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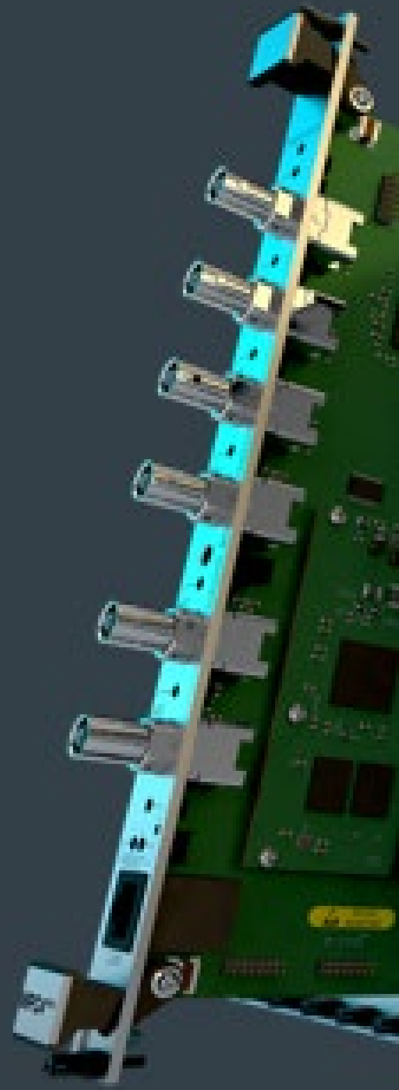
Enabling the Extraordinary
To Fly To Power To Live

vibro-meter

MEASURING VIBRATION AT LONG DISTANCES



Cable length Considerations

Presented by Luc Fromaigeat
Customer Support Engineer

AGENDA

- **Introduction**
  - Motivation
  - Review “State of the Art”
- **Effects: Attenuation, filtering, slew-rate, cross-talk**
  - Voltage mode
  - Current mode
  - I.E.P.E.
  - Particular installations
- **Comparison of vibro-meter solutions**
- **Q&A**

Reasons why this is important

MOTIVATION

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All Balance of plant Protection & Monitoring

- Refineries & applications related to Explosive env.
- LNG: boil-off compressor on jetty
- Nuclear P.P. with “in-core” points, remote water pumps (on sea shore)
- Conveyors
- Underwater measurements
- …

Constraints & issues
/ Wi-fi

- Reliability,
- Safety, cybersecurity
- EM disturbances (emissions)

/ Distributed systems

- Synchronisation (ms or µs?)

- Control in real-time (ex: speed)

- Dependence on other parameters available in centralized system

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Available on the market

SHORT REVIEW

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Well known issues

- with dynamic signals : frequency content
- Signal loss, Power supply loss : attenuation
- Power supply distortion (I.E.P.E. mode)

Addressed by solution providers

- Old “line-drive” (in single-ended piezo. systems)
- Dynamic 4..20 mA

Restriction to 1000 ft.: 305 m

- Oil&Gas API670 standard

Improvements:

First level:

- By current-modulation

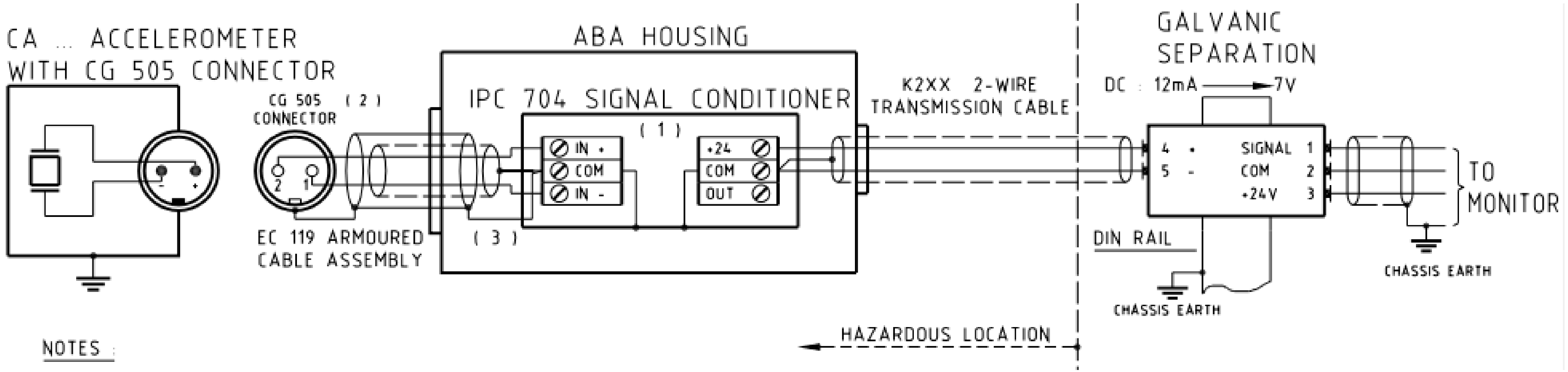
Second level:

