ULTRA LOW QUIESCENT CURRENT 250mA LOW-DROPOUT VOLTAGE REGULATORS

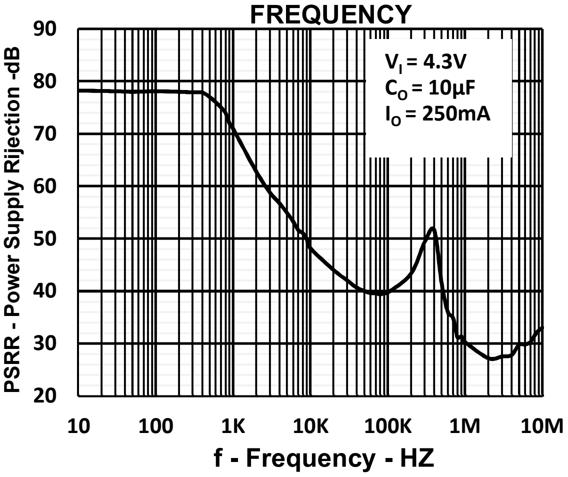
Features

- **250-mA Low-Dropout Voltage Regulator**
- **Available in 1.5V,1.8V,2.5V,2.7V, 2.8V,3.0V,3.3V,5.0V, Fixed Output and Adjustable Versions**
- **Dropout Voltage to 140 mv (typ) at 250 mA (TS6112-33)**
- **Ultra-Low 40-μA Typical Quiescent Current**
- **Open Drain Power Good Output**
- **Compatible with Low ESR Capacitor**
- **Thermal Shutdown Protection**
- **8-Pin SOIC Package**

Applications

- **Battery-Powered Applications**
- **Power Converter/Inverter**
- **Portable Devices**

POWER SUPPLY RIPPLE REJECTION vs FREQUENCY



Product Description

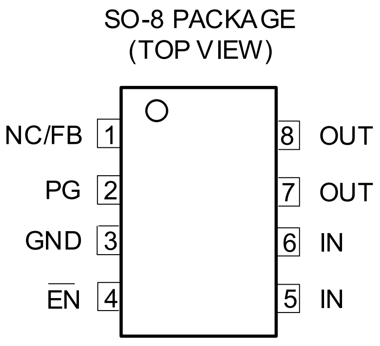
The TS6112-xx series regulators are designed to have ultra-low quiescent currents and be stable with low ESR ceramic output capacitors and a wide range of capacitance (0.1μF or greater). The combination of the above characteristics provides high performance at lower cost.

The TS6112-xx series is designed with very low dropout voltages (e.g. typically 200 mV for the TS6112-33 at an output current of 250 mA). The quiescent current is very low at light load (typically 40 μA at 10uA load), however, it is designed to be dependent of output loading (approximately 1/250 of the output current at heavy load), in order to provide much improved control loop stability and fast transient response. The low quiescent feature yields a significant improvement in operating life for battery-powered systems. This LDO family also features a sleep mode; applying a TTL high signal to EN (enable) shuts down the regulator, reducing the quiescent current to less than 1μA (typ).

Power good (PG) is an active high output, which can be used to implement a power-on reset or a low-battery Indicator.

The TS6112-xx is offered in 1.5V, 1.8V, 2.5V, 2.7V, 2.8V, 3.0V, 3.3V and 5.0V fixed-voltage versions and in an adjustable version (programmable over the range of 1.25 V to 5.5 V). Output voltage tolerance is specified as a maximum of 3% over line, load, and temperature ranges. The TS6112-xx family is available in 8 pin SOIC package.

PIN CONFIGURATION AND FUNCTIONS



TERMINAL		I/O	DESCROPTION
NAME	NO		
EN	4	I	Enable input
FB/NC	1	I	Feedback input voltage for adjustable device (no connect for fixed option)
GND	3		Regulator ground
IN	5	I	Input voltage
IN	6	I	Input voltage
OUT	7	O	Regulated output voltage
OUT	8	O	Regulated output voltage
PG	2	O	PG output

