worms

Application Note

Measuring with Dragonfly®

1 Choosing the acquisition system

There are several options to measure Dragonfly® sensors. The objective of this document is to detail these methods and provide general good practices for optimal measurement.

1.1 Acquisition of passive Dragonfly® sensors (dgf-xxx-**aa**00000-00)

The Dragonfly® passive sensor behaves electrically as a capacitance, in parallel with a leakage resistor. It can be measured in two different modes (voltage or charge) depending on the needs of the user, and on the available acquisition systems.

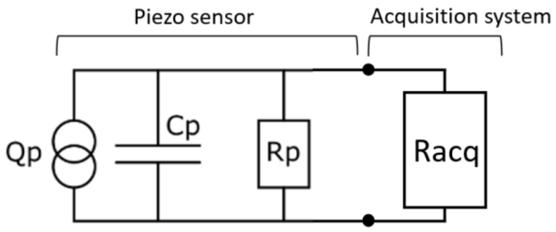
Warning: It is not possible to measure passive Dragonfly® sensors on IEPE inputs.

Voltage mode

It is possible to directly measure the voltage output of Dragonfly®.

Pros	Cons
Simple acquisition hardware	The low cut-off frequency depends both on the sensor and on the acquisition system and is typically higher than 2Hz.
Lowest power consumption	Limited cable length or use of low noise cable
	High temperature sensitivity

A piezoelectric sensor equivalent electrical schematic is shown below.



In voltage mode, the lower cut-off frequency (f_{lc}) is determined by the sensor electrical properties (R_p and C_p) and the acquisition system input impedance (R_{acq}).

$$R_{eq} = (R_p * R_{acq})/(R_p + R_{acq})$$

$$f_{lc} = \frac{1}{2\pi C_p R_{eq}}$$

The lowest achievable cutting frequency is typically of the order of 1Hz for acquisition systems with a very high input impedance (10MΩ)

Charge mode

The Dragonfly® can be connected to a charge amplifier before entering the acquisition system.

Pros	Cons
Acquisition of at low frequencies (quasi-static)	Charge amplifier required
	Limited cable length or use of low noise cable

When operated in charge mode (using a charge amplifier), the cut-off frequency (f_{lc}) is determined by the charge amplifier itself and can be very low (<0.01Hz) with a dedicated design. Piezo-electric sensors cannot measure infinitely slow strain variations, due to the leakage currents in the amplifier. However stable measurements over several minutes are possible with a limited error (<1%).

Cables in voltage & charge mode

Standard coaxial cables may create triboelectric noise when they are deformed. The friction produced by cable deformation generates charges that are not related to the mechanical deformation of the sensor. Special low noise coaxial cables exist if you encounter this problem. If this is an issue for your context, IEPE Dragonfly® sensors are much more robust against triboelectric noise from the cables as they are pre-amplified.

1.2 Acquisition of IEPE Dragonfly® sensors (dgf-xxx-**w**00000-00)

IEPE Dragonfly® sensors integrate an onboard charge amplifier, which is powered by a constant current supplied by the acquisition system. These sensors are compatible with all acquisition systems which follow the IEPE standard (also called ICP, CCLD, IsoTron or DeltaTron depending on the manufacturer) which is often used for accelerometers.

Pros	**Cons**
Acquisition at low frequency (quasi-static)	Power consumption through the IEPE
Long cable distance is possible with simple coaxial cables	

Below are the schematics of a typical IEPE interface.

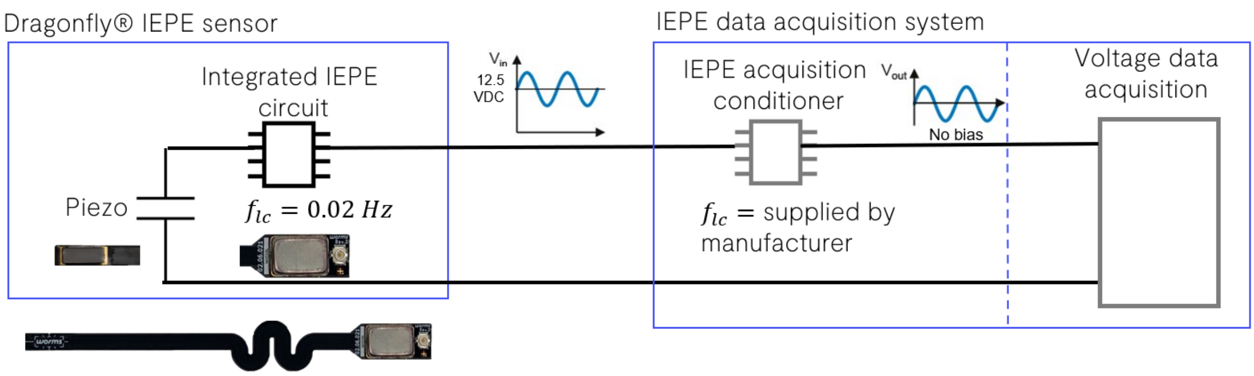


Figure 1: Schematics of a typical IEPE interface.

