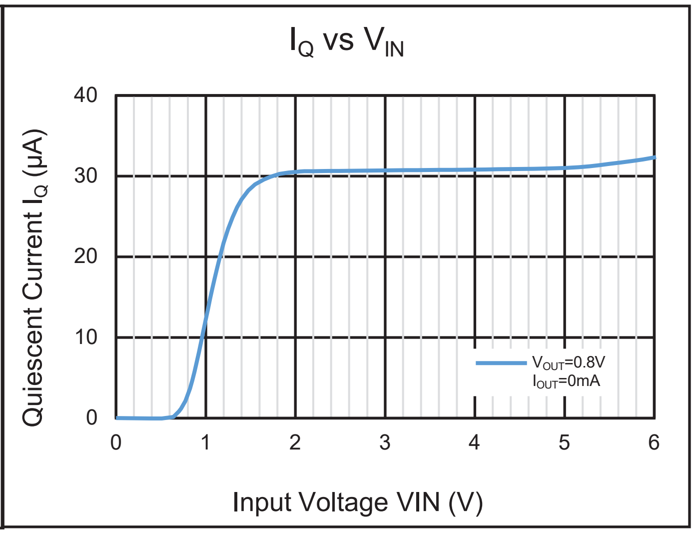
6.6 Typical Characteristics(continue)

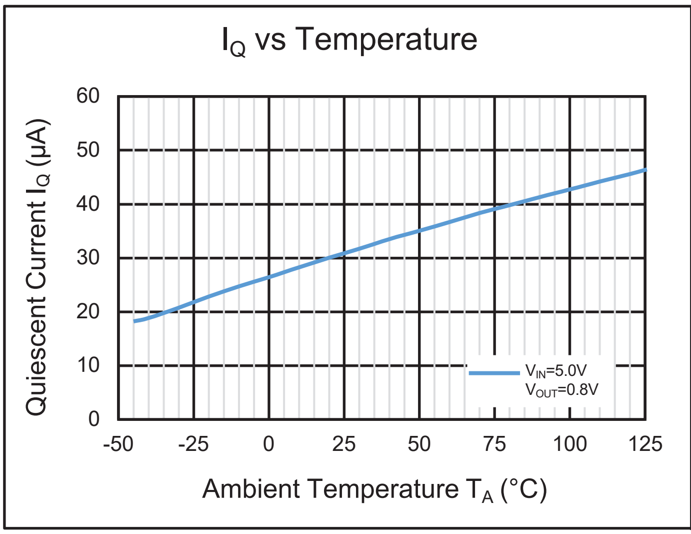
VS6300E Series, V_{OUT}=0.8V (V_{IN}= 4.3V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)