TYPICAL APPLICATION

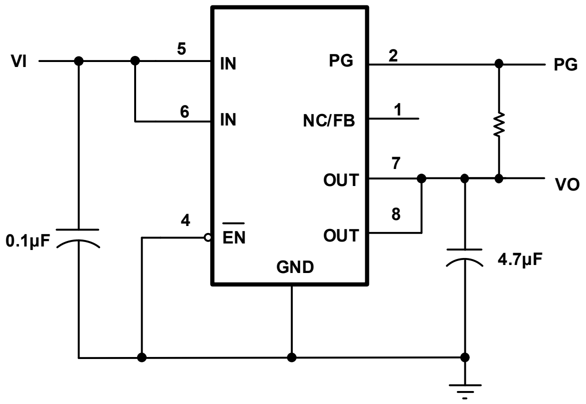


Figure 1. Typical Application Configuration for Fixed Output Options

RECOMMENDED OPERATING CONDITIONS

	MIN	MAX	UNIT
Input voltage, V_{IN} [1]	2.7	12	V
Output voltage range, V_{OUT}	1.2	5	V
Output current, I_{OUT} [2]	0	250	mA
Operating virtual junction temperature, TA [2]	-40	125	℃

[1] To calculate the minimum input voltage for your maximum output current, use the following equation: $V_{IN}(min) = V_{OUT}(max) + V_{DO}$ (max load).
[2] Continuous current and operating junction temperature are limited by internal protection circuitry, but it is not recommended that the device operate under conditions beyond those specified in this table for extended periods of time.

ABSOLUTE MAXIMUM RATINGS

Parameter	Min	Max	Unit
Input voltage range	-0.3	14	V
Voltage range at $\overline{EN}$	-0.3	16.5	V
PG voltage		16.5	V
Peak output current	Internally limited		
Output voltage, V_{OUT} (OUT, FB)		7	V
Junction Temperature	-40	125	°C
Storage Temperature Range	-65	150	°C
ESD HBM		±2000	V

ESD CAUTION

ESD (electrostatic discharge) sensitive device
Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjects to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

ORDERING INFORMATION

Model	Part Number	Eco Plan	Package	OUTPUT VOLTAGE (V)	Container, Pack Qty
TS6112-50	TS6112-50SO8R	Rohs	SO-8	5.0	Reel,2500
TS6112-33	TS6112-33SO8R	Rohs	SO-8	3.3	Reel,2500
TS6112-30	TS6112-30SO8R	Rohs	SO-8	3.0	Reel,2500
TS6112-28	TS6112-28SO8R	Rohs	SO-8	2.8	Reel,2500
TS6112-27	TS6112-27SO8R	Rohs	SO-8	2.7	Reel,2500
TS6112-25	TS6112-25SO8R	Rohs	SO-8	2.5	Reel,2500
TS6112-18	TS6112-18SO8R	Rohs	SO-8	1.8	Reel,2500
TS6112-15	TS6112-15SO8R	Rohs	SO-8	1.5	Reel,2500
TS6112-01	TS6112-01SO8R	Rohs	SO-8	Adjustable(1.25V to 5.5V)	Reel,2500

The TS6112-01 is programmable using an external resistor divider.

ELECTRICAL CHARACTERISTICS: At T_A = +25°C, Vi = Vo (type) + 1 V, Io = 10μA, EN= 0V, CO=4.7μF, unless otherwise noted. **Boldface** limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

