

NORIMOS 3000
Mean value Monitoring

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1 General

With many applications, it is not so much the absolute measured value which is of interest but rather the deviations of the measured values from each other, e.g. in the case of diesel engines, very different exhaust-gas temperatures (cylinder temperatures) indicate that the cylinders are being driven with different loads or that something is defective (valve blow-by, misfiring).

A mean value monitor system is therefore used here. It generates a mean value from the individual measured values of a mean value group and monitors the measured values for deviations from this mean value.

During mean value monitoring, the size of the deviations can vary, depending on the mean value. In the case of the above example with the exhaust-gas temperatures of diesel engines, the deviations are much more spread out with a partial load than with a higher load. This is normal and is not intended to lead to an alarm. A so-called trumpet curve is therefore used which permits a larger deviation in the case of a lower mean value temperature than in the case of a higher one. Below a certain mean value, the mean value monitoring system can be switched off completely.

In many applications the monitoring for mean value deviation is not enough. That is, why further features can be added:

- Monitoring of the individual channels for violation of maximum or minimum limit values.
- Monitoring of the mean value for violation of maximum or minimum limit values.

1.1 Annotation for thermocouples

Thermocouples cannot perform measurements of absolute temperatures. They only can measure the difference in temperature between the two ends. That is, a so called cold point correction measurement has to be performed, to measure the temperature at the cold end of the thermocouple. Mostly a Pt100 sensor is used fort hat. (The hot end of the thermocouple also may be colder than the cold end.)

1.2 Definition for the used terms

In this description the following abbreviations are used:

- CPC = Cold point correction.
- DEV = Deviation
- ABS = absolute limit value
- MVL = mean value

1.3 Equipment

For mean value monitoring, the following channels are required:

- at least 2 mean value channels.

As an option, the following can be added:

- 1 channel for specifying the first (and second) deviation limit.
- 1 channel with which limit values can be specified which apply to each individual mean value channel. These can be maximum or minimum limit values.
- 1 mean value maximum channel which monitors the mean value in relation to a maximum limit value

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2 Channels

2.1 Guide channel for group deviation (= DEV Channel):

The DEV channel sets up to 2 levels for he allowed deviation, and also for the related delay times. These parameters are valid for all individual measuring channels of the same monitoring group. In case a related measurement channel exceeds one of the deviation levels, then alarm is generated for the related measurement channel as well as for the guide channel.
Guide value for the allowed deviation(s) may be the mean value over all individual measurement channels. But lately the engines change the exhaust gas temperatures only slightly related to their load. So the possibility is created to use the measurement value of any channel as guide value fort he allowed deviation. Reasonable is the load of the engine. Condition is, that this channel is situated in the same unit.

The guide channel for group deviation has no direct hardware input. So it is possible to use this channel additionally for measuring of the cold point temperature, in case that the monitoring group is used for exhaust gas temperatures, that are measured with thermocouples.

The allowed deviations are set by deviation tables. They may be edited via the display during setting the parameters of the DEV channel.

In the display either the cold point temperature is shown in case this temperature is measured via the DEV channel or the calculated mean value over all individual channels.

2.2 Guide channel for absolute limits (= ABS Channel):

The ABS Channel sets up to 2 levels for absolutely valid limit values and also for the related delay times. In case a related measurement channel exceeds one of the absolute levels, then alarm is generated for the related measurement channel as well as for the guide channel.

The guide channel for group deviation has no direct hardware input. So it is possible to situate it inside the monitoring unit in a way, like it is best for using the available hardware. Especially it is possible to use it as a so called imaginary channel. That is, it is visible in the display and via the CANbus, but no LED is concerned.

The display shows the highest occurring measurement value of the related individual channels.

2.3 Channel for mean value maximum (= DEV MAX Channel):

The DEV MAX Channel sets up to 2 levels for the mean value itself. The channel issues alarm if the mean value exceeds one of the limit values. In case of exhaust gas monitoring this indicates, that the engine is healthy, but that it is overloaded.

The display shows the mean value.

2.4 Individual mean value channels (MVL Channels):

These are the measuring channels which are monitored for cases of deviation from the mean value and for exceeding of the absolute limits.

The mean value is calculated from the measured values of all the mean value channels of a group. Channels with faulty sensors are not included in the calculation of mean values.

