

ULTRA LOW QUIESCENT CURRENT 250mA LOW-DROPOUT VOLTAGE REGULATORS

FEATURES

- 250mA 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 of 230mV (TYP) at 250mA (TS6833)
- Ultra-Low 36µA Typical Quiescent Current
- 3% Tolerance over Specified Conditions
- Open Drain Power Good Output
- Compatible with Low ESR Capacitor
- Thermal Shutdown Protection
- 8 Pin SOP Package

APPLICATIONS

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

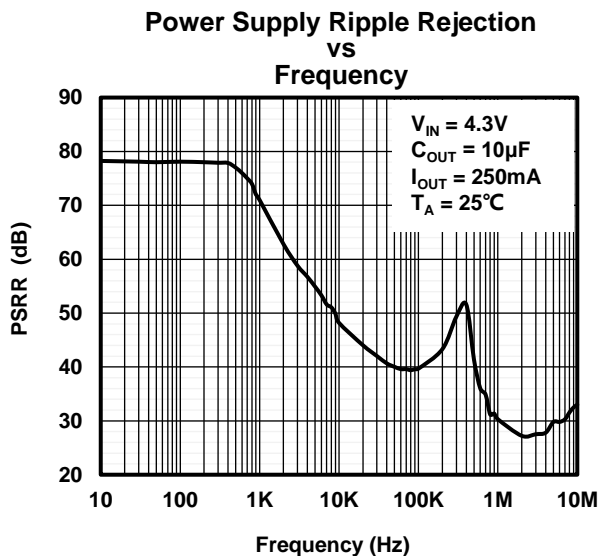
PRODUCT DESCRIPTION

The TS68xx series regulators are designed to have ultra-low quiescent currents and be stable with very low ESR output capacitors with a wide range of capacitance (0.47µF or greater). The combination of the above characteristics allows for a small ceramic capacitor to be used at the output with high dynamic performance at low cost.

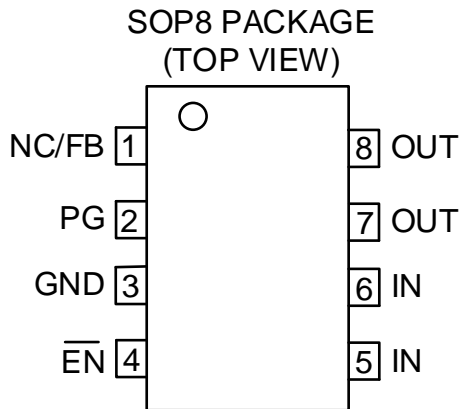
The TS68xx series is designed with very low dropout voltages (e.g. typically 230mV for the TS6833 at an output current of 250mA). The quiescent current is very low at light load (typically 36µA at 10µA load), however, it is designed to be dependent of output loading (approximately 1/250 of the output current at heavy load), in order to provide much improved transient response over competitions. 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 \overline{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 TS68xx 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 1.25V to 5.5V). Output voltage tolerance is specified as a maximum of 3% over line, load, and temperature ranges. The TS68xx family is available in 8 pin SOIC package.



PIN CONFIGURATION AND FUNCTIONS



TERMINAL		I/O	DESCRIPTION
NAME	NO		
$\overline{\text{EN}}$	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

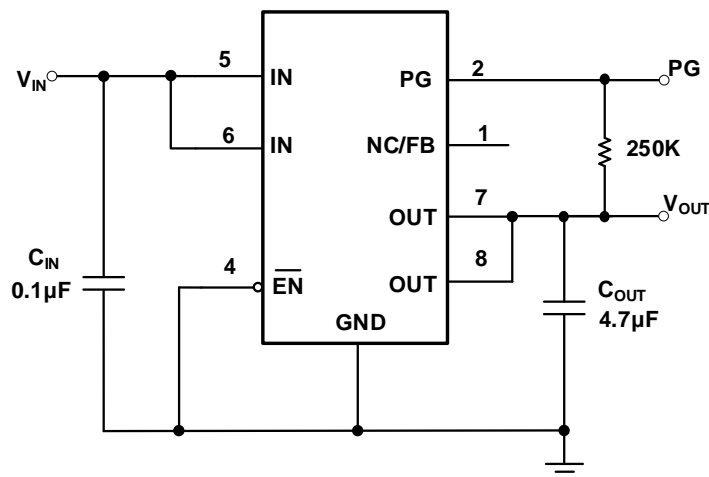


Figure 1. Typical Application Configuration for Fixed Output Option

RECOMMENDED OPERATING CONDITIONS

Parameter		MIN	MAX	UNIT
V _{IN} [1]	Input Voltage	2.7	12	V
V _{OUT}	Output Voltage Range	1.2	5	V
I _{OUT} [2]	Output Current	0	250	mA
T _J [2]	Operating Virtual Junction Temperature	-40	125	°C

[1] To calculate the minimum input voltage for your maximum output current, use the following equation: $V_{IN_min} = V_{OUT_max} + V_{DO_max\ load}$, where V_{DO} is the dropout voltage.