Warning: IEPE Dragonfly® sensors will not work without the supply current and require dedicated IEPE inputs. The supply current must be in the range between 2mA and 20mA.

The lower cut-off frequency of the Dragonfly® measured by an IEPE acquisition system depends on two components:

- The charge amplifier embedded in the Dragonfly® sensor itself, whose lower cut-off frequency is $f_{lc}(\text{Dragonfly®})$ in the sensor datasheet.
- The cutting frequency of the IEPE input, which depends on the acquisition system only. Depending on the model of the IEPE acquisition system, the lower cut-off frequency may typically vary in the range $f_{lc}(\text{Acquisition}) =$ 0.01Hz to 1Hz. Please refer to the technical information of your acquisition device.

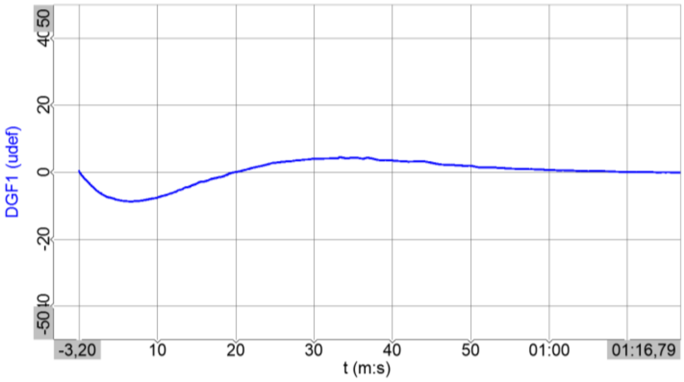
The final cutting frequency of the IEPE sensor connected to the IEPE acquisition system will be the highest cutting frequency: $f_{lc} = \max\left(f_c(\text{Dragonfly®}), f_c(\text{Acquisition})\right)$

Cables in IEPE mode

As the signal is pre-amplified, standard coaxial cables can be used over long distances, up to more than 100 meters.

Signal stabilization after power-up

When the IEPE Dragonfly® is connected to the IEPE input, the current loads the embedded charge amplifier, which results in oscillations of the measured signal during a period around 300s. Please wait until the signal has stabilized before starting your measurements.



- Right after power-up, the signal DC is expected to fluctuate before stabilizing at zero within 300 seconds.
- Wait for 300s after connecting the Dragonfly® to the IEPE supply before starting your measurements.

Figure 2:Typical measured signal obtained right after connecting the Dragonfly® sensor to the IEPE acquisition system.

2 Grounding and shielding

Warning: The whole system should be shielded, from the sensor to the acquisition device.
Coaxial wires (BNC, SMA or microdot) should be used on the complete line.

The signal must be acquired in "referenced" mode: the negative pin of the sensor (the shield of the coaxial cable) must be connected to the ground.

In some cases, the acquisition system is not directly grounded. Adding an external ground can help to reduce ambient electromagnetic radiation noise on the measured signal (see figure below).

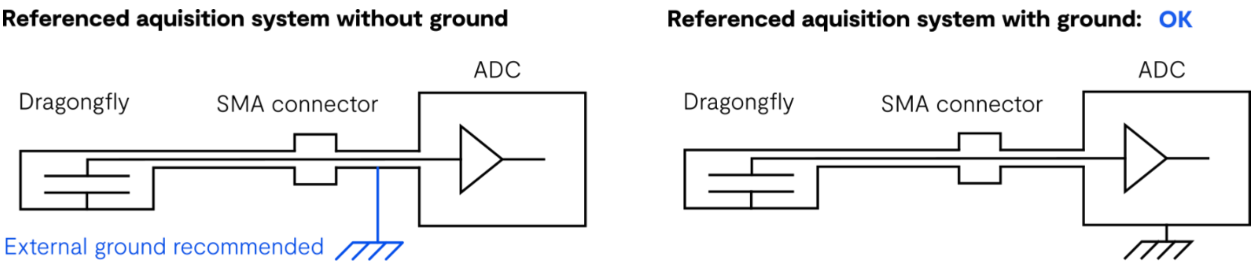


Figure 3: Grounding recommendations.

