ISSN 1726-5749

SENSORS & TRANSDUCERS

8/09 vol. 6 Special

Modern Sensing Technologies II

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 6, Special Issue
August 2009

www.sensorsportal.com

ISSN 1726-5479

Editors-in-Chief: professor Sergey Y. Yurish, phone: +34 696067716, fax: +34 93 4011989, e-mail: editor@sensorsportal.com

Guest Editors: Subhas Chandra Mukhopadhyay, Gourab Sen Gupta and Ray Yueh Min Huang

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and on CD.

Sensors & Transducers Journal

Contents

Volume 6
Special Issue
August 2009

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

International Frequency Sensor Association (IFSA).

Sensors & Transducers Journal, Vol. 6, Special Issue, August 2009, pp. 92-104

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Sensitivity Enhancement of Wheatstone Bridge Circuit for Resistance Measurement

[1*]Tarikul ISLAM, [1]Shakeb A. KHAN, [2]Sheikh S. ISLAM, [3]HARSH
[1]Deptt. of Electrical Engg., F/O Engg. & Technology, Jamia Millia Islamia (J. M. I University), New Delhi -110025, India
[2]Deptt. of App. Sciences and Humanities, F/O Engg. & Technology, J. M. I. University, New Delhi -110025, India
[3]Solid State Physics Laboratory, Lucknow Road, Teemarpur, Delhi – 110054, India
Tel.: +91-11-26982674
E-mail: tislam.el@jmi.ac.in

Received: 10 July 2009 /Accepted: 31 July 2009 /Published: 10 August 2009

Abstract: Present work deals with the development of a low cost, appreciably accurate and sensitive electronic circuit for resistive sensor. The circuit is based on the modification of the Wheatstone bridge using active devices. It helps measurement of the incremental resistance precisely and linearly. It requires few components for its hardware implementation and found to be suitable in case there is small change in resistance due to change in physical quantity or chemical analytes to be measured. Theory of the proposed bridge circuit has been discussed and experimental results have been compared with conventional full bridge circuit. Experiments have been conducted with metallic strain gauge sensor but it can be utilized to other resistive sensors. Results show that the output of the circuit is almost four times more than usual full Wheatstone bridge circuit. Experimental results show that the errors due to the effects of the ambient temperature and connecting lead resistance are minimized. *Copyright © 2009 IFSA.*

Keywords: Resistive sensor, Wheatstone bridge, Active bridge, Sensitivity enhancement, Temperature effect, Lead resistance

1. Introduction

Resistive sensors are some of the most commonly used sensors in industry because of relatively inexpensive to manufacture and easy to interface with signal conditioning circuits and desktop computer (PC) for online data monitoring. Some of the common physical parameters where resistive sensors find wide application are temperature, strain, pressure, light intensity, fluid flow or mass flow and humidity [1-5]. Commercial metal oxide based Figaro sensors which are used for measuring environment polluting gases also work on resistive technique [5]. For measuring different physical and chemical parameters by resistive sensor, the resistance value can vary from few fraction of ohm to several ohms to several hundred ohms [2, 3, 4]. Normal resistance measurement involves simple bridge circuit excited by DC voltage/current source and few active devices. Measurement of resistance values which change in ohms to several hundred ohms is not much difficult but of small resistance change in presence of several non-ideal effects like ambient temperature, electrical noise and Op-Amp offset voltage may reduces the accuracy of measurement [3-4] significantly. Various techniques have been used over the years to measure the resistance change of the sensor. Measuring resistance indirectly using a simple constant current method requires an accurate current source and an accurate means of measuring the voltage drop across the resistance. Any change in current amplitude or power dissipation in the resistance produces error in the measurement. The error due to self heating should also be considered.

The conventional Wheatstone bridge technique offers an attractive alternative for measuring resistance change of sensor. Fig. 1 shows the four commonly used bridge configurations suitable for strain gauge and RTD sensor applications and the corresponding equations which relate the bridge output voltage to the excitation voltage and the bridge resistance values. In each of the configurations, V_B is the DC excitation voltage, and R is the fixed resistance. The value of the R is chosen to be equal to the nominal value of the sensor resistance which is at initial base line condition. The deviation of the variable resistor(s) about the nominal value is proportional to the quantity being measured, such as strain (in case of a strain gage) or concentration of gas in case of Figaro sensor.

