TECH NOTE #119:: Integrated Electronics Piezo-Electric Sensing

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Abstract

Piezoelectric sensors with integrated electronics explained.

Intro

The abbreviation **IEPE** stands for **I**ntegrated **E**lectronics **P**iezo-**E**lectric. It characterises a technical standard for piezoelectric sensors which contain built-in impedance conversion electronics with constant current supply.

IEPE sensors are used to measure acceleration, acoustics, force or pressure.

Other proprietary names for the same principle include:

- Constant-Current Line-Drive (**CCLD**)
- Integrated Circuit Piezo-Electric (**ICP®**)
- IsoTron
- DeltaTron

The integrated electronic amplifier of the IEPE sensor converts the high-impedance signal of the piezoelectric material (quartz crystals), which experiences small charge changes due to motion, into a voltage signal with a low impedance. Special low-noise cables are not necessary.

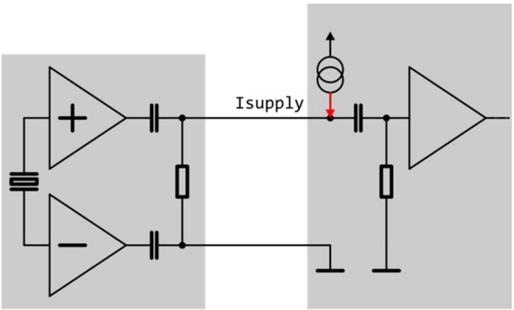
The sensor circuit is supplied with a constant current of typically to 6 mA. In the inactive state, the sensors produce a constant DC bias voltage (zero voltage/U_{bias}) typically ranging between 7 and 14 V. Depending on the physical signal of the sensor, an analogue AC voltage generated proportionally to the movement is added to the sensor's Ubias; e.g. a 10 Hz sinusoidal deflection with an amplitude of 1 g (= 9.81 m/s2) produces a 10 Hz sinusoidal output voltage of U_{bias} +/- 10 mV in the case of a sensor with a sensitivity of 10 mV/g. A sensor’s maximum output signal is usually U_{bias} +/- 5 V. Typically the DAQ input offers a compliance voltage of 20 to 25 V and a power consumption of 100 mW per channel. Low-power IEPE sensors are also available, which can be operated at only 0.1 mA constant current from a 12 V supply.

A distinguishing feature of the IEPE principle is that the power supply and the sensor signal are transmitted via one shielded wire (coax) that is typically connected via BNC or µdot to a device or embedded in another electronics. Longer cable lengths result in increasing cable capacitance (typically 100 pF/m) so that the control capability of the integrated amplifier drops with increasing signal frequency. This can be partly compensated for by increasing the supply current.

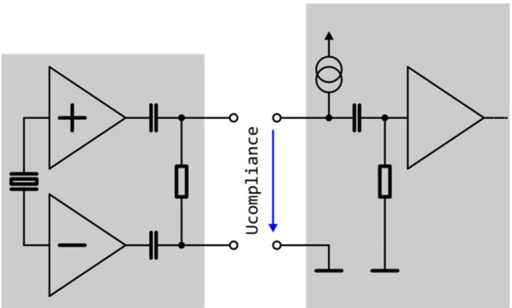
In our HBK measurement instruments, the IEPE sensor’s bias voltage is used for sensor detection. A signal close to the saturation voltage indicates a short-circuit in the sensor or cable. In between these two limits a functional sensor has been detected. The bias voltage is cut off by a coupling capacitor at the instrument input and only the AC signal is processed further.

Pure charge-based sensors without embedded sensor electronics can be found in applications with high operating temperatures, an extremely large dynamic range, energy-saving operation or where an extremely small design is required. Charge-based sensors show a drift. In extremely low-dynamic and quasi-static measurements of acceleration, force or pressure, other technologies are much better and more established.

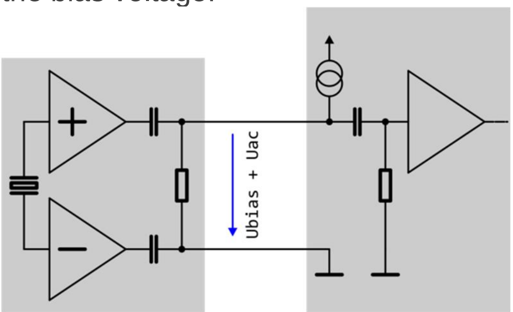
Supply Current
The constant current supplied by the amplifier is known as the supply current or excitation current:



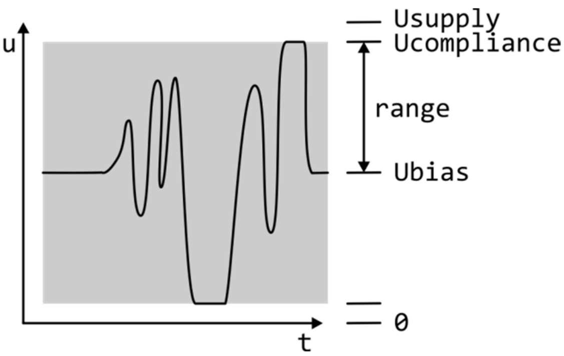
Compliance voltage
The current source's open-circuit voltage is known as the compliance voltage:



Bias voltage
The DC voltage drop across the sensor's internal resistance due to the supply current is known as the bias voltage:



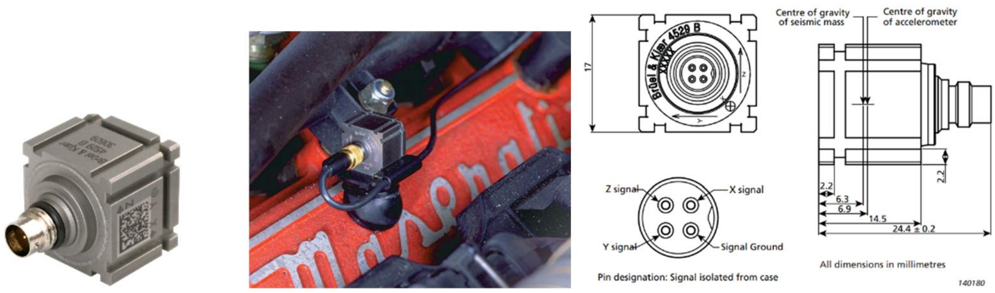
Signal Range
The overall voltage can be seen as a combination of the above:



Accelerometers

IEPE-type acceleration sensors or accelerometers are available as uniaxial or triaxial (x, y, z) accelerometers with a common mass.

Example: Brüel & Kjær **Type 4529-B**



Pictures: Brüel & Kjær Type 4529-B triaxial CCLD accelerometer with bar code for orientation scan with an app

Typical Features

- Easily fitted to different test objects using a selection of mounting clips
- Hermetically sealed and robust titanium housing
- Electrically insulated for ground loop protection
- Transducer Electronic Data Sheet (TEDS) saves set-up time

Typical Sensor Datasheet/Specifications

- Frequency range: 0.3 – 12800 Hz
- Sensitivity: 10 $\frac{mV}{m/s^2}$
- Measuring range: ±50 g
- Constant current supply: 2 to 10 mA
- Output impedance: <2 Ω
- DC output bias voltage: DC 12 ± 1 V
- TEDS
- Temperature operating range: -60 – 125 C
- Weight: 14.5 gram
- Maximum Operational Level (peak): 71 g
- Maximum Shock Level (± peak): 5100 g
- Electrical connector: 4-pin
- Triaxial: yes
- Typical applications: automotive, modal, general-purpose

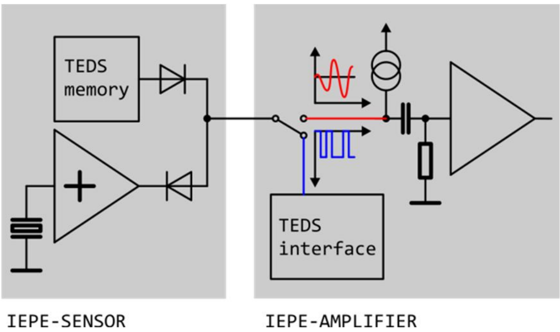
TEDS

TEDS stands for **T**ransducer **E**lectronic **D**ata**s**heet, which is a sensor-integrated memory chip that contains information regarding the sensor characteristics and meta information allowing clear traceability.

Using an “intelligent sensor” with integrated IEEE 1451-standardized TEDS technology provides many advantages:

- Information is fully integrated and cannot get lost / no paper
- Automatic and quick channel configuration right after plugging in the sensor
- Minimizing faults in use and thus enhancing quality

IEEE 1451 describes the memory structure and the interface. Part 4 of this standard describes a subgroup of TEDS sensors that can be used at IEPE inputs. The memory can be accessed via the signal cable using a sequence of negative logic pulses. If, however, the sensor is supplied with constant current, it works like a standard IEPE sensor.



The IEPE sensor comprises, for instance, the DS2430A TEDS chip with a 1-Wire® interface from Dallas/Maxim. This memory is subdivided into a 64-bit ROM area (OPT application register) that can be written to only once and a 256-bit EEPROM area that can be rewritten. The application register, which is known as the “basic TEDS”, contains data stored by the manufacturer that cannot be modified:

- Manufacturer code
- Type identifier
- Version number
- Version letter
- Serial number

Whereas the EEPROM contains data that can be modified by the user for calibration purposes. The data types and data structure depend on the TEDS template that is being modified. Standard templates are available on the IEEE server: http://standards.ieee.org/regauth/1451

Furthermore, there are manufacturer-specific templates available. Amplifiers for IEPE sensors often support templates #25 for piezoelectric acceleration sensors and force transducers as well as templates #27 and #28 for measurement microphones. These templates allow specification with and without the transfer function depending on a control bit.

