Averaging / Filter types

Introduction

The output signal of sensors is often subject to influences complicating the interpretation and further processing of the signal. Various forms of noise, invalid measurement values or signal peaks are some of the effects which can be reduced using skilful averaging or filter settings.

Averaged measurements

Choosing an averaged measurement is recommended for static or slowly changing measured values. Depending on the type of sensor, either the measured values or the video signal can be averaged out. The averaging process for the measured values is carried out in the sensor after calculation of the distance values and before output via the selected interface.

The measurement rate or data rate is independent from averaging. However, a reduction of the output rate is possible. Depending on the product group, different averaging forms, which will be briefly presented can be implemented.

Arithmetic average

The arithmetic average M is formed and output via the selectable number N of successive measured values. This method leads to a reduction of the output data volume as the measured values are collected initially and only output after every nth measured value.

Example where: N = 3

.... 01[234] ... turns into $\frac{2+3+4}{3}$ average n

.... 34[567] ... turns into $\frac{5+6+7}{3}$ average n + 1

Moving average

The arithmetic mean value is calculated using the number N (1...128) of sequential measured values (window) and output according to the following formula.

$$MA = \frac{\sum_{k=1}^{N} MV(k)}{N}$$

MV = measured value
N = average
k = running index (in window)
MA = moving average or output value

Example where: N = 7

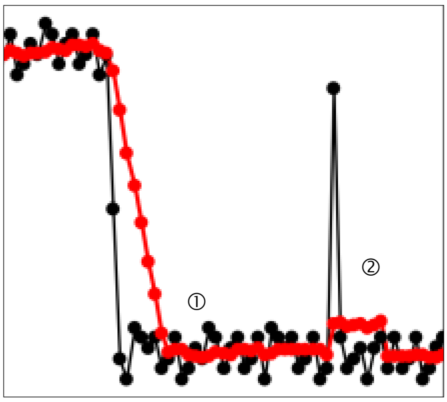
.... 01[2345678] turns into $\frac{2+3+4+5+6+7+8}{7}$ average n

.... 12[3456789] turns into $\frac{3+4+5+6+7+8+9}{7}$ average n + 1

When doing this, a new measured value is added to the window with the oldest value being removed. In this way, it is possible to achieve short transition response times even with relatively large measured value jumps.

<u>Guidance on applying the moving average:</u>

- Used to smooth measurement values
- Exactly adjustable effect via the quantity N of measured values. The higher the number, the greater the smoothing of the values
- With continuous noise without spikes
- With low surface roughness
- For short transition response times



Signal with moving average (red) and without it (black)

The illustration shows the effect of the moving average. The values settle quickly ① whereas spikes significantly affect the averaged value over the window width ②.

Recursive average

Recursive averaging makes possible very strong smoothing of the measured values; however, it needs very long response times for measured value jumps. Each new measured value $MV_{(n)}$ is added, as a weighted value, to the sum of the previous ones $M_{rec(n-1)}$. The following formula is used for the calculation:

$$M_{rec}(n) = \frac{MV_{(n)} + (N-1) \times M_{rec(n-1)}}{N}$$

MV = measured value
N = average
n = index measured value
M_{rec} = recursive average or output value

Example where: N = 8

1st measured value = 5,
2nd measured value = 6,
3rd measured value = 4,
$M_{rec(n-1)}$ = 3 (Assumption for first calculation)

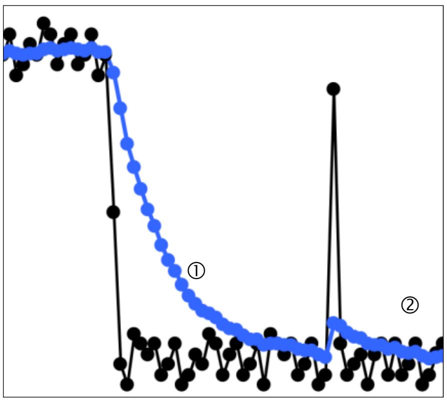
1st value $3{,}25 = \frac{5 + 7 \times 3}{8}$

2nd value $3{,}59 = \frac{6 + 7 \times 3{,}25}{8}$

3rd value $3{,}64 = \frac{4 + 7 \times 3{,}59}{8}$

etc.

