



# Gain of 2 Fully Differential Input/Output Amplifier/Driver

July 2003

## FEATURES

- Differential Inputs
- Differential Outputs
- Fixed Gain of  $2 \pm 0.3\%$  (Max) Gain Error from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$
- $C_{\text{LOAD}}$  Stable from 0 to 10,000pF
- Adjustable Output Common Mode Voltage
- Output Common Mode Level Independent of Input Common Mode Level
- Low Supply Current 1mA(Max)
- High Output Current 10mA (Min)
- Rail-to-Rail Output Swing
- Specified on a Single 2.7V to  $\pm 5\text{V}$  Supply
- DC Offset Voltage  $< 2.5\text{mV}$  (Max)
- 8-Lead MSOP Package

## APPLICATIONS

- Differential Driver/Receiver
- Differential Amplification
- Single-Ended to Differential Conversion
- Level Shifting

## DESCRIPTION

The LTC<sup>®</sup>1992-2 is a fully differential amplifier with a fixed gain of 2. The LTC1992-2 has a separate internal common mode feedback path for better common mode noise rejection, outstanding output gain and phase balancing and reduced second order harmonics. The  $V_{\text{OCM}}$  pin sets the output common mode level independent of the input common mode level. This feature makes level shifting of signals easy. The integrated precision gain setting resistors ensure high gain accuracy without external components.

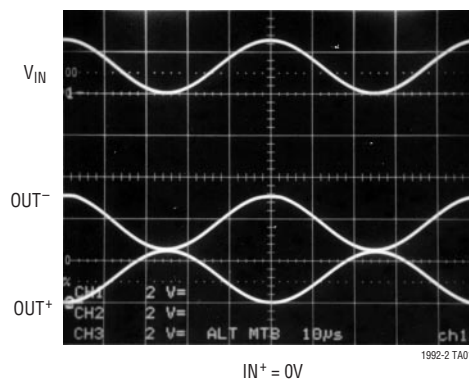
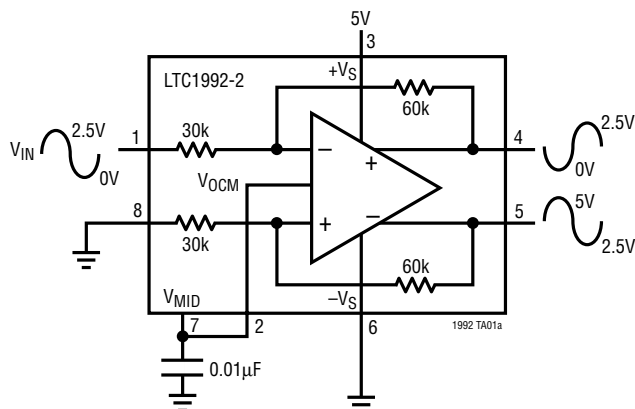
The differential inputs operate with signals ranging from rail-to-rail with a common mode level from the negative supply up to 1.3V from the positive supply. The differential input DC offset is typically  $250\mu\text{V}$ . The rail-to-rail outputs sink and source 10mA. The LTC1992-2 is stable for all capacitive loads up to 10,000pF.

The LTC1992-2 can be used in single-supply applications with supply voltages as low as 2.7V. It can also be used with dual supplies up to  $\pm 5\text{V}$ . The LTC1992-2 is available in an 8-pin MSOP package.