[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

Over operating free-air temperature range (unless otherwise noted) [3]

Parameter	Min	Max	Unit
Input Voltage Range	-0.3	14	V
Voltage Range at 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		±4000	V
ESD MM		±200	V
ESD CDM		±1000	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.

[3] Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ORDERING INFORMATION

Model	Part Number	Eco Plan	Package	OUTPUT VOLTAGE (V)	Container, Pack Qty
TS6850	TS6850SO8R	RoHS	SOP8	5.0	Reel, 2500
TS6833	TS6833SO8R	RoHS	SOP8	3.3	Reel, 2500
TS6830	TS6830SO8R	RoHS	SOP8	3.0	Reel, 2500
TS6828	TS6828SO8R	RoHS	SOP8	2.8	Reel, 2500
TS6827	TS6827SO8R	RoHS	SOP8	2.7	Reel, 2500
TS6825	TS6825SO8R	RoHS	SOP8	2.5	Reel, 2500
TS6818	TS6818SO8R	RoHS	SOP8	1.8	Reel, 2500
TS6815	TS6815SO8R	RoHS	SOP8	1.5	Reel, 2500
TS6801	TS6801SO8R	RoHS	SOP8	Adjustable (1.25V to 5.5V)	Reel, 2500

The TS6801 is programmable using an external resistor divider.

ELECTRICAL CHARACTERISTICS

At $T_J = +25^\circ\text{C}$, $V_{IN} = V_{OUT}$ typ.) + 1 V, $I_{OUT} = 10\mu\text{A}$, $\overline{EN} = 0\text{V}$, $C_{OUT} = 4.7\mu\text{F}$, unless otherwise noted.

Boldface limits apply over the specified Junction temperature range, $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$.

Parameter		Operating Conditions	Min	Typ	Max	Unit	
V_{OUT}	Output Voltage ^[4] (10 μA to 250mA Load)	TS6801	5.5V $\geq V_{OUT} \geq 1.25\text{V}$		V_{OUT}		
			$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		0.97 V_{OUT}		1.03 V_{OUT}
		TS6815	2.7V $\leq V_{IN} \leq 12\text{V}$		1.5		
			$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		1.455		1.545
		TS6818	2.8 $\leq V_{IN} \leq 12\text{V}$		1.8		
			$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		1.746		1.854
		TS6825	3.5 $\leq V_{IN} \leq 12\text{V}$		2.5		
			$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2.425		2.575
		TS6827	3.7 $\leq V_{IN} \leq 12\text{V}$		2.7		
			$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2.619		2.781
TS6828	3.8 $\leq V_{IN} \leq 12\text{V}$		2.8				
	$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2.716		2.884		
TS6830	4.0 $\leq V_{IN} \leq 12\text{V}$		3.0				
	$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2.910		3.090		
TS6833	4.3 $\leq V_{IN} \leq 12\text{V}$		3.3				
	$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		3.250		3.350		
TS6850	5.0 $\leq V_{IN} \leq 12\text{V}$		5.0				
	$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		4.850		5.150		
I_{GND}	Quiescent Current ^[4] (GND Current)	$\overline{EN} = 0\text{V}$		36		μA	
		$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$			60		
Output Voltage Line Regulation ^{[4][5]} ($\Delta V_{OUT}/V_{OUT}$)		$V_{OUT} + 1\text{V} \leq V_{IN} \leq 12\text{V}$,		0.005		$\%/V$	
Load Regulation		$I_{OUT} = 10\mu\text{A}$ to 250mA $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		0.5%			
Output Noise Voltage		BW = 300Hz to 50kHz, $C_{OUT} = 4.7\mu\text{F}$		150		μVrms	
Output Current Limit		$V_{OUT} = 0\text{V}$		0.78		A	
Thermal Shutdown Junction Temperature				150		$^\circ\text{C}$	
Thermal Shutdown Hysteresis Temperature				20		$^\circ\text{C}$	
I_{STB}	Standby Current	$\overline{EN} = V_{IN}$, 2.7V $\leq V_{IN} \leq 12\text{V}$		1		μA	
		$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$			10		
I_{FB}	FB Input Current	TS6801	FB = 1.5V		2	nA	
V_{IH_EN}	High Level Enable Input Voltage		$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2	V	
V_{IL_EN}	Low Level Enable Input Voltage		$T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$			0.8 V	
PSRR	Power Supply Ripple Rejection ^[3]		f = 1kHz, $I_{OUT} = 10\mu\text{A}$, $C_{OUT} = 4.7\mu\text{F}$		67	dB	
PG	Minimum Input Voltage for Valid PG		$I_{OUT(PG)} = 300\mu\text{A}$		1.25	V	
	Trip Threshold Voltage		V_{OUT} Decreasing $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		92	98 $\%/V_{OUT}$	
	Hysteresis Voltage		Measured at V_{OUT}		0.5	$\%/V_{OUT}$	
	Output Low Voltage		$V_{IN} = 2.7\text{V}$, $I_{OUT(PG)} = 1\text{mA}$		0.16	V	
	Leakage Current		$V_{(PG)} = 5\text{V}$ $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$			1 μA	
I_{EN}	Input Current (\overline{EN})		$\overline{EN} = 0\text{V}$		-1	0	μA
			$\overline{EN} = V_{IN}$		-1	1	μA

