Condition Monitorung using the IoT ready functionality

Summary

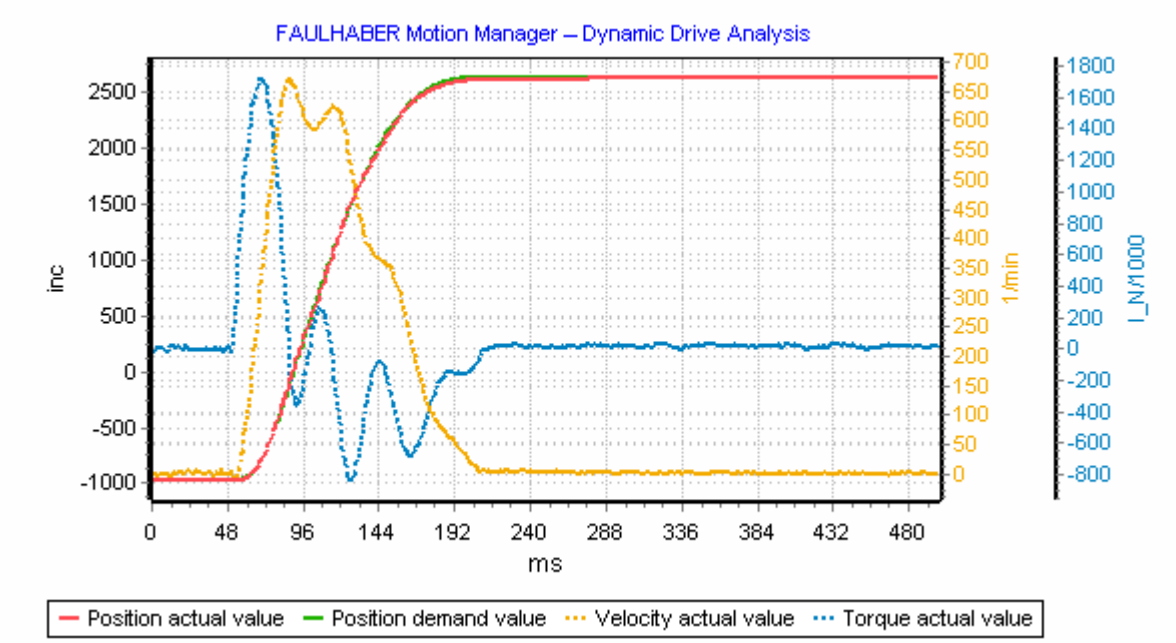
FAULHABER MC V3.0 devices can compute statistics on most actual values like minimum, maximum mean or rms value of current, speed or following error. These statistical values are a better fit for the available bandwidth of even EtherCAT than the original values which are sampled every 100µs. The cacluation can either be triggered on time, on turns or on reaching a target speed or target position.

Applies To

FAULHABER MotionControlSystems and MotionControllers out of Product Family V3.0

Why and when to use IoT ready function?

When supervising a moving drive typical signals to supervise can be the current over time, the speed of a drive or the time required to reach a position.
When still being connected to the drive via the graphical analysis of the FAULHABER MotionManager it's mostly current, speed or position over time that are indicating the performance or rather the change in the drive's performance.
Using the recoder functionality of the FAULHABER MotionManager's Graphical Analysis the data can be captured based on a configureable trigger and up to 4 signals can be recorded in parallel.
The relevant characteristics can then be assessed based on the captured signal sequence.



Later in a productive environment that's usually no longer possible. While technically possible to route the MotionManager communication to a drive via the PLC, there is usually no one following all these moves. Even when not using the MotionManager simply streaming all the data is not an option either. None of the available communication interfaces would be able to provide the required bandwidth.

Whenever algorithms like condition monitoring being used pre-processed process variables are required.

