

LB-20

LB-20 A Fully Differential Input Voltage Amplifier



Literature Number: SNOA689

A Fully Differential Input Voltage Amplifier

National Semiconductor
Linear Brief 20
December 1972



INTRODUCTION

The instrumentation amplifier is useful for amplifying small differential signals which may be riding on high common mode voltage levels. These amplifiers are particularly useful in amplifying signals in the milli-volt range which are supplied from a high impedance source ($> 2 \text{ k}\Omega$).

This brief will demonstrate how a low cost, high performance instrumentation amplifier can be built using the newly introduced LM3900 quad amplifier. It is also indicated how a compact transducer bridge amplifier system can be developed to take advantage of the versatility of the LM3900.

BASIC AMPLIFIER OPERATION

Figure 1 shows the basic operation of the amplifier. The bias of the LM3900 is set by the resistors R_2 and R_3 (neglecting for now, the transistors Q_1 and Q_2). Current which enters the non-inverting input of the LM3900 will be "mirrored" about V^- and then will be drawn into the inverting input terminal. This causes the current to flow through the feedback resistor, R_3 , which establishes the output voltage level. If $R_2 = R_3$ and further, if R_2 is connected to ground (0V), then the output voltage biasing level will also be exactly zero volts. It should be noticed that an *OUTPUT OFFSET CONTROL* can be implemented by supplying a reference voltage, E_R , between R_2 and ground.

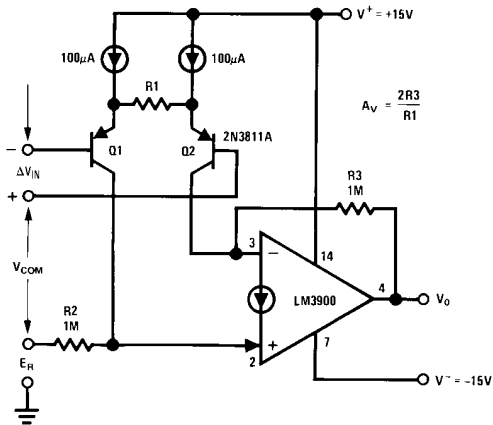


FIGURE 1. Basic Instrumentation Amplifier

Adding transistors Q_1 and Q_2 , as shown in Figure 1 will not disturb this biasing if the two collector currents of the transistors are well matched for a 0V differential input signal. The current sources which bias Q_1 and Q_2 , are chosen to be $100 \mu\text{A}$ each to guarantee high β and low offset voltage in Q_1 and Q_2 .

The gain of the amplifier is calculated as follows:

Any differential input voltage, ΔV_{IN} , appears across R_1 , and produces a current change ΔI , which is given by:

$$\Delta I = \frac{\Delta V_{IN}}{R_1} \quad (1)$$

This current change will show up in the collectors of Q_1 and Q_2 with opposite polarity. The input mirror of the LM3900 returns ΔI_{Q1} to the inverting input terminal where it is added (with sign) to ΔI_{Q2} yielding a total current change of $2\Delta I$. This current flows through the feedback resistor, R_3 , which causes an output voltage change, ΔV_o , which is given by:

$$\Delta V_o = 2\Delta I \times R_3 = 2 \times \frac{\Delta V_{IN}}{R_1} \times R_3 \quad (2)$$

to yield a gain,

$$A_v = 2 \frac{R_3}{R_1} \quad (3)$$

At this point it is convenient to evaluate the result obtained. The gain can be established by one resistor (R_1) according to equation (3). Conventional instrumentation amplifiers usually have a gain given by:

$$A_v = 1 + \frac{\text{Constant}}{R} \quad (4)$$

This means that the minimum gain of unity is obtained if R is left out ($R = \infty$). Note that this is different from the result indicated in equation (3) where unity gain is obtained for

$$R_1 = 2R_3 \quad (5)$$

and minimum gain (or maximum attenuation) is obtained if R_1 is left out ($R_1 = \infty$). This suggests that the amplifier can be turned OFF without disturbing the output voltage dc bias.

The two current sources for Q_1 and Q_2 are implemented with a dual transistor (Q_3 and Q_4) in conjunction with an additional amplifier of the LM3900 as shown in Figure 2. The operation can be easily understood if R_4 and R_5 are incorporated within the amplifier, which then takes the form of a conventional opamp closed loop regulator which maintains a reference voltage (the drop across R_6) at the emitter of Q_4 .

PERFORMANCE

The performance of the complete instrumentation amplifier of Figure 2 is outlined below (Table I and Figure 3).