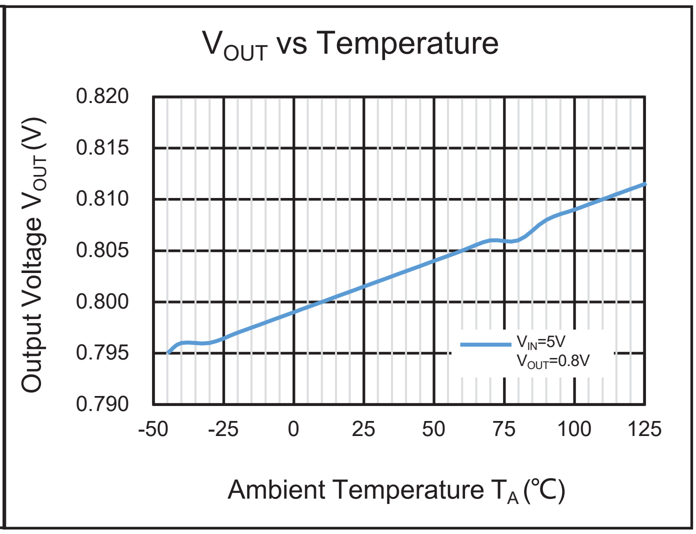








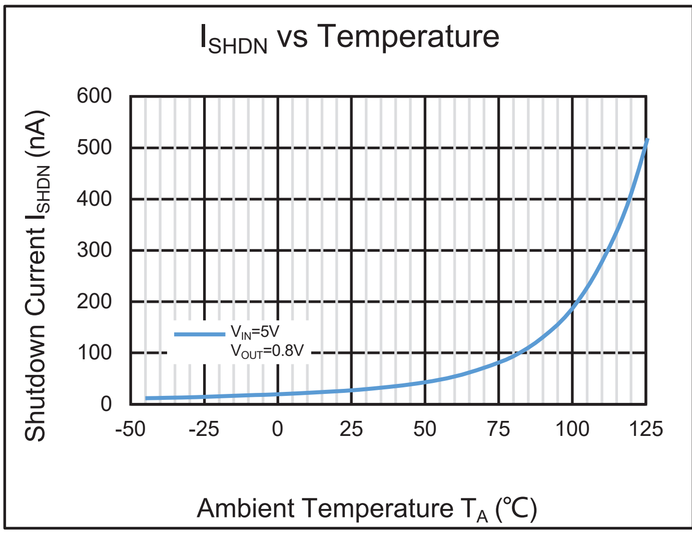


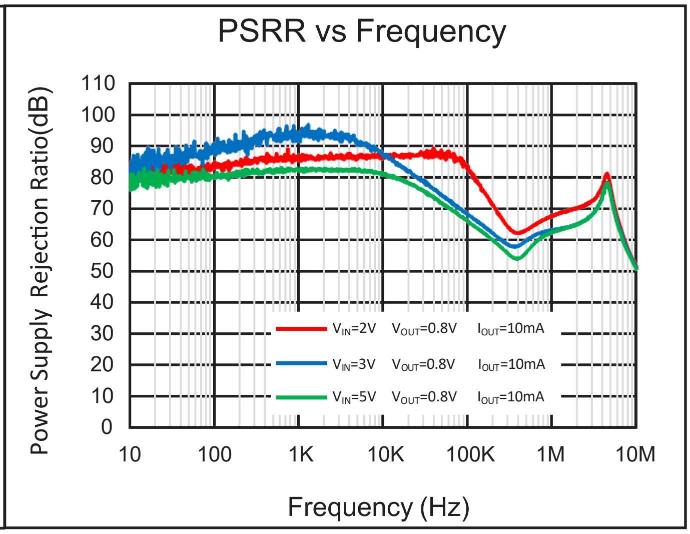


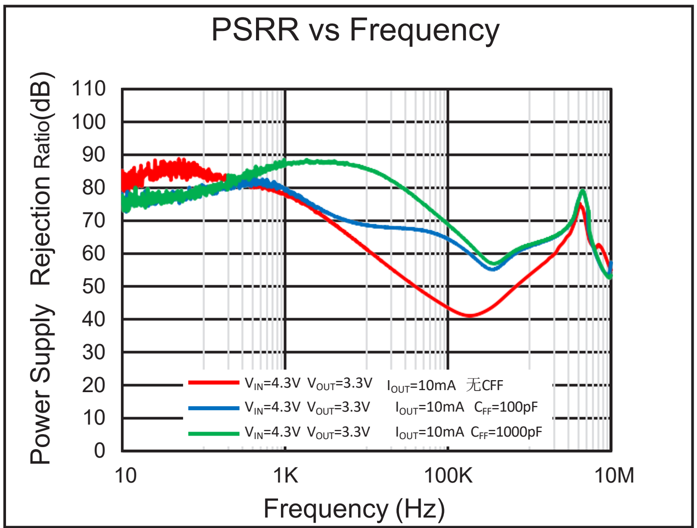
6 Specifications

6.6 Typical Characteristics(continue)

VS6300E Series, V_{OUT}=0.8V (V_{IN}= 4.3V, C_{IN} = 1μF, C_{OUT} = 1μF, T_A = 25°C, unless otherwise specified)