The IoT ready function of FAULHABER Motion Controller can record all signals that could have been visualized with the MotionManager but can directly compute typical characteristics like the minimum, maximum, mean or rms of a signal. It can also compute the standard deviation or the period time of a signal.
To do so the IoT function re-uses the signal buffers the Graphical Analysis to record signals and computes the characteristics at a configurable event.

How to configure the IoT ready function?

To use the IoT ready function there are several steps of configuration.

Step 1: Configure the recoder for IoT ready

The behavior of the trace recorder unit can be configured either using object
0x2370.04: trigger mode or the object
0x2370.0F: trigger mode IoT

0x2370.04 is used by the MotionManager. As it is possible to use the logger of the MotionManager in parallel to the IoT ready function use 0x2370.0F to configure the IoT ready mode without conflicting with the MotionManager.

0x2370.0F trigger mode

MSB							
reserved	reserved	reserved	reserved	reserved			isLogicTrigger

							LSB
Mode [1]	Mode [0]	Logging Type [1]	Logging Type [0]	Edge2	Edge1	Edge0	EN

Relevant are Mode and Logging Type settings:

Entry	value
Logging Type	0: std. recorder 1: IoT ready
Mode	0: no trigger (recoder only) 1: single shot 2: repeating

For continued updates of the calculated statistics set 0x2370.0F = 0x0090
For a single calculation sequence set 0x2370.0F = 0x0050

Step 2: Select up to 4 signals to be recorded

Up to 4 signals can be recorded and evaluated in parallel. Different events for start, update and stop of the recording can be configured for each of the signals.
The objects to configure the sources are:

Object (hex)	Sub-Index (dec)	Entry	Format
2370	11	Signal @ channel 1	uint8 | uint16 | uint8 / 00 | index | Sub-idx
	12	Signal @ channel 2	
	13	Signal @ channel 3	
	14	Signal @ channel 4	

Typical signals could be out of the control loop being updated every 100µs which is too fast for real-time uploads.

Object	Signal	Format	Bits
0x6078.00	Current actual value	00 60 78 00	S16
0x6077.00	Torque actual value	00 60 77 00	S16
0x6074.00	Torque demand value	00 60 74 00	S16
0x606C.00	Velocity actual value (user scaling)	00 60 6C 00	S32
0x6068.00	Velocity demand value	00 60 68 00	S32
0x2360.05	Velocity act int. value	00 23 60 05	S16
0x6064.00	Position actual value (user scaling)	00 60 64 00	S32
0x6063.00	Position actual value (int. scaling)	00 60 63 00	S32
0x6062.00	Position demand value (user scaling)	00 60 62 00	S32
0x2360.06	Position actual internal value	00 23 60 06	S16
0x60F4.00	Following error actual value	00 60 F4 00	S32

Additional ones could be

Object	Signal	Format	Bits
0x2314.01	IA	00 23 14 01	S16
0x2314.02	IB	00 23 14 02	S16
0x2314.03	IC	00 23 14 03	S16
0x2325.06	Device supply voltage	00 23 25 06	S16
0x2325.07	Motor supply voltage	00 23 25 07	S16

Step 3: Configure the sampling interval and the pre-filter that might be required

The sampling rate for each signal can be set individually.
Sampling rates are configured in the channel configuration:

Object	Signal	Values
0x2378.02	Sampling rate for signal @ channel 1	(0), 1 … uint16
0x2379.02	Sampling rate for signal @ channel 2	
0x237A.02	Sampling rate for signal @ channel 3	
0x237B.02	Sampling rate for signal @ channel 4	

With a value of 0 there is no sampling on time but the value of 0 can be used for more advanced features which will be explainded in a next chapter.

As there is a maximum amount of 2kbyte per signal to be recorded it might be necessary not to use the maximum sampling rate of 1 x 100µs.
Using the maximum sampling rate of 1 x 100µs will give you a maximum recoring time of
>> 51ms for a 32 bit signal or
>> 102 ms for a 16 bit signal.