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After mean value calculation and before monitoring for mean value deviation, a so-called deviation correction is carried out. It may be that certain channels deviate from the mean value by a certain amount even when the engine is "healthy". By means of deviation correction, the mean value deviation is monitored from the point of view of this healthy deviation.

2.4.1 Deviation Correction

Assumption:

Mean value temperature	MVL	= 453°
Allowed deviation up/down:	DEVallowed	= 30° / 30°
Temperature Cylinder B5	CYLTEMP B5	= 471°

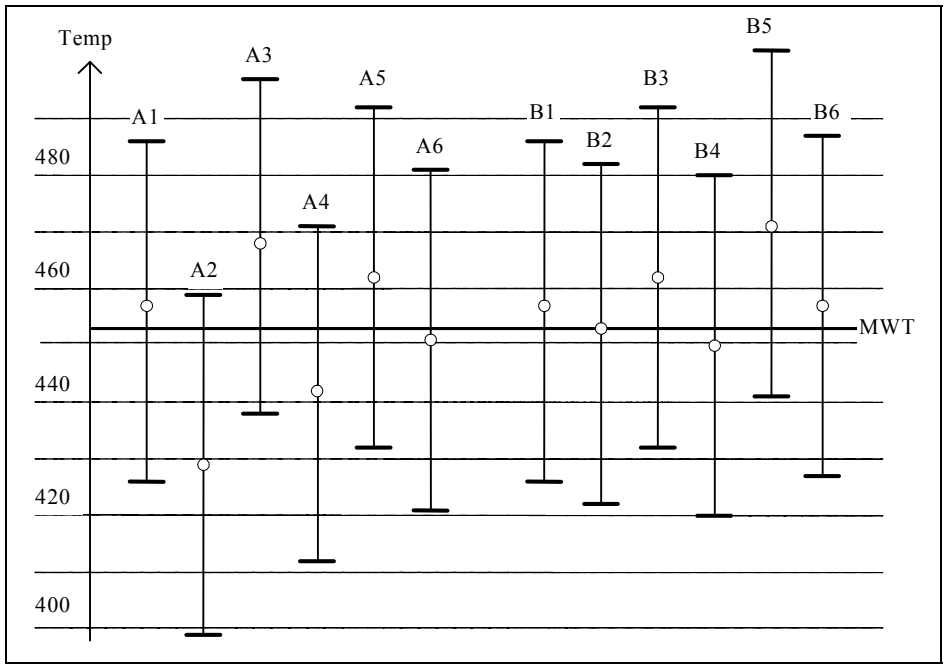
Among these assumptions cylinder B5 operates 18° warmer than the average of all cylinders. Its temperature (without performing cylinder correction) only needs to rise by 12° but would have to fall by 48° to trigger an alarm.
It should be able to oscillate, however, around 30 degrees before an alarm is issued. This is enabled by deviation correction. If a deviation correction of C = +18 has been set, cylinder B5, at 471 degrees, does not deviate from its normal temperature which it calculates from MVL + C. The deviation is given by

DEV = CYLTEMP - (MVL + C)

The cylinder temperature must now rise to 501 or fall to 441 in order to trigger an alarm. It can therefore, in fact, oscillate around 30.

The following illustration is based on the data from a measurement record for a healthy 12-cylinder V-engine. It shows the permitted temperature ranges when MVT = 453 and the allowed deviation is 30 and when no mean value correction has been set. It can be seen from this that, for example, cylinder A2 with value 429 can deviate downwards only by around 6 degrees but, upwards, by approximately 54, a circumstance which is not acceptable.

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2.4.2 Fading out of Channels

Measuring channels may be faded out by the operator. But that should be the last way out before the service engineer arrives, when an again and again disturbing defective channel cannot be repaired at once.
No alarm is created, neither when a sensor failure occurred nor when a limit value is exceeded. Internally they are processed normally, only the setting of alarms is disabled. On the display they are marked by that, that the message text and the fade out hint is shown alternate with each other. Measuring values are shown further for help when looking for failures.
They are marked by channel LEDs with a special flashing signal. Their LEDs are switched on only during one of eight time periods.
Fading out and fading in of channels are recorded.
Some channels cannot be faded out. These are all channels from whose other channels depend on. Namely inhibition channels, the guide channels for mean value deviation, group alarms. Also channels, whose measured value is used by an other channel, cannot be faded out.

