

Instrumentation

1. Transducers with Charge Output

Transducers with charge output have some special properties which require particular attention in order to obtain precise measuring results:

- Always use special low noise cables.
- The cable length must not exceed 10 meters.
- The cable should not be moved during measurement.
- All connector nuts must be tightened.

Preferably charge amplifiers should be used. It is also possible to use AC voltage amplifiers with high impedance input. Both principles are described below.

1.1 Charge Amplifiers

Accelerometers with charge output generate an output signal in the range of some picocoulombs ($1 \text{ pC} = 1000 \text{ fC}$) with a very high impedance. To process this signal by standard AC measuring equipment it needs to be transformed into a low impedance voltage signal.

Preferably, charge amplifiers are used for this purpose. The input stage of a charge amplifier features a capacitive feedback circuit which balances the effect of the applied charge input signal. The feedback signal is then a measure of input charge. Figure 10 shows a typical charge input stage.

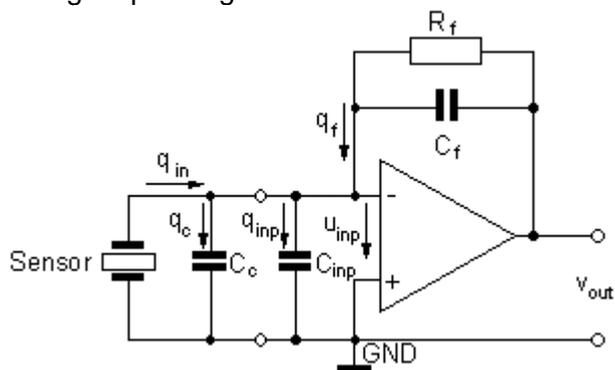


Figure 10: Charge amplifier

The input charge q_{in} is applied to the summing point (inverting input) of the amplifier. It is distributed to the cable capacitance C_c , the amplifier input capacitance C_{inp} and the feedback capacitor C_f . The node equation of the input is therefore:

$$q_{in} = q_c + q_{inp} + q_f$$

Using the electrostatic equation:

$$q = u \cdot C$$

and substituting q_c , q_{inp} and q_f :

$$q_{in} = u_{inp} \cdot (C_c + C_{inp}) + u_f \cdot C_f$$

Since the voltage difference between the inverting and the non-inverting input of a differential amplifier becomes zero under normal operating conditions, we can assume that the input voltage of the charge amplifier u_{inp} will be equal to GND potential. With $u_{inp} = 0$ we may simplify the equation:

$$q_{in} = u_f \cdot C_f$$

and solving for the output voltage u_{out} :

$$u_{out} = u_f = \frac{q_{in}}{C_f}$$

The result clearly shows that the output voltage of a charge amplifier depends only on the charge input and the feedback capacitance. Input and cable capacitances have no influence on the output signal. This is a significant fact when measuring with different cable lengths and types.

Referring to Figure 10, the feedback resistor R_f has the function to provide DC stability to the circuit and to define the lower frequency limit of the amplifier. The circuit in Figure 10 represents only the input stage of a charge amplifier. Other stages like voltage amplifiers, buffers filters and integrators are not shown.

1.2 High-Impedance AC Voltage Amplifiers

Instead of charge amplifiers, high impedance voltage amplifiers can be used with charge mode transducers. In this case, however, the capacitances of sensor, cable, and amplifier input must be considered (Figure 11).

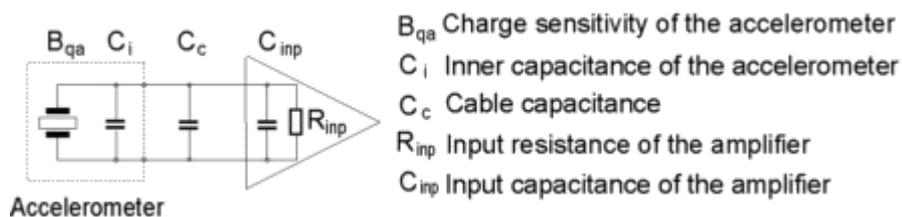


Figure 11: Charge mode sensor at voltage amplifier

The voltage sensitivity of an accelerometer with known charge sensitivity B_{qa} and inner capacitance C_i is calculated to:

$$B_{ua} = \frac{B_{qa}}{C_i}$$

B_{qa} and C_i can be found in the sensor data sheet.

