The measurement of strain with single strain gages is an important part of experimental stress analysis. The type of circuitry employed influences the linearity and sensitivity of the measurements. Wheatstone bridge circuits and constant current circuits are the two types of circuits mainly used in the field of strain gage measuring technique. Constant current circuits measure resistance with almost no nonlinearity whereas Wheatstone bridge circuits show a nonlinear behaviour between resistance change and output voltage. If the resistance change was really proportional to the strain \( \frac{\Delta R}{R_0} = k \cdot \varepsilon \) \( (k = \text{constant}) \) the Wheatstone bridges would be nonlinear. But the upper formula is an approximation, valid only for small strain values. An analysis shows that the relationship between resistance change and strain is also rather nonlinear. Luckily the nonlinearity of the Wheatstone bridge compensates the nonlinearity of \( \frac{\Delta R}{R_0} = f(\varepsilon) \) almost completely. And as a result, what is even more important than linearity, the sensitivity of Wheatstone bridge circuits remains almost constant even in the case of a very high bridge unbalance.

1. Introduction

In strain gage specialist circles it is an almost fundamental fact that unbalanced Wheatstone bridge circuits display a characteristic nonlinearity. Reference paper [1] e.g. states: “The nonlinearity occurs when strain measurements are made with an “unbalanced” Wheatstone bridge circuit.” And the paper continues: “....the error is about 0.1% at 10 000 microstrain, 1% at 10 000 microstrain, and 10% at 100 000 microstrain; or as a convenient rule of thumb, the error, in percent, is approximately equal to the strain, in percent.” and “...the voltage output of the bridge is not proportional to the resistance changes, and thus the output is nonlinear with strain, and the instrument indication is in error.” There is no doubt that, with Wheatstone bridge circuits, resistance change measurements show nonlinearity. But is this also true for strain measurements?

The assumption is wrong that a resistance change, also in cases of very high strain, is absolutely proportional to strain.

\[
\frac{\Delta R}{R_0} = k \cdot \varepsilon \quad (k = \text{constant}) \quad (1)
\]

Formula (1) is only an approximation, suitable for measurements of relatively small elastic strain in metals \( (\leq 2,000 \mu \text{m/m}) \).

The relationship between a relative resistance change \( \frac{\Delta R}{R_0} \) and a large strain is a nonlinear function.

And even the definition of formula (2) for the so-called technical strain \( \varepsilon_t \) is a simplified approximation, valid only for small strains.

\[
\varepsilon_t = \frac{(l_i - l_0)}{l_0} \quad (2)
\]

\[
\varepsilon_t = \frac{\Delta l}{l_0} \quad (3)
\]

Strain test measurements carried out in 1976 [3] and 1988 [5] showed this nonlinear behavior between resistance change \( \frac{\Delta R}{R_0} \) and strain. The conclusion, mentioned in this paper, was that the gage factor of the strain gages changes when high strain values are applied. But such an assumption is not really necessary; everything becomes quite clear after replacing the approximation formulas by correct functions.

The correction calculations normally used to correct the so-called bridge nonlinearity correct only the approximation errors of the formulas and are therefore misleading in several aspects.

2. The chain of transfer functions from strain to electrical signal

The stages of all process functions from natural strain to the eventual generation of the electrical bridge output signal are shown in Fig.1.
What we want to measure is the strain on the surface of a specimen to be tested, e.g. a measuring body. The transmission of this strain to the strain gage already shows some deviations. But this is not to be discussed in this article.

The strain gage then is exposed to strain, the natural strain \( \varepsilon_n \). Technical strain \( \varepsilon_t \) is an approximation of natural strain \( \varepsilon_n \), and almost equal to it when strain values are small \((\leq 2,000 \mu \text{m/m})\). But large technical strain values deviate from natural strain values considerably, as shown later.

The relationship between the relative resistance change \( \Delta R/R_0 \) and the technical strain \( (\Delta l/l) \) also shows nonlinear behavior.

And, of course, the relationship between the electrical bridge output signal \( V_m/V_e \) and the relative resistance change \( \Delta R/R_0 \) also has a well known nonlinearity.

The diagram clearly shows the elongation of the rod from an original state 0 to a final state 2 by two successive strains (process A) and by a single strain (process B).