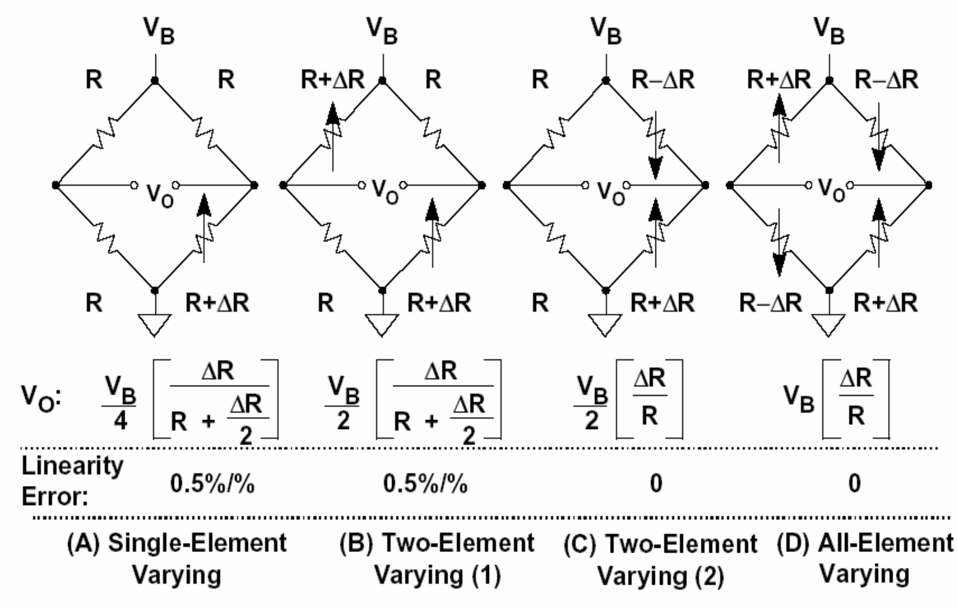

Fig. 1. Different bridge configurations used in practice. The output voltage of each configuration is also shown in the figure.

Among the four different configurations shown in Fig. 1, the all-element varying full bridge configuration as shown in Fig. 1(d) produces the maximum change in voltage output for a given resistance change. The circuit output is directly proportional to the change in resistance. Apart from linear output it has other advantage like, minimization of error due to self heating of resistive element and the noise signals [7]. Because of these features, it is an industry-standard configuration for measurement of force in load cells which are constructed from four identical strain gauges. Major problem encountered in the bridge circuit is lower voltage output due to very small change in resistance and large dc excitation voltage for sufficient full-scale output. The large dc excitation may results in power dissipation and the possibility of error due to sensor self heating. On the other hand, low value of excitation voltage requires more gain in the conditioning circuits which can increase error due to ambient temperature, non-ideal Op-Amp offset voltage and the sensitivity to noise [3]. This is because, large gain may amplify the errors due to Op-Amp dc offset voltage and noise signal. Also, if the sensor is placed at remote location, the resistance of the connecting lead and its dependence on the ambient temperature introduces significant errors in the accuracy of the measurement [5].

In the recent past authors in [1] proposes an active bridge circuit for direct measurement of in-circuit resistances of equivalent π - networks of arbitrary configuration. This circuit is self-balanced, capable of measuring resistors in a production line. However, the shunt resistances of π - networks appearing between the output of the amplifier and the input must be small enough otherwise it affects the accuracy and start loading the Op-Amp. Also, if the resistance change is only a fraction of ohm, the circuit is less sensitive and if the output signal is amplified, the effect of the offset voltage of the Op-Amp causes significant measurement error. In another work reported in [2], the self-balancing bridge was modified for the direct measurement of incremental resistances of strain gauges and RTD based temperature sensor. It consists of the self-balancing bridge together with an inverting adder to obtain the incremental value ΔR directly in terms of the output voltage. The output of the current to voltage converter under the bridge balance condition is directly proportional to the change in resistance ΔR_X. This bridge circuit eliminates error due to shunt arm resistance of the above active bridge circuit. However, to improve the sensitivity, it requires high excitation voltage or large gain of the amplifier or Op-amp with low offset voltage. Again if the sensor is placed at remote location connecting lead resistance of sensor should be minimized [2, 6].

In the present work, a linear and sensitive active bridge circuit based on the Wheatstone bridge with modification using operational amplifier to increase the sensitivity of the conventional bridge circuit has been proposed [2,8]. It can be useful for measuring incremental resistance change where change in resistive value due to physical quantity is very small. The theory of the proposed electronics has been discussed, experiment has been conducted with metallic strain gauge and the results are compared with conventional bridge circuit. Experimental results to observe the effect of the ambient temperature and connecting lead resistance are also given.

2. Working Principle of the Active Bridge Circuit

Fig. 2 shows the circuit diagram of the proposed measurement scheme. It consists of a Wheatstone bridge modified with active device together with current to voltage converter. All elements varying bridge configuration is used, with four sensor output is connected across the four arms of the bridge circuit. The sensors with positive resistance change (R+ΔR) and negative resistance change (R- ΔR) are placed on the adjacent sides of the bridge, two on the top of the cantilever beam and other two on the bottom of the beam where stress is maximum. In the arm PQ, a buffer is employed to provide isolation from the adjacent arm PS. For ac excitation voltage V_s, the signal at the output of the buffer and the inverting amplifier maintain 180˚ phase opposition over wide frequency. Two out of phase signals promote measurement of ac conductivity of the sensor over large input signal frequency [9]. The output of the inverting amplifier at terminal R is given by

$$V_R = -\left(\frac{V_s}{R_2}\right) \cdot R_3 \tag{1}$$

Application of Kirchhoff's Current Law (KCL) at node Q and substituting V_R from equation 1 with simplifications, the voltage V_1 at the output of the inverting adder is given by [2]

$$V_1 = -\left(\frac{V_s}{R_4}\right) \cdot R_5 \cdot \left(\frac{R_4}{R_1} - \frac{R_3}{R_2}\right) \tag{2}$$