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## TYPICAL APPLICATION

Single-Supply Single-Ended to Differential Conversion



## ABSOLUTE MAXIMUM RATINGS

(Note 1)

Total Supply Voltage (+V <sub>S</sub> to -V <sub>S</sub> ) .....	12V
Maximum Voltage on any Pin .....	$(-V_S - 0.3V) \leq V_{PIN} \leq (+V_S + 0.3V)$
Output Short-Circuit Duration (Note 3) .....	Indefinite
Operating Temperature Range (Note 5)	
LTC1992-2CMS8 .....	-40°C to 85°C
LTC1992-2IMS8 .....	-40°C to 85°C
LTC1992-2HMS8 .....	-40°C to 125°C
Specified Temperature Range (Note 6)	
LTC1992-2CMS8 .....	-40°C to 85°C
LTC1992-2IMS8 .....	-40°C to 85°C
LTC1992-2HMS8 .....	-40°C to 125°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 sec) .....	300°C

## PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
	LTC1992-2CMS8 LTC1992-2IMS8 LTC1992-2HMS8
	MS8 PART MARKING
	LTYV LTZD LTAGA

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T<sub>A</sub> = 25°C. +V<sub>S</sub> = 5V, -V<sub>S</sub> = 0V, V<sub>INCM</sub> = V<sub>OUTCM</sub> = V<sub>OCM</sub> = 2.5V, unless otherwise noted. V<sub>OCM</sub> is the voltage on the V<sub>OCM</sub> pin. V<sub>OUTCM</sub> is defined as (V<sub>+OUT</sub> + V<sub>-OUT</sub>)/2. V<sub>INCM</sub> is defined as (V<sub>+IN</sub> + V<sub>-IN</sub>)/2. V<sub>INDIFF</sub> is defined as (V<sub>+IN</sub> - V<sub>-IN</sub>). V<sub>OUTDIFF</sub> is defined as (V<sub>+OUT</sub> - V<sub>-OUT</sub>). Typical values are at T<sub>A</sub> = 25°C.

SYMBOL	PARAMETER	CONDITIONS	LTC1992-2CMS8 LTC1992-2IMS8			LTC1992-2HMS8			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
G <sub>DIFF</sub>	Differential Gain		●	2			2		% ppm ppm/°C	
	Differential Gain Error		●	±0.1	±0.3	±0.1	±0.35			
	Differential Gain Nonlinearity		●	50		50				
	Differential Gain Temperature Coefficient		●	35		35				
V <sub>OSDIFF</sub>	Differential Offset Voltage (Amplifier Input Referred)(Note 7)	V <sub>S</sub> = 2.7V	●	±0.25	±2.5	±0.25	±4	mV		
		V <sub>S</sub> = 5V	●	±0.25	±2.5	±0.25	±4	mV		
		V <sub>S</sub> = ±5V	●	±0.25	±2.5	±0.25	±4	mV		
ΔV <sub>OSDIFF</sub> /ΔT	Differential Offset Voltage Drift (Amplifier Input Referred)(Note 7)	V <sub>S</sub> = 2.7V	●	10		10		μV/°C		
		V <sub>S</sub> = 5V	●	10		10		μV/°C		
		V <sub>S</sub> = ±5V	●	10		10		μV/°C		
e <sub>n</sub>	Input Referred Noise Voltage Density	f = 1kHz		45		45		nV/√Hz		
R <sub>IN</sub>	Input Resistance, Single-Ended +IN, -IN Pins		●	22.5	30	37.5	22	30	38	kΩ
V <sub>INCMR</sub>	Input Signal Common Mode Range	V <sub>S</sub> = 5V		-0.1V to 4.3V			-0.1V to 4.3V			V
CMRR	Common Mode Rejection Ratio (Amplifier Input Referred)(Note 7)	V <sub>INCM</sub> = -0.1V to 3.7V	●	55	60		55	60		dB
PSRR	Power Supply Rejection Ratio (Amplifier Input Referred)(Note 7)	V <sub>S</sub> = 2.7V to ±5V	●	75	80		72	80		dB
G <sub>CM</sub>	Common Mode Gain(V <sub>OUTCM</sub> /V <sub>OCM</sub> ) Common Mode Gain Error Output Balance Error(ΔV <sub>OUTCM</sub> /V <sub>OUTDIFF</sub> )	V <sub>OUTDIFF</sub> = -2V to +2V	●	1		1				% dB
			●	±0.1	±0.3	±0.1	±0.35			
V <sub>OSCM</sub>	Common Mode Offset Voltage (V <sub>OUTCM</sub> - V <sub>OCM</sub> )	V <sub>S</sub> = 2.7V	●	±0.5	±12	±0.5	±15	mV		
		V <sub>S</sub> = 5V	●	±1	±15	±1	±17	mV		
		V <sub>S</sub> = ±5V	●	±2	±18	±2	±20	mV		
ΔV <sub>OSCM</sub> /ΔT	Common Mode Offset Voltage Drift	V <sub>S</sub> = 2.7V	●	10		10		μV/°C		
		V <sub>S</sub> = 5V	●	10		10		μV/°C		
		V <sub>S</sub> = ±5V	●	10		10		μV/°C		