For the technical strain, process A produces:

\[
0 \to 1 \quad 1 \to 2
\]

\[
e_{t01} = \frac{l_1 - l_0}{l_0} \quad e_{t12} = \frac{l_2 - l_1}{l_1}
\]

If the final state is achieved in one phase (process B), this does not correspond to the sum of the individual strains:

\[
0 \to 2
\]

\[
e_{t02} = \frac{l_2 - l_0}{l_0} \neq e_{t01} + e_{t12}
\]

An example is to illustrate the problem. Let us assume a rod length \( l_0 = 100 \text{ mm} \), the first extension \( \Delta l_1 = 20 \text{ mm} \) and the second extension \( \Delta l_2 = 20 \text{ mm} \) resulting in a total extension of 40 mm.

\[
e_{t01} = \frac{\Delta l_1}{l_0} \to 20/100 \to 20% \\
e_{t12} = \frac{\Delta l_2}{l_1} \to 20/120 \to 16.66% \\
e_{t01} + e_{t12} \to 36.66% \\
e_{t02} = \frac{\Delta l_1 + \Delta l_2}{l_0} \to 40/100 \to 40% 
\]

The difference of the two results is 3.33% strain. The strain value of process B (elongation in a single strain) shows a 9% higher result than process A (elongation by two successive strains).

This example obviously proves that the technical definition of strain \( \varepsilon_t \) is not suited to describe large strains. The technical definition of strain \( \varepsilon_t \) is the tangent at the starting point of a strain process and therefore describes only a small section of the much more complex function of natural strain by linear approximation. The technical definition of strain \( \varepsilon_t \) is therefore only suited to describe strain values as long as the tangent is close to the real (natural) strain function. Strain measurements with metal test specimens normally show strain values <2000 \mu \text{m/m} \ and, therefore, the difference between technical and natural strain is <0.1% and may be neglected in most cases.

With large strain values the lack of linearity and symmetry can be avoided by representing large strain values as a sum of small strains.

\[
e = \sum \left( \frac{\Delta l_1}{l_{01}} + \frac{\Delta l_2}{l_{02}} + \frac{\Delta l_3}{l_{03}} + \frac{\Delta l_4}{l_{04}} + \ldots \right) \quad (3)
\]

If \( \Delta l \) is made infinitely small and divided by length \( l \), the total strain becomes an integral.

3. Technical and natural strain

The so-called technical strain \( \varepsilon_t \) in formulas (2) and (3) is the normally used definition for strain. It is very simple and clear, and expresses an absolute, linear relationship between the change in length of the specimen and the strain \( \varepsilon_t \).

With greater deformations, however, it provides results that seem to be contradictory. If length \( l_1 \) gets very long \((l_1 \to \infty)\), this also produces extremely high positive strain \( (\varepsilon_t \to \infty) \). On the other hand, if length \( l_1 = 0 \), the strain is \( (\varepsilon_t \to -1) \). The range for technical strain is therefore defined to be \(-1 \leq \varepsilon_t \leq +\infty\).

This obvious asymmetry leads to difficulties in adding and subtracting large strain values, as shown in Fig. 2.

![Fig. 2: Elongation of a rod from an original state 0 to a final state 2 by...](image)

The diagram clearly shows the elongation of the rod from an original state 0 to a final state 2 by two successive strains (A) and a single strain phase (B).

The range for technical strain is \( -\infty < \varepsilon_t < +\infty \). The technical definition of strain \( \varepsilon_t \) is the normally used definition for strain. It is very simple and clear, and expresses an absolute, linear relationship between the change in length of the specimen and the strain \( \varepsilon_t \).
\[
E_n = \int_{l_0}^{l_0 + \Delta l} \frac{dl}{l} \quad (4)
\]

Equations (4) and (5) describe the natural or "effective" strain which has been known since 1909 [2]. Every strain value can be regarded as the sum of an infinite number of infinitely small strain values. If e.g. a wire of the length \(l_0\) is stretched to a length of \(l_0 + \Delta l\), the natural strain \(\varepsilon_n\) is calculated by

\[
\varepsilon_n = \ln\left(1 + \frac{\Delta l}{l_0}\right) \quad (5)
\]

\[
\varepsilon_n = \ln(1 + \varepsilon_t) \quad (6)
\]

\[
\varepsilon_n = \exp(\varepsilon_t) - 1 \quad (7)
\]

Formulas (6) and (7) show the relationship between natural strain \(\varepsilon_n\) and technical strain \(\varepsilon_t\).