2.4.3 Alarms

Alarms are issued under the following conditions:

- Sensor failure always at occurrence, not depending on inhibitions.
- Measurement value alarm only then, when the related inhibition is not active:
  - if the measurement value exceeds one of the limit values, that are set by the ABS-Channel.
  - if the measurement value after the deviation correction exceeds one of the allowed deviations, that are set by the DEV channel.

Delay times: The following delay times are used:

- Sensor failure ON: Delay time ON of the channel itself
- Sensor failure OFF: Fixed OFF delay of 10s
- Mean value deviation 1: Delay times 1 of the DEV channel
- Mean value deviation 2: Delay times 2 of the DEV channel

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- Absolute limit 1: Delay times 1 of the ABS channel
- Absolute limit 2: Delay times 2 of the ABS channel

2.4.4 Reoccurrence of an alarm

For the occurrence of a 2nd alarm in the case of one channel, the following applies.
If a channel for mean value monitoring already has an alarm and a 2nd alarm condition is added, the acknowledgement is reset, the horn is operated again and the relevant LEDs flash again.
Example:

The mean value monitoring system does not have an alarm.
A 1st mean value channel exceeds its 1st permitted deviation.
⇒ The alarm indices are set in the 1st mean value channel.
⇒ After expiry of the ON-delay time, the mean value channel and DEV channel both receive an alarm; the horn is operated and the relevant LEDs flash.
The acknowledgement keys, HORN and OPTO are pressed and both channels change to acknowledgement status.
A second mean value channel exceeds its 1st permitted deviation.
⇒ An alarm index is set in the 2nd mean value channel.
⇒ After expiry of the ON-delay time, the 2nd mean value channel receives an alarm; the horn is operated and the relevant LED flashes.
⇒ The acknowledgement status of the DEV channel is reset, horn is operated, and the relevant LED flashes.
The acknowledgement keys, HORN and OPTO are pressed and both channels changes to acknowledgement status.
The 1st mean value channel deteriorates and exceeds the 2nd perm
⇒ After expiry of the ON-delay time, the 1st mean value channel changes to not acknowledged status, the horn is operated, it's LED flashes.
⇒ The DEV channel receives an alarm; the horn is operated and the relevant LED flashes.
The HORN and OPTO acknowledgement keys are pressed and the 1st mean value channel and the DEV channel change to acknowledgement status.
And so on...

3 Recommendations for setting of mean value monitoring

The setting instructions of the engine manufacturer are always to be complied with.
Otherwise, the following recommendations can be made:
Mean value monitoring is usually used for the exhaust-gas temperatures of the individual cylinders.
Setting of deviation correction is best carried out during trial operation or during a trial trip. It must be ensured that the engine is 'healthy'.

- The engine is operated for a long time in the most-used load range so that thermal equilibrium is created.
- After this, setting mode is started, each individual mean value channel is selected - usually designated with "Exhaust-gas temperature cyl. X" - and the limit value, which here performs the function of deviation-correction, is simply set to 0.
- After the deviation correction has been set for the individual exhaust-gas channels, the permitted deviation can be set for the DEV channel. Usually, it is simultaneously used for cold point correction. For this, the deviation table(s) are edited for well suitable values.
- If it later turns out that the permitted deviation(s) are too small because false alarms for the exhaust-channels occur, the permitted deviation(s) can be set to a higher level.

Note:

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If deviation correction is set incorrectly, it is often necessary to set the permitted deviation(s) to an unnecessarily large amount because, otherwise, (false) alarms are given again and again. After correction of the setting, the permitted deviation(s) can be made smaller again. This results in more exact monitoring without the danger of frequent false alarms.

4 Other channels

When speaking of mean value monitoring, one normally thinks of the exhaust gas temperatures of the individual cylinders. But one also has to think of the temperatures before and after the turbocharger. Additionally in this description already was spoken about measuring the load of the engine.

4.1 Turbocharger temperature:

The temperatures before and after the turbocharger are not monitored for deviation from the mean value. For them fixed limit values are valid. Then one can set their limit values via the normal setting of limit values.

In some cases these limit values depend on the load of the engine. Then an instruction for calculating them has to be deposited. In NORIMOS 3000 they are indicated as dynamic. For calculation during the operation the PLC is used.