When it is not possible to sample every time, using the pre-filter might be a way to at least capture the signal als close as possible. The filter time of the pre-filter is again configured individually for each channel:

Object	Signal	values
0x2378.01	Filter time channel 1 in multiples of 100µs	(0), 1 … uint16
0x2379.01	Filter time channel 2 in multiples of 100µs	
0x237A.01	Filter time channel 3 in multiples of 100µs	
0x237B.01	Filter time channel 4 in multiples of 100µs	

A value of 0 disables the pre-filter and allows for unfiltered values to be recorded.

Minimum, maximum, mean-value, rms, std. deviation and period time of a signal are always calculated based on the recorded values.

There are additional two signals: absolute minimum and absolute maximum which are not calculated based on the buffered values but are upated while the recording of a signal is active, even when the statistics values are refreshed multiple times for multiple recordings.

This absolute minimum and absolute maximum values are always unfiltered and are reset only when a channel is explicitly stopped.

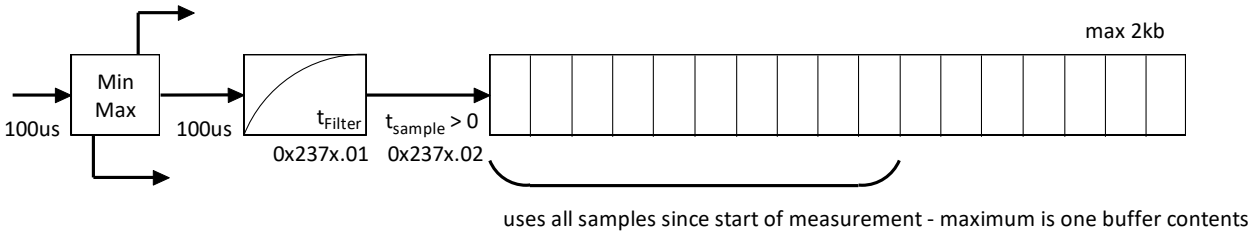


Figure 1 Filter and buffer configuration of a single channel

Step 4: Configure when to start the recording and when to upate the characteristic values

As the last step the start- and stop/update event for the update of the per buffer statistics have to be selected.

There are two main possibilies:

- Record and upate continuously – no start event used or needed
- Record the signals synchronously to specific movements like a move from a to b (position control) or during the acceleration phase in speed-control. In such a case an explicit start event is to be configured.

The stop- or update-event is always required as only then the interal calculations are triggered.

Start Event

When a single move or repeated moves shall be recorded and assessed via the statistics an explicit start of the recoding for this signal is to be configured. This configuration again can be done for each channel:

Object	Signal	values
0x2378.05	Start event of channel 1	(0),1 … 3
0x2379.05	Start event of channel 2	
0x237A.05	Start event of channel 3	
0x237B.05	Start event of channel 4	

Start events can be:

Event #	when
0	No start event configured – recording starts when an update event ≠ 0 is selected
1	Start recording when speed ≠ 0
2	Start recording when target speed reached
3	Start recording when a new pos-move is started

Update/Stop Event

The event when to update the statistic values for the recorded sequence is mandatory.

Object	Signal	values
0x2378.06	Update/Stop event of channel 1	(0),2, 4 … 14
0x2379.06	Update/Stop event of channel 2	
0x237A.06	Update/Stop event of channel 3	
0x237B.06	Update/Stop event of channel 4	

Statistic values of a channel are updated when:

Event #	when
0	No update/stop event configured – channel is disabled, abs. max/min being reset.
2	Update statistics when target speed reached Typical length in **0x237x.03** = 1
4	Update the statistics when actual pos enters the target corridor Typical length in **0x237x.03** = 1
5	Update the statistics when position reached is finally flagged typical length in **0x237x.03** = 1
6	Update the statistics after the number of ms configured in **0x237x.03** passed
7	Update the statistics after the number of index signals configured in **0x237x.03**
8	Update the statistics when EVENT occurs in a BASIC script Length in **0x237x.03** = 1
9	Reserved
10	Update the statistics when statistic values are read via interface Length in **0x237x.03** = 1
11-14	Advanced recording

Computed Characteristics

The statistic values that can be calculated are configured for each channel in the channel settings:

Object	Signal	values
0x2378.04	Selection of values for channel 1	Bit-mask 0x0001: minimum value 0x0002: maximum value 0x0004: mean value 0x0008: rms value 0x0010: std. deviation 0x0020: period time of a signal
0x2379.04	Selection of values for channel 2	
0x237A.04	Selection of values for channel 3	
0x237B.04	Selection of values for channel 4	

To have not only one of the signals calculated but multiple like minimum+maximum+mean the signals can be combined by by combining the bits in 0x237x.04.

Summary of the parameters

0x2370.xx Global configuration

Entries are

0x2370.00	
0x0090:	IoT mode with repeated evaluation of the recorded sequences until channels are stopped
0x0050.	IoT mode with only a single sequence being recorded and computed

0x237x.xx Channel Configuration

Basic configuration

Object	Signal	Bits
0x237x.01	1… uint16: Filter-time of the pre-filte in multiples of 100µs 0: switched off	
0x237x.02	1 … uint16: sampling frequency in multiples of 100µs 0: sampling only on specific events	
0x237x.03	Number of events to accumulate before the update is calculated 0: off 1: typical for moves or on EVENT or on Rx 1 … 5: typical values when updated after turns 1 … 512, … 2048: typical value for update after numer of ms	
0x237x.04	Selection of the signals to be updated on event selected in .06	
0x237x.05	1 … 5: Select the start ot the recording 0: no explicit start – start as soon as update is selected	
0x237x.06	1 …15: Select the event when to update the statistics 0: channel switched off	

Calculated values

Object	Signal	Bits
0x237x.0x10	Absolute minimum since start of this channel	
0x237x.0x11	Absolute maximum since start of this channel	
0x237x.0x12	Minimum value of the recorded signal in last buffer	
0x237x.0x13	Maximum value of the recorded signal in last buffer	
0x237x.0x14	Mean value of the recorded samples of the signal	
0x237x.0x15	Rms value of the recorded samples of the signal	
0x237x.0x16	Std. deviation of the recorded samples of the signal	
0x237x.0x17	Period time of the recorded signal based on one last recording	

Additional information

Object	Signal	Bits
0x237x.07	**Number of eval cycles:** Counts the number of cycles for repeated updates of the calculated values. A number of 5 denotes the statistics being 5 times updated meanwhile	
0x237x.0E	**Number of buffer overflows:** How often did the buffer overflow until the values were updated. An overflow can happen if the required buffer length exeeds the available 2 kbyte. Consider reducing the sampling rate as information is lost.	
0x237x.0F	**Status of this channel:** 0: configured and waiting for first event 1: data capture running 2: single sequence was configured which is completed	

Calculating an average of mean-values – adavanced features

In the usage modes above the selected signal was always captured cyclically with a configurable pre-filter (0x237x.01) and sampling rate (0x237x.02) which is convenient when tracking moves over time.
A more advanced usage is to have a first channel do exactly that – track a movement and calculate statistics after each move or after a given number of turns or a certain time. Then use a second channel which is triggered by the first channel to capture one of the resulting statistics values of the first channel.
This can e.g. be used to cyclically update mean- or rms-values of the motor current over defined moves and then sample the results into a second channel where e.g. the minimum and maximum for these mean- or rms-values are to be identified.

