MiR
A BETTER WAY

Technical Guide (en)

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MiR 250

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1. About this document

This document describes the components, sub-systems, and connections in the MiR250 robot, providing an overview of how the robot works.

This guide is intended to be used to provide additional information regarding how MiR250 robots and their key components work. The guide focuses mainly on providing information that may be used for troubleshooting the robot.

2. Robot sub-systems

The following sections describe these robot sub-systems:

- **The navigation and control system** determines the path the robot should follow to reach its goal destination.
- **The safety system** monitors the robot's components and surroundings through several functions and brings the robot to a stop if an unsafe situation occurs.
- **The motor and brake system** is part of the two previous systems and is used to either move the robot along its path or to bring the robot to a stop.

2.1 Navigation and control system

The navigation and control system is responsible for driving the robot to a goal position while avoiding obstacles.

System overview

The purpose of the navigation and control system is to guide the robot from one position on a map to another position. The user provides the map and chooses the goal position the robot must move to. The diagram in *Figure 2.1* describes the processes in the navigation and control system. The main processes involved in the navigation system are:

- **Global planner**
  The navigation process starts with the global planner determining the best path for the robot to get from its current position to the goal position. It plans the route to avoid walls and structures on the map.
- **Local planner**
  While the robot is following the path made by the global planner, the local planner continuously guides the robot around detected obstacles that are not included on the map.
- **Obstacle detection**
  The safety laser scanners, 3D cameras, and proximity sensors are used to detect obstacles in the work environment. These are used to prevent the robot from colliding with obstacles.
- **Localization**
  This process determines the robot's current position on the map based on input from the motor encoders, inertial measurement unit (IMU), and safety laser scanners.

- **Motor controller, motors, and brakes**
  The motor controller determines how much power each motor must receive to drive the robot along the intended path safely. Once the robot reaches the goal position, the brakes are engaged to stop the robot.

Each part of the process is described in greater detail in the following sections.

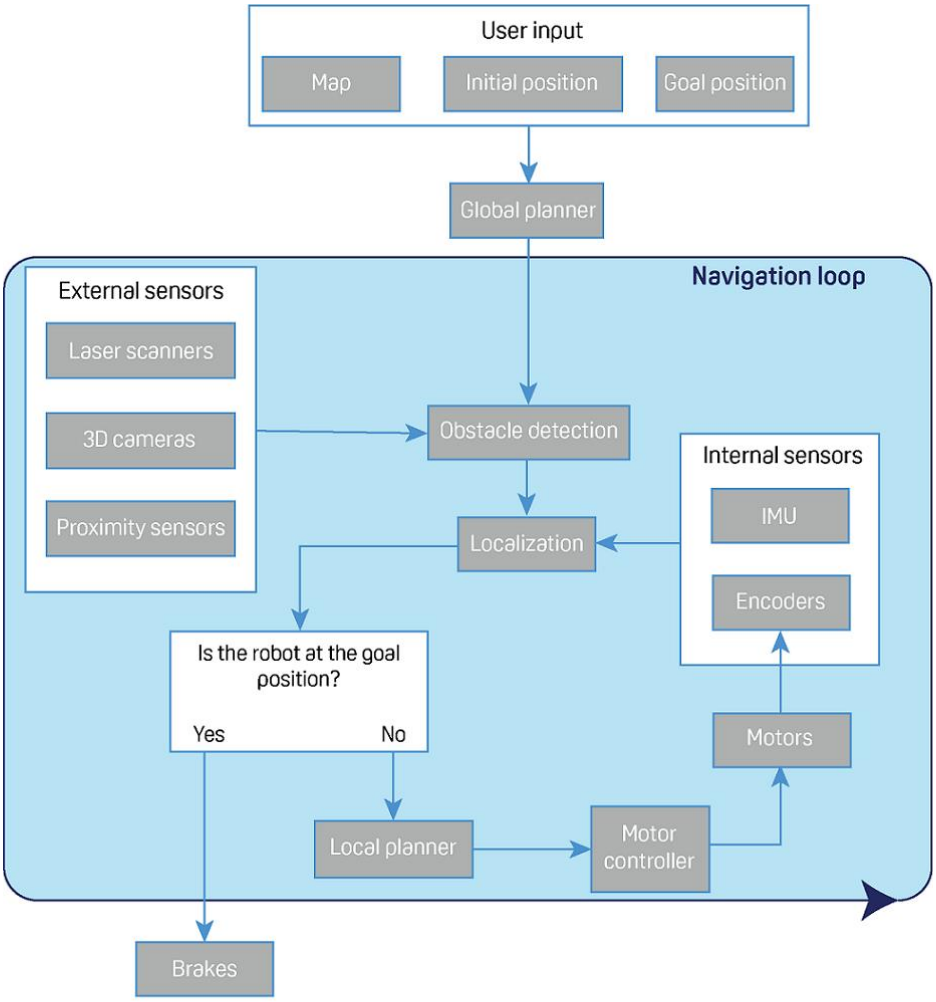


Figure 2.1. Flow chart of the navigation and robot system. The user provides the necessary input for the robot to generate a path to the goal position. The robot executes the steps in the navigation loop until it reaches the goal position and stops by engaging the brakes.

User input

To enable the robot to navigate autonomously, you must provide the following:

- A map of the area, either from a .png file or created with the robot using the mapping function.
- A goal destination on that map.
- The current position of the robot on the map. This usually only needs to be provided when a new map is activated.

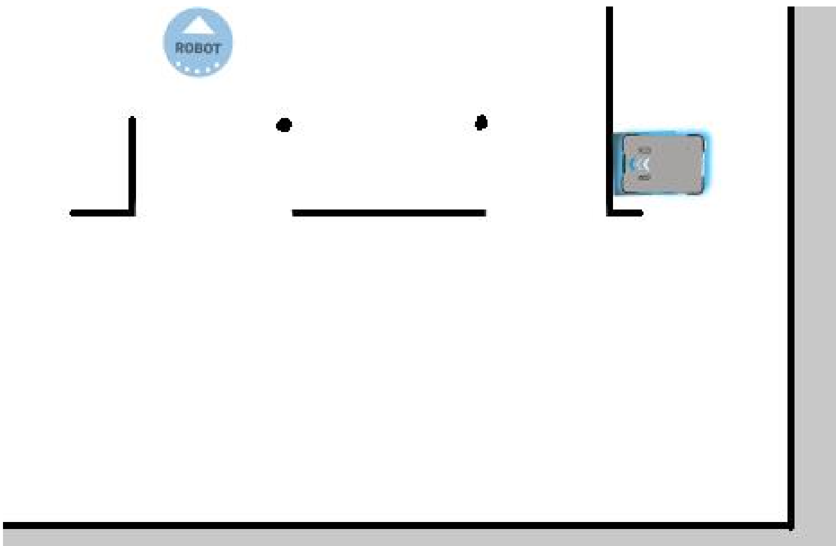


Figure 2.2. On the map, the current position of the robot is identified by the robot icon, and the goal destination is the robot position in this example. The robot computer now determines a path from the current position to the goal position.

Once the robot computer has a map with the robot's current position and a goal destination, it begins planning a route between the two positions on the map using the global planner.

Global planner

The global planner is an algorithm in the robot computer that generates a path to the goal position. This path is known as the global path.

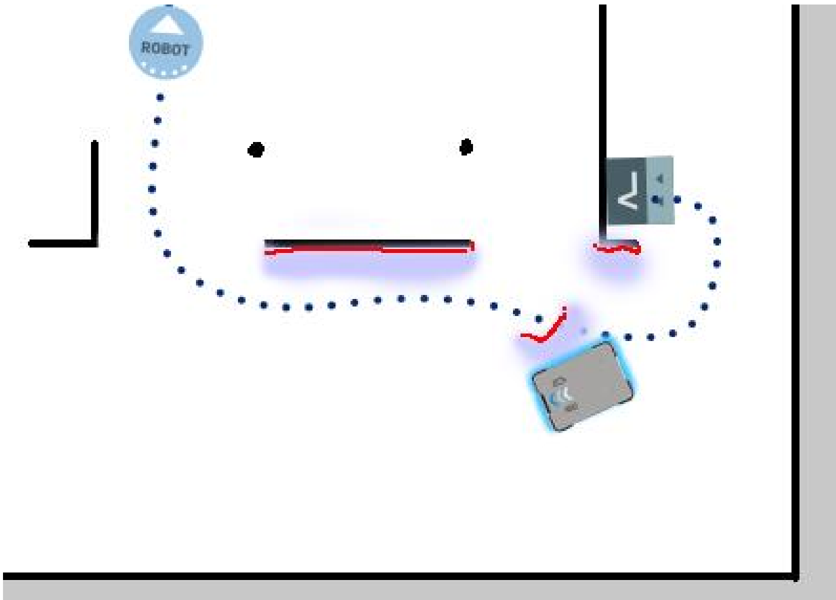


Figure 2.3. The global path is shown with the blue dotted line that leads from the start to the goal position.

The global path is created only at the start of a move action or if the robot has failed to reach the goal position and needs to create a new path. The generated path only avoids the obstacles the robot detected when the path was made and the obstacles marked on the map. The global path can be seen in the robot interface as a dotted line from the robot's start position to the goal position.

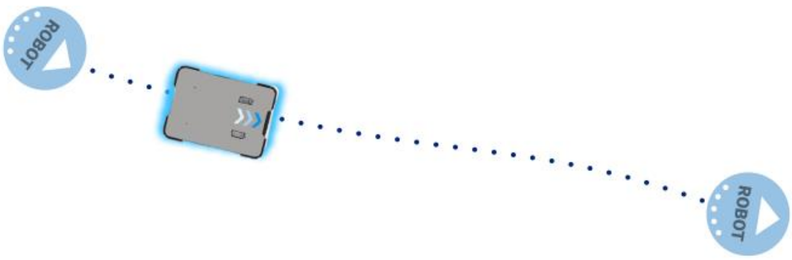


Figure 2.4. The dotted line from the start position of the robot to the goal position is the global path generated by the robot computer.

Local planner

The local planner is used continuously while the robot is driving to guide it around obstacles while still following the global path.

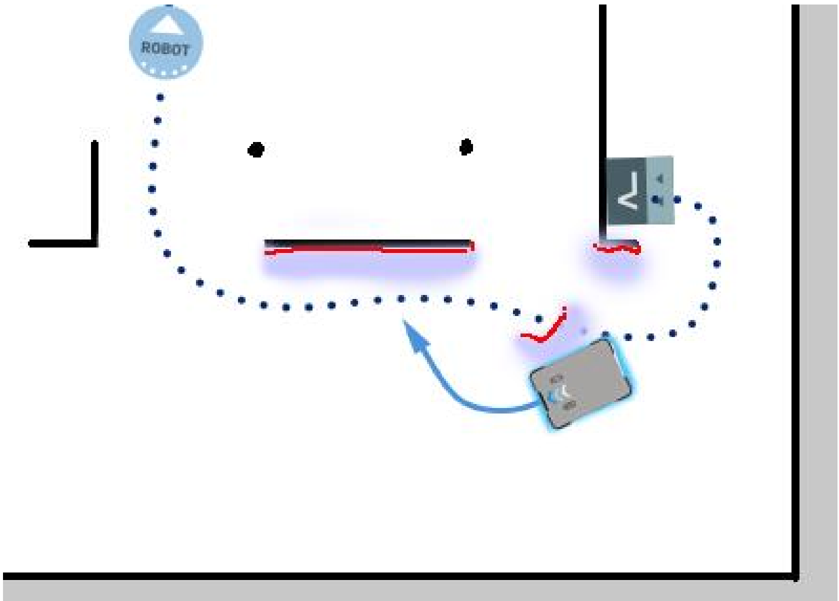


Figure 2.5. The global path is indicated with the dotted blue line. The local path is indicated with the blue arrow, showing the robot driving around a dynamic obstacle.

Whereas the global planner creates a single path from start to finish, the local planner continues to create new paths that adapt to the current position of the robot and the obstacles around it. The local planner only processes the area that is immediately surrounding the robot, using input from the robot sensors to avoid obstacles.

The local path is not displayed in the robot interfaces. The arrows in the images here are visual aid used in this guide only.

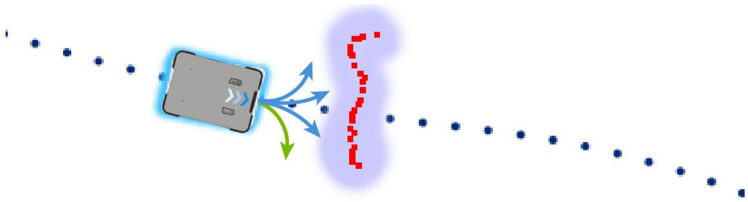


Figure 2.6. The local planner usually follows the global planner, but as soon as an obstacle gets in the way, the local planner determines which immediate path will get the robot around the obstacle. In this case, it will likely choose the path indicated with a green arrow.

Once the local path is determined, the robot computer derives the desired rotational velocity of each drive wheel to make the robot follow the local path, and sends the desired velocities for each motor to the motor controllers—see Motor controller and motors on page 19.

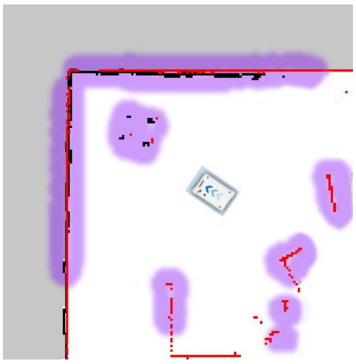
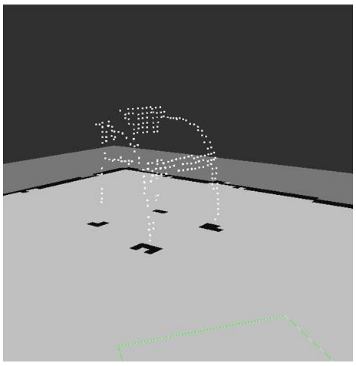
Obstacle detection

The robot detects obstacles continuously while driving. This enables the robot to use the local planner to drive around obstacles and to determine the robot's current position on the map.

Three sensor types are responsible for detecting obstacles:

- The safety laser scanners
- The 3D cameras
- The proximity sensors

The following illustrations show how the robot sees the surrounding environment and how it is portrayed in the robot interface.

What a human sees	What the laser scanners see	What the 3D cameras see
		
A chair placed in the corner of a room is detectable by the robot.	In the robot interface, the red lines on a map are obstacles detected by the laser scanners, and the purple clouds are an aggregate of the 3D camera and laser scanner data. The scanners only detect the four legs of the chair.	The 3D cameras detect more details of the chair when the robot gets close enough to it. This view cannot be seen in the robot interface.

Safety laser scanners

The safety laser scanners on MiR250 are of the type AOPDDR (active opto-electronic protective device responsive to diffuse reflection). AOPDDR is a protective device that uses opto-electronic transmission and reception elements to detect the reflection of the optical radiation generated by the protective device. The reflection is generated by an object in a defined two-dimensional area. This is a type of ESPE (electro-sensitive protective device). In this guide, the term safety laser scanner is used.

Two safety laser scanners, diagonally placed on front and rear corners of the robot, scan their surroundings. Each safety laser scanner has a 270° field of view, overlapping and thus providing a full 360° visual protection around the robot.

When in motion, the safety laser scanners continuously scan the surroundings to detect objects.