- Solving also ground difference, power supply, impedance, limitation for Exi

vibro-meter solutions

- Current mode (not so unique)
- GSI 127 : unique

Length, attenuation and frequency content



Typical vibro-meter chain

Piezoelectric part

here: possibly of long distance transmission

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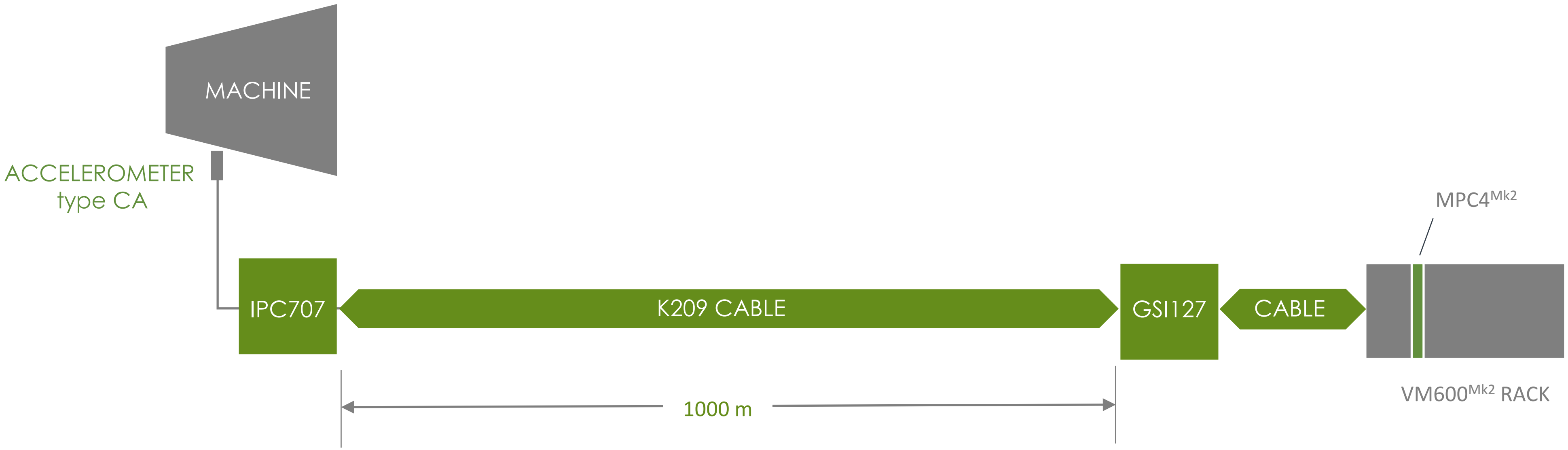
MACHINE
ACCELEROMETER
type CA
IPC707
K209 CABLE
GSI127
CABLE
MPC4Mk2
VM600Mk2 RACK
1000 m

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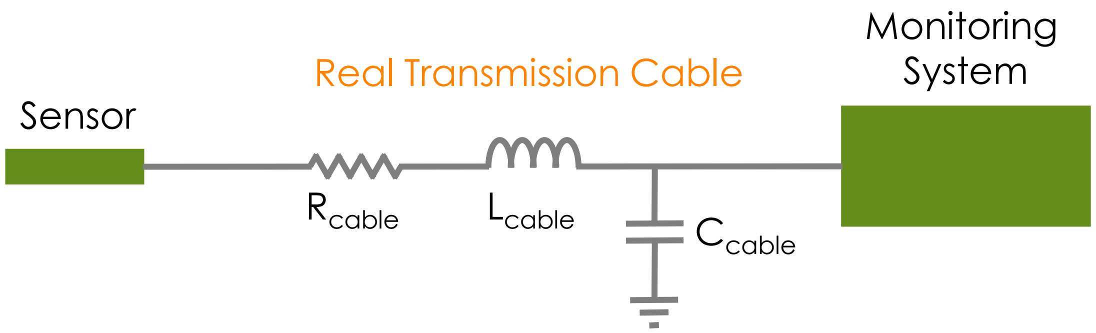
Monitoring System
Sensor
Ideal Transmission Cable


Monitoring System
Real Transmission Cable
Sensor
R_{cable}
L_{cable}
C_{cable}

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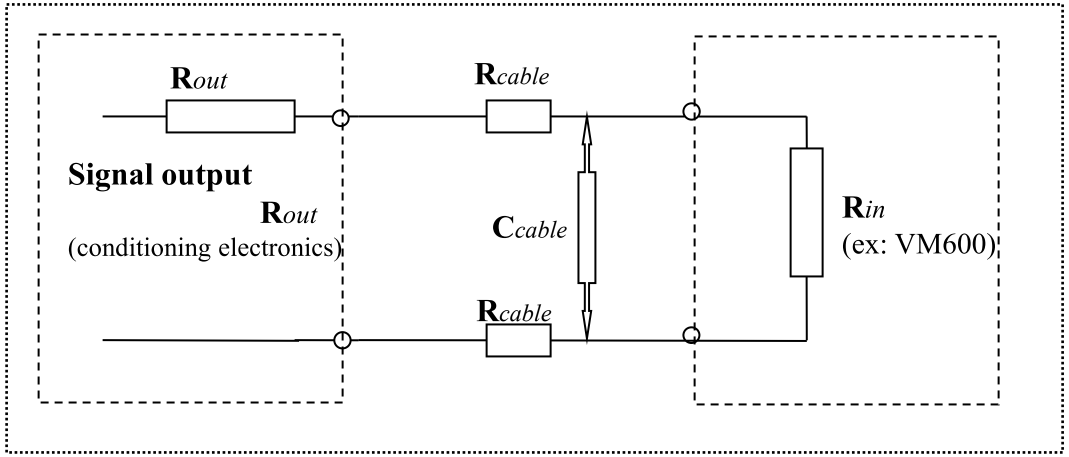
Case of a differential measurement chain



Differential sensors chains offer better immunity to EM disturbances.
Note: are generally compulsory for aviation.

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VOLTAGE MODE OF TRANSMISSION

