Application Note

FESTO

Asset Type Motion Insights Pneumatic



GSDA-ATP-*-PCY

This document includes how to set up AX Motion Insights Pneumatic from connectivity to asset onboarding and monitoring of pneumatic actuators.

100677

Title ..... Festo AX Motion Insights Pneumatic
Version 1.90
Document no. 100677
Original ..... en
Author ..... Festo SE & Co. KG

Last saved 18.11.2026

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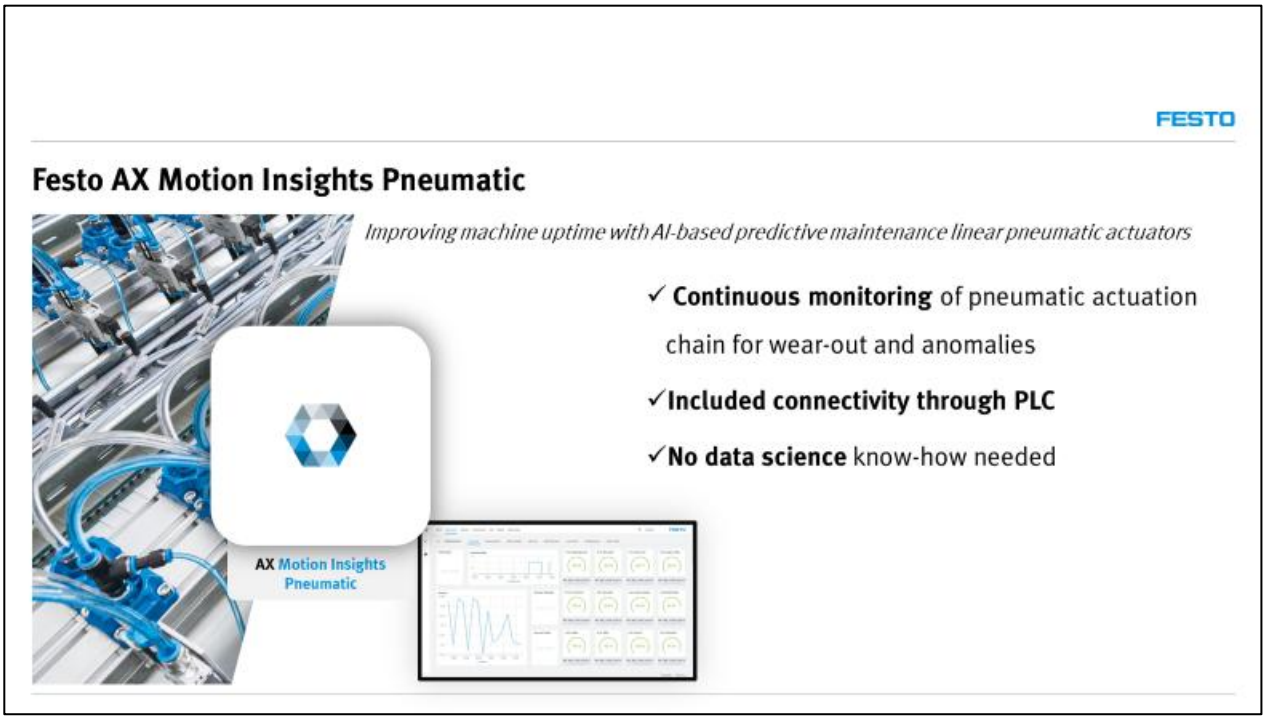
1 Introduction

Festo AX Motion Insights Pneumatic (AX MIP) is an Asset Type package for continuous monitoring of pneumatic cylinders. It comes with a standardized AI model chain and a user interface as well as a connectivity adapter to support the separately available PLC function blocks for data acquisition.



In the Asset Type package there are 2 Asset Types included: 'AssetType-MIP' and 'AssetType-MIP-Single'.

They are designed to work on the same principle but for different hardware configurations.

- **AssetType-MIP**: The monitored cylinder must be equipped with 2 limit switches, one for each end position. The required PLC function block for this variant is called 'FB_MIP' and is provided separately.
- **AssetType-MIP-Single**: The monitored cylinder is equipped with only 1 limit switch, which can be placed either at extracted or retracted position of the cylinder. The required PLC function block for this variant is called 'FB_MIP_Single' and is provided separately.

Besides the different PLC function blocks, the connectivity and onboarding mechanism is the same.

The model chain has the equivalent structure but has been adapted to the specific input features. Thus, the classifications also differ slightly. Essentially, however, the same errors can be detected.

Because MIP offers more features for monitoring cylinder movement, more accurate monitoring results are expected there than with MIP-Single.

2 System Requirements

2.1 PLC

For each monitored cylinder one instance of the Motion Insights Pneumatic FB (function block) needs to be implemented in the PLC. Requirements and compatibility are listed in the PLC specific Motion Insights Pneumatic FB Application Notes.

2.2 Automation equipment

- 1 or 2 limit switches on each cylinder depending on the Asset Type variant (AssetType-MIP-Single / AssetType-MIP)
- Cylinder travel time must fit to this formula:
    - Travel time of cylinder **greater than** 10 times PLC cycle time

2.3 AX Industrial AI Core environment

2.3.1 Core Version

The Asset Type requires a running instance of AX Industrial AI Core version 26 or higher.

2.3.2 Network

Ethernet network access to all involved PLCs must be available.

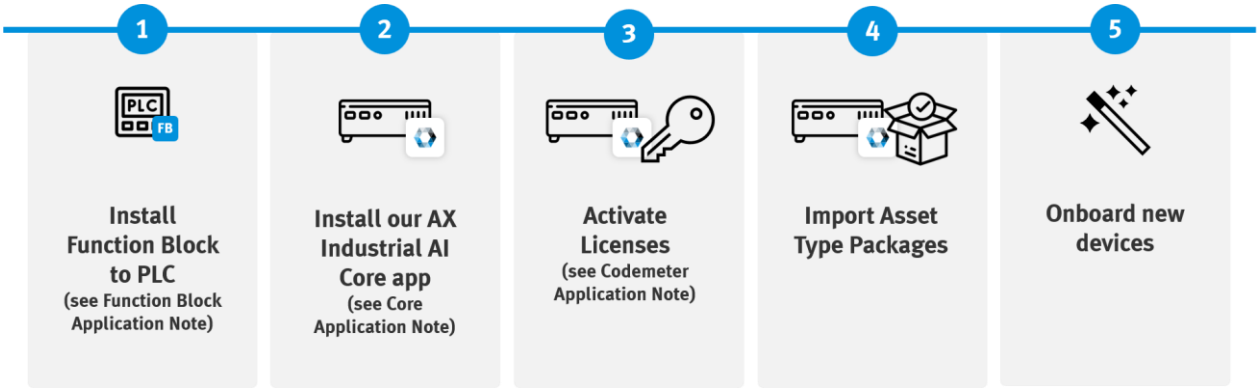
2.3.3 License

Festo AX Motion Insights Pneumatic consists of two parts: the Asset Type Package and the Industrial AI Core that builds the foundation for it. For both a valid license is needed.