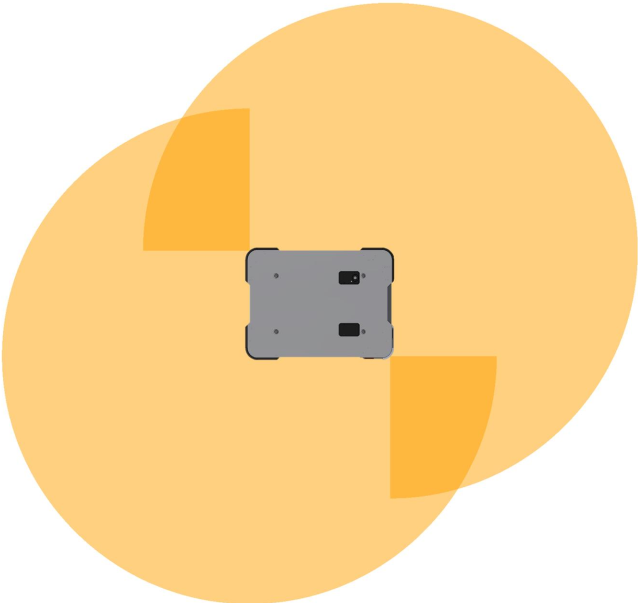


Figure 2.7. The two safety laser scanners together provide a full 360° view around the robot.

The laser scanners have the following limitations:

- They can only detect objects that intersect a plane at 200 mm height from the floor.
- They do not detect transparent obstacles well.
- The scanner data can be inaccurate when detecting reflective obstacles.
- The laser scanners may detect phantom obstacles if they are exposed to strong direct light.

If you are using the robot in an area with walls made of glass or reflective material, mark the walls as Forbidden zones on the map and not as a walls. Walls in the map that the robot cannot detect will confuse the robot's navigation system.

3D cameras

Two 3D cameras positioned on the front of the robot detect objects in front of the robot. The 3D cameras detect objects:

- Vertically up to 1800 mm at a distance of 1200 mm in front of the robot.
- Horizontally in an angle of 114° and 250 mm to the first view of ground.

The 3D cameras are only used for navigation. They are not part of the robot's safety system.

The camera readouts are used as 3D point cloud data. They are not recording recognizable objects or people.

Figure 2.8 shows the field of view of the cameras.

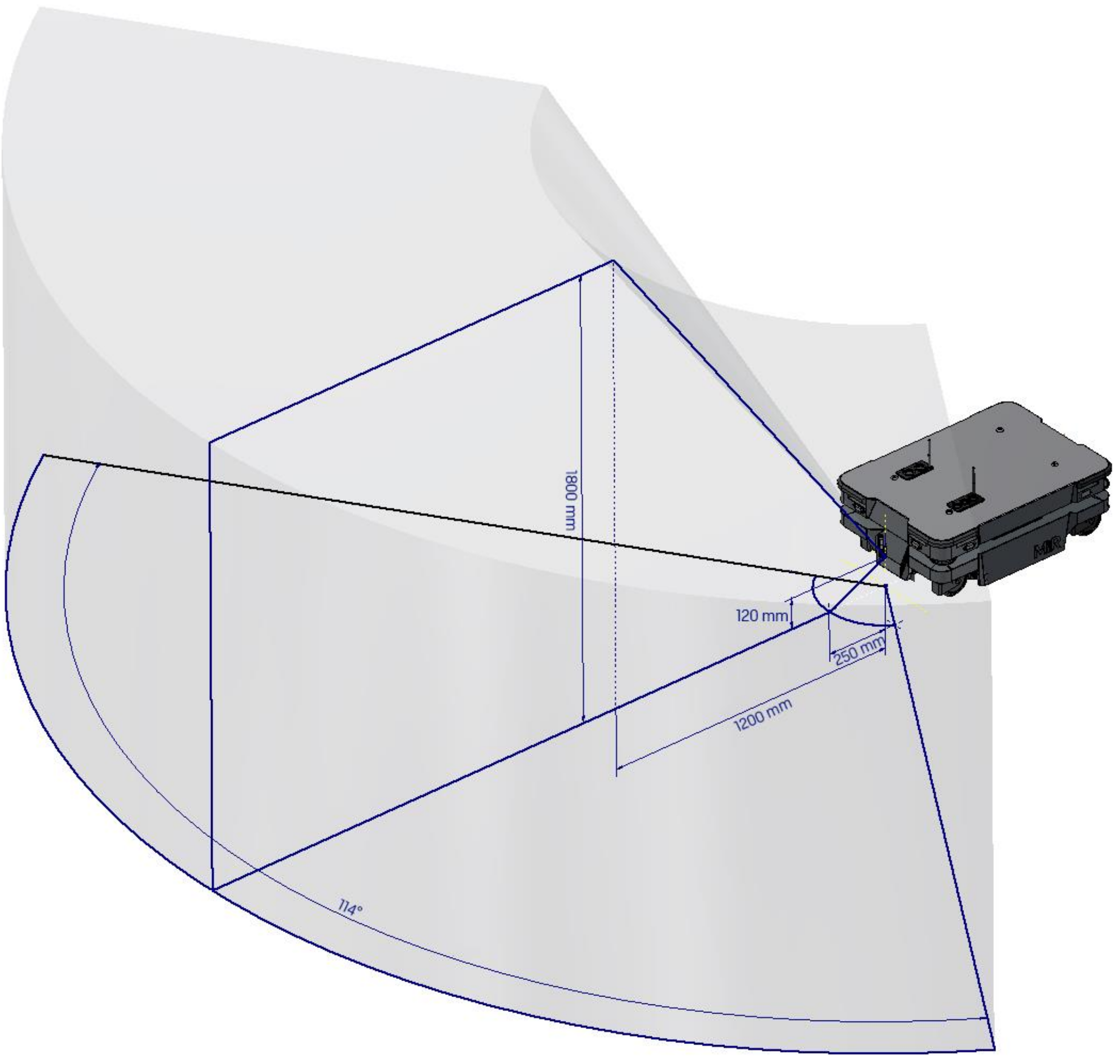


Figure 2.8. The two 3D cameras can see objects up to 1800 mm above floor height at a distance of 1200 mm in front of the robot and have a horizontal field of view of 114°.

The 3D cameras have the following limitations:

- They can only detect objects in front of the robot, unlike the full 360° view of the laser scanners.
- They do not detect transparent or reflective obstacles well.
- They do not detect holes or decending stairways.
- The cameras are not reliable at determining depth when viewing structures with

repetitive patterns.

- The cameras may detect phantom obstacles if they are exposed to strong direct light.

Proximity sensors

Proximity sensors placed in all four corners of the robot detect objects close to the floor that cannot be detected by the safety laser scanners.

Using infrared light, the proximity sensors point downwards and make sure that the robot does not run into low objects, such as pallets and forklift forks. They have a range between 5-20 cm around the robot.

Because of the proximity sensor's limited range, the data from them is only useful when the robot is standing still or moving at reduced speeds, for example, when the robot it pivoting or docking.

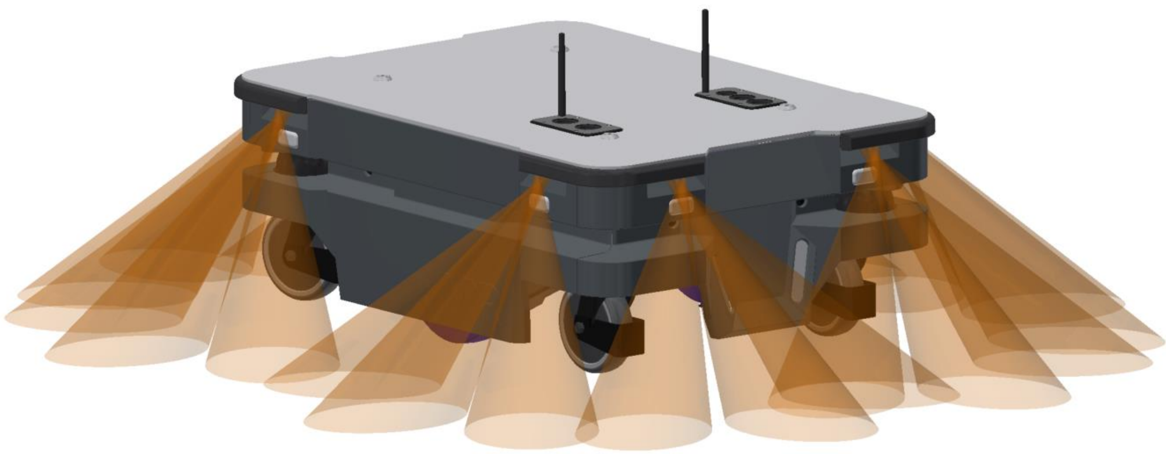


Figure 2.9. The proximity sensors in the corners of the robot detect objects below the safety laser scanners plane of view.

The proximity sensors have the following limitations:

- They do not have a long range and are mainly used to detect obstacles missed by the laser scanners and cameras.
- When the robot is driving fast, obstacles detected by the proximity sensors are too close for the robot to stop for or avoid them.

Localization

The goal of the localization process is for the robot to determine where it is currently located on its map. The robot has three inputs for determining where it is:

- The initial position of the robot. This is used as a reference point for the methods used to determine the robot position.
- The IMU and encoder data. This is used to determine how far and fast the robot has traveled from the initial position.
- The laser scanner data. This is used to determine the likely positions of the robot by comparing the data with nearby walls on the map.

This data is used by a particle filter to determine the most likely position of the robot on the map.

IMU and motor encoders

Both the data from the IMU (Inertial Measurement Unit) and motor encoders is used to derive where and how fast the robot has traveled over time from its initial position. The combination of both sets of data makes the derived position more accurate.

The IMU measures the acceleration and pivot speed of the robot. From this, the robot can derive the distance the robot has driven and how much it has turned.

The motor encoders measure how many times the motor of each drive wheel has rotated. With each rotation of the motor, the robot has driven forward the same length of the circumference of the drive wheel. Measuring it from both encoders also enables the robot to determine when it is turning.

If the drive wheels are worn down significantly or the robot is running with an incorrect gear ratio, the robot will miscalculate how far it has traveled based on the encoder data.

Laser scanners and particle filtering

The robot computer compares the input from the laser scanners with the walls on the map to try to find the best match. This is done using a particle filter algorithm. The robot computer only compares with the area where it expects the robot to be based on the encoder and IMU data. This means it is important that the initial position of the robot is correct.

The robot computer uses the comparison and the odometry data from the encoders and IMU to produce a number of points where the robot is most likely to be. As the robot moves and the sensors collect another set of data, the robot computes another set of likely positions based on new data and the previous data. This process is known as particle filtering.

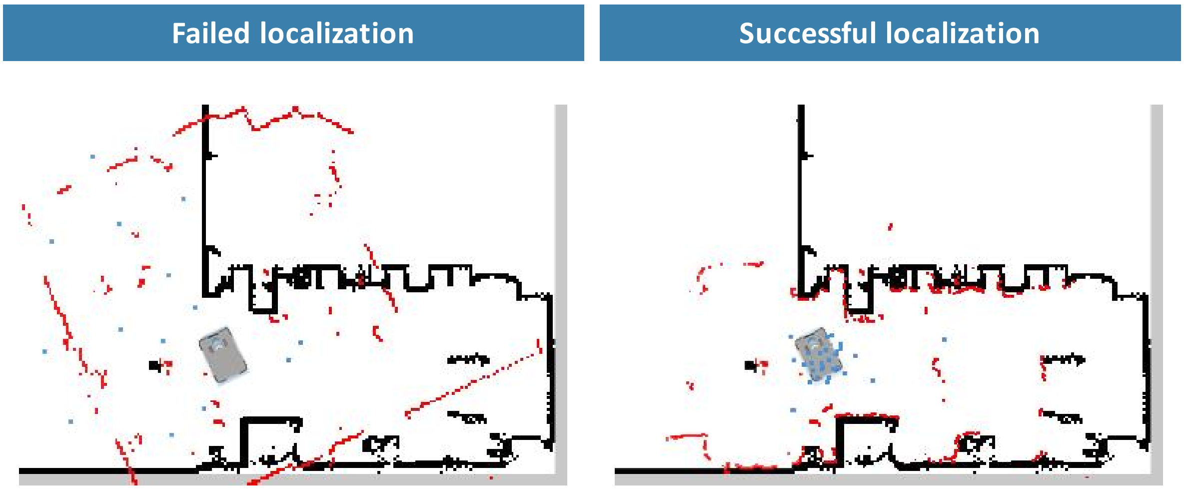
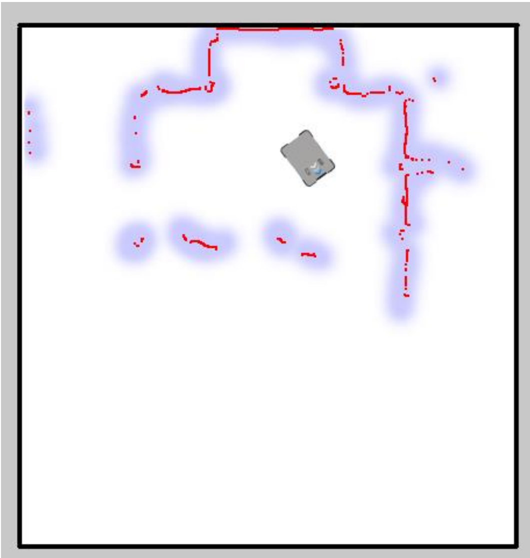


Figure 2.10. In a failed localization, the robot cannot determine a position where the red lines (laser scanner data) align with the black lines on the map. When the robot can localize itself, it determines a cluster of likely positions, indicated in the images above as blue dots.

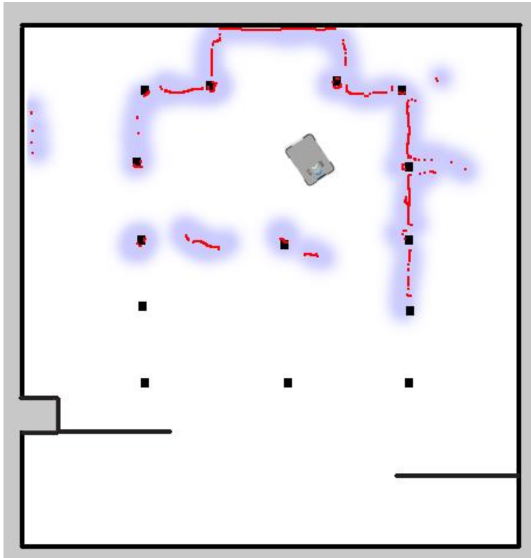
To make sure the robot can localize itself well using particle filtering, consider the following when creating a map:

- There must be unique and distinguishable static landmarks on the map that are easily recognizable. A landmark is a permanent structure that the robot can use to orient itself, such as corners, doorways, columns, and shelves.

No distinguishable landmarks

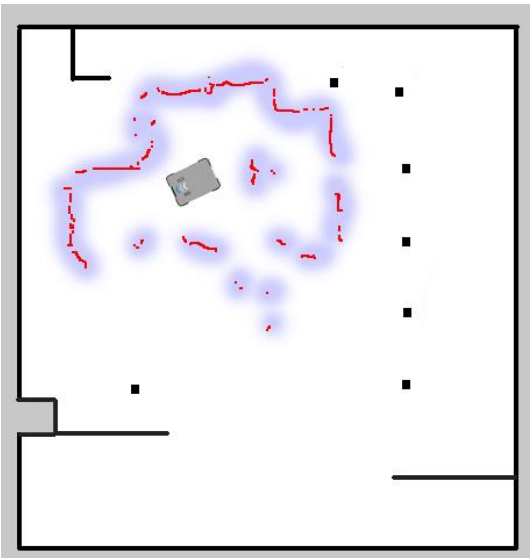


Many distinguishing landmarks

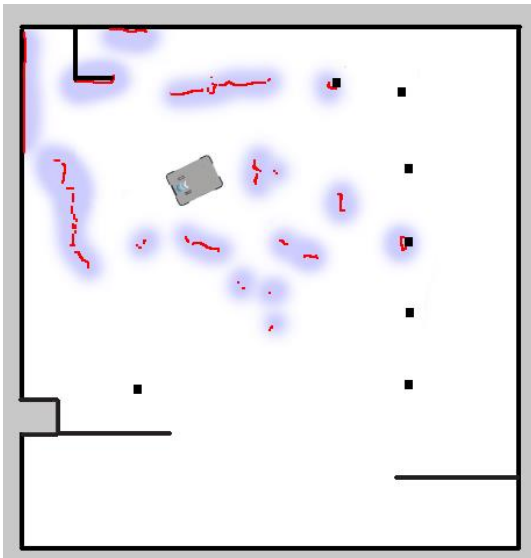


- The robot must be able to detect the static landmarks that are marked on the map to be able to approximate its current position. Make sure there are not too many dynamic obstacles around the robot so that it cannot detect any static landmarks.