Replacing R_4 by R - ΔR, R_3 by R + ΔR, R_1 by R + ΔR and R_2 by R - ΔR, the equation (2) can be written as

$$V_1 = -\left(\frac{V_s}{R - \Delta R}\right) \cdot R_5 \cdot \left(\frac{R - \Delta R}{R + \Delta R} - \frac{R + \Delta R}{R - \Delta R}\right) \tag{3}$$

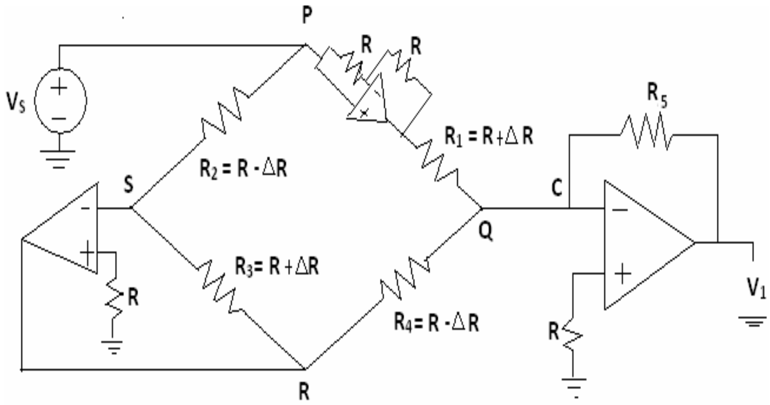

Fig. 2. Proposed active bridge circuit for resistance measurement.

After simplification, equation (3) can be written as

$$V_1 = \left(\frac{V_s}{R - \Delta R}\right) \cdot R_5 \cdot \left(\frac{4\Delta R.R}{R^2 - \Delta R^2}\right), \tag{4}$$

Since, incremental resistance ΔR is a smaller quantity, typically varies 0.1 to 0.5 % over entire range with respect to the nominal value of sensor resistance R [6]. The equation (4) can be simplified as

$$\Delta R^2 \langle\langle R^2 \text{ and } V_1 = \left(\frac{V_s}{R - \Delta R}\right) \cdot R_5 \cdot \frac{4\Delta R}{R}, \tag{5}$$

If the feedback resistance of the inverting adder amplifier is chosen to be equal to the nominal value of the sensor resistance, i.e. $R_5 = R$, then equation (5) can be rewritten as

$$V_1 = V_s \cdot \frac{4\Delta R}{R - \Delta R} \tag{6}$$

Again, ΔR is much smaller than the nominal value of R, with good approximation, expression for output voltage of the bridge gives

$$V_1 = V_s \cdot 4 \cdot \frac{\Delta R}{R}, \tag{7}$$

The equation (7) clearly shows that the sensitivity of the proposed bridge circuit is approximately four times more than the conventional all-element varying bridge circuit of Fig. 1(d).

3. Modified Form of the Bridge Circuit to Analyze the Effect of Lead Resistance of the Sensor

If the four resistive sensors (strain gauges) are located at remote distance from the signal conditioning circuit, the resistance of the connecting leads of the strain gauges may introduce error in the measurement. Normally the connecting wire is made of copper or aluminium. When the working temperature of the sensor is variable, the lead resistance may vary with temperature. Thus accurate measurement system should not only consider the effect of the lead resistance, but its variation with ambient temperature and possible minimization. In the recent work reported in [3], the authors analyze the effect of lead resistance for remotely located RTD temperature sensor and propose signal conditioning utilizing active subtraction to minimize the effect of the lead resistance [3,6]. However, the effect of the Op-Amp offset variation with ambient temperature should be carefully taken care of.
In the present work, further experiments have been conducted to study the effect of the lead resistance. To minimize the error, the active bridge circuit shown in Fig. 2 has been modified. The modified form of the bridge circuit has been shown in Fig. 3. When the bridge is unbalanced, the detector current I_d will change and is directly proportional to the incremental resistance change of the sensor. Since for metallic strain gauge, change in resistance is only 0.1 to 0.5 % of the nominal value, the unbalanced detector current will be very small and if the signal conditioning circuit is remotely located, the lead resistance of the connecting wire will affect the measurement accuracy significantly. The detector current is converted into voltage signal by passing the current through a small value fixed resistance (R_5) connected in series with the detector output terminal as shown in Fig. 3(a). At point Q, the two ends of R_1 and R_4 are connected together and the other two ends of R_1 and R_4 are in differential form. All the connecting wires of four sensors are of identical length and of similar material normally made of copper. Considering ΔR_l is the lead resistance change due to ambient temperature, the equation (2) can be rewritten as

$$V_1 = -\left(\frac{V_s}{R_4 + \Delta R_l}\right) \cdot R_5 \cdot \left(\frac{R_4 + \Delta R_l}{R_1 + \Delta R_l} - \frac{R_3 + \Delta R_l}{R_2 + \Delta R_l}\right), \qquad (8)$$