3 Measuring dynamic strain

Contrary to resistive strain gauges, Dragonfly® is a dynamic strain sensor and cannot measure static strains. Its ability to measure slow variations depends on its high-pass filter cutting frequency (f_{lc}). The methods to compute f_{lc} for the different sensor version (passive or IEPE), and for the different acquisition systems (voltage, charge, or IEPE) has been described in section 1.

In this section we will analyze the effect of the sensor high-pass filter cutting frequency on strain measurements.

3.1 Influence of the sensor high-pass filter

The frequency responses of first-order high-pass filters with different cutting frequencies are plotted in Figure 4.

Figure 4 shows that if the frequency of input signal (the mechanical deformation) is much higher than the cutting frequency of the filter, the output signal (the sensor signal) will be equal to the measured deformation.

On the other hand, if the input signal is below the cutting frequency of the sensor, the sensor signal will have a decreased amplitude. The loss in amplitude can be obtained from the frequency response of the filter, for example, in Figure 4, for the filter with f_{lc}=10Hz, the amplitude at 1Hz is 0.1. (black dot). This means that the response of the sensor to a sine wave at 1Hz of amplitude 1 will be a sine wave of amplitude 0.1, as shown in Figure 4(b).

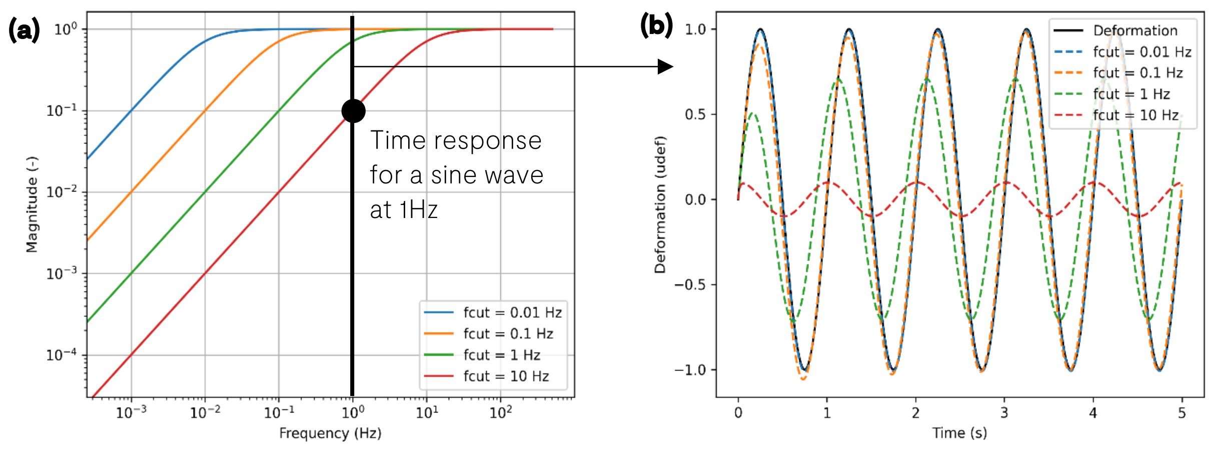


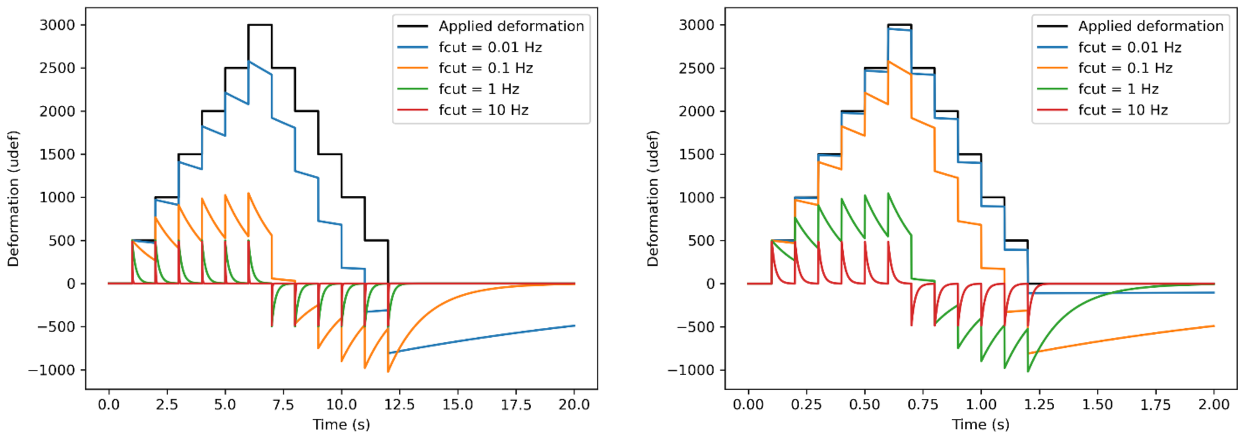
Figure 4: (a) Frequency response of first-order high-pass filters. (b) Time response of the different filters to a sine wave at 1Hz.