Ohmic loss on the signal

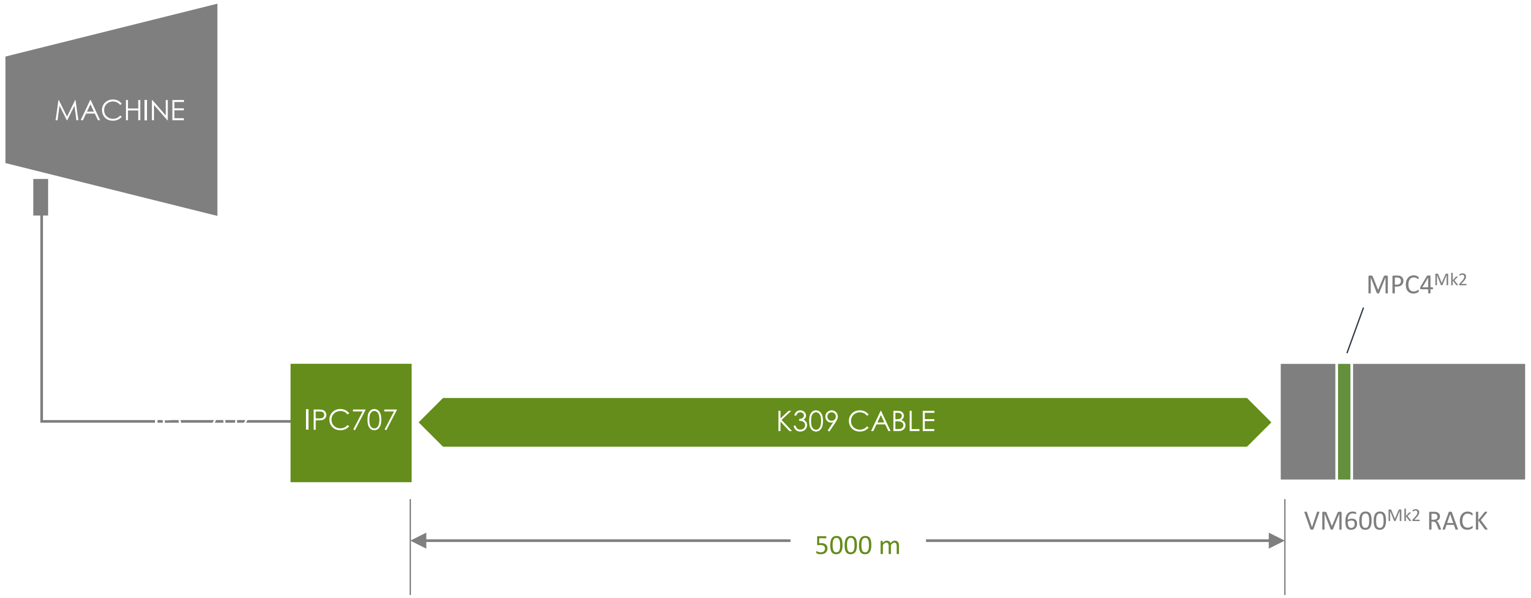
$$V_{in} = V_{out}\left(\frac{R_{in}}{R_{in} + 2\,(R_{cable}) + R_{out}}\right)$$

Example: IQS900

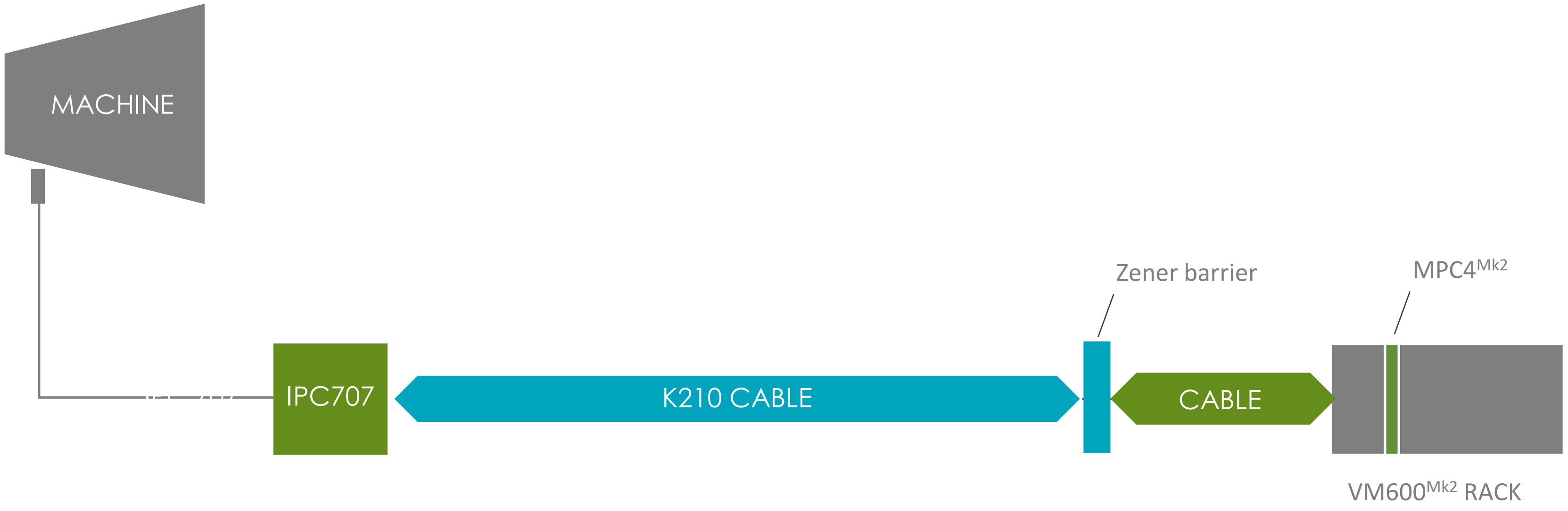
Output impedance (small signal)	: <100 Ω at DC. <300 Ω at 20 kHz. Note: Recommended monitoring system input impedance: ≥50 kΩ.

IPC707

Output impedance	: <500 Ω



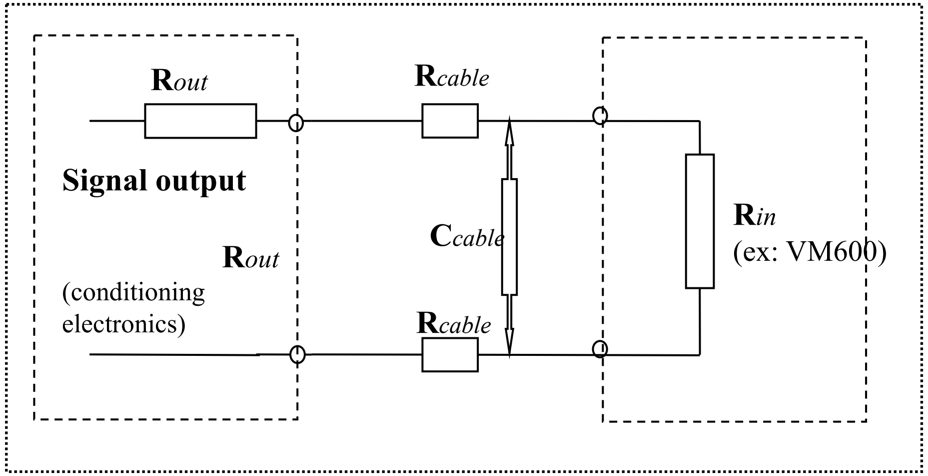
Example 1,5% → is ok
can be compensated in the MPC4 configuration


MACHINE
IPC707
K210 CABLE
Zener barrier
CABLE
MPC4Mk2
VM600Mk2 RACK

Filter by the cable:

Estimation:

$$F_c = \frac{1}{2\pi\,(R_{out} + 2\,R_{cable})\,.C_{cable}}$$



Discussion : 2x ***Rcable***… or 1x ?