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**ELECTRICAL CHARACTERISTICS** The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $+V_S = 5\text{V}$ ,  $-V_S = 0\text{V}$ ,  $V_{\text{INCM}} = V_{\text{OUTCM}} = V_{\text{OCM}} = 2.5\text{V}$ , unless otherwise noted.  $V_{\text{OCM}}$  is the voltage on the  $V_{\text{OCM}}$  pin.  $V_{\text{OUTCM}}$  is defined as  $(V_{+\text{OUT}} + V_{-\text{OUT}})/2$ .  $V_{\text{INCM}}$  is defined as  $(V_{+\text{IN}} + V_{-\text{IN}})/2$ .  $V_{\text{INDIFF}}$  is defined as  $(V_{+\text{IN}} - V_{-\text{IN}})$ .  $V_{\text{OUTDIFF}}$  is defined as  $(V_{+\text{OUT}} - V_{-\text{OUT}})$ . Typical values are at  $T_A = 25^\circ\text{C}$ .

SYMBOL	PARAMETER	CONDITIONS	LTC1992-2CMS8 LTC1992-2IMS8			LTC1992-2HMS8			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{\text{OUTCMR}}$	Output Signal Common Mode Range (Voltage Range for the $V_{\text{OCM}}$ Pin)		●	$(-V_S) + 0.5\text{V}$	$(+V_S) - 1.3\text{V}$	$(-V_S) + 0.5\text{V}$	$(+V_S) - 1.3\text{V}$		V	
$R_{\text{INVOCM}}$	Input Resistance, $V_{\text{OCM}}$ Pin			500			500		M $\Omega$	
$I_{\text{BVOCM}}$	Input Bias Current, $V_{\text{OCM}}$ Pin	$V_S = 2.7\text{V}$ to $\pm 5\text{V}$		2			2		$\mu\text{A}$	
$V_{\text{MID}}$	Voltage at the $V_{\text{MID}}$ Pin		●	2.44	2.50	2.56	2.43	2.50	2.57	V
$V_{\text{OUT}}$	Output Voltage, High (Note 2)	$V_S = 2.7\text{V}$ , Load = 10k	●	2.60	2.69		2.60	2.69		V
		$V_S = 2.7\text{V}$ , Load = 5mA	●	2.50	2.61		2.50	2.61		V
		$V_S = 2.7\text{V}$ , Load = 10mA	●	2.29	2.52		2.29	2.52		V
	Output Voltage, Low (Note 2)	$V_S = 2.7\text{V}$ , Load = 10k	●		0.02	0.10		0.02	0.10	V
		$V_S = 2.7\text{V}$ , Load = 5mA	●		0.10	0.25		0.10	0.25	V
		$V_S = 2.7\text{V}$ , Load = 10mA	●		0.20	0.35		0.20	0.41	V
	Output Voltage, High (Note 2)	$V_S = 5\text{V}$ , Load = 10k	●	4.90	4.99		4.90	4.99		V
		$V_S = 5\text{V}$ , Load = 5mA	●	4.85	4.90		4.80	4.90		V
		$V_S = 5\text{V}$ , Load = 10mA	●	4.75	4.81		4.70	4.81		V
	Output Voltage, Low (Note 2)	$V_S = 5\text{V}$ , Load = 10k	●		0.02	0.10		0.02	0.10	V
		$V_S = 5\text{V}$ , Load = 5mA	●		0.10	0.25		0.10	0.30	V
		$V_S = 5\text{V}$ , Load = 10mA	●		0.20	0.35		0.20	0.42	V
	Output Voltage, High (Note 2)	$V_S = \pm 5\text{V}$ , Load = 10k	●	4.90	4.99		4.85	4.99		V
		$V_S = \pm 5\text{V}$ , Load = 5mA	●	4.85	4.89		4.80	4.89		V
		$V_S = \pm 5\text{V}$ , Load = 10mA	●	4.65	4.80		4.60	4.80		V
