4810

Instructions and Applications

ARKIV

Mini-Shaker
Type 4810

The Mini-Shaker is a small, extremely versatile vibration exciter which can be used in any position and over a wide frequency range.

BRÜEL & KJÆR

030-0144

MINISHAKER TYPE 4810

February 1971

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1. DESCRIPTION AND OPERATION

1.1 DESCRIPTION

This model is a small vibration exciter, stably constructed and easy to transport. It was designed primarily for calibrating accelerometers, but of course could also be set up for experimental and educational use. Its frequency range is wide enough for most applications and its motion is almost perfectly rectilinear, allowing less than 3% transverse acceleration up to 5 kHz. The vibrator table has a threaded hole (10—32 NF) which enables it to be connected to all B & K equipment. The construction of the Shaker is such that it can be used in any position.

1.2 CONSTRUCTION AND OPERATION

The cross-section in Fig.1.1 shows the construction of the 4810.

A Columnax permanent magnet is fastened to the bottom of the housing and projects up into the cylindrically shaped hollow of the vibration table. The driver coil is wound about the core element in such a way that it is always in the magnetic field. The homogeneous leaf springs stiffen the vibrating system and provide the steering action necessary to insure rectilinear vertical motion.

The housing, with the magnet and vibration element, is built into a protective case, within which the rubber washer between the vibrator table and the case acts as an elastic seal. A 10—32 NF threaded hole in the bottom of the housing allows the 4810 to be rigidly fixed into place.

A glimpse at electromagnetic theory provides the basis for the operation of the 4810. A sinusoidal current, taken from a generator at a chosen frequency and power, is fed into the coil winding. Consequently, an oscillating electrical field is set up, which overlays the permanent lines of magnetic force. The coil, therefore, carries out a mechanical movement. The direction of movement of the vibrator elements is vertical and symmetrical about the centerline of the Mini-Shaker.

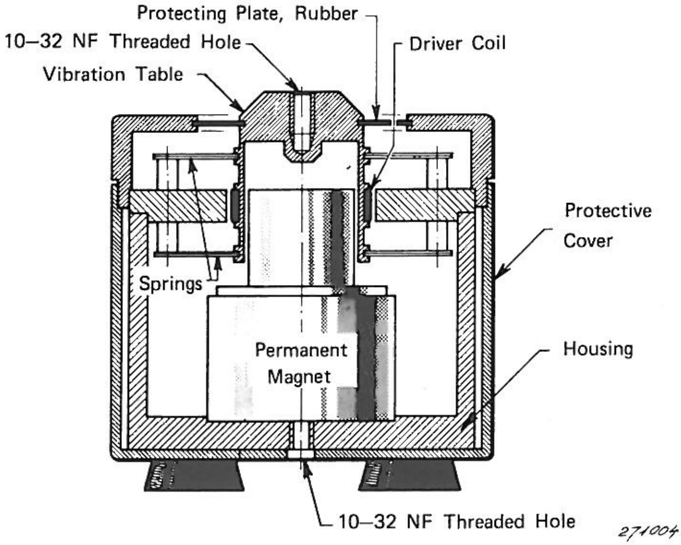

Fig. 1.1. Sectional drawing of the Mini-Shaker Type 4810.

The strength of the current flowing through the coil is a measure of the acceleration rate. From mechanics, it is known that:

1) $F = m \cdot a$

The force derived from the magnetic field by the current flowing in the coil at an angle of 90^o is:

2) $F = \overline{B} \cdot i \cdot l$

where
- F = Force in Newtons
- m = Mass of the Vibration Table, in kg.
- a = Acceleration, m/sec^2 (g = 9.806 m/sec^2)
- $\overline{B}$ = Vector of the magnetic flux, in Gauss
- i = Current through the coil, Amperes
- l = Length of conductor in magnetic field, Meters

If the expression for the magnetic force is substituted into Equation 1 and solved for a, the acceleration can be determined. There follows:

$$\overline{B} \cdot i \cdot l = m \cdot a$$

3a) $$a = \frac{\overline{B} \cdot i \cdot l}{m}$$

or

3b) $$g = \frac{\overline{B} \cdot i \cdot l}{9.806\ m}$$

2. CHARACTERISTICS

Fig.2.1 shows the typical frequency response of the 4810. The current i_d, voltage v_d, and impedance of the driver coil z_d, are plotted with respect to the frequency, for a constant acceleration rate of 1 g. One can see that, between 50 Hz and 60 Hz, the impedance rises and current drops, indicating a resonance peak. This is suspension resonance, occurring between the element and its fastening. There is a second peak at 18 kHz, which is the first major resonance peak of the moving element itself.