- AX Motion Insights Pneumatic: GSDA-ATP-*-PCY
- AX Industrial AI Core: GSDA-AIC

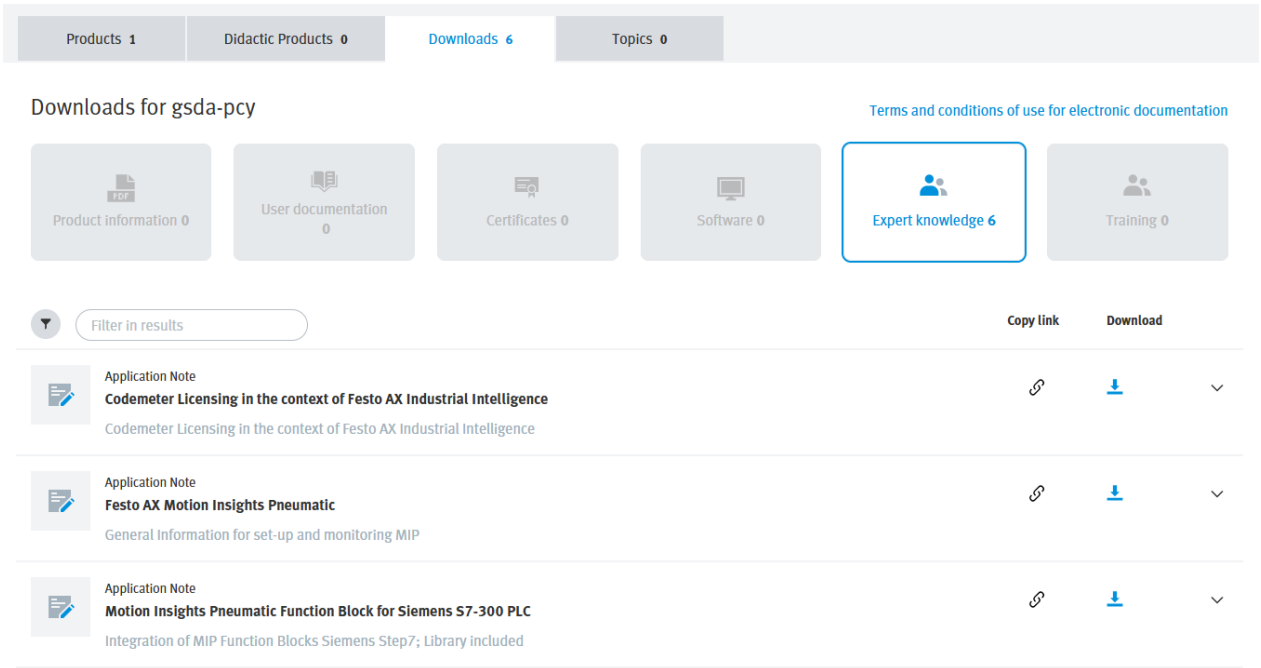
3 Installation and Commissioning

To set up the entire AX Motion Insights Pneumatic (AX MIP) industrial app, these steps have to be taken:



3.1 Install Function Block to PLC

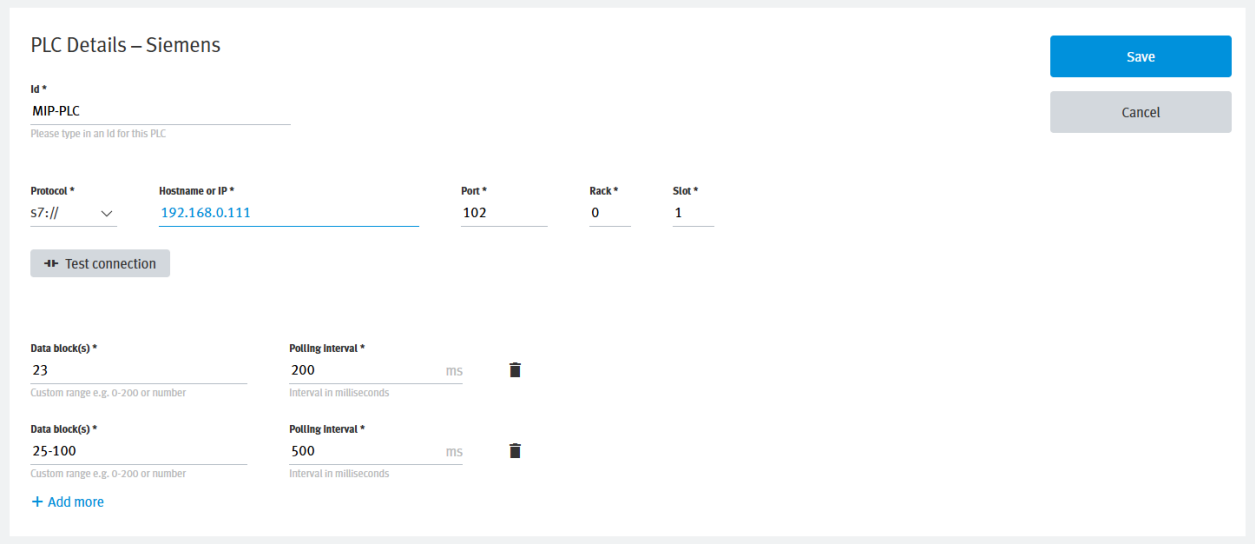
The installation of the MIP function block is described in detail separately for each supported PLC, please refer also to the according documents on [festo.com](). Therefore, search for GSDA-PCY and switch to Downloads -> Expert knowledge.



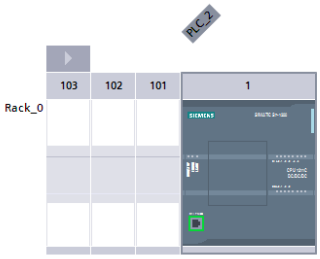
3.2 Configuration of Connector

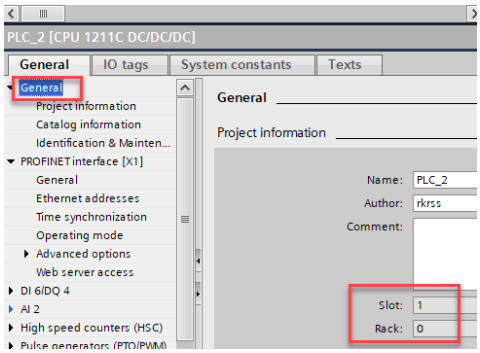
To establish the connection to AX MIP devices, some settings must be configured. Browse to <ip-address> :8007 on your AX MIP installation and follow the instructions of the wizard.