Taking into account the capacitance of the sensor cable C_c and the input capacitance C_{inp} of the voltage amplifier, the resulting voltage sensitivity B'_{ua} will become lower than B_{ua} :

$$B'_{ua} = B_{ua} \frac{C_i}{C_i + C_c + C_{inp}}$$

A typical 1.5 m low noise cable has a capacitance of approximately 135 pF.

The lower frequency limit f_l will also be influenced by C_c , C_{inp} and R_{inp} :

$$f_l = \frac{1}{2 \pi R_{inp} (C_i + C_c + C_{inp})}$$

The lower frequency limit increases with decreasing input resistance.

Example : A charge mode accelerometer with inner capacitance $C_i = 370$ pF is connected to a typical scope input with $R_{inp} = 10$ MOhms and $C_{inp} = 20$ pF. The sensor cable has a capacitance of 135 pF.

Result: The lower frequency limit will be at about 30 Hz.

2. IEPE Transducers

A special feature of IEPE compatible transducers is that power supply and measuring signal are transmitted via the same cable. So, an IEPE compatible transducer requires, like a transducer with charge output, only one single-ended shielded cable.

Figure 12 shows the principle circuit diagram.

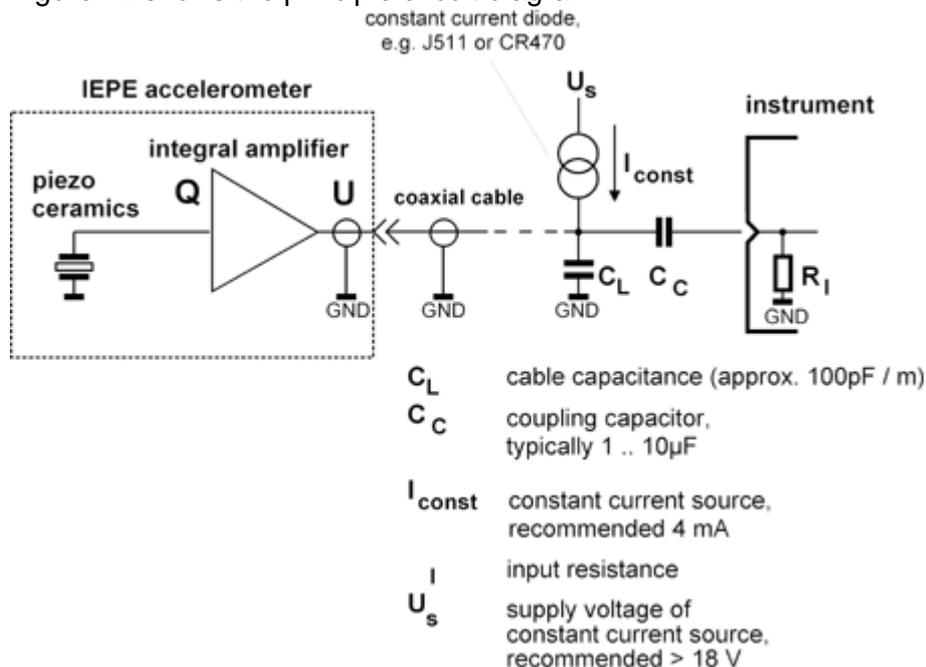


Figure 12: IEPE principle

The integrated sensor electronics is powered with constant current in the range between 2 and 20 mA. A typical value is 4 mA. Some battery powered instruments even work at 1 mA.

The constant current I_{const} is fed into the signal cable of the sensor. The supply current and the length of the cable may influence the upper frequency limit.

The de-coupling capacitor C_c keeps DC components away from the signal conditioning circuit. The combination of C_c and R_{inp} acts as a high pass filter. Its time constant should be sufficiently high to let all relevant low frequency components of the sensor signal pass.

Important:

- Do not apply a voltage source without constant current regulation to an IEPE transducer.
- False polarization of the sensor cable may immediately destroy the built-in electronics.

