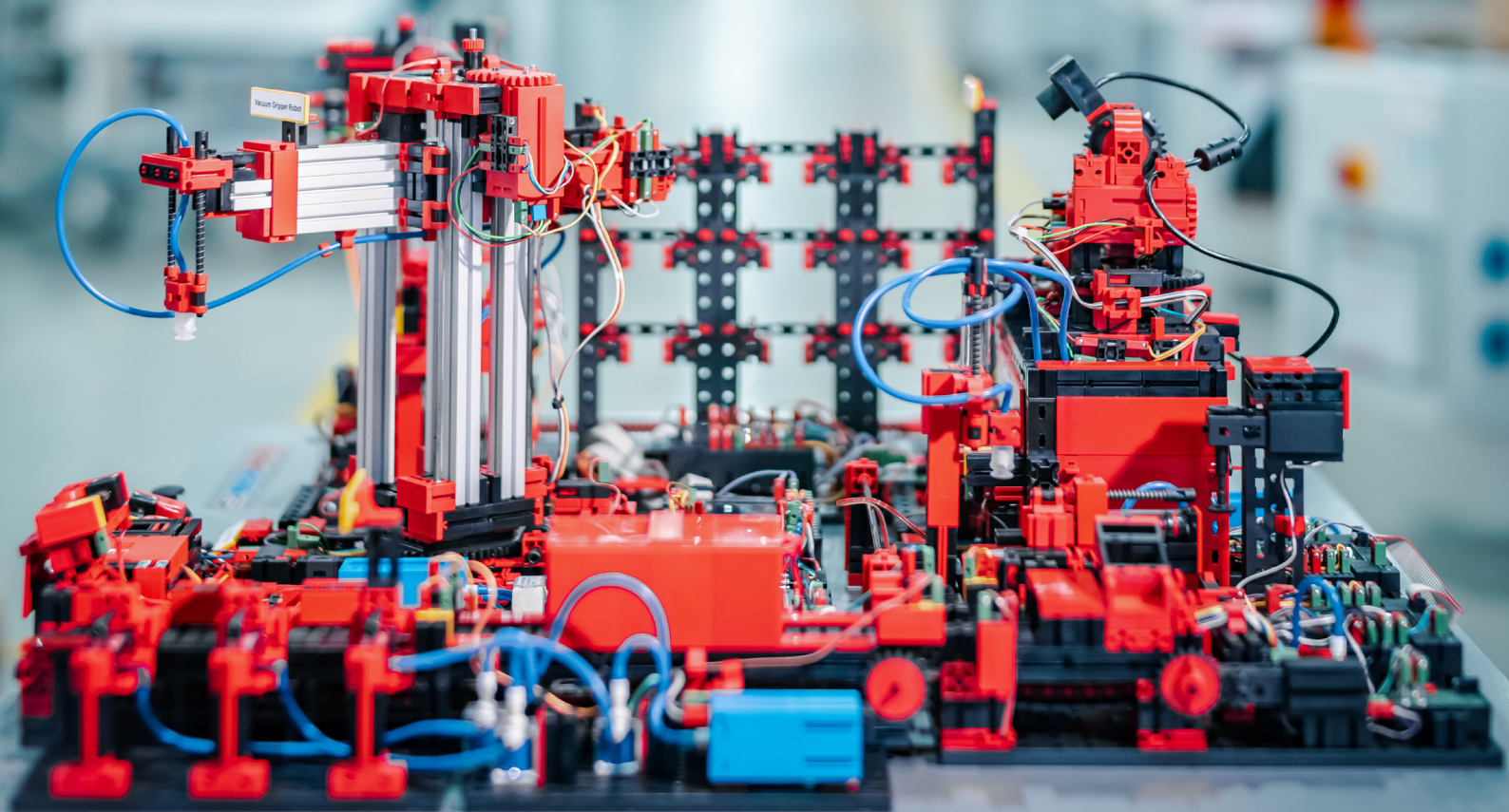# fischertechnik

LERNFABRIK 4.0

TRAINING FACTORY INDUSTRY 4.0
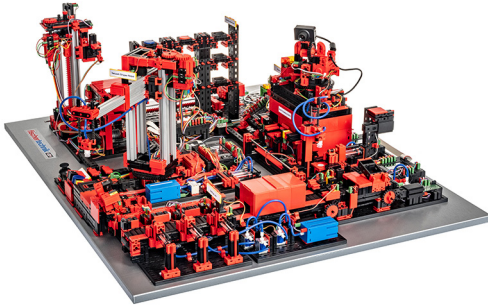FÁBRICA DE FORMACIÓN INDUSTRIA 4.0

Begleitheft
Activity booklet
Manual d'accompagnement
Begeleidend boekje
Cuaderno adjunto
Folheto
Libretto di istruzioni
Сопроводительная инструкция
附带说明书

Contents

Introduction

Digitisation in industrial production calls for stronger networking and smarter information at all levels of production. With fischertechnik Learning Factory 4.0, these digitisation activities can be simulated, learned and applied on a small scale before they are implemented on a large scale. A highly flexible, modular, cost-effective and robust training and simulation model that can be used to carry out highly technical logistical processes.

The fischertechnik learning environment is used for learning and understanding industry 4.0 applications in vocational schools and training sessions as well as for research, teaching and development at universities, in companies and IT departments. The simulation depicts the ordering process, the production process and the delivery process in digitised and networked process steps.

It consists of factory modules like storage and retrieval stations, vacuum suction grippers, a high-bay warehouse, a multi-processing station with kiln, a sorting section with colour detection, an environmental sensor and a pivoting camera.

After the order has been placed using the dashboard, the workpieces pass through the respective factory modules and the current status is immediately visible on the dashboard. The integrated environmental sensor reports values for temperature, humidity, air pressure and air quality. The camera can be used to view the entire system through the vertical and horizontal pan range and can thus be used for web-based remote surveillance.

Individual workpieces are tracked using NFC (Near Field Communication): A unique identification number (ID) is assigned to each workpiece, which enables traceability and visibility of the current status of the workpieces in the machining process.

The Learning factory 4.0 is controlled by six fischertechnik TXT controllers, which are powered by three 9V power supplies. These are networked within the factory and communicate with each other via MQTT. MQTT (Message Queuing Telemetry Transport) is an open message protocol that enables the transmission of data in the form of messages between devices.
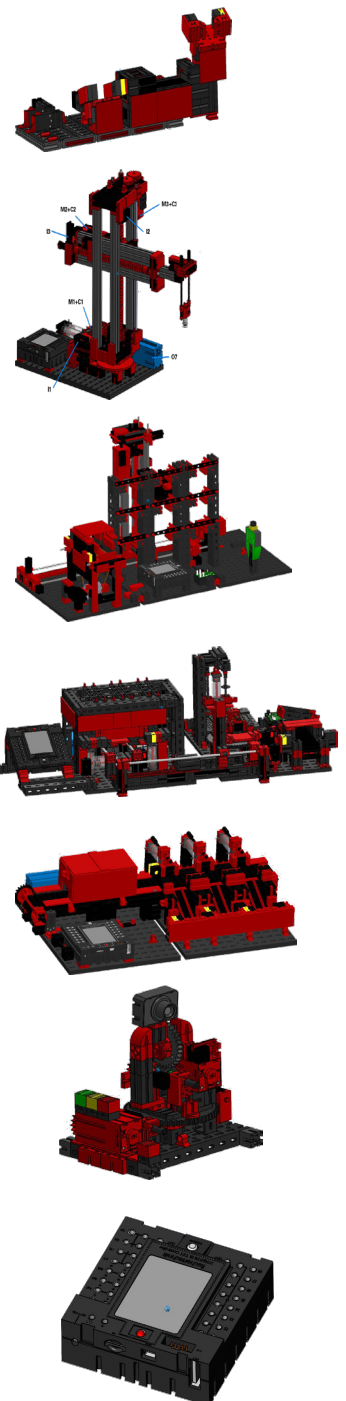
New developments for Learning Factory 4.0

The basis for developing Learning Factory 4.0 is the well-known fischertechnik factory simulation, which works automatically. Here is a brief overview of how it operates for those who are interested as well as newcomers. You can also watch the video at:
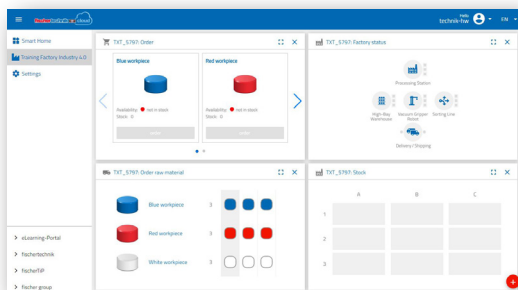
https://youtu.be/BApxuYlsT_w
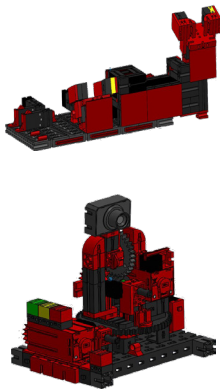
The vacuum suction gripper populates the stacker crane with workpieces. The stacker then stores the workpieces in the high bay and sorts them by colour. Next, the workpieces are brought to the multi-processing station where they are processed. The machined workpieces are then sorted by colour in the sorting line and transported to storage locations. From there, the workpieces are transported by the vacuum suction gripper back to the high bay. This is a **never-ending, repetitive cycle.**

New additions to Learning Factory 4.0 are:

- Additional input / output station with quality control
- The TXT controllers are networked to each other (WLAN, MQTT)
- Control programs written in C/C++
  - Sensor station with integrated camera and environmental sensor
  - NFC / RFID are used to identify workpieces
  - Integrated wireless router
  - fischertechnik cloud connection
  - Data are presented and used on a dashboard
  - 2 joysticks for calibrating and manually controlling the vacuum suction gripper and the high bay operating device
  - A traffic light that displays the system's current status
- The built-in camera can be remotely controlled over two axes
- Elements can be marked

The individual innovations are explained in more detail in the following chapters.

Software: C/C++ API programming interface

The software applications are written in C/C++ and are already loaded on the controller in the ready-to-start status. The corresponding C/C++ library and the API are published on GitHub:

https://github.com/fischertechnik.

This library can be used to write customised C/C++ programs for the learning factory.

First steps

After carefully unpacking the "factory simulation" and removing the transport lock, inspect for any transport components that have become loose or damaged. If necessary, put loose components back in the right place. Compare your model with the "factory simulation" comparison images, which are stored on the eLearning website. Make sure that all cables and hoses are connected. You can use the assignment diagrams to connect any cables that are not connected correctly.

If all possible errors have been remedied, connect the system to the mains. It is best to use a 5-gang socket strip with power switch. This allows you to switch the system on and off.

Tip: Stick the multiple socket strip with double-sided adhesive tape next to the high bay.

Three 9V DC / 2.5A power supplies supply 2 TXT controllers each.
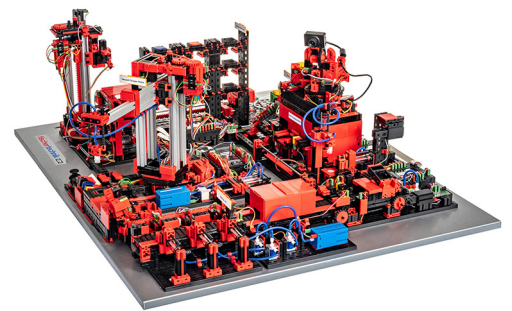
Each power supply is connected to one of the 3 DC mini adapters.

The location of the DC adapters is as follows:

1   2   3

DC adapter 1: For high-bay warehouse and sensor station on building board 1 next to blue compressor.
DC adapter 2: For sorting plant and vacuum suction gripper between structural panels 1 and 2 of the multi-processing station.
DC adapter 3: For multi-processing station on the second structural panel on the multi-processing station.
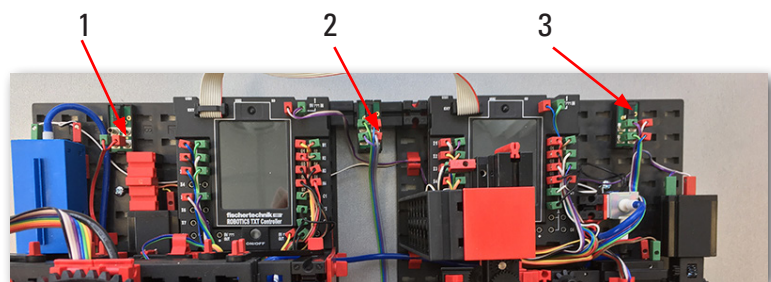
Switch on the individual controllers to test them (ON / OFF). If everything works, the displays and controllers should start up and the indicator lights light up.

Finally, load the high-bay warehouse with the 9 empty black containers included in the delivery.

The individual factory components

This chapter introduces the individual factory components and briefly explains their function.

What are robots?

The Association of German Engineers (VDI) defines industrial robots in VDI Guideline 2860 as follows:

"Industrial robots are universally applicable multi-axis motion machines whose movements with respect to movement sequence and paths or angles are freely programmable and, if necessary, sensor-guided (i.e., without mechanical or human intervention). They can be equipped with grippers, tools or other means of production and can perform handling and / or manufacturing tasks".

Vacuum Suction Gripper 9V (VGR)
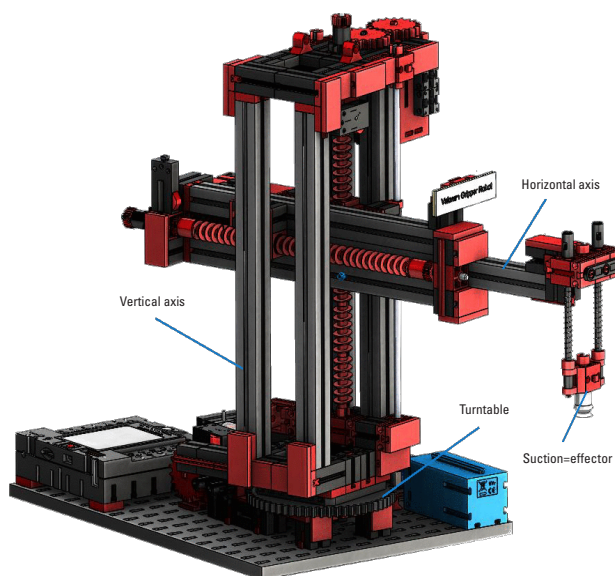
Three-axis robot with vacuum suction gripper positions workpieces quickly and precisely in three-dimensional space. Workspace: X-axis 270°, Y-axis (forwards / backwards) 140 mm, Z-axis (up / down) 120 mm.

Horizontal axis

Vertical axis

Turntable

Suction=effector

Buttons

Mini motor

Encoder engine

The 3D vacuum suction gripper is therefore an industrial robot that can be used for handling tasks. The vacuum gripper picks up workpieces and moves them within a working space. This working space is based on the robot's kinematic structure and defines the area that the robot effector can work within. In the case of the vacuum suction gripper, the vacuum unit is the effector and the working space corresponds to a hollow cylinder whose vertical axis coincides with the robot's axis of rotation.
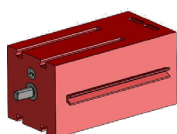
The geometric shape of the working space is based on the kinematic structure, which is shown in the illustration and which is composed of a rotary and two translational axes.
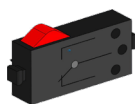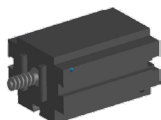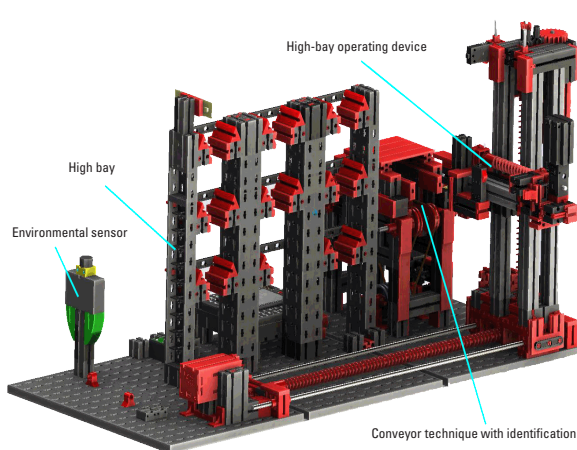
The typical work order for this kind of robot can be subdivided into the following work steps:

- Positioning the suction gripper on the workpiece
- Picking the workpiece up
- Transporting the workpiece within the workspace
- Storing the workpiece

Positioning the suction gripper or transporting the workpiece can be defined as a point-to-point movement or as a continuous path. Controlling the individual axes takes place sequentially and / or in parallel and it is significantly influenced by workspace obstacles that exist in the workspace or by predefined intermediate stations. A 3/2-way solenoid valve and two coupled pneumatic cylinders that generate negative pressure control the suction gripper.

Compressor

Cylinder

3/2-way compressor
Solenoid valve

Vacuum

Automated high-bay warehouse 9V (HBW)

What is a high-bay warehouse?

High-bay operating device
High bay
Environmental sensor
Conveyor technique with identification

A high-bay warehouse is a storage area that saves space and allows computer-aided storage and retrieval of goods. In most cases, high-bay warehouses are designed as pallet-rack warehouses. This standardisation enables a high degree of automation and connection to an ERP system (Enterprise Resource Planning). High-bay warehouses effic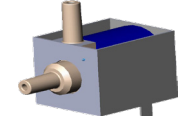iently utilize space to a high degree and require a great amount of upfront investment. Stacker cranes store and retrieve goods that are then moved into an alley, which is located between two rows of high-bay shelves. This area is part of the pre-zone where the goods are identified. Conveyor technology, e.g., chain conveyors, roller conveyors or vertical conveyors ready the goods for being shipped out, and in the next step, the goods are handed off to the stacker crane. No one should be present in this area if the storage and retrieval machines are automated. In the case of the automated high bay, a conveyor belt transports the goods.
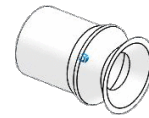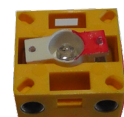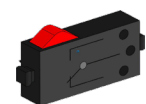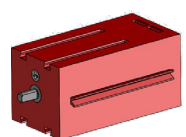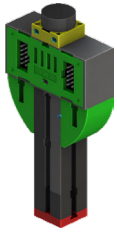
Photo-transistor
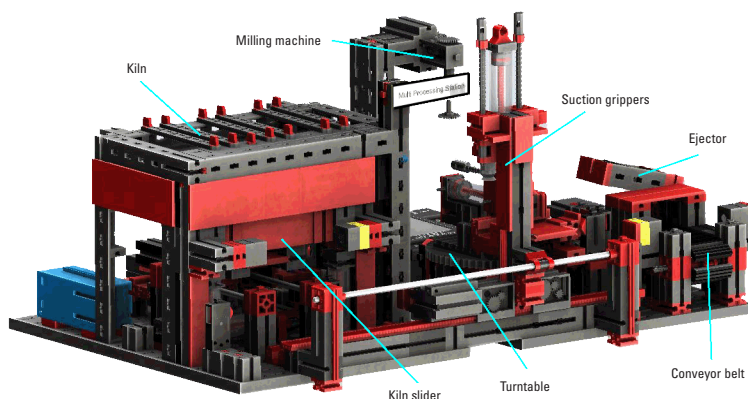
Colour sensor

Buttons

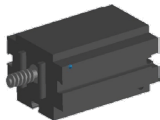Mini motor

Encoder engine

Environment sensor

The environmental sensor was built on the base plate of the high-bay warehouse for technical reasons (i.e., space). The electrical connections, however, are on the TXT 0.