ELECTRICAL CHARACTERISTICS (CONTINUE)

At $T_J = +25^\circ\text{C}$, $V_{IN} = V_{OUT}(\text{typ}) + 1\text{ V}$, $I_{OUT} = 10\mu\text{A}$, $\overline{EN} = 0\text{V}$, $C_{OUT} = 4.7\mu\text{F}$, unless otherwise noted.

Boldface limits apply over the specified Junction temperature range, $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$.

Parameter		Operating Conditions		Min	Typ	Max	Unit
V_{DO}	Dropout Voltage [6]	TS6828	$I_{OUT} = 250\text{mA}$ $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		310	540	mV
		TS6830	$I_{OUT} = 250\text{mA}$ $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		270	470	
		TS6833	$I_{OUT} = 250\text{mA}$ $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		230	400	
		TS6850	$I_{OUT} = 250\text{mA}$ $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$		140	250	

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

[5] If $V_{OUT} < 1.7\text{V}$ then $V_{IN_min} = 2.7\text{ V}$, $V_{IN_max} = 12\text{ V}$:

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

If $V_{OUT} \geq 1.7\text{V}$ then $V_{IN_min} = V_{OUT} + 1\text{V}$, $V_{IN_max} = 12\text{ V}$:

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

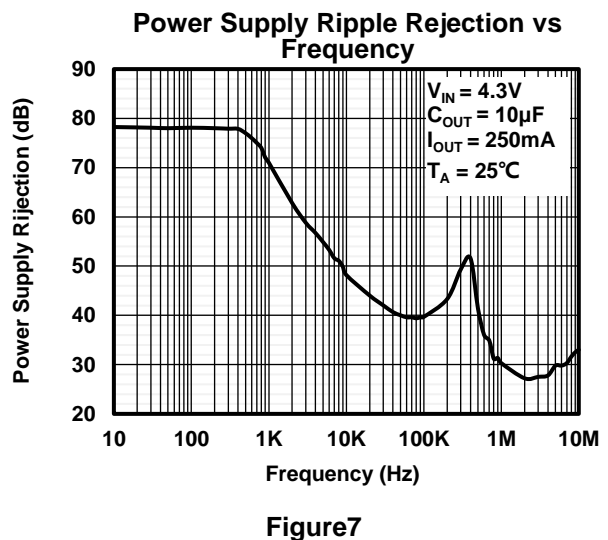
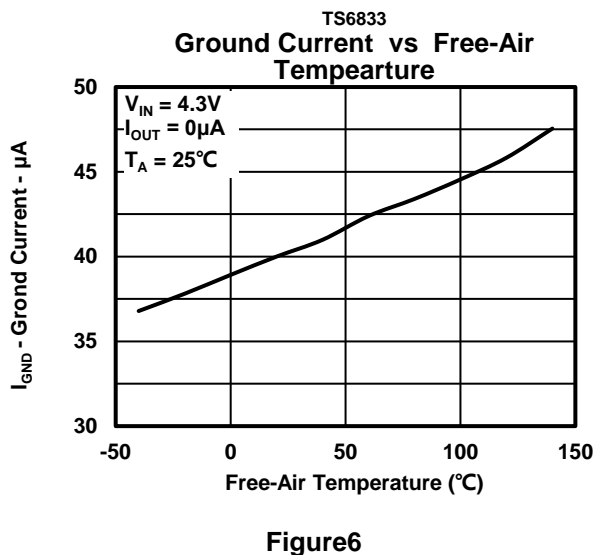
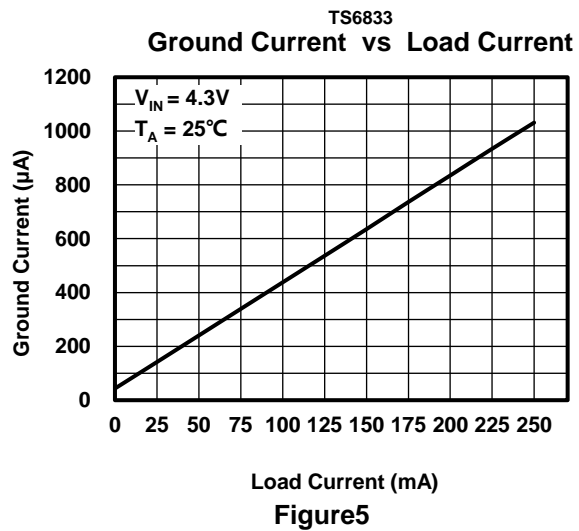
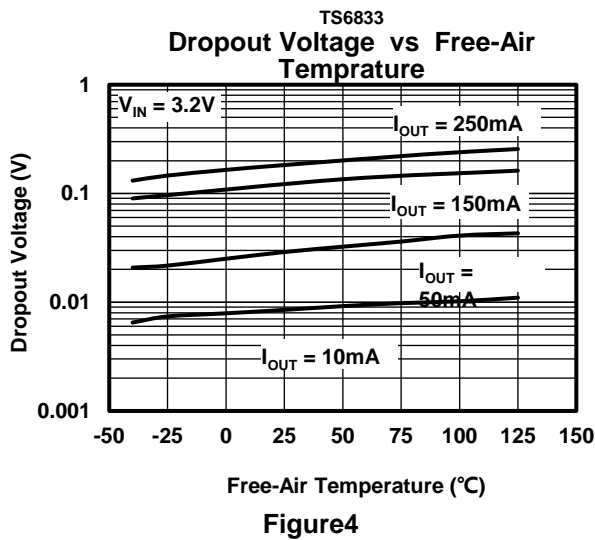
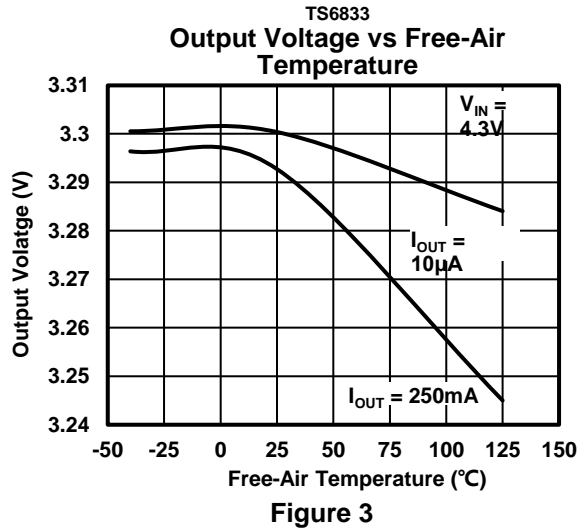
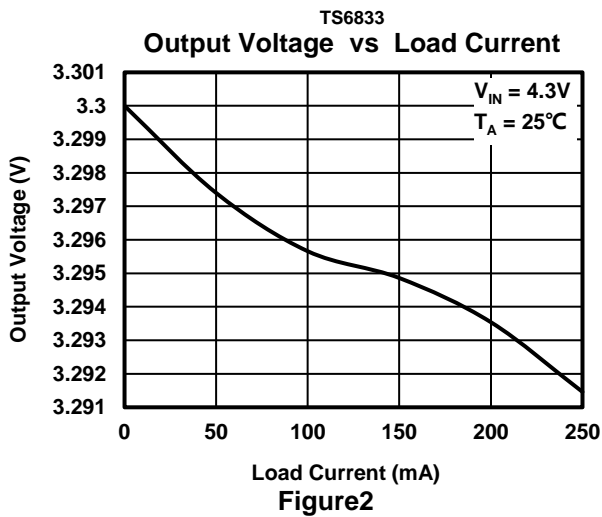
[6] IN voltage equals $V_{OUT}(\text{typ}) - 100\text{mV}$ (e.g., TS6833 input voltage needs to drop to 3.2V for purpose of this test); For TS6801, set the nominal output voltage to 3.3V with an external resistor divider. For TS6815, TS6818, TS6825, and TS6827, dropout voltages are limited by input voltage range limitations.

