TECH NOTE :: Integrated Electronics Piezo-Electric Sensing (IEPE)

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Abstract

Sensors based on piezo-electric and with integrated electronics explained in detail.

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.

There are also proprietary names for the same principle:
- Integrated Circuit Piezo-Electric (**ICP®**)
- Constant-Current Line-Drive (**CCLD**)
- IsoTron
- DeltaTron

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

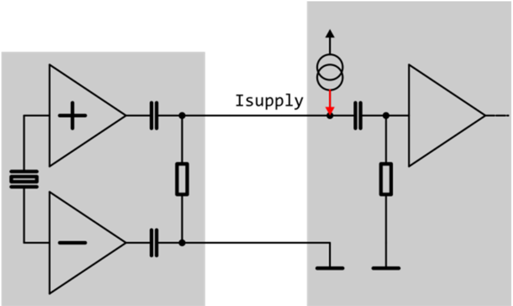
The sensor circuit is supplied with constant current of typically 220 mA. In inactive state they produce a constant DC bias voltage (zero voltage/U_{bias}) between typically 7…14 V. Depending on the physical signal of the sensor, an analog AC voltage generated proportionally to the movement is added to the sensor's U_{bias}; 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. The maximum output signal of a sensor is usually U_{bias} +/- 5 V. Typically the DAQ input offers a 20 … 25 V compliance and a power consumption of 100 mW per channel. There are also low-power IEPE sensors 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) and is typically connected via BNC or µdot to a device or embedded in another electronics. Increasing cable length results 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 by increasing the supply current.

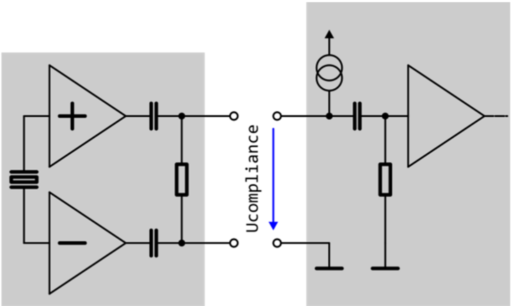
In our HBK measurement instruments the bias voltage of the IEPE sensor is used for sensor detection. A signal close to the saturation voltage, indicates a short-circuit in the sensor or cable. In between these two limits a functional sensor has been detected. The bias voltage is cut off by a coupling 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 extremely small design is required. Charge-based sensors drift. In extremely low dynamic and quasi static measurements of acceleration, force or pressure other technologies are much better and more established.

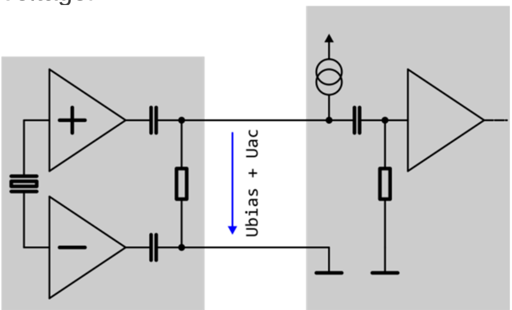
Supply Current
The constant current supplied by the amplifier is known as the supply current or excitation current:



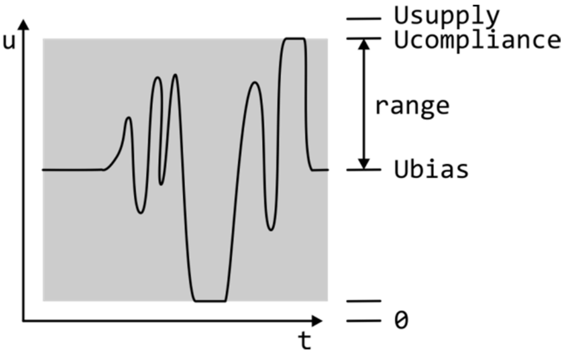
Compliance voltage
The current source's open-circuit voltage is known as the compliance voltage:



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



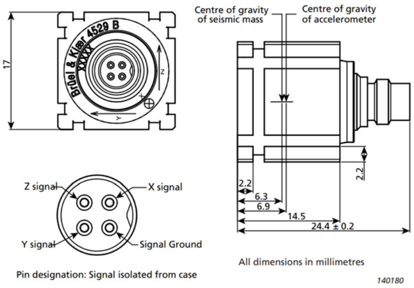
Signal Range
The overall voltage can be seen as a combination of the above parts:



Accelerometers

IEPE type of acceleration sensors or accelerometers come along with single direction or triaxial direction (x, y, z) 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 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 / Specification