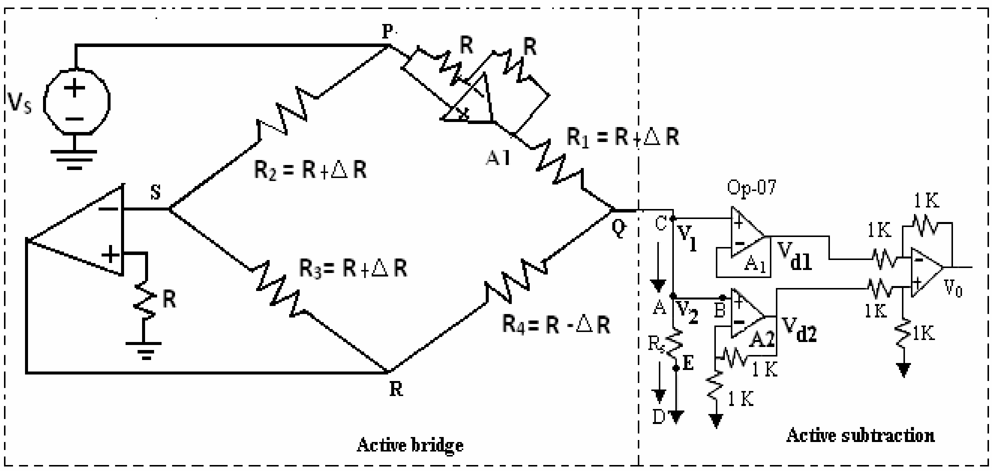

Fig. 3 (a). Active bridge circuit to obtain lead compensated voltage output [2-3].

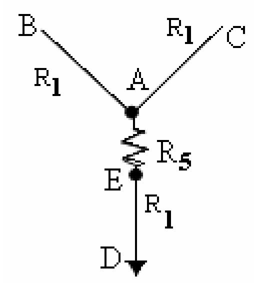

Fig. 3(b). Three wire configuration of the resistance R_5.

The sensors R_1 to R_4 in equation (8) are in ratio-metric and differential form and hence the effect of ambient temperature on the lead resistance will be almost identical and negligible. However, the lead wire of R_4 may introduce error in the measurement which can be eliminated by having modified form of the circuit as shown in Fig. 3. To eliminate the effect of lead resistance, the three-terminal connections of the resistance (R_5) as shown in Fig. 3(b) are used. In Fig. 3(b), R_5 is the fixed small value resistance, R_l is the lead resistance of each lead wire. All the three lead wires have the identical length. The points C and Q are tied together. The unbalanced detector current passes through the leads C and D. The point D is connected to the ground point of the measuring circuit. The terminal C is also connected to the non-inverting input of the voltage follower circuit. The voltage drop $V_1 = \Delta I_d$ (R_5 +2 R_l) and the output of the voltage follower circuit is [3]

$$V_{d1} = V_1 = \Delta I_d\left(R_s + 2R_l\right), \tag{9}$$

where ΔI_d is the change in detector current due to change in sensor resistance. The lead B is connected to the input of the non-inverting amplifier whose gain has been set to 2. Since the terminal B is connected to non-inverting terminal of the Op-amp, the voltage drop at A and B is identical. The output of non-inverting amplifier can be given as

$$V_{d2} = 2.\Delta I_d\left(R_s + R_l\right). \tag{10}$$

The outputs V_{d1} and V_{d2} are applied to the inputs of the active subtractor circuit with gain unity and thus the output of the subtractor can be given as

$$V_0 = V_{d2} - V_{d1} = \Delta I_d . R_s \tag{11}$$

The output voltage V_0 is directly proportional to the change in detector current which is proportional to the change in resistance of sensors only. The expression of equation (11) does not have any term of lead resistance R_l. Thus the circuit can minimize the error due to the variation of lead resistance with ambient temperature.

4. Testing of the Proposed Signal Conditioning Circuit

4.1. Experiments with the Conventional Full Wheatstone Bridge Circuit

The experiments have been conducted on metallic strain gauges of nominal resistance 120 Ω. The schematic diagram of the set up is shown in Fig. 4. It consists of a cantilever beam fixed on a rigid support. Two strain gauges with resistances R_1 and R_3 are placed on the top of the cantilever plate and another two R_2 and R_4 are placed on the bottom of plate. On application of loads, the values of the R_1 and R_3 are increased while R_2 and R_4 are decreased. The four strain gauges form the four arms of the Wheatstone bridge. The resistance for the metallic strain gauge when force is applied can vary from 0.1 to 0.5 % of its nominal value.