TABLE OF GRAPHS

Parameter		FIGURE
Output voltage	vs Load current	2
	vs Free-air temperature	3
Ground current	vs Load current	4
	vs Free-air temperature	7
Dropout voltage	vs Free-air temperature	5
Power supply ripple rejection	vs Frequency	6
Line transient response		8
Load transient response		9
Output voltage	vs Time	10
Output spectral noise density	vs Frequency	11

TYPICAL CHARACTERISTICS

At $T_A = +25^\circ\text{C}$, $V_S = 5\text{V}$, $R_L = 10\text{k}\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)



TYPICAL CHARACTERISTICS (CONTINUE)

At $T_A = +25^\circ\text{C}$, $V_S = 5\text{V}$, $R_L = 10\text{k}\Omega$ connected to $V_S / 2$, and $V_{OUT} = V_S / 2$ (unless otherwise noted)

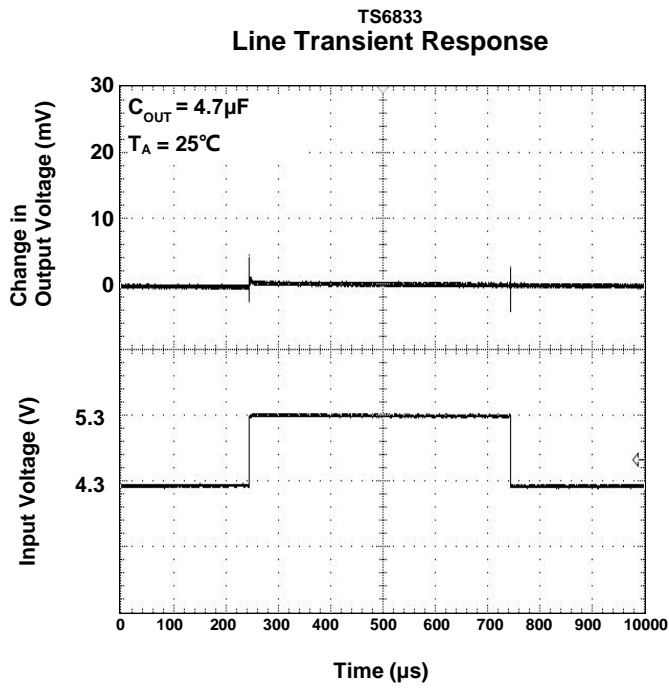


Figure8

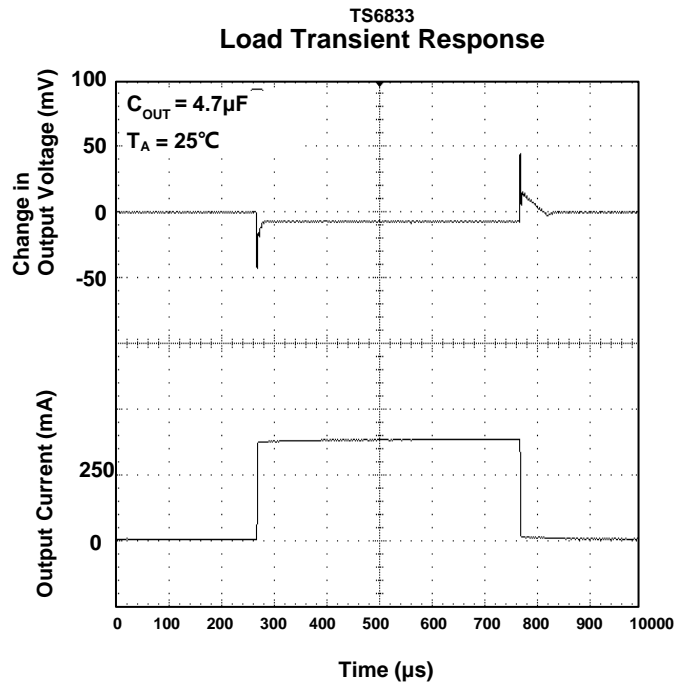


Figure9

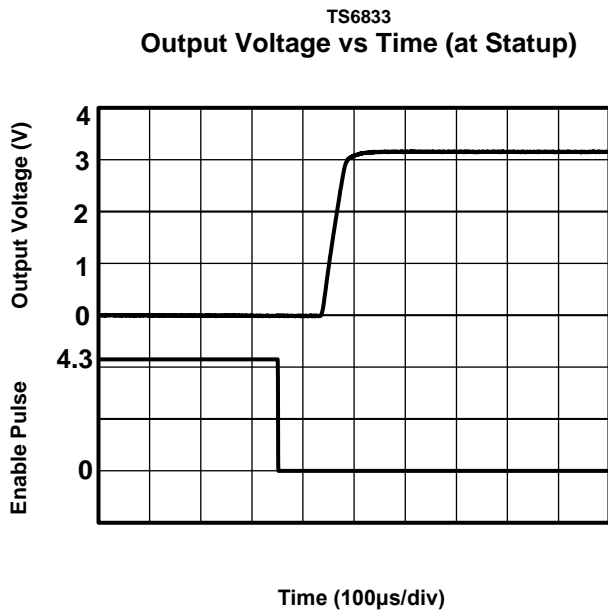


Figure10

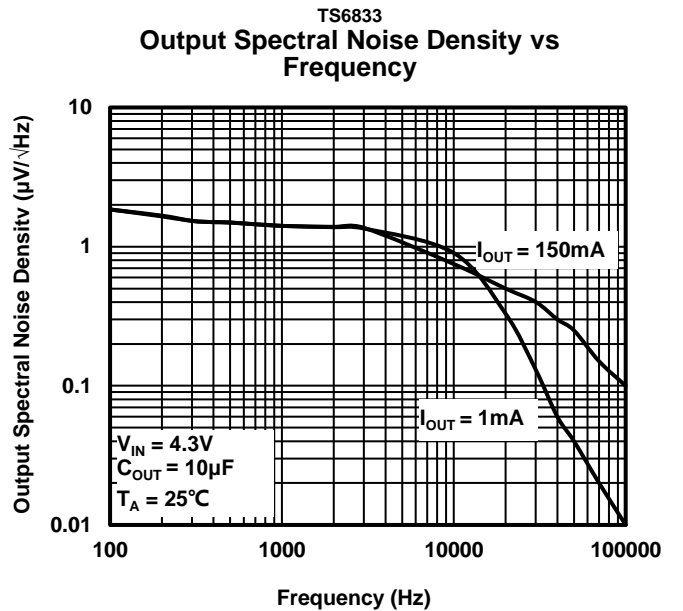


Figure11

APPLICATION INFORMATION

The TS68XX family includes eight fixed-output voltage regulators (1.5V, 1.8V, 2.5V, 2.7V, 2.8V, 3.0V, 3.3V, and 5.0V), and an adjustable regulator, the TS6801 (adjustable from 1.25V to 5.5V). A typical application circuit for fixed-output versions is shown in Figure 12.

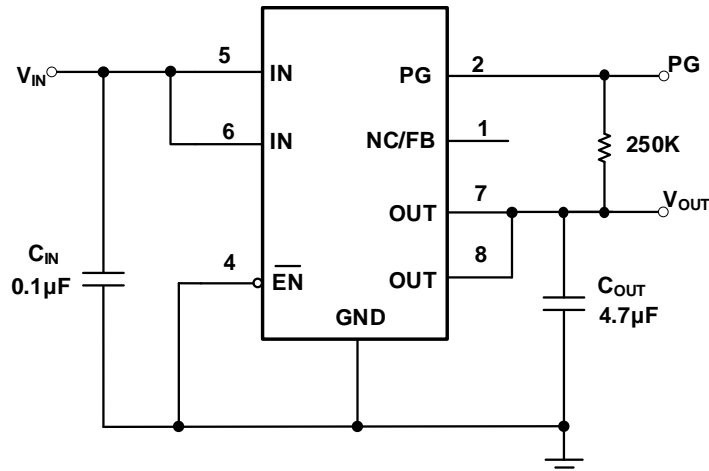


Figure 12. Typical Application Circuit (Fixed Version)

Device Operation

The TS68xx features very low quiescent current at light load (typically 36 μ A at 10 μ A 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 transient response over competitions. This dependency hardly has any effect on the operation efficiency at light or heavy load. When load current approaches the maximum output current (250mA), the ground pin current will only be approximately 1mA, which is independent of the supply voltage.