Multi-processing station with kiln 9V (MPO)

Milling machine

Kiln

Suction grippers

Ejector

Kiln slider

Turntable

Conveyor belt

Mini motor

Photo-transistor

Buttons

Vacuum

The workpiece automatically passes through several stations that simulate different processes in the multi-processing station with kiln. Various conveyor techniques are used, such as a conveyor belt, a turntable and a vacuum suction gripper. The machining process starts with the kiln. To initiate processing, the workpiece is placed on the oven pusher. This action interrupts the photoelectric barrier, which causes the kiln door to open and then retract the kiln slider. At the same time, the vacuum suction gripper, which brings the workpiece to the turntable after the firing process, is requested. Following the firing process, the kiln gate is re-opened and the kiln slider re-extended. The positioned vacuum suction gripper that is already in place picks the workpiece up, transports it to the turntable and places it there. The turntable positions the workpiece under the miller, waits there throughout the machining time and then moves the workpiece to the pneumatically-actuated ejector. The ejector pushes the workpiece onto the conveyor belt, which conveys the workpiece to a photoelectric barrier and then to the sorting system. Passing through the photoelectric barrier causes the turntable to return to its original position and for the conveyor belt to stop with a time delay.
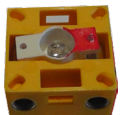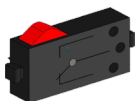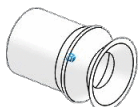
Two TXT controllers, which operate in the master extension network, control the multiprocessing station with kiln. The second controller acts as an extension, allowing the master controller to control a total of 16 universal inputs, eight fast counter inputs and eight motor outputs.

The program is executed in parallel due to the large number of inputs and outputs. The subdivision is carried out in the three units: kiln, vacuum suction gripper and turntable. The respective processes communicate with each other to prevent collisions.
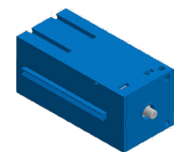
For example, the kiln triggers the movement of the vacuum suction gripper at two points in the program sequence, which ensures that the vacuum suction gripper is not only in the right spot at the right time, but also that it does not reach into the void. Likewise, the turntable is activated after the workpiece has been deposited by the vacuum suction gripper.

Compressor

Cylinder

Compressor 3/2-way solenoid valve

Sorting line with colour recognition 9V (SLD)

The sorting path with colour recognition automatically separates differently coloured workpieces. In this case, a conveyor belt feeds geometrically identical but differently coloured components into a colour sensor, where they are then separated according to colour.

An S-motor dries the conveyor belt and an impulse sensor measures the conveying path. Pneumatic cylinders, which are assigned to the corresponding storage locations and operated by solenoid valves, eject the workpieces. Several photoelectric barriers control the flow of the workpieces and determines whether there are workpieces in the storage locations.

Colour recognition
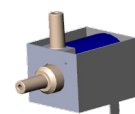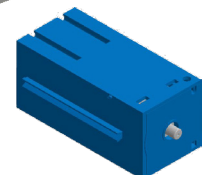Sorting Line
Ejector
Bearing locations

An optical colour sensor that emits light and can close based on a colour's surface reflectance identifies the various colours. Thus, the colour sensor is strictly a reflection sensor that indicates how well a surface reflects light. The measured value of the sensor is therefore not proportional to the wavelength of the measured colour and assigning colour coordinates or colour spaces (for example RGB or CMYK) is not possible. In addition to an object's colour, ambient light, the object's surface and the distance of the object from the sensor, affect the quality of the reflection. This is why it is critical that the colour sensor is protected from ambient light and that the surface of the objects is comparable.
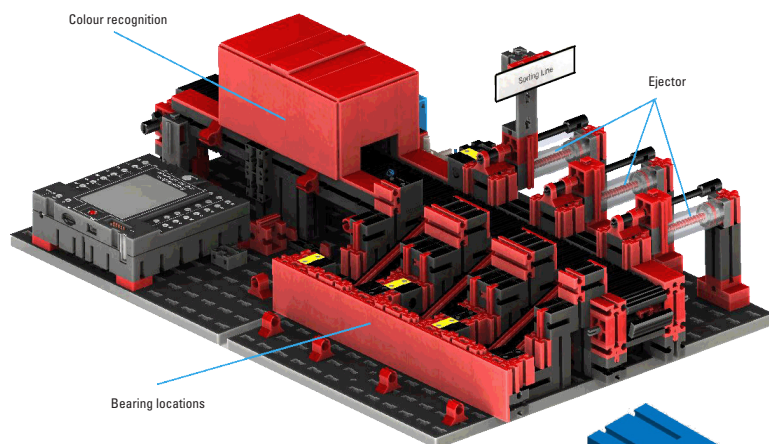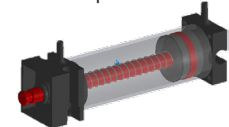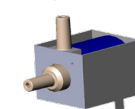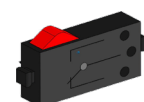

Compressor

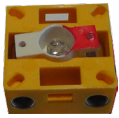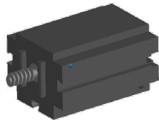Cylinder

3/2-way compressor solenoid valve

Buttons

Photo-transistor

Colour sensor

Mini motor

It is also important that the sensor is installed perpendicular to the surface of the object. Distinguishing among the coloured workpieces is done in thresholds that compare the measured values of the individual colours against each other. Since the value ranges for different colour sensors very, these limit values must be adapted unconditionally.

Both the process and the conveyor belt start if a workpiece is placed on the conveyor belt and the workpiece interrupts the photoelectric barrier. For a colour to be recognised, the workpiece passes through a darkened lock in which a colour sensor is installed. During this time interval, the minimum value of the measured colour values is determined and assigned to the workpiece. In the time required for the workpiece to pass the colour sensor, the previous minimum value is compared with the current measured value, which may then replace the earlier measured value.

The photoelectric barrier, which is located before the first ejection point, controls whether a workpiece is ejected. Depending on the detected colour value, the corresponding pneumatic cylinder is time-delay triggered after the workpiece interrupts the photoelectric barrier. Next, the pulse button is activated. It registers the rotation of the gear that drives the conveyor. Unlike a time-based delay, this approach is robust in withstanding conveyor speed disruptions. The ejected workpieces are fed through three slides to the respective depositories.

The storage locations are equipped with photocells that recognize whether the storage location is filled or not. However, the photocell cannot determine how many workpieces are in a single storage location.

Environmental station with surveillance camera (SSC)

The environmental station with surveillance camera is used to record measured values within the factory. The mobile camera station is located on the multi-processing station and visually monitors the system.

The new environmental sensor and a photo resistor allow the air temperature, humidity, air pressure, air quality and brightness to be measured. The values are displayed graphically.

The camera can be rotated using a virtual joystick and it can be tilted to monitor the factory. The images are also displayed on the monitor screen.
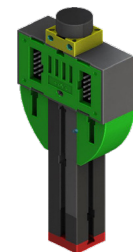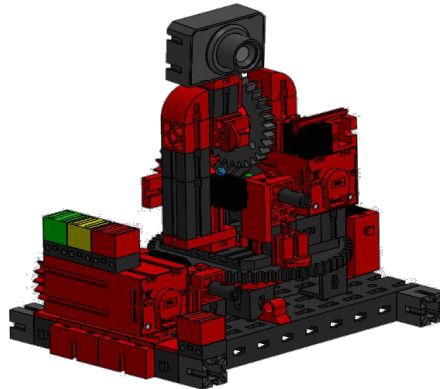
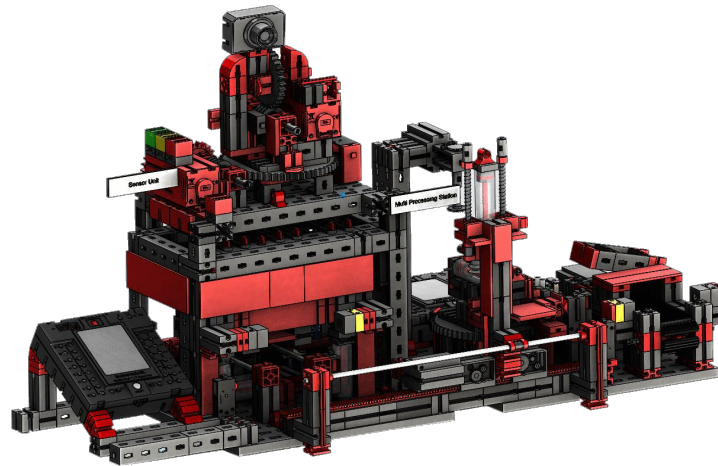Photo-resistor, environmental sensor
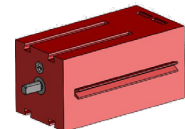
Encoder engine

Camera
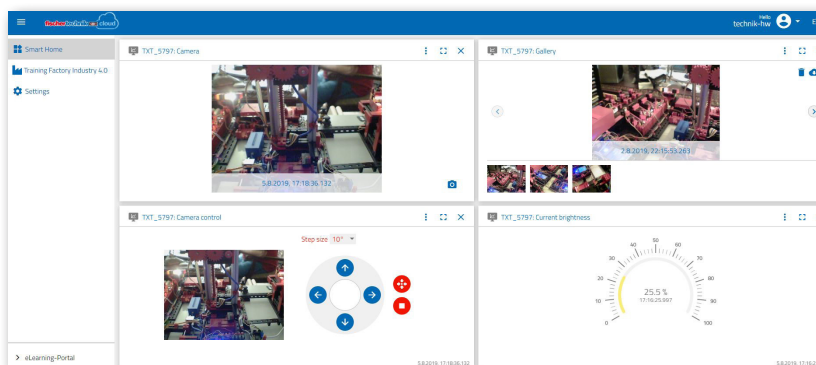
The various sensor data and the camera's movement axes are constantly monitored on a user interface referred to as a "dashboard". An LED indicator indicates when the set limits are being exceeded. The red LED always lights up when an image from the camera is being transferred to the cloud.
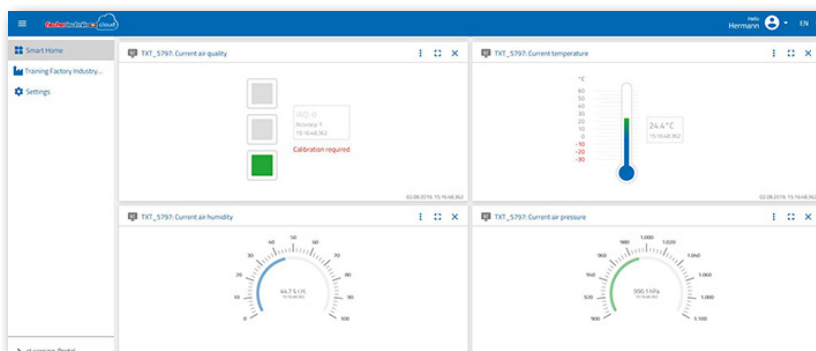
Multi-processing station with security camera

The two "multi-processing centre and surveillance camera" modules have been combined into one overall module at the factory. The advantage here is that the camera is at the highest point in the factory and can thus monitor the entire system.

The associated controller is integrated between the high-bay warehouse and the multi-processing centre.
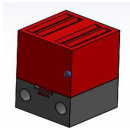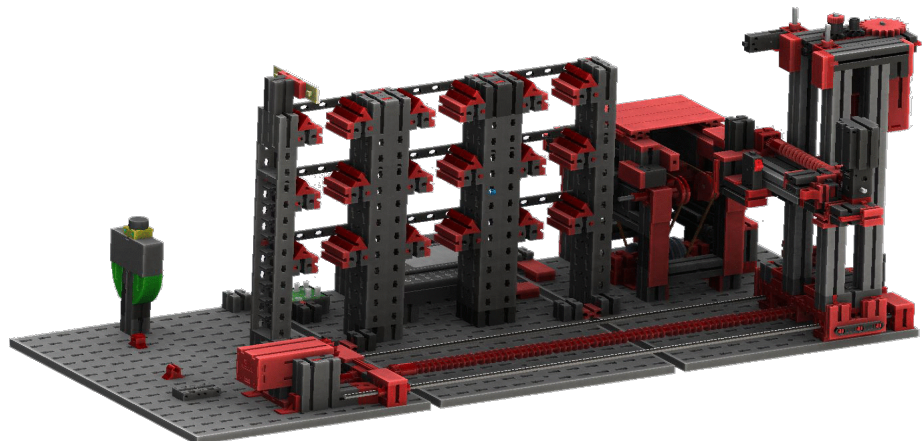

Control lamp red

The surveillance camera still has a visual display (red lamp). Blinking indicates images are being recorded.

Environmental sensor and photo-resistor

The environmental sensor and photo-resistor are located on the high-bay module. Both are connected to the controller, which also controls the camera.

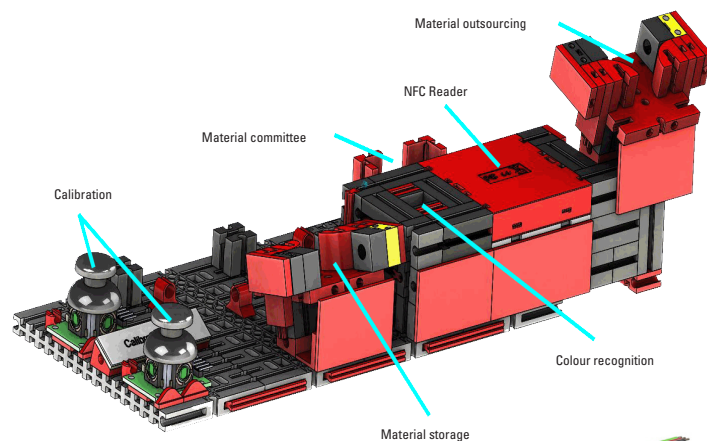## Input-output station with colour recognition and NFC reader

The in- and output station consists of a total of 4 work areas:

- The input and output unit
- Colour recognition
- The NFC reader
- The calibration station for the vacuum suction gripper and high-bay warehouse

The photoelectric barrier located at the input station determines whether a workpiece to be stored in it is there. If a workpiece is there, then this information is passed on to the program (vacuum suction gripper picks up the workpiece).

Before the workpiece is processed any further, the colour sensor determines the workpiece colour.

Various data are assigned to the workpiece once its colour has been detected. To detect a workpiece's colour, the vacuum suction gripper places the workpiece on the NFC reader.

First, all data in the memory is deleted and the workpiece marked as "raw." The reader describes the **NTAG213 NFC tag** located on the workpiece using workpiece-relevant data.
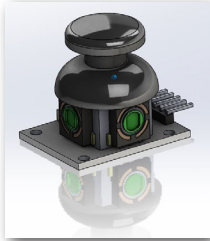
Important: An NFC tag has a unique ID. It does not have to be assigned and cannot be changed.

If one or more workpieces are ordered, they will be sent to the output area after various tasks have been carried out. Previously, additional production data for each workpiece could be stored in the available memory on the NFC tag.

Material outsourcing

NFC Reader

Material committee

Calibration

Colour recognition

Material storage

Colour sensor

Photo-transistor

The NFC reader

Adapter board

The calibration station

Joystick

The two built-in joysticks each provide 2 analogue values (potentiometer) and a digital value – button – when pressed. The control always uses analogue values to control the speed of the motors.

This way it is possible to adjust both fine and coarse movements of the axes by using the joystick.

Factory status display

Status display

Three LEDs indicate factory status.

Green means all stations are waiting.
Yellow means that at least one station is active.
Red means an error that must be acknowledged on the dashboard in the cloud for the learning factory to continue.

Block diagram of the factory

The block diagram shows you how the individual factory components communicate with each other and how the system is integrated with the Internet and the fischertechnik cloud. The block diagram also shows which information the user can retrieve via his PC, tablet or smartphone.
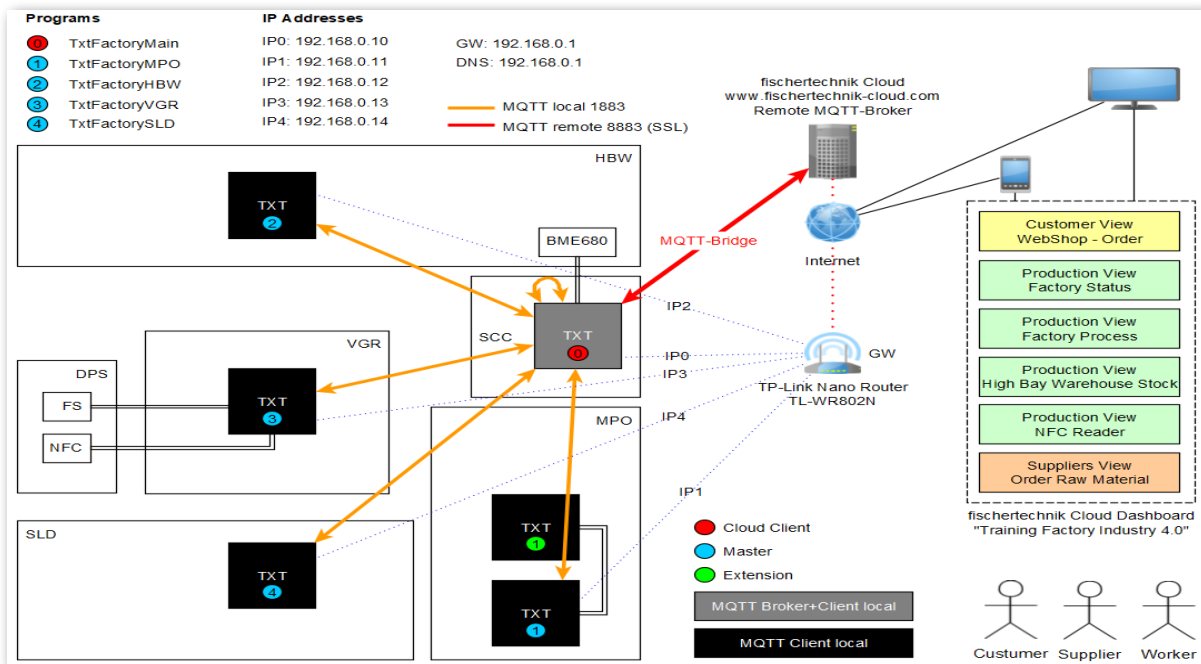
The central TXT controller is the TXT 0, which acts as a local MQTT broker and at the same time as an MQTT client and forwards the data from learning factory 4.0 to the more distant MQTT broker. The data between the two MQTT brokers (local and remote) are encrypted via an MQTT bridge when transmitted to port 8883. Local communication between the MQTT clients is done through port 1883.

MQTT stands for **M**essage **Q**ueuing **T**elemetry **T**ransport. MQTT is an open messaging protocol for machine-to-machine (M2M) communication. It enables telemetry data in the form of messages between the individual TXTs to be transmitted.

Physically, the TXT controllers (TXT 0 - 4) on the TP-link nano router are connected to a fixed IP address via WLAN. They are all operated in WLAN client mode. The TP-link nano router also connects to the Internet. Either an Ethernet cable (default setting) or another WLAN router can be used for this purpose.

The TP-link is the interface between Internet and the factory.

TP-link

The black and red dotted lines show the data flow between the individual controllers, the router and the fischertechnik cloud.

The two black lines represent the data transmission to the terminals (PC, laptop, smartphone).

The block diagram shows the individual representations on the "Training Factory Industry 4.0" dashboard

Customer View
WebShop - Order

Production View
Factory Status

Production View
Factory Process

Production View
High Bay Warehouse Stock

Production View
NFC Reader

Suppliers View
Order Raw Material

Customer View
WebShop - Order

Production View
Factory Status

Production View
Factory Process

Production View
High Bay Warehouse Stock

Production View
NFC Reader

Suppliers View
Order Raw Material

Connecting Learning Factory 4.0 to the Internet

There are two alternatives for connecting Learning Factory 4.0 to the Internet.

Wireless Router (default setting)

As the following diagram shows, the TP-link is connected to the supplied power supply or to the TXT controller on the vacuum gripper for power supply. The Ethernet cable is connected by TP-link directly to a free socket on the router or to an Internet connection.