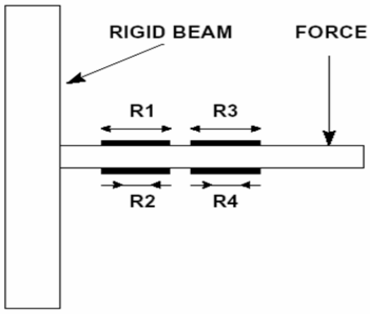

Fig. 4. Schematic diagram of the cantilever beam with four identical strain gauge sensors (R_1 and R_3 have positive resistance change while R_2 and R_4 have negative resistance change).

The conventional full bridge circuit used for comparing the results of the active bridge circuit is shown in Fig. 5. The bridge circuit was hardware implemented on a bread board. Three matched FET input Op-Amps (OP-07) which have very small offset voltage and noise along with metal film resistances have been used [10]. The different resistance values used for the circuit were matched with a digital multimeter (Keithley Model 2000). The dc excitation voltage to the bridge circuit is taken from precision voltage regulator (REF01).

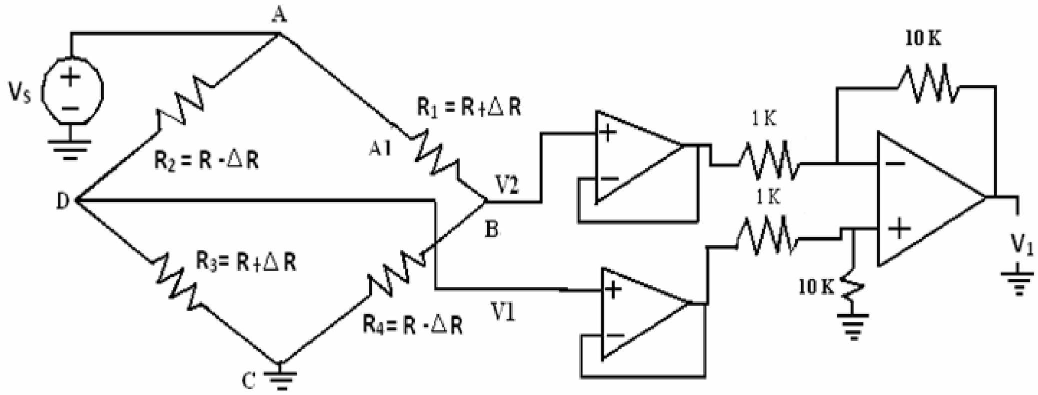

Fig. 5. Conventional full bridge circuit used in experiments.

In Fig. 5, the voltage V_1 at point D is given as

$$V_1 = V_s \times \frac{R+\Delta R}{R-\Delta R+R+\Delta R} = V_s \cdot \left(\frac{R+\Delta R}{2R}\right), \tag{12}$$

and at B

$$V_2 = V_s \times \cdot \left(\frac{R-\Delta R}{R+\Delta R+R-\Delta R}\right) = V_s \times \frac{R-\Delta R}{2R}. \tag{13}$$

On applying both the voltages V_1 and V_2 into subtractor circuit, output voltage V_{01} is given as

$$V_{01} = V_1 - V_2 = V_s.\left(\frac{\Delta R}{R}\right), \tag{14}$$

The gain inverting amplifier is set to 10, so the output voltage of the circuit comes out to be

$$V_{01} = 10.Vs.\left(\frac{\Delta R}{R}\right), \tag{15}$$

The variation of the output voltage with loads is shown in Fig. 6. Here the output voltage has been noted both for increase and decrease in loads applied on the beam and average values of the voltages are shown in the figure. The response of the strain gauge sensor is linear with application of the loads. The initial offset voltage at no load condition is very high due to mismatch of the four strain gauges. The sensitivity of the signal conditioning circuit defined as the percentage change in output voltage of the circuit to the full scale applied loads is 0.6 %. To observe the effect of excitation voltage experiments have been conducted with the variation of excitation voltage. The results of output voltage variation with change in the excitation are shown in Fig. 7. It is observed that for a fixed applied load, the sensor output is varied linearly with the excitation voltage [11].

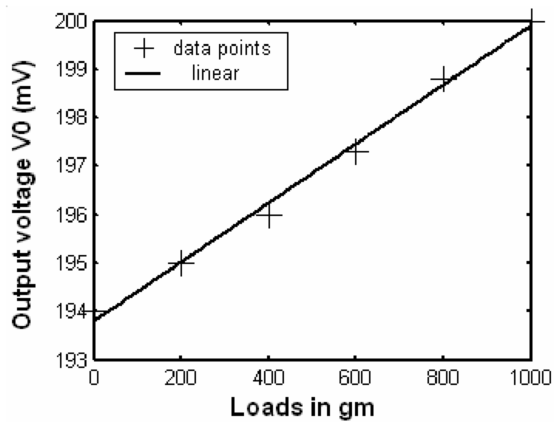

Fig. 6. Output of the conventional bridge circuit with the variation of loads in gms (V_i = 1.01 V).