General guidelines are that:

- At the cutting frequency, 70% of the signal passes through the filter.
- At twice the cutting frequency, 90% of the signal passes through the filter.
- At 3 times the cut frequency, 95% of the signal passes through the filter.

3.2 Response of the sensor to quasi-static signals

The response of Dragonfly® sensors with different low cutting frequencies are plotted in Figure 5, when steps deformation are applied.



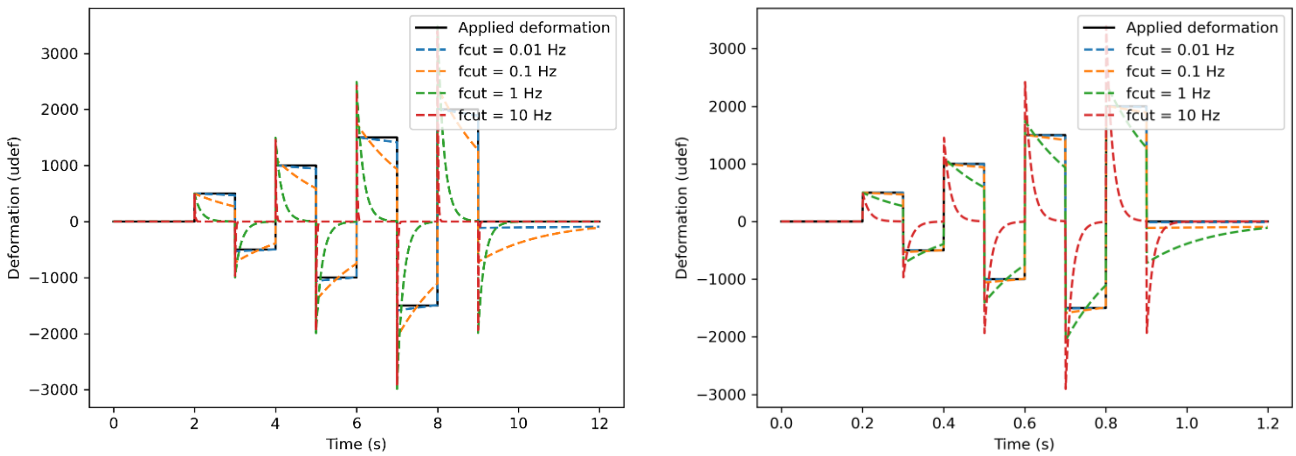
(a) Response to steps of 1s. **(b) Response to steps of 0.1s.**

Figure 5: Time response of Dragonfly® sensors with different cutting frequencies to steps of deformation.

Figure 5 shows that if the variations of the deformation occur on a timescale which is much shorter than the timescale defined by the cutting frequency ($\tau = 1/f_{lc}$), the sensor signal will follow the applied deformation (typically the first steps in Figure 5(b)). If the variations of the deformation are too slow, then the sensor signal will drift back to zero.

Also, the applied deformation consists in short steps, but altogether they create a slow variation of the mean of the signal, which cannot be measured due to the high-pass filter. This is why the offset between the applied deformation and the sensor response with $f_{lc} = 0.01$ (in blue) Hz increases with time in Figure 5.

If we apply a similar deformation but this time centered around zero, the drift of the sensor will be minimized, as shown in Figure 6.



(c) Response to steps of 1s. **(d) Response to steps of 0.1s.**

Figure 6:Time response of Dragonfly® sensors with different cutting frequencies to steps of deformation, centered on zero.

Compared to the response of the sensors to the deformation in Figure 5, the response to the deformation shown in Figure 6 follows better the applied deformation. The reason is that the mean of the deformation stays at zero, so there is no slow variation of the signal (below f_{lc}) superimposed to the square oscillations.

