LINEAR TECHNOLOGY

LT1783

1.25MHz, Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amp in SOT-23

FEATURES

- **Operates with Inputs Above V⁺**
- **Rail-to-Rail Input and Output**
- **Micropower: 300µA Supply Current Max**
- Small SOT-23 Package
- Gain Bandwidth product: 1.25MHz
- Slew Rate: 0.42V/µs
- Low Input Offset Voltage: 800µV Max
- Single Supply Input Range: 0V to 18V
- High Output Current: 18mA Min
- Specified on 3V, 5V and ±5V Supplies
- Output Shutdown on 6-Lead Version
- Reverse Battery Protection to 18V
- High Voltage Gain: 1500V/mV
- Operating Temperature Range: –40°C to 85°C

APPLICATIONS

- Portable Instrumentation
- Battery- or Solar-Powered Systems
- Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- MUX Amplifiers
- 4mA to 20mA Transmitters

DESCRIPTION

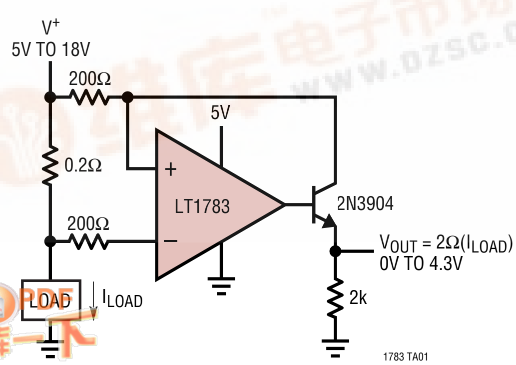
The LT®1783 is a 1.25MHz op amp available in the small SOT-23 package that operates on all single and split supplies with a total voltage of 2.5V to 18V. The amplifier draws less than 300µA of quiescent current and has reverse battery protection, drawing negligible current for reverse supply voltages up to 18V.

The input range of the LT1783 includes ground, and a unique feature of this device is its Over-The-Top™ operation capabilitity with either or both of its inputs above the positive rail. The inputs handle 18V both differential and common mode, independent of supply voltage. The input stage incorporates phase reversal protection to prevent false outputs from occurring even when the inputs are 9V below the negative supply.

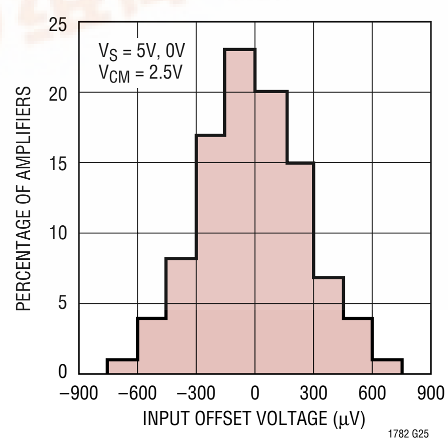
The LT1783 can drive loads up to 18mA and still maintain rail-to-rail capability. A shutdown feature on the 6-lead version can disable the part, making the output high impedance and reducing quiescent current to 5µA. The LT1783 op amp is available in the 5- and 6-lead SOT-23 packages. For applications requiring lower power, refer to the LT1782.

TYPICAL APPLICATION

Positive Supply Rail Current Sense



Distribution of Input Offset Voltage

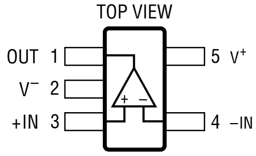


ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-) 18V
Input Differential Voltage 18V
Input Pin Voltage to V^- .... +24V/–10V
Shutdown Pin Voltage Above V^- 18V
Shutdown Pin Current .... ±10mA
Output Short-Circuit Duration (Note 2) .... Indefinite
Operating Temperature Range (Note 10) –40°C to 85°C
Specified Temperature Range .... 0°C to 70°C
Junction Temperature .... 150°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW

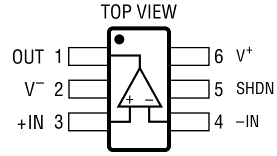


S5 PACKAGE
5-LEAD PLASTIC SOT-23

T_{JMAX} = 150°C, θ_{JA} = 250°C/W

ORDER PART NUMBER
LT1783CS5
S5 PART MARKING
LTLF

TOP VIEW



S6 PACKAGE
6-LEAD PLASTIC SOT-23

T_{JMAX} = 150°C, θ_{JA} = 230°C/W

ORDER PART NUMBER
LT1783CS6
S6 PART MARKING
LTIU

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the specified temperature range, otherwise specifications are T_A = 25°C. V_S = 3V, 0V; V_S = 5V, 0V, V_{CM} = V_{OUT} = half supply, for the 6-lead part V_{PIN5} = 0V, pulse power tested unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	T_A = 25°C			400	800	µV
		0°C ≤ T_A ≤ 70°C	●			950	µV
	Input Offset Voltage Drift (Note 7)	0°C ≤ T_A ≤ 70°C	●		2	5	µV/°C
I_{OS}	Input Offset Current		●		4	8	nA
		V_{CM} = 18V (Note 3)	●			7	µA
I_B	Input Bias Current		●		45	80	nA
		V_{CM} = 18V (Note 3)	●		35	60	µA
		SHDN or V_S = 0V, V_{CM} = 0V to 18V			0.1		nA
	Input Bias Current Drift	0°C ≤ T_A ≤ 70°C	●		0.06		nA/°C
	Input Noise Voltage	0.1Hz to 10Hz			0.6		μV_{P-P}
e_n	Input Noise Voltage Density	f = 1kHz			20		$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f = 1kHz			0.14		$pA/\sqrt{Hz}$
R_{IN}	Input Resistance	Differential		0.65	1.3		MΩ
		Common Mode, V_{CM} = 0V to (V_{CC} – 1V)			1		GΩ
		Common Mode, V_{CM} = 0V to 18V		0.3	0.5		MΩ
C_{IN}	Input Capacitance				5		pF
	Input Voltage Range		●	0		18	V
CMRR	Common Mode Rejection Ratio (Note 3)	V_{CM} = 0V to V_{CC} – 1V	●	90	100		dB
		V_{CM} = 0V to 18V (Note 6)	●	68	80		dB
PSRR	Power Supply Rejection Ratio	V_S = 3V to 12.5V, V_{CM} = V_O = 1V	●	90	100		dB
A_{VOL}	Large-Signal Voltage Gain	V_S = 3V, V_O = 500mV to 2.5V, R_L = 10k		200	1500		V/mV
		V_S = 3V, 0°C ≤ T_A ≤ 70°C	●	133			V/mV
		V_S = 5V, V_O = 500mV to 4.5V, R_L = 10k		400	1500		V/mV
		V_S = 5V, 0°C ≤ T_A ≤ 70°C	●	250			V/mV