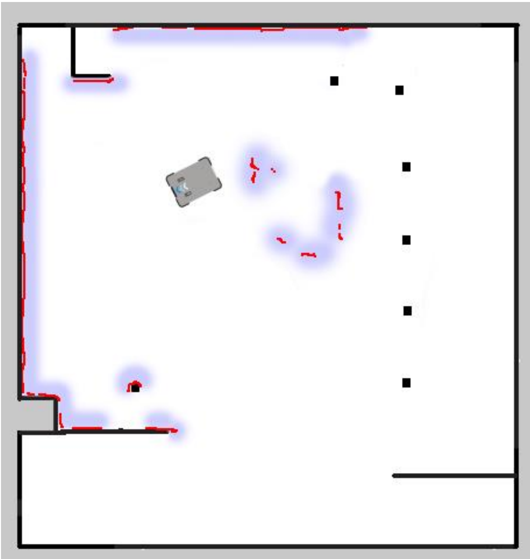
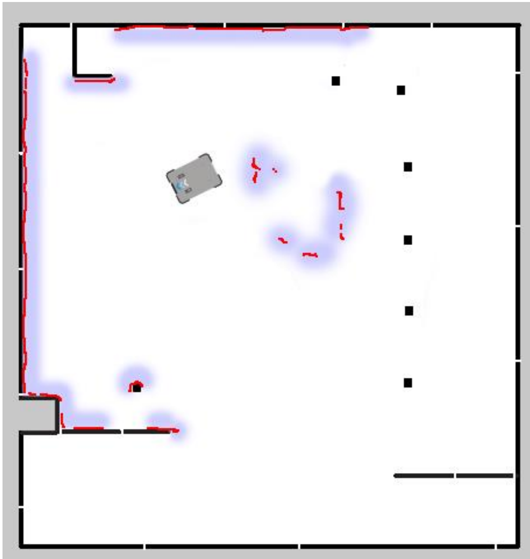
Cannot detect any landmarks



Can detect enough landmarks



- To improve the robot's localization, it can often help to divide long continuous walls on the map. Even if the walls are connected in the actual work environment, it can help the localization process if the walls on the map are divided into smaller sections.

Undivided walls	Divided walls
	

- The robot does not compare the laser scanner data with the entire map, but only around the area that it expects to be close to based on the IMU and encoder data and its initial position. This is why it is important that the initial position you place the robot at on the map is accurate.
- The robot can drive for a short distance without being correctly localized. As it drives, the estimated positions should converge to a small area, indicating the robot has determined an accurate estimate. If this does not occur within a set time limit, the robot reports a localization error.

Motor controller and motors

The robot computer compares the desired velocity of the robot with its current velocity. The computer determines how far the rotational velocity of each motor is from the desired velocity of each motor needed to make the robot follow the intended path. The robot computer sends the necessary changes in velocity for each motor to the motor controllers.

The motor controller translates the difference into the amount of power that must be sent to each motor to achieve the desired velocity. The motor controller regulates whether the amount of power sent to the motors is resulting in the correct velocity by translating the motor encoder data into the robot's velocity and comparing this to the desired velocity—see Motor and brake control system on page 39.

The robot computer keeps checking that the position derived from the localization process is following the intended path. If the robot begins to drive away from the path, the computer corrects the desired velocity that it sends to the motor controllers to ensure that the robot drives with the correct trajectory.

In this way, the robot uses its sensors to determine how far it is from achieving the desired trajectory, enabling it to correct itself as it drives.

Brakes

Once the approximated position of the robot determined from localization is the same as the goal position calculated by the global planner, the robot stops by using the dynamic brake function.

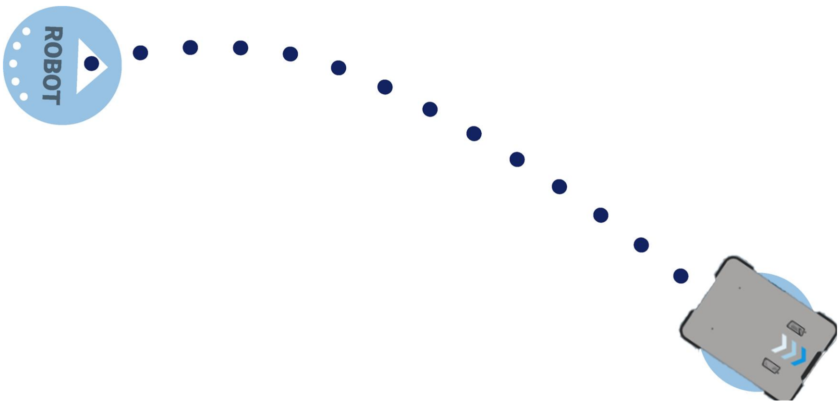


Figure 2.11. The robot has reached the goal position and stops by engaging the brakes.

The dynamic brake function stops the robot by short circuiting the power that was used to rotate the motor. When this happens, the power that was used to drive the robot forward is now reversed to stop the rotation of the drive wheels

Once the robot has stopped, the mechanical brakes are enabled. These brakes are used to keep the robot in place once it has stopped. You can compare it with the parking brake or hand brake in a car.

The mechanical brakes are only used to stop the robot when in motion in emergency situations triggered by the safety system.

The mechanical brakes are automatically released again when the robot receives a new order requiring it to move.

Common issues

- **The robot is reporting localization issues**
  If the robot is not able to determine its current location with a level of certainty, it will report localization issues. The most common reasons and remedies for localization issues are listed below:
  - The laser scanners, cameras, motor encoders, or IMU are not connected. In this case, you will also receive error messages regarding the missing connection to that component. The reason for the missing connection can be a faulty cable, faulty component, or an incorrect serial number.
  - The robot's initial position was placed incorrectly on the map by the user. Check whether the robot on the map is close to its actual position and orientation in the work environment.
  - There are not enough distinctive landmarks on the map that the particle filter can use to provide a reliable approximation of the robot's position.
  - The gear ratio is wrong.
  - The laser scanners or IMU need to be calibrated.
- **The robot jumps around on the map**
  The robot will jump around on the map when it is trying to correct its current position based on the most likely position determined from the laser scanners and particle filter. This often occurs in areas where there are few distinguishable landmarks. In these cases you can choose to either add landmarks for the robot to navigate by or mark the area with a Planner zone that turns off scanner localization.

- **Encoder stall and skid detection errors**
  This error is not directly related to navigation, but occurs whenever the robot registers that it is not moving as expected based on encoder data.
  - Stall errors occur if the power is delivered to the robot but it doesn't move. This can occur if something is physically blocking the robot.
  - Skid errors occur if the robot begins to wheel spin. That is, the wheels are turning, but the robot does not have enough traction to move itself forward. This can occur if the surface the robot is driving on is slippery or slanted.

  These errors can lead to or be caused by a localization issue, since it indicates that there is a discrepancy between sensor data that the robot uses to navigate.

2.2 Safety system

The robot's safety system is responsible for stopping or slowing down the robot and its top module in situations where personnel are at risk of injury.

MiR250 is equipped with a range of built-in safety-related functions as well as safety-related electrical interfaces designed for integration with a top module. Each safety function and interface is designed according to the standard ISO 13849-1. The safety-related functions and interfaces are selected to support compliance with EN 1525 and ISO 3691-4.

System overview

The safety system is controlled mainly by the safety PLC. The PLC regulates inputs and outputs from safety-related functions or interfaces involved with ensuring the safety of personnel working nearby the robot.

If a safety function is triggered, the robot uses its STO (Safe Torque Off) contactors to bring the robot to a category 0 stop (stopping by “immediate removal of power to the machine actuators" according to IEC 60204-1) followed by a controlled brake using an SS1 (Safe Stop 1) function. This is known as bringing the robot into Emergency stop or Protective stop, depending on the function—see Types of stop on the next page.

Some interfaces are also used to signal safety-related states between the top module and robot, for example whether the robot is in motion or if the top module is in a state where the robot must stop or slow down. Each of these are connected through the safety-related electrical interfaces through two identical circuits to ensure redundancy.

Types of stop

There are four different stopped states:

- Operational stop
- Protective stop
- Emergency stop
- Manual stop

The last three types of stop are monitored by the safety PLC.

Operational stop

The robot is in Operational stop when it is stopped through the robot interface either through a mission action or by pausing the mission. The top module and all moving parts are still connected to a power supply.

Protective stop

The robot enters Protective stop automatically to ensure the safety of nearby personnel. When the robot enters Protective stop, internal safety contactors are switched so the robot's top application and all moving parts of the robot do not receive power. You can hear the safety contactors emit audible clicks when they are switched.

When the robot is in Protective stop, the status lights of the robot turn red, and you are not able to move the robot or send it on missions until you bring the robot out of the Protective stop. The following cases describe the various Protective stops and how to bring the robot out of them:

- **A safety laser scanner detects an object in its active protective field**
  Remove the object from the active protective field—see Safety system on the previous page. The robot will resume its operating state after two seconds.
- **The robot finishes the startup process**
  The Resume button will flash after startup. Press the flashing Resume button to bring the robot out of Protective stop.
- **Switching between Manual mode and Autonomous mode**
  After turning the Operating mode key to switch operating modes, the robot enters Protective stop, and the Resume button flashes. Press the Resume button to bring the robot out of Protective stop.

- **The safety system detects a fault, or the motor control system detects a discrepancy**
  To bring the robot out of Protective stop, resolve the fault causing the error. Use information regarding the error from the robot interface to determine the fault. For further guidance, see the troubleshooting guides on the Distributor site.

Emergency stop

The robot enters Emergency stop when an Emergency stop button has been pressed physically. When you press the Emergency stop button, internal safety contactors are switched so the robot's top application and all moving parts of the robot do not receive power. You can hear the safety contactors emit audible clicks when they are switched.

When the robot is in Emergency stop, the status lights of the robot turn red, and you are not able to move the robot or send it on missions until you bring the robot out of the Emergency stop. To do this, you must release the Emergency stop button and then press the Resume button. The Resume button begins flashing blue after you have released the Emergency stop button. If the robot is in Emergency stop, it will immediately resume an operating state after you press the flashing Resume button.

MiR250 has one Emergency stop button that must be through the electrical interface. You can also connect the interface to series of additional Emergency stop buttons

CAUTION

Emergency stop buttons are not designed for frequent use. If a button has been used too many times, it may fail to stop the robot in an emergency situation, and nearby personnel may be injured by electrical hazards or collision with moving parts.

- Only press Emergency stop buttons in emergencies.
- Verify that all Emergency stop buttons are fully functional before starting up the robot.

Manual stop

The robot enters Manual stop when the red Manual stop button in the control panel is pressed. Manual stop brings the robot into the same state as a Protective stop where it can only be brought to an operational state by pressing the Resume button.

Safety-related functions

The following functions are integrated within the robot itself and cannot be modified or used with other applications freely. The following list introduces the main safety-related functions integrated in MiR250:

- **Collision avoidance**
  This function ensures that the robot stops before it collides with personnel or an object. If the laser scanners detect an object or person within a defined protective field, the robot is

brought to a stop. The function determines the speed of the two drive wheels using motor encoder data and switches between predefined protective fields accordingly. The faster the speed, the larger the protective field is.

- **Overspeed avoidance**
  The safety system monitors if the motor encoder data indicates that the speed of each motor is above the limits for maximum rated speed. If the limit is exceeded, the robot enters Protective stop.
- **Stability**
  The safety system monitors if the motor encoder data indicates that the speed difference between the two motors are above predefined limits. If the limit is exceeded, the robot enters Protective stop.

Safety-related electrical interfaces

The following interfaces are parts of the Auxiliary emergency stop and Auxiliary safety function interfaces that can be used to connect the safety PLC to a top module. Each electrical interface is redundant, meaning they use two identical circuits. If one of the circuits fail, the robot enters Protective stop until both circuits are working correctly again and the robot is restarted, ensuring safe communication between the top module and robot.

The following list introduces the main safety-related electrical interfaces between MiR250 and its top module:

- **Emergency stop circuit**
  The Emergency stop circuit goes through the Auxiliary emergency stop interface and connects to the top module. It is intended that any number of Emergency stop buttons can be connected to the circuit. When the circuit is broken, the robot goes into Emergency stop.
- **Safeguarded stop**
  This function consists of a circuit that goes through the Auxiliary safety function interface that connects to the top module. This circuit can be used to bring the robot into Protective stop until it is signaled otherwise.
- **Locomotion**
  The locomotion function signals when the robot is driving. A top module can be connected to this interface if the top module should operate differently when the robot is driving, such as activating brakes or disconnecting the power to actuators.
- **Shared emergency stop**
  This function consists of a shared circuit between the robot and top module, enabling them to trigger each other into an Emergency stop.

- **Reduced speed**
  The reduced speed function can be connected to a top module, enabling it to make the robot reduce its speed to 0.3 m/s. This is for example used by MiR lifts to ensure that the robot does not drive fast when the lift is raised.

These functions are described in further detail in the following sections.

The diagram in *Figure 2.12* shows the inputs to these functions and interfaces and how they are all connected and monitored in the safety PLC. The safety PLC is able to switch the contactors to cut off power to the robot motors and the top module. Also, the safety PLC sends information to the robot computer to be displayed in the robot interface and to indicate the robot's status through the signal lights and the speaker.