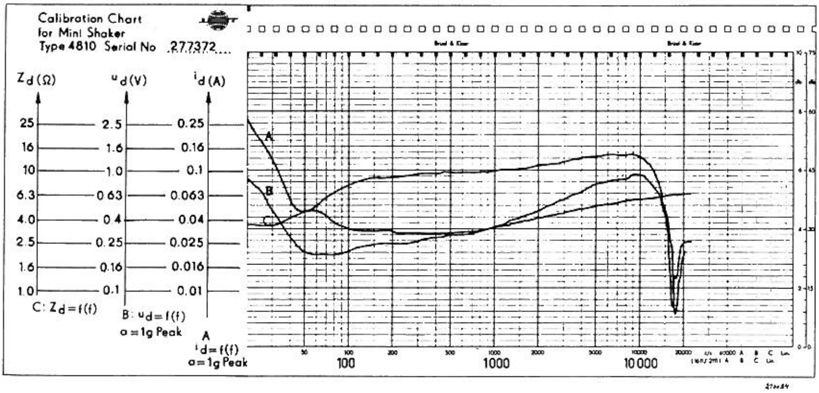

Fig.2.1. Impedance, current and voltage frequency responses of the Mini-Shaker Type 4810, loaded with an Accelerometer Type 4332 (30 g).

For the above chart, the vibration table was loaded with a 4332 Accelerometer, which weighs 30 grams, thus making a total effective mass of 48 g.

The resonant frequency is calculated in the following manner:

$$f_o = \frac{1}{2\pi} \sqrt{\frac{k}{m_o}}$$

where m_o is the effective mass and k is the spring constant. If one increases the original mass by a mass m_1, the resonant frequency is diminished to a new value f_1, as follows:

$$f_1 = f_o \sqrt{\frac{m_o}{m_1 + m_o}}$$

An increase, for example, of 10%, causes a reduction of the resonant frequency of around 5%.

3. APPLICATIONS

Because of its small size, light weight, and ability to be used in any position, the mini-shaker is very versatile and possibilities for its application are almost unlimited. While it would not be practical to thoroughly cover the possibilities, a few examples will be cited.

Foremost among its uses, of course, is that of accelerometer calibration.

ACCELEROMETER CALIBRATION

Fig.3.1 shows the set-up for relative calibration of an accelerometer at a fixed frequency.

The reference accelerometer is mounted on the mini-shaker and the accelerometer to be calibrated is affixed to it. A signal is fed to the mini-shaker by a beat frequency oscillator, and the resulting output voltages from the accelerometers are amplified and compared on a measuring amplifier. The voltage difference in dB is then equal to the ratio in dB between the respective sensitivities of the accelerometers, and the unknown sensitivity can be calculated in mV/g from the known value of the reference accelerometer.

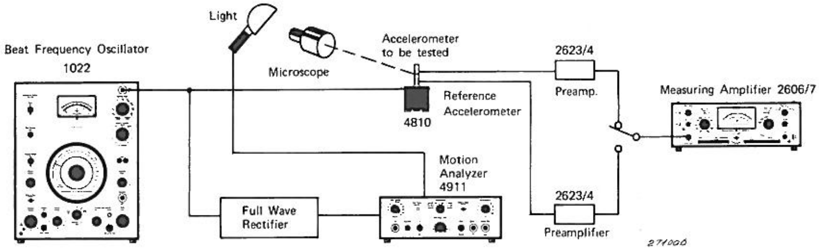

Fig.3.1. Arrangement of apparatus for calibration of accelerometers.

During calibration, the exact vibration amplitude can be determined with the aid of the Brüel & Kjær 4911 Motion Analyzer.

With the full-wave rectifier acting as a frequency doubler, the motion analyzer can be adjusted so that it illuminates a point on the accelerometer at maximum amplitude in both directions. The point then appears to the eye as two static dots. The distance between these dots can be measured with a microscope and is equal to the amplitude of the vibration.