Assumption:

0123	= channel	"Engine Load",	measured in %
0142	= channel	"Turbocharger temperature",	measured in °C

There is a possible example for the instructions inside the PLC of the NORIMOS 3000. All inside curly parentheses is comment:

```
.E/A                          { IN-/OUT-Definitions begin here          }
   E1 = F01-23-W,             { E1 is measurement value   of channel 0123  }
   A1 = F01-42-GWE            { A1 is limit 1             of channel 0142  }
.LOGIK                        { Logic instructions begin here           }
  IF [P[ E1 < 25 ]]
    THEN
      F [ A1 = 65535 ]
    ENDIF

  IF [P[ E1 >= 25  ] AND
      P[ E1 <= 100 ]]
    THEN
      F [ A1 = 480 - ( 480 - 380 ) * ( E1 - 25 ) / 75]
    ENDIF

  IF [P[ E1 > 100 ]]
    THEN
      F [ A1 = 380 ]
    ENDIF
.ENDE                         { End of PLC }
```

The letter 'P' inside the IF-instruction means, that a calculation of a polynomal follows.
The letter 'F' after the THEN-instruction means, that a calculation of a function follows.

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Note

The formula between 25 and 100% might be improved:

F [A1 = (A1 * 7 + 480 – 100 * (E1 – 25) / 75) / 8]

With that the latest calculated limit value is weighted by factor of 7 and the newly calculated value is weighted by factor of 1. Consequently there has to be devided by 8. So one gets a better smoothed output value.

The instructions mean, that below of 25% no limit value monitoring is active, that at 25% load the limit value is set to 480°, that it decreases to 380° at a load of 100%, and that it is fixed at 380° above 100% load.

4.2 External Channel for calculating the allowed deviation:

Like noted above, for calculation of the allowed deviation either the mean value over all related individual measuring channels or the measured value of another channel can be used.

Such an external channel concerns the mean value monitoring only by that, that it's measured value is used. Otherwise the common criteria of its channel specification are valid.

Note:

Inside the deviation tables the reference value must be related to the measurement range of the external channel.

5 Specification

5.1 Used channels:

Please refer the further literature.

5.2 Deviation tables:

For each mean value group 2 deviation tables are reserved, one for the 1st, and one for the 2nd allowed deviation. The numbering concerns to the numbering of the mean value groups. Each table may have 4 entries, consisting of a guide value, one allowed deviation up and one allowed deviation down. Beneath the 1st guide value no monitoring is performed. Above the last guide value the allowed deviation is constant.

Each NORIMOS 3000 may have 4 mean value groups, that is there are 8 deviation tables. They are fix assigned:

Table 1.1	1st	allowed deviation for mean value group 1
Table 1.2	2nd	allowed deviation for mean value group 1
....		
Table 4.2	2nd	allowed deviation for mean value group 4

Valid is all between quotation marks. All other is treated as comment.

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Example:

Table 1.1, determines the 1st allowed deviation of the 1st mean value group. Here it is made for an external guide channel (load of the engine), that has a measuring range of 100%:

```
" 25     90     -80"
"100     50     -30"
"  0      0       0"
"  0      0       0"
```

The Table means:

Last < 25%.	Monitoring is switched off	
Last = 25%	Deviation up	< 90°
	Deviation down	< 80°
Last = 100%	Deviation up	< 50°
	Deviation down	< 30°
25% < Last < 100%	linear interpolation	
Last > 100%	Deviation like at 100%	

The table is linear, so one can let away the remaining 2 possible combinations and inscribe 0.

Example for a non valid table:

```
"  0      0       0"
"  0      0       0"
" 25     90     -80"
"100     50     -30"
```

Example for a valid, but not reasonable table:

```
"  0      0       0"
" 25     90     -80"
"100     50     -30"
"  0      0       0"
```

Example for a table with the mean value as guide value:

```
"280     90     -80"
"350     60     -50"
"400     40     -35"
"420     30     -30"
```

6 Further Literature

Information scripts:

I602e_Vxxx_N3000-user-handbook.doc	
I603e_Vxxx_N3000-channel-spec.doc	Channel-Specification, examples are added.
I604e_Vxxx_N3000-node-spec.doc	Node-Specification

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