TABLE I. Typical Performance Characteristics

GAIN	
Range of gain	-34 dB ($R_1 = \infty$) to 72 dB ($R_1 = 0$)
Gain is set according to:	$A_v = \frac{2R_3}{R_1}$
INPUT	
Voltage offset referred to input is adjustable to zero.	Pos supply less 2.4V
Common-mode and differential input voltage	Neg supply less 300 mV
Common-mode rejection ratio at 10 Hz	115dB (gain of 1000)
Bias current (either input)	200 nA
OUTPUT	
Output offset is adjustable to zero.	12 mV _{rms} (open loop)
Output noise	3 mV _{rms} ($A_{CL} = 66 \text{ dB}$)
FREQUENCY RESPONSE	
Small signal frequency response (-3 dB)	1 MHz (gain of 1000) 3 MHz (gain of 1)

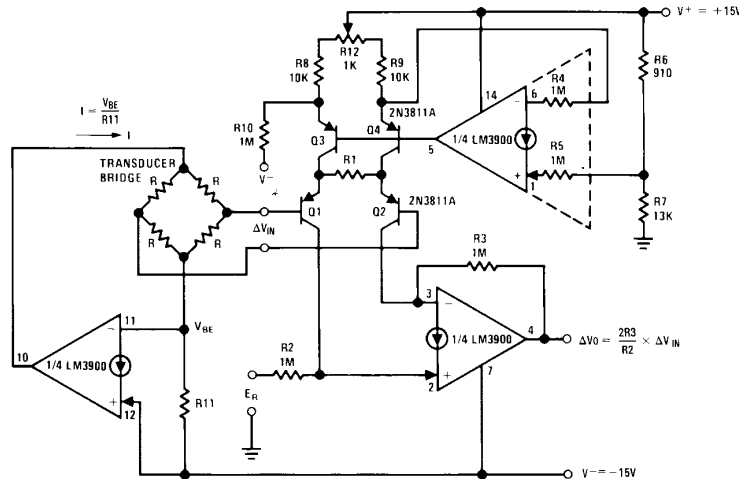


FIGURE 2. Bridge Amplifier

TL/H/8468-2

Since quantitative discussion of the sources of offset voltage is beyond the scope of this brief, only the procedure for nulling the amplifier will be included.

Letting R_1 go to zero causes the amplifier to operate in the open-loop mode. The main offset voltage source is now the V_{BE} mismatch of Q_1 and Q_2 . The output can be nulled by the *OUTPUT OFFSET CONTROL* (the reference voltage for R_2) or by adjusting the value of R_2 . With $R_1 = \infty$, the main offset voltage source is the mismatch in the collector currents of Q_3 and Q_4 . This is easily adjusted via R_{12} . These first and second adjustments interact, however, after repeating the procedure a couple of times a good result is obtained.

TRANSDUCER BIAS SOURCE

Having in mind that the LM3900 consists of four independent amplifiers makes it relatively easy to bias a transducer bridge with a constant current source using only one more of the amplifiers and one resistor. The technique is self-explanatory and is also shown in *Figure 2*.

CONCLUSION

A brief review of a new concept for an instrumentation amplifier has been presented. Many applications can be de-

rived from this basic connection which require amplifying the low level differential signals which are obtained from sensors such as strain gages, pressure transducers, and thermocouples. The performance of this instrumentation amplifier is adequate for many system applications. (See National Semiconductor Application Note 72, "The LM3900 — A New Current-Differencing Quad of \pm Input Amplifiers" for further information.)

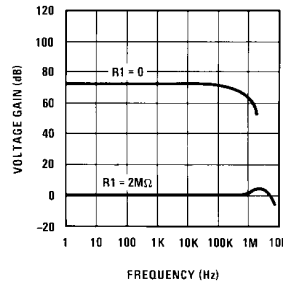



FIGURE 3. Frequency Response

TL/H/8468-3

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

 <p>National Semiconductor Corporation 1111 West Bardin Road Arlington, TX 76017 Tel: (800) 272-9959 Fax: (800) 737-7018</p>	<p>National Semiconductor Europe</p> <p>Fax: (+49) 0-180-530 85 86 Email: cnjwge@tevm2.nsc.com Deutsch Tel: (+49) 0-180-530 85 85 English Tel: (+49) 0-180-532 78 32 Français Tel: (+49) 0-180-532 93 58 Italiano Tel: (+49) 0-180-534 16 80</p>	<p>National Semiconductor Hong Kong Ltd. 13th Floor, Straight Block, Ocean Centre, 5 Canton Rd. Tsimshatsui, Kowloon Hong Kong Tel: (852) 2737-1600 Fax: (852) 2736-9960</p>	<p>National Semiconductor Japan Ltd. Tel: 81-043-299-2309 Fax: 81-043-299-2408</p>
--	---	---	---

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Transportation and Automotive	www.ti.com/automotive
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated