# Accelerometers 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.

## Charge Amplifiers

Accelerometers with charge output generate an output signal in the range of some picocoulombs (1 pC = 1000 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 1 shows a typical charge input stage.

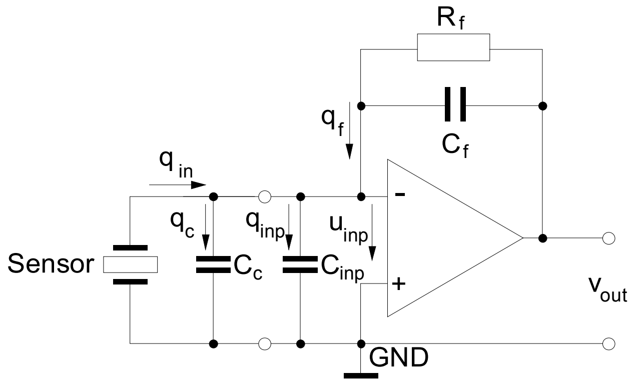


Figure 1: Charge amplifier

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 noninverting 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 $u_{out}$:

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

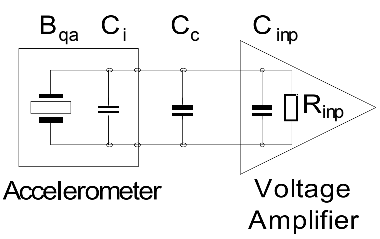
The result shows clearly that the output voltage of a charge amplifier depends only on the charge input and the feedback capacitance. Input and cable capacitances have no influence on the output signal. This is a significant fact when measuring with different cable lengths and types.

Referring to Figure 1, 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 1 represents only the input stage of a charge amplifier. Other stages like voltage amplifiers, buffers filters and integrators are not shown.

Typical charge amplifiers are, for example, the **M68** series Signal Conditioners and the **IEPE100** Remote Charge Converter made by Metra.

## High Impedance 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 2).




$B_{qa}$ Charge sensitivity of the accelerometer
$C_i$ Inner capacitance of the accelerometer
$C_c$ Cable capacitance
$R_{inp}$ Input resistance of the amplifier
$C_{inp}$ Input capacitance of the amplifier

Figure 2: Charge accelerometer at high impedance voltage input

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 Model 009 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 Model KS50 with inner capacitance $C_i$ = 1.4 nF is connected to a typical scope input with $R_{inp}$ = 10 MΩ and $C_{inp}$ = 20 pF. The sensor cable capacitance is 135 pF.

Result: The lower frequency limit will be at about 10 Hz.

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## IEPE Accelerometers

A special feature of IEPE transducers is that power supply and measuring signal are transmitted via the same cable. So, an IEPE transducer requires, like a transducer with charge output, only one single-ended shielded cable. Figure 3 shows the principle circuit diagram.

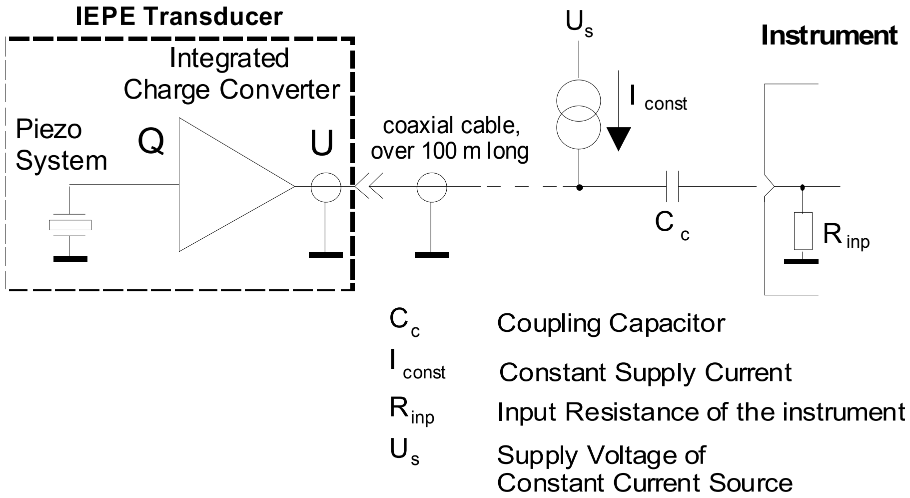


Figure 3: IEPE principle

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 with 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 (compare Application Note AN4E).

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:**

- Under no circumstances a voltage source without constant current regulation should be connected to an IEPE transducer.
- False polarization of the sensor cable may immediately destroy the built-in electronics.