Symbol	Parameter		Operating Conditions	Min	Typ	Max	Unit
V_{OUT}	Output voltage [3] (10uA to 250mA load)	TS6112-01	5.5V≥V_{OUT}≥1.25V		V_{OUT}		V
			TA = −40°C to +125°C	**0.97V_{OUT}**		**1.03V_{OUT}**	
		TS6112-15	2.7V≤V_{IN}≤12V		1.5		
			TA = −40°C to +125°C	**1.455**		**1.545**	
		TS6112-18	2.8 ≤ V_{IN} ≤ 12V		1.8		
			TA = −40°C to +125°C	**1.746**		**1.854**	
		TS6112-25	3.5 ≤ V_{IN} ≤ 12V		2.5		
			TA = −40°C to +125°C	**2.425**		**2.575**	
		TS6112-27	3.7 ≤ V_{IN} ≤ 12V		2.7		
			TA = −40°C to +125°C	**2.619**		**2.781**	
		TS6112-28	3.8 ≤ V_{IN} ≤ 12V		2.8		
			TA = −40°C to +125°C	**2.716**		**2.884**	
		TS6112-30	4.0 ≤ V_{IN} ≤ 12V		3.0		
			TA = −40°C to +125°C	**2.910**		**3.090**	
		TS6112-33	4.3 ≤ V_{IN} ≤ 12V		3.3		
			TA = −40°C to +125°C	**3.250**		**3.350**	
		TS6112-50	5.0 ≤ V_{IN} ≤ 12V		5.0		
			TA = −40°C to +125°C	**4.850**		**5.150**	
I_{GND}	Quiescent current [3] (GND current)		EN = 0V		40		μA
			TA = −40°C to +125°C			**60**	
Output voltage line regulation [3][4] (ΔVO/VO)			V_{OUT} + 1V ≤ V_{IN} ≤ 12 V,		0.005		%/V
Load regulation			**I_{OUT} = 10μA to 250mA TA = −40°C to +125°C**		**0.5%**		
Output noise voltage			BW = 300Hz to 50kHZ, C_{OUT} =4.7μF		150		μVrms
Output current Limit			V_{OUT} = 0V		0.87		A
Thermal shutdown junction temperature					150		℃
Thermal shutdown hysteresis temperature					20		℃
I_{STB}	Standby current		EN = V_{IN} , 2.7V≤V_{IN}≤12V		1		μA
			TA = −40°C to +125°C			**10**	
I_{FB}	FB input current	TS6112-01	FB = 1.5V		2		nA
VIH_{EN}	High level enable input voltage		**TA = −40°C to +125°C**	**2**			V
VIL_{EN}	Low level enable input voltage		**TA = −40°C to +125°C**			**0.8**	V
PSRR	Power supply ripple rejection [3]		f = 1kHz, I_{OUT} = 10μA, C_{OUT} = 4.7μF		67		dB
PG	Minimum input voltage for valid PG		I_O (PG) = 300μA		1.25		V
	Trip threshold voltage		**V_{OUT} decreasing TA = −40°C to +125°C**	**92**		**98**	%/V_{OUT}
	Hysteresis voltage		Measured at V_{OUT}		0.5		%/V_{OUT}
	Output low voltage		V_{IN} = 2.7V, I_O(PG) = 1mA		0.16		V
	Leakage current		**V(PG) = 5 V TA = −40°C to +125°C**			**1**	μA
I_{EN}	Input current (EN)		EN = 0V	-1	0	1	μA
			EN = V_{IN}	-1		1	μA

ELECTRICAL CHARACTERISTICS: At T_A = +25°C, Vi = Vo (type) + 1 V, Io = 10μA, EN= 0V, CO=4.7μF, unless otherwise noted. **Boldface** limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

Symbol	Parameter		Operating Conditions	Min.	Typ.	Max.	Unit
V_{DO}	Dropout voltage [5]	TS6112-28	I_{OUT} = 250mA		310		mV
			TA = −40°C to +125°C			**540**	
		TS6112-30	I_{OUT} = 250mA		270		
			TA = −40°C to +125°C			**470**	
		TS6112-33	I_{OUT} = 250mA		200		
			TA = −40°C to +125°C			**400**	
		TS6112-50	I_{OUT} = 250mA		140		
			TA = −40°C to +125°C			**250**	

[3] Minimum IN operating voltage is 2.7 V or V_{OUT} (typ.) + 1V, whichever is greater. Maximum IN voltage 12V

[4] If $V_{OUT} \leq$ 1.8V then V_{INmin} =2.7 V, V_{INmax} = 12 V:

$$\text{Line Reg.(mV)} = \frac{V_{OUT}\,(V_{INmax} - 2.7V)}{100} \times 1000 \times (\%/V)$$

If $V_{OUT} \geq$ 2.5V then V_{INmin} = V_{OUT} + 1V, V_{INmax} = 12 V:

$$\text{Line Reg.(mV)} = \frac{V_{OUT}\,(V_{INmax} - (VOUT+1V))}{100} \times 1000 \times (\%/V)$$

[5] In voltage equals V_{OUT}(typ.) – 100mV; TS6112-01 out voltage set to 3.3V nominal with external resistor divider. TS6112-15, TS6112-18, TS6112-25, and TS6112-27 dropout voltage limited by input voltage range limitations (i.e., TS6112-30 input voltage needs to drop to 2.9 V for purpose of this test).

Table of Graphs

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Line transient response		8
Load transient response		9
Output voltage	vs Time	10
Output spectral noise density	vs Frequency	11