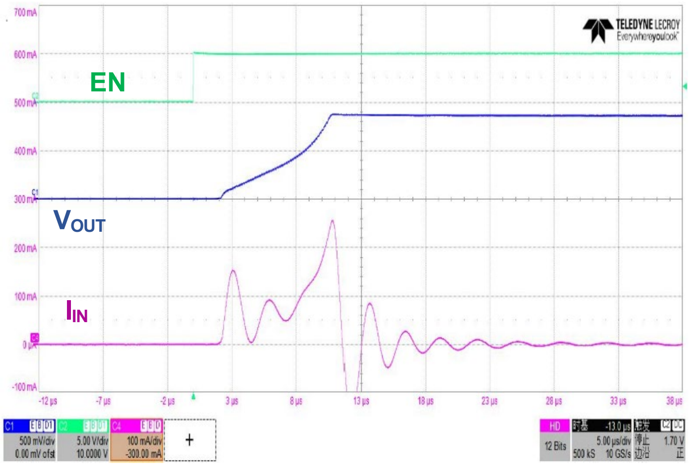




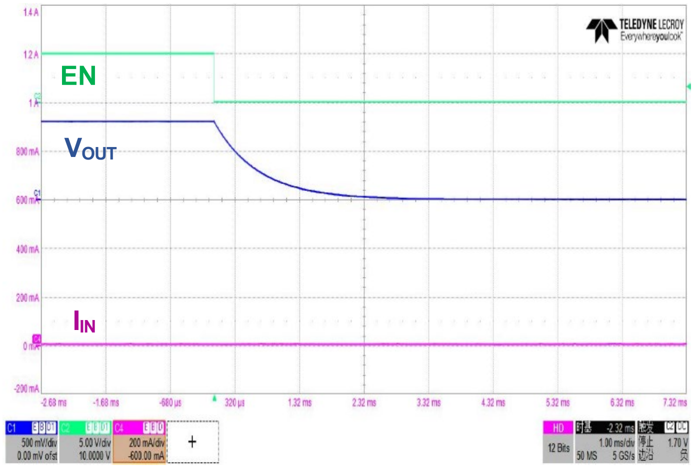
6 Specifications

6.6 Typical Characteristics(continue)

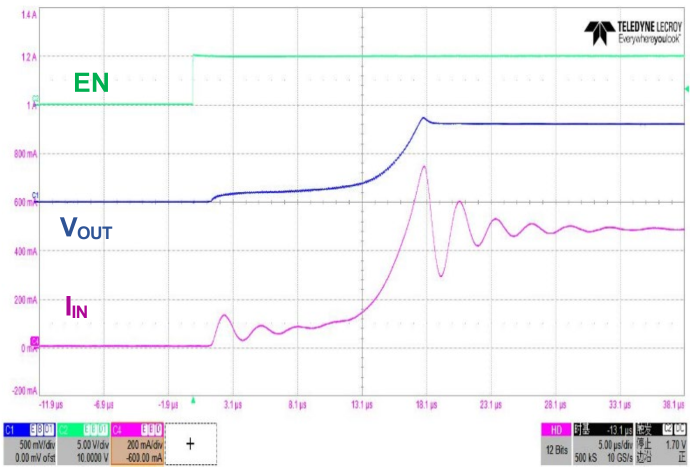
En On Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 0mA)



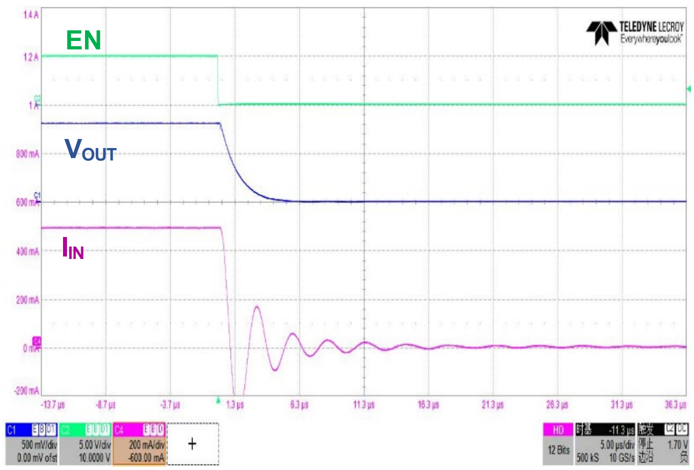
En Off Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 0mA)



