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DMP41 – A NEW CHAPTER OF ULTRA-PRECISION INSTRUMENT FOR STRAIN GAUGE TRANSDUCERS

A. Schäfer, H. Kitzing

Hottinger Baldwin Messtechnik GmbH (HBM), Darmstadt, Germany, andre.schaefer@hbm.com

Abstract: The strain gauge principle is a resistive principle. If a strain is applied only a very small change of resistance occurs. By a Wheatstone bridge the change of resistance can be transferred into a voltage. However this voltage signal on the output of the bridge is still very small. Therefore it must be gained by sophisticated methodes. This paper describes the new strain gauge precision instrument DMP41 with highest resolution and highest stability for the use in calibration tasks with e.g. force, torque, pressure transducers or load cells.

Keywords: Precision instrument, strain gauge, high resolution, high stability

1. INTRODUCTION

An excellent read-out of the signal benefits from three main principles used in the instrument, which should be discussed and briefly explained in this introduction.

In the elastic deformation range of materials the methods of calculating the material stresses from the measured strains are based on Hooke's Law. In its simplest form for uniaxial stress state Hooke's law is [1]:

$$\sigma = \varepsilon \cdot E \qquad (1)$$

σ = material stress
ε = strain
E = modulus of elasticity of the material

The strain can be picked up by the strain gauge [2], [3] is:

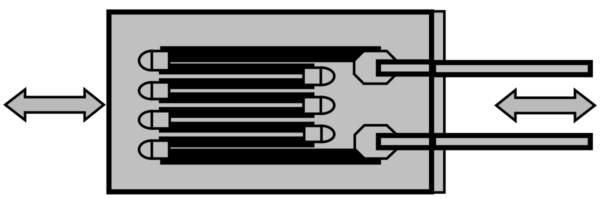

Figure 1. Schematic sketch of a strain gauge changing resistance under load

The variation of resistance is

$$\Delta R/R_0 = k \cdot \varepsilon \,. \qquad (2)$$

ε = strain
k = gauge factor
ΔR = change of resistance
R_0 = basic resistance

Figure 2 shows the schematic electric circuit of such an amplifier (DAQ) with a Wheatstone bridge (WB) based on the strain gauge principle.

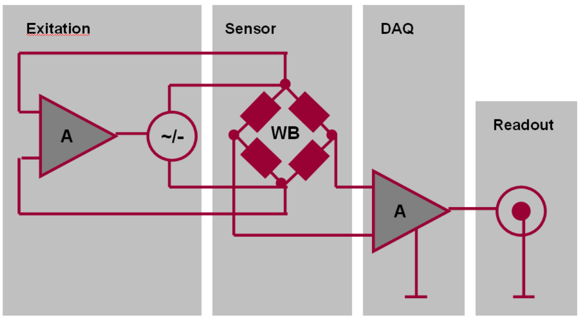

Figure 2. Principle of strain gauge amplifier

The second basic principle is the six-wire circuit, a method for full bridge strain gauge circuits to avoid voltage drop due to resistance of cables. Fig. 3 shows the principle. An adjustable voltage generator provides the voltage for the supply of the transducer fitted with full bridge strain gauge circuit. As a consequence of the voltage drop arising due to the supply current through the cable resistances of the supply leads, the transducer receives the lower supply voltage. The two sensing leads return the voltage to the comparator which compares it with a reference voltage. The reference voltage is equal to the required bridge supply voltage. The cable resistances of the sensing leads do not have any detrimental effect because no current flows through them. If the actual supply voltage deviates from reference supply voltage, then the generator, controlled by the comparator, increases its voltage until the sensing leads signal is the same as the from reference supply voltage. By this method the required voltage is then present across the transducer.

The new instrument DMP41 additionally provides the possibility the use of TEDS (Transducer Electronic Data Sheet) for unique identification and parameter storage.

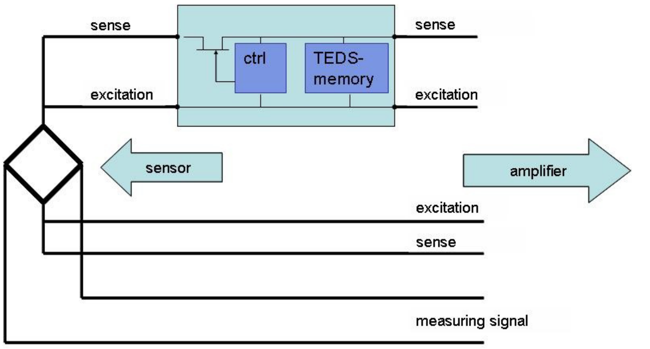

Figure 3. Principle of the 6 wire circuit and TEDS-Option

The third principle is the use of a CF (carrier frequency). Hereby the transducer is fed by a sinus-wave voltage and works therefore like a modulator. Details of this can be seen in [4].

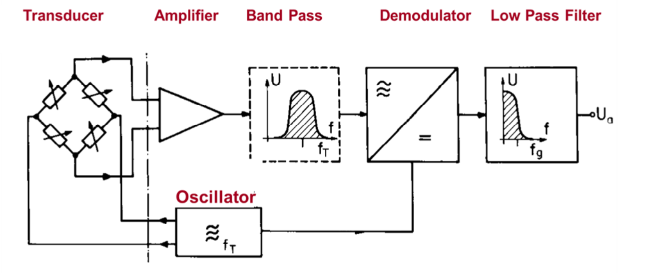

Figure 4. HBM High Precision Amplifiers are based on CF (carrier frequency)

In the result the use of a carrier frequency allows a much better signal noise ratio. HBM is using a carrier frequency of 225 Hz for its DMP series [5].

2. THE HISTORY OF THE INSTRUMENT

In the 1970´s HBM had big success with the DK38 instrument, a so called digital compensator throughout the world and in many different markets. The trend to arising requirement for even higher accuracy in calibration was picked up by HBM as early as 1980. Together with the German National Metrology Institute, the PTB [6], HBM started to think about an instrument beyond the demands of industry, able to go up to the physical limits. This was first true with the introduction of the DMP39 in 1980, followed by the DMP40 in 1992. The DMP39 was a big leap in the attempt to have an instrument of an accuracy "close to ideal", what could nearly be neglected in the total accuracy:

$$c^2 = sqr\,(a^2 + b^2) \qquad (3)$$

c = total accuracy of measuring chain
a = accuracy of transducer (e.g. force or torque)
b = accuracy of precision instrument

And if b = 0 , what is about true, so

$$c = a \qquad (4)$$

In other words: Considering the effort that has to be put into building up a good transducer, one should not waste this accuracy on the amplifier. The development of this instrument series always had this goal in mind [7]. For this reason it became the "reference-instrument" in approx. one hundred standard institutes around the world.

3. MAIN PARAMETERS OF THE INSTRUMENT

The new released DMP41 is the ultimate successor of these instruments, reflecting the development due to new needs in calibration, what should be discussed in the following chapters [8].

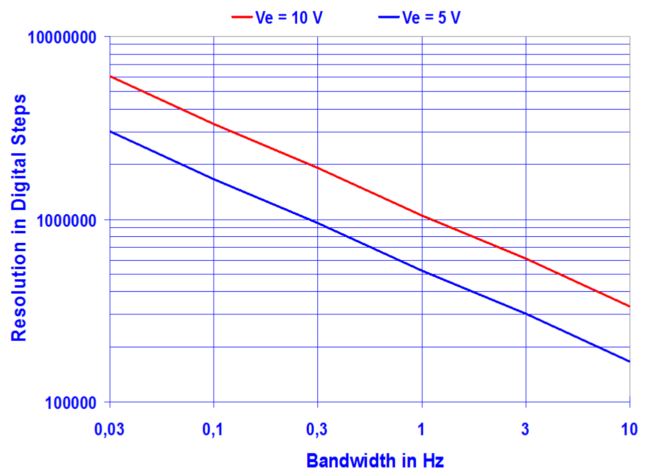

Figure 5. Resolution versus Bandwidth

Figure 5 shows the physical limits of resolution of a strain gauge transducer caused by the thermal noise:

$$V_{rms} = sqr\,(4 \cdot k \cdot T \cdot R \cdot B) \qquad (5)$$

V_{rms} = Root Mean Square Noise Voltage
k = Boltzmann Constant (1.380662×10^{-23} J/K)
T = Absolute Temperature in K
R = Resistance in W
B = Bandwidth in Hz

As it can be seen, high resolution with strain gauge transducers is only reachable with low bandwidth, i.e. slow filters. The input of the amplifier should not produce more noise than the transducer, and the instrument needs digital filters with very high resolution und slow response.

However one can easily understand that an accuracy of only 0.0005%, corresponding to 5ppm, reached in this instruments series unique principle and system, cannot be improved again.

The long term stability of the instrument series should be demonstrated on the example of DMP39, as for the predecessor of DMP40 values is available over a period of over a period of 30 years. It has been taken for the DMP39 with S/N_001, the first DMP39 ever made together with the calibration unit BN100. The result is shown in figure 6.

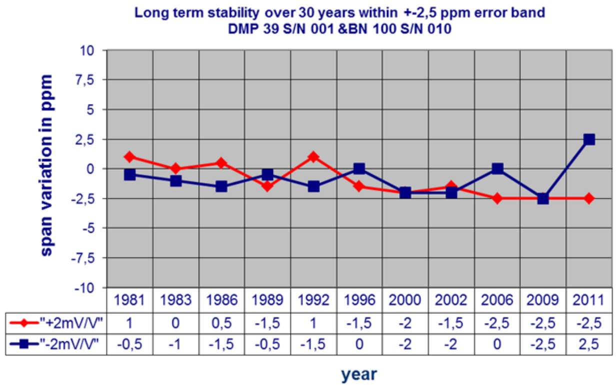

Figure 6. Measured values for long term stability of BN 100 and DMP39

The whole measuring chain does not leave an error band of only +- 2,5 ppm. Beside of what it means for the instrument series, it also shows the excellence of BN100 (used was one of the first devices produced the one with S/N010), simulating a strain gauge transducer with the highest accuracy and long term stability.

As a result we got the following preliminary specifications for DMP41:

Accuracy Class	0.0005 % = 5 parts per million
Resolution	2.000.000 d
Linearity Error	<5 ppm (part per million)
Zero Point Drift	<3 ppm / 10K
Span Drift	<3 ppm / 10K
Long-term Drift	<5 ppm / year

4. NEW POSSIBILITIES BY MEANS OF PC REMOTE OPERATION

Let us imagine the use in a force laboratory. For some hydraulic force machine it is as follows: A force calibration machine applies force to the reference transducer and the specimen at the same time. Therefore two channels are needed. DMP40S2 was used for that.

Thus a difficult task is the requirement to compatibility, as it is used by different groups or users, such as programmers, system integrators or even manufacturers of load cells at the same time. For this reason the basic commands have all been maintained.

Better than with DMP40S2 it now can be done by DMP41T2 as the readout and control of the two channels can be done one hundred per cent by some remote place, say in the office of the operator with the same functionality as at the instrument itself, it can be operated by some touch screen or conventionally by functional and alphanumerical keys, just as desired by the user.

Figure 7 shows the new front of the DMP41. On the left hand side you find the touch screen, on the right hand side the function keys. Although numerous new features have been introduced, the device still looks familiar and the desk to housing maintains the size of DMP40.

Figure 7. Front view of the new device (subject of change)

Figure 8 shows the clearly structured menu for setting up the instrument. All operations can be done by function keys on the instrument as well as by the newly introduced touch screen as well as from the PC as a remote operation.

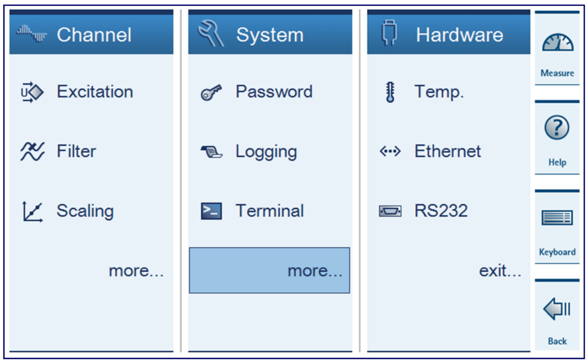

Figure 8. Configuration menu of the new device (preliminary, subject of change)

Figure 9 shows the rear side of the instrument with new possibility for connection. Each channel can be equipped with a transducer either by DP15P-plug or MS-plug. Thus adapter cables are not needed anymore. New interfacing possibilities are Ethernet and several USB connectors.

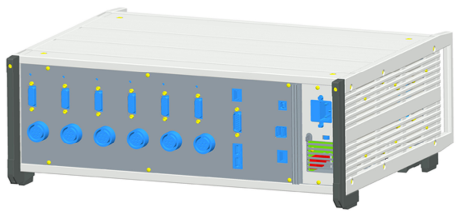

Figure 9. Schematic sketch of the backside of the device in version DMP41-T6 (six simultaneous channels as well as several interface connections)

5. MULTICHANNEL APPLICATIONS

Beside of the DMP41-T2 version there is a more versatile DMP41-T6 version what can run up to six channels absolutely simultaneously. Definitely there will be many applications for this. One application example for the six channel device is a wind tunnel for aerospace or wind energy [9]; [10].

In addition to the maximum six channels in the device, several DMP41 can be switched together by using the master-slave function. By this there are practically no limits to high channel ultra-precision measurement anymore and this will be certainly one of the future trends opening up new possibilities and help the user to be prepared for new tasks.

6. CONCLUSION

DMP 40 is a standard device in many laboratories in standard institutes around the world. Mainly the instrument is used in force, torque, pressure (especially in the research fields of high and ultra-high pressure) as well as voltage, flow and mass laboratories and has been the basis for most accurate measuring chains for the last decade.

By now the new DMP41 is the logical successor of the DMP40. Since the introduction of the first device of the DMP series, the so called DMP39, the series has proven its outstanding accuracy and long term stability. Now DMP 41 is offering up-to-date features, plus a much better connectivity and usability.

One more remarkable step has been done toward more complex calibration tasks. At least two and up to six really simultaneous channels, a much better network integration and the use of sophisticated programming languages are only some of the new features with the new instrument. Also that each channel can be equipped with a transducer either by DP15P-plug or MS-plug will make daily use more easy.

For inter-comparison programs between National Metrology Institutes for a couple of mainly mechanical quantities the user can even better rely on the instruments excellent performance.

At the same time, by the outstanding accuracy of the instrument, total accuracy of the whole measuring chain is about the same as the one of the transducer in front of DMP41. This is especially important if it is about high nominal forces and thus big transducer units with quite high price and it is more the transducers much higher effort to make them accurate [12]; [13].

For the other users in several industrial fields, such as load cell and other transducer manufacturer as well as calibration services, automation of any kind of calibration processes will be much easier with this new instrument.

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