TYPICAL CHARACTERISTICS

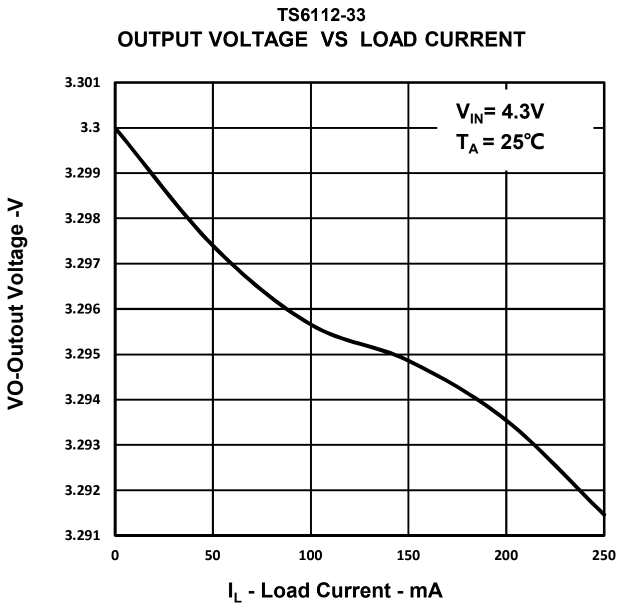


Figure2

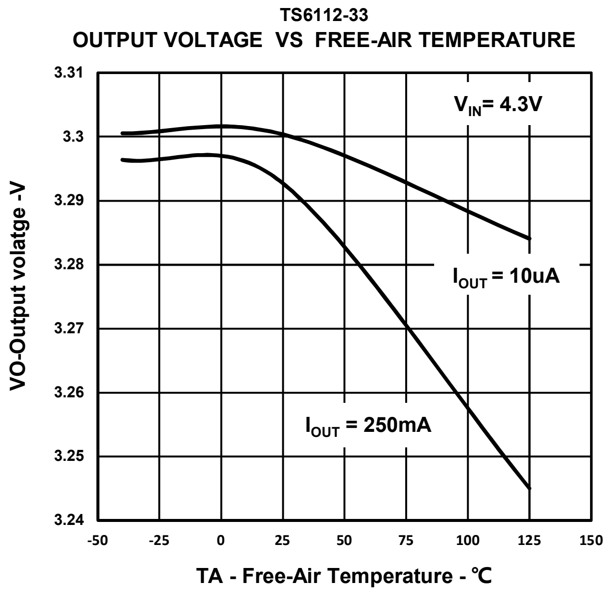


Figure 3

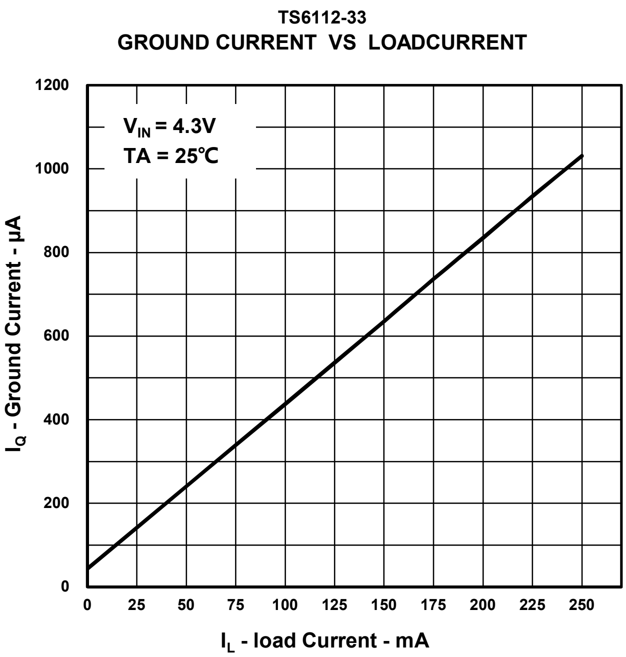


Figure4

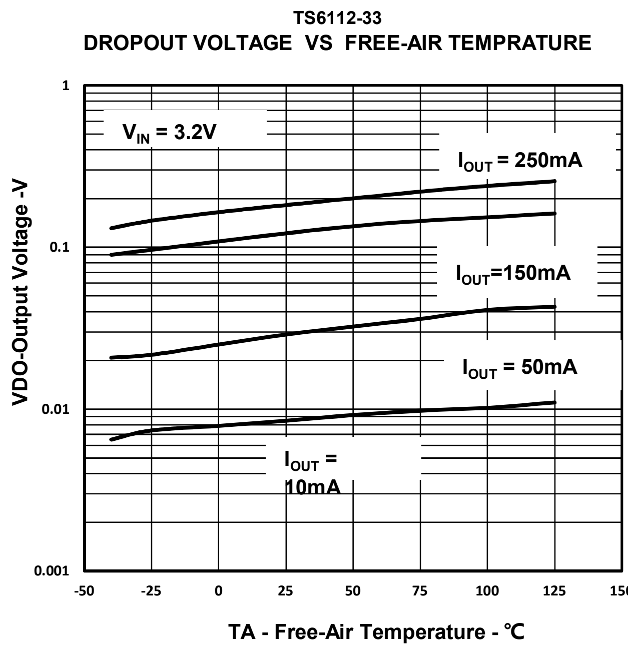


Figure5

TYPICAL CHARACTERISTICS

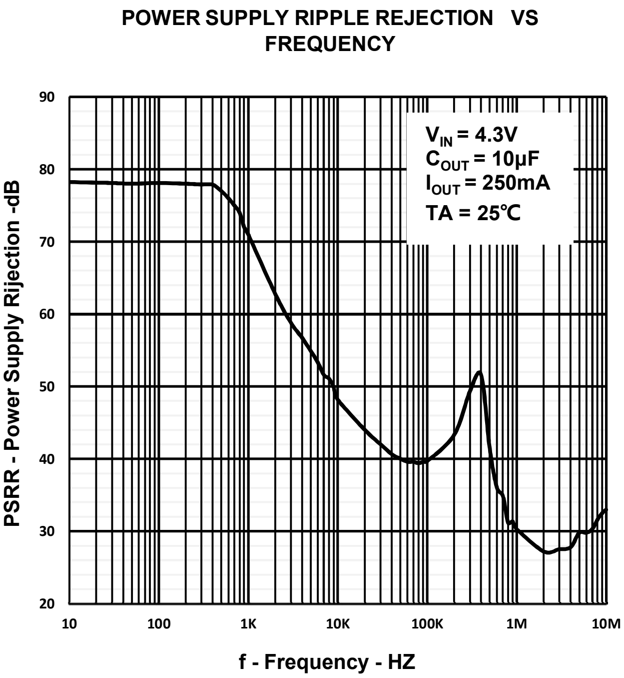


Figure6