- 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

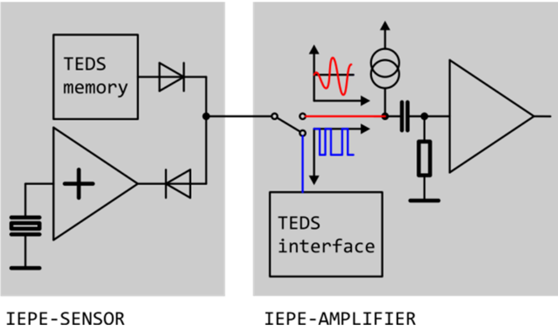
TEDS stands for **T**ransducer **E**lectronic **D**ata**s**heet which is basically a sensor integrated memory chip that contains information regarding the sensor characteristics and meta information allowing clear traceability.

There are many advantages using “intelligent sensor” with an integrated IEEE 1451 standardized TEDS technology:

- information is fully embedded and cannot get lost / no paper

- automatic and quick channel configuration right after plugging in the sensor
- minimizing faults in use and thus winning 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.

HBK 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: 29.25kHz @ 100 kS/s or 59.5 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 are MX1601B / -R which come along with the input type, but different signal bandwidth.

Frequently Asked Questions

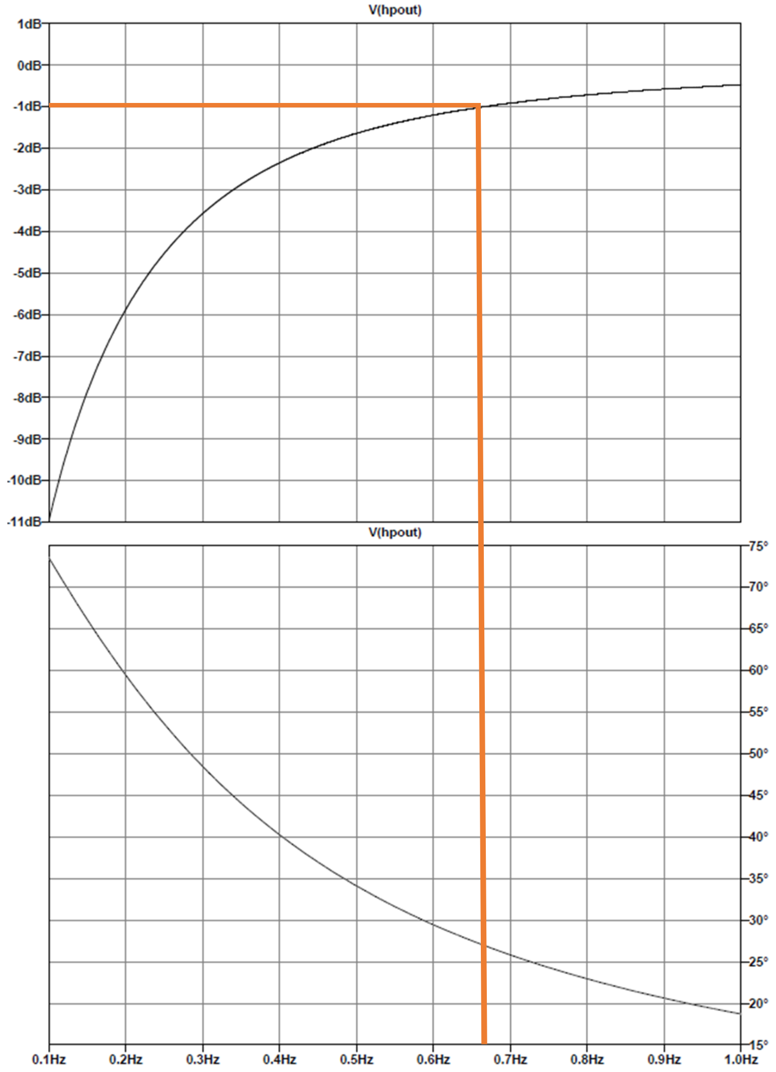
Q: What is the Brüel & Kjær Type 4524 sensor's min/max span and does it fit MX840B?
A: Sensor min: 6 V – 5 V = 1 V, Sensor max: 13 V + 5 V = 18 V. MX840B: Compliance voltage = 21 V. So OK.

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

Q: What is the sensor's TE 7104A overall voltage output and does it fit to MX840B input?
A: TE 7104A: ±50 g; 100 mV/g → ± 5 V. So the sensor voltage output range is between 6 to 13 V. So 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?

Modules Frequency curve and -1dB line:



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