First channel – on time – calculate the rms per move
In such a chase the 1st channel (e.g. 0x2370.11) could be configured to calculate the mean- and rms of the current actual value (0x6078.00) for single moves:

- Start @ new move: 0x237x.05 = 3
- Update @ being in position: 0x237x.06 = 4 or 5
- Select filter and sampling according to the expected duration
- Select number of samples 0x237x.03 = 1 (each move)

Second channel – on event – calculate the min/max of the rms values
A second channel could caputere the calculated mean-value or rms-value of the current 0x2370.12 = 00 23 78 14 or 00 23 78 15

Here no filter and sampling. Sampling = 0 is the key to select this advanced version.
To be triggered whenever channel 1 is updated:
0x237x.06 = 11.

Configure the 2nd channel to update maximum and minimum of the recorded values whenever the values are read: 0x237x.04 = 10.

Sources for such an advanced update can be:

Event #	when
0	No update/stop event configured – channel is disabled.
8	Sample the configured signal when EVENT occurs in a BASIC script
9	Sample the configured signal at the occurrence of a configured trigger
11	Sample the configured signal when IoT channel 1 flags having updated
12	Sample the configured signal when IoT channel 2 flags having updated
13	Sample the configured signal when IoT channel 3 flags having updated
14	Sample the configured signal when IoT channel 4 flags having updated

Using the characteristics in a cloud or edge environment

Main advantage of the IoT ready function is to provide pre-processed statistics about the drive function which are based on the full information out of the control loop but can easily be tracked via typical communication interfaces.
Any edge device reading them can then even use them locally to supervise the moves or even upload them to whatever used cloud service where it is then simple to accumulate the basic statistics of the moving drive and use it for whatever state of health monitoring is intended.

Examples

The exampes are in .vbs format which can directly be executed using the MotionManager 6.

Evaluate the actual velocity over either time or turns

```
'-----------------------------------------
'Author:  MCSupport
'Date:    2024-01-23
'-----------------------------------------
'Description:  configure the IoT Monitor
'-----------------------------------------
Sub Main

nodeNr = 1

   'Init channels for log/monitoring
   MC.SetObj nodeNr, &h2370,11, &h00606C00, 4  'Velocity Actual Value
   MC.SetObj nodeNr, &h2370,12, &h00606C00, 4  'Velocity Actual Value

   'configure the timings of the channels
   MC.SetObj nodeNr, &h2378, 1, 10, 2    'ch1 - C_Filter32
   MC.SetObj nodeNr, &h2378, 2, 10, 2    'ch1 - SampleTime
   MC.SetObj nodeNr, &h2379, 1, 10, 2    'ch2 - C_Filter32
   MC.SetObj nodeNr, &h2379, 2, 10, 2    'ch2 - SampleTime

   'configure the samples = 5 Turns or 512 samples
   MC.SetObj nodeNr, &h2378, 3, 5, 2    'ch1 - BuffLength
   MC.SetObj nodeNr, &h2379, 3, 512, 2    'ch2 - BuffLength

   'configure the values to be updated
   MC.SetObj nodeNr, &h2378, 4, 15, 2 'ch1 - update min,max,mean and rms
   MC.SetObj nodeNr, &h2379, 4, 15, 2 'ch2 - update min,max,mean and rms

   'reconfigure the trace to be used for monitoring
   MC.SetObj nodeNr, &h2370, &hF, &h0090, 2   'this is monitoring mode |
                                              'repeating trigger
   'configure the finish source
   MC.SetObj nodeNr, &h2378, 5, 2, 1    'ch1 - on turns
   MC.SetObj nodeNr, &h2379, 5, 1, 1    'ch2 - on time

End Sub
```

