

ROTATIONAL ANALYSIS – RPM DETECTION

Measuring rotational speed

When unwanted noise in rotating systems is perceived, the noise is often due to the various rotating parts themselves. Miscellaneous analysis methods allow for an identification of the noise sources in order to eliminate them.

All these methods have one thing in common: They all require capturing the revolutions per minute (rpm) before one can relate the various base quantities (sound pressure, acceleration, etc.) to the rotation at hand. Depending on the method being used, the high accuracy of rpm measurement can be more or less important. This white paper will discuss different methods of capturing the rpm signals and what to keep in mind while doing so.

Sensors and signal types

The acronym TTL stands for Transistor-Transistor Logic and denotes a particular circuit technology that is implemented in specific sensors. These sensors consequently provide **TTL signals** which may have either a high or a low amplitude. The value of the amplitude as well as the transition between their levels can look quite different, depending on the design of the sensors being used.

Figure 1a shows an example of a TTL signal. The transition between the high and low level occurs whenever an rpm sensor detects a marking. Sensors which provide TTL signals include inductive sensors which can detect every single tooth of rotating gear-wheels and optical sensors which detect the optical or reflector markings of an attached strip-band. Every pulse is detected individually for each TTL signal. So this signal type is well suited to all analyses requiring a high-precision detection of rpms, e.g. torsional-rotational analysis or angle-based analyses. Short-time analyses (e.g. Wavelet analyses) can also be applied for other objectives. This white paper focuses on the FFT analysis.

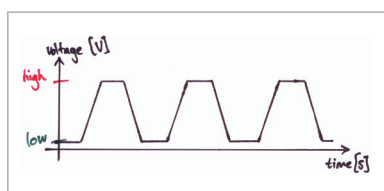


Figure 1a:
TTL signal

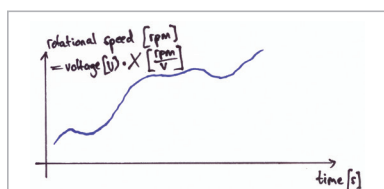
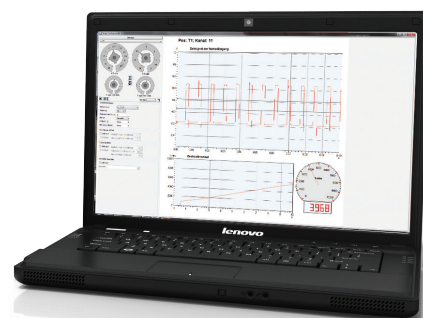


Figure 1b:
Voltage-proportional rpm signal



A voltage-proportional rpm signal is the output from sensors which are already equipped with a preprocessing unit for TTL signals. Test benches also usually provide this kind of signal. Here, the voltage curve over time is available and the voltage values can be directly translated into an rpm signal via a calibration factor [rpm/V]. An example of this is depicted in Figure 1b. As there is no detection of individual pulses, neither torsional-rotational nor angle-based analyses can be performed by means of this method of measuring rotational speed. This type of signal is only sufficient, however, for a representation of various base quantities over rpm or an order analyses (with an order being a multiple of that rpm).

Another way of acquiring rpm signals is to use digital bus systems (e.g. CAN, FlexRay™, ...). Irrespective of the physical principle of the rpm sensors, the signal is preprocessed and is provided by the respective bus directly as an rpm curve over time. Digital bus systems often have a low sampling rate and can feature significant delays of their output due to their architecture. For this reason, rpm signals coming for digital bus systems are not recommended for more advanced analyses, although they can offer a first overview of the rpm curve. They are often recorded along with other data offered by digital bus systems so they are easily available.

Parameters of pulse detection

Several intermediate steps are necessary in order to acquire an rpm signal from the TTL signal. Each step features specific parameters which have a direct impact on the quality of the signal.

Trigger levels: Two trigger levels are required to transform a TTL signal into Tacho times. A distinction is made between the actual trigger level and the arming level. Once the trigger level is passed, a pulse is detected for this time. It is recommended that the trigger level should be set to the steepest point of the TTL slope to be independent of the changing steepness of the TTL slope. As disturbances can occur at this point, one additionally utilizes an arming level. This ensures that a flank can only be triggered once it first reaches the arming level. It should be set in between the high and low level of the TTL signal while being as far as possible from the trigger level. This enables a high error tolerance of the signal and prevents false pulses.

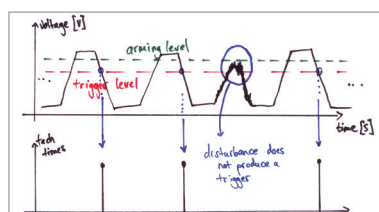


Figure 2:
Triggering of a TTL signal and
creating a pulse curve

Impulses per revolution: The number of impulses per revolution is determined by the number of markings that are applied on the rotating part used for the rpm detection. In the case of an inductive sensor that detects every individual tooth, this is the number of teeth of the gear wheel. In the case of an optical sensor, the number of markings that were applied to the rotating part must be used. The impulse number cannot be changed for inductive sensors, as it is closely related to the design of the investigated system. For optical sensors, the number of impulses per revolution can be set according to the number of optical markings applied to the component. This is an advantage over the inductive sensors, as the sufficiently higher number of impulses per revolution required by more advanced analyses can always be realized by using appropriately fine optical markings. One can liken the impulses per revolution to a calibration factor [pulse/ revolution] for rpm sensors, which translates the Tacho times to an rpm signal.

Averaging: When using a signal with more than one impulse per revolution, the signal contains not only momentary rpm but also a torsional component. It is necessary to analyze this part of the signal too in order to analyze the torsional rotation. For other analyses, it might be more useful to discard this part of the signal via averaging procedures. The number of impulses per revolution should be averaged over a defined number of revolutions, not over a specific time interval, as the number of impulses per revolution is fixed for a revolution. Generally, a changing rpm makes it impossible to determine how many pulses will fall into one specific time interval.

Conclusion

When analyzing rotating systems, it is necessary to capture the rpm of the system. Depending on the further analyses to be done, the rpm signal has to fulfill different requirements.

- **TTL signal:** suitable for all analyses. For torsional-rotational or angle-based analyses, a high number of impulses per revolution is preferable
- **Voltage-proportional rpm signal:** suitable for order analyses. Provides an overview of the momentary rpm / rotational speed
- **The rpm signal from digital bus systems (CAN, FlexRay™, etc.):** Provides an overview of the rotational speed, but is not recommended for order analyses

When using a TTL signal for highly accurate analyses, the signal has to be appropriately parameterized. The parameterization serves to create a pulse curve / pulse rate from the signals coming from the sensor, which enables the rpm to be computed.

- **Trigger levels:** Set the trigger level to the steepest part of the TTL flank; set the arming level within the limits (high, low) of the TTL signal while maximizing the distance to the TTL flank
- **Impulses per revolution:** The calibration factor is necessary to translate the rpm from a pulse curve/pulse rate
- **Averaging:** The rpm signal has to be averaged over a fixed number of revolutions and not be averaged over time in order to eliminate the torsional components from the signal

The PAK software offers a multitude of tools for data acquisition and data analysis, especially for the fields of acoustic, vibration, structural and rotational analyses. PAK provides a flexible, effective and compact set of tools for all applications and is most effective in the context of highly standardized tasks and procedures, quality control or troubleshooting.

If you would like to gain a deeper insight into the field of Rotational analysis – rpm detection and other topics related to the analysis tools provided by Müller-BBM VibroAkustik Systeme, you are welcome to attend one of our practical training sessions. More information can be found at <http://www.muellerbbm-vas.com/services/training/>.

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