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the specified temperature range, otherwise specifications are T_A = 25°C. V_S = 3V, 0V; V_S = 5V, 0V, V_{CM} = V_{OUT} = half supply, for the 6-lead part V_{PIN5} = 0V, pulse power tested unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OL}	Output Voltage Swing LOW	No Load	●		3	8	mV
		I_{SINK} = 5mA	●		200	400	mV
		V_S = 5V, I_{SINK} = 10mA	●		330	600	mV
V_{OH}	Output Voltage Swing HIGH	V_S = 3V, No Load	●	2.91	2.94		V
		V_S = 3V, I_{SOURCE} = 5mA	●	2.6	2.8		V
		V_S = 5V, No Load	●	4.91	4.94		V
		V_S = 5V, I_{SOURCE} = 10mA	●	4.5	4.74		V
I_{SC}	Short-Circuit Current (Note 2)	V_S = 3V, Short to GND		5	10		mA
		V_S = 3V, Short to V_{CC}		15	30		mA
		V_S = 5V, Short to GND		15	30		mA
		V_S = 5V, Short to V_{CC}		20	40		mA
	Minimum Supply Voltage		●		2.5	2.7	V
	Reverse Supply Voltage	I_S = –100µA	●	18			V
I_S	Supply Current				210	300	µA
	(Note 4)		●			350	µA
	Supply Current, SHDN	V_{PIN5} = 2V, No Load (Note 8)	●		5	18	µA
I_{SHDN}	Shutdown Pin Current	V_{PIN5} = 0.3V, No load (Note 8)	●		0.5		nA
		V_{PIN5} = 2V, No Load (Note 8)	●		2	8	µA
		V_{PIN5} = 5V, No Load (Note 8)			5		µA
	Shutdown Output Leakage Current	V_{PIN5} = 2V, No Load (Note 8)	●		0.05	1	µA
	Maximum Shutdown Pin Current	V_{PIN5} = 18V, No Load (Note 8)	●		10	30	µA
V_L	Shutdown Pin Input Low Voltage	(Note 8)	●			0.3	V
V_H	Shutdown Pin Input High Voltage	(Note 8)	●	2			V
t_{ON}	Turn-On Time	V_{PIN5} = 5V to 0V, R_L = 10k (Note 8)			25		µs
t_{OFF}	Turn-Off Time	V_{PIN5} = 0V to 5V, R_L = 10k (Note 8)			3		µs
GBW	Gain Bandwidth Product	f = 5kHz		750	1250		kHz
	(Note 3)	0°C ≤ T_A ≤ 70°C	●	600			kHz
SR	Slew Rate	A_V = –1, R_L = ∞		0.24	0.42		V/µs
	(Note 5)	0°C ≤ T_A ≤ 70°C	●	0.21			V/µs
FPBW	Full-Power Bandwidth (Note 9)	V_{OUT} = $2V_{P-P}$			66		kHz
t_S	Settling Time	V_S = 5V, ΔV_{OUT} = 2V to 0.1%, A_V = –1			12		µs
THD	Distortion	V_S = 3V, V_O = $2V_{P-P}$, A_V = 1, R_L = 10k, f = 1kHz			0.001		%
V_S = ±5V, V_{CM} = 0V, V_{OUT} = 0V, for the 6-lead part V_{SHDN} = $V^–$							
V_{OS}	Input Offset Voltage	T_A = 25°C			500	900	µV
		0°C ≤ T_A ≤ 70°C	●			1050	µV
	Input Offset Voltage Drift (Note 7)	0°C ≤ T_A ≤ 70°C	●		2	5	µV/°C
I_{OS}	Input Offset Current		●		4	8	nA
I_B	Input Bias Current		●		40	80	nA
	Input Bias Current Drift	0°C ≤ T_A ≤ 70°C	●		0.06		nA/°C
	Input Noise Voltage	0.1Hz to 10Hz			1		$µV_{P-P}$
e_n	Input Noise Voltage Density	f = 1kHz			20		nV/√Hz
i_n	Input Noise Current Density	f = 1kHz			0.14		pA/√Hz