For small strain values \(\varepsilon_t \approx \varepsilon_n\) as a first approximation, which is apparent if equation (7) is written as a series:

\[
\varepsilon_t \approx \varepsilon_n + \frac{1}{2} \left(\varepsilon_n^2\right) + \frac{1}{6} \left(\varepsilon_n^3\right) \quad (8)
\]

The difference between both strain definitions is shown in Fig. 3.

![Fig. 3: Deviation of technical strain \(\varepsilon_t\) from natural strain \(\varepsilon_n\) in \(\mu m/m\)](image)

The difference between both strains in percent of the natural strain \(\varepsilon_n\) is shown in Fig. 4. The difference in percent is approximately half of the strain percentage value.

![Fig. 4: Deviation of technical strain \(\varepsilon_t\) from natural strain \(\varepsilon_n\) in % of \(\varepsilon_n\)](image)

If the test shown in Fig. 2 is made by calculating the natural strain \(\varepsilon_n\), the sum of the strains of the two phases in process A is identical with the overall strain resulting from the one-phase process B.

\[
0 \rightarrow 1 \quad \varepsilon_{n0} \approx \ln\left(\frac{l_1 + \Delta l_1}{l_0}\right) \quad \varepsilon_{n1} = 18.23\% \\
1 \rightarrow 2 \quad \varepsilon_{n1} \approx \ln\left(\frac{l_1 + \Delta l_1}{l_1}\right) \quad \varepsilon_{n2} = 33.65\% \\
0 \rightarrow 2 \quad \varepsilon_{n2} \approx \ln\left(\frac{l_0 + \Delta l_1 + \Delta l_2}{l_0}\right)
\]

\[
\varepsilon_{n2} = 33.65\%
\]

Proving equation (12)

If the test shown in Fig. 2 is made by calculating the natural strain \(\varepsilon_n\), the sum of the strains of the two phases in process A is identical with the overall strain resulting from the one-phase process B.

\[
\varepsilon_{n0} = 18.23\% \quad \varepsilon_{n1} = 15.42\% \\
\varepsilon_{n2} = 33.65\%
\]

4. Relative resistance change

The following observations are only valid for strain gages having metal grids and a gage factor \(k\) of approximately 2. However, since these are the most popular types of strain gages the restriction is of no importance in the majority of practical applications. The definition of the gage factor is

\[
\frac{\Delta R}{R} = k \cdot \varepsilon \quad (18)
\]

Therefore, \(k = 2\) means that the relative change in resistance is twice the strain \(\varepsilon\).

In the elastic range of metal strain gages with a gage factor of 2, a change in form accounts for...
approximately 80% of the gage factor and a change in specific resistance for only about 20%.

In the plastic range of a material, the relative change in resistance is caused exclusively by the change in form with simultaneous constancy of volume and specific resistance. The gage factor of all metal materials in the case of pure plastic deformation always is \( k = 2 \).

Therefore, strain gages with a gage factor of 2 possess a constant sensitivity in both the elastic and plastic ranges and are best suited for measuring large strain values. The readings are almost entirely independent of the prior treatment and use of the strain gage, and that is another big advantage.

The resistance of a conductor is calculated according to equation (19)

\[ R = \frac{\rho \cdot l}{A} \quad (19) \]

Where \( l \) is the length, \( A \) the cross section and \( \rho \) the specific resistance of the conductor. If the volume \( V \) and the specific resistance \( \rho \) are assumed to remain constant (plastic strain), the following relationship between the resistance and the length can be derived:

\[ V = l \cdot A \quad \rightarrow \text{constant} \quad (20) \]

giving

\[ A \sim \frac{1}{l} \quad (21) \]

and

\[ R \sim l^2 \quad (22) \]

\[ R = R_0 + \Delta R \quad (23) \]

\[ (R_0 + \Delta R) \sim (l_0 + \Delta l)^2 \quad (24) \]

\[ \Delta R \sim (2\Delta l + \Delta l^2) \quad (25) \]

This gives the relative change in resistance

\[ \frac{\Delta R}{R_0} = \frac{2\Delta l}{l_0} + \frac{\Delta l^2}{l_0} \quad (26) \]

Substituting equation (3) in equation (26) gives

\[ \frac{\Delta R}{R_0} = 2\varepsilon_t + \varepsilon_t^2 \quad (27) \]

This gives the relative resistance change as a function of technical strain \( \varepsilon_t \)

\[ \frac{\Delta R}{R_0} = \sqrt{1 + \frac{\Delta R}{R_0}} - 1 \quad (28) \]

And solved for \( \varepsilon_t \) gives

\[ \varepsilon_t = \frac{1}{2} \cdot \frac{\Delta R}{R_0} - 1 \quad (29) \]

Equation (27) and (28) show that the relationship between the technical strain \( \varepsilon_t \) and the relative resistance change also is a nonlinear function, and that a constant gage factor of 2 is only an approximation according to equation (29).