Example of using Siemens S7 connection:



- Add a name for the PLC as ID to recognize the machine etc. later in AX.
- The rack and slot information of the PLC details are taken from TIA Portal:



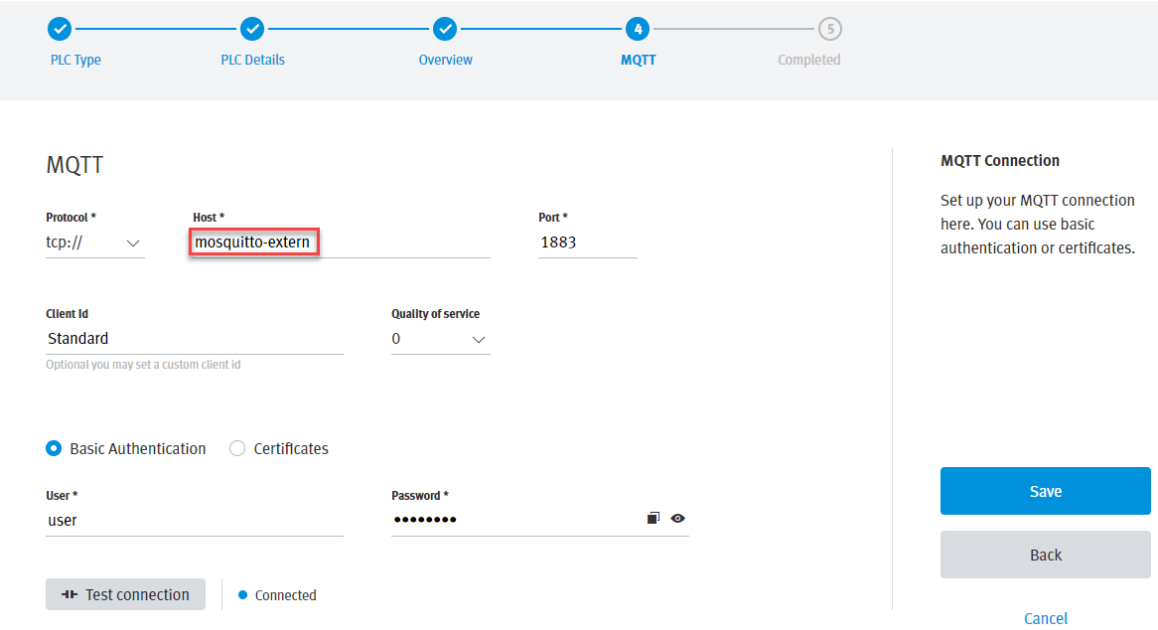


- To add the data blocks that have been created in TIA, click the “+ Add more” icon.
- Either single values or ranges to scan can be entered for the DBs.
- The polling interval should be assigned according to the cycle time of the cylinder to be monitored. E.g. if the cylinder moves every 5s, the polling interval can be down to 1s.

Note

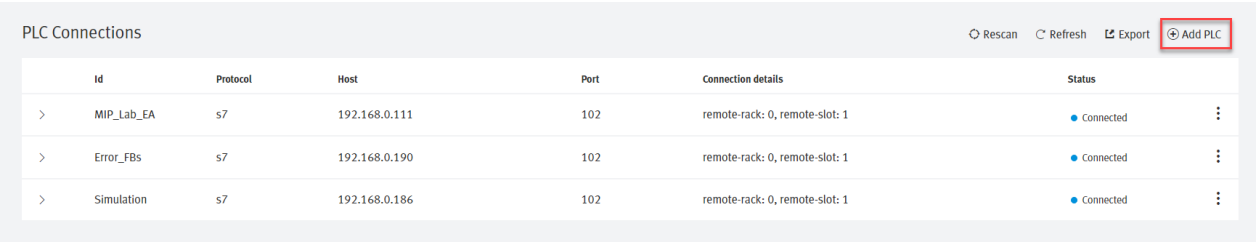
- **Configuration and settings are slightly different with other PLC connections like Beckhoff, Rockwell or OPC-UA.**

For the MQTT connection a broker, which is part of the docker-compose.yml, can be used with standard settings:



- user/PW: the broker is configured to allow anonymous connections, so you can define user and password by your own. Changes can be made in the mosquitto.conf file and/or by adding a password file: Authentication methods | Eclipse Mosquitto

3.2.1 Adding more than one PLC connection



3.3 Onboard new devices

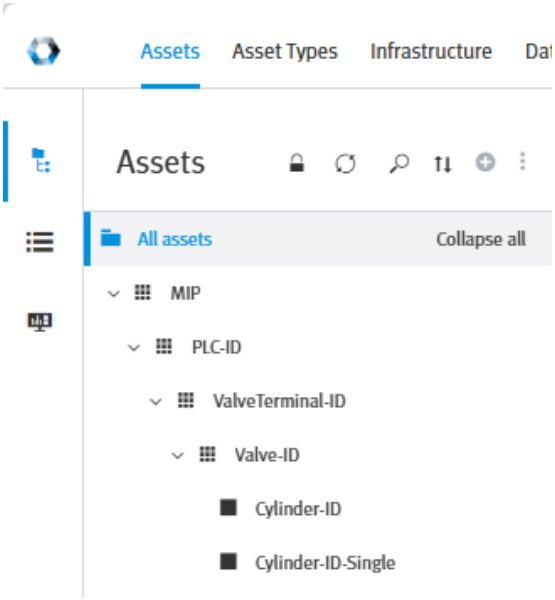
3.3.1 Automatic Onboarding

Once the connectivity with the PLC function block is set up and the connectivity wizard is completed to set up the connection to the PLC(s), AX MIP Connector scans the PLC for existing assets (identified by data blocks).

⇨ **AX MIP onboards newly found assets automatically to the application!**

These new assets will be shown besides the already onboarded assets in the asset hierarchy (under “Assets/MIP”) according to their structure:

“PLC Name” > “Valve Terminal ID” > Valve ID > “Cylinder ID” (Asset name).