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the specified temperature range, otherwise specifications are T_A = 25°C. V_S = ±5V, V_{CM} = 0V, V_{OUT} = 0V, for the 6-lead part V_{SHDN} = V^-, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
R_{IN}	Input Resistance	Differential Common Mode, V_{CM} = –5V to 13V	● ●	0.65 0.3	1.3 0.5		MΩ MΩ
C_{IN}	Input Capacitance				5		pF
	Input Voltage Range		●	–5		13	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –5V to 13V	●	68	80		dB
A_{VOL}	Large-Signal Voltage Gain	V_O = ±4V, R_L= 10k 0°C ≤ T_A ≤ 70°C	 ●	70 50	160		V/mV V/mV
V_{OL}	Output Voltage Swing LOW	No Load I_{SINK} = 5mA I_{SINK} = 10mA	● ● ●		–4.997 –4.8 –4.67	–4.992 –4.6 –4.4	V V V
V_{OH}	Output Voltage Swing HIGH	No Load I_{SOURCE} = 5mA I_{SOURCE} = 10mA	● ● ●	4.91 4.6 4.5	4.94 4.8 4.74		V V V
I_{SC}	Short-Circuit Current (Note 2)	Short to GND 0°C ≤ T_A ≤ 70°C	 ●	18 15	30		mA mA
PSRR	Power Supply Rejection Ratio	V_S = ±1.5V to ±9V	●	90	100		dB
I_S	Supply Current		 ●		230	325 375	µA µA
	Supply Current, SHDN	V_{PIN5} = –3V, V_S = ±5V, No Load (Note 8)	●		6	20	µA
I_{SHDN}	Shutdown Pin Current	V_{PIN5} = –4.7V, V_S = ±5V, No load (Note 8) V_{PIN5} = –3V, V_S = ±5V, No Load (Note 8)	● ●		0.5 2	 8	nA µA
	Maximum Shutdown Pin Current	V_{PIN5} = 9V, V_S = ±9V (Note 8)	●		10	30	µA
	Shutdown Output Leakage Current	V_{PIN5} = –7V, V_S = ±9V, No Load (Note 8)	●		0.05	1	µA
V_L	Shutdown Pin Input Low Voltage	V_S = ±5V (Note 8)	●			–4.7	V
V_H	Shutdown Pin Input High Voltage	V_S = ±5V (Note 8)	●	–2.8			V
t_{ON}	Turn-On Time	V_{PIN5} = 0V to –5V, R_L = 10k (Note 8)	●		25		µs
t_{OFF}	Turn-Off Time	V_{PIN5} = –5V to 0V, R_L = 10k (Note 8)	●		3		µs
GBW	Gain Bandwidth Product	f = 5kHz 0°C ≤ T_A ≤ 70°C	 ●	800 700	1300		kHz kHz
SR	Slew Rate	A_V = –1, R_L = ∞, V_O = ±4V, Measured at V_O = ±2V 0°C ≤ T_A ≤ 70°C	 ●	0.26 0.23	0.45		V/µs V/µs
FPBW	Full-Power Bandwidth (Note 9)	V_{OUT} = 8V_{P-P}			18		kHz
t_S	Settling Time	ΔV_{OUT} = 4V to 0.1%, A_V = 1			10		µs

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: A heat sink may be required to keep the junction temperature below absolute maximum.

Note 3: V_S = 5V limits are guaranteed by correlation to V_S = 3V and V_S = ±5V or V_S = ±9V tests.

Note 4: V_S = 3V limits are guaranteed by correlation to V_S = 5V and V_S = ±5V or V_S = ±9V tests.

Note 5: Guaranteed by correlation to slew rate at V_S = ±5V, and GBW at V_S = 3V and V_S = ±5V tests.

Note 6: This specification implies a typical input offset voltage of 1.8mV at V_{CM} = 18V and a maximum input offset voltage of 7.2mV at V_{CM} = 18V.

Note 7: This parameter is not 100% tested.

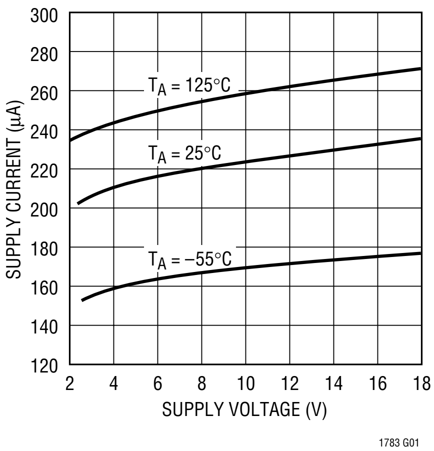
Note 8: Specifications apply to 6-lead SOT-23 with shutdown.

Note 9: Full-power bandwidth is calculated from the slew rate. FPBW = SR/2πV_P.

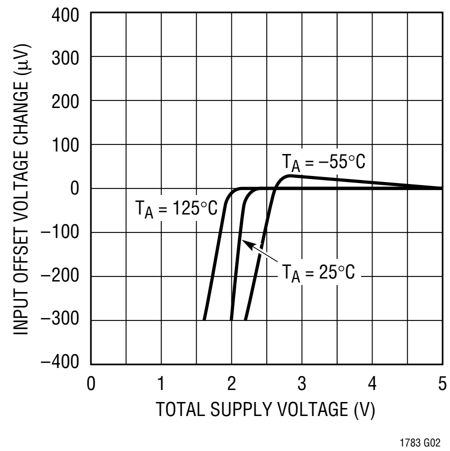
Note 10: The LT1783 is guaranteed functional over the operating temperature range –40°C to 85°C.