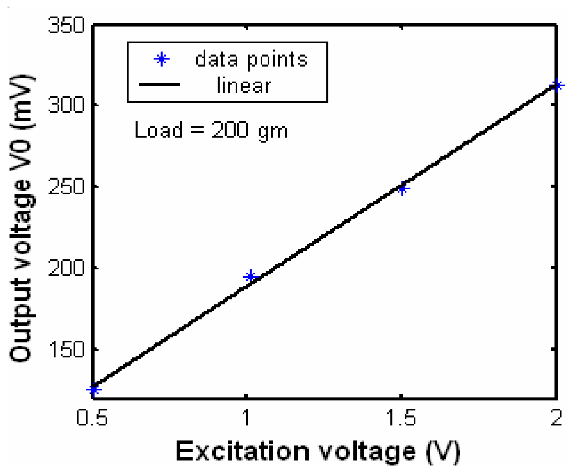

Fig. 7. Output voltage variation with the variation of excitation voltage.

4.2. Active Bridge Circuit

Experiments were conducted with the help of same experimental setup using active bridge circuit shown in Fig. 2. The bridge circuit has been hardware implemented using an instrumentation type Op-Amp like TLC-271. The TLC271 provides extremely high input impedance of the order of TΩ and very low offset voltage [11]. The output voltage of the active subtractor was amplified by ten times as in case of Fig. 3. Fig. 8 shows the photograph of the complete experimental setup. The experimental results with the variation of applied loads in the range of 0 to 1000 gms are shown in Fig. 9. The sensitivity of the active bridge circuit is 2.1. The output of the active bridge circuit is almost 4 times more than that of the conventional bridge circuit. The experimental results verify the theoretical value predicted in equation (7). The response of the active bridge circuit with the variation of loads at different excitation voltages is shown in Fig. 10. For a small change in excitation voltage, the output of the conditioning circuit is also changed appreciably.

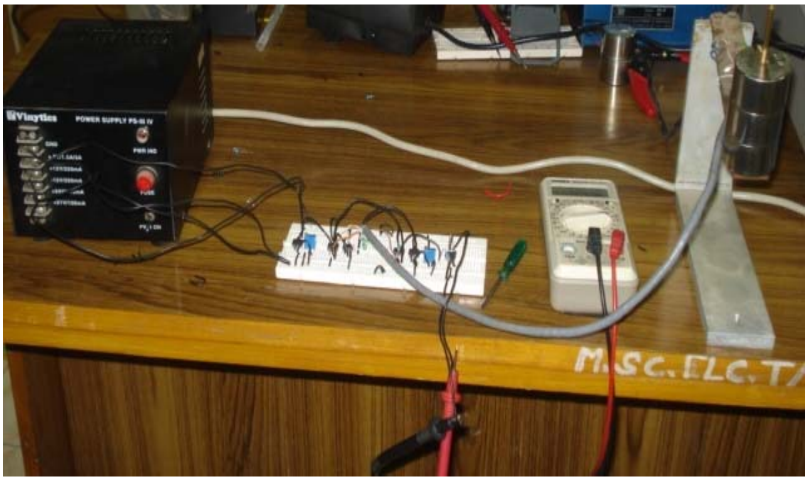

Fig. 8. Photograph of the measurement setup**.**

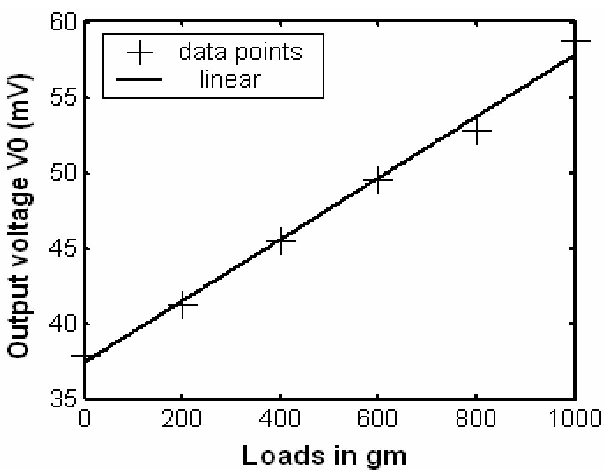

Fig. 9. Output of the active bridge circuit with the variation of loads (V_i = 1.0V, T = 30˚C).

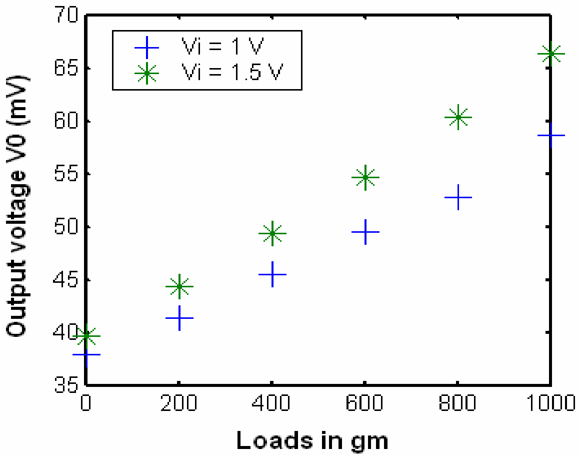

Fig. 10. Response of the active bridge circuit with the variation of loads at different excitation voltages.