Note

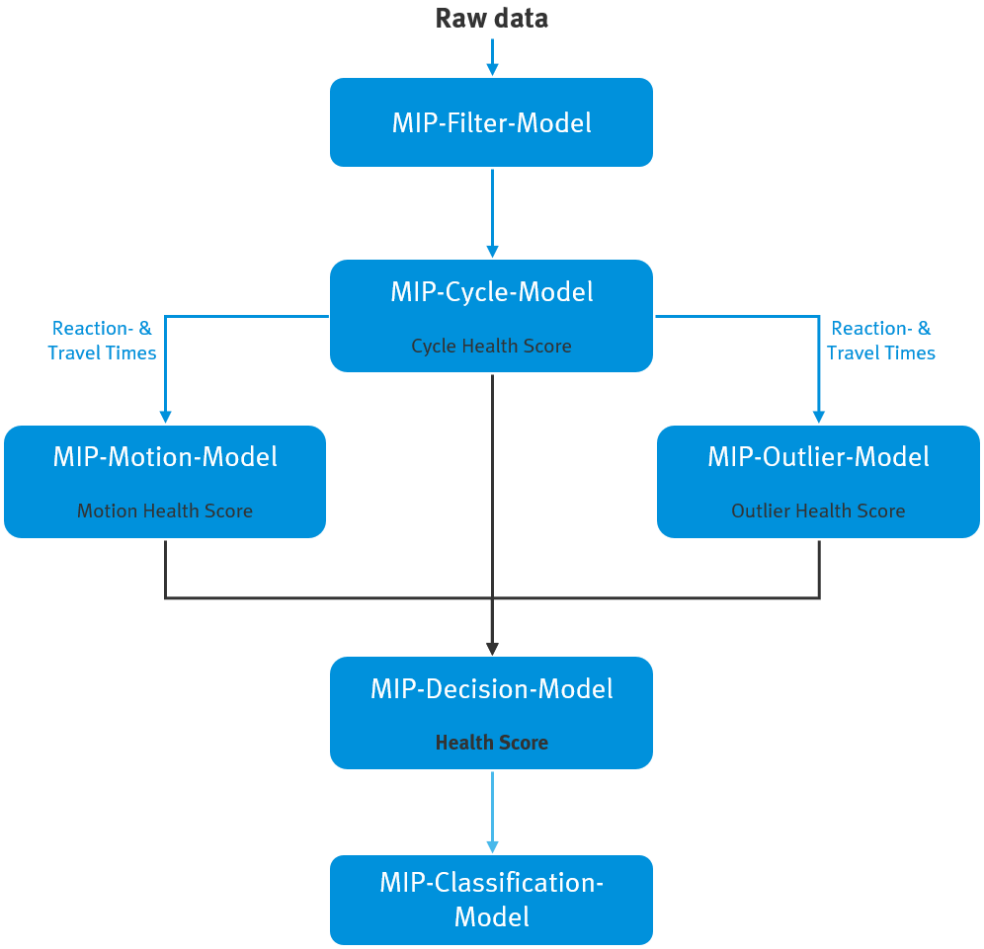
- **Be aware that most of the values shown in the dashboard are aggregated data calculated by a model which is only available after the initial model training. Thereby the dashboard is mostly empty right after the onboarding of a new asset although the connectivity is working fine.**

4 Model

4.1 Model structure and functionality

To detect anomalies in the behavior of the monitored cylinder a model chain consisting of six models is used. To be able to distinguish between different kinds of issues that can occur, multiple models are used to identify specific errors. The results of all models are rated and combined to the Health Score which shows the condition of the asset. There is also a classification which provides detailed information about the error detected.

If a machine is running with different part numbers or recipes which lead to different behavior of the cylinder, the current part numbers need be provided via the according input variable of the FB. Then the motion model analyzes the different part numbers separately. The part number with the worst condition result dominates the Health Score. Thereby the part number which is responsible for the model-detected anomaly is provided.



4.1.1 MIP-Filter-Model / MIP-Filter-Model-Single

The raw input features are timestamps of signal edges from the sensors and valves. They come in with a high frequency, being unchanged most of the time. Only the points when the timestamps changed are relevant. Everything else is filtered out here. The model is ready for use and does not require any training.

4.1.2 MIP-Cycle-Model / MIP-Cycle-Model-Single

This model requires training with 200 data samples (timestamps) before it can be applied. During training, the order in which the raw timestamps are updated is worked out. The recognized signal sequence for a cycle (valve signal, leaving the initial position, reaching the end position, ...) is analyzed, and the necessary information for calculating travel and reaction times is stored.

Errors detected during training:

Problems in the signal sequence that occur during training, as well as the failure that no clear sequence is recognizable, result in a Health Score of 0. Travel and reaction times cannot be calculated, which means that the subsequent models (Motion-Model and Outlier-Model) cannot be trained. An event is displayed on the dashboard on the Overview page. This contains more specific information about the problem at hand. Error classifications recognized by the MIP-Cycle-Model during training start with "Train".

Most of the problems detected while training come from the wrong mapping of the signals in the PLC or from the hardware configuration.

After successful training:

The learned signal sequence is applied to every new cycle. If the signal sequence of the training and the cycle matches, the times are calculated and sent to both the Outlier-Model and the Motion-Model. If the cycle's signal sequence differs, no times are calculated and the reason which is leading to the divergent pattern is worked out. The deviation results in a falling Health Score which is passed on to the decision model.

The detectable errors / classifications are:

- **EPosInsidePosition** and/or **IPosInsidePosition** (**PosSensorInsidePosition** for MIP-Single)
  The position sensor is located inside the hub movement rather than at the end of the cylinder
- **EndPositionBouncing** / **InitalPositionBouncing** (**PositionBouncing** for MIP-Single)
  Bouncing of the cylinder is detected at the end or inital position
- **Missing_Features_**<missing feature names>
  Example: Missing_Features_IPos_ON, the feature timestamp_DI_IPos_ON is missing in the complete history
- **MissingFeatureinCurrentSample:**<missing feature names>
  The specified feature is missing in the current cycle
- **ZeroTimeDetectedin_**<affected feature names>
  The calculated time is zero – a parameter can be set to indicate whether this corresponds to IO or NIO
- **NegativTimeDetectedin_**<affected feature names>
  The calculated time is negative
- **SwitchedValveSignals**
  The valve signals, which indicated the movement toward the inital or end position, are swapped or inverted

4.1.3 MIP-Outlier-Model / MIP-Outlier-Model-Single

This model requires training with 300 data samples (cylinder cycles) before it can be applied. It detects strong deviations from normal behavior even if the cylinder is running with a new part number that has not been trained in the Motion-Model yet.

The detectable errors / classifications are:

- Stucked cylinder or outliers for not trained partnumber

4.1.4 MIP-Motion-Model / MIP-Motion-Model-Single

This model requires initial training with 750 data samples (cylinder cycles) before it can be applied. It analyses the reaction and travel times of the cylinder calculated by the Cycle-Model and detects deviations from the learned normal behavior of the cylinder movement.

This model also handles different part numbers to enable accurate analysis results. The input feature 'part_number' represents the part number or recipe that is produced by the machine. The behavior of the cylinder can

differ between different part numbers which must not lead to a false analysis result of the model (false positive). Therefore, the Motion-Model distinguishes between part numbers and learns the normal behavior of each. The model detects automatically if there is a new part number and starts collecting training data in batches of 300 cycles. As soon as 300 cycles of the new part number have been collected a model update is executed.

The analysis result is passed to the Decision-Model in the form of the Motion Health Score, which corresponds to the part number with the lowest score. In the dashboard both the current part number and the part number responsible for the current Health Score are shown.

The detectable errors / classifications are:

- Problem in End to Init direction / Problem when leaving the position
- Problem in Init to End direction / Problem when returning to the position

4.1.5 MIP-Decision-Model / MIP-Decision-Model-Single

In the decision model, all information from the Cycle-Model, Outlier-Model and Motion-Model are processed. For each of the three sub-models, a Health Score is calculated. The Global Health Score of the asset is the minimum of the Health Scores of these three models. If the Cycle-Model has already detected a problem during training, no information from the Outlier-Model and Motion-Models is available and the Global Health Score is 0.