Internet

or
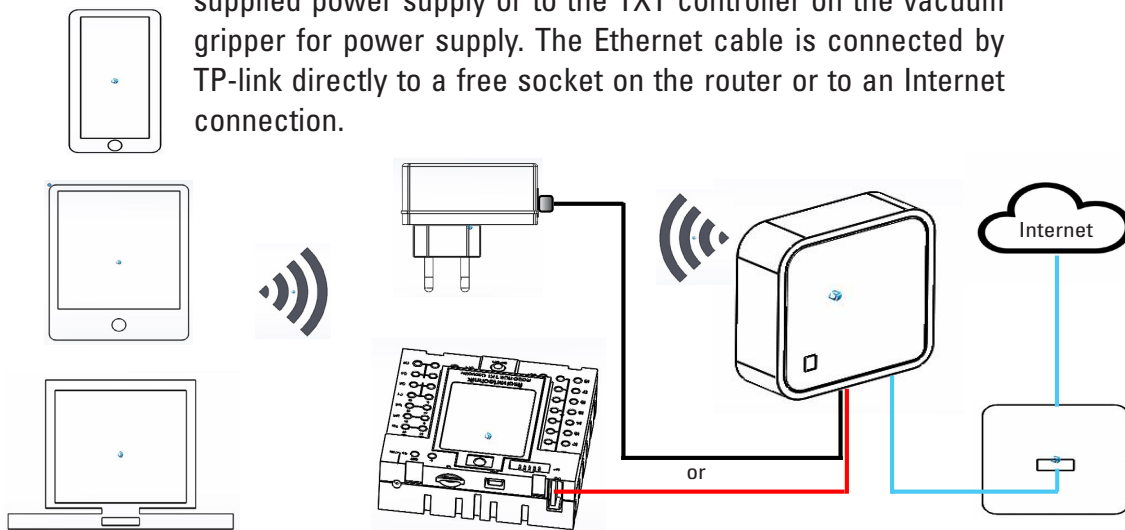
No further configuration is necessary if you use the Ethernet cable connection. The TP-link can be removed from the model if the supplied Ethernet cable is too short. Next, the TP-link is supplied with power via the enclosed power supply unit and connected to an Ethernet socket via the Ethernet cable.

Hotspot router

As an alternative to the wireless router, you can also set up a hotspot router connection using a WLAN router. The following graphic shows its structure.

Internet

WLAN router
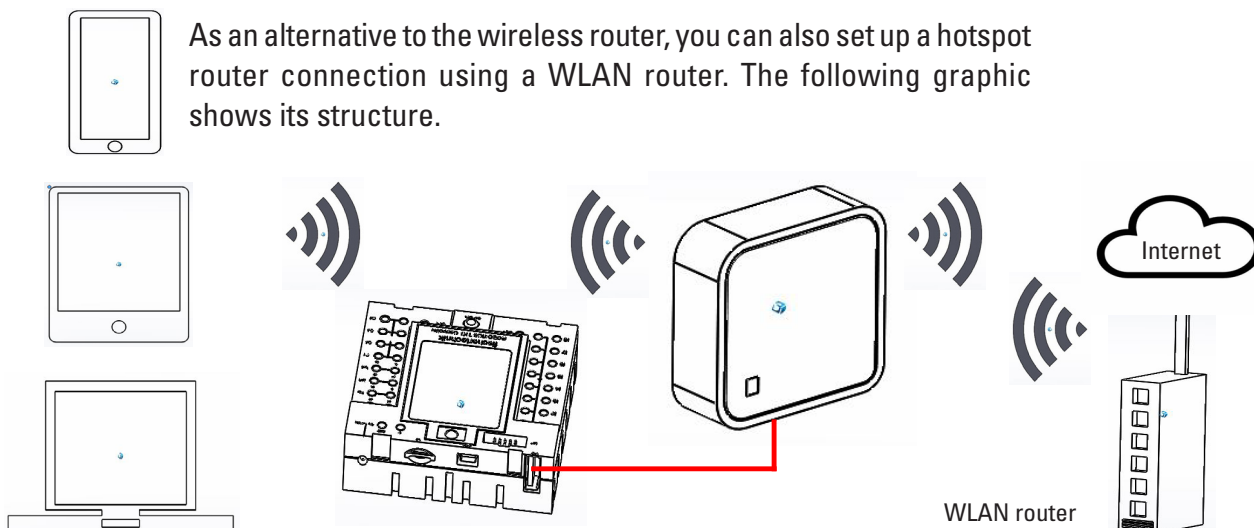
The TP-link must be configured in order to establish this connection.

Use your PC or a tablet to access it.
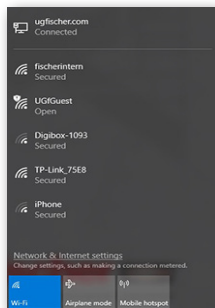
Important: Disconnect an existing Internet connection with the router on your main computer (WLAN capable). It is best to disconnect the Ethernet LAN cable from the computer.

The TP-link is permanently installed in your system. You must first perform a reset before you integrate (configure) it into your working environment. Turn on the TXT controller that is connected to the TP-link (TXT 0). The green lamp will flash on the TP-link. Use a pointed object (small screwdriver) to press the reset button for 5 seconds. The lamp will go off. The TP link will restart. The lamp will flash again.

Press the "Internet access" button to open the "Internet access" context menu on your main computer. A screen will appear showing the networks in your area. Your network router may not appear on this list. But the TP-link should still appear. Click on "WLAN" once and then once again if it doesn't. It will search for all WLAN networks.
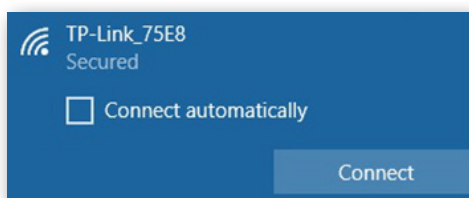
In the next step, activate the displayed TP-link. An additional context menu will appear. Select the "Connect" button.
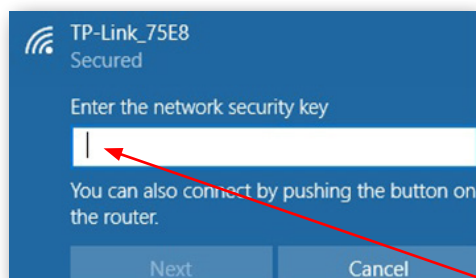
After a short while, a pop-up window will appear asking you to enter the network security key for your TP-link.

This is located on the bottom of the TP-link.
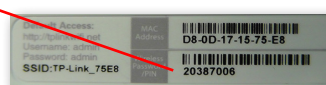
After entering the key, confirm by pressing the "Next" button.
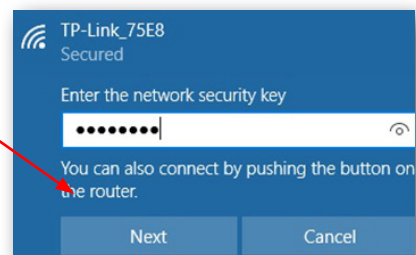
The next step checks the security key after which the TP-link is now connected to your computer via WLAN.
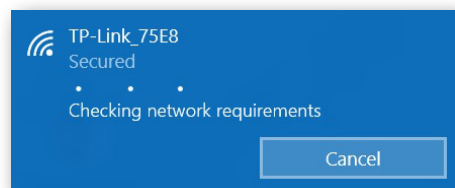
The last pop-up window will show you that the connection is successful.
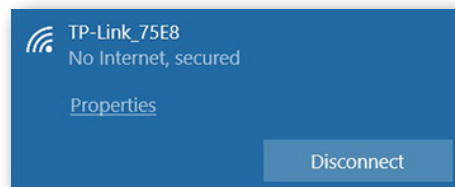
Next, you need to configure the TP-link for your network. To do this, open a WEB browser (Firefox or Chrome).
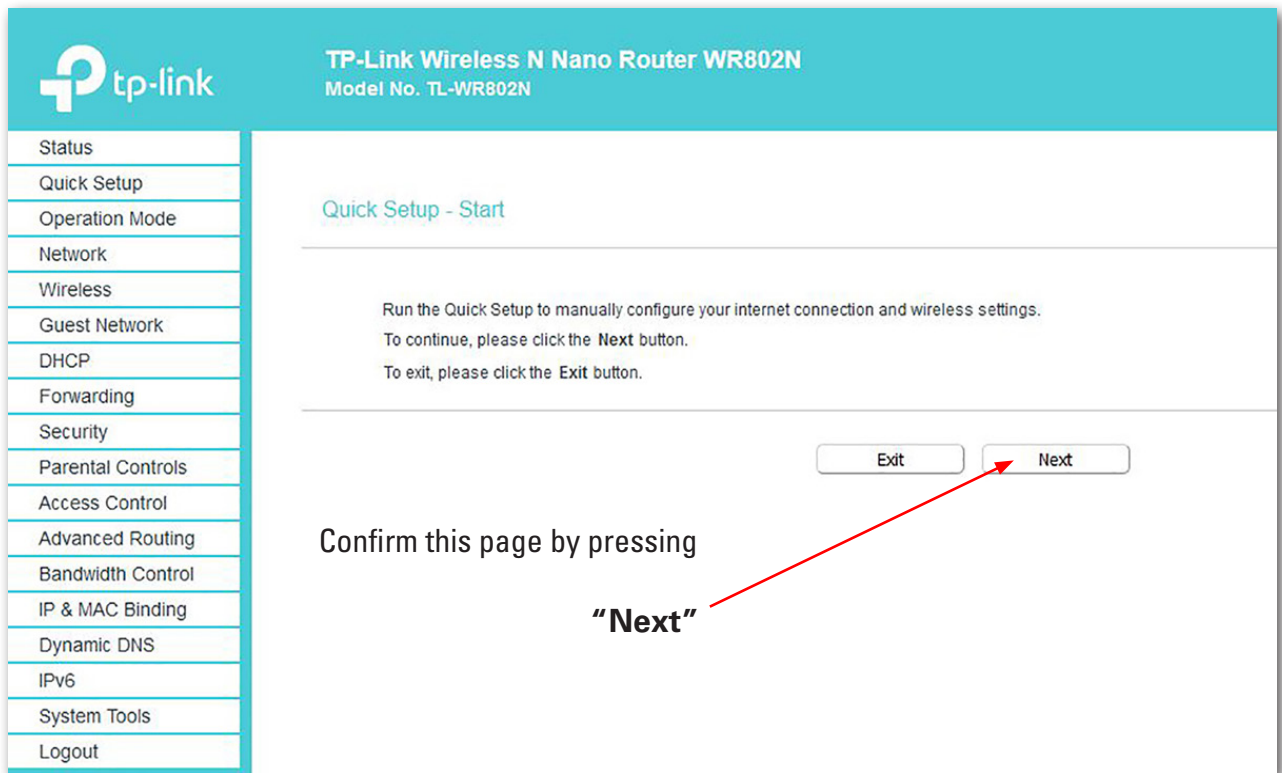
Enter the URL
http://tplinkwifi.net

Important: Do not enter "www."

and press Enter. The following page will appear:
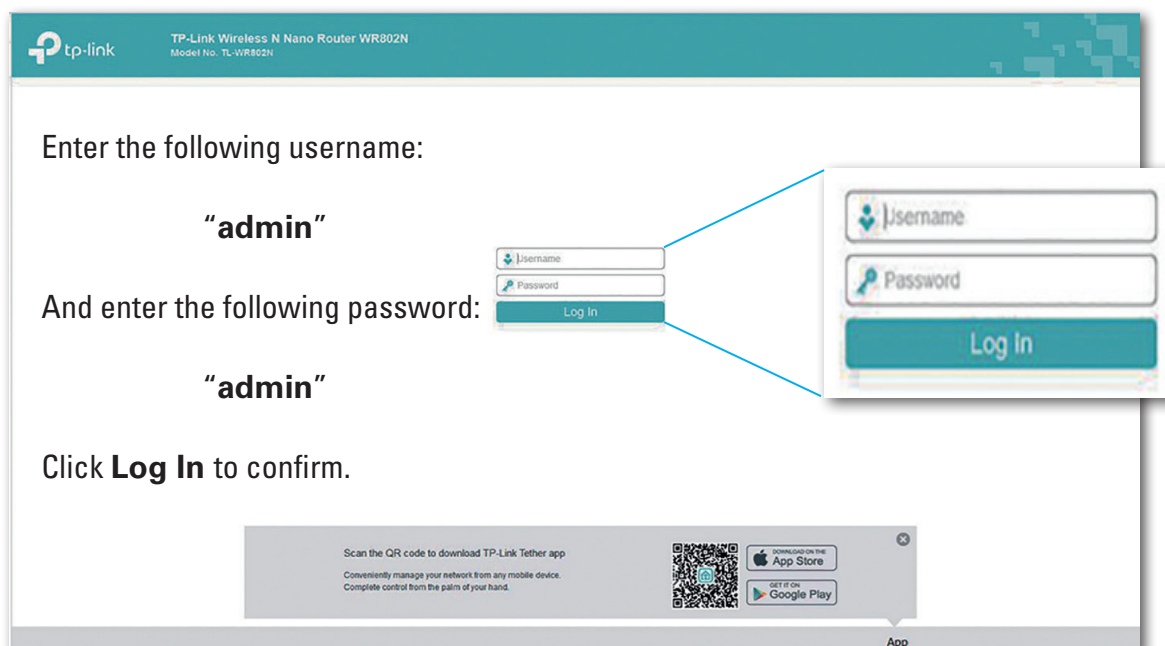
Enter the following username:

"**admin**"

And enter the following password:

"**admin**"

Click **Log In** to confirm.
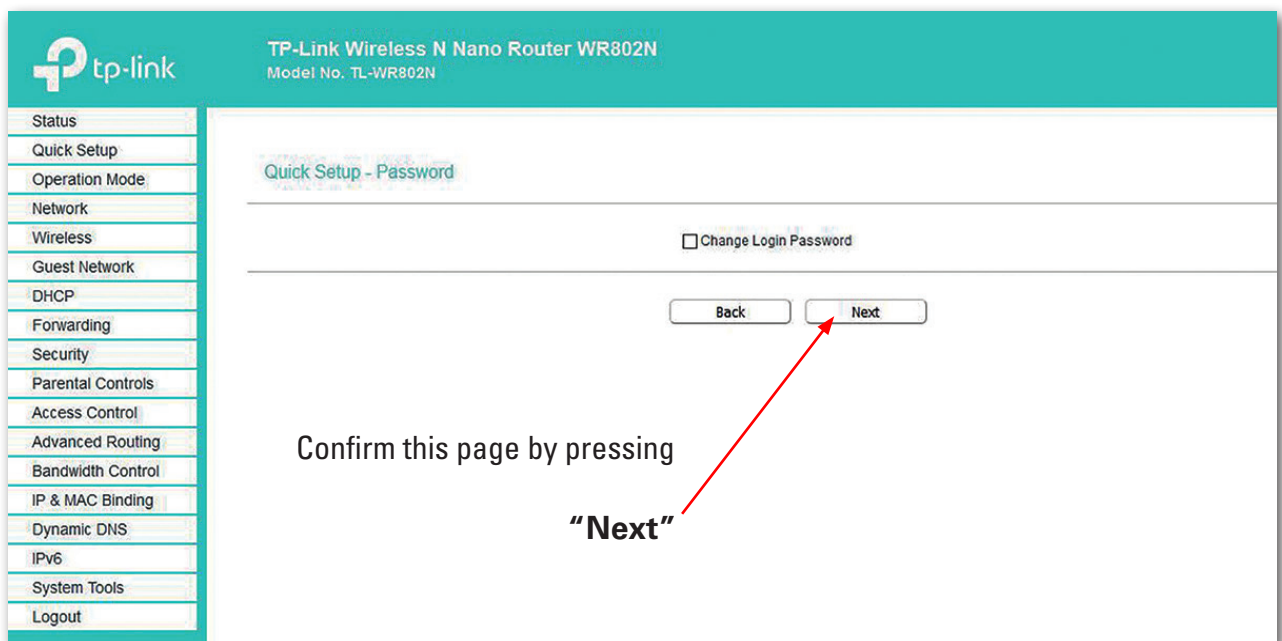
Confirm this page by pressing

"Next"

The password should not be changed, otherwise it has to be changed on all the other controllers.

Confirm this page by pressing

"Next"

Switch to "Operation Mode" in the selection window for the next settings.

The following screen will appear:

In this window, select "**Hotspot Router**".

Save this setting by clicking on **"Save".**
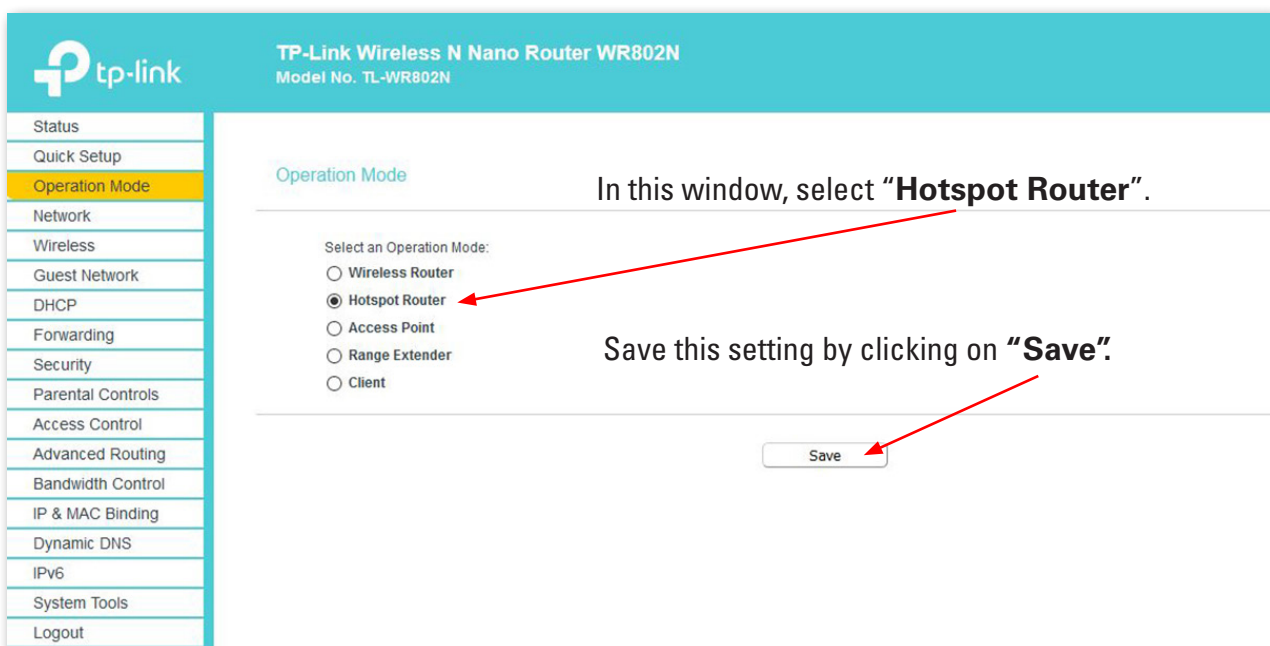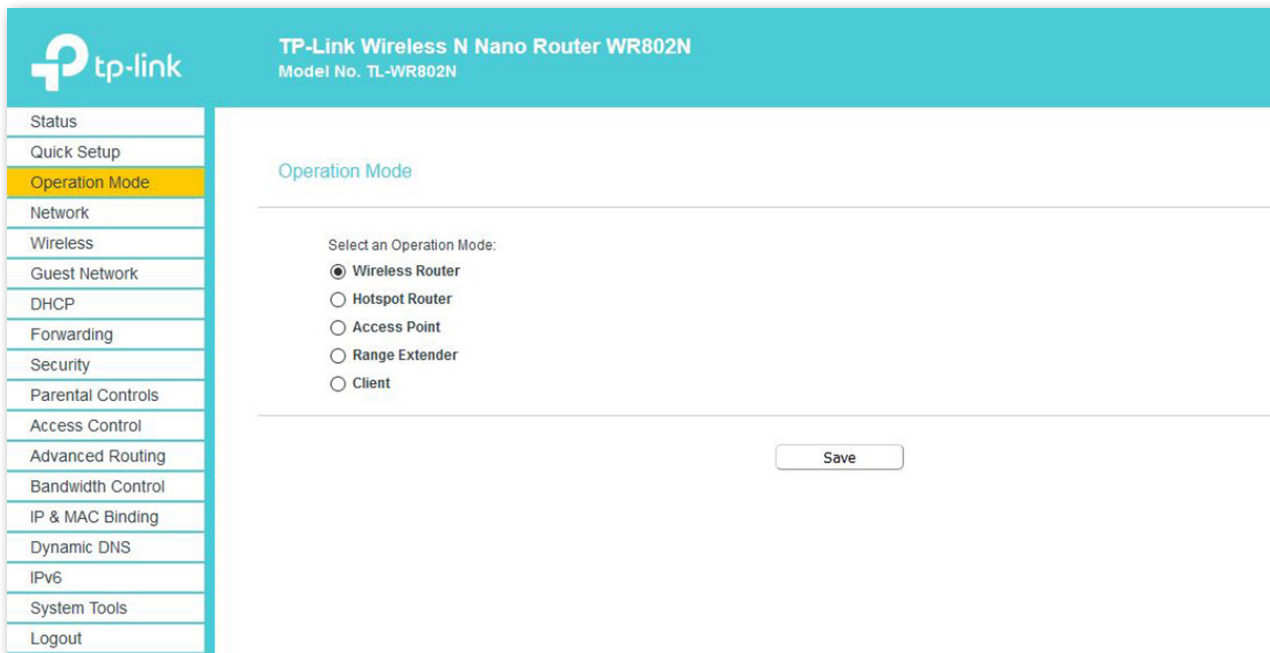
Click on OK to confirm the following message.