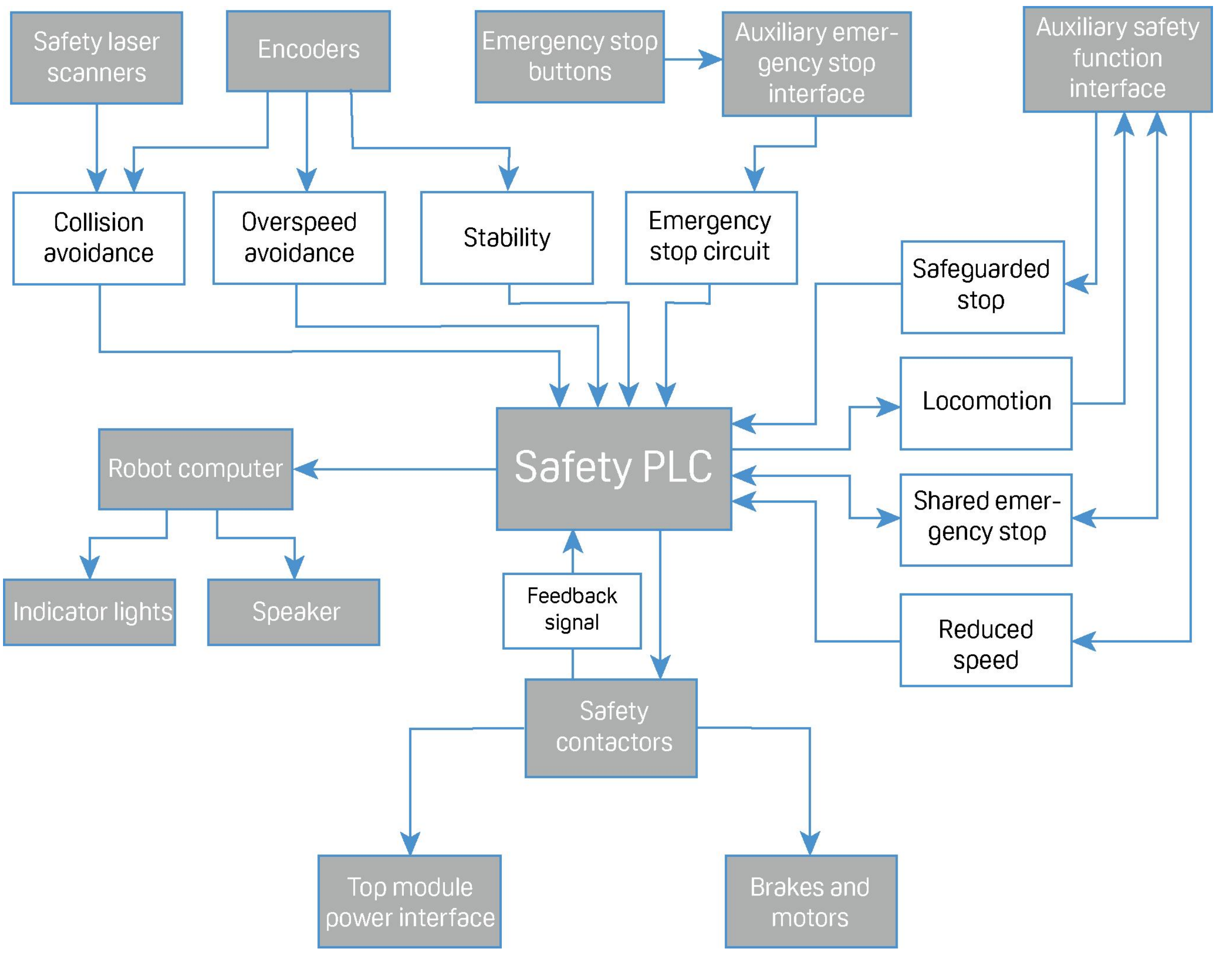


Figure 2.12. Overview of components involved in each safety function and interface. When a safety function is triggered, the safety PLC switches the STO and brake contactors so the brakes, motors, and safe power supply to the top module no longer receive power.

Collision avoidance

The collision avoidance function prevents the robot from colliding with personnel or obstacles by stopping it before it collides with any detected obstacles. It does this using the safety laser scanners.

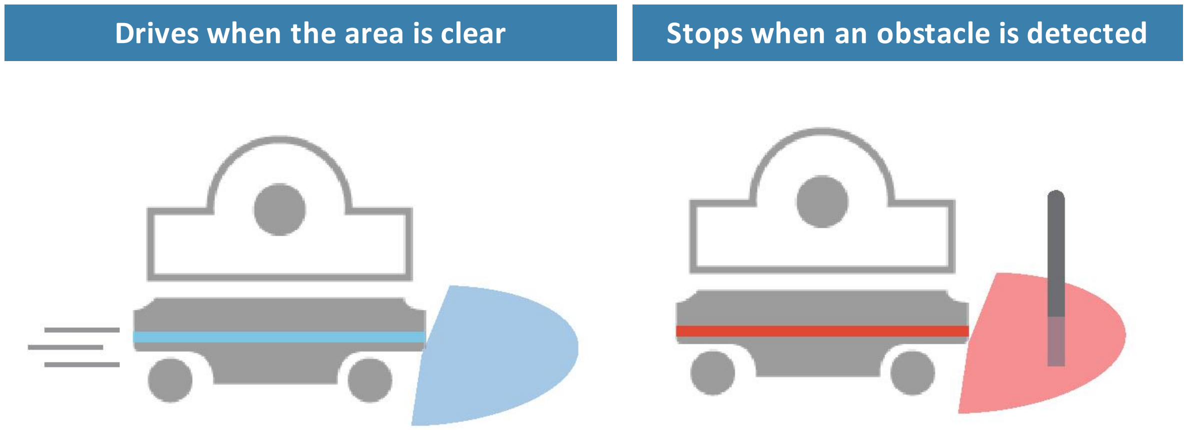


Figure 2.13. Collision avoidance ensures that the robot drives when its path is clear and stops if an obstacle is detected within its protective field.

The safety laser scanners are programmed with two sets of protective fields. One field set is used when the robot is driving forward and the other when it is driving backward. The protective field sets are part of the robot's personnel detection means. The protective field sets consist of individually configured contours around the robot. The robot activates the correct field based on the speed. If a person or object is detected within the active protective field, the robot enters Protective stop until the protective field is cleared of obstacles for at least two seconds.

The tables in the following sections show the sizes of the protective fields at given speeds. The faster the robot moves, the larger the scanners' field is. The speed of the robot is determined based on the encoder data.

The fields on each side of MiR250 are 210 mm at all speeds. If you are using a MiR250 Dynamic the fields on each side decrease at low speeds—see Field sets to the sides on page 32.

WARNING

The protective field sets are configured to comply with the safety standards of MiR250. Modifications may prevent the robot from stopping in time to avoid collision with personnel and equipment. Any modifications of the configuration file in the safety software will void the CE mark and compliance to all safety standards listed in the specification of the application and in other way declared.

- Do not modify the safety system without a competent third party to evaluate the safety of the design and performance of the robot after the modifications are applied.

Field set when driving forward

The following table shows the range of the protective fields when the robot is driving forward. The table describes the length of the field in front of the robot in different cases. Each case is defined by a speed interval that the robot may operate at. The colors and cases in the table correspond to the field set shown in the illustration below.

Case	Speed	Protective field range	Comments
1	0.0 to 0.10 m/s	80 mm	When pivoting
2	0.10 to 0.30 m/s	180 mm	
3	0.10 to 0.50 m/s	360 mm	
4	0.50 to 0.90 m/s	780 mm	
5	0.90 to 1.30 m/s	1350 mm	
6	1.30 to 1.70 m/s	2100 mm	
7	1.70 to 2.10 m/s	2850 mm	Forward at max. speed

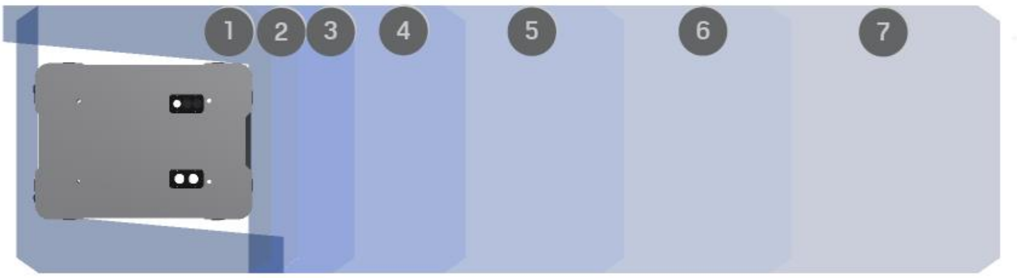


Figure 2.14. The illustration shows the field set contours when driving forward. The range of the field set changes with the robot's speed.

Field set when driving backward

The field set for driving backward is the same as the field set for driving forward. However, the robot is limited to a top speed of 1.0 m/s when driving backward and therefor only have five fields.

Case	Speed	Protective field range	Comments
1	0.0 to -0.10 m/s	80 mm	When pivoting
2	-0.10 to -0.30 m/s	180 mm	
3	-0.10 to -0.50 m/s	360 mm	
4	-0.50 to -0.90 m/s	780 mm	
5	-0.90 to -1.00 m/s	1350 mm	Backward at max. speed

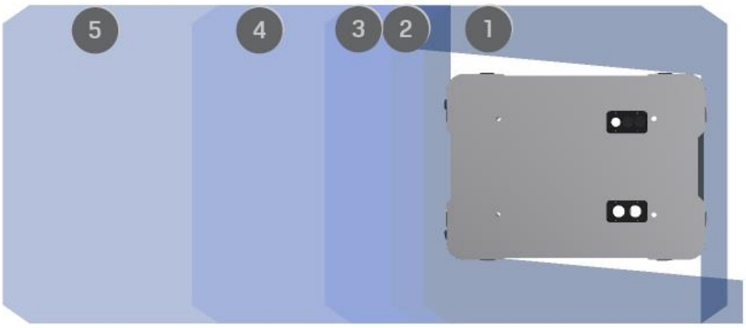


Figure 2.15. The illustration shows the field set contours when driving backward. The range of the field set changes with the robot's speed. The illustration also shows how the front scanner reduces its protective field sets to a minimum when the robot moves backward.

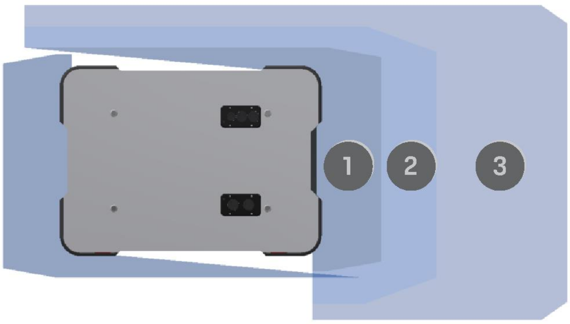
NOTICE

Scanners measure distances to diffuse reflections, which means that a tolerance is added to the protective field sets to secure a safe detection of persons crossing the protective field sets. The tolerance distance is 65 mm.

Field sets to the sides

The field sets on each side of MiR250 Dynamic varies with the speed of the robot. At speeds below 0.5 m/s, the field sets are very small, making it possible for the robot to traverse narrower corridors. The field sets in the front and back of the robot are also smaller on MiR250 Dynamic when driving at very low speeds.

Case	Speed	Field set on each side of the robot
1	0.0 to 0.30 m/s	50 mm
2	0.30 to 0.50 m/s	125 mm
3	0.50 to 0.90 m/s	210 mm



Muted personnel detection means

When performing tasks that require the robot to move very close to surrounding objects, the robot mutes the personnel detection means.

CAUTION

When the robot has muted personnel detection means, it may not stop in time to avoid collisions with obstacles or personnel in its path.

- Mark areas where the robot mutes its personnel detection means as operating hazard zones, and inform personnel not to enter the zone while the robot is operating in it.

When muting the personnel detection means, the robot does the following:

- Reduces the size of the field sets
- Turns off Collision detection
- Decreases the speed
- Flashes the yellow signal lights

You can also mute the personnel detection means using the robot interface:

1. Put the robot into Manual mode.
2. In the robot interface, select **Muted personnel detection means** in the joystick control.
3. In the dialog, select **Yes** to acknowledge the muting of personnel detection means.

The status and the signal lights start flashing yellow, and the robot is ready to drive with muted personnel detection means.

Overspeed avoidance

The overspeed avoidance function prevents the robot from driving if the motor encoders measure that the robot is driving faster than the predefined safety limit. This can occur if there is a hardware error in the robot, or if it drives down a steep slope.

If the robot is driving faster than the predefined safety limit, it is immediately brought into a Protective stop. This ensures that the robot cannot drive if its speed cannot be controlled.

Stability

The stability function prevents the robot from driving if the motor encoders measure that the expected difference between how fast each wheel turns is outside the predefined safety limits. This indicates that the robot is not driving as intended, for example, if one of the wheels loses traction.

If the robot detects instability, it is immediately brought into a Protective stop. This ensures that the robot cannot drive if it has lost control of the speed of each drive wheel.

Emergency stop circuit

The Emergency stop circuit goes through the Auxiliary emergency stop interface and uses external input to bring the robot into an Emergency stop. The interface uses two output pins to provide a 24 V signal and two input pins to bring the robot into Emergency stop.

It is intended that the circuit is set up so the 24 V signal delivered from the safety PLC outputs passes through all Emergency stop buttons of the top module and then continues to the two input pins. When the input pins both receive 24 V, the robot can operate. The connected Emergency stop buttons must break the circuit when you press them so both inputs receive a 0 V signal that will bring the robot into Emergency stop.

If the circuit or an Emergency stop button is installed incorrectly so the input signals are not the same, the robot enters Protective stop until the circuit is fixed.

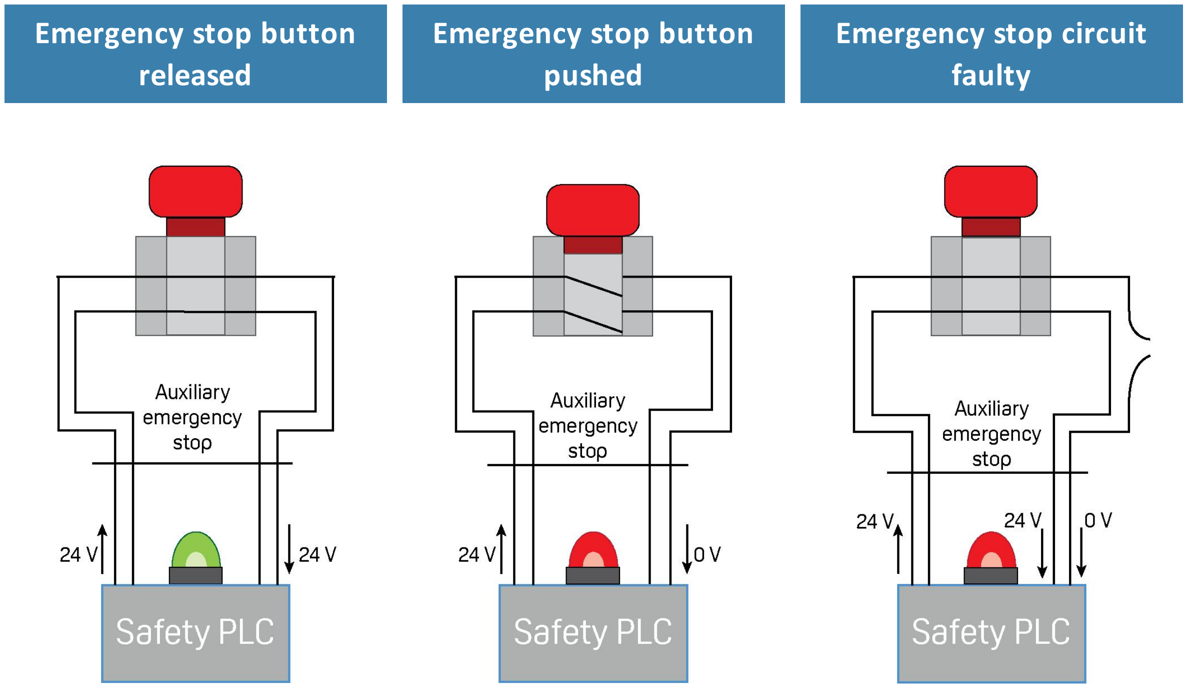


Figure 2.16. If the input pins deliver 24 V to the robot, it can operate. When you push a connected Emergency stop button, both pins deliver 0 V, and the robot enters Emergency stop. If the pins do not deliver the same input, the robot enters Protective stop until the circuits are fixed.

In the Auxiliary emergency stop interface, pins 2 and 3 deliver 24 V from the safety PLC, and pins 4 and 5 connect to the Emergency stop circuit inputs of the safety PLC. 24 V must be delivered to pins 4 and 5 for the robot to operate.

Safeguarded stop

The safeguarded stop interface provides an input to the robot that can bring the robot into Protective stop. This interface uses two input pins, where both pins must receive 24 V for the robot to be able to operate. If either or both pins receive 0 V, the robot is brought into

Protective stop. The robot can be brought out of Protective stop again if both pins receive 24 V again.

If the pins are unequally set for more than three seconds, the safety PLC registers this as an error in the system and needs to be reset before the robot can operate again. To do this, you must restart the robot.