MEASUREMENT OF THE COMPLEX MODULUS OF ELASTICITY

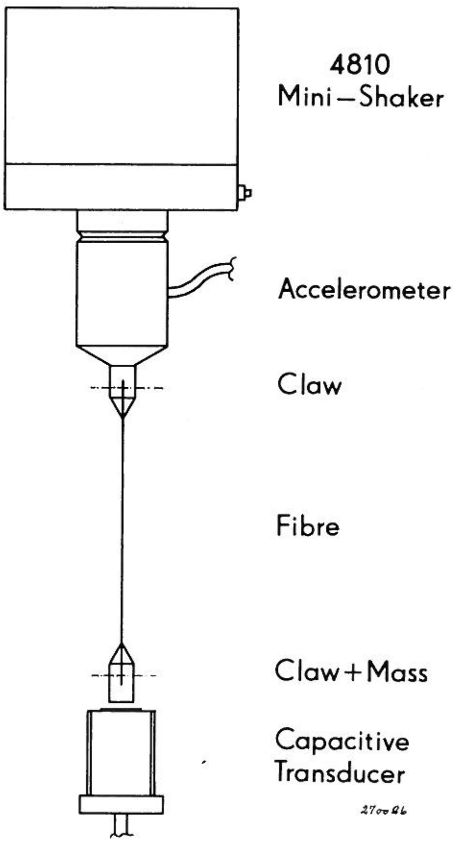

Fig.3.2. Experimental set-up for the determination of the complex modulus of a fiber.

Under static conditions the modulus of elasticity of a material is defined simply as the ratio of stress to strain. Under dynamic conditions, internal and external friction causes a phase shift between stress and strain. Hence the modulus is expressed as a complex quantity:

$$E = E'(1 + jd)$$

where d = loss factor = tan δ
and δ = the phase shift caused by friction.

The real part of the equation, E', can be found at the resonant frequency of a sample of the material, and the loss factor, d, can be determined by stopping the vibration force instantly and measuring the decay time for a set drop in amplitude. The arrangement of the specimen and the test apparatus for the determination of the complex modulus is shown in Fig.3.2.

The specimen is suspended from an accelerometer attached to the mini-shaker. At the lower end of the specimen is attached a mass. Just below this mass, with a gap of approximately 1 mm, is a capacitive transducer. Changes

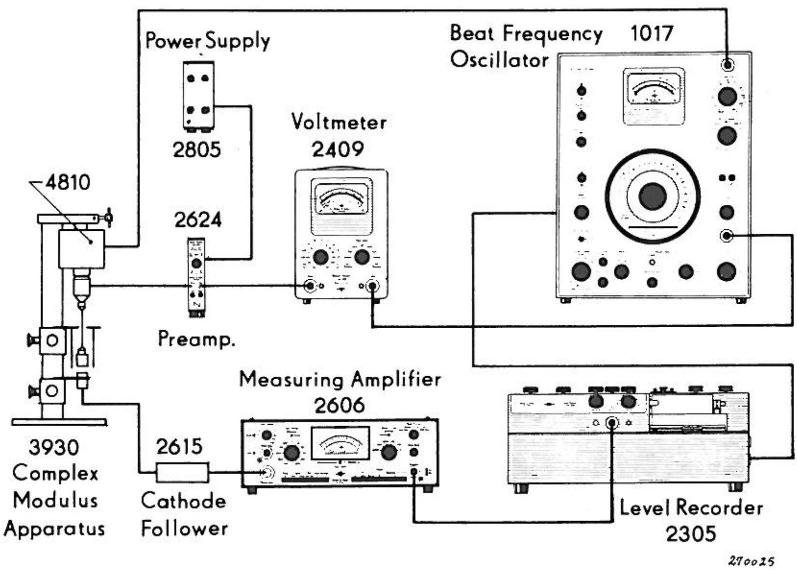

Fig.3.3. Schematic diagram for measurement of complex modulus of elasticity.

in length of the specimen are reflected as changes in capacitance and hence can be shown as voltage changes.

The complete layout of equipment for measuring the complex modulus of elasticity is shown in Fig.3.3.

MEASUREMENT OF MECHANICAL IMPEDANCE

Mechanical impedance is a measure of the motion of a mechanical structure to an applied sinusoidal force. It is equal to the ratio of the applied force to the resulting velocity, or $\overline{Z} = \frac{\overline{F}}{\overline{V}}$

This quantity can be obtained directly with the aid of the Impedance Head Type 8001. The Impedance Head features a built-in accelerometer coupled with a piezoelectric force gage. (See Fig.3.4).