The change of operation mode will not take effect until the device reboots. Would you like to change the operation mode?

OK Abbrechen
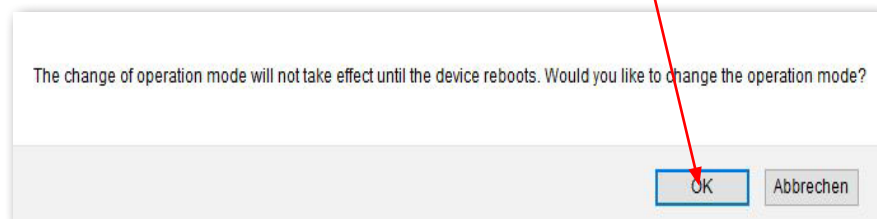
The settings are saved (reboot will start).
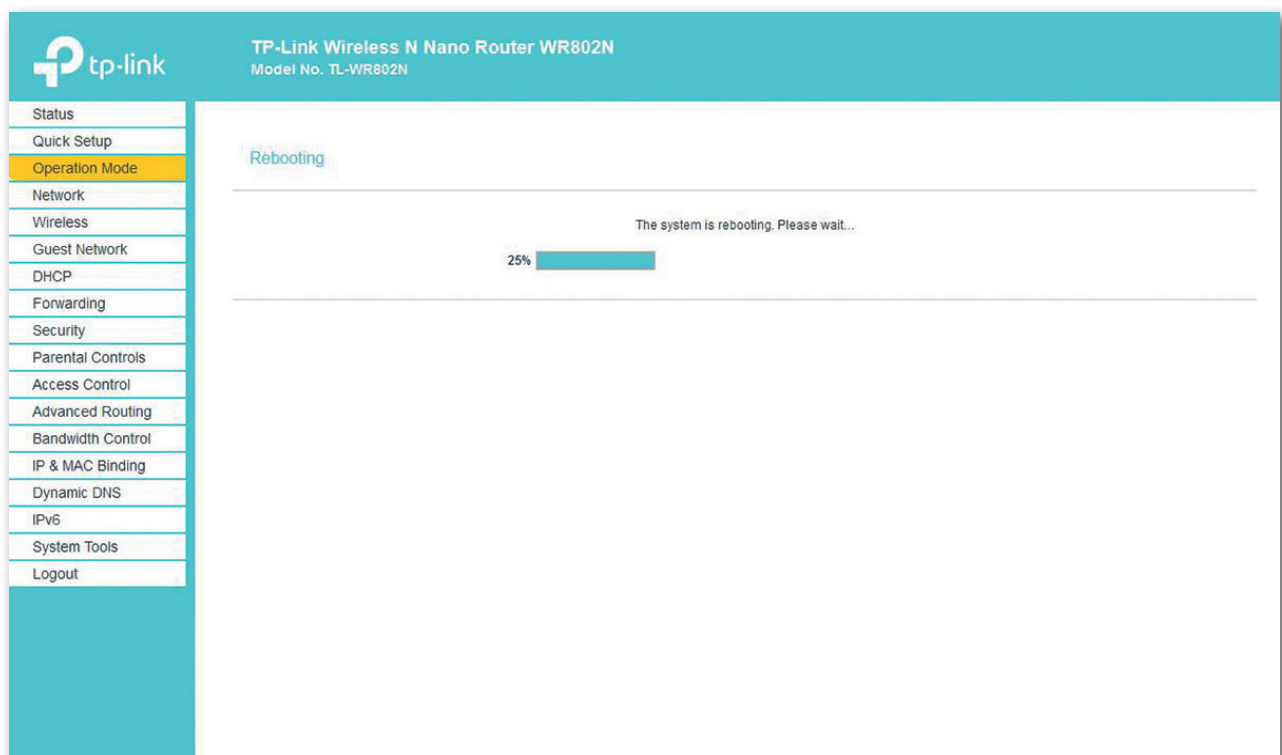
The status display shows the progress of the reboot.
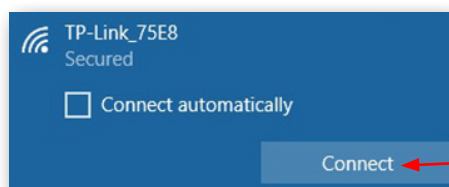
Important: It might happen that the connection from the computer to the TP-link was interrupted during the reboot. Connect them by clicking on "Connect".

You can read the different values on the status screen once the reboot has finished.

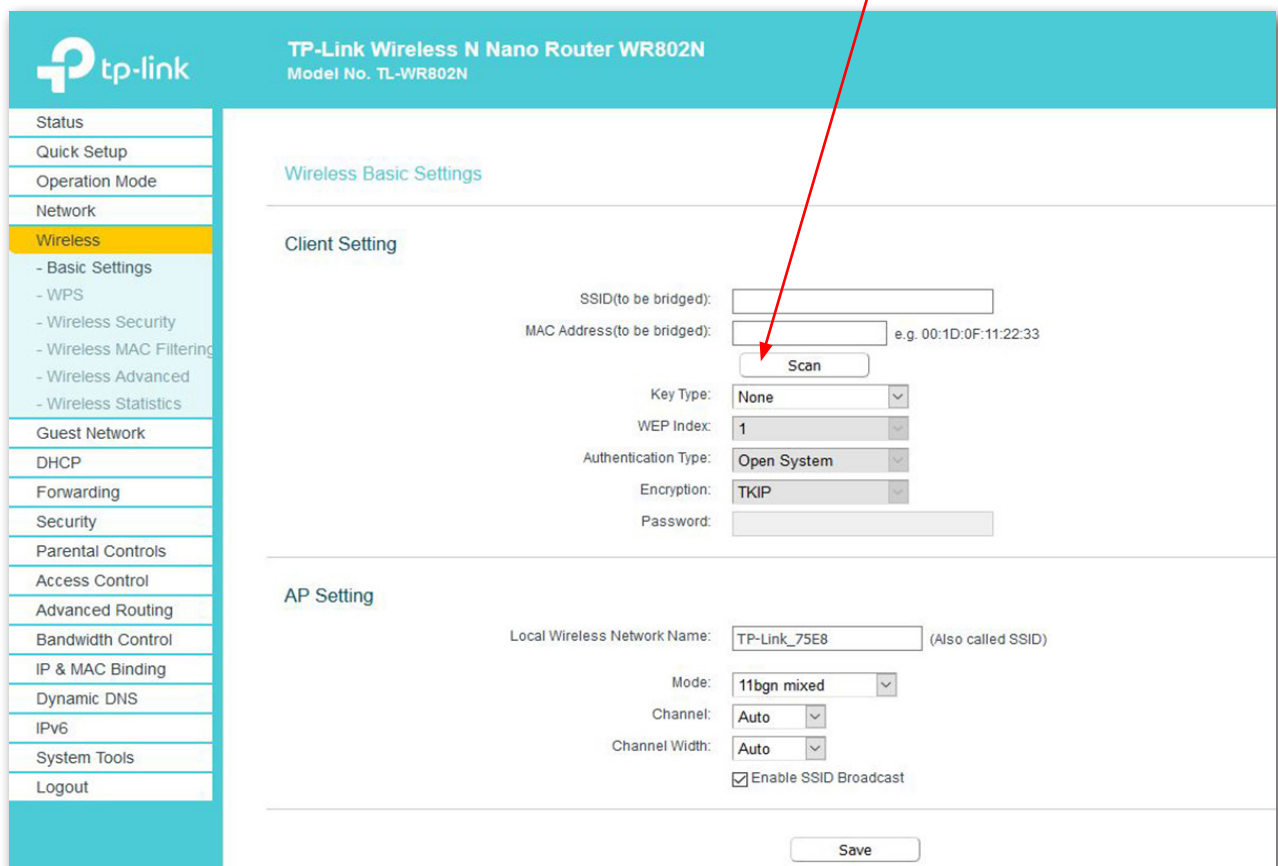In the next step, switch to "Wireless" in the selection window.
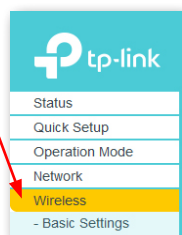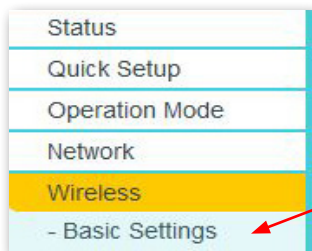
Activate "Wireless" – "Basic Settings" in the selection window.

Click on "Scan" in the input window (Basic Settings).

Important: If a different window is displayed, then the "Hotspot Router" operation mode was not selected in the previous step; this means that the step has to be repeated.
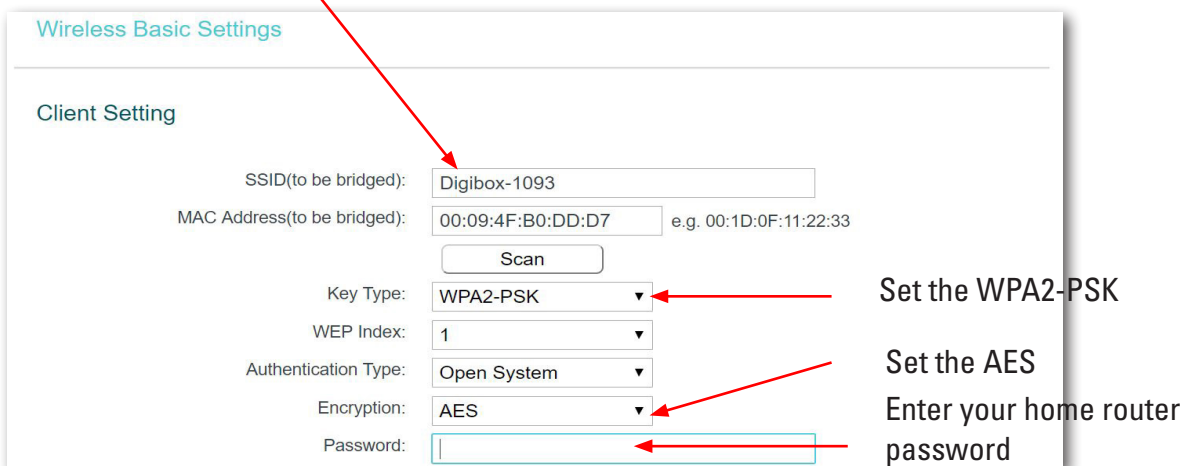

All of the routers in your vicinity will be searched for and shown in a second window.
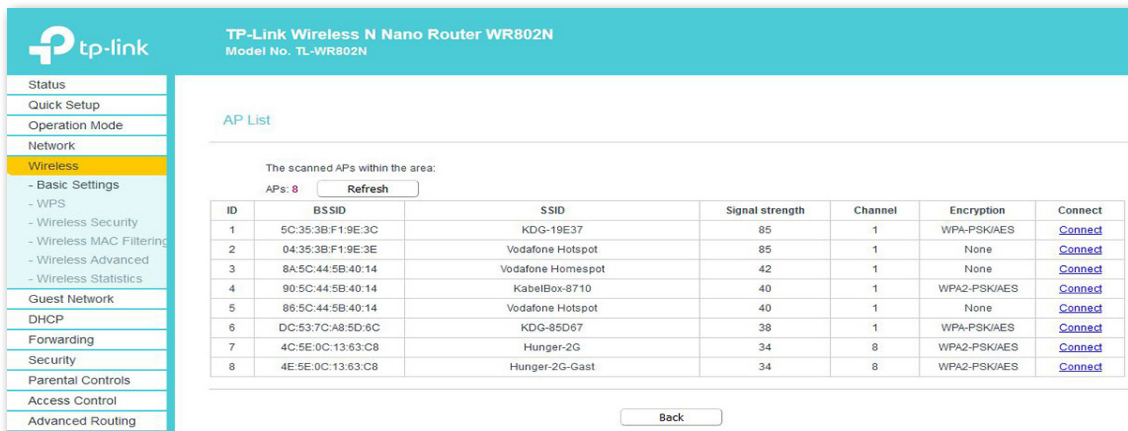
Select the

"**Connect**"

button on the router that is supposed to be connected to the TP-link. The "Basic Settings" (detail) will appear on the screen again. The data that was previously missing will now automatically be entered under "Client Setting".

Close out of this configuration by clicking "Save". After a brief period of time the TP-link light will light up and stay on. At this point, your TP-link is now connected to the Internet through your router. **Note:** If someone enters the wrong password, an error message will appear – and the page will simply remain static. The correct password will have to be entered.

Important: Now re-connect your Ethernet-LAN cable to your computer. You can now disconnect the connection you did have between your computer and the TP-link.
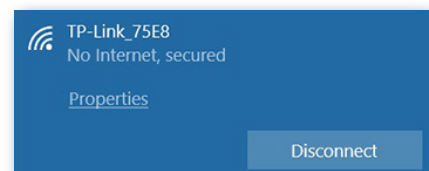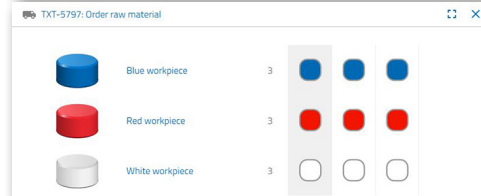
Learning factory dashboard in the fischertechnik cloud

The dashboard can be accessed and operated via mobile devices such as tablets and smartphones as well as laptops and PCs. It enables factory scenarios to be displayed from three different perspectives:

Customer view
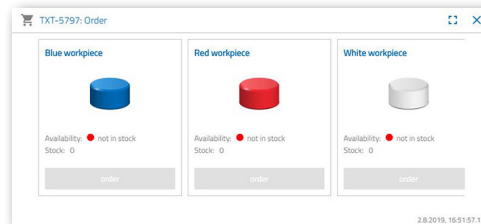
Supplier view

Production view

User login

You have to log in before you can use the dashboard. To log in, call up

<p align="center">**www.fischertechnik-cloud.com**</p>

The two best Internet browsers to use are "Firefox" or "Google Chrome".

Enter the address (URL). It will now appear on the following screen.

Important: If this page doesn't load, press "CTRL + F5" at the same time to reload the page. This is a general browser problem.

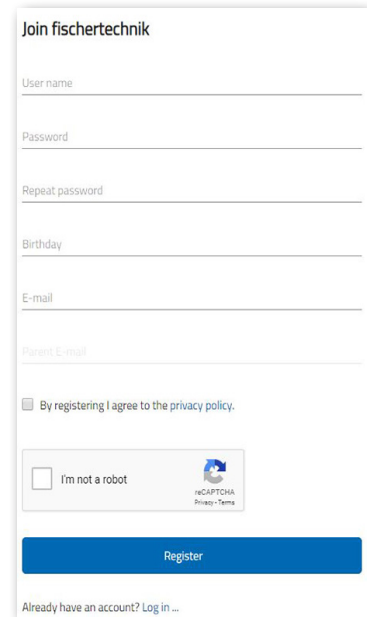Click here to log in for the first time:

Are you new to fischertechnik? Sign up now ...

Fill out all fields and accept the data privacy policies. Check the box, "I am not a robot" and answer the questions.

Confirm log-in by clicking:

After signing up, you will always be able to log in using your user name and password. As soon as you have done this, the dashboard will start up. After carrying out the next item, the dashboard will populate with data.

Cloud connection

Only one TXT controller will link from the learning factory 4.0 to the cloud, the TXT 0, which also controls the movable camera. The WLAN connection to the TP-link comes with settings already set at the factory.
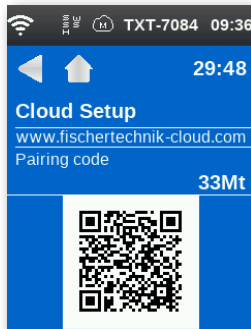
The following settings are required for this TXT to connect to the fischertechnik cloud:

On the TXT, activate the "Settings – Characteristics – Cloud Client". Now click on the "Home" button to return to the "Home" screen.
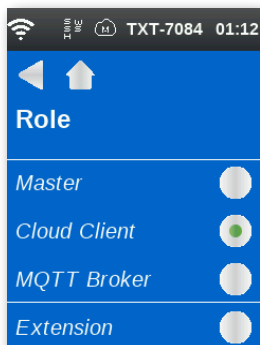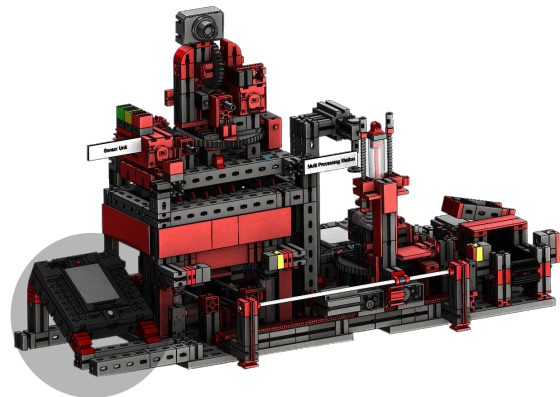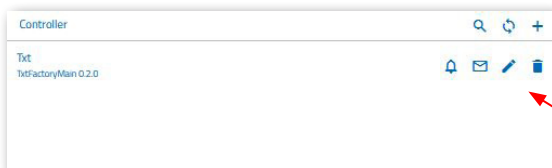
Now connect the TXT controller to the fischertechnik cloud by going through "Settings – Network – Cloud Settings – Pairing New".
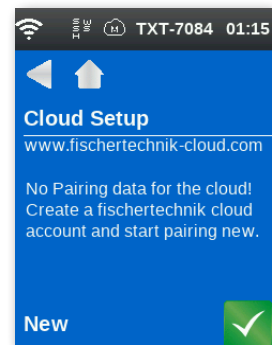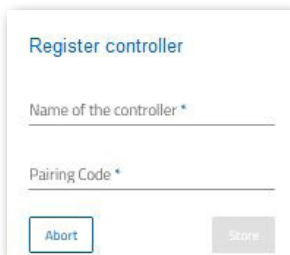
If the TXT controller is able to connect to the cloud, then a QR-code and pairing code will display. You now have 30 minutes to add your TXT controller to your account in the cloud. If this period of time elapses before you have done this, you will have to start the pairing process all over.
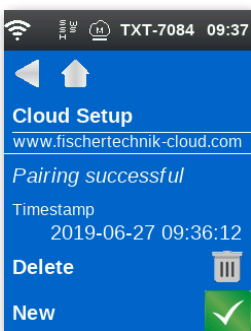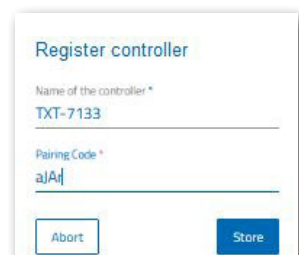
Use the "Quick Scan" app to scan the QR code, after which you will be automatically directed to the fischertechnik cloud.