4.3. Modified Active Bridge Circuit for Lead Resistance Minimization

To study the effect of the lead resistance of the sensor, the experiments have been conducted with the modified form of the bridge circuit shown in Fig. 3 (a). The circuit was hardware realized on the breadboard. The connecting leads between the outputs of Op-Amps in the bridge circuit to the series connected strain gauges are identical copper wires. To measure the detector current, the standard resistance R_s of value equal to the nominal value of metallic strain gauge has been selected. Three terminals lead wires again of copper having identical length. To convert the current change into the proportional voltage ultra low offset Op-Amp like OP-07 has been selected [10]. The output of the active subtractor circuit has been scaled 10 times to obtain the output voltage range from 0 to 5 V for the full scale input loads. The experimental results are shown in Fig. 11.

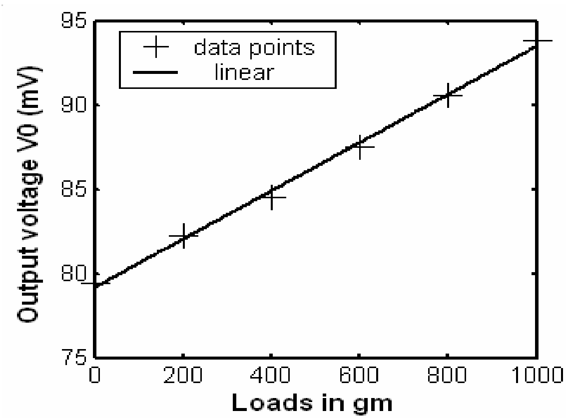

Fig. 11. Output of the modified active bridge circuit with the variation of loads (V_i = 1.5V, T = 30°C).

The sensitivity of the active bridge circuit is 1.5 %. It is almost three times of the conventional bridge circuit. The small deviation from its theoretical value may be due to Op-Amp offset voltage which can be taken care of by using Op-Amp with very small offset voltage or utilizing suitable offset compensating mechanism. The experimental results with different values of the lead resistances are shown in Table I. Here, three arms of the bridge circuit have fixed value resistances and other arm with variable resistance has been used. For lead resistance small fixed resistance has been used. Results show that there is very small change in output with variation of lead resistance.

Table I. Change in output voltage of the circuit with the change in discrete resistance for different value of lead resistance (Keithley Meter Model 2000, Working temperature of 30 ºC).

$\Delta R(\Omega)$ ($R_s = 9.8\ \Omega$)	$Rl_1 = 0\ \Omega$ $Rl_2 = 0\ \Omega$ $Rl_3 = 0\ \Omega$	$Rl_1 = 10.1\ \Omega$ $Rl_2 = 9.90\ \Omega$ $Rl_3 = 10.0\ \Omega$	$Rl_1 = 14.72\ \Omega$ $Rl_2 = 14.73\ \Omega$ $Rl_3 = 14.74\ \Omega$	$Rl_1 = 32.94\ \Omega$ $Rl_2 = 32.96\ \Omega$ $Rl_3 = 33.04\ \Omega$	$Rl_1 = 47.41\ \Omega$ $Rl_2 = 47.04\ \Omega$ $Rl_3 = 47.08\ \Omega$
	Output of the circuit (mV)	Output of the circuit (mV)	Output of the circuit (mV)	Output of the circuit(mV)	Output of the circuit(mV)
5.08	340	344	340	340	340
9.93	372	370	370	370	368
14.6	398	400	400	399	399
47.2	550	550	550	553	554
66.0	670	670	670	668	670
79.8	740	740	740	739	739
99.68	850	850	851	851	852

4.4. Error due to Variation of the Working Temperature of the Sensor

To analyze the effect of output voltage change due to the change in ambient temperature, the sensor in the arm RQ has been placed inside a controlled temperature oven. The other arms of the active bridge circuit have fixed value metal film resistances of value equal to the nominal sensor resistance. Temperature of the oven was varied from 30° C to 70° C so that only the resistance of the sensor arm varies with temperature. The voltage output of the signal conditioning circuit is shown graphically in Fig. 12.

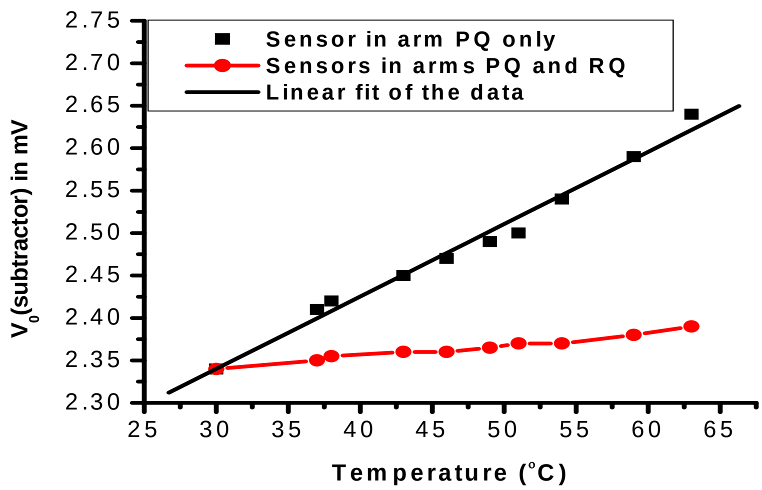

Fig. 12. Effect of ambient temperature on the output of the signal conditioning circuit (Vi = 1.0 V, R1).