This estimation does NOT over-estimate the filtering.

Estimation of the capacitance:

If already measured: core to the rest of conductors (clamped together) in the cable

Otherwise:

For a triad: $$C_{cable} \cong 2.C_{c-c} + C_{c-s}$$

(Voltage mode: 3 wires + shield)

(Current mode: 2 wires + shield)

For a pair: $$C_{cable} \cong C_{c-c} + C_{c-s}$$

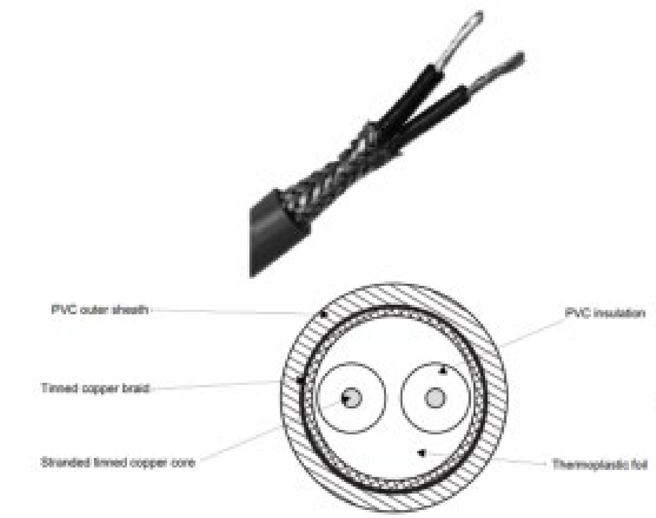
Depends on which data gives the cable manufacturer.
Also : can be measured with a capacimeter.

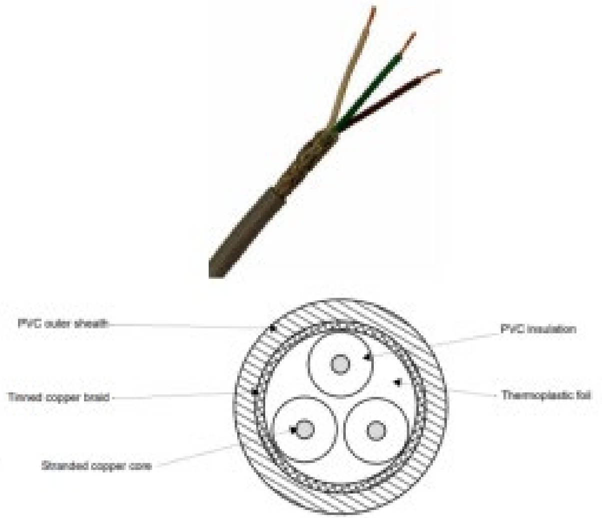
Example of calculation for distance: 1000 meters

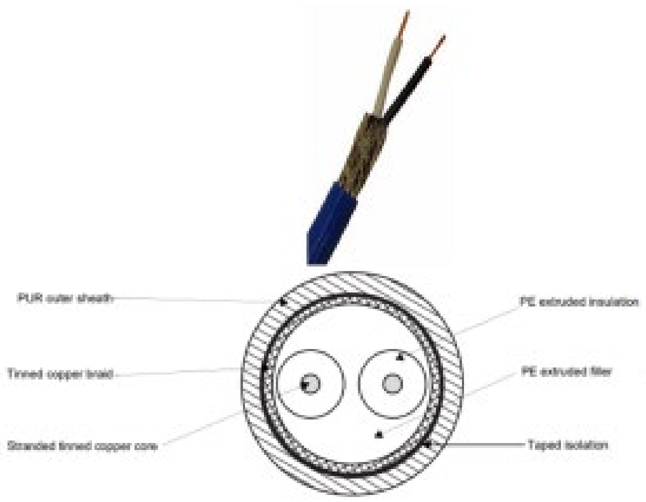
$$F_c = \frac{1}{2\pi\,(R_{out} + 2\,R_{cable})\,C_{cable}} = \frac{1}{2\pi\,(500 + 112)\,(0.57\,x\,10^{-6})} = 456\ \text{Hz}$$

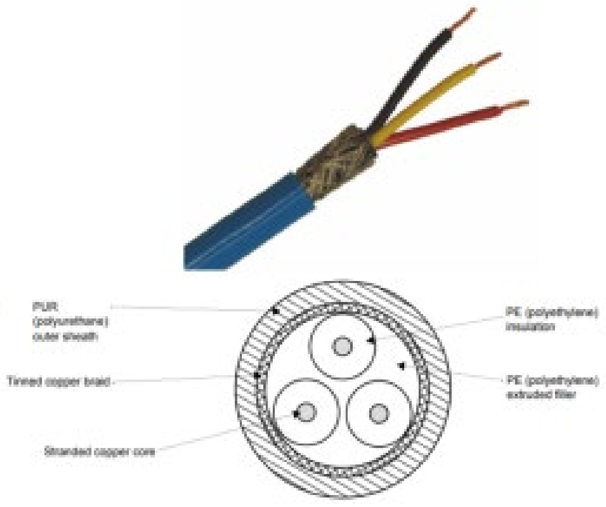
Unfortunately, this will almost always be insufficient for vibration protection and monitoring except for shaft-relative vibration on very low-speed machines (such as hydro units) or for thrust position measurements (~DC). In addition, this frequency band does not comply with ISO 20816-x standards for protection where a minimum passband of [10..1000 Hz] is required. A better cable can probably be found, but for a higher cost of installation.

→ Importance of the quality of the cable: distributed capacitance









Examples: **K209** **K309**

K210 **K310**

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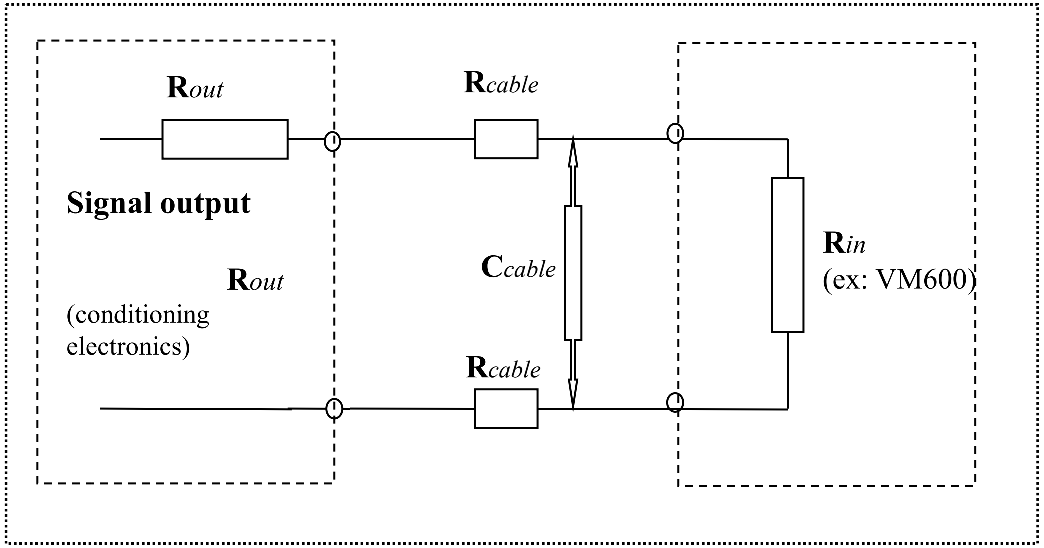
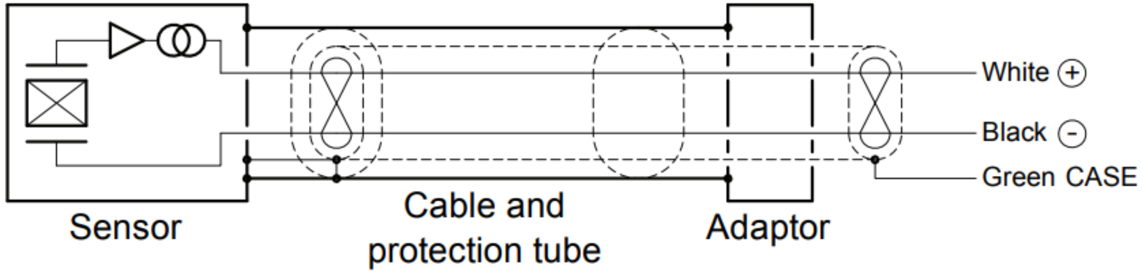
CURRENT MODE OF TRANSMISSION

Current modulation mode of transmission





- IPC707 in current mode
- IQS900 in current mode
- CE1xx, CE2xx, CE31x

Rin (monitor side) instead of ***Rout*** (sensing side)

→ significant improvement

Filter by the cable:

$$F_c = \frac{1}{2\pi\,(R_{in} + 2\,R_{cable})\,C_{cable}}$$

Examples of ***Rin***:

MPC4mk2

Input impedance

- Voltage : ≥100 kΩ, between the differential (high and low) inputs
- Current : 200 Ω ±0.2%

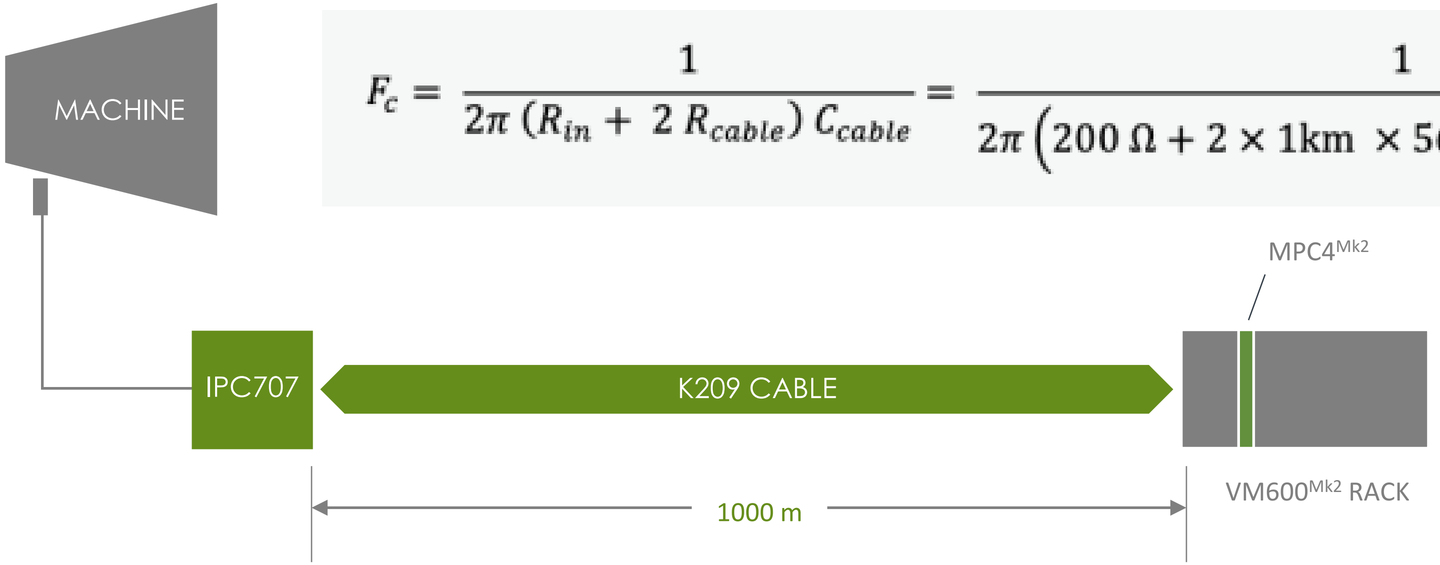
GSI127 (code _B0x)

Impedance

- Ordering options B0x : ≤30 Ω

→ even more improvement with the GSI127

$$F_c = \frac{1}{2\pi\,(R_{in} + 2\,R_{cable})\,C_{cable}} = \frac{1}{2\pi\left(200\,\Omega + 2 \times 1\text{km} \times 56\,\frac{\Omega}{\text{km}}\right) \times 0.42 \times 10^{-6}\,\text{F}} = 1215\ \text{Hz}$$



Compared to previous example:

Improving by factor ~ 2.5 !

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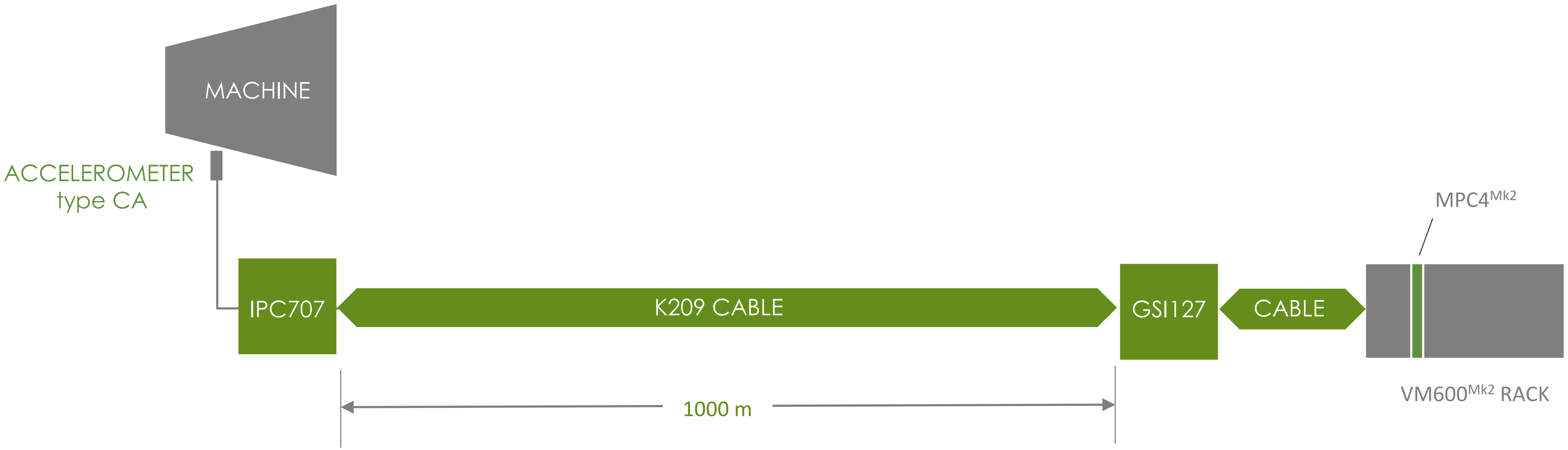
GSI127 (& legacy: GSI122, GSI130, GSI124)

provides numerous capabilities including:

- prevents ground loops (up to +-4000 Volts), with a very high Common Mode Rejection Ratio ("CMRR" is specified
- uses current modulation mode as a standard,
- passes a regulated power supply to the sensing apparatus
- provides a very low-impedance (<30 Ω) input for the sensor signal
- energy limiting for intrinsically safe installations by serving as a safety barrier. *: optional*
- 0 - 20kHz frequency bandwidth response (unlike other commonly used galvanic separation devices designed only for quasi-static signals)

Versions exist for accelerometers, for proximity probes, and for IEPE sensors.

GSI127 (standard version)



In same example: Fc = 2670 Hertz

Improvement by another factor ~ 2.5

Depends on each and every case.