	Output Voltage, Low (Note 2)	$V_S = \pm 5\text{V}$ , Load = 10k	●		-4.98	-4.90		4.98	-4.85	V
		$V_S = \pm 5\text{V}$ , Load = 5mA	●		-4.90	-4.75		4.90	-4.75	V
		$V_S = \pm 5\text{V}$ , Load = 10mA	●		-4.80	-4.65		4.80	-4.55	V
$I_{\text{SC}}$	Output Short-Circuit Current Sourcing (Notes 2,3)	$V_S = 2.7\text{V}$ , $V_{\text{OUT}} = 1.35\text{V}$	●	20	30		20	30		mA
		$V_S = 5\text{V}$ , $V_{\text{OUT}} = 2.5\text{V}$	●	20	30		20	30		mA
		$V_S = \pm 5\text{V}$ , $V_{\text{OUT}} = 0\text{V}$	●	20	30		20	30		mA
	Output Short-Circuit Current Sinking (Notes 2,3)	$V_S = 2.7\text{V}$ , $V_{\text{OUT}} = 1.35\text{V}$	●	13	30		13	30		mA
		$V_S = 5\text{V}$ , $V_{\text{OUT}} = 2.5\text{V}$	●	13	30		13	30		mA
		$V_S = \pm 5\text{V}$ , $V_{\text{OUT}} = 0\text{V}$	●	13	30		13	30		mA
SR	Slew Rate (Note 4)		●	0.35	1.0		0.35	1.0	V/ $\mu\text{s}$	
GBW	Gain-Bandwidth Product	$f_{\text{TEST}} = 180\text{kHz}$			4			4	MHz	
$V_S$	Supply Voltage Range		●	2.7		11	2.7		11	V
$I_S$	Supply Current	$V_S = 2.7\text{V}$ to $5\text{V}$	●		0.65	1.0		0.65	1	mA
			●		0.75	1.2		0.8	1.5	mA
		$V_S = \pm 5\text{V}$	●		0.70	1.2		0.7	1.2	mA
			●		0.80	1.5		0.9	1.8	mA

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

**Note 2:** Output load is connected to the midpoint of the  $+V_S$  and  $-V_S$  potentials. Measurement is taken single-ended, one output loaded at a time.

**Note 3:** A heat sink may be required to keep the junction temperature below the absolute maximum when the output is shorted indefinitely.

**Note 4:** Slew Rate is measured single-ended. The numbers listed are also single-ended and the differential slew rate would double the listed numbers.

**Note 5:** The LTC1992-2CMS8, LTC1992-2IMS8 and LTC1992-2HMS8 are guaranteed functional over the extended operating temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**Note 6:** The LTC1992-2CMS8 is guaranteed to meet the specified performance limits over the  $0^\circ\text{C}$  to  $70^\circ\text{C}$  temperature range and designed, characterized and expected to meet the specified performance from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  but is not tested or QA sampled at these temperatures. LTC1992-2IMS8 is guaranteed to meet specified performance limits over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  temperature range. The LTC1992-2HMS8 is guaranteed to meet the specified performance limits over the  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  temperature range.