TYPICAL PERFORMANCE CHARACTERISTICS

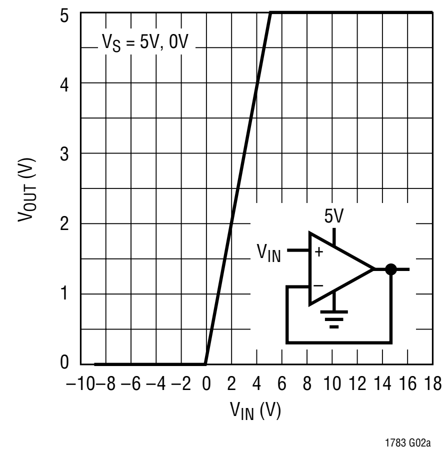
Supply Current vs Supply Voltage



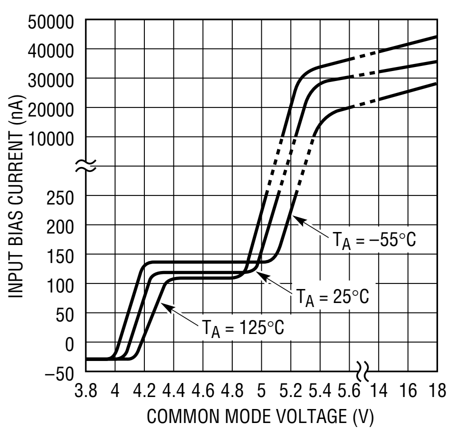
Minimum Supply Voltage



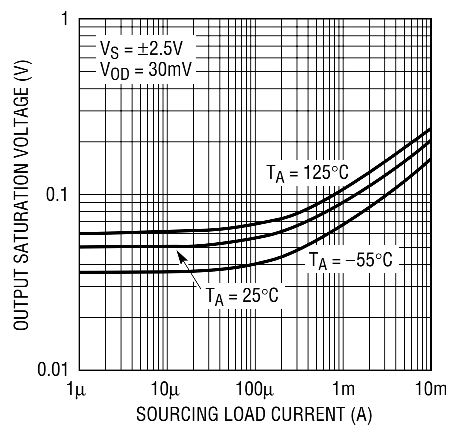
Output Voltage vs Large Input Voltage



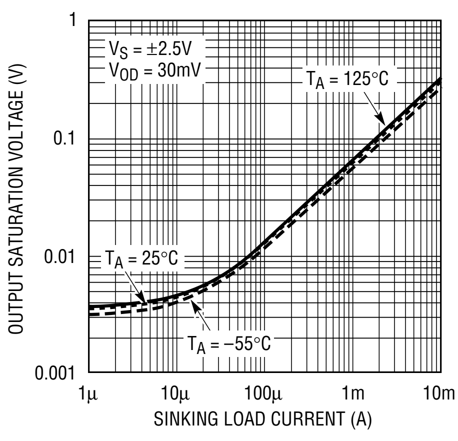
Input Bias Current vs Common Mode Voltage



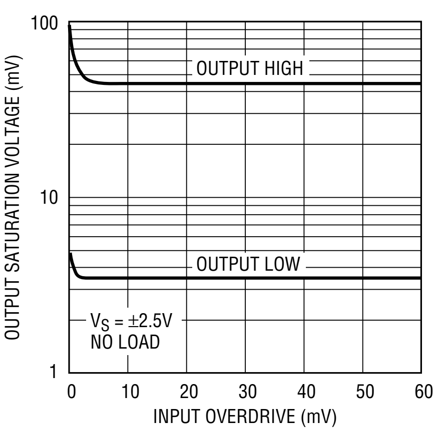
Output Saturation Voltage vs Load Current (Output High)



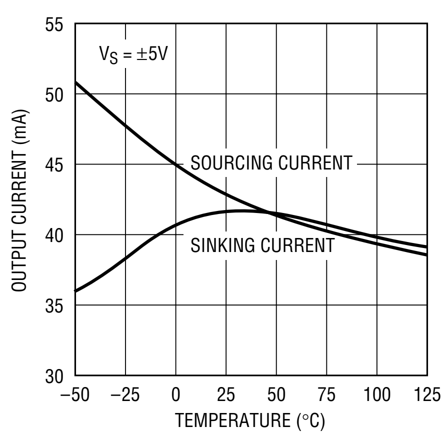
Output Saturation Voltage vs Load Current (Output Low)



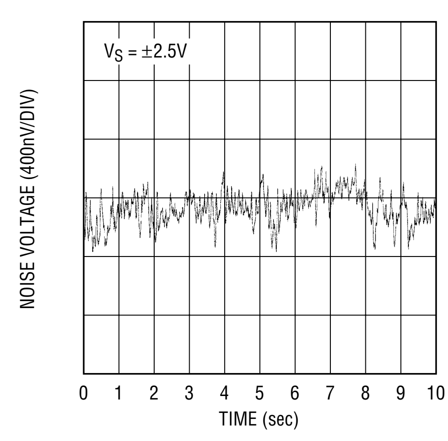
Output Saturation Voltage vs Input Overdrive