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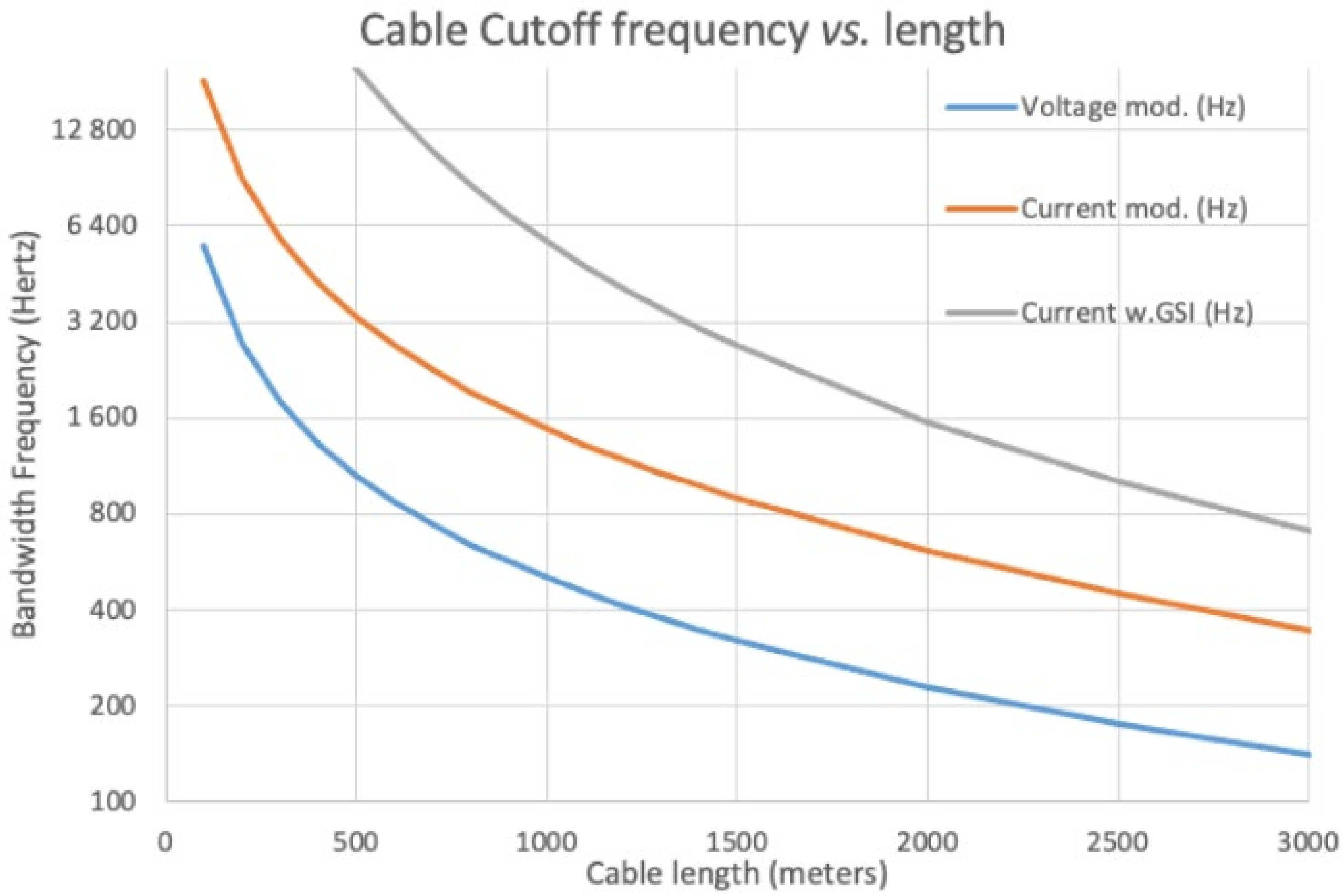
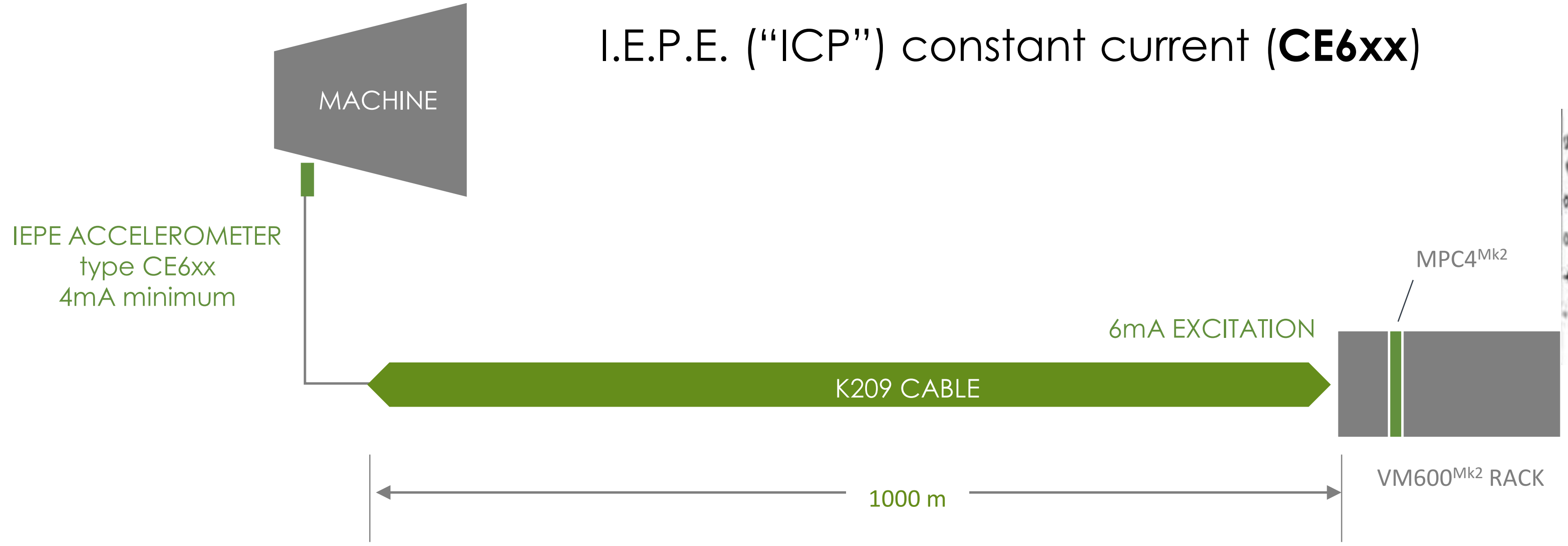


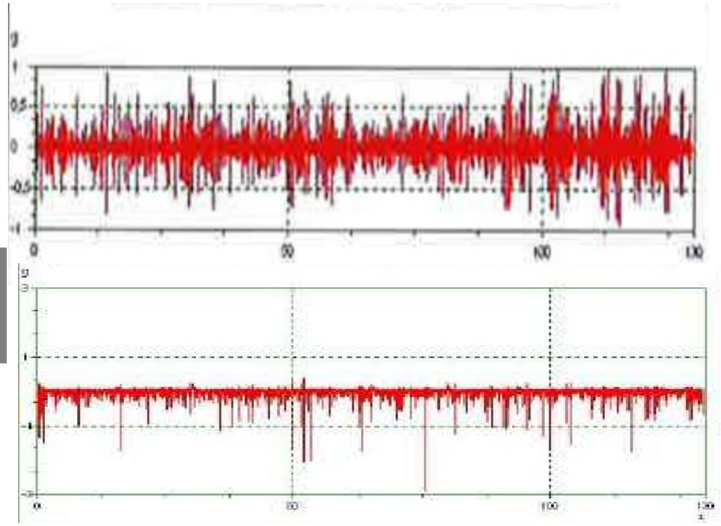
Common exemple with IPC707
Applicable to CA or CP sensors

PARTICULARS I.E.P.E.