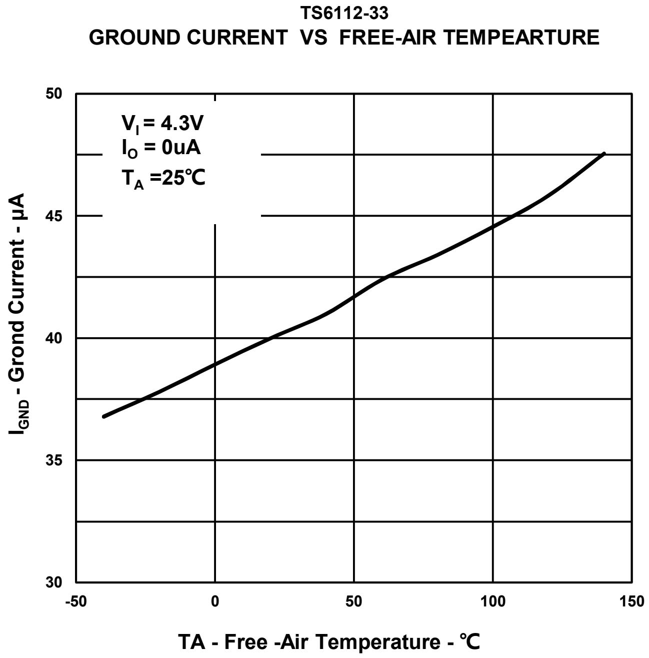


Figure7

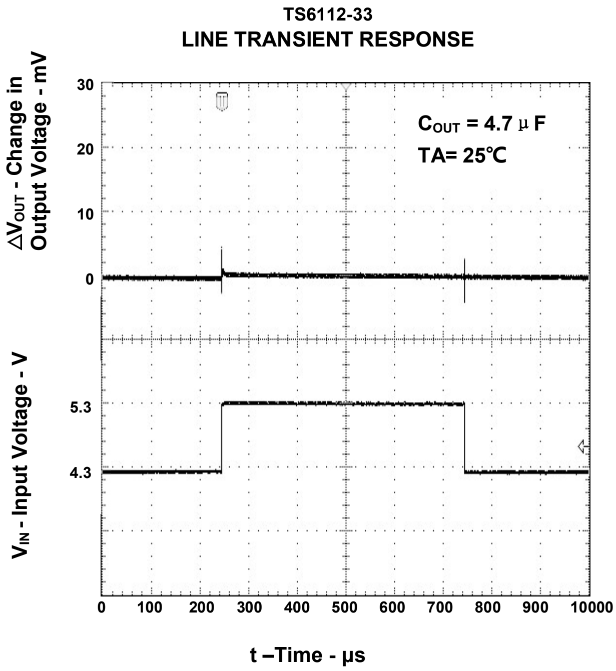


Figure8

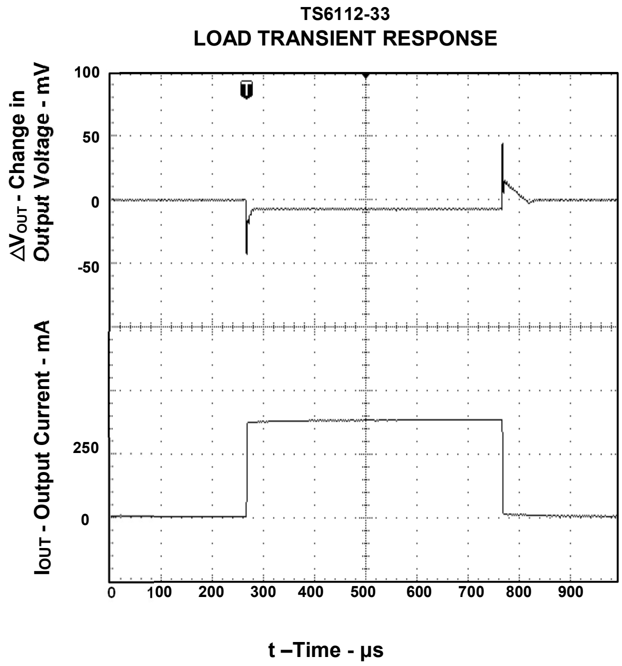


Figure9

TYPICAL CHARACTERISTICS

TS6833
OUTPUT VOLTAGE VS TIME (AT STATUP)

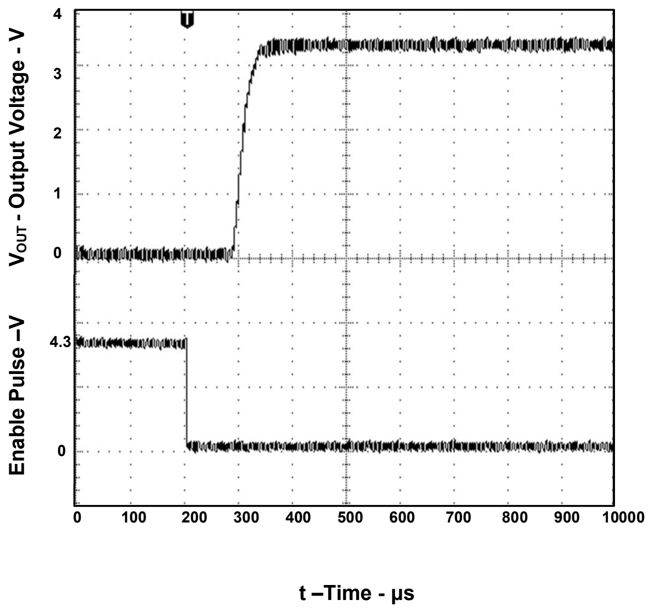


Figure10

TS6112-33
OUTPUT SPECTRAL NOISE DENSITY