Output Short-Circuit Current vs Temperature

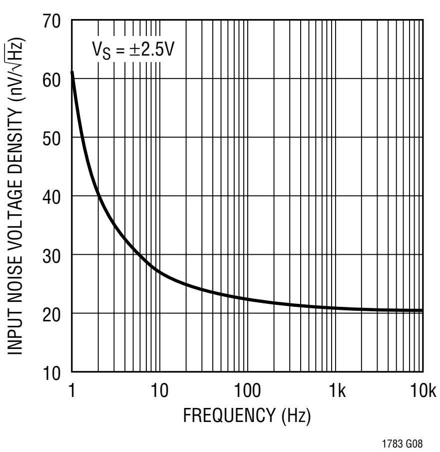


0.1Hz to 10Hz Noise Voltage

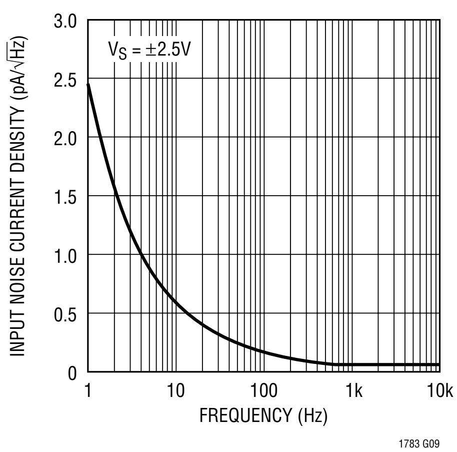


TYPICAL PERFORMANCE CHARACTERISTICS

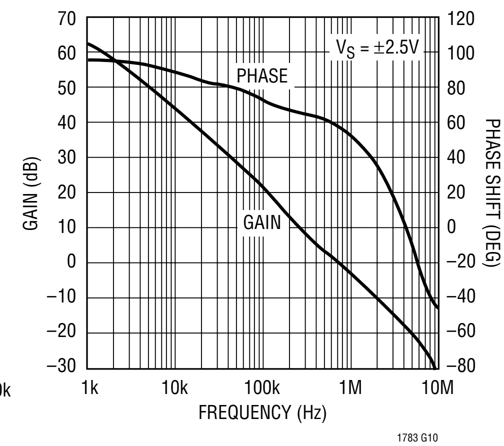
Noise Voltage Density vs Frequency



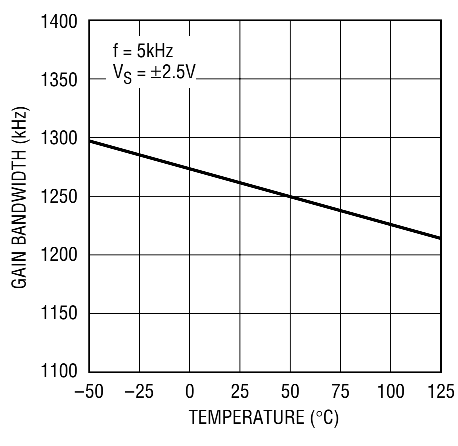
Input Noise Current vs Frequency



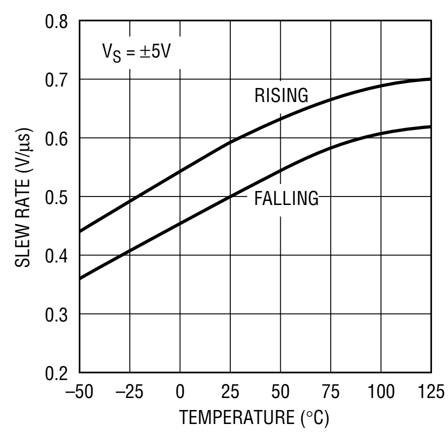
Gain and Phase Shift vs Frequency



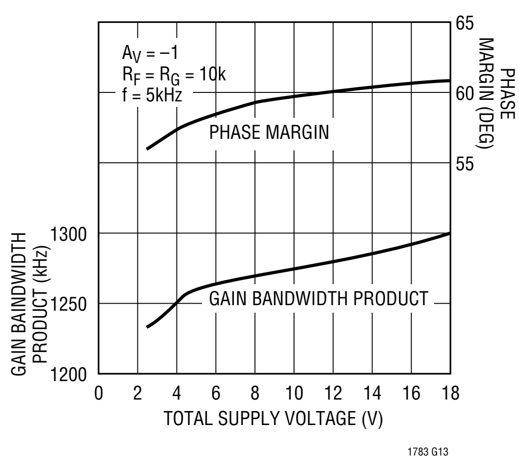
Gain Bandwidth Product vs Temperature



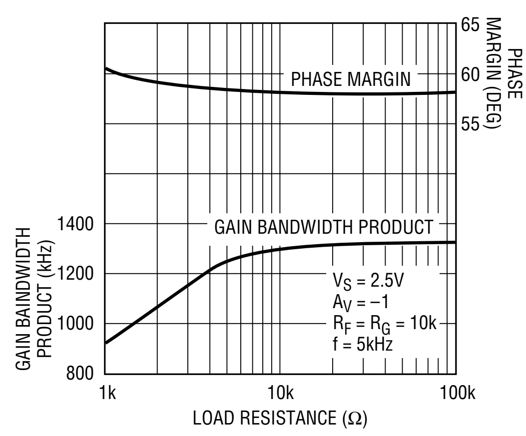
Slew Rate vs Temperature



Gain Bandwidth Product and Phase Margin vs Supply Voltage

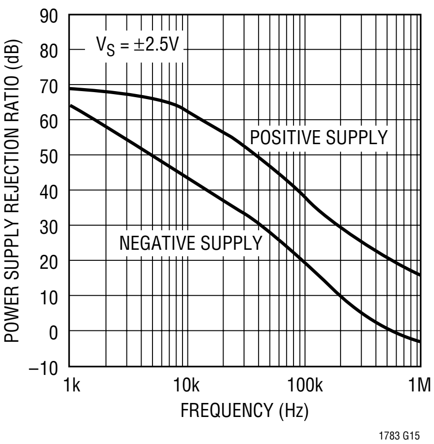


Gain Bandwidth and Phase Margin vs Load Resistance

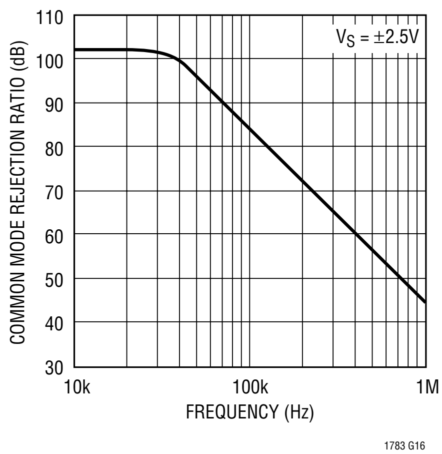


TYPICAL PERFORMANCE CHARACTERISTICS

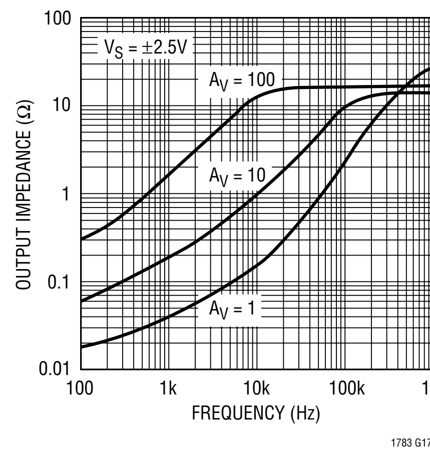
PSRR vs Frequency



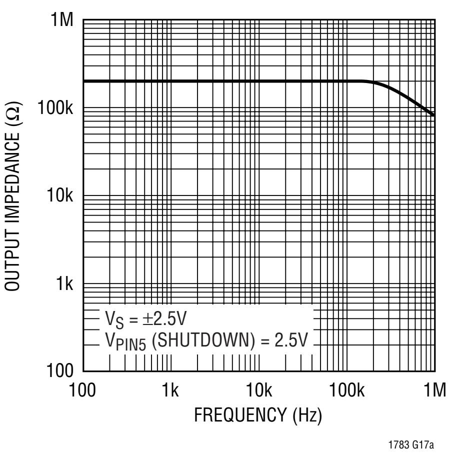
CMRR vs Frequency



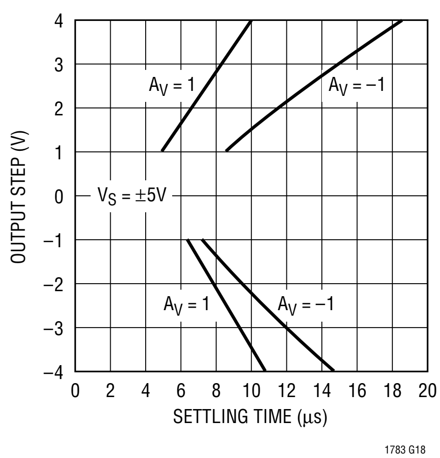
Output Impedance vs Frequency



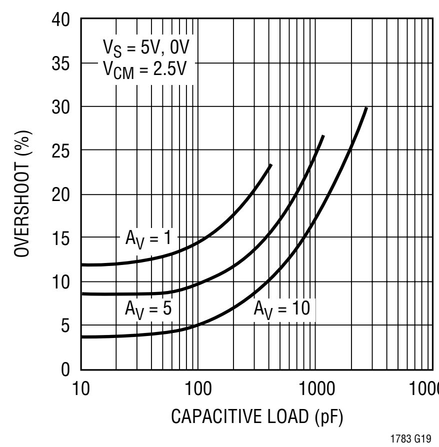
Disabled Output Impedance vs Frequency (Note 8)



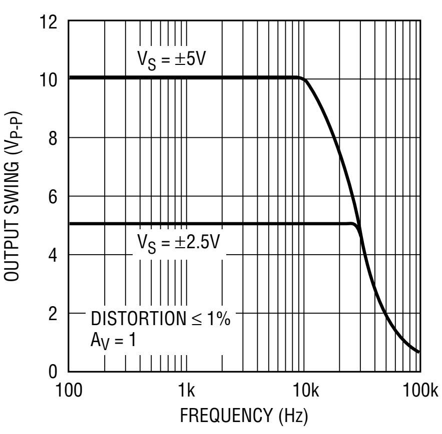
