TECH NOTE :: PMX CASMA-filter

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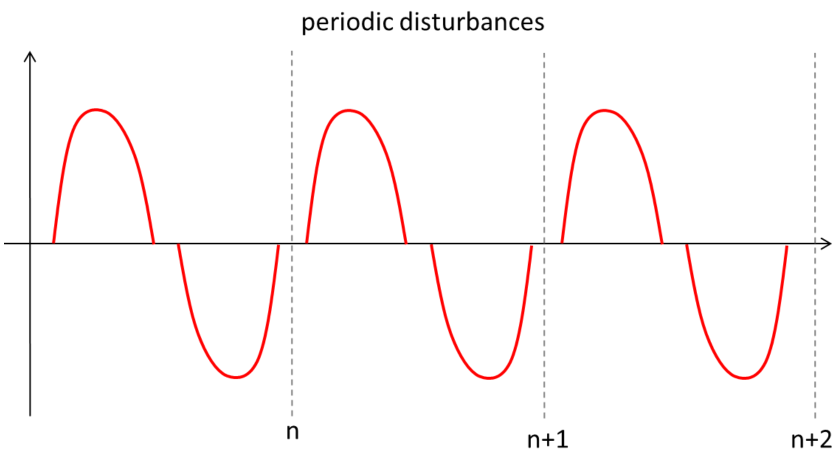
Brief description

This is an instruction to take the mean of a noisy torque signal with the use of a special filter. The CASMA-filter (*Crank Angle Sampled Moving Average*) works with angular synchronism and is time independent, which makes it able to react to changes of the revolution speed. The PMX provides an own calculated channel for this purpose. On the basis of a short example the usage of a CASMA-filter with a T40B torque transducer mounted to a 5-cylindric motor should be demonstrated.

Basic knowledge

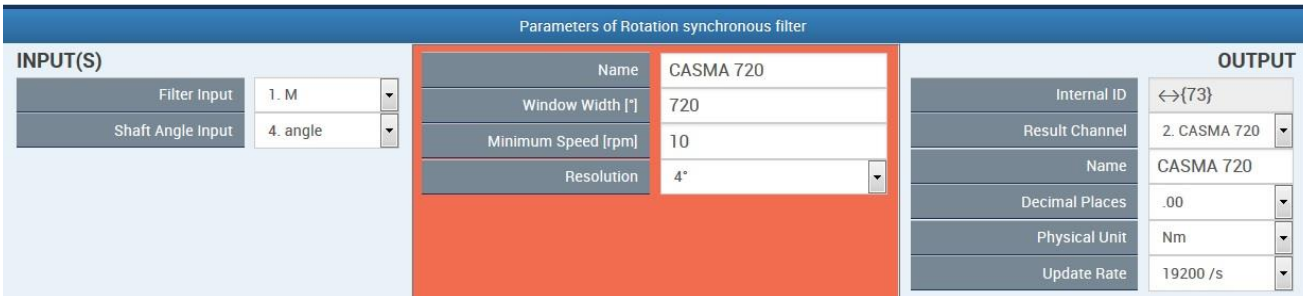
Due to the work cycle with compression and expansion in the individual cylinders and the corresponding fluctuations in combustion, the torque generated by an engine exhibits highly dynamic behavior. These disturbances are systemic and can affect the desired measurement significantly. In many measurement systems it appears as noise.
The CASMA-filter eliminates periodic disturbances that are synchronous to the rotation of a shaft. It performs a moving average. The filter does not work time synchronous as usual. It rather works synchronously to the shaft rotation. Thus the filter effect does not depend on the rotation speed. The filter's calculation period is proportional to the rotation speed. When the rotation stops, the filter stops operating as well.



The CASMA-Filter

Create a calculated channel

Create a new calculated channel “rotation synchronous filter” in the *Analysis* category.