VS
FREQUENCY

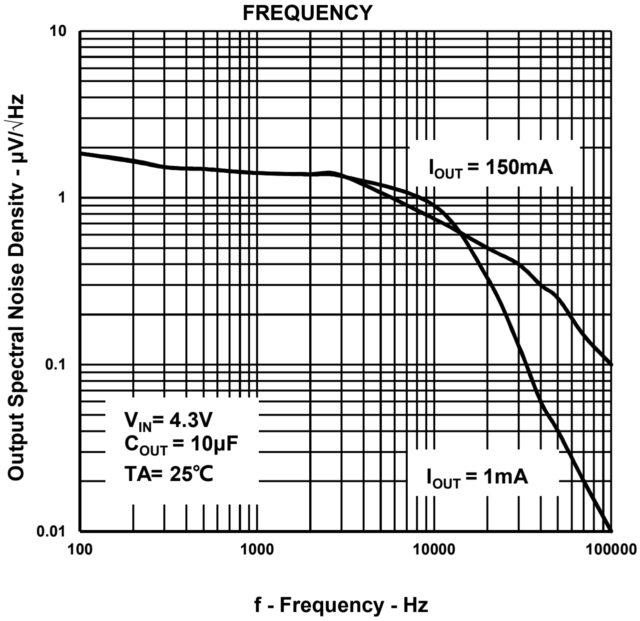


Figure11

APPLICATION INFORMATION

The TS6112-XX family includes eight fixed-output voltage regulators (1.5 V, 1.8 V, 2.5 V, 2.7 V, 2.8 V, 3.0 V, 3.3 V, and 5.0 V), and an adjustable regulator, the TS6112-XX (adjustable from 1.25 V to 5.5 V).

