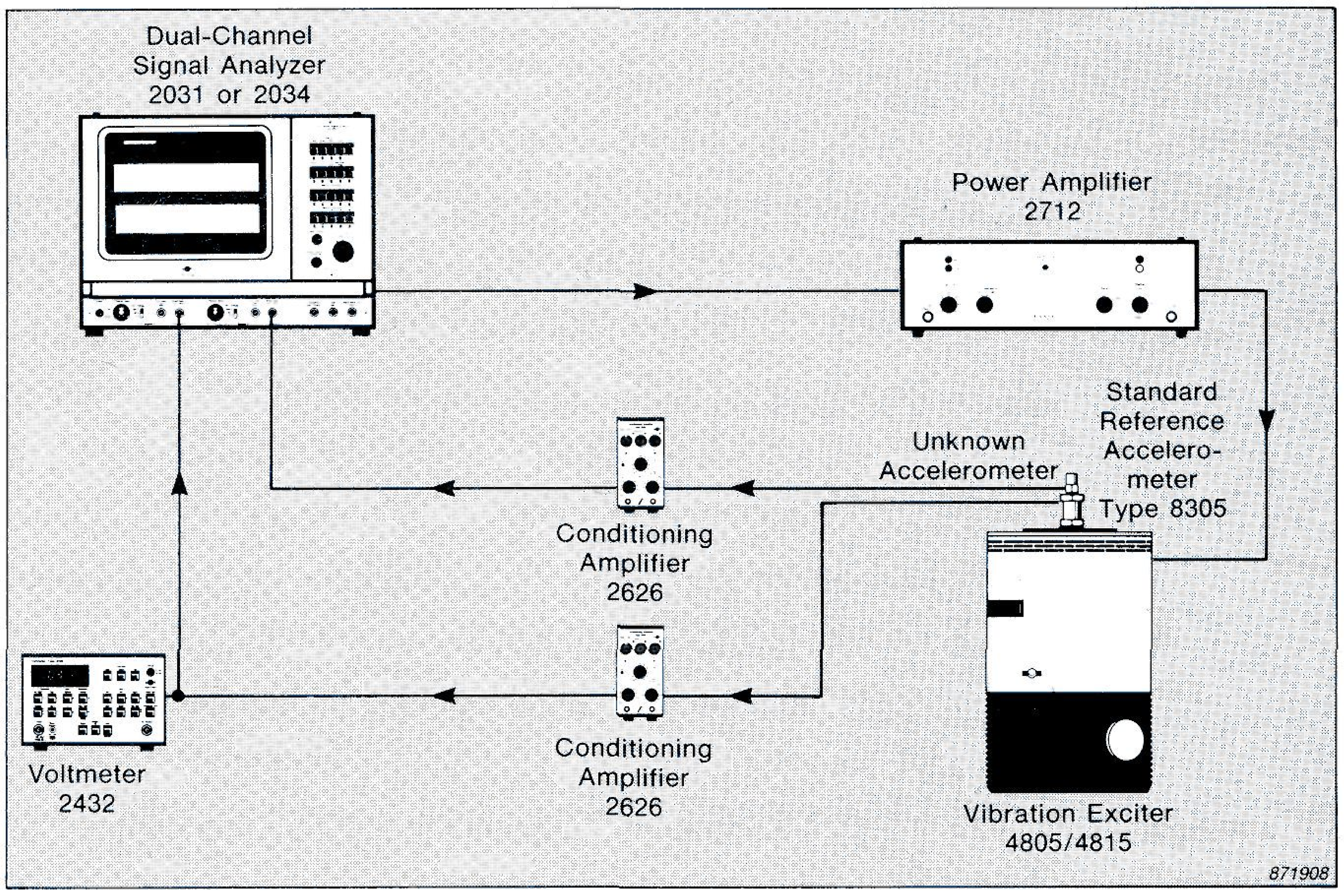
Brüel & Kjær application notes

Back-to-back calibration of accelerometers, using FFT analysis for sensitivity comparison at 800 frequencies

This application note describes a back-to-back comparison method, using the Dual-Channel Analyzer Type 2032 or 2034, for accelerometer calibration simultaneously at 800 frequencies. By using broadband random noise excitation, this technique can be used to produce sensitivity and phase measurements with an accuracy similar to that produced by traditional sine calibration techniques.