4.1.6 MIP-Classification-Model / MIP-Classification-Model-Single

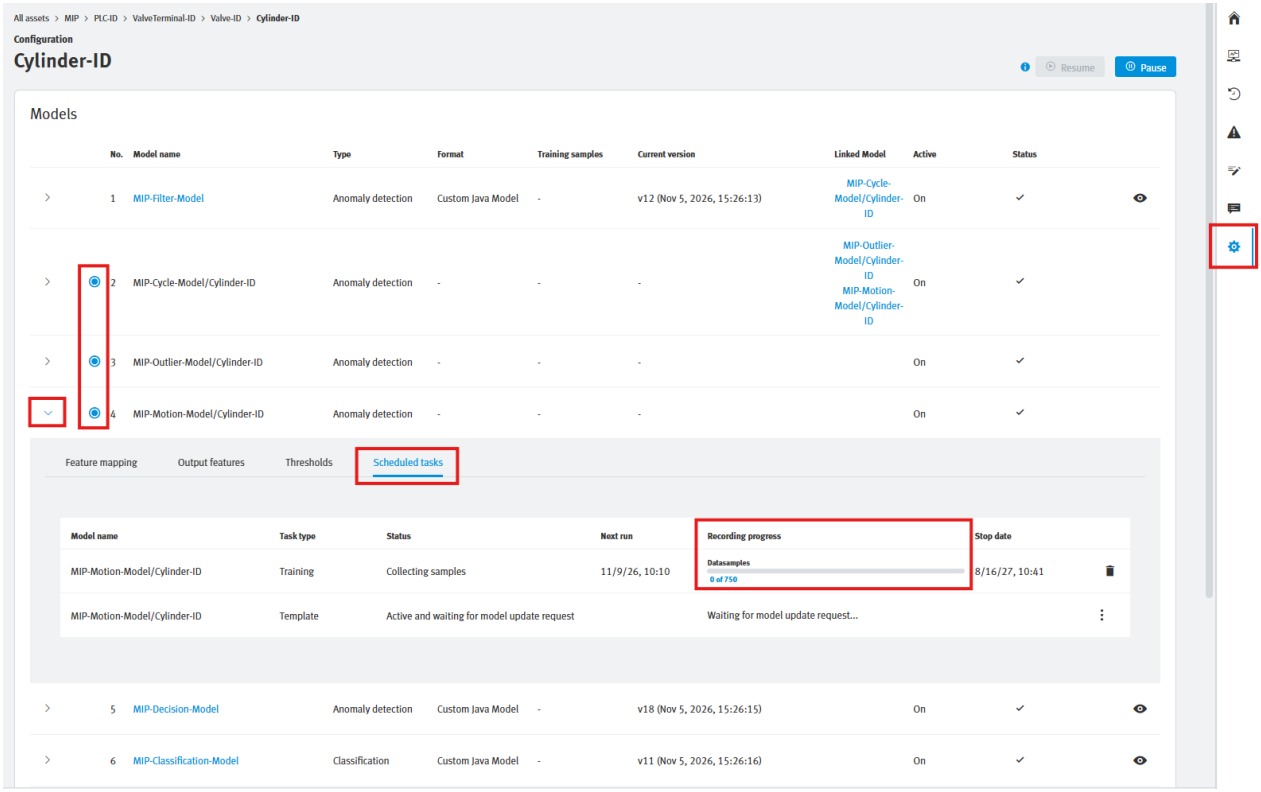
The Classification-Model receives all the necessary information from the Decision-Model. In the event of an error, a classification is compiled from this.

Detected errors in the Cycle-Model start with "Condition" and in the Motion-Model with "Model".

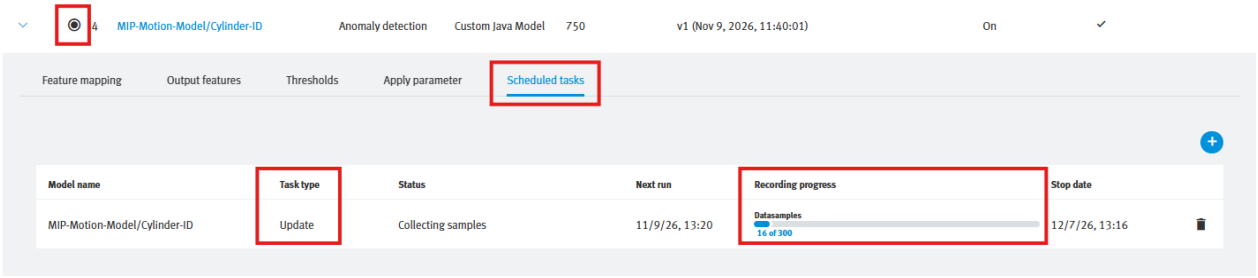
4.2 Model training and update

Before the anomaly detection is active, the first initial training must be finished. Therefore, a scheduled training is configured by default. You can check the progress in the asset settings.

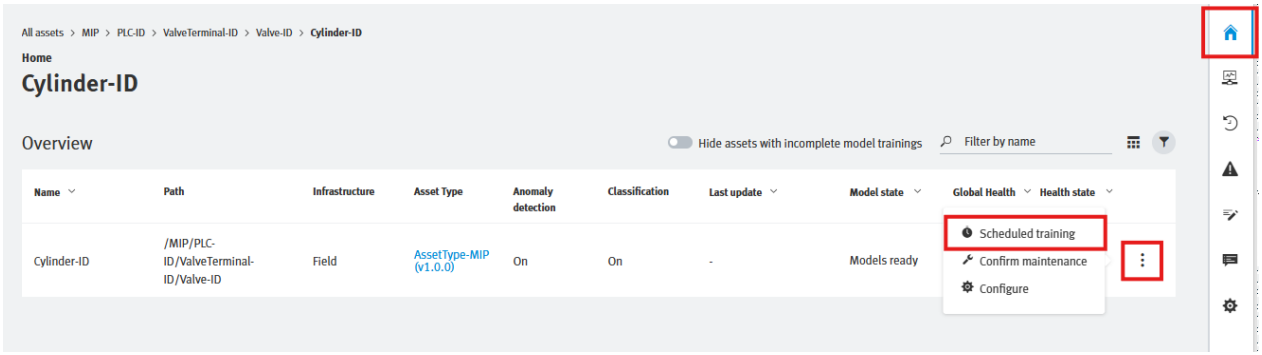
AX MIP needs a few cycles to train the Cycle-Model and afterwards at least 750 “good” cycles for initialization. “Good” means, the cylinder must be in a good condition working in its usual behavior. This is the “baseline” for the ongoing anomaly detection.



The input feature ‘part_number’ represents the part number or recipe that is produced by the machine. The behavior of the cylinder can differ between different part numbers which should not lead to a false analysis result of the model (false positive). Therefore, the Motion-Model distinguishes between part numbers and learns the behavior of each. The model detects automatically if there is a new part number and starts collecting training data in batches of 300 cycles. As soon as 300 cycles of the new part number have been collected a model update is executed.



A retraining of all models can be triggered from the “Asset Overview” by scheduling a new training.