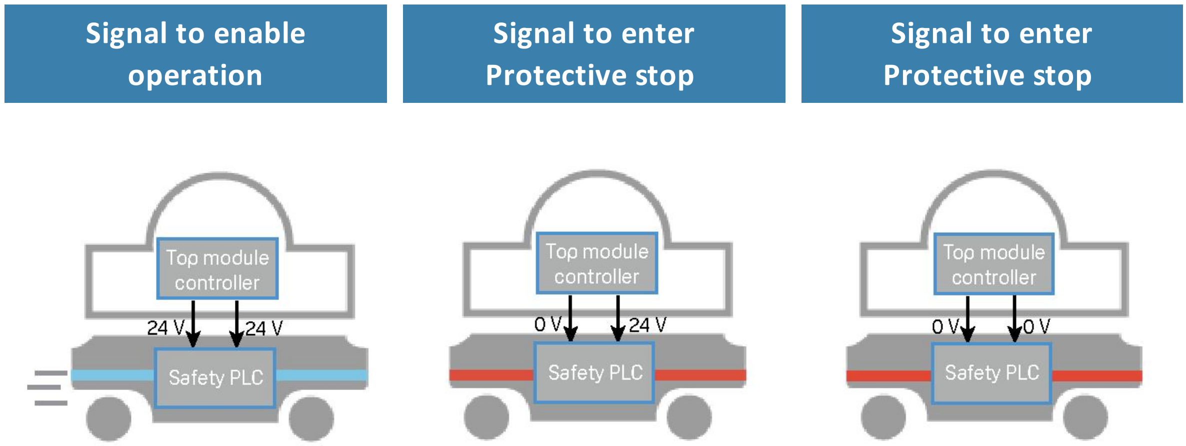


Figure 2.17. If both pins deliver 24 V to the robot, it can operate. If either or both of the pins deliver 0 V, the robot enters Protective stop.

Pins 2 in interfaces A and B of the Auxiliary safety functions are used for the Safeguarded stop function.

Locomotion

The Locomotion interface is used to signal to a top module that the robot is driving. This function uses two output pins, where both pins deliver 0 V when the robot is driving and 24 V when the robot is stopped. You can use this interface to make your top module behave differently depending on whether the robot is driving or not. The interface is intended to be used to ensure that the top module is programmed to go into a safe state when the robot is driving. For example by engaging the brakes in any actuators that may result in injury to personnel.

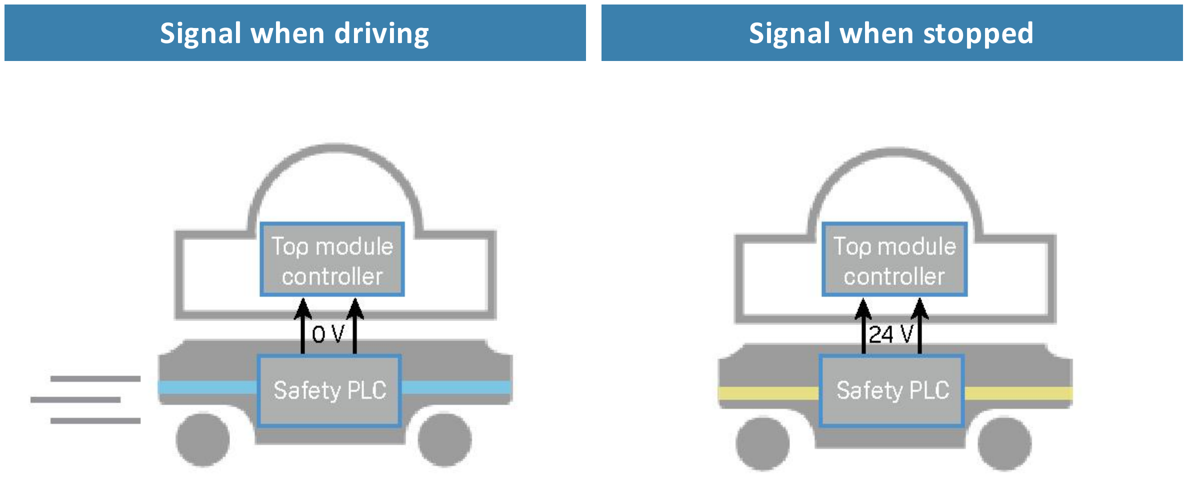


Figure 2.18. When the robot is driving, the safety PLC sends a 0 V signal to the top module through the Auxiliary safety function interface. When the robot is stopped, the signal becomes 24 V.

Pins 5 in interfaces A and B of the Auxiliary safety functions are used for the Locomotion function.

Shared emergency stop

The Shared emergency stop interface is used to control the Emergency stop state between the robot and a top module. The interface has two inputs for bringing the robot into Emergency stop and two outputs for signaling when the robot is in Emergency stop.

The outputs are used to signal to the top module that the robot is in Emergency stop. When the robot is in an operational state, the outputs deliver 24 V. As soon as the robot enters Emergency stop, they deliver 0 V.

The inputs are used to enable the top module to bring the robot into Emergency stop. When both inputs deliver 24 V, the robot can operate, but as soon as either or both of the inputs deliver 0 V, the robot enters Emergency stop.

These signals can be used if the top module has its own Emergency stop system and you want both the robot and the top module to enter Emergency stop when either system is triggered.

If the pins are unequally set for more than three seconds, the safety PLC registers this as an error in the system and needs to be reset before the robot can operate again. To do this, you must restart the robot.

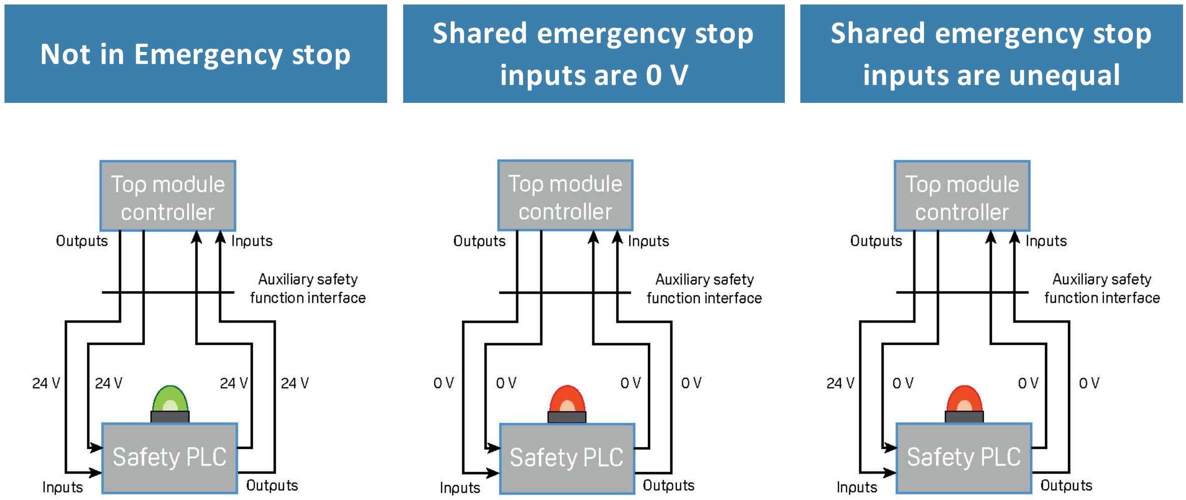


Figure 2.19. There are three cases described above. Respectively, they illustrate: 1. the robot is not in Emergency stop so the output is 24 V, 2. the robot is in Emergency stop because it receives 0 V input from the Shared emergency stop interface, 3. the robot is in Emergency stop because the inputs are unequal.

In interfaces A and B of the Auxiliary safety functions, pins 3 are used for the input and pins 6 are used for the input of the Shared emergency stop function.

Reduced speed

The Reduced speed interface is used to signal to the robot that it must drive at a reduced speed of 0.3 m/s. This is the same speed used when the robot mutes its personnel detection means. The interface uses two input pins where the robot drives at a reduced speed if either input is 0 V.

This can for example be used in cases where the top module can register whether the load it is carrying is not securely placed or the module is currently under operation.

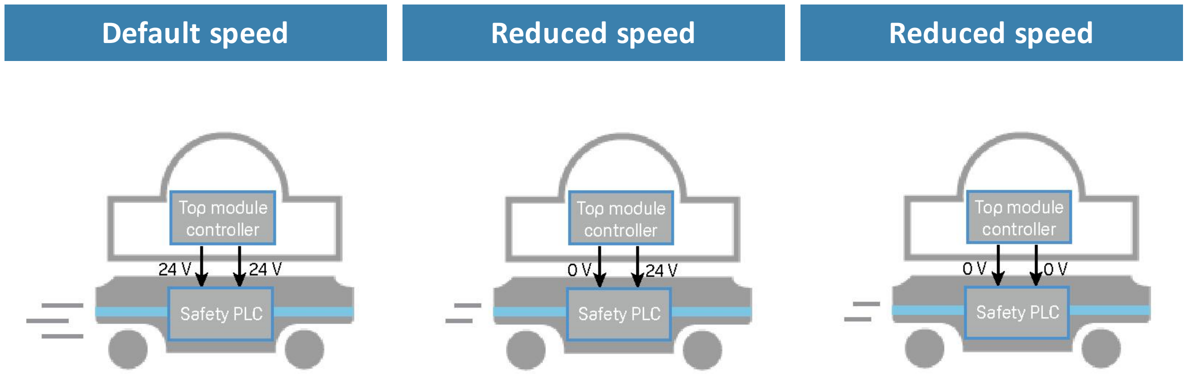


Figure 2.20. The robot drives at its default speed only when both inputs are 24 V. If either or both pins are 0 V, the robot drives at 0.3 m/s.

Pins 4 in interfaces A and B of the Auxiliary safety functions are used for the Reduced speed function.

Robot computer

The robot computer is connected to the safety PLC via an Ethernet cable. The safety PLC sends all of the statuses of its various inputs to the robot computer so the information can be sent to the robot interface. This enables you to identify which part of the safety system may be causing a Protective or Emergency stop.

Additionally, the robot computer sends the current robot state to the power board, which regulates the indicator lights, ensuring that the status lights indicate which state the robot is in.

Common issues

When the robot enters Protective or Emergency stop due to a component in the safety system, you can identify exactly which component is causing the issue by signing in to the robot interface and viewing the errors displayed under **Monitoring > Hardware Health > Safety system**.

2.3 Motor and brake control system

The motor and brake control system is responsible for driving the robot. The robot computer translates the global and local paths into velocity and acceleration instructions that it sends to the motor controller. The motor controller then derives how much power needs to be sent to the motors to reach the correct velocity. Once the robot reaches the goal position, the system engages the brakes. The brakes must also be engaged if the safety system initiates an Emergency or Protective stop state—see Safety system on page 22.

System overview

Two main systems control the motion of the robot:

- **Control system**
  Controls how much power each motor receives and monitors that the robot is driving as intended. Control system components are outlined in blue in *Figure 2.21*.
- **Safety system**
  Ensures that the robot is brought to a stop if the safety PLC initiates a Protective or Emergency stop state. Safety components are outlined in red in *Figure 2.21*.

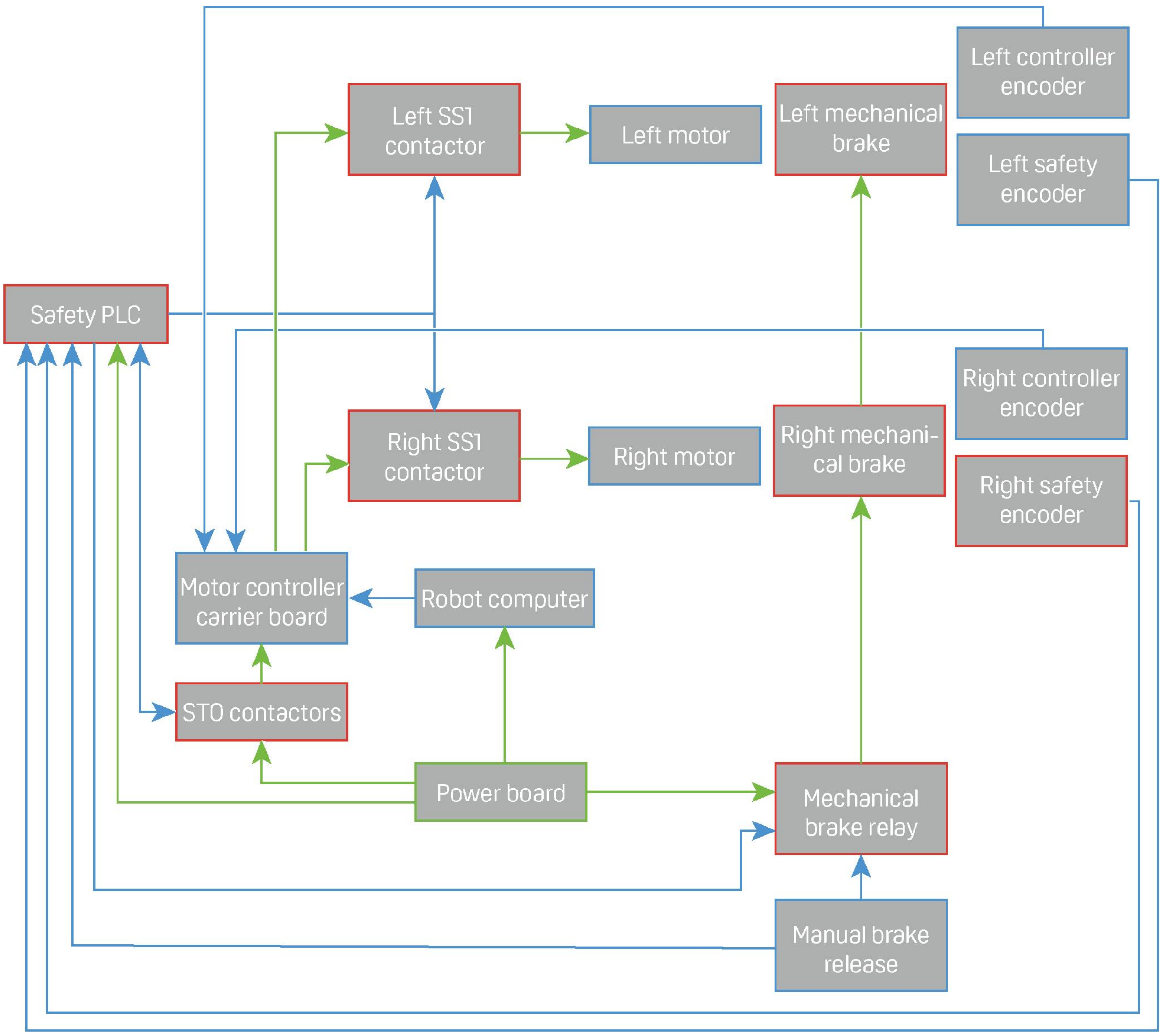


Figure 2.21. Diagram of the motor and brake control system. The blue arrows indicate data or signal connections, the green arrows indicate power connections. Components with a red outline are part of the safety system, blue components are part of the control system, and green components are part of the power system.

Motor control

MiR250 uses two brushless DC motors to power the drive wheels. The amount of torque applied to each wheel is controlled by the amount of power each motor receives. The two motor controllers in the motor controller carrier board determine how much current each motor must receive for the robot to drive at the desired velocity. A simplified illustration of the motor control system is shown in *Figure 2.22*.