Alternatively, you can also get to the fischertechnik cloud page via "Settings – Add Controller" and manually input the pairing code there.

At this point enter any name you wish for the TXT controller, e.g., its ID, "TXT-7133".

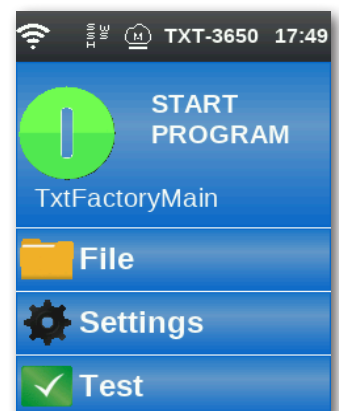Now the TXT controller is connected to the cloud.

Click on

load

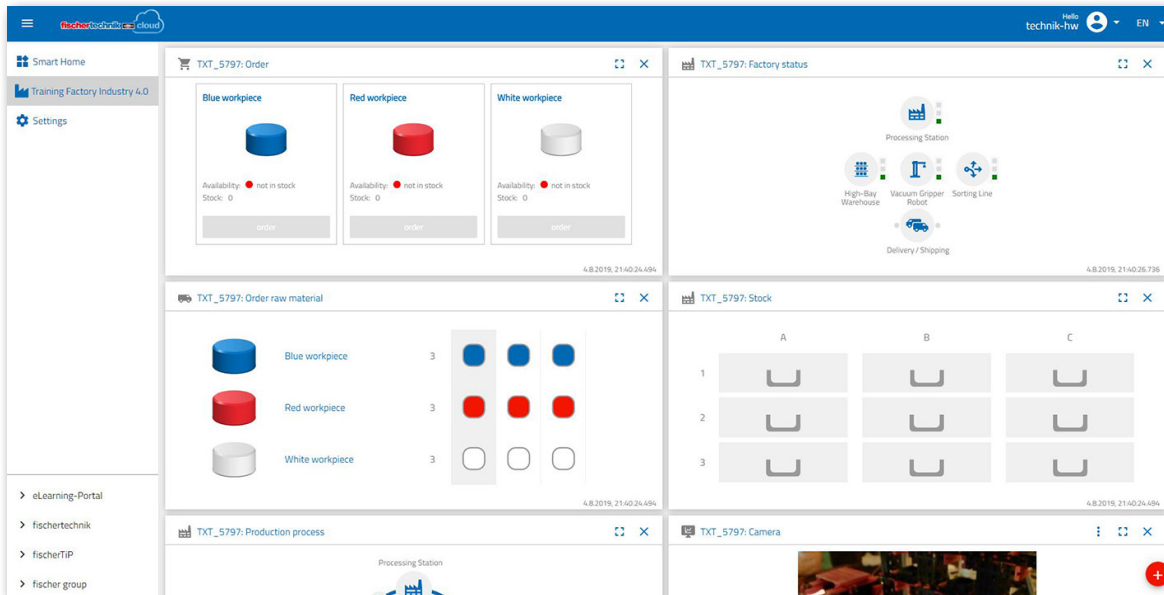under "File – Cloud" to get to the **TxtFactoryMain** application.

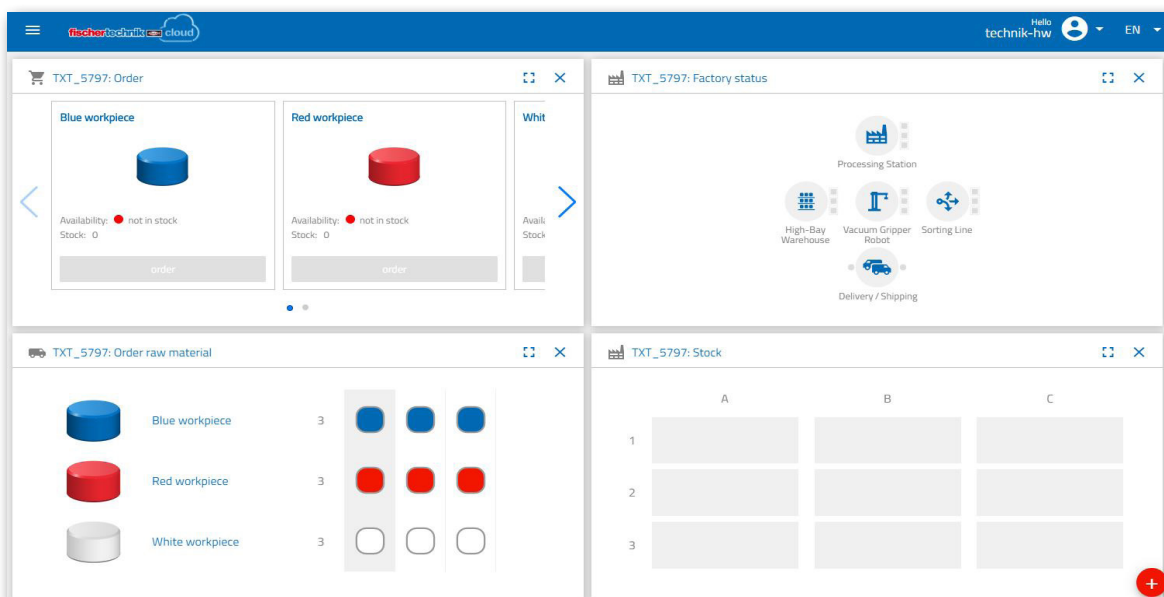As soon as you have connected to the cloud, start the applications on the TXT controller.

Factory dashboard
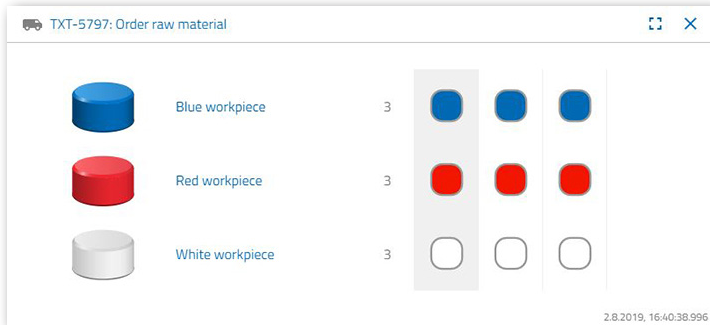
The following screen will now display:

The individual screens can be moved around in the sequence you want and be adapted to your needs.

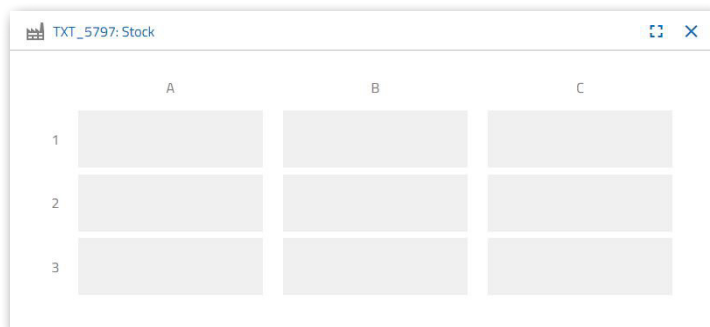Click this button to close or expand the main menu for the cloud.

The individual windows and their functions at a glance:

Order raw material

The "Order raw material" view indicates which raw material is missing and needs to be reordered.

Inventory

The "Inventory" window shows you how much raw material has been stored in the high bay. The stock is changed according to the number and colour if goods are removed.

Purchase order
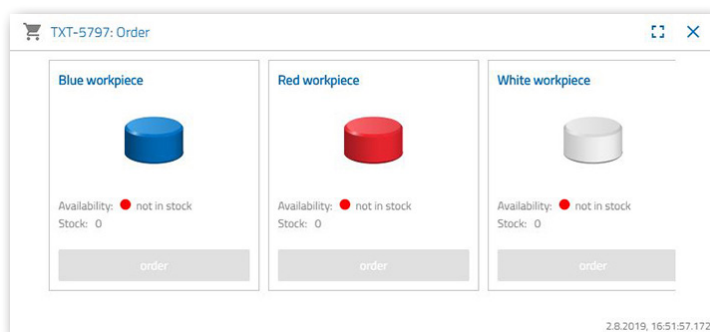
This window shows how much raw material (blue, red, white) is in the warehouse. If, for example, a red workpiece is placed on the shelf, the colour display and stock value changes accordingly.

Factory status

The "Factory status" window displays the current work status for the entire factory. "Icon is highlighted in blue" will be displayed if, for example, the vacuum suction gripper is currently being used.
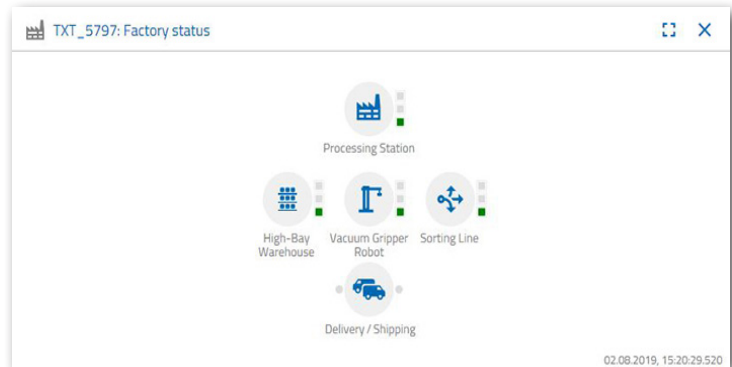

Production status

In this window, you see the blueprint of the production process right after you have ordered a workpiece. This allows you to keep track of where the workpiece currently is in the factory.
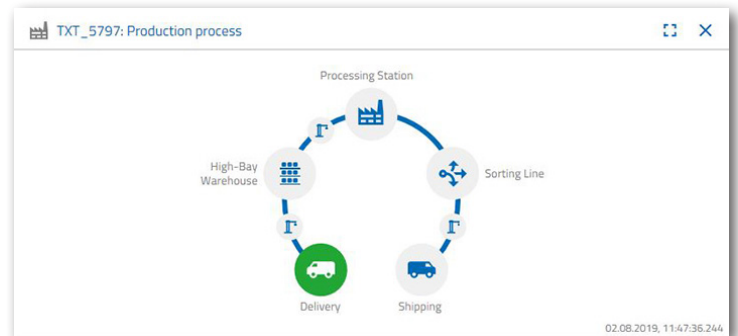
The NFC reader

This window always displays the NFC reader's current status.

But you can also display a workpiece and read out the data of the NFC tag.

Click "Delete" to delete the contents on the NFC tag.

Dashboard camera
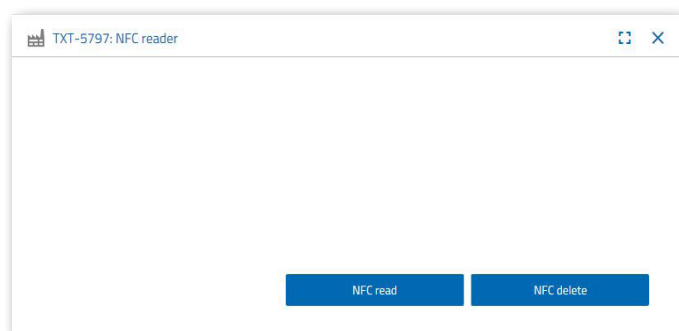
Camera

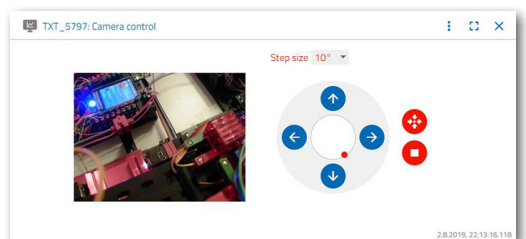The camera screen displays the camera section for your factory.

This is a live recording of the factory.

Camera control

This screen gives you the power to control your camera live. You can thus get an overview of the entire factory.

Use the virtual joystick to control the camera. The red dot indicates where the centre of the camera is. Use the "Step size" button to set the degree by which the camera rotates when the arrow is clicked. The two red buttons can be used to centre or stop the camera.

Take a snapshot

The "Snapshot for the Current Image" button lets you place the current image in the Gallery screen.

Gallery

All images that you have created are stored in the "Gallery" window. Use the arrow keys to scroll through the gallery. The current picture is displayed zoomed. Click "Delete" to remove an image from the gallery.
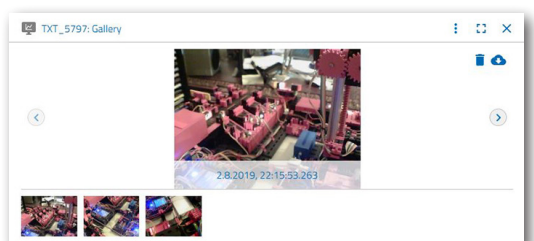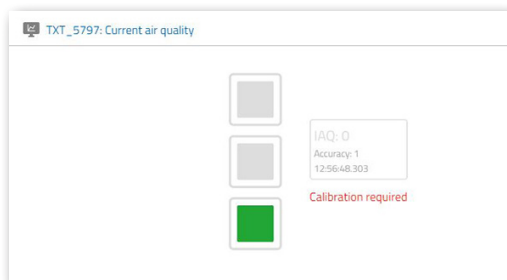

Use the "Download" command to use the image. Specify a storage location in the context menu that opens.

![fischertechnik logo]

Dashboard Environmental Station

In addition to the camera function, you can view and process the information from the environmental sensor.
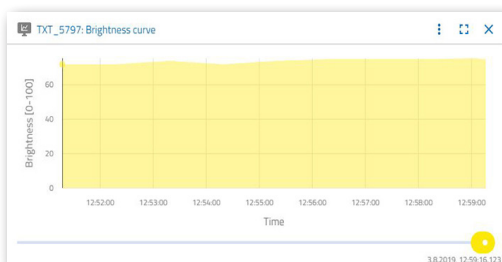
Current air quality

The "Current air quality" window lets you see a value of the air quality, which is indicated by the three rectangles. The display that is switched on depends on the quality of the air at the time it is measured. Green means that the air quality is very good; green and yellow indicate that it is good; yellow

means satisfactory; green and red signify that the air quality is adequate and red means that the air quality is bad.

The "More" button (this applies to all environmental sensor windows) let's you choose between "Graph", "Single value" and "Download".

You will get a graphical representation of the measured values when you select "Graph". Use the scroll bar to scroll through all recorded data.


If you select "Download", the data will be downloaded as a .csv file and can be downloaded and displayed in OpenOffice Calc or Excel. The data can then be further processed.

Current brightness

The "Current Brightness" window displays a brightness value as a percentage, including the time at which the measured value was generated. Also visible are the brightness variations.
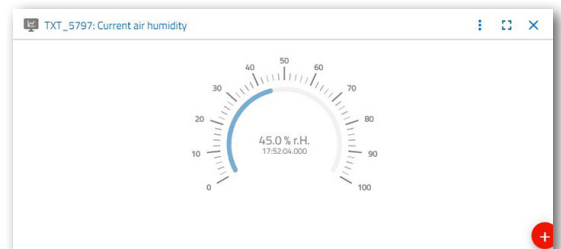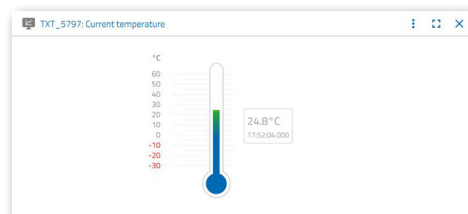
Current air pressure
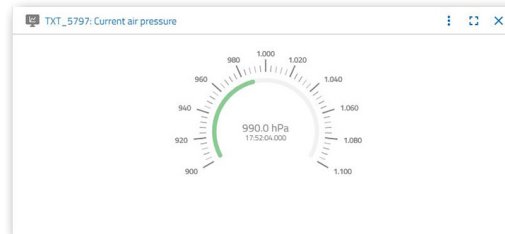
The "Current air pressure" window displays the air pressure in hPa (Hecto-Pascal) and the time at which the measured value was generated.

Current humidity

The "Current air humidity" window displays a value of the relative humidity as a percentage.

Current temperature

The "Current temperature" window displays the current temperature (ambient temperature) of the measuring sensor in ° C.
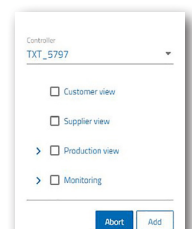
More buttons

Use the "Add window" button to a hidden window. If you activate the button, a context menu appears from which you can show a dashboard window.

Use this button to close the current window.

Use this button to zoom the current window to full screen mode.

This button shows and hides the left status bar.

The button shows that you have logged in under your profile. Clicking on the arrow will bring up a context menu where you can select "Profile" or "Logout". Selecting "Profile" will open another context menu in which you can set settings for your profile. Click "Logout" to log out of the fischertechnik cloud.
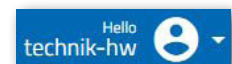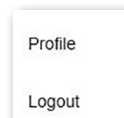
A context menu for selecting the language will display if you activate the arrow to the right of "EN".

The status bar shows three selection points that you can activate with a single mouse click. The first two buttons let you choose whether you want to work with the factory simulation dashboard or just the environmental station dashboard.

Activating the "Settings" button will display a context menu where you can view and change various parameters relating to your TXT controller.
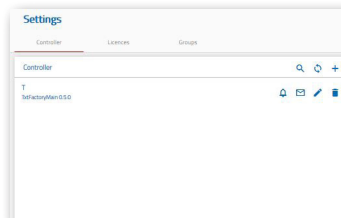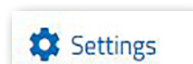
Factory management

To start the factory operation, start the applications on the four controllers as described:

When the TXT controllers are switched on, "Auto Load" automatically loads the programs, and they just have to be started.

Multi-processing station

TxtFactoryMPO

Sorting system

TxtFactorySLD

High-bay warehouse

TxtFactoryHBW

Vacuum suction gripper with a swap station

TxtFactoryVGR
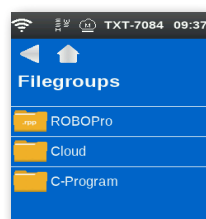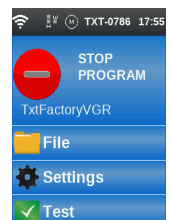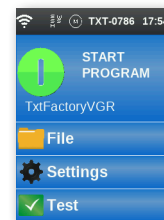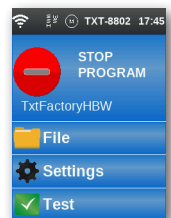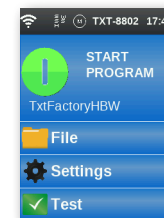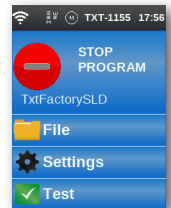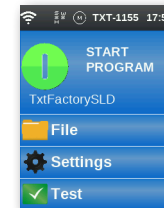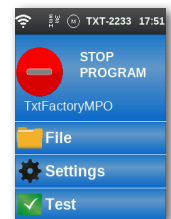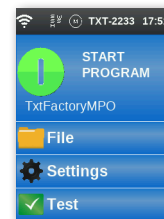
These applications are located on the respective TXT controller under:

File – C program

Control at end: The red symbol on the controller display shows that the programs that are supposed to be running on each TXT controller are running.

Once all programs are started, learning factory 4.0 is ready for use.

You will learn to operate the factory and the dashboard by carrying out various tasks.