AS we want to use the natural strain for large strain values, the relationship between natural strain and the relative resistance change must be derived.

Substituting equation (7) in equation (27) gives

\[ \frac{\Delta R}{R_0} = 2 \cdot (\exp(\varepsilon_n) - 1) + (\exp(\varepsilon_n) - 1)^2 \]

and derived

\[ \frac{\Delta R}{R_0} = \exp(2\varepsilon_n) - 1 \quad (30) \]
For metal strain gages with a gage factor of 2, equation (30) represents the relationship between the natural strain \( \varepsilon_n \) and the relative change in resistance \( \Delta R/R_0 \). The series expansion of equation (30) gives

\[
\frac{\Delta R}{R_0} \approx 2(\varepsilon_n + \varepsilon_n^2)
\]

(31)

Which is a rather good approximation. Practical measurements showed the same result in the past [3].

Equation (30) solved for natural strain gives

\[
\varepsilon_n = \frac{1}{2} \ln\left(\frac{R_0 + \Delta R}{R_0}\right)
\]

(32)

5. Electrical bridge signal caused by change in resistance

When a strain gage is connected as shown in Fig. 9 using three equal resistors \( R_0 \) to form a Wheatstone bridge, and the resistance of the strain gage changes from \( R_0 \) to \( R_0 + \Delta R \) due to the strain, the ratio of measuring voltage \( V_m \) divided by bridge excitation voltage \( V_e \) can be calculated

\[
\frac{V_m}{V_e} = \frac{1}{2} \cdot \frac{\Delta R / R_0}{2 + \Delta R / R_0}
\]

(33)

The relationship between the measured electrical signal and the change in resistance is nonlinear; it is known as the so-called bridge nonlinearity.

6. The Wheatstone bridge signal as a function of natural strain \( \varepsilon_n \)

In chapter 3, we have shown that with large strain values the technical strain definition leads to inconsistencies and errors and therefore the real, natural strain definition should be used.

To determine the overall transmissibility of the applied value of “natural strain \( \varepsilon_n \)” and the measured electrical signal \( V_m/V_e \), the formula has to be derived.

In order to obtain the relationship between the natural strain \( \varepsilon_n \) and the electrical signal \( V_m/V_e \), equation (30) is substituted in equation (33), giving

\[
\frac{V_m}{V_e} = \frac{1}{2} \cdot \frac{\exp(2\varepsilon_n) - 1}{\exp(2\varepsilon_n) + 1}
\]

(34)

Multiplying the numerator and denominator of equation (34) by \( \exp(-\varepsilon_n) \) gives

\[
\frac{V_m}{V_e} = \frac{1}{2} \cdot \tanh(\varepsilon_n)
\]

(35)

Therefore, the theoretical relationship between the electrical signal \( V_m/V_e \) and the natural strain \( \varepsilon_n \) for an ideal metal strain gage with a gage factor of 2 is determined by the hyperbolic tangent.

A very precise approximation of the hyperbolic tangent is given by

\[
\frac{V_m}{V_e} \approx \frac{1}{2} \cdot \left(\varepsilon_n - \frac{1}{3} \cdot \varepsilon_n^3\right)
\]

(36)

The error of this approximation is extremely small; even with a very large strain of 100,000 \( \mu \text{m/m} \) it is only – 0.0013% of the actual value.

Equation (36) shows that the measured signal is proportional to the strain, even up to rather high strain values.
7. The Effect of extreme initial bridge unbalance on measuring sensitivity

So far, this article has dealt mainly with nonlinearity in case of large strain values. However, for most strain measurements, errors in linearity are not of overwhelming interest because the strains to be measured with metal strain gages are normally so small that nonlinearity can be neglected. A more important question is:

“What happens with the sensitivity of extremely unbalanced Wheatstone bridge circuits?” When e.g. large pre-strain or very large tolerances of the strain gage resistance cause extreme bridge unbalance, if the statement quoted in the introduction (1st chapter) [1] was true, a 5% bridge unbalance would change the sensitivity also by 5%.