**Note 7:** Differential Offset Voltage, Differential Offset Voltage Drift, CMRR and PSRR are referred to the internal amplifier's input to allow for direct comparison with discrete amplifiers. The LTC1992-2 is an inverting topology with a gain of two. The output referred offset is three times the amplifiers input offset.

## PIN FUNCTIONS

**-IN, +IN (Pins 1,8):** Inverting and Noninverting Inputs of the Amplifier. These pins are connected to on-chip gain setting resistors. The input resistors are nominally 30k.

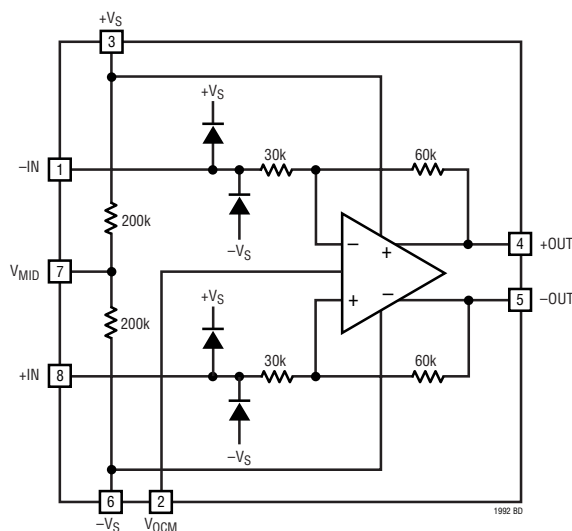
**V<sub>OCM</sub> (Pin 2):** Output Common Mode Voltage Set Pin. The voltage on this pin sets the output signal's common mode voltage level. The output common mode level is set independent of the input common mode level. This is a high impedance input and must be connected to a known and controlled voltage. It must never be left floating.

**+V<sub>S</sub>, -V<sub>S</sub> (Pins 3, 6):** The +V<sub>S</sub> and -V<sub>S</sub> power supply pins should be bypassed with 0.1μF capacitors to an adequate analog ground or ground plane. The bypass capacitors should be located as closely as possible to the supply pins.

**+OUT, -OUT (Pins 4,5):** The Positive and Negative Outputs of the Amplifier. These rail-to-rail outputs are designed to drive capacitive loads up to 10,000 pF.

**V<sub>MID</sub> (Pin 7):** Mid-Supply Reference. This pin is connected to an on-chip resistive voltage divider (two 200k ±25% resistors) to provide a mid-supply reference. This provides a convenient way to set the output common mode voltage level at half-supply. If used for this purpose, the pin should be bypassed with a 0.1μF capacitor to ground and connected to V<sub>OCM</sub> (Pin 2). If this reference voltage is not used, leave the pin floating.

## BLOCK DIAGRAM



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1565-31	650kHz Continuous Time, Linear Phase Lowpass Filter	7th Order Lowpass Filter, Differential Inputs/Output
LTC1566-1	Low Noise 2.3MHz Continuous Time Lowpass Filter	7th Order Lowpass Filter, Differential Inputs/Output
LT1567	1.4nV/√Hz, 175MHz Op Amp and Inverter/Filter Building Block	2nd Order Filter with up to 5MHz Cutoff, Single-Ended to Differential Conversion
LT6600-2.5	Very Low Noise, Differential Amplifier and 2.5MHz Lowpass Filter	Fully Differential Amplifier with 4th Order Lowpass Filter
LT6600-10	Very Low Noise, Differential Amplifier and 10MHz Lowpass Filter	Fully Differential Amplifier with 4th Order Lowpass Filter
LT6600-20	Very Low Noise, Differential Amplifier and 20MHz Lowpass Filter	Fully Differential Amplifier with 4th Order Lowpass Filter

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