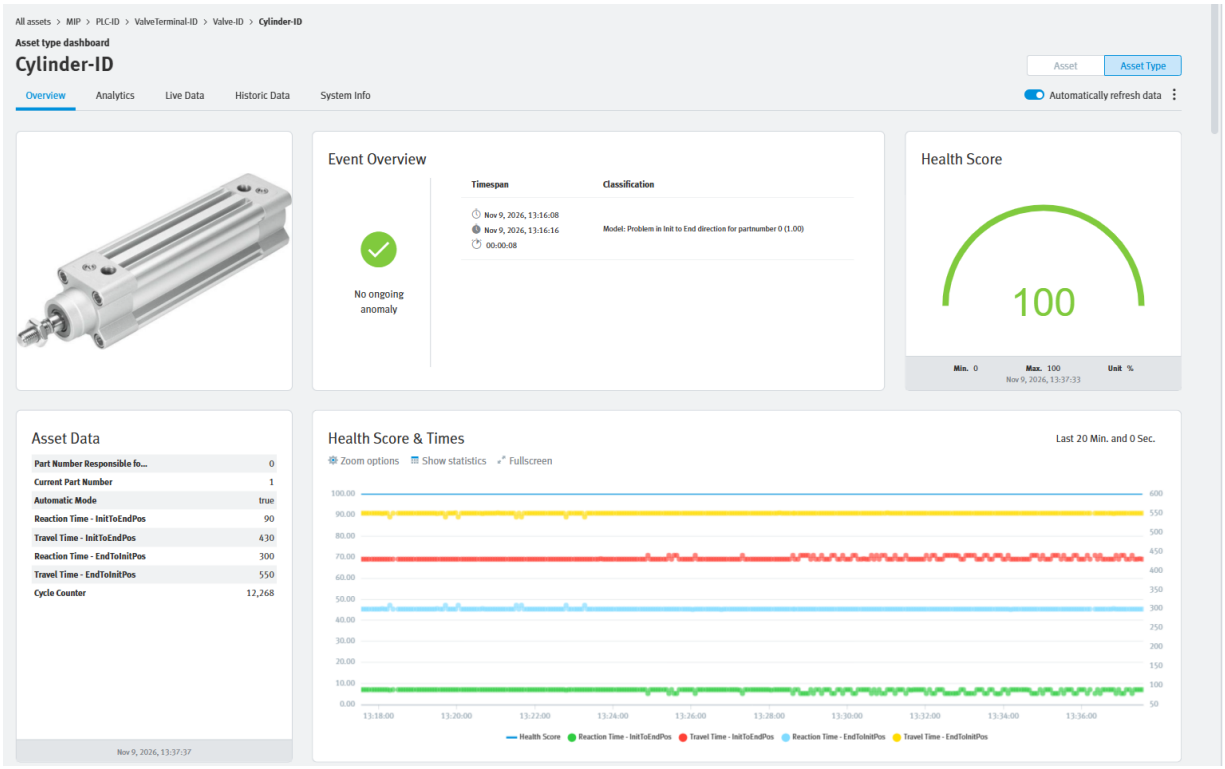
5 When the application is running

5.1 Asset Main Screen (3)

The main screen section displays the respective sub menu content that is selected through the sub menu on the right side. For example: it contains the dashboard section for an asset when “Dashboard” is selected on the right side.

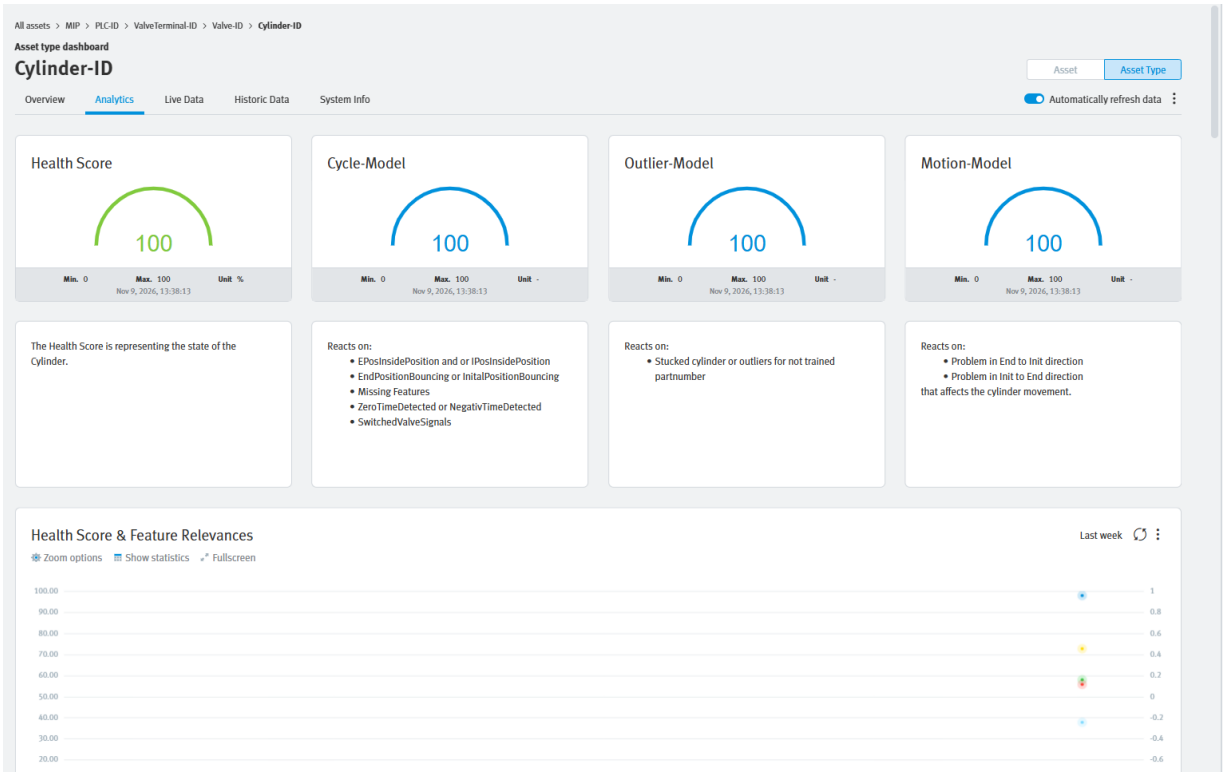
5.1.1 Overview

The Overview tab displays information about the Health Score and classification, along with the primary measurement data. It provides a summary of all critical information related to the current condition of the cylinder.



5.1.2 Analytics

The Analytics tab contains all relevant information regarding the Health Score. It also includes a historical data view that displays the Health Score trend over the past week. Insights into the current and historical results of the 3 anomaly detection models are given as well.