Eval the performance of a single servo move

```
'-------------------------------------------
'Author:   MCSupport
'Date:     2025-01-08
'
'-------------------------------------------
'Description:  Eval Motor Current and speed over a single move
'-------------------------------------------
Sub Main
   nodeNr = 1

   'Init channels for log/monitoring
   MC.SetObj nodeNr, &h2370,11, &h00607800, 4  'Current actual value
   MC.SetObj nodeNr, &h2370,12, &h00606C00, 4  'Speed actual value

   'configure the timings of the channels
   MC.SetObj nodeNr, &h2378, 1, 0, 2    'ch1 - C_Filter32
   MC.SetObj nodeNr, &h2378, 2, 10, 2    'ch1 - SampleTime
   MC.SetObj nodeNr, &h2379, 1, 10, 2    'ch2 - C_Filter32
   MC.SetObj nodeNr, &h2379, 2, 10, 2    'ch2 - SampleTime

   'configure the samples
   MC.SetObj nodeNr, &h2378, 3, 1, 2    'ch1 - BuffLength
   MC.SetObj nodeNr, &h2379, 3, 1, 2    'ch2 - BuffLength

  'configure the values to be updated
   MC.SetObj nodeNr, &h2378, 4, 15, 2 'ch1 - update min,max,mean and rms
   MC.SetObj nodeNr, &h2379, 4, 15, 2 'ch2 - update min,max,mean and rms

   'reconfigure the trace to be used for monitoring
   MC.SetObj nodeNr, &h2370, &hF, &h0090, 2   'this is monitoring mode |
                                              'repeating trigger

   'configure the start event source
   MC.SetObj nodeNr, &h2378, 5, 3, 1    'ch1 - on new Pos
   MC.SetObj nodeNr, &h2379, 5, 3, 1    'ch2 - on new Pos

   'configure the finish source
   MC.SetObj nodeNr, &h2378, 6, 5, 1    'ch1 - on in Corridor
   MC.SetObj nodeNr, &h2379, 6, 5, 1    'ch2 - on in Corridor

End Sub
```

Check the min/max-value of rms-current of cycling moves

```
'-------------------------------------------
'Author:   MCSupport
'Date:     2025-01-08
'
'-------------------------------------------
'Description: Check the min/max-value of rms-current of cycling moves
'-------------------------------------------
Sub Main
   nodeNr = 1

   'Init channels for log/monitoring
   'Ch1: Current actual value
   MC.SetObj nodeNr, &h2370,11, &h00607800, 4

   'Ch2: rms of the per cyle current
   MC.SetObj nodeNr, &h2370,12, &h00237815, 4

   'configure the timings of the channels
   'assume 70ms of move time - 100µs filtering
   MC.SetObj nodeNr, &h2378, 1, 1, 2    'ch1 - C_Filter32
   MC.SetObj nodeNr, &h2378, 2, 2, 2    'ch1 - SampleTime
   'no filter for the 2nd channel
   'sampling time = 0!
   MC.SetObj nodeNr, &h2379, 1, 0, 2    'ch2 - C_Filter32
   MC.SetObj nodeNr, &h2379, 2, 0, 2    'ch2 - SampleTime

   'configure the samples
   'ch1 - BuffLength: each move
   MC.SetObj nodeNr, &h2378, 3, 1, 2
  'ch2 - BuffLength: update after 100 turns
   MC.SetObj nodeNr, &h2379, 3, 100, 2

  'configure the values to be updated
   MC.SetObj nodeNr, &h2378, 4, 15, 2 'ch1 - update min,max,mean and rms
   MC.SetObj nodeNr, &h2379, 4,  3, 2 'ch2 - update min,max

   'reconfigure the trace to be used for monitoring
   MC.SetObj nodeNr, &h2370, &hF, &h0090, 2   'this is monitoring mode |
                                              'repeating trigger

   'configure the start event source
   MC.SetObj nodeNr, &h2378, 5, 3, 1    'ch1 - on new Pos
   MC.SetObj nodeNr, &h2379, 5, 0, 1    'ch2 - not selected

   'configure the finish source
   MC.SetObj nodeNr, &h2378, 6,  5, 1    'ch1 - on in Corridor
  'ch2 - on channel 1
  'will sample on every of the ch1 on ready events and update the
  'min/Max after the configured number of turns out of 0x2379.03
   MC.SetObj nodeNr, &h2379, 6, 11, 1

End Sub
```

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