HBM Amplifiers

QuantumX/SomatXR MX840B/MX840B-R

- Signal bandwidth: 7.7 kHz @ 40 kS/s with linear phase filter
- Transducer excitation: 4 mA
- Measuring range: AC ±10 V
- Compliance voltage: typ. 21 V
- Internal resistance of connected voltage source: < 2.5 kΩ

QuantumX/SomatXR MX410B/MX411B-R

- Signal bandwidth: 38 kHz @ 100 kS/s or 78 kHz @ 200 kS/s in two-channel mode
- Transducer excitation: 4 mA
- Measuring ranges: AC ±2 V; AC ±10 V
- Compliance voltage: typ. 21 V
- Permissible internal resistance of connected voltage source, typ.: 2.5 kΩ

Other amplifiers such as the MX1601B/-R provide the same input type, but a different signal bandwidth.

Frequently Asked Questions

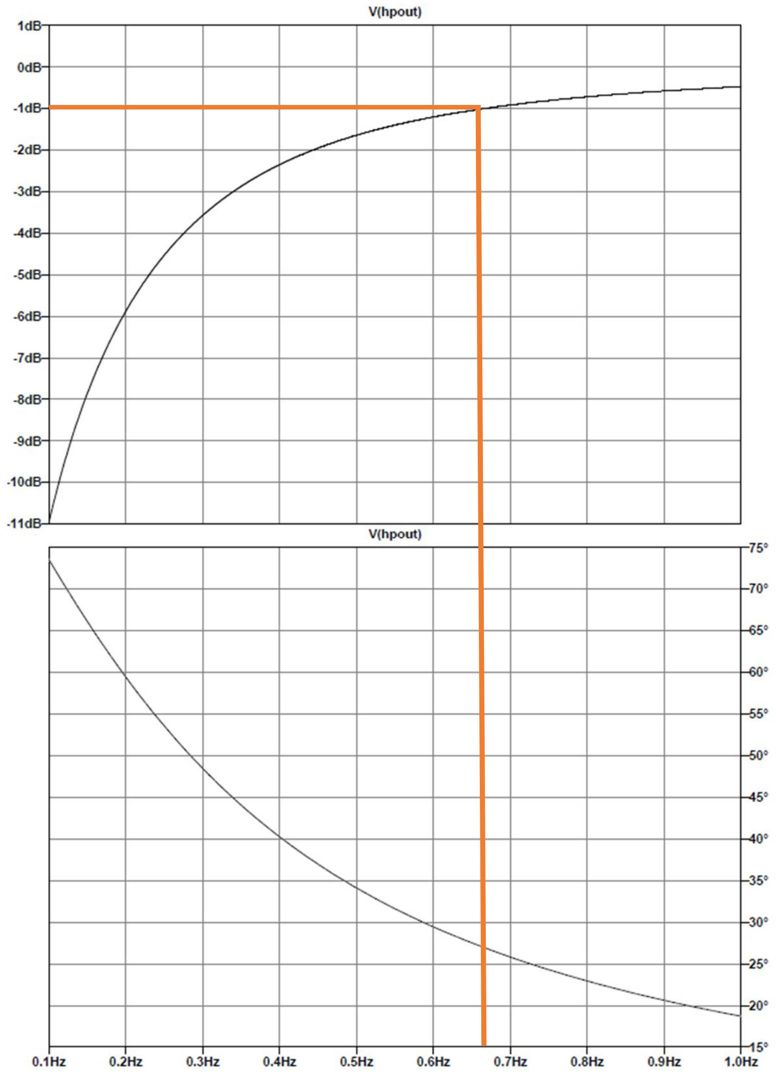
Q: What is the Brüel & Kjær Type 4524 sensor's min/max span and does it match the MX840B?
A: Sensor min: 6 V – 5 V = 1 V, Sensor max: 13 V + 5 V = 18 V. MX840B: Compliance voltage = 21 V. Yes, it can be used.

Q: Does TE Connectivity 7104A match the MX804B?
A: Yes, TE 7104A can be supplied between 2 to 10 mA. Yes, it can be used.

Q: What is the sensor's TE 7104A overall voltage output and does it match the MX840B input?
A: TE 7104A: ±50 g; 100 mV/g → ± 5 V. The sensor voltage output range is between 6 and 13 V. Yes, it can be used with MX840B.

Q: In the MX1601B datasheet you show that the frequency range starts from 0.34 Hz @ -3 dB due to the built-in high-pass filter. What is the lowest signal frequency I can measure with -1 dB?

Module Frequency curve and -1dB line:



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