Task 1

Before raw material can be stored in the high-bay warehouse, the compartments must be equipped with the supplied empty containers. This is the first task you need to perform as a warehouseman.

9 x
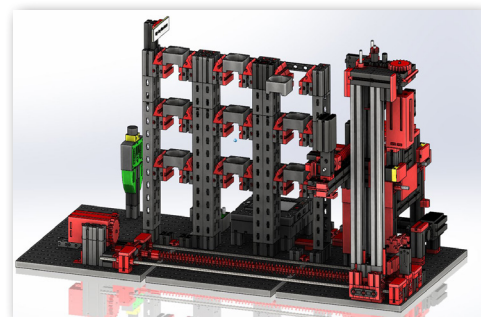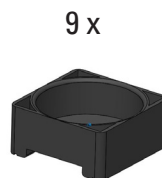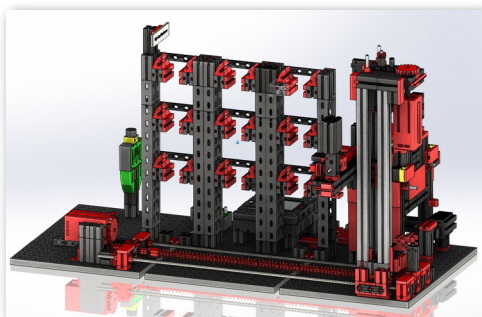
Your dashboard looks like this:
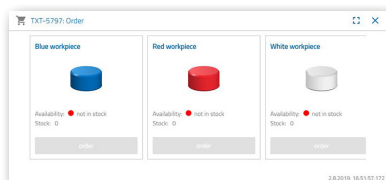
Purchase order
Blue, red, white not available, stock 0
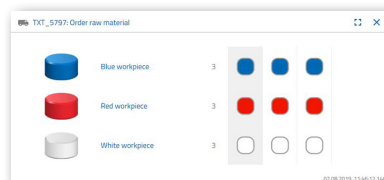
Purchase order raw material
No PO created

Inventory
Inventory empty because no raw material was stored

Important: If this is not the case, you can use the included key fob (with integrated NFC tag) to reset the dashboard windows to their default settings.

Task 2

Order raw material that should be stored in the high-bay warehouse as stock. To do this, manually store the raw material in the input station.

First, only store a white stone as a workpiece.
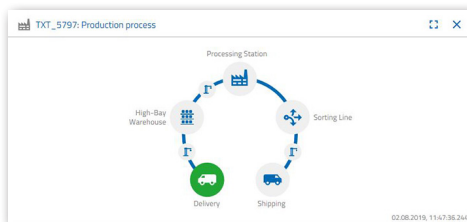
Insert a white stone in the material input. The workpiece (raw material) interrupts the photoelectric barrier. This process is identified as "Inbound Delivery" and highlighted in green in the "Production Process" dashboard window with the "Delivery" icon.
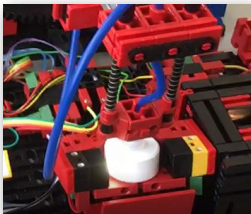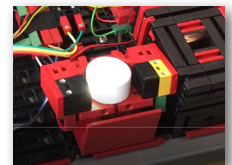
Then the vacuum suction gripper moves to the storage position, picks up the raw material and moves it to the NFC reader.

The dashboard window displays the process as follows:

Delivery and vacuum suction grippers are active and are displayed in green.
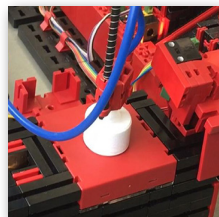
At this point, all data is deleted that is located on the NFC tag for the raw material (already described).

The raw material colour is determined in the next step. To do this, the vacuum suction gripper moves the raw material over the colour sensor. The data is then available to the NFC reader for further processing.
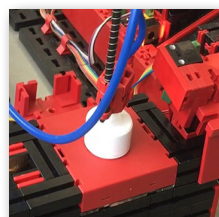
Before the raw material is stored, the NFC reader writes the colour data that has been determined, along with any additional information, such as delivery data and quality control data, to the NFC tag.

Since both factory modules (delivery and vacuum pads) are still active, this will continue to be displayed in green on the production process dashboard.
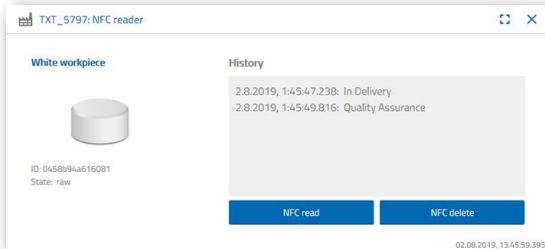
This data is displayed in the "NFC Reader" dashboard window.

What happens next?
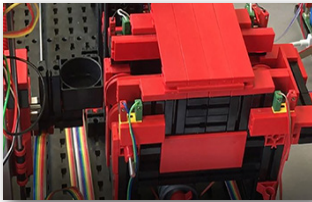
The high-bay warehouse provides an empty container for receiving the raw material. For the raw material to be placed in the empty container, the gripper arm moves into the position for an empty container, picks it up with its slider and deposits it on the input / output device.
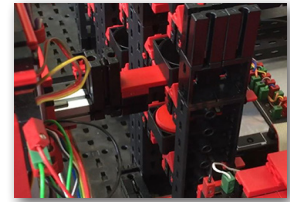
The container is transported via container to the input position.

The vacuum suction arm rotates to the storage position, moves down and places the raw material into the waiting container.
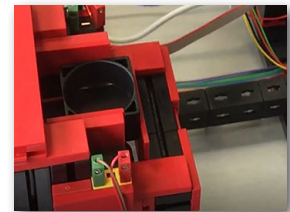
The input / output device then transports the container with the raw material to the high-bay warehouse gripper arm's receiving position. At this point, the container is picked up, transported to the storage location in the high bay and stored there.
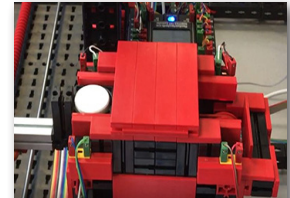
The "Production Process" dashboard window shows you how the put-away process progresses from there. The icons for all active factory modules light up in green when the factory modules are active.
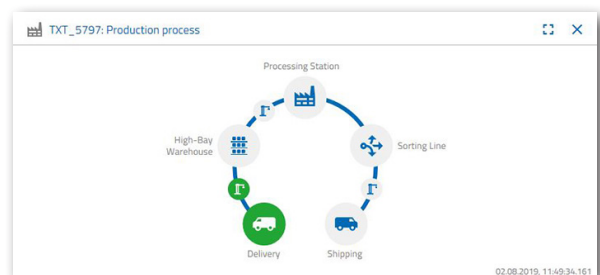
Consider the following dashboard windows - TXT: Order raw material, TXT: Inventory and TXT: Order.

TXT: Order raw material

Three workpieces per colour are available to you as the warehouseman for ordering raw materials.
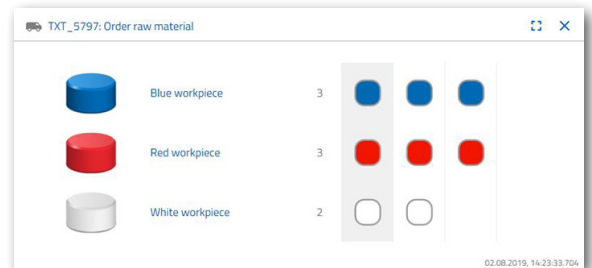
The maximum number of white stones will be reduced by one in the "TXT: order raw materials" dashboard window after you have stored a white stone in task 2. After you have done this, you will still have two workpieces available for storing.

TXT: Inventory

You will now see a white stone displayed in the storage system in the "TXT: Inventory status" dashboard window. This means that you can order this workpiece as a customer and have it processed.

TXT: Purchase order
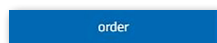
order

The dashboard window "TXT: Order" will now show you that a white stone has been stored, and that it can now be ordered.
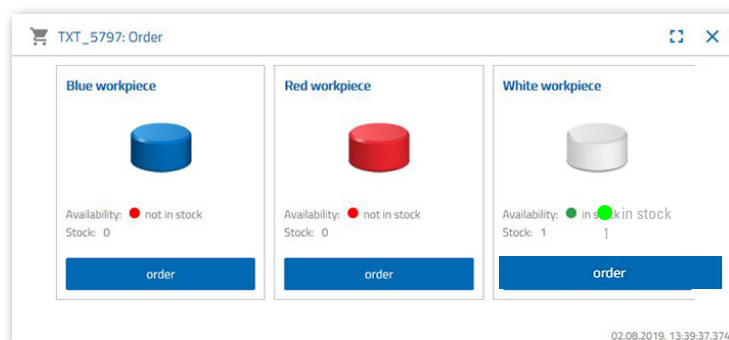
Task 3

Order raw material that is to be stored in the high-bay warehouse as stock. To do this, manually store the raw material in the input station.

Now store a blue stone as a workpiece.

As described in Task 2, insert a blue stone in the high-bay warehouse. The dashboard will display the results once the put-away work has been accomplished.
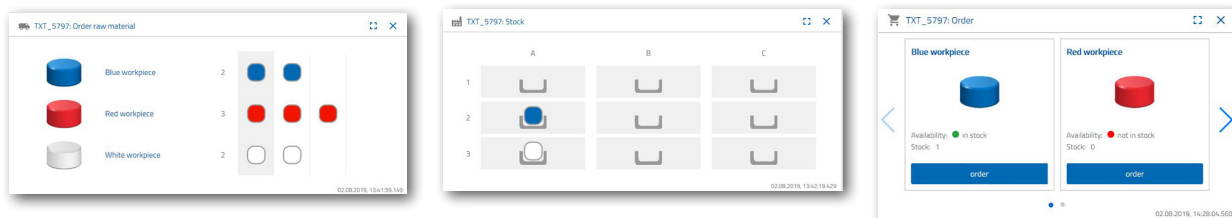
Task 4

Store additional raw materials for storage in the high-bay warehouse. You still need two white and one red workpieces.
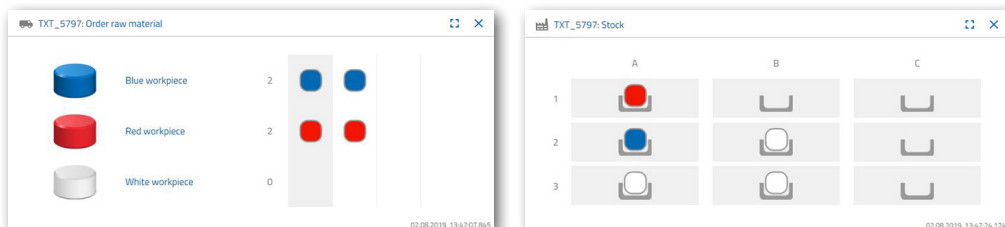
Task 5

Put yourself in the position of a customer, who, for example, would like to order a white workpiece. Order a white workpiece.
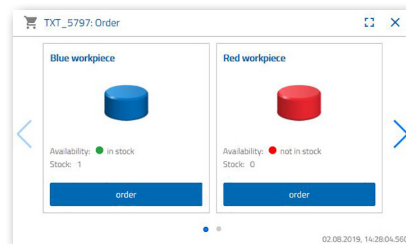
order

To do this, click on the blue "Purchase order" button in the "TXT: PO" dashboard window.

This happens at the factory: The transport arm of the high-bay warehouse moves into the "white workpiece" insert position.
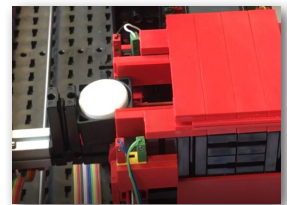
The transport arm picks this up and put it in the high-bay warehouse's in- / output station. From there, it is transported to the receiving position on the vacuum suction gripper.
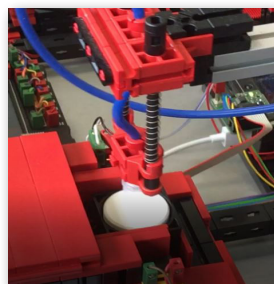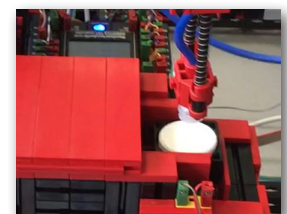
The vacuum suction gripper picks up the workpiece at the picking position and places it on the slider in the kiln.
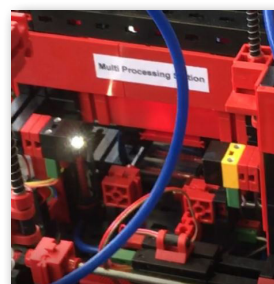
The workpiece is inserted, fired and moved out of the kiln again. The available small transport carriage with vacuum cleaner takes over the transport to the processing machine referred to as the "milling machine".
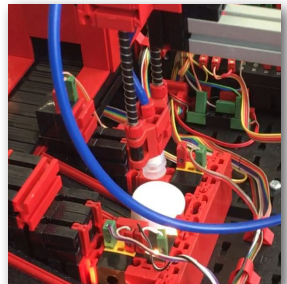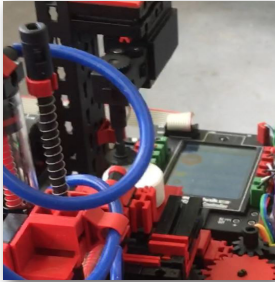
After the milling process has been carried out, the workpiece is rotated 90 degrees horizontally and pneumatically pushed onto a conveyor belt.
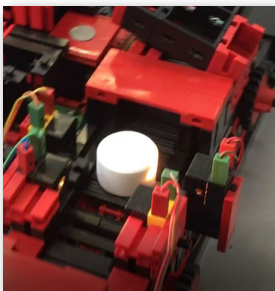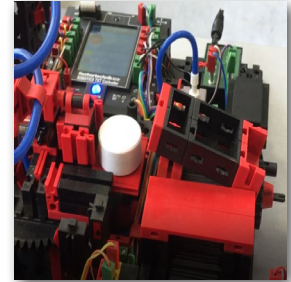
On the way to the sorting device, the workpiece undergoes colour detection.
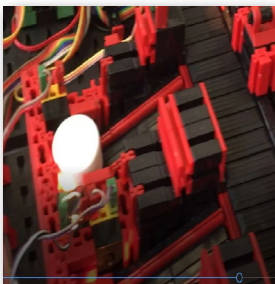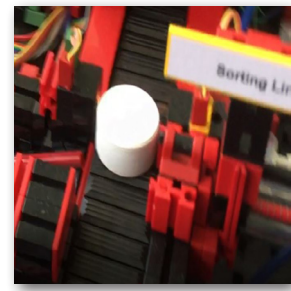
Depending on the detected colour, the workpiece is ejected pneumatically from the conveyor belt in front of a material chute. The workpiece is located in a receiving area and can be transported from here using the vacuum suction gripper.
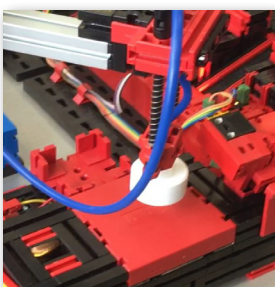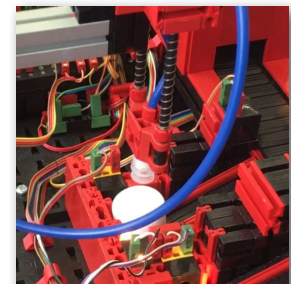
The gripper places the workpiece on the NFC reader for the final inscription. There it is loaded with workpiece-related data such as the order date, manufacturing or delivery data.
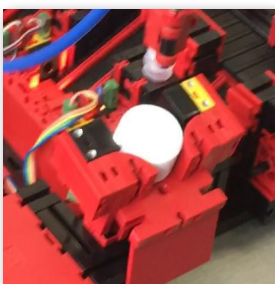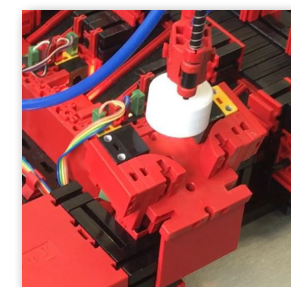
Finally, the workpiece is placed in the output tray at the input-output station.

You can also follow the steps on the dashboard:

Raw material is taken from the high-bay warehouse and fed to the processing process.

Raw material is processed in the multi-processing station (kiln, milling machine).

A machined workpiece is sorted by colour and the NFC reader provides it with workpiece-relevant data.
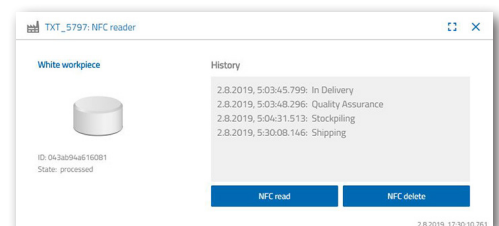
The workpiece is ready for delivery and can be removed from the system.

Task 6

A white stone has accidentally fallen off the high bay and you want to know what data was written on the NFC tag.
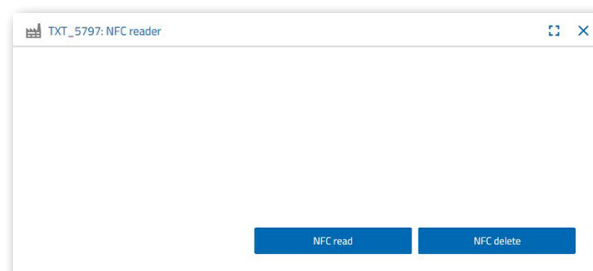
The system must be at rest to do this. Place the workpiece on the NFC reader and activate the "Read NFC" button in the "TXT: NFC Reader" dashboard window.

The NFC reader reads the data and displays it in the dashboard window.

If necessary, you can delete the data using the "Delete NFC" button.
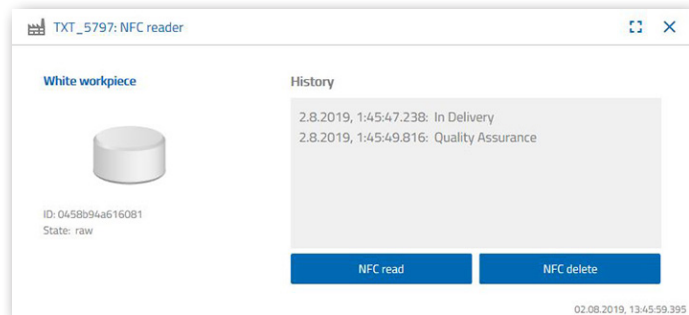
Task 7

Evaluate data from your environmental station. To do this, first show the data in the graph area of the dashboard view. Save the data as a .csv file and use it in a spreadsheet program.

Find data about the brightness environment in your factory.
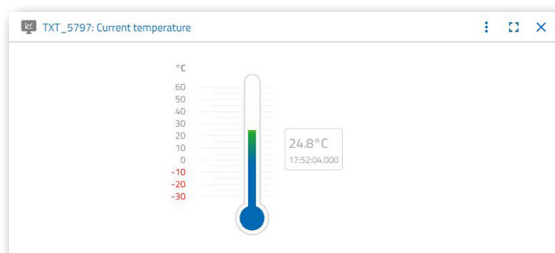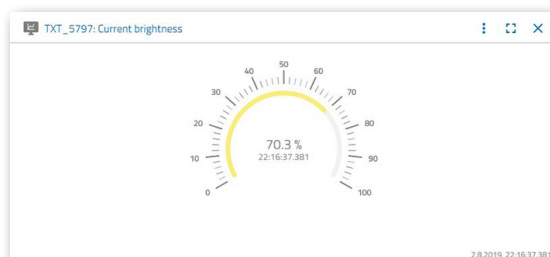
Determine the current temperature data of your factory and process it in a spreadsheet program.

Determine the humidity values over a longer period of time and have them displayed graphically on the dashboard.