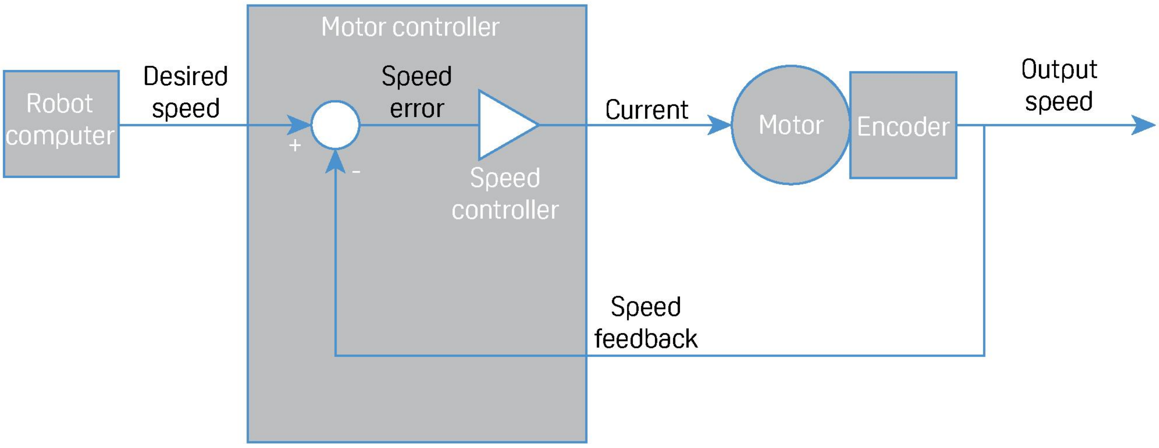


Figure 2.22. A simplified diagram of the motor control loop for one motor.

The process that occurs in the control loop is described with the following steps:

1. The robot computer determines the path that the robot must drive and what the desired rotational speed for each motor must be for the robot to drive the intended path.

2. The robot computer sends this information to the motor controller. The motor controller translates the desired speed into how much current each motor must receive to achieve the desired speed.

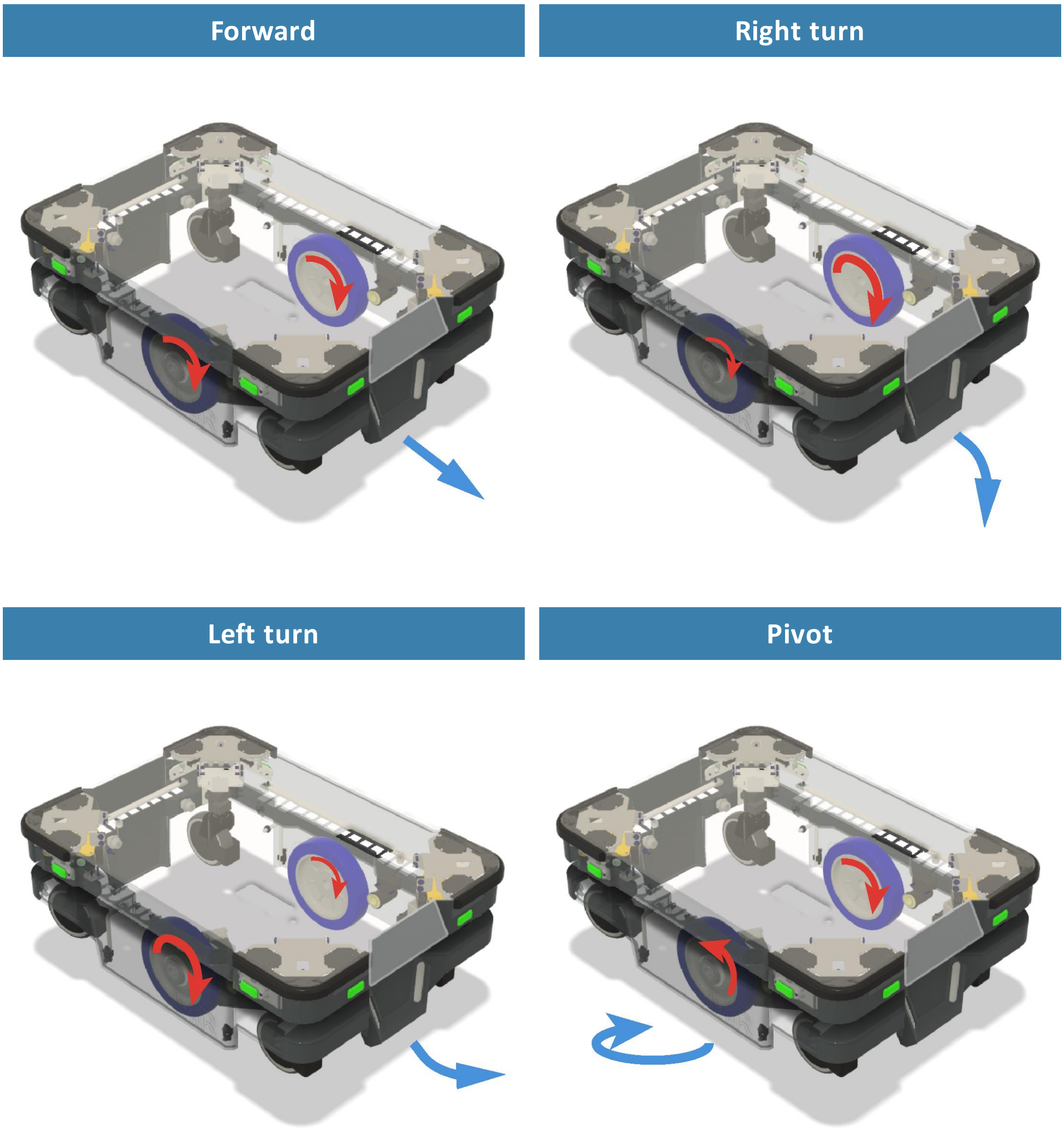


Figure 2.23. When both motors rotate at the same speed, the robot drives straight. When the motor on the right rotates faster, the robot turns to the left, and vice versa for the left motor. When the left and right wheels rotate in opposite directions, the robot pivots.

3. As the robot drives, the motor controller receives feedback from the motor encoders. The motor controller determines how far the actual motor speed is from the desired speed.
4. The resulting value is known as the speed error. The motor controller uses the error to try to correct the amount of current that should be sent to the motor. This helps to ensure that the robot is driving accurately even if there is more friction on one wheel or the robot is driving on a slope.

This is a continuous loop that ensures that the motor controllers correct the amount of current sent to each motor based on the feedback collected from the motor encoders.

Safety stop control

There are two pairs of contactors used to stop MiR250: the STO (Safe Torque Off) contactors and the SS1 (Safe Stop 1) contactors. These are controlled by the safety PLC and are used when the robot goes into Protective or Emergency stop. The following processes occur to stop the robot safely:

1. The safety PLC first turns off the STO contactors so power is cut from the motors.

> To ensure that the STO contactors switch states as expected, there is a feedback circuit that signals to the safety PLC each time the contactor switches states. When the robot is starting up, the feedback circuit and STO contactors are checked before allowing the robot to be operated.

2. The safety PLC turns off the SS1 contactors to activate the dynamic brake function in the motors.
3. The safety PLC monitors data from the motor encoders to determine whether the robot has stopped within the expected amount of time.
4. Once the robot has stopped, the mechanical brakes are engaged to keep the robot in place, similar to the parking brake in a car.

The mechanical brakes are only intended to engage when the robot has stopped. Only when the dynamic brake function does not stop the robot within the expected amount of time, are the mechanical brakes engaged to stop the robot while it is in motion. This is considered an emergency situation where the dynamic brake has failed, and an error is reported in the robot interface. This can occur, for example, if the robot drives on surfaces that are not within specifications or the load on the robot does not fulfill the payload specifications.

The safety PLC controls the mechanical brakes using the brake relay. To engage the brakes, the safety PLC turns the relay off to cut the power to the brakes. It is also possible to override the signal from the safety PLC using the Manual brake release switch. When the Manual brake release switch is turned on, the brakes are released, and the safety PLC receives a status signal from the switch.

When the mechanical brakes do not receive power, they engage immediately. This ensures that if a cable in the brake system is disconnected, the robot is brought to an immediate stop and cannot be operated until the brake system is functional again.

Common issues

- **Dynamic brake errors**
  The robot will report an error in the dynamic brakes if the robot does not stop before the set time limit. If the robot is not loaded according to the payload specifications, the robot may not stop within the expected time limit and will report an error in the dynamic brakes even though they are working as they should. Continuing to do this results in the mechanical brakes wearing down from being used in an unintended way.

3. Robot components

Once you have determined which component on your robot may be failing, you may need to understand the component itself to further troubleshoot the issue. This section describes the various robot components in more detail, enabling you to troubleshoot the exact issue you are experiencing with a component.

3.1 Safety laser scanners

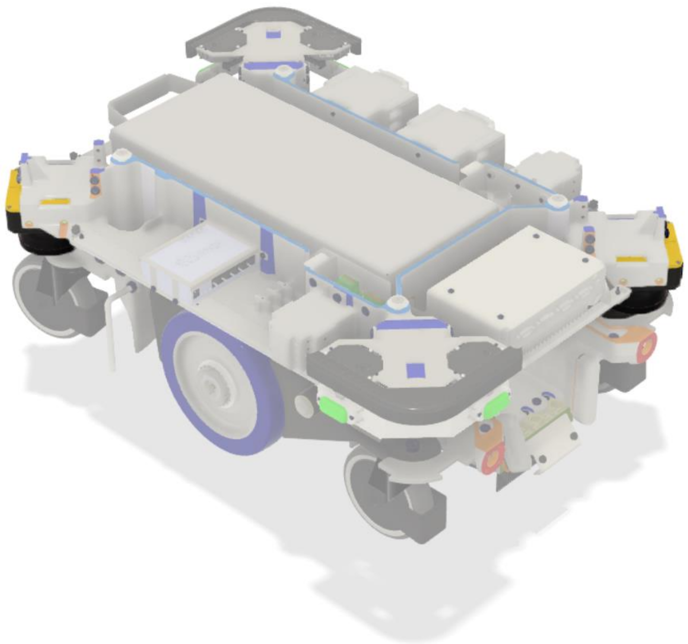
There are two nanoScan3 safety laser scanners in the robot: one in the rear and one in the front. The scanners are used to detect objects around the robot for safety, localization, mapping, and guidance purposes:

- **Safety**
  The robot goes into Protective stop if an object is detected by the scanners within the active protective field.
- **Localization**
  The robot uses the data from the laser scanners to recognize distinct features on the map to localize itself correctly.
- **Mapping**
  When the robot is mapping, the map is created using both the scanner and odometry data of the robot.

- **Guidance**
  The robot detects obstacles with the laser scanners so it can maneuver around anything in its path and continue to its goal.

Location and connection

The laser scanners are located in the front-left corner and rear-right corner of the robot.



The scanners send data to both the safety PLC and the robot computer. They receive power from the safety PLC.

The data sent to the safety PLC is used to monitor whether an obstacle has entered the active protective field. When this happens, the safety PLC triggers a Protective stop.

The data sent to the computer is used to generate maps, to guide the robot when it is driving autonomously, and to localize the robot whenever it is operating in either Autonomous or Manual mode.

For more information on how the laser scanners are used by the robot see Obstacle detection on page 10 and Collision avoidance on page 28.

How it works

Figure 3.1 illustrates the working principle of the safety laser scanner. In the illustration, the laser scanner (1) constantly emits laser pulses (2) through the optics cover. When the laser pulse hits an opaque object (3), the laser pulse is reflected (4) back through the scanner's optics cover, and its return is detected by the scanner. The scanner processes the time passed between the emission of the pulse and the return of the pulse to determine the distance from the scanner to the nearest obstacle in the direction the laser pulse was emitted.

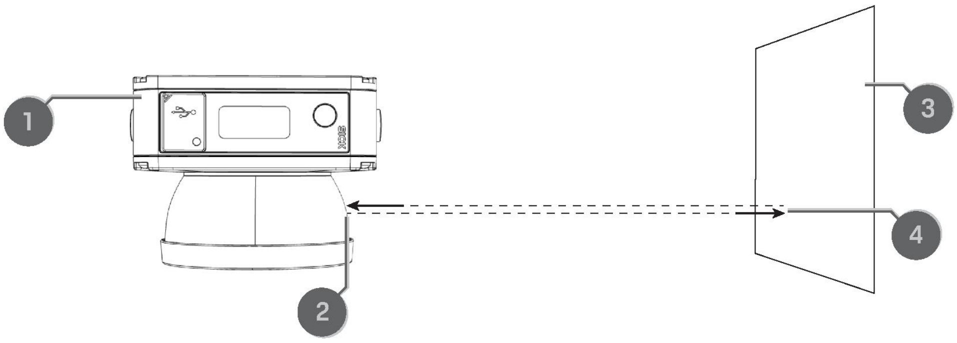
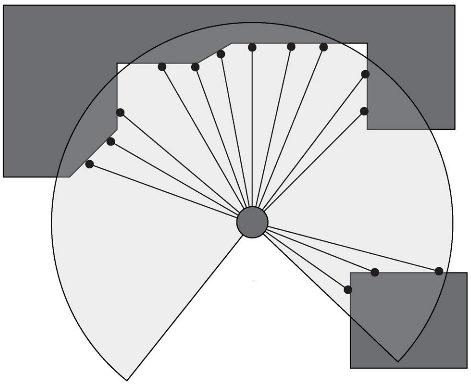


Figure 3.1. The laser scanner (1) emits a laser pulse (2) that is reflected on an opaque surface (4) and is sent back to the scanner. When the scanner receives the reflected pulse, it determines the distance between itself and the object.

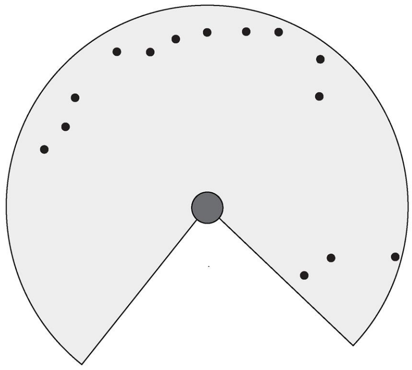
This process is repeated while the orientation of the laser pulse changes with small rotational steps. This is done using a small mirror inside of the scanner, which rotates continuously to reflect the laser pulses in any directions from the scanner. The scanner rotates with 0.17° rotational steps. With each rotational step, a new laser pulse is sent that provides the distance to the nearest obstacle in that direction. The output data from a laser scanner is multiple coordinate points describing the edges of obstacles where a laser pulse was reflected.

Obstacles reflecting laser pulses



The laser scanner detects the nearest obstacles by emitting multiple pulses in all directions in the scanners field of view and receiving the reflected pulses.

Obstacles detected by the scanner



The scanner does not necessarily detect the entire obstacle, only the edges of the obstacles within its range and field of view. The data from the laser scanner consists of coordinate points of each points where an obstacle has reflected a laser pulse.

With MiR robots you can also see at what point the laser scanners are currently detecting objects. Under **Monitoring > Safety system**, a visualization of the MiR robot is displayed—see *Figure 3.2*. Each blue dot represents a point where the laser scanner has calculated that an emitted laser pulse has been reflected. In the image below, you can see that the front laser scanner is detecting a VL-marker.