Settling Time to 0.1% vs Output Step



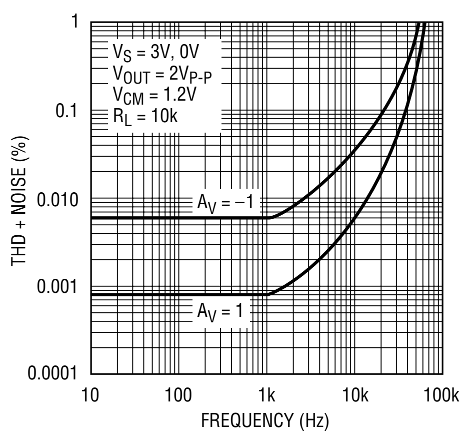
Capacitive Load Handling Overshoot vs Capacitive Load



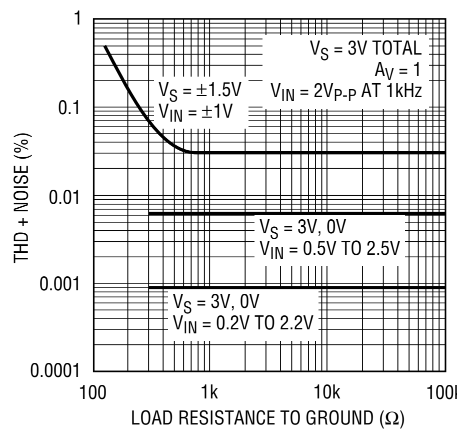
Undistorted Output Swing vs Frequency



Total Harmonic Distortion + Noise vs Frequency

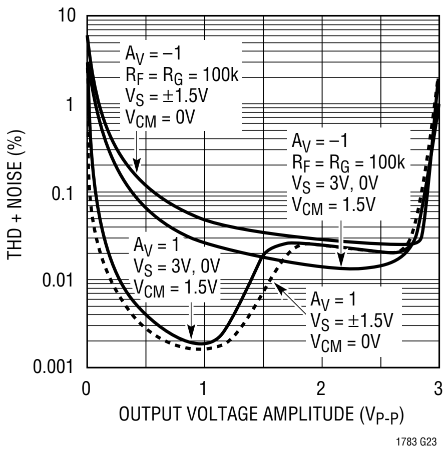


Total Harmonic Distortion + Noise vs Load Resistance

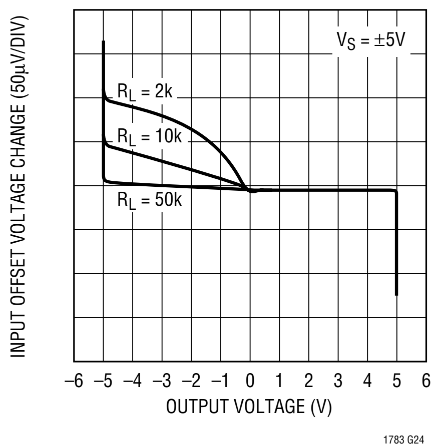


TYPICAL PERFORMANCE CHARACTERISTICS

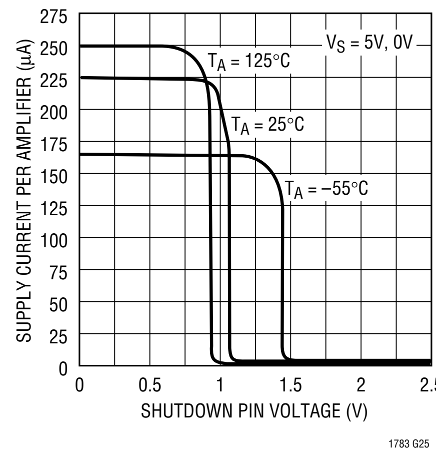
Total Harmonic Distortion + Noise vs Output Voltage Amplitude



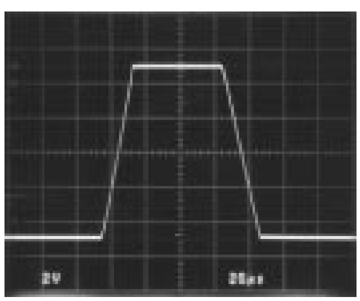
Open-Loop Gain



Supply Current vs SHDN Pin Voltage

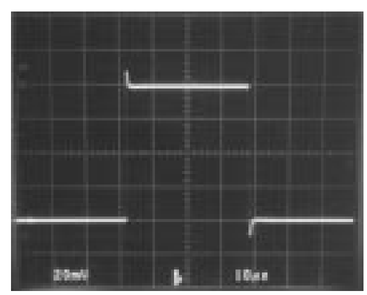


Large-Signal Response



$V_S = \pm5V$
$A_V = 1$
$C_L = 15pF$

Small-Signal Response



$V_S = \pm5V$
$A_V = 1$
$C_L = 15pF$

APPLICATIONS INFORMATION

Supply Voltage

The positive supply pin of the LT1783 should be bypassed with a small capacitor (typically 0.1µF) within an inch of the pin. When driving heavy loads, an additional 4.7µF electrolytic capacitor should be used. When using split supplies, the same is true for the negative supply pin.