Fig.3.4. Impedance Head Type 8001.

The Impedance Head can be mounted directly onto the mini-shaker and the entire assembly then mounted to whatever object or structure is to be studied. As the dynamic force is applied by the mini-shaker, the force gage in the impedance head measures it. Simultaneously, information from the accelerometer is fed to an integrator. Thus, the force and the resulting velocity are measured at the same instant.

The Artificial Mastoid Type 4930 is developed for objective calibration of bone vibrators of the type used in bone conduction hearing aids. Among its requirements, it must have the same mechanical impedance as the average human mastoid over the frequency range 125 Hz to 4000 Hz. The mechanical impedance of artificial mastoids is found as shown in Fig.3.5, where a special medical impedance head Type 8000 is used. The Impedance Head Type 8000 is also very well suited for measurements on human mastoids or foreheads. The number 3505 refers to the complete set, consisting of Shaker, Impedance Head and Artificial Mastoid. The mass below the force gage of the Impedance Heads Type 8000 and Type 8001 is only 1 gram and is electrically cancelled by means of the Mass Compensating Unit Type 5565. A constant velocity level is obtained by using the compressor circuit of the Beat Frequency Oscillator. The acceleration signal from the impedance head is fed through a preamplifier and the mass compensating unit and integrated to a velocity signal in the Vibration Pick-up

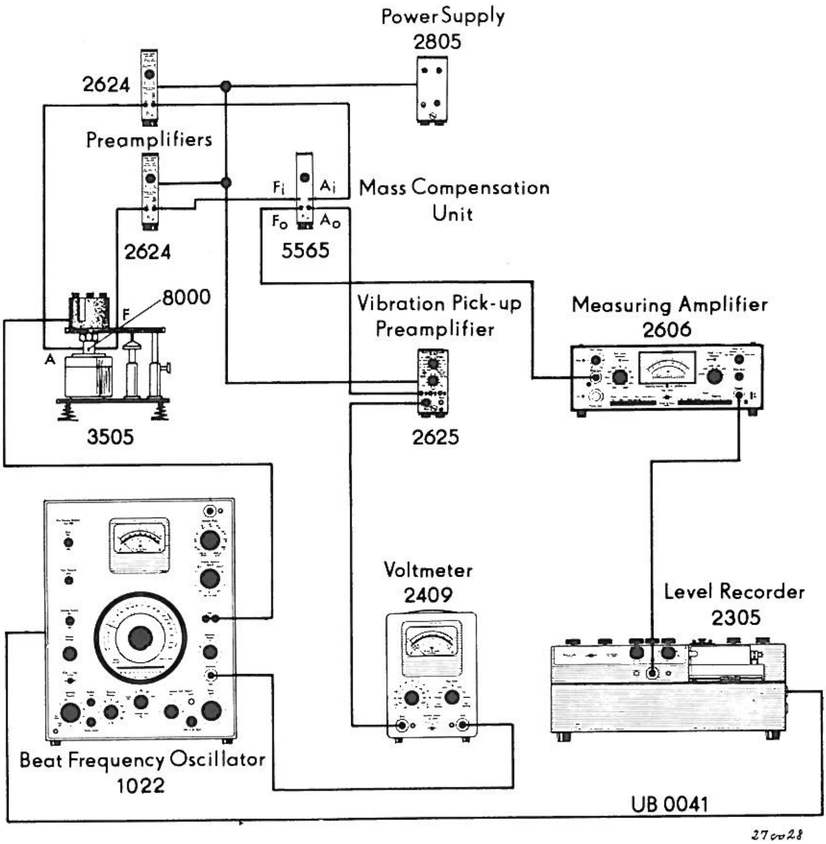

Fig.3.5. Set-up for the measurement of mechanical impedance.

Preamplifier Type 2625. The value of the mechanical impedance is displayed on calibrated impedance paper on the Level Recorder Type 2305. To obtain the reactance and resistance the phase angle between the force and velocity signals can be measured by using a phasemeter or an oscilloscope.

DEMONSTRATIONS

For educational purposes, the 4810 could be mounted to any small object or model whose vibration characteristics are to be studied. For instance, Fig.3.6 shows six blades of different lengths all mounted onto the shaker. As the Beat Frequency Oscillator is swept through a certain range of frequencies, each of the blades in turn reaches resonance. With the aid of the Motion Analyzer, the amplitudes of each blade at the resonant or any other frequency can also be studied.