The average N (1…32768) makes it possible to finely control the effect of recursive averaging. The greater N is selected, the stronger the smoothing will be with the response time increasing too.



Signal with (blue) and without (black) recursive averaging

The illustration clearly shows the slow transient response behaviour ①; it also shows the strong smoothing ② caused by recursive averaging.

Median

With the median, the values of a predefined number of measured values are sorted by size and the medium value (not the average value) is output. In this connection, it is possible to use 3, 5, 7 or 9 values (odd number) for median calculation. The median is used as a filter type to mainly suppress individual interference pulses. Actual smoothing of the signal is not very strong with the median. However, additional averaging can be applied after calculation of the median.

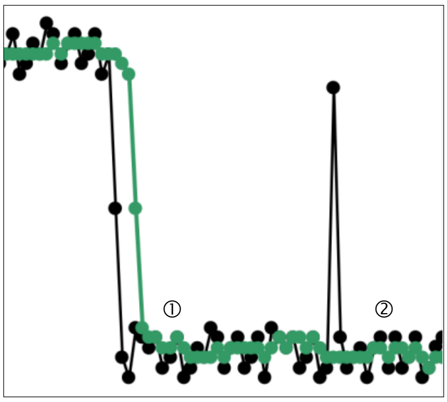
Example where: N = 7

.... 240124513 measured value sorted 0112345 Median $_n$ = 2

.... 401245134 measured value sorted 1123445 Median $_{n+1}$ = 3

Guidance on applying the median:

- Supresses individual interference pulses
- In the case of short, strong signal peaks (spikes)
- With edge jumps
- In harsh, dusty or dirty environments to eliminate dirt particles



Signal with median (green) and without it (black)

The illustration shows suppression of the individual signal peak ②. On the other hand, the signal follows measured value jumps quickly and without long transient response times ①.

Another option to optimise the measured result is to apply filters. By contrast with averaging, filters output or suppress values only under specific preconditions. A newly developed filter by Micro-Epsilon is the

Dynamic noise rejection filter

This filter eliminates the noise of the measured values but maintains the original bandwidth of the measuring signal. To do this, the noise band is calculated dynamically and a change of the measurement value is output only if the noise band is exceeded or not reached. However, value changes within the dynamically calculated limit values are lost as information. The value that causes a signal change is greater than the calculated noise by a factor of 3. With direction changes in the signal, small hysteresis effects occur due to the limit values as they must first be exceeded to cause a change. By contrast with other averaging types, dynamic noise rejection is not based on a definition that originates from classic statistics, but rather on an algorithm developed by Micro-Epsilon.

Guidance on applying dynamic noise rejection:

- Suited to static and dynamic measurements
- Original bandwidth is retained
- Appropriate if the accuracy of the measurement system does not need to be fully exploited
- Signal changes in the magnitude of the noise band are lost

Filter example: unfiltered (blue) - filtered (green)

The illustration shows the noise-free, filtered signal under static and dynamic conditions.

Edge filter

The edge filter smoothes signals at transitions such as edges or surface changes and therefore avoids signal overshooting. This means that it is possible to detect edges precisely and to avoid a slurring signal (change in slope). The filter threshold marks the value which has to be exceeded for it to be recognised as a signal change and not as surface roughness.

When activating the edge filter, the following parameters are set automatically:

- Measurement setup: diffuse reflection or direct reflection - distance measurement
- Peak to be measured: first peak
- Video averaging: no averaging
- Data selection: distance

Areas of use for averagings/filters:

	Full data rate	Uniform noise without spikes	Suppression of spikes	Short transition response times	Strong smoothing
Arithmetic Mean	- -	+	-	+	-
Moving average	+	+	-	-	+
Recursive average	+	+	-	- -	++
Median	+	-	++	+	- -
Dynamic noise rejection	+	++	- -	++	-
Edge filter	+	-	+	+	-

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