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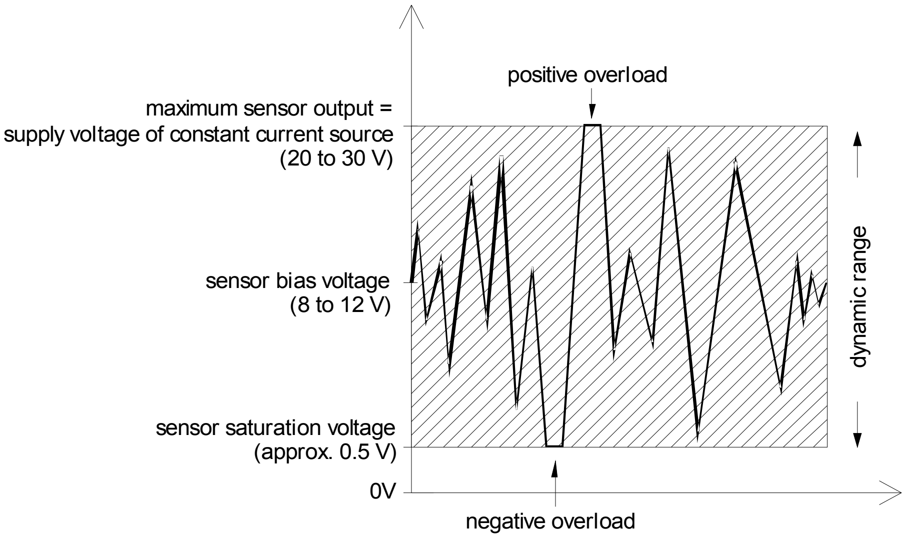


Figure 4: Dynamic range of IEPE transducers

In Figure 4 can be seen that IEPE 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. Examples from Metra are the Signal Conditioners of **M68** series, **M108** and **M32**, the Vibration Monitor Models **M12** or the Vibration Calibrating System **VC110**. The constant current source may also be a separate unit, for example Model **M28**.

# Intelligent Accelerometers to IEEE 1451.4

## Introduction

The standard IEEE 1451complies 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). 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 Figure 5 shows the principle of TEDS.

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.

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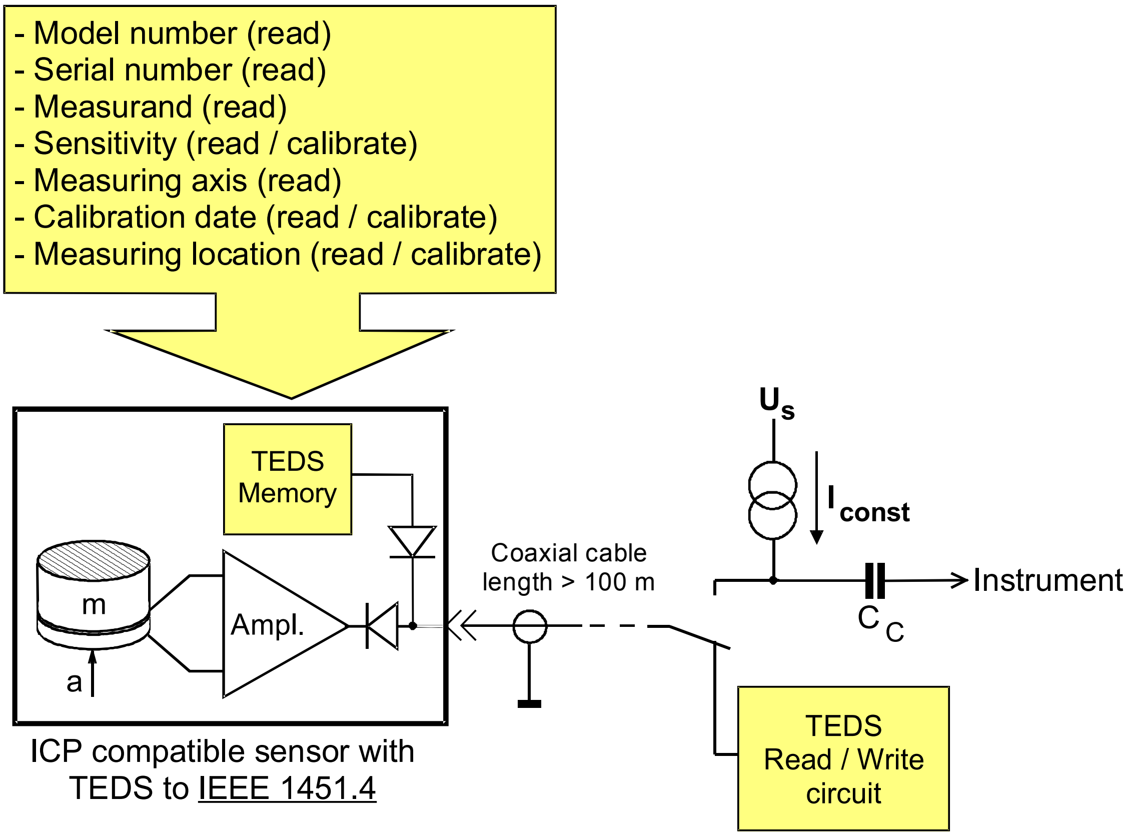


Figure 5: Accelerometer with TEDS to IEEE 1451.4

Metra's 8-channel IEPE signal conditioner M208A provides full TEDS support with automatic transducer sensitivity normalization.

## Sensor Data in TEDS Memory

### 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: Metra stores in this location a coded model number. The actual model number, for example "KS78.100", can be decoded by means of a *.xdl file to IEEE 1451.4 standard, the so-called "Manufacturer Model Enumeration File" which can be found in the download section of our web pages.
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. Metra's manufacturer number is 61. A complete list of manufacturer codes can be found here: http://standards.ieee.org/develop/regauth/manid/public.html

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

### Template Nr. 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

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