![fischertechnik logo]
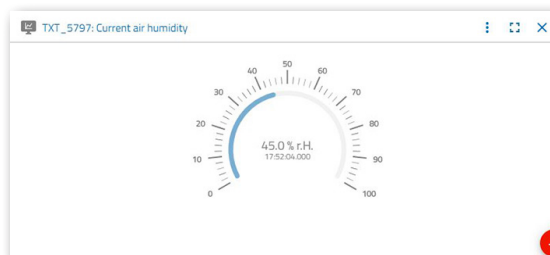
Task 8

Use the built-in camera to monitor your factory. Move the camera around your factory and take 2 pictures of the factory. Save an image for documentation. Delete unnecessary pictures from the gallery.

To move the camera, use the "TXT: Camera control" dashboard window.

The buttons that are important for the task are explained on page 30.

Move the camera around your factory. Move the vertical and horizontal axis of your camera using the "blue arrow keys".
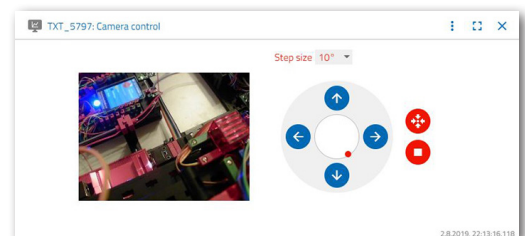
The factory section that the camera is currently recording is also displayed in the "TXT: Camera" dashboard window.

Select three pictures and save them in the "TXT: Gallery" dashboard window. Use the "Take snapshot for the current image" button.
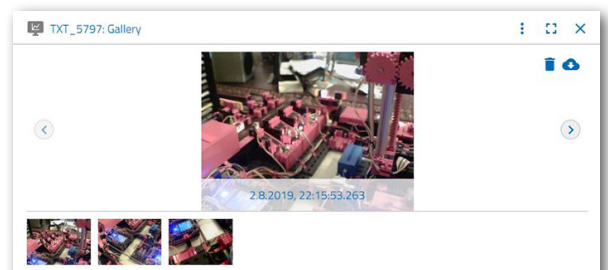
Select 1 picture from the gallery, one that you would like to further process in an image editing program. To do this, click on the "Download" button. A context menu appears in which you specify the storage location and the file name.

Click the "Delete" button to delete unwanted pictures.

Components description

The most important components will be discussed before explaining the individual factory modules.

Actuators

Both encoder motors and fischertechnik-specific mini motors are installed in the individual stations.

Encoder motor:

The encoder motors are permanently excited DC machines that use Hall sensors to measure in incremental angles. The encoder motors operate at a nominal voltage of 9 VDC and have a maximum power of 1.2 W at a speed of 105 RPMs. Power consumption at maximum power is 386 mA. The integrated transmission has a ratio of 21.3:1. That is, the encoder produces three pulses per motor shaft revolution, or 63.9 pulses per revolution of the transmission output shaft. Since only one pulse registers, the encoder used cannot tell which direction the motor is turning.
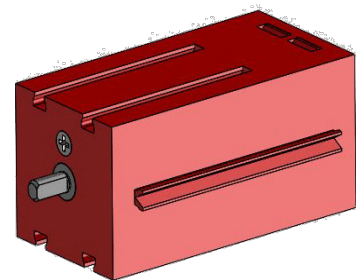
The encoder is connected to the TXT controller via a three-core cable, whose red wire must be connected to a 9V output and its green wire to ground. The black cable transmits the signal (npn open-collector output, max 1kHz) and must be connected to a fast-counting input (C1-C4). A pull-up resistor (4.7-10kΩ) must be used if the encoder signal is not going to be read out using a fischertechnik controller.

Mini motor

A mini-motor drives any conveyor belts or processing machines used in the individual stations. This compact motor is a permanent-magnet DC machine that can be used with an attachable U-transmission. The motor's rated voltage is 9 V and the current consumption is a maximum of 650 mA. This results in a maximum torque of 4.8 mNm and an idling speed of 9500 RPMs. The U-transmission has a ratio of 64.8:1 and a lateral output.
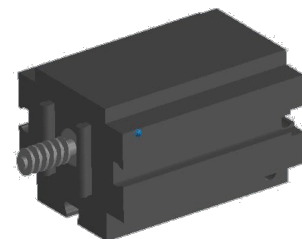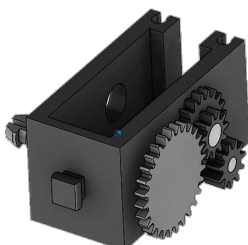
Compressor:
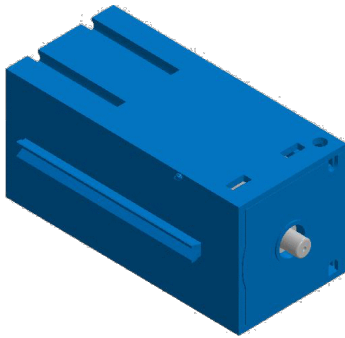
A diaphragm pump if a compressed air source is required at the stations.

Such a diaphragm pump consists of two chambers, which are separated by a membrane (see Figure 1). In one of these two chambers, a piston is moved back and forth by an eccentric, which reduces or increases the volume in the other chamber. When the piston moves to the right, the diaphragm is pulled back, sucking air into the second chamber via the inlet valve. If the piston moves to the left, the diaphragm pushes the air out of the pump head via the outlet valve. The compressor here uses a rated voltage of 9 VDC and generates an overpressure of 0.7 bar. The compressor's maximum current consumption is 200 mA.

Illustration 1
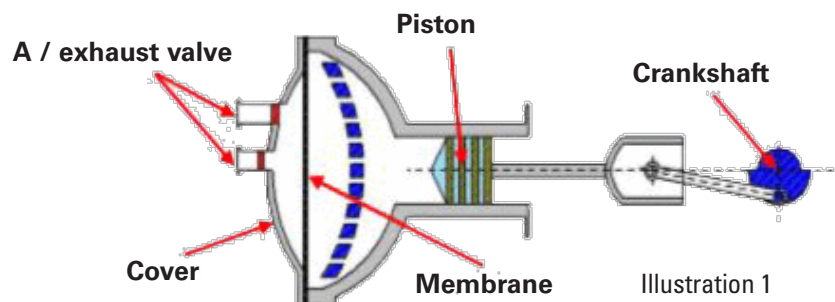
3/2-way solenoid valve:
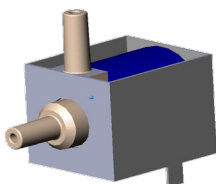
3/2-way solenoid valves are used to control the pneumatic cylinders. These switching valves have three connections and two switching states. A coil (a) that works against a spring (c) carries out the switching operations. When a voltage is applied to the coil, the coil's mounted core (b), which is mounted so that it can slide, moves against the spring and thereby opens the valve due to the Lorentz force. In this case, opening means that the compressed air connection (current designation: 1, old name: P) is connected to the cylinder port (2, formerly A). If this voltage drops, the spring pushes the core back and closes the valve again. In this position, the cylinder port (2, formerly A) is connected to the vent (3, formerly R). The figure shows a schematic representation of the 3/2-way solenoid valve.
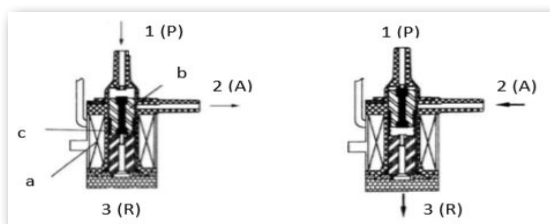
Pneumatic cylinders:

The factory has a total of 5 single-acting cylinders with spring installed. These are controlled by the 3/2-way solenoid valves. A piston divides the volume of the cylinder into two chambers on pneumatic cylinders. A pressure difference between these two chambers results in a force that acts on the piston, thereby displacing it. This shift corresponds to a volume change in both chambers. Installing a return spring saves on a second air connection with 3/2-way valve. When the 3/2-way solenoid valve is opened, the air produced in the compressor flows to port 1 on the cylinder and pushes the piston forward against the spring force. To do this, the piston rod extends forwards. When the solenoid valve closes the air supply, the spring pushes the piston back to the initial position.
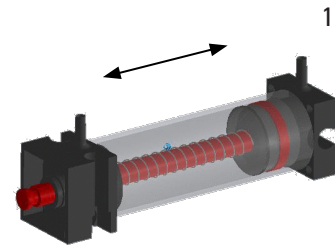
Vacuum cups:

The suction function on the vacuum suction device is achieved by using two pneumatic cylinders which are controlled by means of a 3/2-way solenoid valve. In order to generate a negative pressure, i.e., a pressure which is lower than the ambient pressure, two cylinders are mechanically coupled in the vacuum gripper. If a cylinder is then subjected to overpressure, both piston rods extend, resulting in an increase in volume in the chamber that the suctioner closes. This increase in volume causes a pressure drop in this chamber.
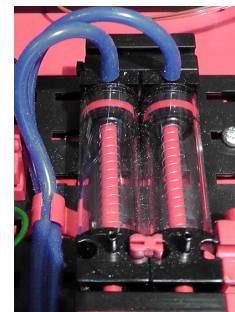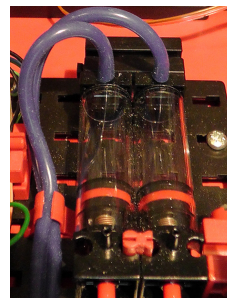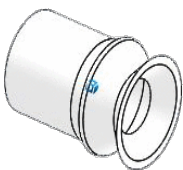
Mini-button:

Mini-pushbuttons are used as reference switches. They are used for position determination using a point-to-point movement, for example, at the turntable. The miniature pushbutton used here is equipped with a changeover contact and can be used both as a normally closed contact and as a make contact. Pressing the button creates a conductive connection between contact 1 and contact 3, whereas the connection between contact 1 and contact 2 is disconnected. The figure shows the schematic circuit diagram of the mini-pushbutton.
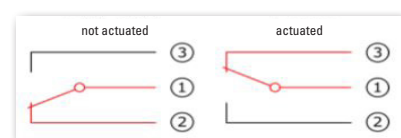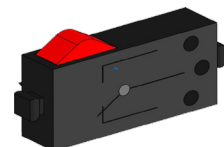
LED

An LED is an electronic component which converts electrical energy into light. The abbreviation LED stems from the English "Light Emitting Diode".

Two different LEDs are installed at the factory.

LED used for generating light in a photoelectric barrier.

This LED's light frequency controls a photo-resistor.
The "+" and "L" identify the module. Another feature is the vitreous body. This bundles the rays, so that the light rays do not scatter, but rather meet in parallel on the photo-transistor.

LED as a lamp

A simple LED is used here. This module has a "+" and "W" (white) imprint. Another feature is the milky-looking lamp cylinder.

Sensors

Photo-transistor
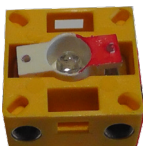
Photo-transistors are electronic components that react to light.
Photo-transistors usually have only two leads out – the collector and the emitter. The base is replaced by the incident light. Light from the LED that hits the photo-transistor switches the current flow. This behaviour can be evaluated programmatically.

Photo-resistor

A photo-resistor is an electronic component whose electrical resistance changes when light strikes it. In many descriptions you will also find the name LDR. This term comes from the English word, "light-dependent resistor".

Important: The photo-resistor has a resistance of 0 -> 1 mohm (in complete darkness). The TXT controller software lets you read a maximum value of 15,000 sensors.

Environment sensor
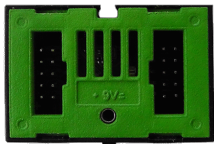
The sensor, which is located on a circuit board in the housing, is used to measure gas, air pressure, humidity and air temperature. The module is connected to the TXT via a ribbon cable.
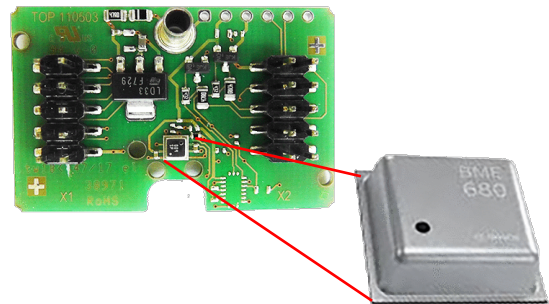
The data is continuously measured and stored in a .csv file that can be opened in Excel, for example. The values can be viewed in the fischertechnik cloud.

These images show part of the environmental station dashboard.
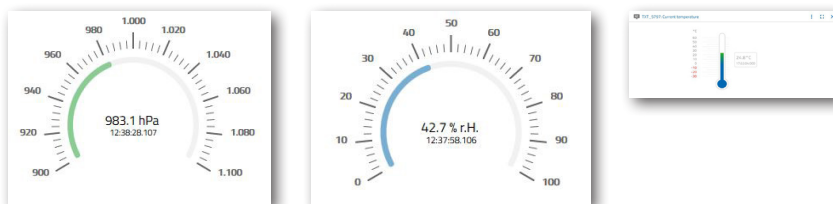
Colour sensor

Colour sensors are often used in automation technology. For example, the colour or a colour print should be checked to make sure that the right components are installed. The fischertechnik colour sensor emits white light, which different colour surfaces reflect to different degrees. The photo-transistor measures the intensity of the reflected light and measures output as a voltage value ranging between 0 V and 9 V. The measured value depends on the ambient brightness as well as the distance of the sensor from the coloured surface. The connection is made via three cables. The red cable is connected to the 9V output on the TXT controller, the green cable to ground and the black cable is connected to a universal input. In this software, this measured value is output as a numerical value between 0 and 9,000.
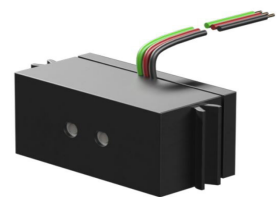
TXT controller

The complete performance data for the TXT controller can be viewed at https://www.fischertechnik.de/en/simulating. Here are the most important features:

- Dual processor: ARM Cortex A8 (32-bit / 600MHz) + Cortex M3
- Storage capacity: 256 MB DDR3 RAM, 128 MB Flash
- Storage extension: Micro SD card slot
- Display: colour 2.4-inch touch display (320x240 pixels) 8 universal inputs: Digital / analogue 0-9VDC, analogue 0-5 kΩ
- Display: colour 2.4-inch touch display (320x240 pixels)
- 4 quick counter inputs: digital, frequency up to 1 kHz
- 4 motor outputs 9 V / 250 mA (maximum: 800 mA): infinitely variable speed, short-circuit-proof, alternatively 8 individual outputs, e.g., for lamps
- Combined Bluetooth / WiFi wireless module: BT 2.1 EDR+ 4.0, WiFi 802.11 b / g / n
- Infrared receiver diode
- USB 2.0 client: Mini USB port for connection with the PC
- USB Host port: USB-A port for fischertechnik USB camera, USB sticks, etc.
- Camera interface: via USB host, Linux camera drivers integrated in the operating system
- 10-pole pin row to increase inputs and outputs as well as I2C-port
- Integrated loudspeaker
- Integrated real-time clock with replaceable buffer battery for recording the measured values in a defined period
- Linux based open-source operating system
- Programming possible with ROBO Pro, C-Compiler, PC-Library, etc.
- Power supply: 9V DC 3.45 mm port, or fischertechnik 2.5 mm ports

Nano router TP-link

The connection to the fischertechnik cloud is established via the WiFi router supplied and integrated into the learning factory. We recommend using Chrome or Firefox web browsers.

The cloud can be used via personal access, which is created once (www.fischertechnik-cloud.com). The cloud servers are located in Germany and ensure that strict European requirements regarding the storage of data are enforced.

Personal data is protected in an account with password access that uses the extremely secure "OAuth2" industry standard. All data sent to the cloud is transmitted encrypted with certificates (https standard, green lock in web browser).

NFC-Tags NTAG213 22mm

Each workpiece has its own unique ID and displays the following data: Status, colour and time stamp from delivery to dispatch. This information is saved on the tags. The tags are integrated into the workpiece, which lets them be used directly.
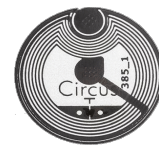
PN532 V3 NFC-reader

This component describes and reads out the NFC-tags. The production view on the NFC / RFID reader displays the workpiece data and can be used to read or delete workpieces manually. The raw data of the NFC tags can be read using a standard NFC app from mobile devices with NFC readers. The NFC-reader is connected to an I²C interface and a 3.3 V power supply at the EXT connection on the TXT controller.
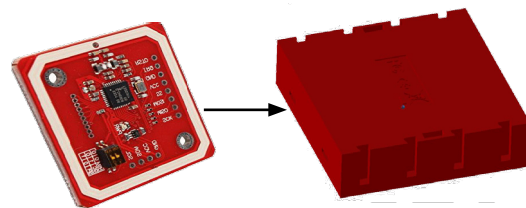
Joystick KY-023

A joystick is an input device used on computers, especially in the computer gaming industry. Individual models can be finely calibrated using the joysticks that are installed in the factor model. There are two kinds of functions: digital and analog. The digital function uses four contacts to record the joysticks orientation.
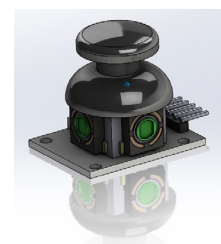
These are mostly micro-switches. Only digital signals can be processed using this technique.

The second variant, which uses analog values, has two built-in potentiometers that generate these values. The read-in values are converted into digital signals in the joystick itself or in the controller.