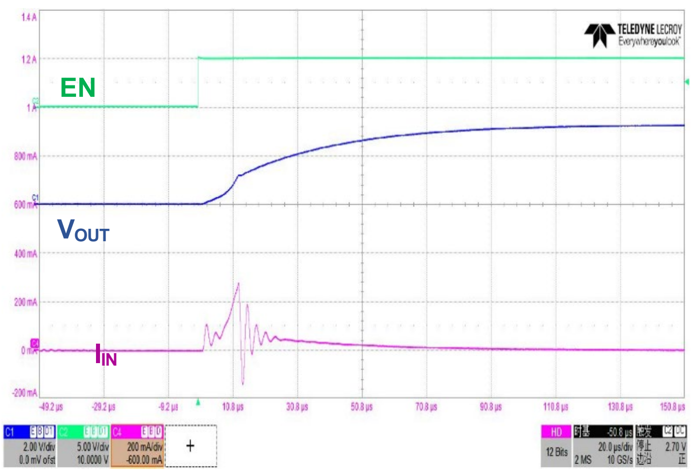
En On Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 500mA)



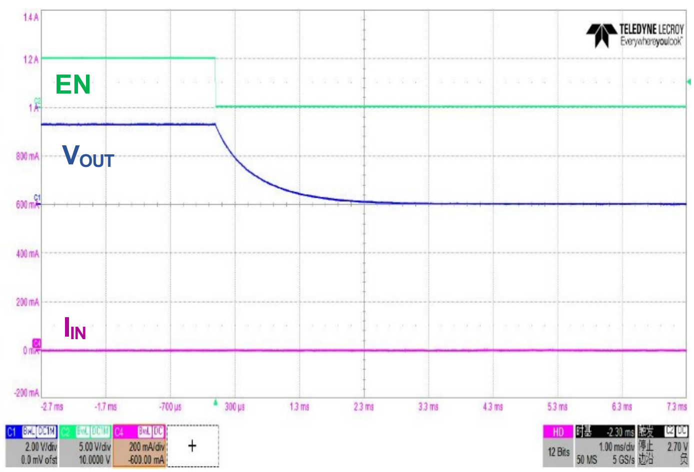
En Off Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 500mA)



En On Response
(V_{IN} = 4.3V, V_{OUT} = 3.3V, 0mA)



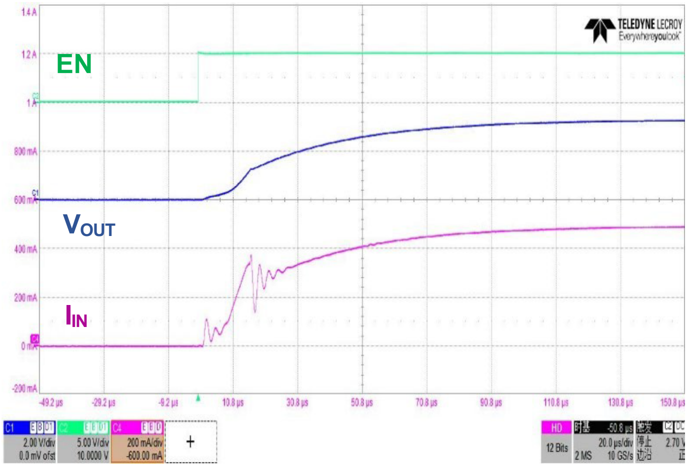
En Off Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 0mA)