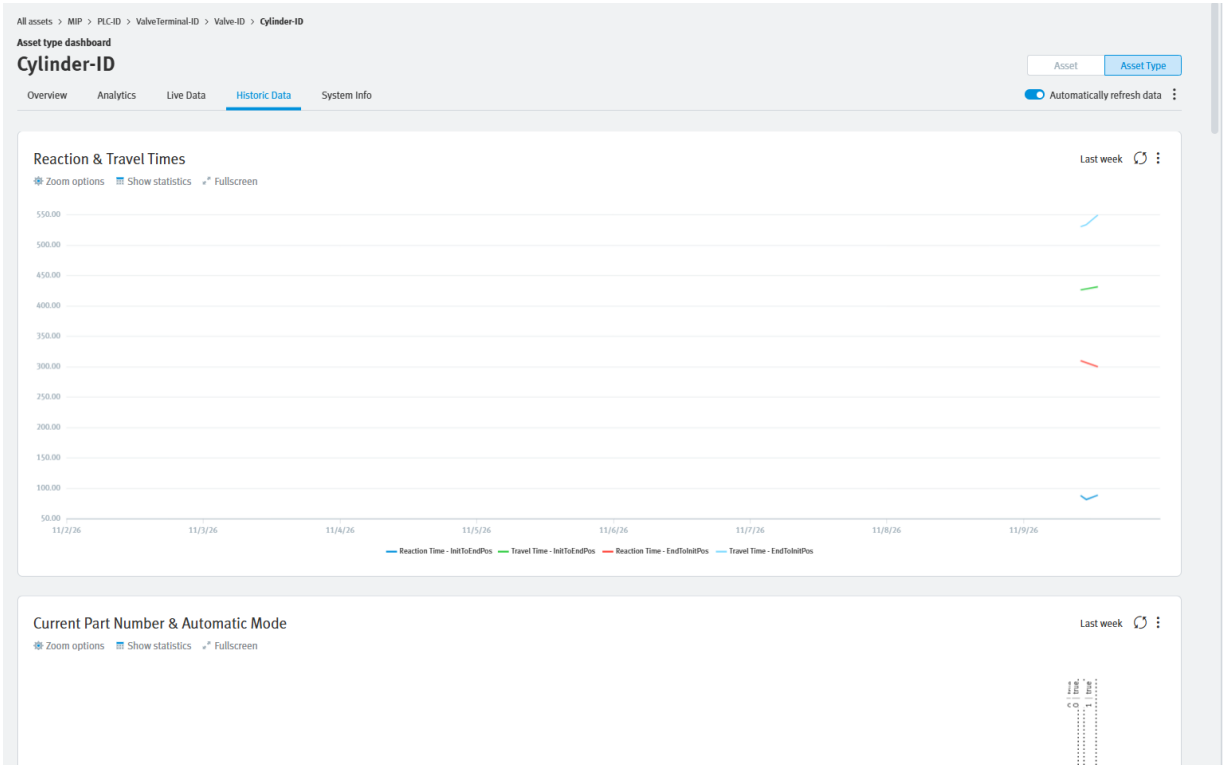
5.1.3 Live Data

The live data view displays the measurement data from the last 20 minutes.



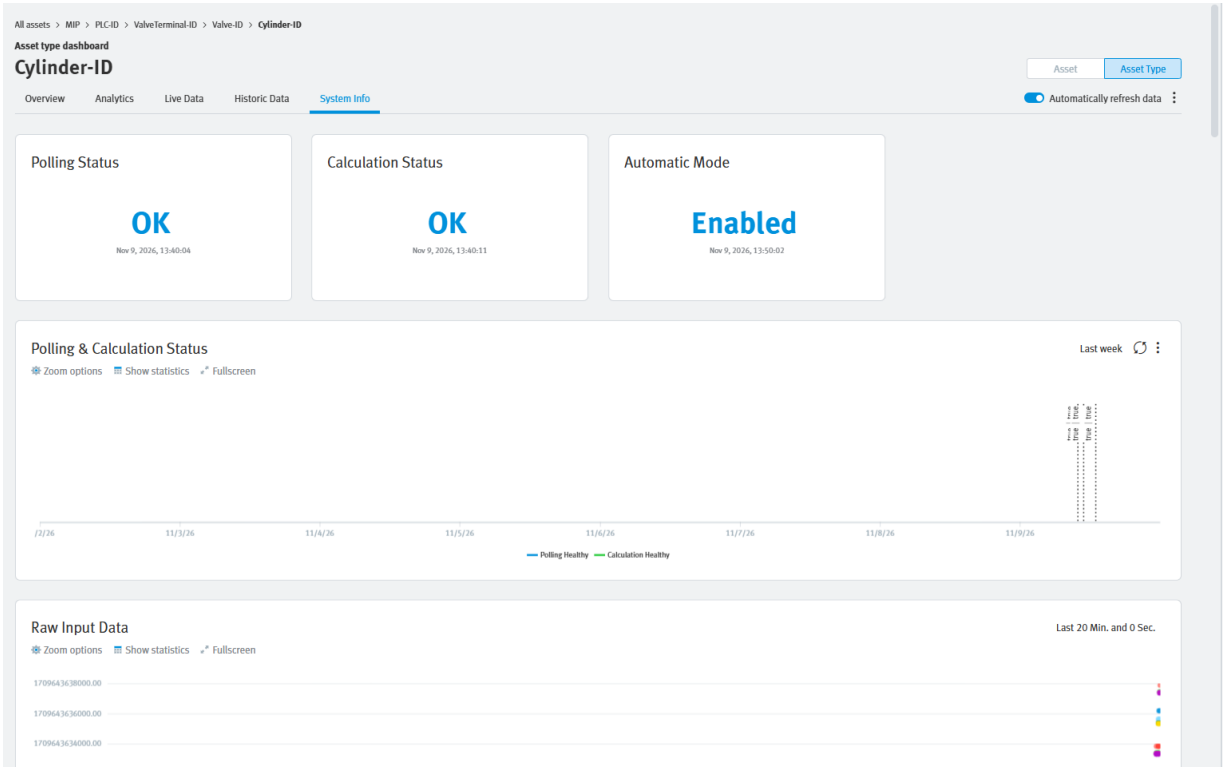
5.1.4 Historic Data

The historic data tab displays all measurement data from the past week, aggregated as mean values over one-hour intervals.



5.1.5 System Info

The system Info tab contains status information regarding data connectivity and the model training. Only after all models have been trained, the full range of functionality is available.