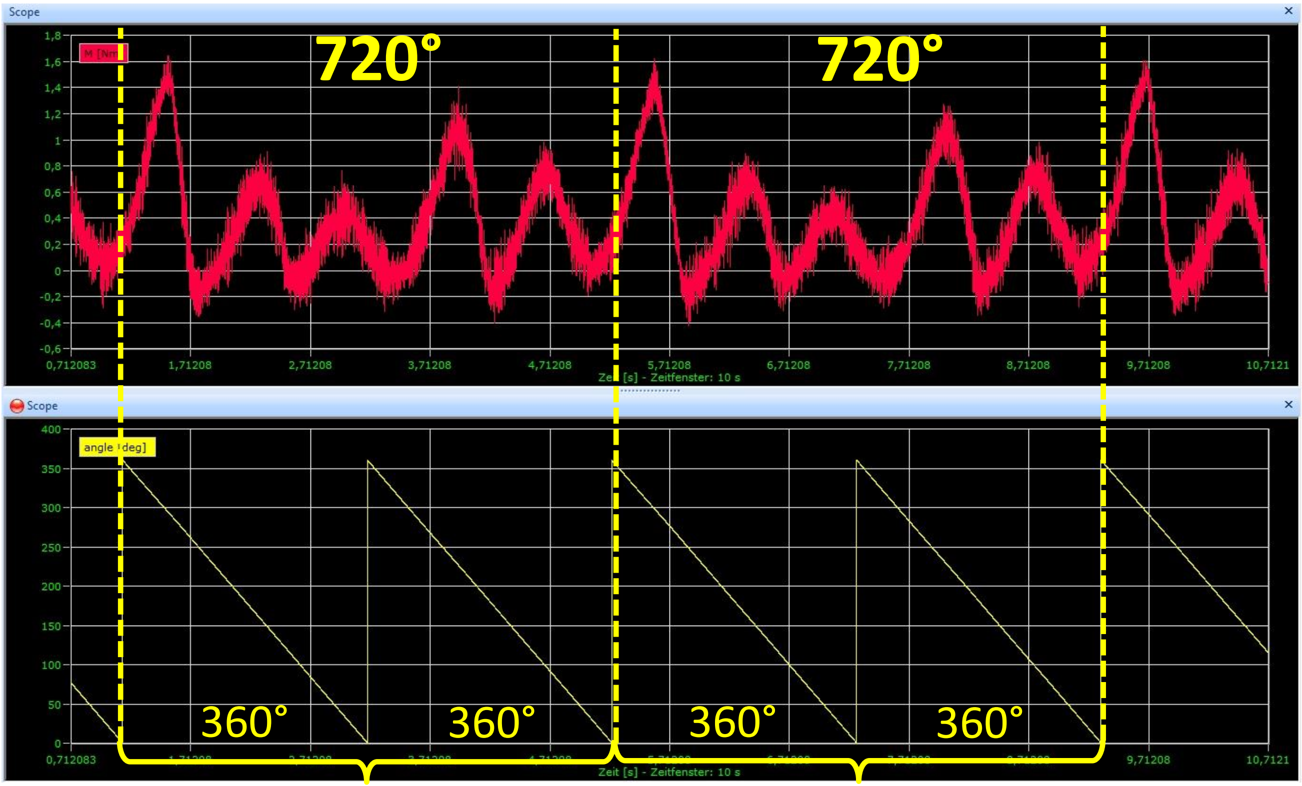
Adjust parameters

Filter input: Enter the signal to be filtered here.

Shaft Angle Input: Enter the signal of the angle of rotation sensor here. The measured values must fall between 0° and 360°.

Window Width: Specify the range over which the moving average will be formed here. The width must be between 30° and 720°. The default setting is 180°. The ratio of the window width to the resolution must be less than 180.

The window width can be easily found out experimentally by projecting the periodic time of interference on the angle of rotation (see screenshot). In this particular example the periodic interference occurs every 720°.



Minimum Speed: This virtual rotation speed is applied when the active rotation speed is less than the defined minimum rotational speed.

Resolution: This value determines how frequently (how many degrees each time) a new average will be calculated. Note that the maximum permitted permissible rotational speed depends on this value because the speed of calculation is determined by the overall update rate.

The theoretical value is derived by: Maximum rotational speed = resolution * overall update rate / 6.

For practical purposes you should use values that amount to only 10 to 20% of this theoretically possible maximum rotational speed.

Resolution	The theoretical maximum rotational speed at an overall update rate of 19,200 Hz	The theoretical maximum rotational speed at an overall update rate of 38,400 Hz
1°	3200 rpm	6400 rpm
2°	6400 rpm	12.800 rpm
4°	12.800 rpm	25.600 rpm
6°	19.200 rpm	38.400 rpm
8°	25.600 rpm	51.200 rpm

The following multiples of the rotational speed are suppressed depending on the window width:

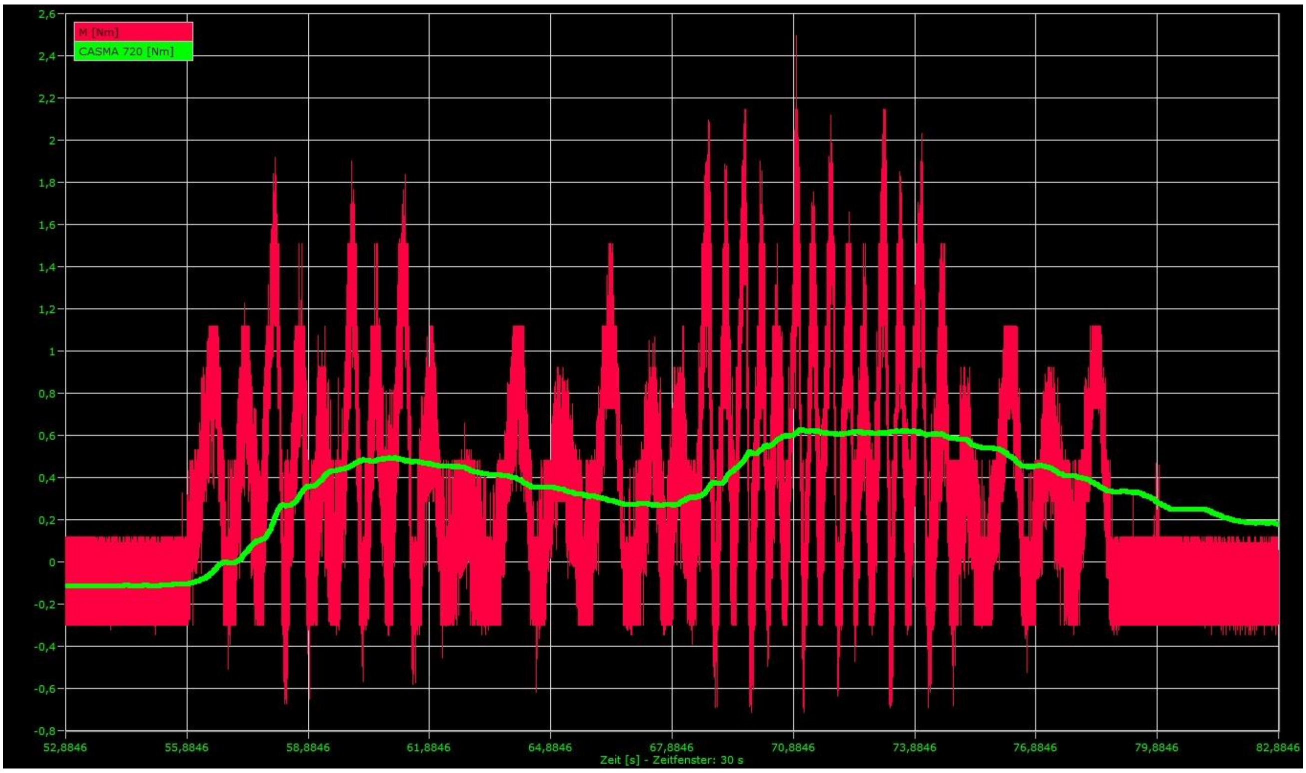
Window width	Multiples
90°	4, 8, 12, …
120°	3, 6, 9, …
180°	2, 4, 6, …
360°	1, 2, 3, …
720°	0, 5, 1, 1, 5, …

Note: If one of the source signals is invalid, the output signal will be invalid as well.

CASMA in action

Unfiltered torque signal (red), filtered torque signal by CASMA (green).

It can be clearly seen that the CASMA filter achieves excellent stabilization of torque measurements in correlation to the engine speed, which also changes over the course of time. The greater the width of this filter, the better the results.



Example

In this short example besides the torque M [Nm] and the corresponding CASMA-filter, the power P[W], the rotation speed n [1/s] and the acceleration [1/s²] are analyzed by the PMX as well. Therefore the calculated channels from the screenshot below have been created. The signals are displayed in catman.

CALCULATED CHANNELS

Default DAQ

Order	Input(s)	Function	Name	Internal ID	Result Channel	Result
		Constant signal	2*pi	↔{72}	4	6
		Constant signal	const 60	↔{78}	3	60
1	n, const 60	Divider	n [1/s]	↔{77}	5	0.00 $\frac{1}{s}$
2	M, angle	Rotation synchronous filter	CASMA 720	↔{73}	2	-0.23 Nm
3	M, n [1/s], 2*pi, 1	Multiplier	P	↔{79}	6	0 W
4	2*pi, n [1/s], 1, 1	Multiplier	w	↔{75}	8	0 $\frac{1}{s}$
5	w	Differentiator	a	↔{76}	1	0.00 $\frac{m}{s^2}$
6	a	Filter	a (filtered)	↔{74}	7	0.00 $\frac{m}{s^2}$

Calculations

Power:

$$P = M \cdot n \cdot 2\pi\,, \quad 1[P] = 1W = 1\frac{kg \cdot m^2}{s^3}$$

Angular speed:

$$\omega = 2\pi \cdot n\,, \qquad 1[\omega] = 1\frac{1}{s}$$

Angular acceleration:

$$\alpha = \frac{d\omega}{dt}\,, \qquad 1[\alpha] = 1\frac{1}{s^2}$$

Important: For all calculations the rotation speed n has to be converted from revolutions per minute in revolutions per second, so divided by 60.