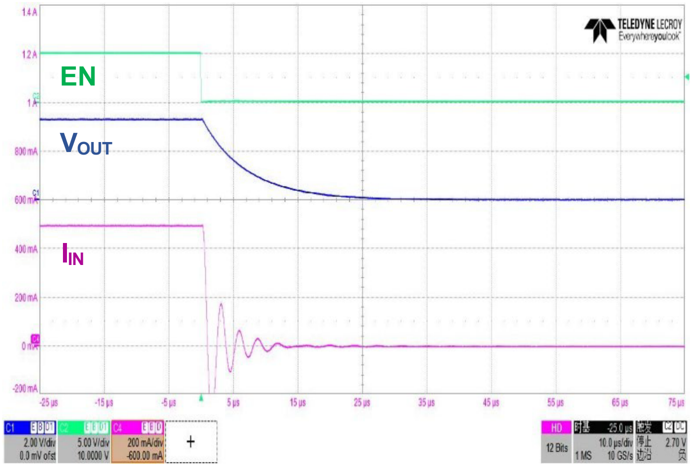
6 Specifications

6.6 Typical Characteristics(continue)

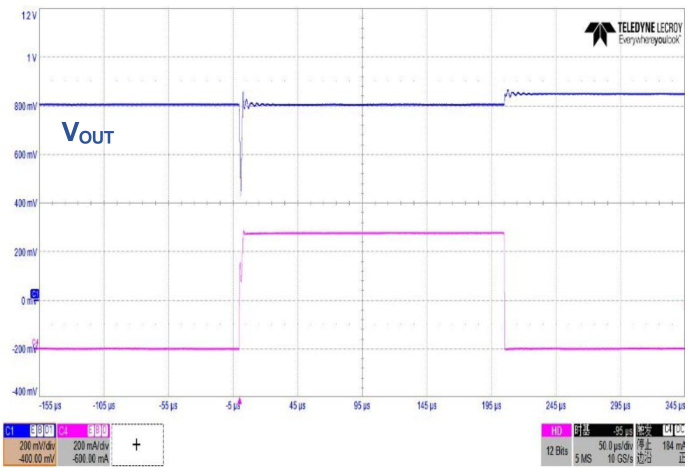
En On Response
(V_{IN} = 4.3V, V_{OUT} = 3.3V, 500mA)



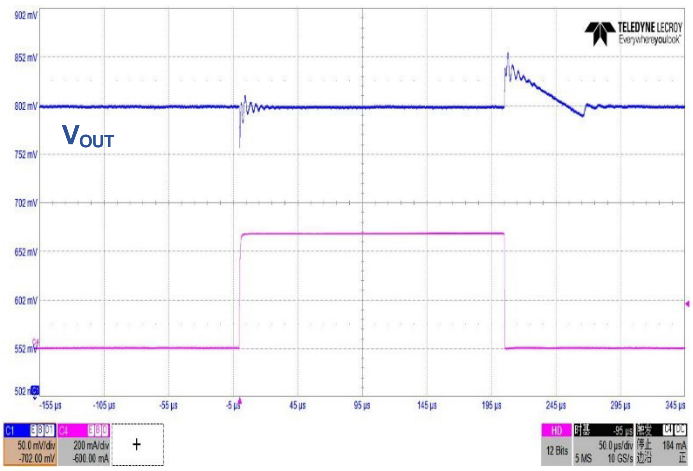
En Off Response
(V_{IN} = 4.3V, V_{OUT} = 3.3V, 500mA)



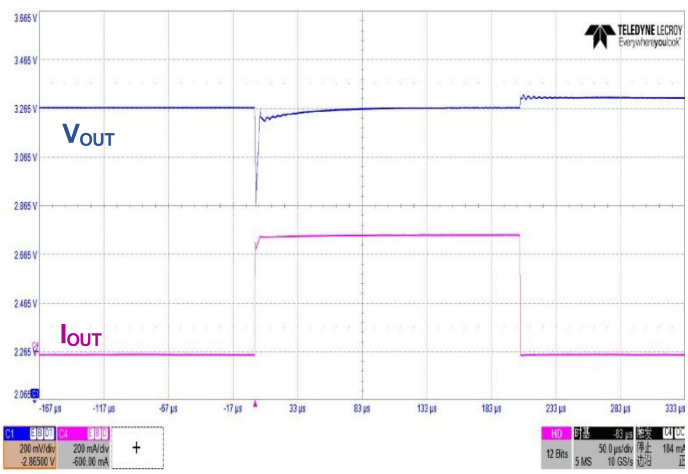
Load Transient Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 0 - 500mA)



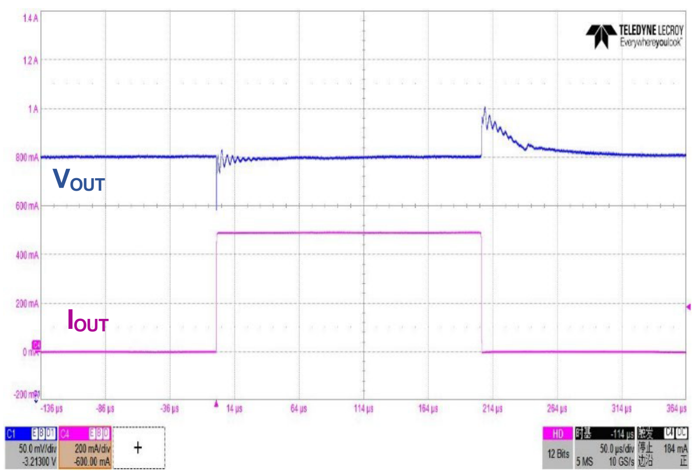
Load Transient Response
(V_{IN} = 1.8V, V_{OUT} = 0.8V, 1 - 500mA)