Device operation

The TS6112-xx features very low quiescent current, which remains virtually constant even with varying loads. Conventional LDO regulators use a pnp pass element, the base current of which is directly proportional to the load current through the regulator ($I_B = I_C/\beta$). The TS6112-xx uses a PMOS transistor to pass current; because the gate of the PMOS is voltage driven, operating current is low and invariable over the full load range.

Another pitfall associated with the pnp-pass element is its tendency to saturate when the device goes into dropout. The resulting drop in β forces an increase in I_B to maintain the load. During power up, this translates to large start-up currents. Systems with limited supply current may fail to start up. In battery-powered systems, it means rapid battery discharge when the voltage decays below the minimum required for regulation. The TS6112-xx quiescent current remains low even when the regulator drops out, eliminating both problems.

The TS6112-xx family also features a shutdown mode that places the output in the high-impedance state (essentially equal to the feedback-divider resistance) and reduces quiescent current to 1 µA (typ). If the shutdown feature is not used, EN should be tied to ground. Response to an enable transition is quick; regulated output voltage is reestablished in typically 160 µs.

Minimum load requirements

The TS6112-xx family is stable even at zero load; no minimum load is required for operation.

FB - pin connection (adjustable version only)

The FB pin is an input pin to sense the output voltage and close the loop for the adjustable option. The output voltage is sensed through a resistor divider network to close the loop as it is shown in Figure 29. Normally, this connection should be as short as possible; however, the connection can be made near a critical circuit to improve performance at that point. Internally, FB connects to a high-impedance wide-bandwidth amplifier and noise pickup feeds through to the regulator output. Routing the FB connection to minimize/avoid noise pickup is essential.

External capacitor requirements

The input capacitor is not required usually, however, a ceramic bypass capacitor (0.1µF or greater) improves load transient performance. A higher capacitance capacitor may be necessary if large load transients with fast rise times are anticipated.

The TS6112-XX series regulators require output capacitors to stabilize the internal feedback loop, however, the ESR (the equivalent series resistance) of the output capacitor is not necessary. Instead, the ESR should be limited to under 1Ω for the benefit of higher phase margin under large load current. The capacitance of the output capacitor should be greater than 0.1µF, though the recommended capacitance for this capacitor is 4.7µF or larger.

APPLICATION INFORMATION

External capacitor requirements (continued)

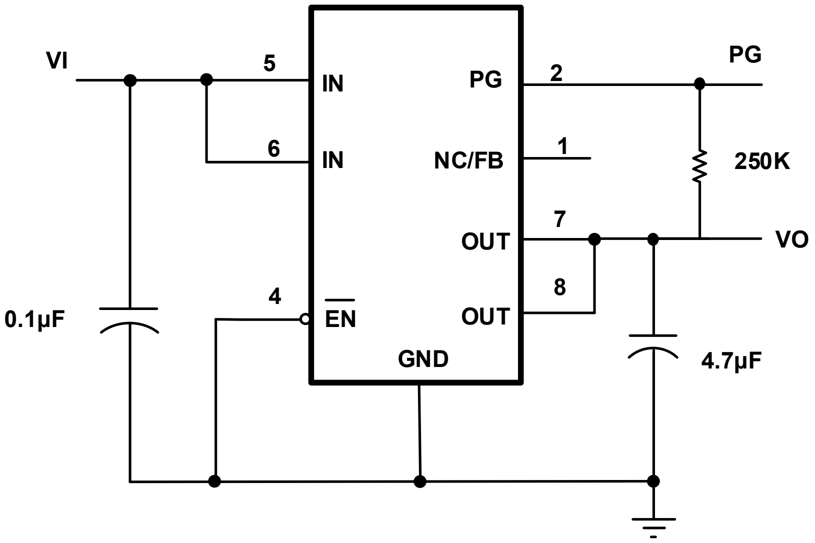


Figure12. Typical Application Circuit (Fixed Version)

Programming the TS6112-01 adjustable LDO regulator

The output voltage of the TS6112-01 adjustable regulator is programmed using an external resistor divider as shown in Figure 29. The output voltage is calculated using:

$$V_O = V_{ref} \times \left(1 + \frac{V_O}{V_{ref}}\right)$$

Where

V_{ref} = 1.224 V typ. (the internal reference voltage)