The calibration system presented can be expanded to a computer-based system for semi-automatic transducer calibration, suitable for large calibration laboratories.



The 2032- or 2034-based system for back-to-back calibration of accelerometers at 800 frequencies.

Introduction

The back-to-back calibration technique is based on the principle illustrated in Figure 1. An accelerometer, the sensitivity of which is unknown, is mounted in a back-to-back manner with a standard reference accelerometer, and the combination is mounted on a suitable vibration source. The input acceleration to each accelerometer is identical; and consequently, the ratio of their sensitivities is simply the ratio of their outputs. Traditionally, the accelerometers are excited at a single frequency, and their outputs are measured (after suitable preamplification) by using a high-quality electronic voltmeter, the accuracy of which is known. This method produces good results. However, it produces a measure of the sensitivity at a single frequency. Therefore, attaining a comprehensive knowledge of an accelerometer's characteristics can be rather time consuming.

Back-to-back calibration using FFT analysis

The advent of the dual-channel analyzer (with built-in broadband random noise generator) enables relatively fast frequency response and phase measurement, at 800 frequencies. Consequently, the sensitivities of two accelerometers can be compared by using a Dual-Channel Signal Analyzer Type 2032 or 2034 to measure the ratio of their outputs. By feeding the output from the reference accelerometer to the *channel A* input, and the output from the unknown accelerometer to the *channel B* input, the unknown sensitivity can be presented on the analyzer's display screen as frequency response and phase response functions.