Unlike a linear regulator with a PNP-pass device, which tends to saturate when the regulator goes into dropout resulting in an increase in quiescent current even at light load or no load, TS68xx uses PMOS transistor as the pass device and a proprietary circuit technique to prevent quiescent current from going up when regulator is in dropout condition. In battery-powered systems, it means longer lasting battery even when the voltage decays below the minimum required for regulation.

The TS68xx 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 μ A (typ). If the shutdown feature is not used, $\overline{\text{EN}}$ should be tied to ground. Response to an enable transition is quick; regulated output voltage is reestablished in typically 160 μ s.

Minimum Load Requirements

The TS68xx 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 terminal 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 13. 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.

APPLICATION INFORMATION

External Capacitor Requirements

The input capacitor is not required usually, however, a ceramic bypass capacitor (0.047µF or greater) improves load transient performance and overall loop stability. A higher capacitance capacitor may be necessary if large load transients with fast rise times are anticipated.

The TS68XX requires an output capacitor to stabilize the feedback loop, however, the often seen minimum ESR (the equivalent series resistance) requirement for the output capacitor is not applicable. Instead, the ESR should be limited to under 1Ω for the benefit of stability under large load current. The capacitance of the output capacitor should be greater than 0.47µF, though the recommended capacitance for this capacitor is 4.7µF or larger. Due to the characteristics of low ESR even at low temperatures, ceramic, solid tantalum and solid aluminum electrolytic capacitors are all suitable for TS68xx series regulators. When non-solid electrolytic capacitors are used, especially for low temperature applications, it is strongly recommended that a ceramic capacitor with values greater than 0.47µF be connected in parallel.