A sensitivity change is caused by nonlinearity. If a system is totally linear, the sensitivity remains constant and vice versa.

In the preceding chapters we have shown that Wheatstone bridge circuits show very small nonlinearity when strain has to be measured. Therefore, we can also expect that the sensitivity is not very much affected by large bridge unbalances.

The measuring sensitivity $S_B$ for small strain values is given by the slope of the transmission curve at the particular working point, e.g. at the particular value of natural strain $\varepsilon_n$:

$$S_B = \frac{d \left( \frac{V_m}{V} \right)}{d \varepsilon_n}$$  \hspace{1cm} (37)

The values of valid natural strain $\varepsilon_n$ are obtained by converting the resistance deviation $\Delta R/R_0$ (which causes the bridge unbalance) due to tolerances and/or pre-strain of the strain gages accordingly:

$$\varepsilon_n = \frac{1}{2} \ln \left( \frac{\Delta R}{R_0} + 1 \right)$$  \hspace{1cm} (38)

The sensitivity $S_B$ of a Wheatstone bridge circuit is then

$$S_B = \frac{d \left( \tanh(\varepsilon_n) \right)}{d \varepsilon_n}$$  \hspace{1cm} (39)

and therefore

$$S_B = 1 - \left( \tanh(\varepsilon_n) \right)^2$$  \hspace{1cm} (40)

Equation (40) can be written in the following series form:

$$S_B \approx 1 - \varepsilon_n^2 + \frac{2}{3} \varepsilon_n^4 \ldots$$  \hspace{1cm} (41)

Fig. 12 a) to 12 c) show that Wheatstone bridges measure strain with almost constant sensitivity. Also in cases of very large bridge unbalances, up to ±15 mV/V (+30000 micro strain), the sensitivity changes less than 0.1%. The nonlinearity of the relationship strain to resistance change $\Delta R$ is almost completely compensated by the nonlinearity of the relationship resistance change $\Delta R$ to electrical signal mV/V of Wheatstone bridges.

On the other hand, if strain gage resistance change is wrongly taken as a representation of strain and measured by a resistance measuring device (constant current circuit), large changes in sensitivity may occur. This is caused by the resistance change of the strain gage from initial $R=R_0$ to $R=R_0+\Delta R$ when strain is applied.

A resistance change $dR$ caused by a small strain $d\varepsilon$ is always proportional to the actual strain gage resistance $R=R_0+\Delta R$. Because the resistance $R$ changes due to large strain values by $\Delta R$, the sensitivity of a constant current circuit also changes proportional to the changing strain gage resistance $R$. And therefore the relationship of electrical signal to strain of constant current measuring circuits is nonlinear.
The relative resistance change $\Delta R/R_0$ follows the function of equation (30), and the sensitivity of a resistance measuring device $S_R$ is given by the slope of the transmission curve at the particular working point and by differentiation of equation (30) with

$$S_R = 2 \cdot \exp(2 \varepsilon_n) \quad (42)$$

Fig. 13: Sensitivity change of a resistance measuring device (constant current) as a function of pre-strain

The sensitivity $S_R$ of a resistance measuring device (constant current) increases very much with positive strain values as shown in Fig. 13. Fig. 13 shows a strain range from $-30\,000 \mu\text{m/m}$ to $+30\,000 \mu\text{m/m}$ and a sensitivity change of 94% to 106%. Constant current measuring units show rather big linearity errors when measuring strain and therefore also rather big sensitivity errors. That is why constant current measuring units have to use some kind of correction calculation to compensate for nonlinearities when measuring strain.

8. Bridge sensitivity as a function of strain gage resistance tolerance

In chapters 3 to 7, strain gage equations were the starting point to prove the high linearity and constant sensitivity of Wheatstone bridge circuits. In this chapter, an independent and even simpler derivation also demonstrates that the Wheatstone bridge sensitivity remains almost constant even with large bridge unbalances.

The resistance change of a strain gage is proportional to its total resistance. Of course, a 350 $\Omega$ strain gage generates about three times as much resistance change than a 120 $\Omega$ strain gage per micro strain. There is the same causal relationship when a strain gage has a lower or higher resistance due to tolerances or large pre-strain. A strain gage with 110% of nominal resistance will generate a 10% higher change in resistance than a strain gage with nominal value.

From equation (33), equation (41) can be derived

$$\frac{V_m}{V_e} = \frac{1}{2} \cdot \frac{\Delta R}{2R_0 + \Delta R} \quad (41)$$

If $\Delta R$ is generated by the strain gage tolerance $T$, then

$$\Delta R = R_0 \cdot T \quad (42)$$

Substituting equation (42) in equation (41) gives

$$\frac{V_m}{V_e} = \frac{1}{2} \cdot \frac{T}{2 + T} \quad (43)$$

Equation (43) gives the bridge unbalance in V/V as a function of the strain gage resistance tolerance. Fig. 14 shows the bridge unbalance in mV/V caused by strain gage resistance tolerances in the range of ±6%. What we want to see is, how the sensitivity of small strain signals changes due to this bridge unbalance caused by the strain gage resistance tolerance. To prove this equation (41) must be changed a little to the form of equation (44)

$$\frac{V_m}{V_e} = \frac{1}{2} \cdot \frac{\Delta R + dR}{2R_0 + \Delta R + dR} \quad (44)$$

$\Delta R$ is caused by the strain gage resistance tolerance whereas $dR$ is caused by a small strain value $\varepsilon$.

$$dR = R \cdot k \cdot \varepsilon \quad (45)$$

$$R = R_0 \cdot (1 + T) \quad (46)$$

$$dR = R_0 \cdot (1 + T) \cdot k \cdot \varepsilon \quad (47)$$

and for a gage factor of 2

$$dR = 2 \cdot R_0 \cdot (1 + T) \cdot \varepsilon \quad (48)$$

Replacing $\Delta R$ and $dR$ by their expressions in equations (42) and (48) changes equation (44) into equation (49)

$$\frac{V_m}{V_e} = \frac{T + 2\varepsilon + 2\varepsilon T}{4 + 2T + 4\varepsilon + 4\varepsilon T} \quad (49)$$

To obtain the sensitivity $S_T$, equation (49) has to be differentiated
The sensitivity $S_T$, the relationship of the electrical measuring signal ($V/V$) to strain $\varepsilon$ ($m/m$), is given by equation (50).

$$S_T = \frac{d(V_m)}{V} \cdot \frac{1}{d\varepsilon}$$

Equation (50) is a rather precise approximation.

$$S_T \approx \frac{1}{2} \cdot \frac{T^2}{1 + \frac{T}{4}(1 + T)}$$

Equation (51) is a rather precise approximation.

Fig. 15 shows the standardized sensitivity change for small strain signals due to the strain gage resistance tolerance and looks the same as Fig. 13 a). The two different ways to derive the change of sensitivity with unbalanced Wheatstone bridges produce equal results. The first way by analysing the whole transfer function from natural strain to the electrical signal and the second way by analysing the impact of the strain gage resistance tolerance $T$.

Because of the constant sensitivity of Wheatstone bridges, also in cases of very large bridge unbalances, it is not necessary to zero balance the bridges. If many successive small strain steps in a test procedure are to be summed up, bridge circuits are best suited to do this task. Resistance measuring devices (constant current devices) cannot do this, because their sensitivity changes proportional to the changing strain gage resistance.

9. Conclusion

The purpose of this article was to draw attention to the fact that the linearity and sensitivity of strain gage measurements cannot be assessed solely from the relationship between the change in resistance and the change in electrical signal. The transmissibility between strain and change in resistance must also be taken into account. And if this is done, the results show that for the use of strain gages in quarter bridge connection, bridge circuits are superior to resistance measuring units (constant current devices) in many ways, primarily because of their linearity which is superior by several powers of ten and similarly better sensitivity stability under conditions of initial detuning. When strain is to be measured with strain gages, Wheatstone bridge circuits make it possible to work in an exceptional large range of up to $\pm 30,000 \, \mu m/m$, corresponding to $\pm 15 \, mV/V$ bridge unbalance or $\pm 6\%$ strain gage initial resistance deviation, and getting less than $0.03\%$ nonlinearity and small signal sensitivity change of less than $0.1\%$. Compared with other error sources in the field of strain gage measurements these very small errors may be neglected in almost any case. Therefore we conclude:

When measuring strain, Wheatstone bridge circuits don’t need additional calculations to correct for nonlinearity.

9. References

Wheatstone Bridge Nonlinearity