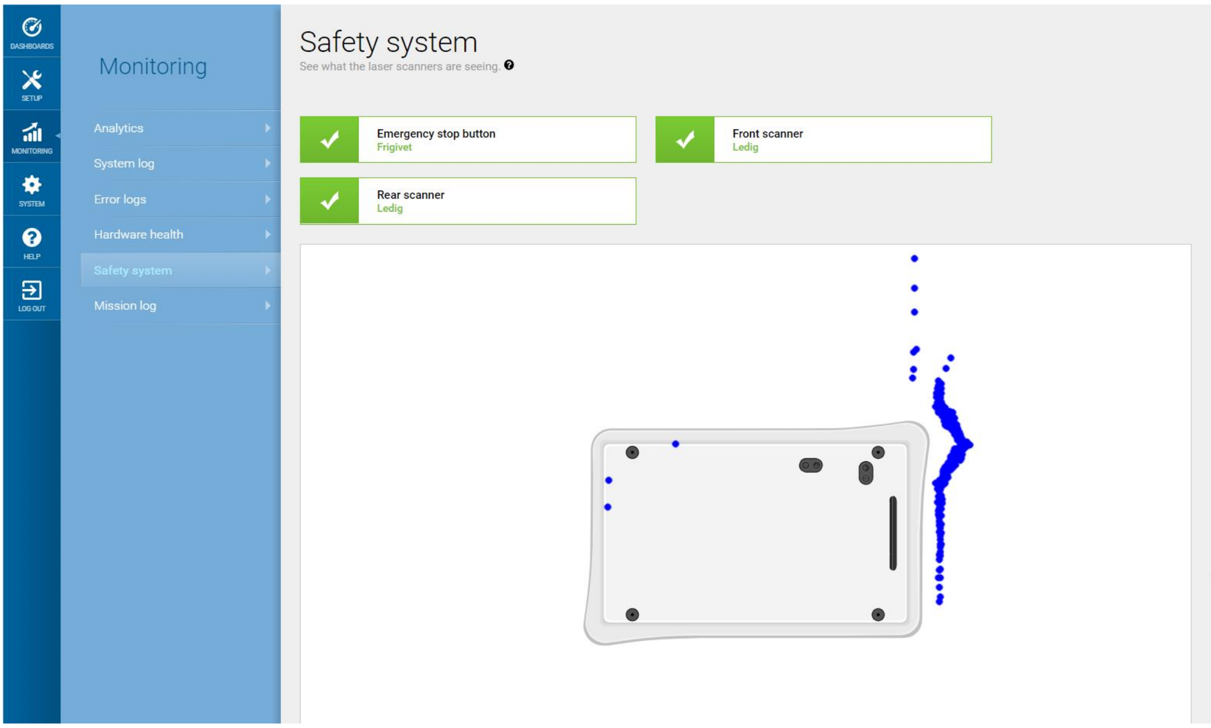


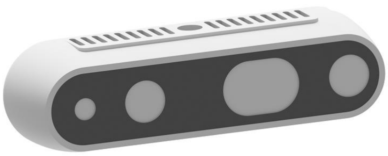
Figure 3.2. In the robot interface, you can see a visualization of what the safety lasers scanners are detecting around the robot.

Common issues

- **The data collected from the laser scanners is incorrect and is interfering with how the robot operates**
  There are often a few data points from the laser scanners that are incorrect. If there are only a few outlying points, the robot disregards them. If there are many incorrect points where the robot is either failing to detect an obstacle or is detecting non-existent obstacles, these are the common causes:
  - If the laser hits an obstacle that is transparent or reflective, the laser pulse can be deflected incorrectly, resulting in the obstacle not being detected.
  - If the optics cover is contaminated or damaged, the laser pulse can be deflected or refracted incorrectly, resulting in the scanner detecting non-existent objects. To clean the optics cover of the scanners correctly, see your robot's user guide.
  - If strong light is shined directly at the laser scanner, it may interfere when the scanner tries to detect the returning laser pulse, resulting in the scanner detecting non-existent objects.

- **The robot cannot localize because it is not receiving data from the laser scanners**
  If the robot cannot connect to the scanners, check whether the scanners are receiving power by removing the corner shield and verifying that the status LED on the scanner is lit. If the scanners are powered, there is a connection issue to the robot computer via the router or the safety PLC. If the scanners aren't receiving power, there is an issue with the connection from the safety PLC to the laser scanners.

3.2 3D cameras

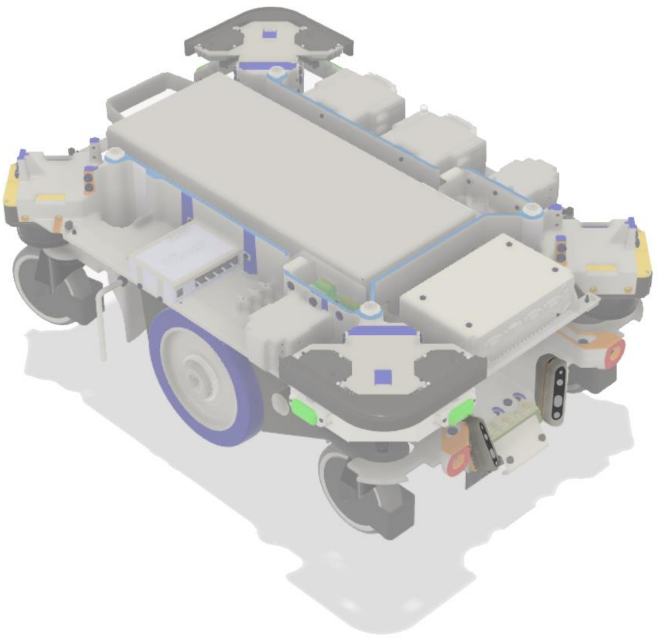


The 3D cameras are used to detect objects in front of the robot that are above or below the height where the laser scanners can detect obstacles—see Safety laser scanners on page 45. This data is used by the robot to:

- Detect low hanging obstacles that the robot may not be able to pass beneath if its footprint height is too high.
- Check whether pallet racks are occupied or empty.
- Detect obstacles that are below the laser scanner's field of view.

Location and connection

The two cameras are located in the front compartment of the robot. They are pointed at an upwards angle, enabling them to detect tall or low hanging obstacles.



They connect directly to the robot computer via USB cables that both power the cameras and retrieve data.

How it works

A 3D camera consists of two displaced cameras that use active infrared stereo vision to create a point cloud describing the depth of detected objects—see Obstacle detection on

page 10 for an example.

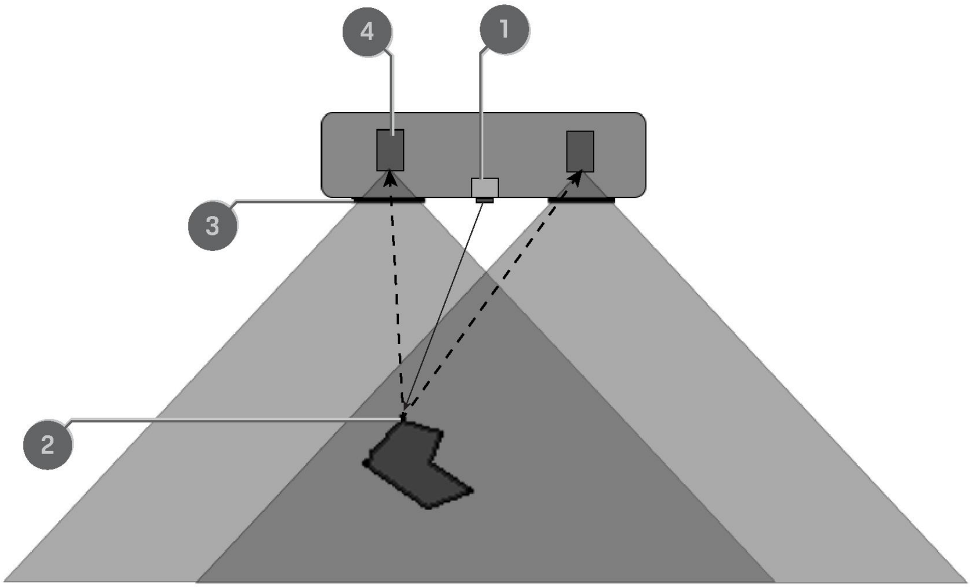


Figure 3.3. Illustration of how active infrared stereo vision works. Infrared light emitted from the camera (1) is reflected off of objects in front of the camera (2). Each wave of infrared light directed back at the cameras (4) are detected and used to create an image. The displacement between the images is used to determine how far away the object is.

Figure 3.3 illustrates the working principle of a 3D depth camera using active infrared stereo vision and describes the following steps:

1. Infrared light is emitted by a projector on the camera.
2. The infrared light is reflected off of objects.
3. The reflected light is detected by the two cameras. Notice that the reflected light reaches each camera from a different angle and goes through the lenses at different points.
4. The cameras generate an image from the reflected infrared light. The images are processed where distinguishable features, such as edges and corners, are detected in each image. Using the difference in the positions of the same feature in the two images, the depth of each feature is determined. The closer the feature is to the cameras, the bigger the displacement difference is in the two images.

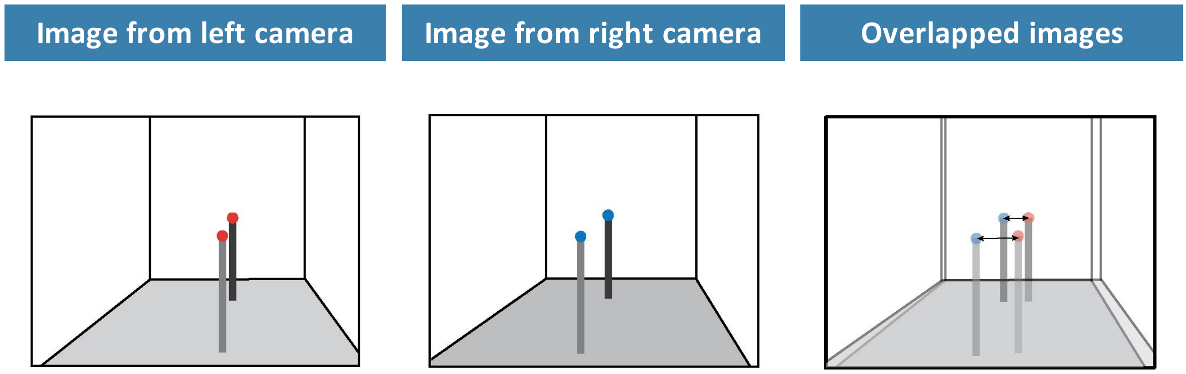
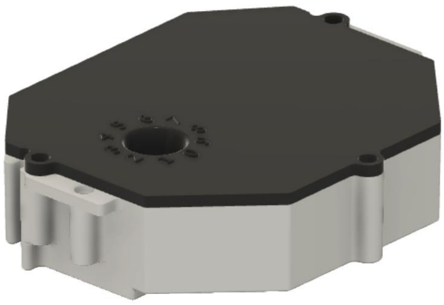


Figure 3.4. The above images illustrate how objects that are further from the camera have a smaller displacement in the two images than objects closer to the camera.

Common issues

- **The robot cannot connect to the cameras**
  This error occurs when the cables between the cameras and the robot computer have disconnected. This can be fixed by pushing the cable connectors back into place. If the camera still cannot connect after checking the cable, you may either have to replace the cable or the camera. Consider trying to connect to the camera with your computer using the cable in the robot and another cable to determine the faulty component.
- **The camera serial numbers are incorrect**
  After replacing a 3D camera or USB restoring your robot, the robot computer must detect the cameras again to determine the correct serial number. You can make the robot computer detect the cameras in the user interface under **System > Robot setup**. When detecting each camera, make sure to unplug the camera you are not trying to detect.
- **The cameras are detecting objects incorrectly**
  The most common causes for the cameras failing to determine the depth correctly are:
  - In certain areas, other sources emitting infrared waves may be interfering.
  - When in front of certain structures or objects, where the pattern of the structure or obstacle is too repetitive, it is difficult for the camera's software to determine which features are the same.
  - If the camera fails everywhere, the lenses may be dirty and should be cleaned, or the camera may need to be calibrated—see the guide *How to calibrate a D435 3D camera*.

3.3 Proximity sensor modules and indicator lights



The proximity sensor modules consist of a circuit board and three infrared proximity sensors. The indicator lights are controlled by the circuit boards within each proximity sensor module. For this reason, although their purposes are different, they are explained in the same section of this guide.

Proximity sensors

The proximity sensors are used to detect obstacles next to the robot that are below the laser scanners' plane of view. This is to avoid the robot colliding or dragging obstacles that have been placed close to it while it was stationary. They also function as a final detection layer for anything that the 3D cameras or laser scanners failed to detect.

Indicator lights

The indicator lights have two categories with each their purpose:

- **Status lights**
  These are the LED bands on each side of the robot. They are used to indicate to the user which status the robot is currently in. There are four status LED bands.
- **Signal lights**
  Two of these are located in each corner of the robot. They are used to indicate the immediate driving direction of the robot, signaling if the robot is turning, braking, or muting its personnel detection means. There are eight signal lights.

Location and connection

The proximity boards and indicator lights connect in a single CAN bus circuit that starts at the power board and runs through each proximity board to the indicator lights.