Channels

On the next page you can find all channels displayed graphically in catman. The colors in brackets are related to the colors of the curves. The signals consist of the following channels:

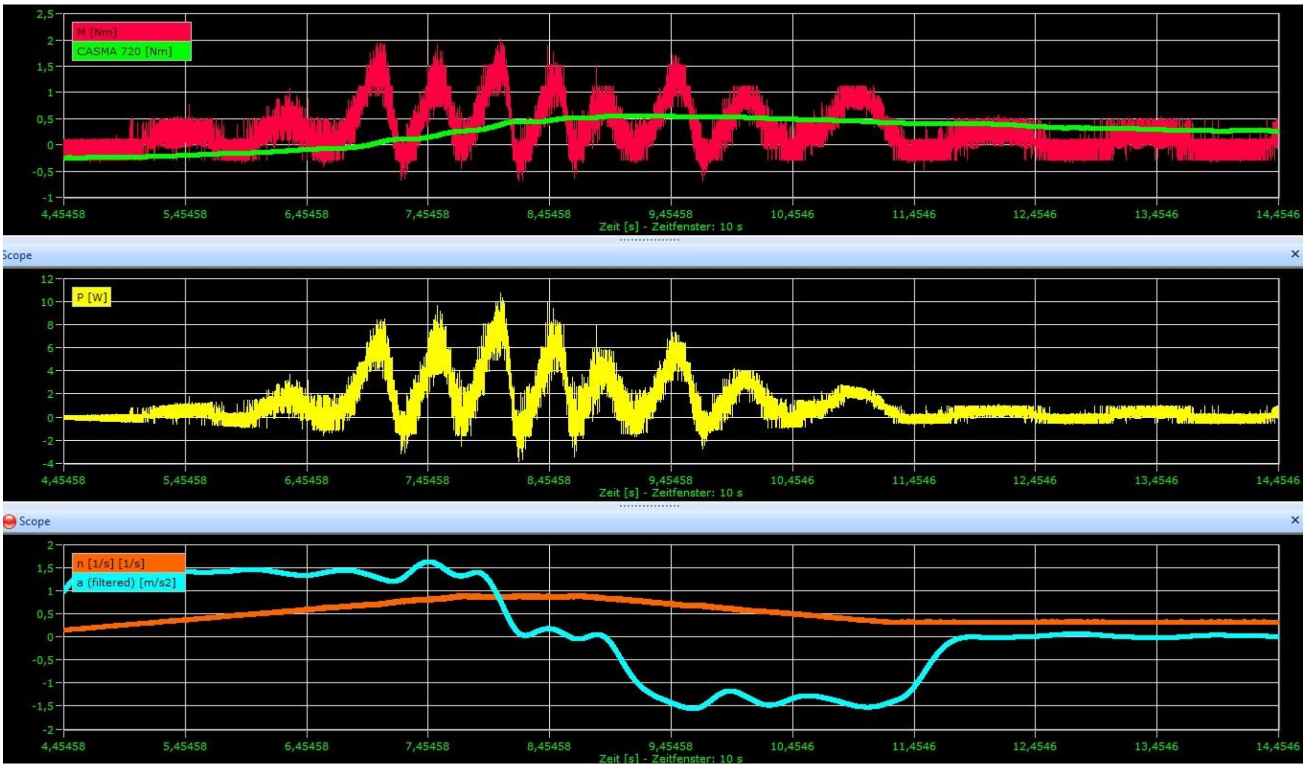
Torque M (red):
- Directly from the measurement channel of the PX460

CASMA-Filter (green):
- Already explained in detail

Power P (yellow):
- Divider (rotations speed n / 60), revolutions per second
- Constant signal (2*pi)
- Multiplier (M * n [1/s] * 2*pi]

Rotation speed n (orange):
- Directly from the measurement channel of the PX460

Angular acceleration (blue):
- Multiplier (2*pi * n [1/s]), results in the angular speed w
- Differentiator (w)



Disclaimer

These examples are for illustrative purposes only. They cannot be used as the basis for any warranty or liability claims.