…

I.E.P.E. (“ICP”) constant current (**CE6xx**)





Additional “**slew rate**” effect
- related to the margin on CC power supply
- Results in an additional constraint (+calculation)

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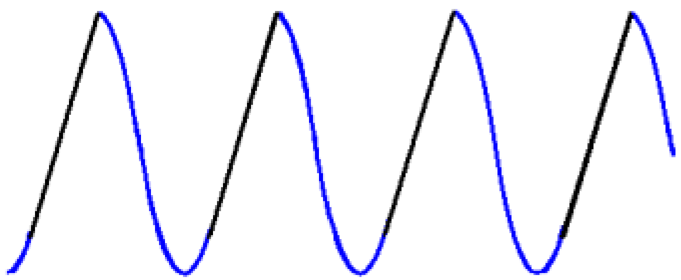
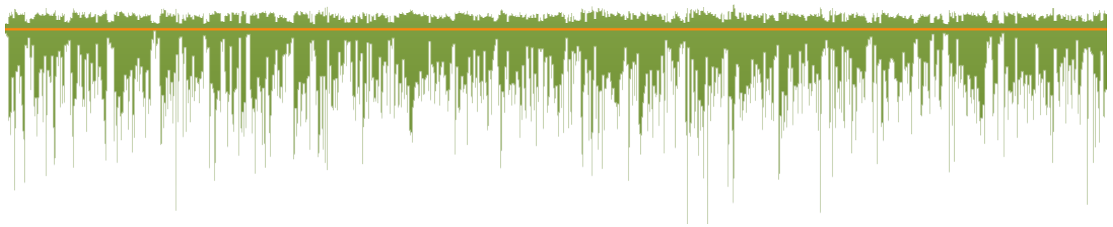
Slew rate effect:



$$I_A = \frac{dQ}{dt} = C_{cable} \times \frac{dV}{dt} = C_{cable} \times sensitivity \times \frac{dA}{dt}$$

$$f = \frac{I_A}{2\pi \times A_f \times sensitivity \times C_{cable}}$$

Extreme effect on IEPE signal out:



Is signal dependant (A):
on the maximum amplitude expected at a maximum frequency

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In-Water measurement

- Challenging
- Filter increasing with immersed length of cable
- Capacitance effect $\varepsilon_{r\ water}$ = 80 !
- Even outside the cable

Tacho pulses

- Affected as well
- But frequency signal remain the same
  → reliability on longer distance
- Beware of cross-talk upon the vibration signals

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THE CALCULATION SHEETS

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LongDistanceCalculator.xlsx

- 3 columns: **Voltage mode** **Current mode** **IEPE additional limit**
- Fill-in green boxes, incl. length
- Read frequency limit

CableGraphsandTransmissionCalculations.xlsx

- Gives values and curves for: **Voltage mode** **Current mode** **Current with GSI**
- Fill-in lines 30..33, column D
- Use graphics to adjust length or bandwidth

Capacitances.xlsx

- Helps defining capacitance, from different measurements.

See also:

Wilcoxon Accelerometer Maximum Cable Length Calculator.xlsx but for ***Imin***=1mA

-3dB Cutoff Frequency Calculator (learningaboutelectronics.com)

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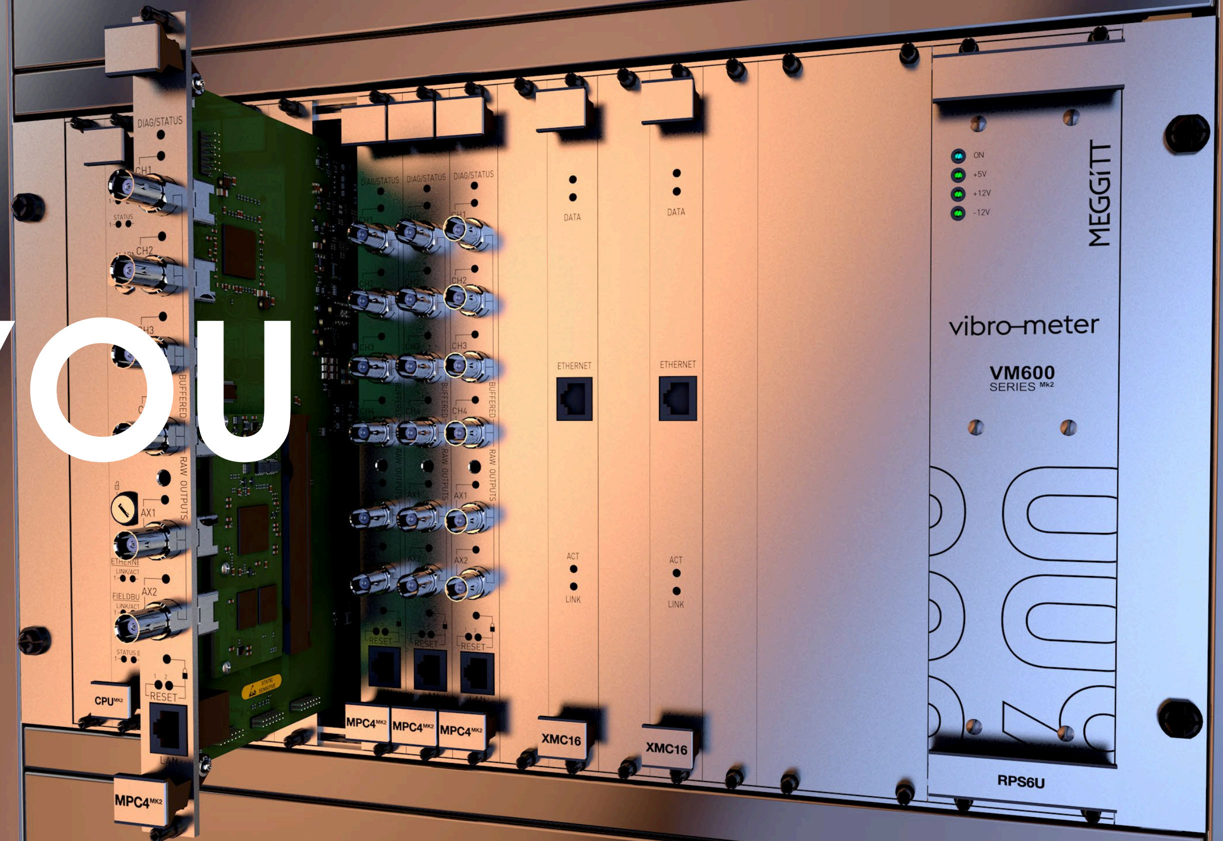
THANK YOU



VM600 Mk2 in comparison to VM600Mk1

Presented by Krzysztof Solinski,
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System Engineer

Webinar Realisation

Peter Ward
Technical Writer

Presentation check

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