When the application is running

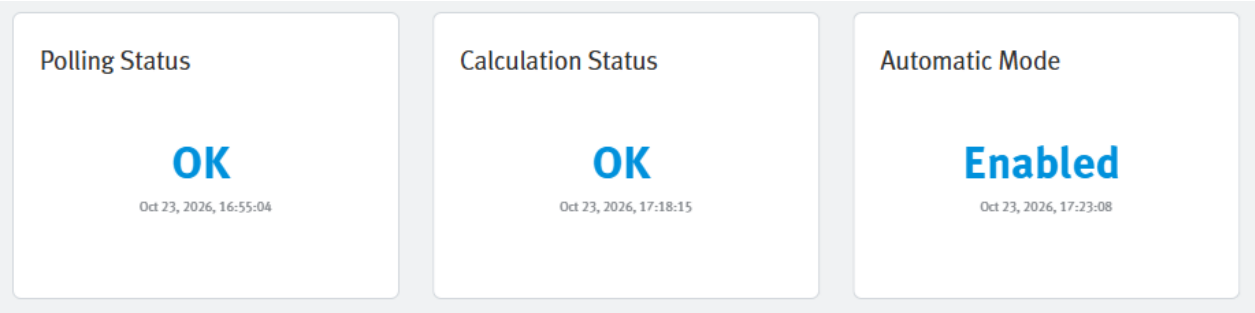
5.2 Debugging: System Info / Status

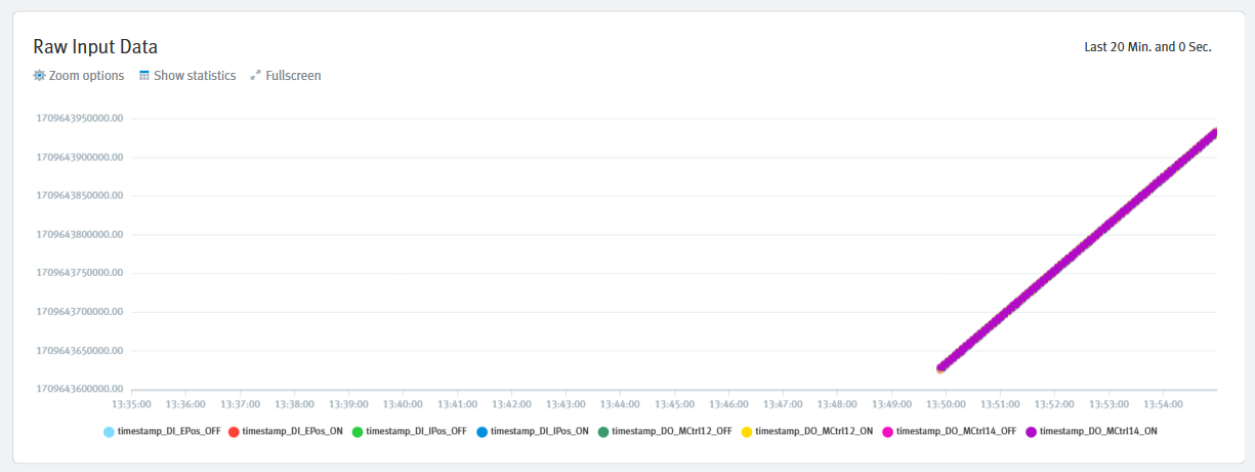
In case of any unexpected behavior, the status of connectivity etc. can be checked in the MIP connector as well as in the System Info tab of each asset dashboard.

MIP Connector:

Data Block	Cylinder Id	Valve Id	Valve Terminal Id	Polling Status
1	thisIsMyCylinder	thisIsMyValve	thisIsMyTerminal	✓ HEALTHY

Asset Dashboard:





Polling Status

The polling status is determined by comparing the actual polling rate with the target rate, taking into account a delta value. If there is a deviation, the status is classified as UNHEALTHY.

State in MIP Connector	**Description**
IN CALCULATION	During the “IN CALCULATION” state, it is determined whether the polling is HEALTHY by counting the individual transmissions from the PLC to MQTT.
HEALTHY	The "HEALTHY" state of the polling status is achieved when the transmissions between the PLC and MQTT fall within the specified delta range. In this state, the actual polling rate closely matches the target polling rate, indicating a healthy polling rate.
UNHEALTHY	The "UNHEALTHY" state of the polling status occurs when the transmissions deviate from the specified delta range, indicating an unstable polling rate.
State in asset dashboard	
OK	Is mapped to the "HEALTHY" status in the MIP Connector, but it only changes when the state transitions from another state.
ERROR	Is mapped to the "UNHEALTHY" status in the MIP Connector, but it only changes when the state transitions from another state.

Table 5.1: Polling Status descriptions

Calculation Status

The "Calculation Status" indicates whether the travel times can be calculated correctly. If the calculation cannot be performed after 8 timestamp value changes, it is assumed that the timestamps are not in the correct order, and the timing is considered to be incorrect.

State in asset dashboard	**Description**
OK	If the travel times can be calculated, the status is classified as “OK”
ERROR	otherwise “ERROR”

Table 5.2: Calculation status descriptions

Automatic Mode

Only if the machine is operating in automatic mode the data of the cylinder is recorded and analyzed. This avoids false anomaly detections based on other operation modes like commissioning or maintenance which can lead to different behavior of the cylinder.

State in asset dashboard	**Description**
Enabled	Machine operates in automatic mode, data is recorded and analyzed
Disabled	Machine operates not in automatic mode, data is discarded

Table 5.3: Automatic Mode descriptions

6 Frequently Asked Questions

- **How many cycles do I need to train the model initially?**

750 cycles of the cylinder are needed to train the Motion-Model. These cycles should include all possible variants of the cylinder (e.g. different weights).

- **What actuators does AX Motion Insights Pneumatic work for?**

It works for linear pneumatic actuators with two (AssetType-MIP) or one (AssetType-MIP-Single) limit switches attached (to detect end position). So:

- Piston rod cylinders
- Rodless cylinders
- Clamp cylinders
- Pneumatic Grippers

Generally, it works for all linear actuators, for which this formula is true:

Travel time actuator ***GREATER THAN*** **ten times PLC cycle time**

- **Can I install Motion Insights to an existing installation or do all the actuators have to be new at start up?**

Motion Insights can be imported on existing, running installations as well as new ones. Cylinders should be in good condition and running optimally. It is great to onboard cylinders especially after a recent maintenance.

- **What happens to the monitoring when an actuator is replaced by a new one?**

You need to retrain the AI for 750 cycles to re-establish norms.

- **Does AX Motion Insights Pneumatic work with non-Festo cylinders?**

Yes, it does. Generally, all pneumatic cylinders that fulfil the criteria defined above.

- **My PLC vendor is not yet officially supported by AX MIP. What can I do?**

Festo updates the support for other PLCs continuously. Generally, all modern PLCs can be added with slightly more individual effort (lacking the plug'n'play approach described in this document). Please get in contact with Festo through your contact person to discuss individual challenges.

- **I have specific questions. How can I get in contact?**

Get in contact with your Festo contact person or through https://www.festo.com/contact

- **I also have other motion components, e.g. electrical axis. Can I monitor them as well?**

A standardized AX Industrial App for e-axis-monitoring is also available, Motion Insights Electric. Generally, the Festo AX Industrial Intelligence suite can be used to tackle various challenges. Find out more here: https://www.festo.com/ax

- **The machine is running but I don’t see any data or Health Score calculated. What is the reason?**

There can be different reasons why no Health Score is calculated and no data received although everything seems to be set up correctly and the machine is running.

- Check for the parameter “ENABLE” in the function block. This must be set to **true**!
- Check for the parameter “bAutomaticMode” in the function block. Only data is taken into account that is generated while this parameter is set to **true**!
- The machine might be running but the monitored cylinders are not moving?
- Is everything wired correctly with the function block?
- Have all the models been trained without errors?

- **Can I use limit switches with N/C (normally closed) contacts?**

Generally, yes, but the signals have to be inverted in the PLC before connecting to the function block. The function block expects N/O (normally open) contacts.