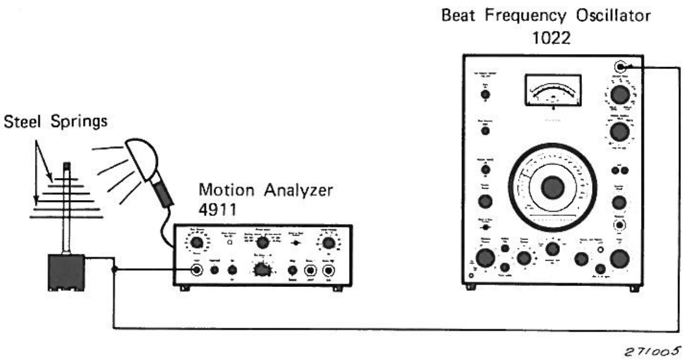

Fig.3.6. Assembly of Mini-Shaker and Motion Analyzer for demonstration purposes.

4. ACCESSORIES

AO 0069 Coaxial, screened cable with 3 pin plug. The plug has a dummy pin in the centre so that it can be plugged into the Beat Frequency Oscillator but cannot be accidently plugged into the mains.

YQ 2960 Five threaded steel studs, 10–32 NF.

5. SPECIFICATIONS 4810

Frequency Range:	20 Hz to 18 kHz.
First Major Armature Resonance:	Above 18 kHz.
Force Rating Vector: (PEAK)	10 Newtons (2.25 lbs) (65 Hz– 4 kHz) 7 Newtons (1.5 lbs) (65 Hz–18 kHz)
Max. Bare Table Acceleration:	50 g (65 Hz – 4 kHz) 35 g (65 Hz – 18 kHz) 1 g = 9.81 m/sec^2
Stroke:	± 3 mm (0.12 inch)
Flexure Stiffness:	20 Newton/cm (12 lbs/inch).
Effective Weight of the Moving System:	18 g.
Magnetic Field:	Columnax permanent magnet.
Max. Input Current:	1.6 A. 1.8 RMS
Coil Impedance:	3.5Ω at 500 Hz.
Distortion:	1% from 150 Hz to 1000 Hz at 10 g acceleration.
Connection:	Microplug NF 10–32.
Total Shaker Weight:	1.1 kg (2.4 lbs).
Temperature Range:	0^o – 50^oC
Relative Humidity:	0 – 100%.
Dimensions:	Diameter 76 mm (3 inch). Height 75 mm (2.9 inch).

Pay Load Capacity in Grams:	65 Hz – 4 kHz	65 Hz – 18 kHz
10 g peak	80	50
20 g peak	35	15

B & K INSTRUMENTS:

ACOUSTICAL....
Condenser Microphones
Piezo-Electric Microphones
Microphone Preamplifiers
Microphone Calibration Equip.
Sound Level Meters
(general purpose-precision-and impulse)
Standing Wave Apparatus
Tapping Machines
Noise Limit Indicators

ELECTROACOUSTICAL....
Artificial Ears
Artificial Mouths
Artificial Mastoids
Hearing Aid Test Boxes
Telephone Measuring Equipment
Audiometer Calibrators
Audio Reproduction Test Equip.

STRAIN....
Strain Gauge Apparatus
Multipoint Panels
Automatic Selectors
Balancing Units

VIBRATION....
Accelerometers
Accelerometer Preamplifiers
Accelerometer Calibrators
Vibration Meters
Magnetic Transducers
Capacitive Transducers
Vibration Exciter Controls
Vibration Programmers
Vibration Signal Selectors
Mini-Shakers
Complex Modulus Apparatus
Stroboscopes

GENERATING....
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators

MEASURING....
Measuring Amplifiers
Voltmeters
Deviation Bridges
Megohmmeters

ANALYZING....
Band-Pass Filter Sets
Frequency Spectrometers
Frequency Analyzers
Real-Time Analyzers
Slave Filters
Psophometer Filters
Statistical Analyzers

RECORDING....
Level Recorders
(strip-chart and polar)
Frequency Response Tracers
Tape Recorders

BRÜEL & KJÆR
DK-2850 Nærum, Denmark. Teleph.: (01) 80 05 00. Cable: BRUKJA, Copenhagen. Telex: 5316

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