In Figure 13 can be seen that IEPE compatible transducers provide an intrinsic self-test feature. By means of the bias voltage at the input of the instrument the following operating conditions can be detected:

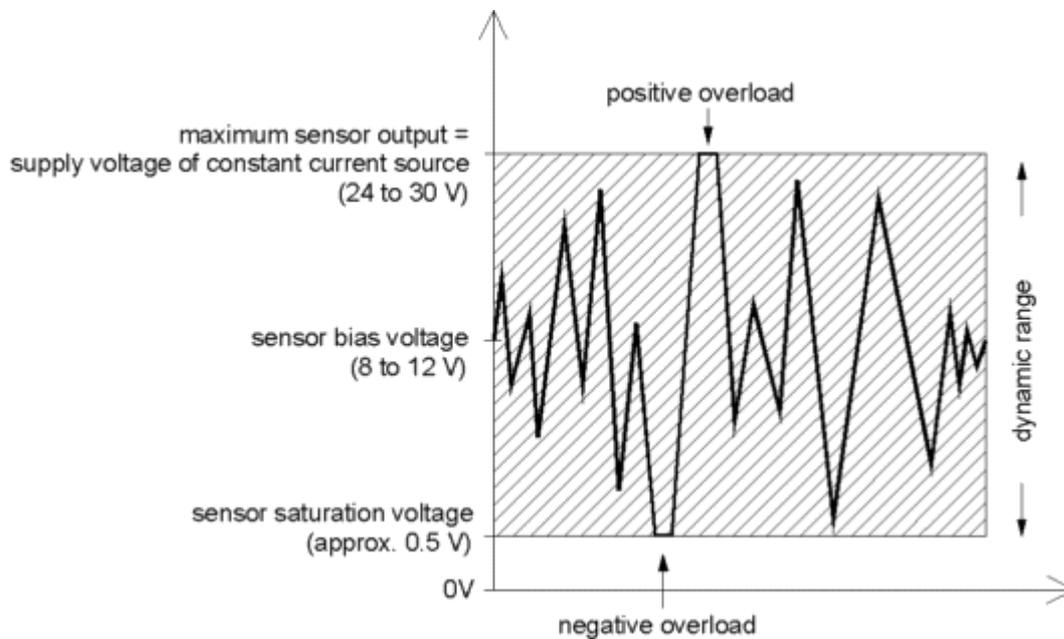


Figure 13: Dynamic range of IEPE compatible accelerometers

In Figure 13 can be seen that IEPE compatible transducers provide an intrinsic self-test feature. By means of the bias voltage at the input of the instrument the following operating conditions can be detected:

- $U_{BIAS} < 0.5$ to 1 V: short-circuit or negative overload
- 1 V $< U_{BIAS} < 18$ V: O.K., output within the proper range
- $U_{BIAS} > 18$ V: positive overload or input open (cable broken or not connected)

A variety of instruments are equipped with a constant current sensor supply. The constant current source may also be a separate unit.

3. Intelligent Accelerometers to IEEE 1451.4 (TEDS)

3.1 Introduction

The standard IEEE 1451 complies with the increasing importance of digital data acquisition systems. IEEE 1451 mainly defines the protocol and network structure for sensors with fully digital output. Part IEEE 1451.4, however, deals with "Mixed Mode Sensors", which have a conventional IEPE compatible output, but contain in addition a memory for an "Electronic Data Sheet". This data storage is named "TEDS" (Transducer Electronic Data Sheet). The memory of 64 + 256 bits contains all important technical data which are of interest for the user. Due to the restrictions of memory size the data is packed in different coding formats. The Transducer Electronic Data Sheet provides several advantages:

- When measuring at many measuring points it will make it easier to identify the different sensors as belonging to a particular input. It is not necessary to mark and track the cable, which takes up a great deal of time.
- The measuring system reads the calibration data automatically. Till now it was necessary to have a data base with the technical specification of the used transducers, like serial number, measured quantity, sensitivity etc.
- The sensor self-identification allows to change a transducer with a minimum of time and work ("Plug & Play").
- The data sheet of a transducer is a document which often gets lost. The so called TEDS sensor contains all necessary technical specification. Therefore, you are able to execute the measurement, even if the data sheet is just not at hand.
- The standard IEEE 1451.4 is based on the IEPE standard. Therefore, TEDS transducers can be used like common IEPE transducers.

Figure 14 shows the principle of TEDS.