Assignment plans

Assignment plan for the vacuum suction gripper
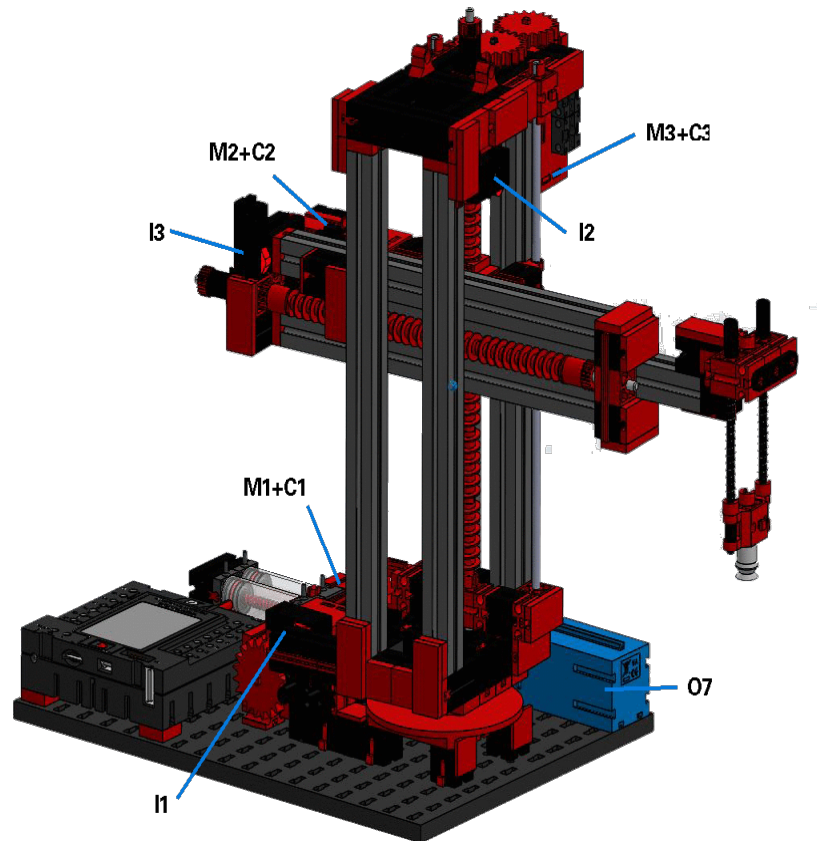
Not shown: O8

Master

TXT-Controller 3

Number	Function	Input / output
1	Turn reference switch	I1
2	Vertical reference switch	I2
3	Horizontal reference switch	I3
4	Photo-transistor - DPS	I7
5	Colour sensor – DPS	I8
6	Turn encoder	C1
7	Encoder vertical axis	C2
8	Encoder horizontal axis	C3
9	Photo-transistor - DPS	C4
10	Turn motor	M1
11	Vertical motor	M2
12	Horizontal motor	M3
13	Compressor	O7
14	Valve	O8

Assignment plan for the automated high-bay warehouse
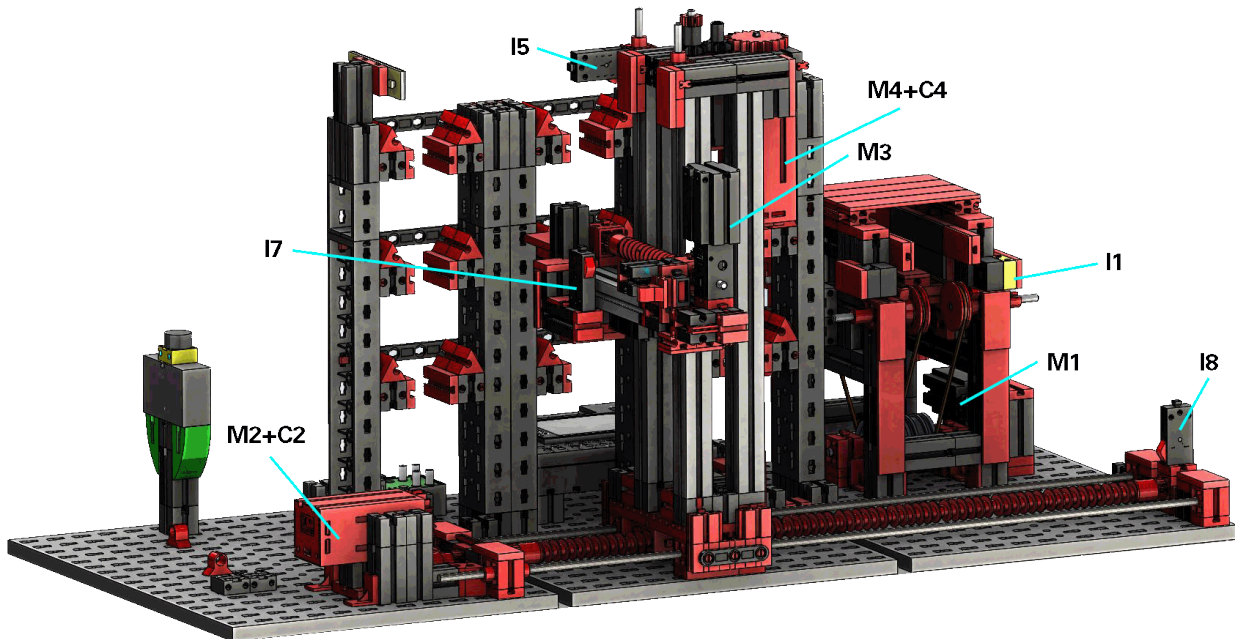
Not shown; 14 and 16

Number	Function	Input / output
1	Photo-transistor external	I1
2	Photo-transistor internal	I4
3	Reference pushbutton horizontal	I5
4	Reference pushbutton probe arm rear	I6
5	Reference pushbutton probe arm front	I7
6	Reference pushbutton vertical	I8
7	Encoder horizontal	C2
8	Encoder vertical	C4
9	Motor conveyor belt	M1
10	Horizontal motor	M2
11	Motor probe arm	M3
12	Vertical motor	M4

Master

TXT-Controller 2

Assignment plan for the multi-processing station with kiln
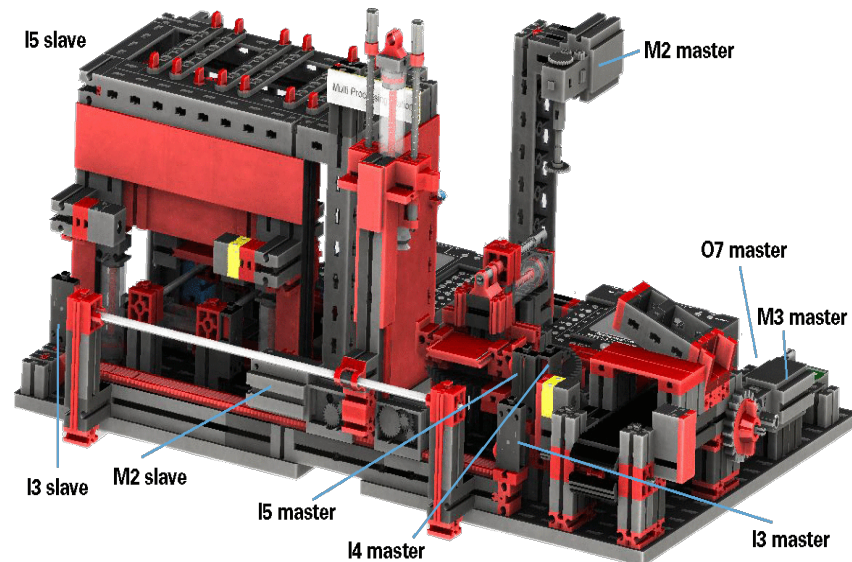
Not shown:
master: I1, I2, M1, O8
slave: I1, I2, M1, O5, O6, O7, O8

Master

TXT-Controller 1

Slave

TXT-Controller 1

Number	Function	Input / output
1	Reference switch turntable (suction position)	I1 (master)
2	Reference switch turntable (saw position)	I2 (master)
3	Reference switch turntable (conveyor belt position)	I3 (master)
4	Photo-transistor and conveyor belt	I4 (master)
5	Reference switch suction (turntable position)	I5 (master)
6	Motor turntable	M1 (master)
7	Motor saw	M2 (master)
8	Motor conveyor belt	M3 (master)
9	Valve ejection	O7 (master)
10	Compressor	O8 (master)
11	Reference switch kiln slider retracted	I1 (slave)
12	Reference switch kiln slider extended	I2 (slave)
13	Reference switch suction (kiln position)	I3 (slave)
14	Photo-transistor	I5 (slave)
15	Motor kiln slider	M1 (slave)
16	Motor suction	M2 (slave)
17	Valve vacuum	O5 (slave)
18	Valve lowering	O6 (slave)
19	Valve kiln door	O7 (slave)
20	Lamp kiln	O8 (slave)

Assignment plan for the sorting line using colour recognition
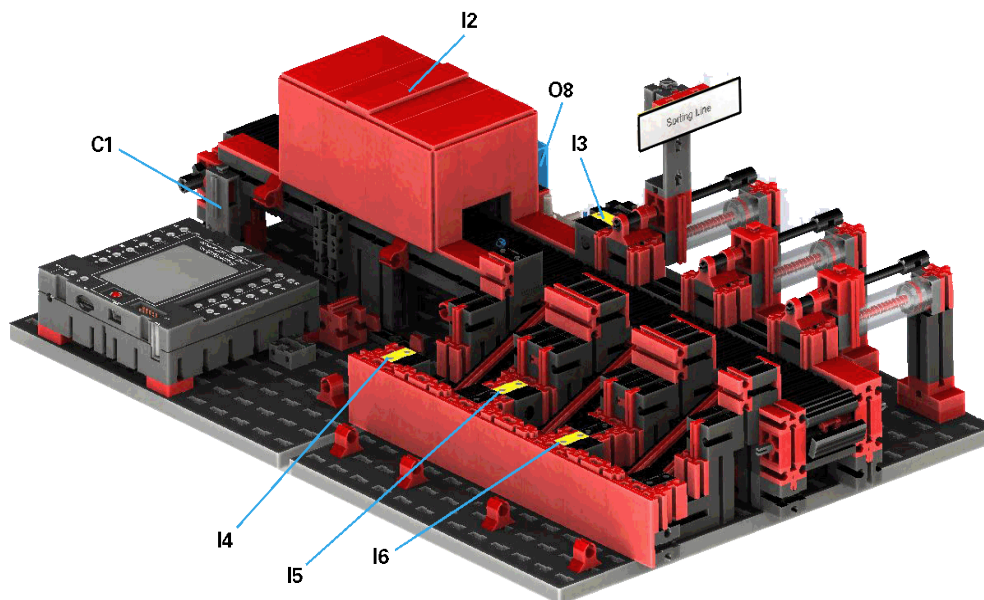
Not shown: M1, O5, O6, O7, I1

Number	Function	Input / output
1	Photo-transistor colour sensor	I1
2	Colour sensor	I2
3	Photo-transistor ejection	I3
4	Photo-transistor white	I4
5	Photo-transistor red	I5
6	Photo-transistor blue	I6
7	Pulse key	C1
8	Motor conveyor belt	M1
9	Valve ejection white	O5
10	Valve ejection white	O6
11	Valve ejection white	O7
12	Compressor	O8

Master

TXT-Controller 4

Assignment plan for the environmental station with surveillance camera
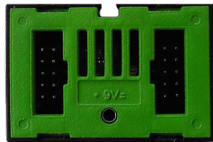
Environment sensor

Photo-resistor
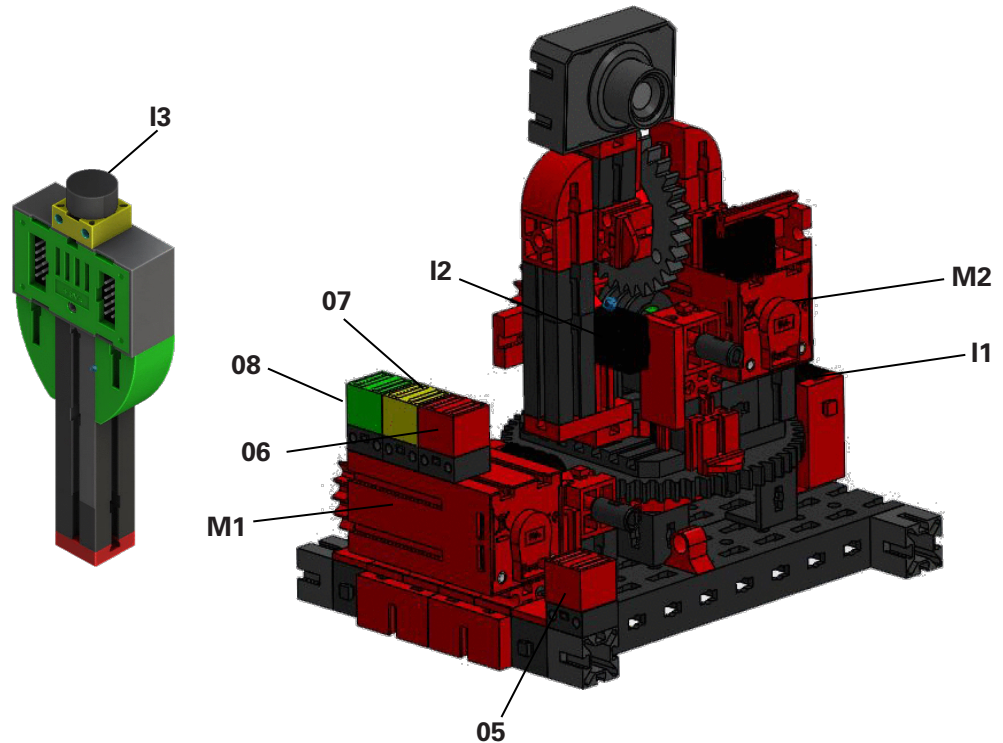
Master

TXT-Controller 0

Number	Function	Input / output
1	Turn reference switch camera	I1
2	Reference switch camera raise / lower	I2
3	Photo-transistor	I3
4	Joystick X front	I5
5	Joystick Y front	I6
6	Joystick X back	I7
7	Joystick Y back	I8
8	Turn encoder	C1
9	Encoder raise / lower	C2
10	Joystick B front	C3
11	Joystick B back	C4
12	Turn motor	M1
13	Motor raise / lower	M2
14	LED camera red	05
15	LED red	06
16	LED yellow	07
17	LED green	08

Assignment plan for the in-output station using colour recognition, NFC reader and calibration station

Controllers TXT 0 and TXT 3 are used in the system for the input / output station connections and the calibration station.

The NFC reader is connected to the TXT 5 controller via the I²C interface.
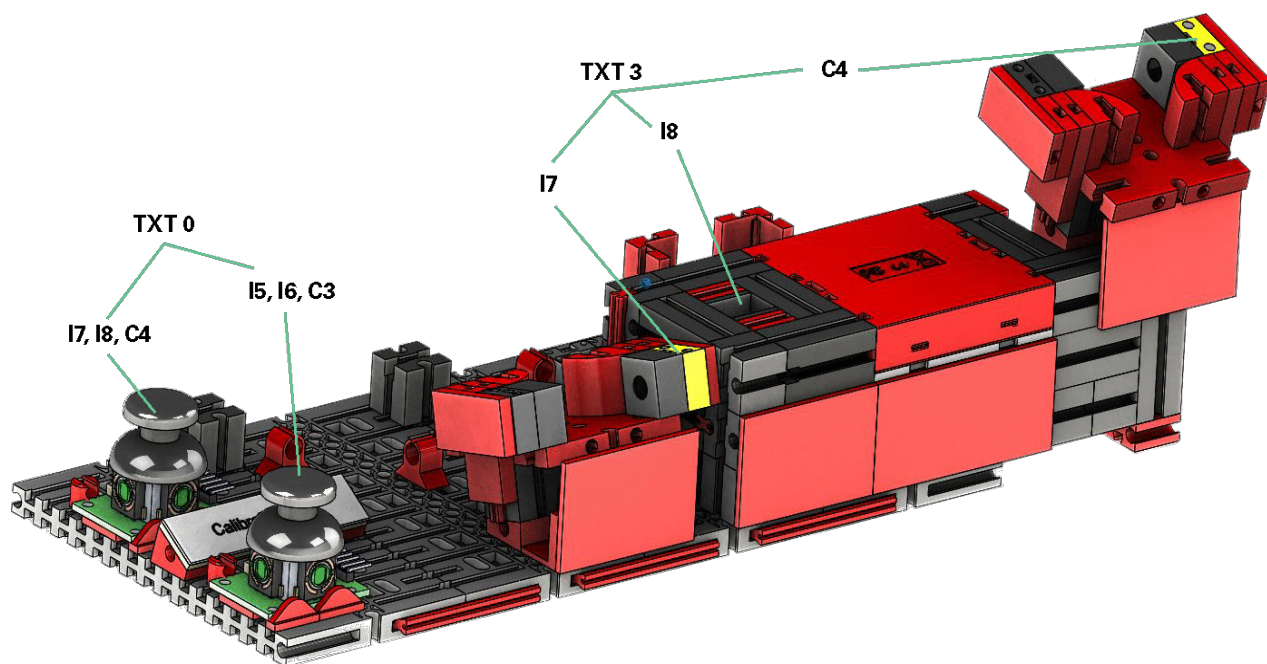
Calibration

Calibrating the high-bay warehouse or vacuum suction gripper

It may happen (for example during transport of the system) that a position in the high-bay warehouse or in the vacuum suction gripper will not start properly. With the calibration unit you can eliminate these errors and adjust the positions in your system.
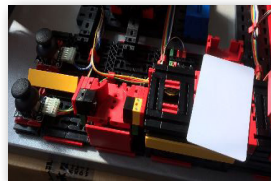
Note: Green LED must be lit to start calibration. To start the calibration mode, place the supplied "white calibration card" on the NFC reader. This card has an NFC tag that allows the system to go into calibration mode.
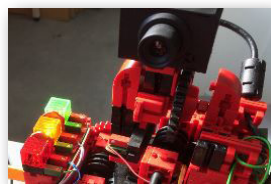

The status display shows when the system is ready for calibration. You can tell by the fact that all 3 lights, or all 3 LEDs – red, yellow, green – light up at the sensor station at the same time. If this happens, you can remove the card.

Next, decide whether to calibrate the high-bay warehouse or the vacuum suction gripper.

Module selection

To do this, move the "J1" joystick once to the left, direction A, to calibrate the high-bay warehouse or to the right, direction B, to calibrate the vacuum suction gripper.
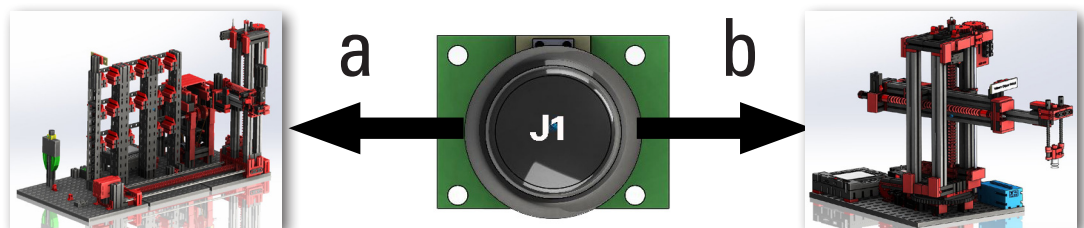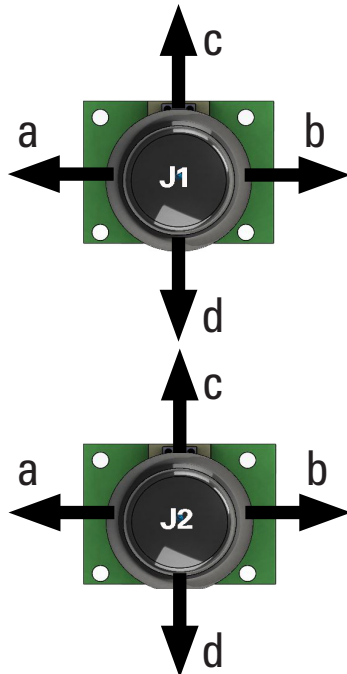

Once you have made a selection, you can use the two J1 and J2 joysticks to start the various positions up and correct them.
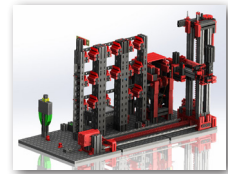
Calibration

The two following tables show the effect of the joystick movements on the factory models.
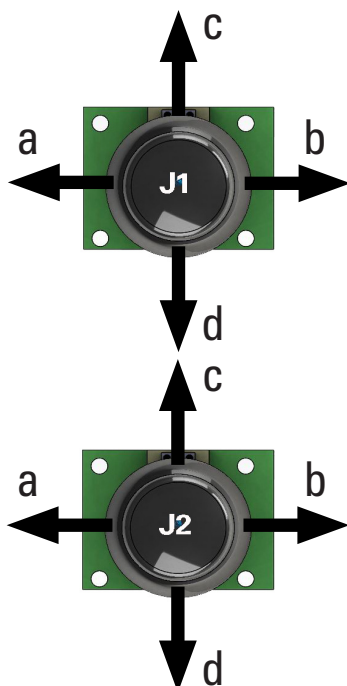
High-bay warehouse

Direction	Joystick J1
a	Return to previous position
b	Go to previous position
c	No function
d	No function
Press button	Cancel calibration

Direction	Joystick J2
a	Stacker crane downwards
b	Stacker crane upwards
c	Stacker crane to the right (X axis +)
d	Stacker crane to the left (X axis -)
Press button	Save position and move to corrected position

Important: Only 3 of the 9 bin locations are calibrated for high-bay warehouses. The other 6 positions of the storage bins are automatically calculated from them.

Vacuum suction gripper

Direction	Joystick J1
a	Return to previous position
b	Go to previous position
c	Move arm upwards
d	Move arm downwards
Press button	Cancel calibration

Direction	Joystick J2
a	Move arm to the left (counter-clockwise)
b	Move arm to the right (clockwise)
c	Move arm forwards
d	Move arm backwards
Press button	Save position and move to corrected position

Each time the corresponding joystick is pressed, the axis moves a small distance around a precisely defined number of pulses.

Save

Press joystick J2 to save any changes you have made.

The model then automatically moves to the corrected position.

End calibration

Press joystick J1 to end system calibration.

After completing the calibration, only the green LED lights up again – the learning factory is ready for use again.