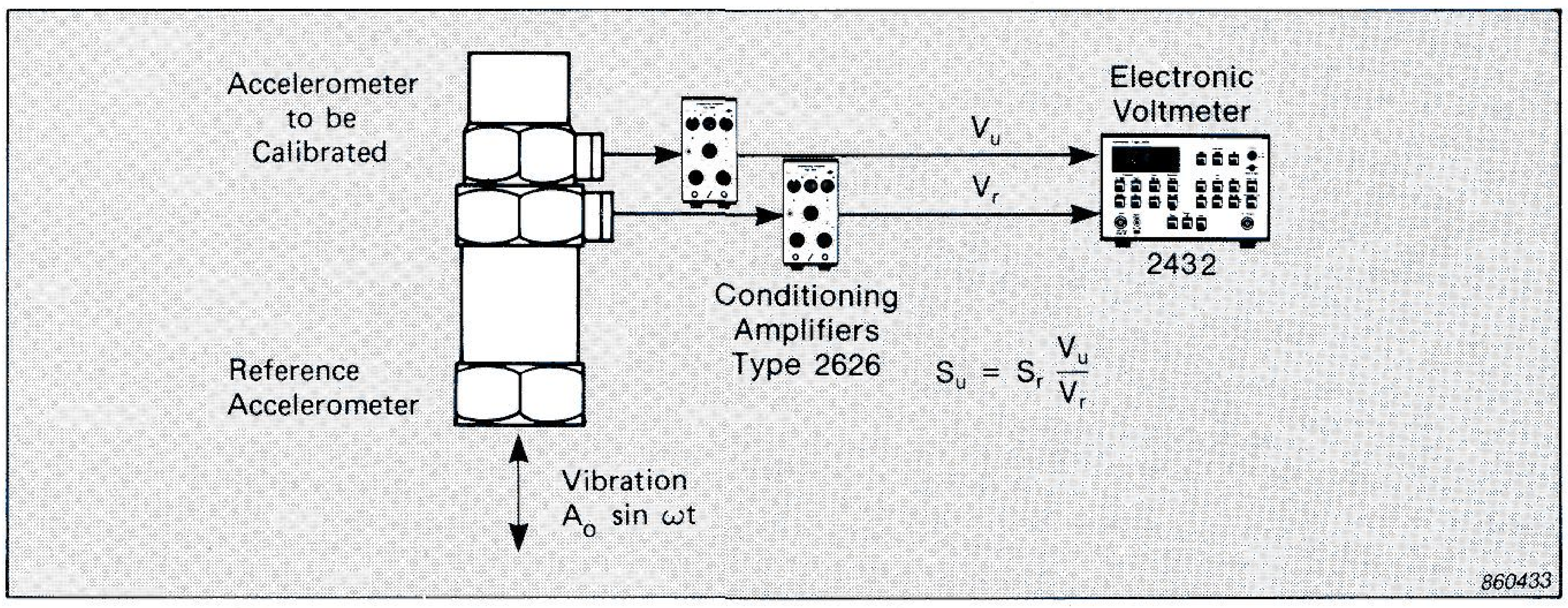


Fig. 1. Principle of the traditional back-to-back calibration technique.

A basic calibration system, centered around the Type 2032 or Type 2034, is presented in the opening figure. The system features the Vibration Exciter Type 4805 and Head Type 4815. This head is especially designed for calibration work, and as such incorporates the Standard Reference Accelerometer Type 8305. An automated calibration system providing hard copy of each accelerometer's sensitivity can be formed by adding a computer and a plotter to the instrumentation.

Calibration by substitution

In practice, it has proved advantageous, with regard to accuracy, to employ the FFT-based back-to-back calibration method, using a self-correcting *calibration by substitution* technique.

The calibration by substitution technique, which is based on the principle shown in Figure 2, involves making two measurements. The reference measurement, in which one reference accelerometer is calibrated against another, is stored before calibration of the unknown accelerometer is made. An accelerometer is used as a reference, and remains fixed to the exciter head. The standard reference accelerometer and the accelerometer of unknown sensitivity are individually compared to the reference. The charge sensitivity of the unknown accelerometer is then calculated as follows:

$$S_u(f) = S_r(f) \times \frac{H_u(f)}{H_r(f)}$$

The ratio $H_u(f)/H_r(f)$ can be found directly from the *equalized* frequency response function. This is a post-processing function of the analyzer, which calculates the complex ratio between the measured and stored frequency response functions.