Load Transient Response
(V_{IN} = 4.3V, V_{OUT} = 3.3V, 0 - 500mA)



Load Transient Response
(V_{IN} = 4.3V, V_{OUT} = 3.3V, 1 - 500mA)



7 Detail Description

7.1 Description

The VS6300E series is a group of low dropout voltage linear regulators manufactured using CMOS technology. It supports the input voltage range of 1.6V to 5.5V, and can also provide current up to 500mA under the condition of good heat dissipation. The VS6300E series has ultra-low quiescent current and low dropout voltage, which can provide large output current even when the input and output voltage difference is very small. In addition, the VS6300E series also features high power ripple rejection, ultralow output noise, and fast response speed. These features make the VS6300E series very suitable for application in battery-powered devices to extend battery life, such as RF applications or other systems that require a quiet voltage source.

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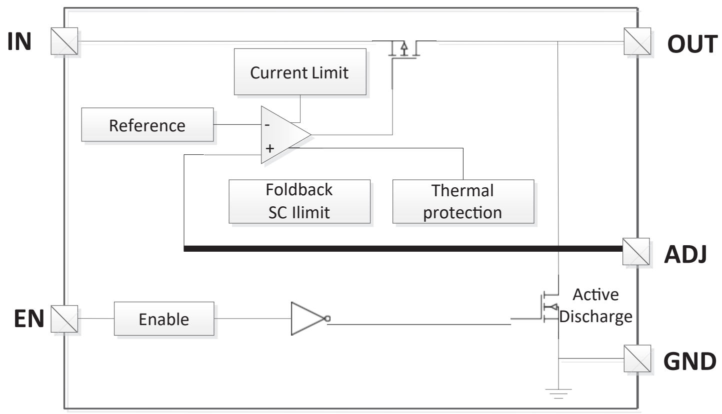
7.2 Function Block Diagram



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 V_{OUT} has decreased to 0V, 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.

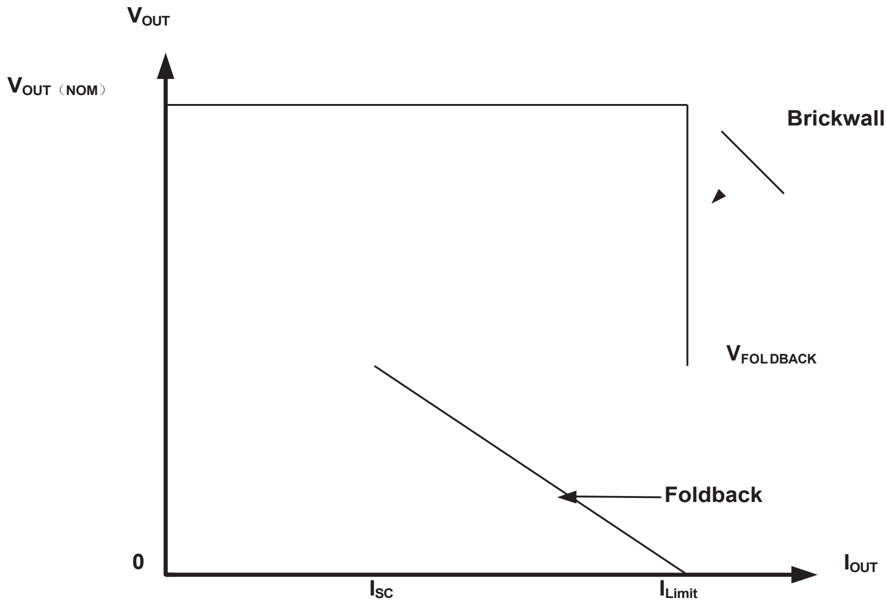
The device has an internal current limit circuit that protects the regulator during transient high-load current faults or shorting events. The current limit is a hybrid brickwall-foldback scheme. The current limit transitions from a brickwall scheme to a foldback scheme at the foldback voltage ($V_{FOLDBACK}$). In a high-load current fault with the output voltage above $V_{FOLDBACK}$, the brickwall scheme limits the output current to the current limit (I_{Limit}). When the voltage drops below $V_{FOLDBACK}$, a foldback current limit activates that scales back the current as the output voltage approaches GND. When the output is shorted, the device supplies a typical current called the shortcircuit current limit (I_{SC}). I_{Limit} and I_{SC} are listed in the Electrical Characteristics table.