The LT1783 is protected against reverse battery voltages up to 18V. In the event a reverse battery condition occurs, the supply current is less than 1nA.

Inputs

The LT1783 has two input stages, NPN and PNP (see the Simplified Schematic), resulting in three distinct operating regions as shown in the Input Bias Current vs Common Mode typical performance curve.

For input voltages about 0.8V or more below V^+, the PNP input stage is active and the input bias current is typically –40nA. When the input common mode voltage is within 0.5V of the positive rail, the NPN stage is operating and the

APPLICATIONS INFORMATION

input bias current is typically 80nA. Increases in temperature will cause the voltage at which operation switches from the PNP input stage to the NPN input stage to move towards V^+. The input offset voltage of the NPN stage is untrimmed and is typically 1.8mV.

A Schottky diode in the collector of the input transistors, along with special geometries for these NPN transistors, allow the LT1783 to operate with either or both of its inputs above V^+. At about 0.3V above V^+, the NPN input transistor is fully saturated and the input bias current is typically 30μA at room temperature. The input offset voltage is typically 1.8mV when operating above V^+. The LT1783 will operate with its inputs 18V above V^- regardless of V^+.

The inputs are protected against excursions as much as 10V below V^- by an internal 1k resistor in series with each input and a diode from the input to the negative supply. The input stage of the LT1783 incorporates phase reversal protection to prevent the output from phase reversing for inputs up to 9V below V^-. There are no clamping diodes between the inputs and the maximum differential input voltage is 18V.

Output

The output of the LT1783 can swing to within 60mV of the positive rail with no load and within 3mV of the negative rail with no load. When monitoring input voltages within 60mV of the positive rail or within 3mV of the negative rail, gain should be taken to keep the output from clipping. The LT1783 can sink and source over 30mA at ±5V supplies, sourcing current is reduced to 10mA at 3V total supplies as noted in the Electrical Characteristics.

The LT1783 is internally compensated to drive at least 400pF of capacitance under any output loading conditions. A 0.22μF capacitor in series with a 150Ω resistor between the output and ground will compensate these amplifiers for larger capacitive loads, up to 10,000pF, at all output currents.

Distortion

There are two main contributors to distortion in op amps: output crossover distortion as the output transitions from sourcing to sinking current, and distortion caused by nonlinear common mode rejection. If the op amp is operating inverting, there is no common mode induced distortion. If the op amp is operating in the PNP input stage (input is not within 0.8V of V^+), the CMRR is very good, typically 100dB. When the LT1783 switches between input stages, there is significant nonlinearity in the CMRR. Lower load resistance increases the output crossover distortion but has no effect on the input stage transition distortion. For lowest distortion, the LT1783 should be operated single supply, with the output always sourcing current and with the input voltage swing between ground and (V^+ – 0.8V). See the Typical Performance Characteristics curves, "Total Harmonic Distortion + Noise vs Output Voltage Amplitude."

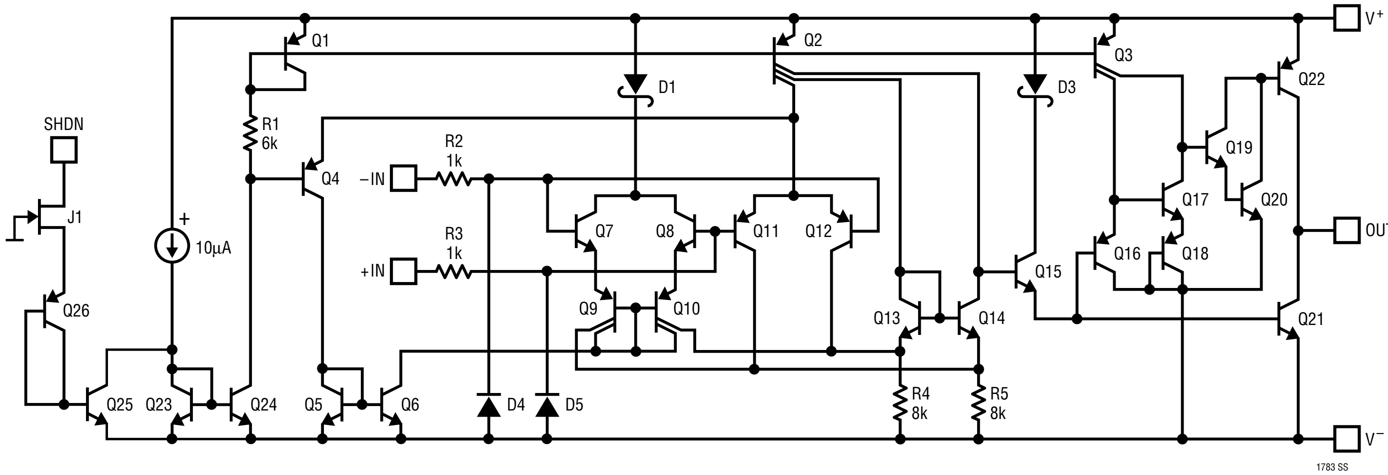
Gain

The open-loop gain is almost independent of load when the output is sourcing current. This optimizes performance in single supply applications where the load is returned to ground. The typical performance curve of open-loop gain for various loads shows the details.