It shows that the output voltage rises with increase in ambient temperature and the variation is almost linear. This is because, resistance of arm RQ increases with increase in temperature causing increase in unbalance current. Further experiment was performed by replacing the arm PQ with another strain gauge and putting both the gauges inside the oven. Temperature of the oven was varied over the same range and the output voltage was noted. Results as shown in Fig. 12 (red line) indicate that the output change due to ambient temperature is significantly reduced. Small variation in the output can be attributed due to mismatch of the strain gauge resistance. The arms PQ and RQ are in differential form. The strain gauges in both arms have identical temperature effects and neglect each other. The more accurate compensation of the temperature drift is possible using combination of the hardware and software techniques but at the cost of more hardware components and complexity of the signal conditioning system [12].

5. Conclusions

The work reported in this paper is aimed at the development of linear active bridge circuit with sensitivity larger than the conventional bridge circuit. The output of the bridge circuit has almost four times more than the conventional bridge for the similar circuit components. Because of higher sensitivity, the error due to offset voltage variation of Op-Amp and noise signal will have small effect on the overall output of the bridge. The proposed circuit requires only few components for its hardware implementation and simple to operate. It is capable of measuring incremental resistance change of both metallic and metal oxide based resistive sensor where the resistive value change due to physical quantity or chemical analytes is very small. The modified form of the circuit is suitable for measuring resistance change where sometimes the effect of lead resistance compensation is essential. Experiments have been conducted to observe the effects of both lead resistance and ambient temperature. It is found that the error due to ambient temperature and lead resistance is minimum. The experimental results confirm the theoretical values predicted. However, the output voltage variation due to the fluctuation of dc excitation can be minimized by utilizing the normalization mechanism or more efficiently using soft computing. The future work involves studying the effect of offset voltage and compensation of error due to excitation voltage using artificial neural network based soft computing technique.

Acknowledgements

Authors like to thank Department of Science and Technology (DST), New Delhi for providing the financial grant (no. SR/S2/CMP-73/2007) for this work.

References

[1]. M. Rehman, M. T. Ahmed, M. Arif, A Self-balancing bridge for in-circuit Measurement, in *Proc. of the IEEE, Inst & Meas.,* Vol. 73, 1985, pp. 1680-1682.
[2]. M. Rehman, M. T. Ahmed, M. Arif, Critical study and application of a selfbalancing bridge for in-circuit measurement, in *Proc. of the IEEE, Inst & Meas.,* Vol. 137, Part A, 1990, pp. 23-26.
[3]. S. Pradhan, S. Sen, An improved lead compensation technique for three wires resistance temperature detectors, *IEEE Tran on Inst. & Meas.,* 48, 5, 1999, pp. 903-905.
[4]. A. L. Araujo, R. C. S. Freire, etc, DC amplifier-input offset voltage control in a constant temperature thermoresistive sensor measurement instrument, *IEEE Tran. IEEE, Inst & Meas.,* Vol. 56, No. 3, 2007, pp. 778-782.
[5]. Z. M. Rittersma, Recent advances in miniaturized humidity sensors – a review of transduction techniques, *Sensors and Actuators A,* 96, 2002, pp. 196-210.
[6]. T. K. Maiti, Development of lead resistance compensation technique for remote variable resistive sensors, *Meas. Sci. Tech*., 17, 2006. pp. 1424-1427.
[7]. Kester, W., Strain, Force, Pressure, and Flow measurements, *Analog Devices, Inc.,* 1993.
[8]. Islam T., F. A. Siddiqui, Khan S. A., Islam, S. S., A sensitive detection electronics for resistive sensor, in Proc. of the *3rd International Conference on Sensing Technology (ICST´ 2008)*, Tainan, Nov. 30 – Dec. 3, 2008, pp. 259-264.

[9]. D. H. J. Baert, Circuit for the generation of balanced output signals, *IEEE Trans on Inst. & Meas.*, Vol. 6, 1999, pp. 108-110.
[10].Op-07 Datasheet, *Analog Devices*, http://www.analog.com
[11].TLC271 Datasheet, *Texas Instruments*, Available http://www.ti.com
[12].S. Poussier, H Rabah, S. Weber, Smart adaptable Strain gauge conditioner: Hardware/Software Implementation, *J. IEEE Sensors* 4, 2, 2003, pp. 252-267.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2009.pdf