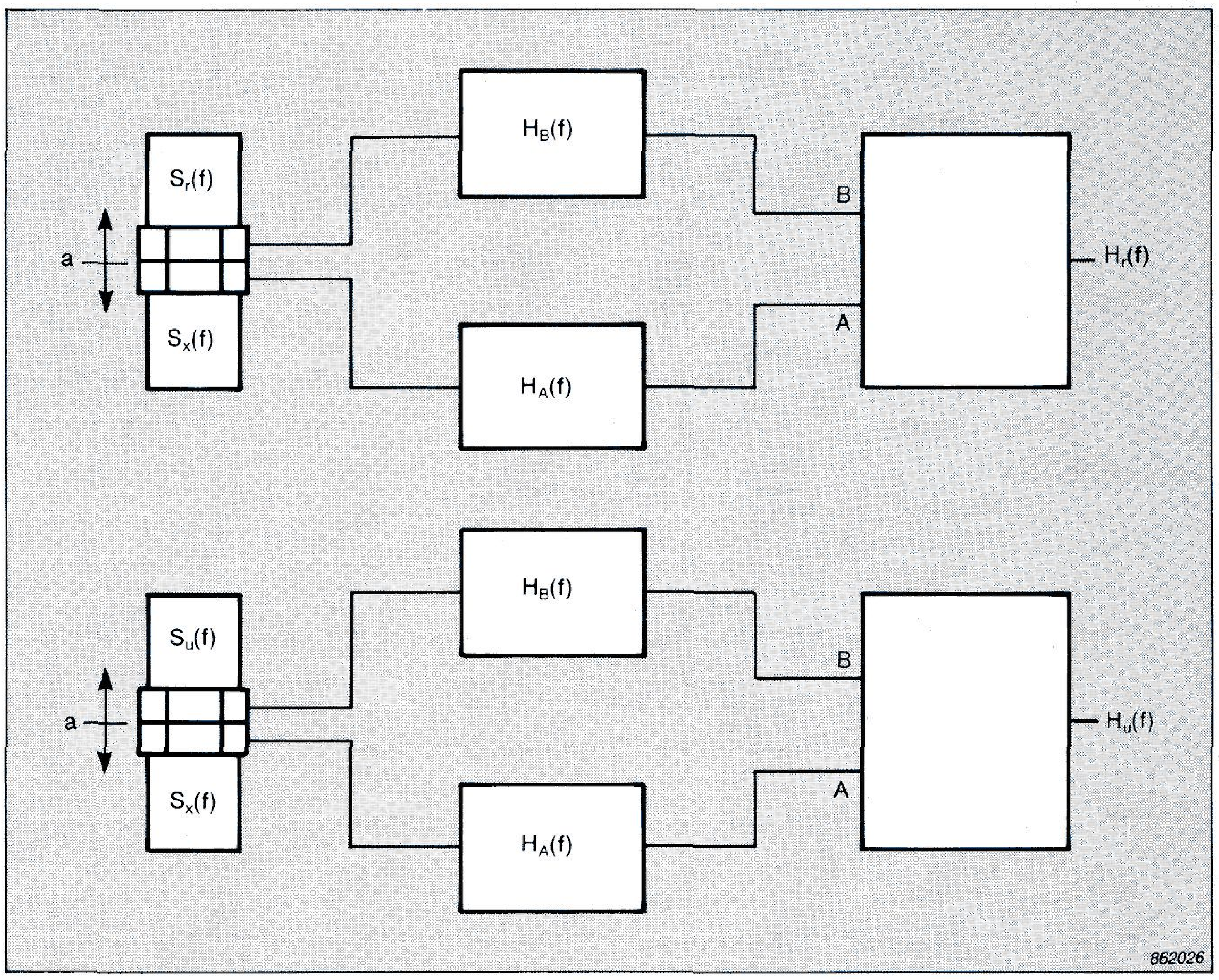


Fig. 2. Principle of the back-to-back calibration method using the correction by substitution method.

Advantages of using a random-noise based system

Back-to-back calibration of accelerometers, using FFT analysis for sensitivity comparison, is especially suitable for making frequency response checks against a standard reference accelerometer. If the Calibration Exciter Type 4290 is used, then accelerometer frequency responses up to 26 kHz can be checked.

The accuracy of the presented FFT-calibration technique, using the substitution method, is comparable to the accuracy attained by dedicated comparison systems. The calibration by substitution method produces results having uncertainties in the order of 1% with 99% confidence limits, for low to medium frequency measurements.

If your calibration standard requires the use of sine excitation, then the sine generator of the Type 2032 or Type 2034 can be used to make a point by point calibration. By making the calibration at frequencies corresponding to the actual analysis lines, and by using rectangular weighting, very accurate calibration results are attainable.

Conclusions

The Dual-Channel Signal Analyzers Type 2032 and 2034 offer an alternative approach to accelerometer calibration. By using broadband random noise excitation with the FFT calibration technique, accelerometers can be easily calibrated at 800 frequencies, with an accuracy comparable to traditional methods. This provides the opportunity for fast frequency response checking against a reference accelerometer, particularly when the analyzer is used in a computer based system.

Brüel & Kjær

WORLD HEADQUARTERS: DK-2850 Nærum · Denmark · Telephone: +45 2 80 05 00 · Telex: 37316 bruka dk

Australia (02) 450-2066 · Austria 02235/7550*0 · Belgium 02 · 242-97 45 · Brazil 246 8149 · Canada (514) 695-8225 · Finland (90) 80 17 044 · France (1) 64 57 20 10
Federal Republic of Germany (04106) 4055 · Great Britain (01) 954-2366 · Holland 03 402-39 994 · Hong Kong 5-487486 · Italy (02) 52 44 141
Japan 03-435-4813 · Republic of Korea 02-793-6886 · Norway 02-78 70 96 · Singapore 225 8533 · Spain (91) 268 10 00 · Sweden (08) 711 27 30 · Switzerland (042) 65 11 61
Taiwan (02) 713 9303 · USA (617) 481-7000 · Local representatives and service organisations world-wide

Printed in Denmark: K. Larsen & Søn A/S · DK-2600 Glostrup