Programming the TS6801 Adjustable LDO Regulator

The output voltage of the TS6801 adjustable regulator is programmed using an external resistor divider as shown in Figure 13. The output voltage is calculated using:

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

Where

$$V_{ref} = 1.219 \text{ V (the typical internal reference voltage)}$$

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

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

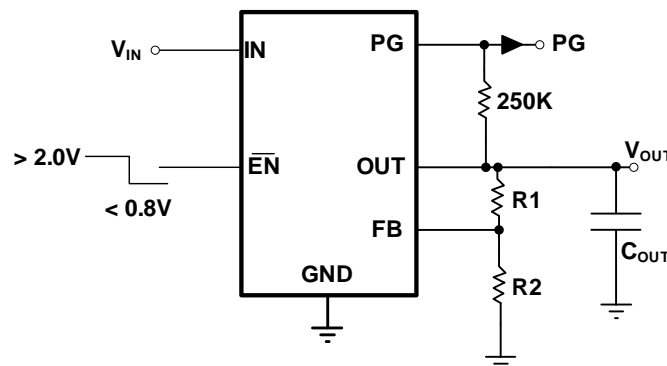


Figure 13. TS6801 Adjustable LDO Regulator Programming

APPLICATION INFORMATION

Power-Good Indicator

The TS68xx 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, it can be left floating if not used. PG can be used to drive power-on reset circuitry or used as a low-battery indicator.

Regulator Protection

The TS68xx 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 TS68xx also features internal current limiting and thermal protection. During normal operation, the TS68xx limits output current to approximately 0.78A (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°C (typ), thermal-protection circuitry shuts it down. Once the device has cooled below +130°C (typ), regulator operation resumes.

Power Dissipation and Junction Temperature

Specified regulator operation is assured to a junction temperature up to +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 that the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, $P_{D(max)}$, and the actual dissipation, P_D , which must be less than or equal to $P_{D(max)}$.

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

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

Where:

T_{Jmax} is the maximum allowable junction temperature.

$R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package, i.e., 176°C/W for the SOP8 package.

T_A is the ambient temperature.

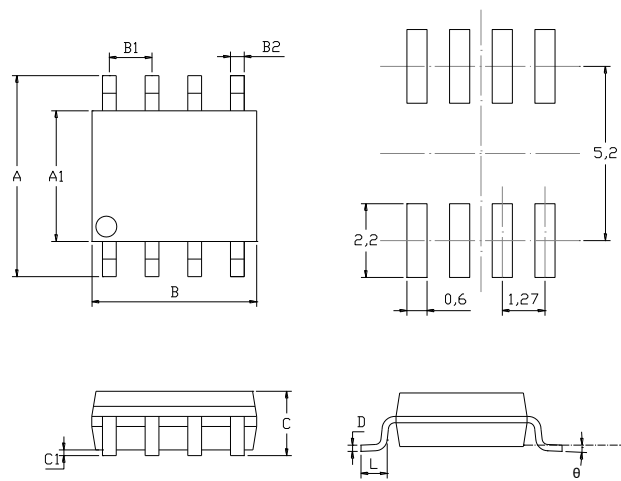
The regulator dissipation is calculated using:

$$P_{D(max)} = (V_{IN} - V_{OUT}) \times I_{OUT}$$

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

MECHANICAL DIMENSIONS

SOP8 PACKAGE MECHANICAL DRAWING

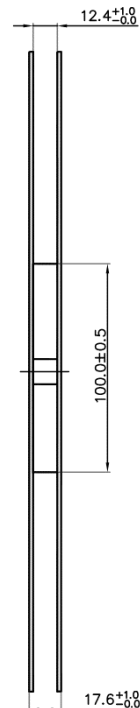
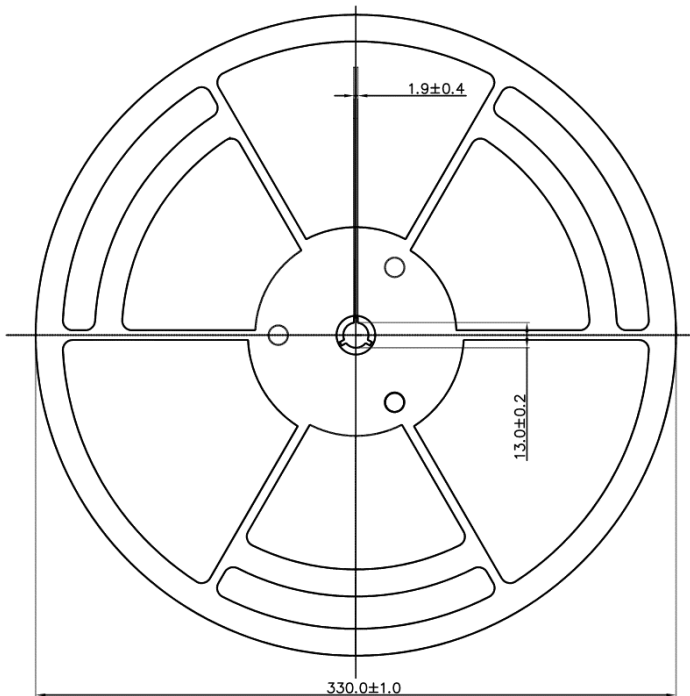
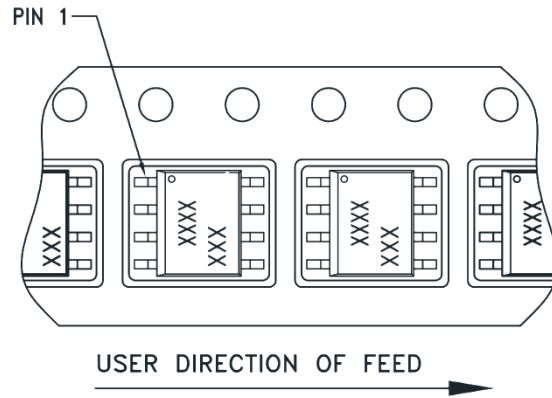
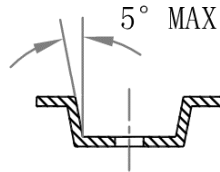
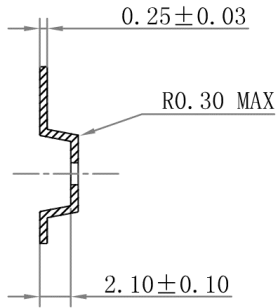
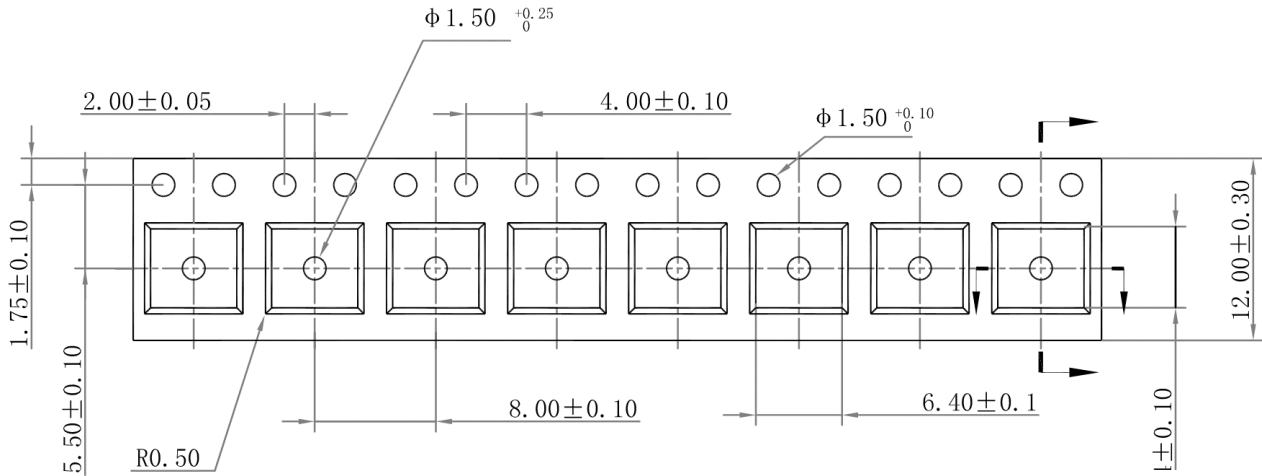


SOP8 PACKAGE MECHANICAL DATA

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.80	6.20	0.228	0.244
A1	3.80	4.00	0.150	0.157
B	4.70	5.10	0.185	0.201
B1	1.27		0.050	
B2	0.33	0.51	0.013	0.020
C		1.75		0.069
C1	0.10	0.25	0.004	0.010
L	0.40	1.27	0.016	0.050
D	0.17	0.25	0.007	0.010
θ	0°	8°	0°	8°

TAPE AND REEL INFORMATION

SOP8



REVISION HIETORY

2020/8/7— REV KY1.0.6 TO REV KY1.0.7

Updated Figure107

Updated MECHANICAL DIMENSIONS11

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