Finally, if the measured signal consists in the superposition of a slow variation and faster oscillations, the response will be dominated by the oscillations, but modulated by the drift caused by the slow variations, as shown in Figure 7.

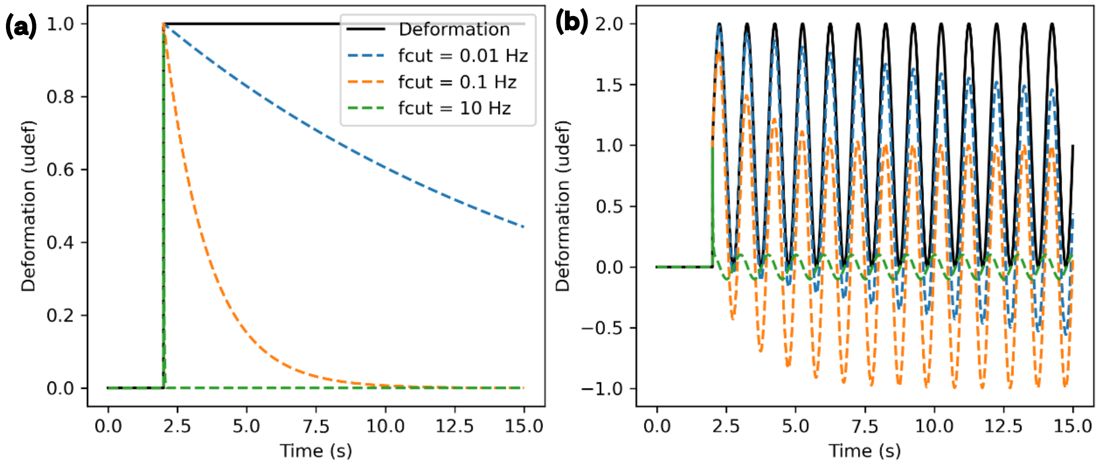


Figure 7: Response of sensors with different cutting frequencies to the combination of a step and a sinewave at 1Hz.

Figure 7(a) shows the response of the sensors to a simple strain step. In Figure 7(b), a sine oscillation beginning at 2s is superimposed to the strain step. This plot shows clearly that the sensors capture accurately the oscillation as soon as their cutting frequency is lower than 1Hz, but they cannot capture new static level after the step, as the mean value converges to zero.

3.3 Conclusion

When preparing your measurement setup and when analyzing the recorded signals, please keep in mind that Dragonfly® cannot measure static levels. Depending on the timescale of the phenomena you are interested in, you should select a sensor version and a corresponding acquisition system which fits your needs in terms of cutting frequency.

4 Analyzing Dragonfly® signals

4.1 Discovering nano-deformations

The sensitivity of Dragonfly® sensors outperforms the sensitivity of traditional strain gauges, so many events and small deformations which could not be measured are now accessible. Don't be surprised if the sensor signal does not look like standard strain gauge signals!

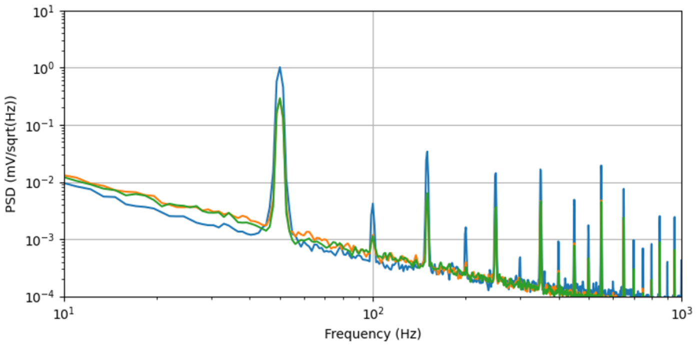
Please check our whitepapers to see how Dragonfly® behaves in real situations:

[Tuning Fork Resonance] [Structural Health Monitoring]

[Human-Machine Interfaces] [Robot Arm: Position and Force]

4.2 Common issues

EMC noise



If you encounter EMC noise in the measured signal, please check the grounding of your measurement system. EMC noise typically arises as peaks in the spectrum of the measured signals at multiples of the power grid frequency (50Hz or 60Hz). Please also check that you have used **shielded cables** and connectors from the sensor to the acquisition device.

The sensor does not seem to work

If you think that the sensor does not behave as expected, please perform the sensor test as described in the Application Note: Sensor Check.

For more information

- Consult our web site at www.wormsensing.com
- Contact us at contact@wormsensing.com