Shutdown

The 6-lead part includes a shutdown feature that disables the part, reducing quiescent current and making the output high impedance. The part can be shut down by bringing the SHDN pin 1.2V or more above V^-. When shut down, the supply current is about 5μA and the output leakage current is less than 1μA ($V^- \le V_{OUT} \le V^+$). In normal operation, the SHDN pin can be tied to V^- or left floating. See the Typical Performance Characteristics curves, "Supply Current vs Shutdown Voltage."

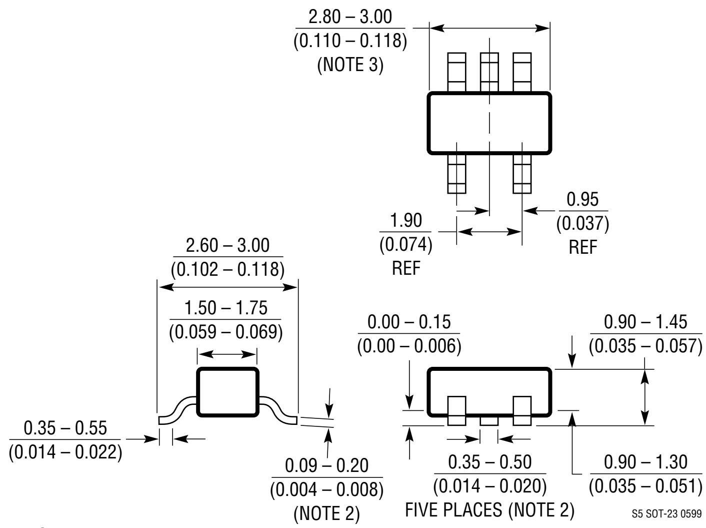
SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

S5 Package
5-Lead Plastic SOT-23
(LTC DWG # 05-08-1633)

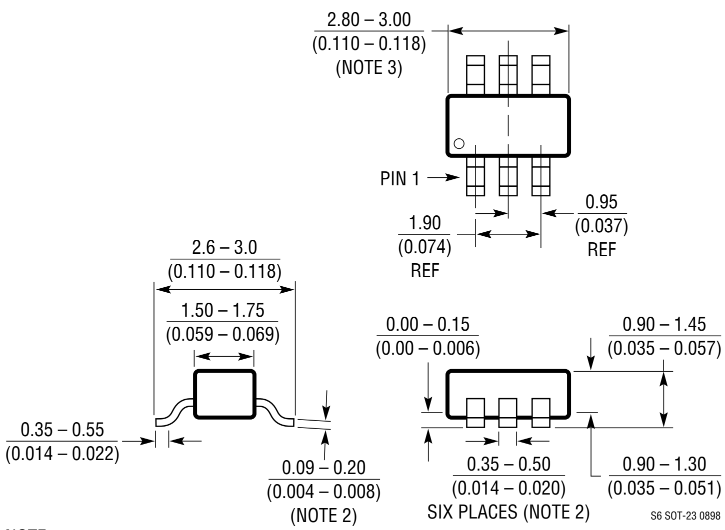


NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DIMENSIONS ARE INCLUSIVE OF PLATING
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
4. MOLD FLASH SHALL NOT EXCEED 0.254mm
5. PACKAGE EIAJ REFERENCE IS SC-74A (EIAJ)

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

S6 Package
6-Lead Plastic SOT-23
(LTC DWG # 05-08-1634)



NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DIMENSIONS ARE INCLUSIVE OF PLATING
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
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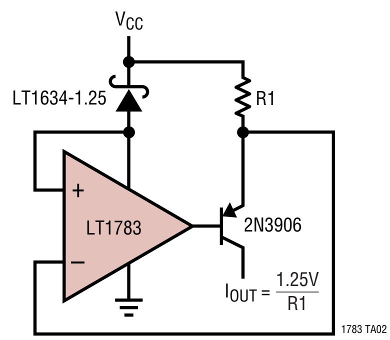
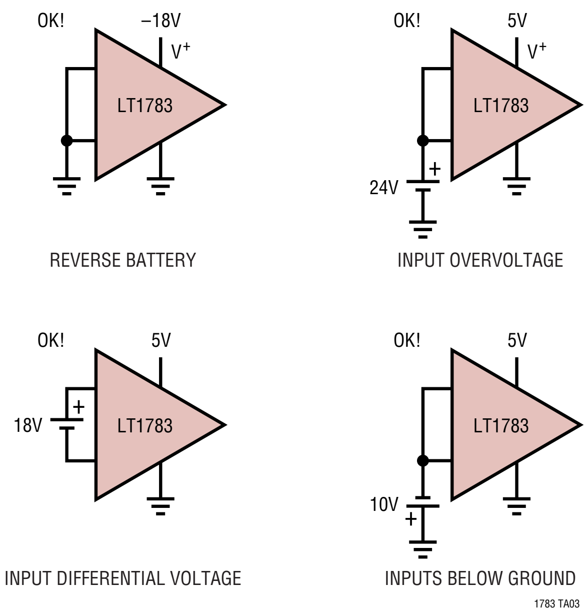
TYPICAL APPLICATIONS

Current Source



Protected Fault Conditions



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1782	Micropower, Over-The-Top SOT-23 Rail-to-Rail Input and Output Op Amp	SOT-23 Package, Micropower 40µA per Amplifier, Rail-to-Rail Input and Output , 200kHz GBW
LT1490/LT1491	Dual/Quad Over-The-Top Micropower Rail-to-Rail Input and Output Op Amps	Single Supply Input Range: –0.4V to 44V, Micropower 50µA per Amplifier, Rail-to-Rail Input and Output , 200kHz GBW
LT1636	Single Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp	55µA Supply Current, V_{CM} Extends 44V Above V_{EE}, Independent of V_{CC}, MSOP Package, Shutdown Function
LT1638/LT1639	Dual/Quad, 1.2MHz, 0.4V/µs, Over-The-Top Micropower Rail-to-Rail Input and Output Op Amps	170µA Supply Current, Single Supply Input Range: –0.4V to 44V, Rail-to-Rail Input and Output