The output voltage is not regulated when the device is in current limit. When a current limit event occurs, the device begins to heat up because of the increase in power dissipation. When the device is in brickwall current limit, the pass transistor dissipates power [(V_{IN} – V_{OUT}) × I_{Limit}]. When the device output is shorted and the output is below $V_{FOLDBACK}$, the pass transistor dissipates power [(V_{IN} – V_{OUT}) × I_{SC}]. If thermal shutdown is triggered, the device turns off. After the

7 Detail Description

7.2 Function Block Diagram (continue)

device cools down, the internal thermal shutdown circuit turns the device back on. If the output current fault condition continues, the device cycles between current limit and thermal shutdown.



Foldback Current Limit

Thermal Protection

Internal thermal shutdown (T_{SD}) circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When T_{SD} activated, the regulator output turns off. When cooling down under the low temperature threshold, device output is activated again. This T_{SD} 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 +150°C maximum.

8 Application and Implementation

8.1 Adjustable Output Voltage

VS6300E has a wide range of output voltage. The output voltage is programmed by an external resistor divider as shown in Figure 1. Where V_{REF} is the internal reference voltage, which is 0.8V in VS6300E. Choose R_2 max = 200 kΩ to maintain a 4μA minimum load. The R_2 can be calculated be by the following equation:

$R_2 = (V_{OUT} / V_{REF} - 1) \times R_1$ (Equation.1)

For most application, to ensure stability under no-load conditions, the recommended divider resistance is 40kΩ to 200kΩ ,the recommended feedforward capacitance of C_{FF} is optional ,from 10pF to 4.7nF.

Resistors R_1 should be used with values in the range from 40kΩ to 1000kΩ. Lower values increase current consumption, $R_1 \geq 40kΩ$.

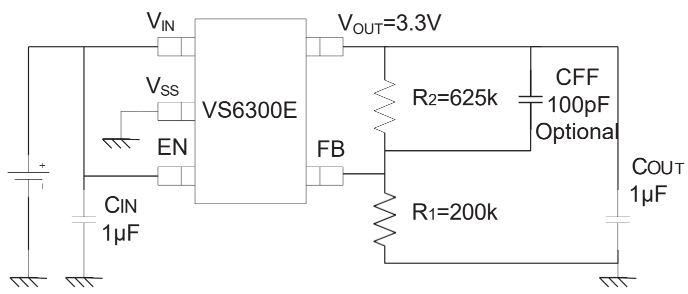


Figure 1

R_1 (Ω)	R_2 (Ω)	V_{OUT} (V)	$IR_1 = 0.8 / R_1$(μA)
40k	125k	3.3	20
100k	312.5k	3.3	8
200k	625k	3.3	4
1M	3.125M	3.3	0.8

8.2 Feed-Forward Capacitor (C_{FF})

For the adjustable-voltage version device, a feed-forward capacitor (C_{FF}) can be connected from the OUT pin to the FB pin. C_{FF} improves transient, noise, and PSRR performance, but is not required for regulator stability.

Recommended C_{FF} values are listed in the Recommended Operating Conditions table. A higher capacitance C_{FF} can be used; however, the startup time increases.

8.3 Input and Output Capacitors

For the VS6300E 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 VS6300E 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.

8 Application and Implementation

8.4 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).

8.5 Operation in Dropout Mode

The VS6300E 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.

8.6 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.

8.7 Recommended Continuous Operating Areas

As an LDO, the working area of VS6300E 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 VS6300E series is limited by the rated V_{INMIN} and V_{INMAX}.