Resistors R1 and R2 should be chosen from approximately 7-µA divider current . Lower value resistors can be used but offer no inherent advantage and waste more power. Higher values should be avoided as leakage currents at FB increase the output voltage error. The recommended design procedure is to choose R2 = 169 KΩ to set the divider current at 7µA and then calculate R1 using:

$$R1 = \left(\frac{V_O}{V_{ref}} - 1\right) \times R2$$

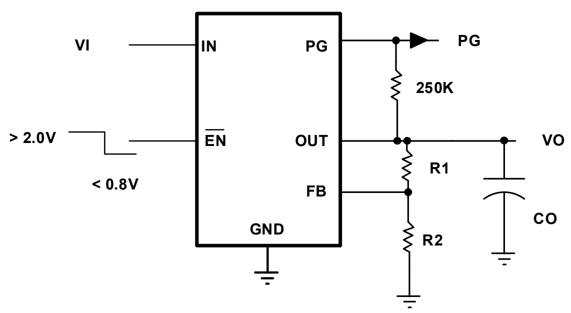


Figure13. TS6112-01 Adjustable LDO Regulator Programming

APPLICATION INFORMATION

Power-good indicator

The TS6112-xx features a power-good (PG) output that can be used to monitor the status of the regulator. Internal comparator monitors the output voltage: when the output drops to between 92% and 98% of its nominal regulated value, the PG output transistor turns on, taking the signal low. The open-drain output requires a pullup resistor. If not used, it can be left floating. PG can be used to drive power-on reset circuitry or used as a low-battery indicator.

Regulator protection

The TS6112-xx PMOS-pass transistor has a built-in back diode that conducts reverse currents when the input Voltage drops below the output voltage (e.g., during power down). Current is conducted from the output to the Input and is not internally limited. When extended reverse voltage is anticipated, external limiting may be appropriate.

The TS6112-xx also features internal current limiting and thermal protection. During normal operation, the TPS768xx limits output current to approximately 0.8 μA (typ). When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care should be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds 150℃(typ), thermal-protection circuitry shuts it down. Once the device has cooled below 130℃(typ), regulator operation resumes.

power dissipation and junction temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature should be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, PD(max), and the actual dissipation, PD, which must be less than or equal to PD(max).

The maximum-power-dissipation limit is determined using the following equation:

$$P_{D(max)} = \frac{T_J max - T_A}{R_{\theta JA}}$$

Where

T_{Jmax} is the maximum allowable junction temperature

$R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package, ie., 176℃/W for the 8-terminal soic.

T_A is the ambient temperature.

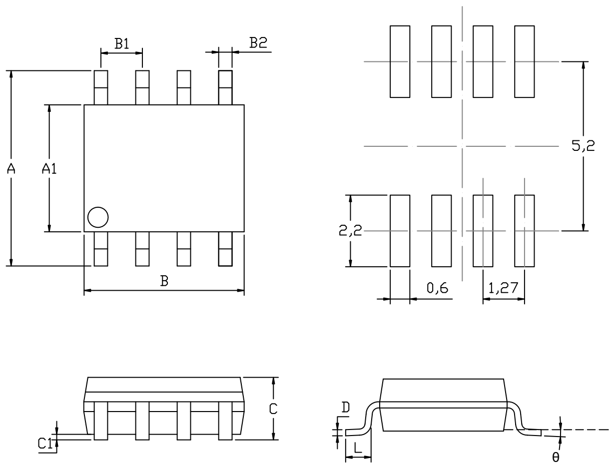
The regulator dissipation is calculated using:

$$P_{D(max)} = (V_I - V_O) \times I_O$$

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation will trigger the thermal protection circuit.

MECHANICAL DIMENSIONS

SO-8 PACKAGE MECHANICAL DRAWING



SO-8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.8	6.2	0.2283	0.2441
A1	3.8	4	0.1496	0.1575
B	4.8	5	0.1890	0.1969
B1	1.27		0.0500	
B2	0.31	0.51	0.0122	0.0201
C		1.75MAX		0.0689MAX
C1	0.1	0.25	0.0039	0.0098
L	0.4	1.27	0.0157	0.0500
D	0.13	0.25	0.0051	0.0098
θ	0º	8º	0º	8º

CONTACT INFORMATION

Trusignal Microelectronics

Phone: +86 512-65923982
Fax: +86 512-65923995
Email: support@kunyuanic.com; sales@kunyuanic.com