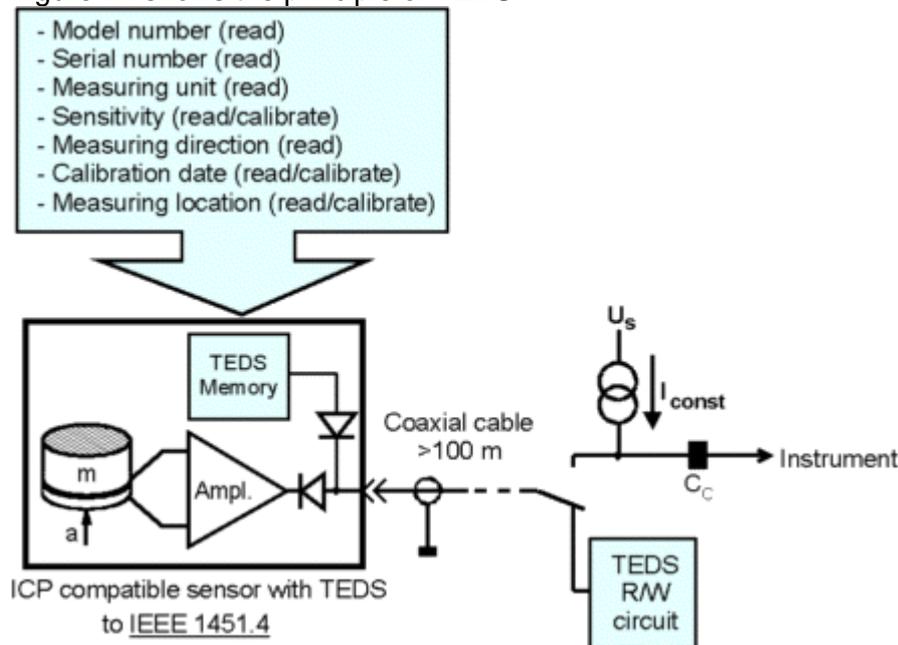


Figure 14: Accelerometer with TEDS to IEEE 1451.4

If a constant current source is applied, the sensor will act like a normal IEPE compatible sensor. Programming and reading the built-in non-volatile 64 + 256 Bit memory DS2430 is also done via the sensor cable.

The communication uses Maxim's 1-Wire® protocol (www.ibutton.com). For data exchange TTL level with negative polarity is used. This makes it possible to separate analog and digital signals inside the sensor by two simple diodes.

3.2 Sensor Data in TEDS Memory

3.2.1 Basic TEDS

A 64 bit portion of the memory is called application register. It includes the so-called Basic TEDS with general information to identify the sensor:

1. Model and version number
2. Serial number:
This is the actual serial number of the sensor which can be found on its case.
3. Manufacturer code: A manufacturer-specific number assigned by IEEE.

Basic TEDS can exclusively be modified and stored by the manufacturer.

3.2.2 Template No. 25

Calibration data is stored in a 256 byte section. The arrangement of the data is defined in TEDS templates. For accelerometers in most cases the standard template no. 25 will be applied. Some switch bits determine whether the memory includes a transfer function or not. Metra stores, if no other format is desired by the customer, the version with transfer function including data like resonance or lower frequency limit.

Template no. 25 includes the following data:

1. Sensitivity in V/m/s²: Sensitivity value at reference conditions according to the supplied calibration chart
2. Calibration frequency of sensitivity in Hz
3. Lower frequency limit in Hz: Typical value according to sensor data sheet
4. Measuring direction: Relevant for triaxial accelerometers
(0 = X; 1 = Y; 2 = Z; 3 = no data)
5. Sensor weight in grams
6. Polarity of output signal for positive acceleration: 0 = positive, 1 = negative
7. Low pass frequency in Hz (if the sensor includes a low pass filter)
8. Resonance frequency in Hz: Typical value according to sensor data sheet
9. Amplitude slope in percent per decade
10. Temperature coefficient in percent per Kelvin:
Typical value according to sensor data sheet
11. Calibration date (DD.MM.YY)
12. Initials of calibrating person (3 capital letters)
13. Calibration interval in days: Recommended time until next calibration

This data can be modified by the calibration lab of the manufacturer or later by other calibration labs.

In addition, TEDS memory provides some bytes for application specific data which may be entered by the user:

1. Measurement point ID (1 to 2046)
2. **User text: 13 characters**