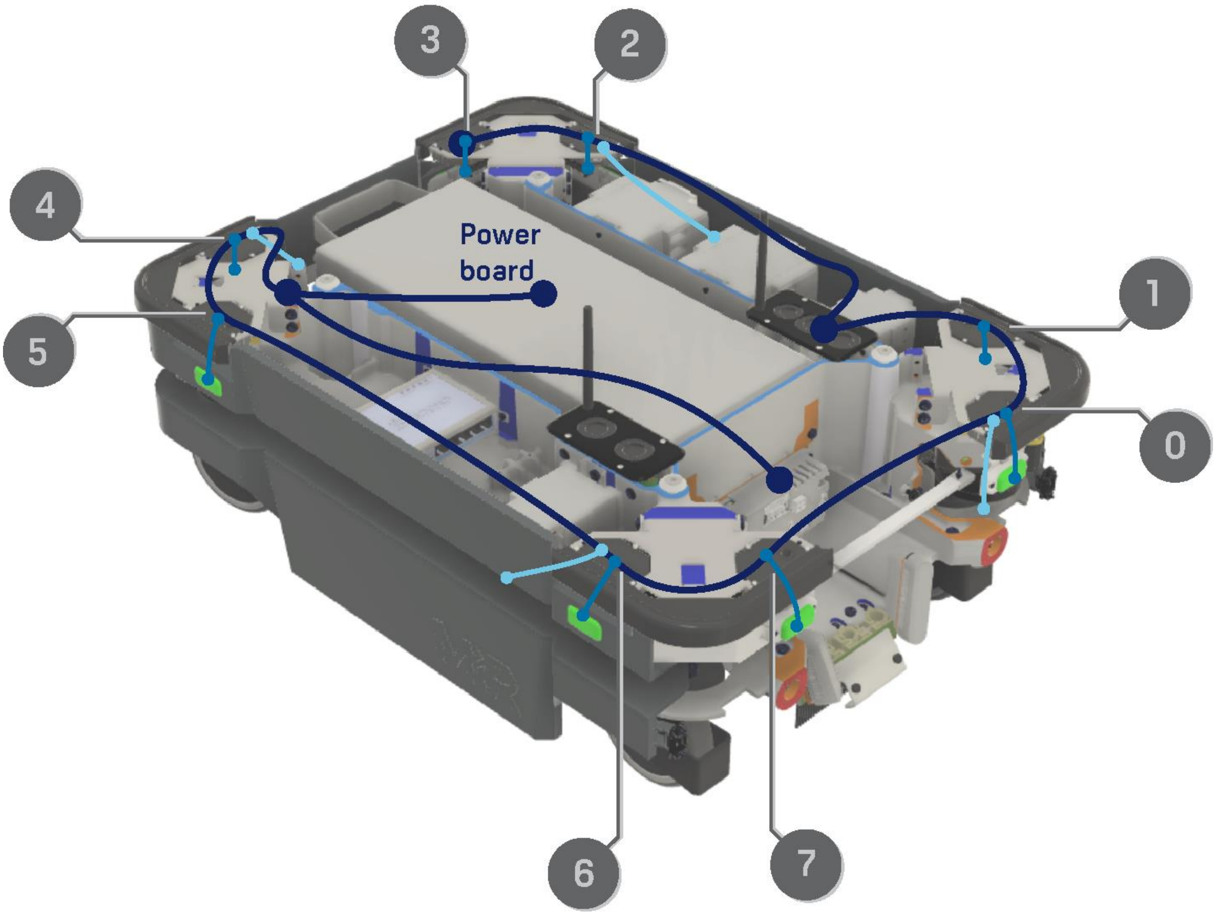


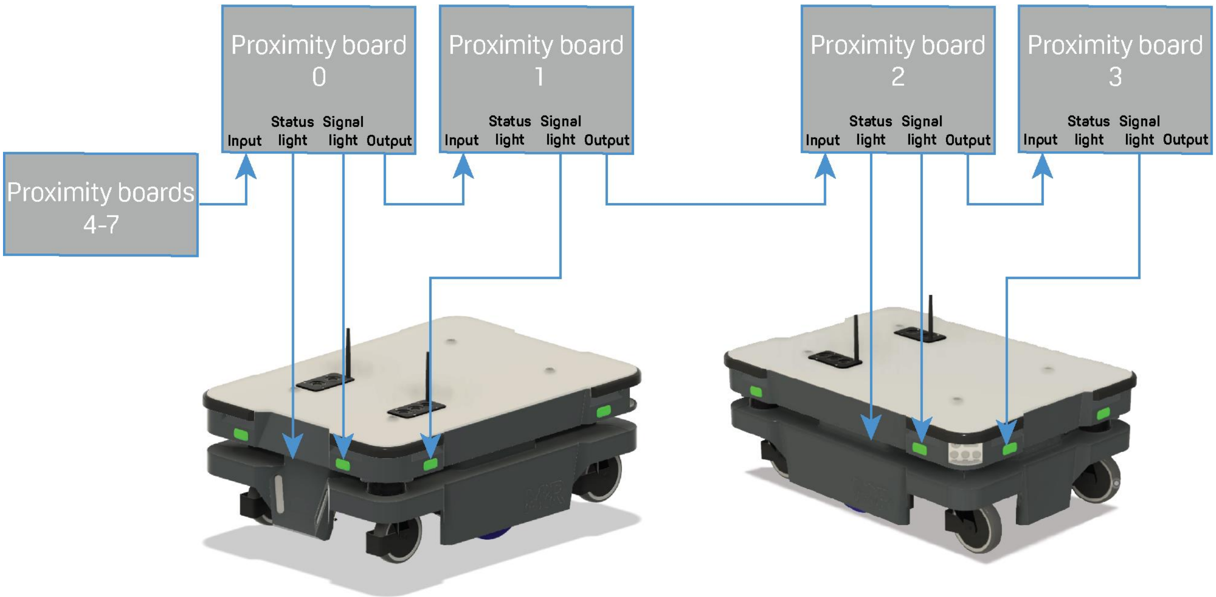
Figure 3.5. The CAN bus begins at the power board and connects to a PCBA board where the connection splits to the motor controller carrier board. The rest of the CAN bus continues through all of the proximity boards in the following order: 4, 5, 6, 7, 0, 1, 2, 3. Each board connects to a signal light, and every second board connects to a status light.

Each proximity board has:

- A CAN bus ID number. The ID numbers do not follow the order of the CAN bus connection.
- A CAN bus input.
- A CAN bus output.

- A status light connector
- A signal light connector.

The proximity boards are connected together through the CAN bus inputs and outputs: each signal light is connected to one proximity board, and the status light LED bands are connected to every second proximity board, starting with the first one.



The circuit board of each proximity board enables the CAN bus communication to go through it and connect to the next proximity board. This means that if the connection through a single proximity board is faulty, all of the boards connected after it will disconnected too.

The dial on top of each proximity module determines the node ID number in the software. The digit chosen with the dial represents the second digit in the node ID number displayed in the interface. For example, a node set to 5 has the node ID number 15, and a node set to 6 has the ID 16.

How it works

The circuit board in each proximity sensor module controls the indicator lights and monitors input from the proximity sensors.

Indicator lights

The indicator lights change based on the robot's status and the intended driving direction, which are determined by the robot computer. The robot computer relays the information to the power board, which then sends the information through the CAN bus connection to the circuit boards. If the clocks of the circuit boards are all synchronized correctly, the indicator lights will change as intended.

Proximity sensors

Each circuit board is also connected to three small infrared proximity sensors. Infrared proximity sensors work by emitting infrared light that is then reflected into the sensor. When the infrared light is reflected from an object that is close to the sensor, the strength of the reflected light is greater than those that are reflected further away from the sensor.

By measuring the strength of the reflected light, the sensor determines whether there are objects that are closer to the sensor than the ground. When an object is large enough and close to the sensor, the robot registers it as an obstacle that it should avoid.

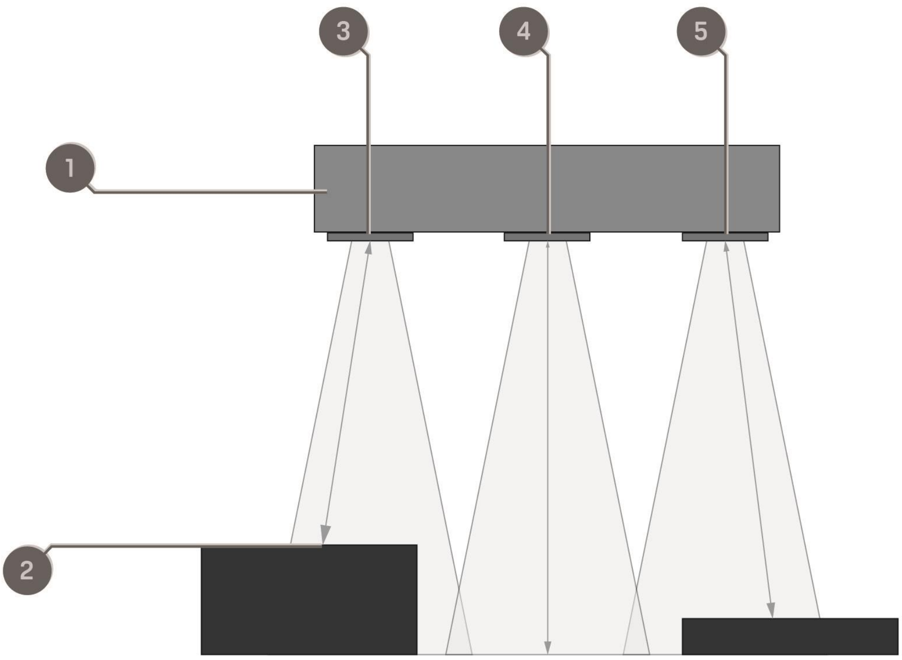
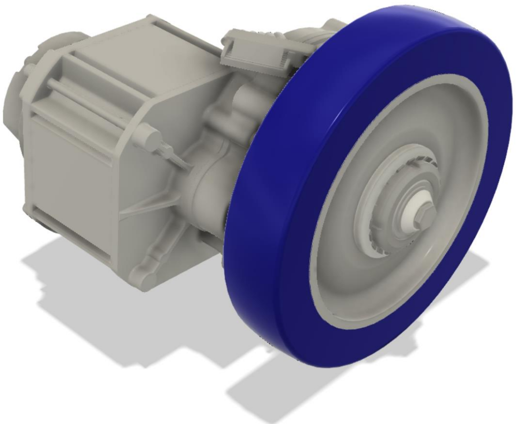


Figure 3.6. The proximity sensor (1) contains three smaller infrared proximity sensors (3, 4, 5). The infrared sensors emit infrared light that is reflected from objects (2) back into the sensor. The closer the objects are to the sensor, the stronger the reflected light is. At (3), the strongest light is reflected, since the reflection occurs closest to the sensor, and at (4), the reflected light is weaker, since the reflection occurs further away.

Common issues

- **Faulty or desynchronized lights**
  If only one light does not work, it is likely the light or the connection to the light is faulty. If multiple consecutive lights are disconnected, one of the proximity boards is likely faulty or disconnected. If a board is disconnected, all of the following nodes in the CAN bus also disconnect. You can see the status of each node under **Monitoring > Hardware health > Power board > CAN communication bus**. Keep in mind that the nodes are connected in the following order from the power board: 14, 15, 16, 17, 10, 11, 12, 13. This means that if node 17 is disconnected, nodes 17, 10, 11, 12, and 13 will also be disconnected.
- **The data collected from the proximity sensors is incorrect and is interfering with how the robot operates**
  If the proximity sensors are either failing to detect an obstacle or are detecting nonexistent obstacles, these are the common causes:
  - If the infrared light hits an obstacle that is transparent or reflective, the light can be deflected incorrectly, resulting in the obstacle not being detected.
  - If the lenses are contaminated or damaged, the infrared light can be deflected or refracted incorrectly, resulting in the sensor detecting non-existent objects.
  - If strong light is shined directly at the proximity sensor, the light may interfere when the sensor tries to detect the returning infrared light, resulting in the sensor detecting non-existent objects.
- **Status lights are emitting uneven light, causing the robot to enter Protective stop due to the laser scanners**
  If the status lights are contaminated, the light they emit may be reflected unevenly or blocked. This can also affect the safety laser scanners if the light is reflected into their optics covers. It is a good idea to clean the status lights often to make sure they are not affecting the laser scanners.
- **The indicator lights are flashing very fast**
  This sometimes occurs if the robot computer has not been connected to the power board correctly. Check the connection from the robot computer to the power board, and make sure the cable is intact.

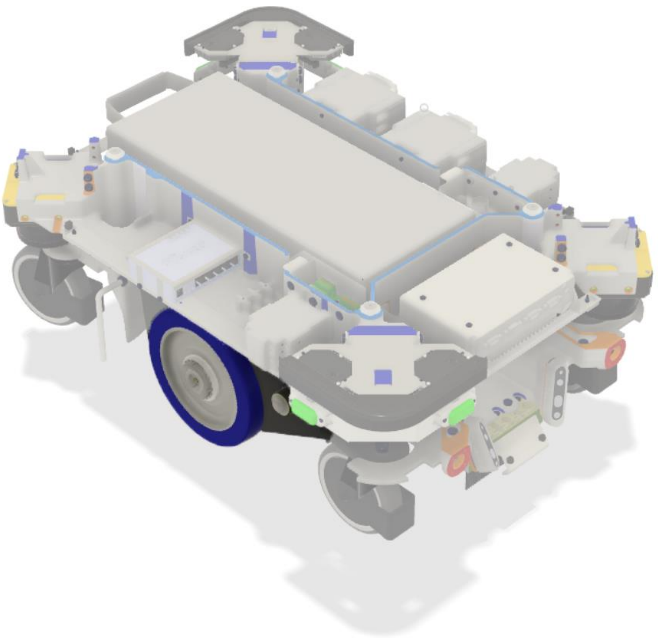
3.4 Drive train



There are two drive trains in the robot; one on each side. Each drive train consists of a drive wheel, a motor, a mechanical brake, a gear box, and two motor encoders (one for the safety system and one for the control system). The drive train contains the components used to make the robot move.

Location and connection

The drive trains are mounted to the robot bogies. There are bogies on the left and right side of the robot.



The motor and the controller encoder are connected to the motor controller carrier board, the safety encoder is connected to the safety PLC, and the mechanical brake is connected to the motor controller carrier board via the mechanical brake relay controlled by the Manual brake release switch. The mechanical brake is powered directly from the power board, whereas the motors and encoders are powered via the motor controller carrier board.

How it works

When the motors receive power from the motor controller carrier board, they rotate the gears in the gear box. The gears rotate the shaft of the drive wheel, making the drive wheel rotate.

While the motors run, the encoders measure the number, direction, and speed of rotations and translate this to the velocity and the distance the robot has traveled. This data is used by the safety PLC to determine whether the robot is driving outside of the safety limits, and the data is used by the motor controller to determine whether the correct amount of power is being delivered to the motors.

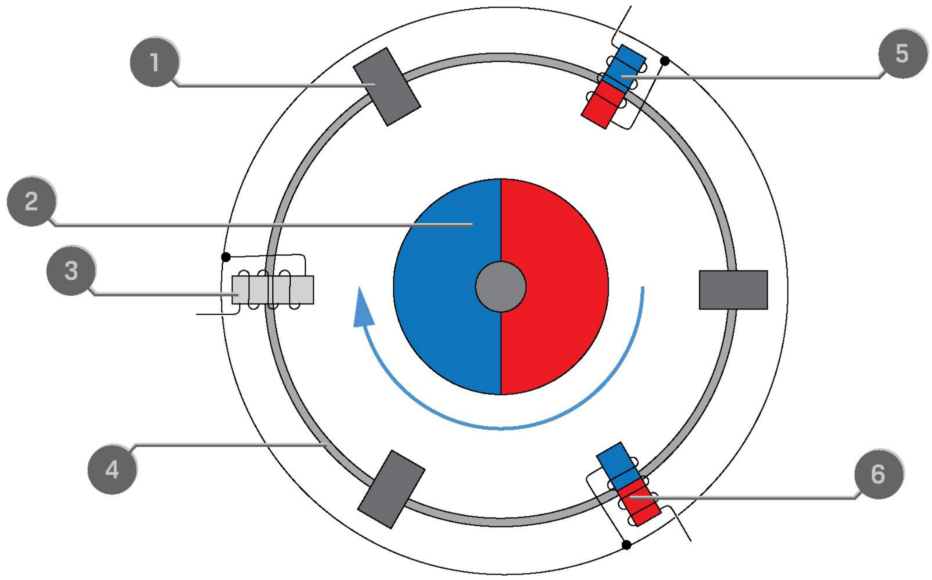
Motors

The two motors are brushless DC motors. A brushless motor consists of two main parts: a rotor and a stator.

The rotor is the center piece in the motor that rotates. It has two magnetic poles.

The stator is the surrounding frame containing the following two components to make the rotor rotate:

- **Electric coils**
  Coils are mounted to the stator. Electric current travels through the coils to create magnetic fields. The current is controlled to travel in either direction to create alternating magnetic fields that make the rotor rotate.
- **Hall sensors**
  Three hall sensors are used to measure the magnetic fields to determine whether the rotor is rotating as intended and to control when the coils should be activated.



Pos.	Description	Pos.	Description
1	Hall sensor	2	Magnetic rotor
3	Inactive coil	4	Stator
5	Coil	6	Reversed coil

Dynamic brake function

The coils are both used to rotate the rotor and to slow it down when current is no longer passing through them. This is known as the dynamic brake function. It is initiated by switching the SS1 relays so power is no longer delivered to coils but instead absorbs the remaining rotational energy in the rotor. When the coils are not powered, the changing magnetic field from the rotor instead acts upon the coils to create a current.

Mechanical brakes

The mechanical brakes are engaged as soon as the robot stops moving. Unlike the dynamic brakes, the mechanical brakes block the wheels from rotating physically. For this reason, the mechanical brakes are only used once the robot has stopped to prevent the robot from moving again until the robot control system and safety system release the brakes—see Motor and brake control system on page 39.

Because the brakes are only activated when the robot stands still, they do not wear down over time. The only case where the mechanical brakes are engaged while the robot is in motion is when the dynamic brakes fail to stop the robot within the predefined expected time for the robot to stop safely.

If your robot often reports that the dynamic brakes failed while braking, this means the mechanical brakes have been engaged while the robot was moving. If this happens too often, the mechanical brakes will be worn down.

The mechanical brakes release only when they receive 48 V. If they do not receive enough power, they engage immediately. This ensures that the robot cannot be pushed or pulled easily when it is turned off and that if a cable connection to the mechanical brakes is disconnected, the robot is stopped and remains stopped until the connection to the brakes is fixed.

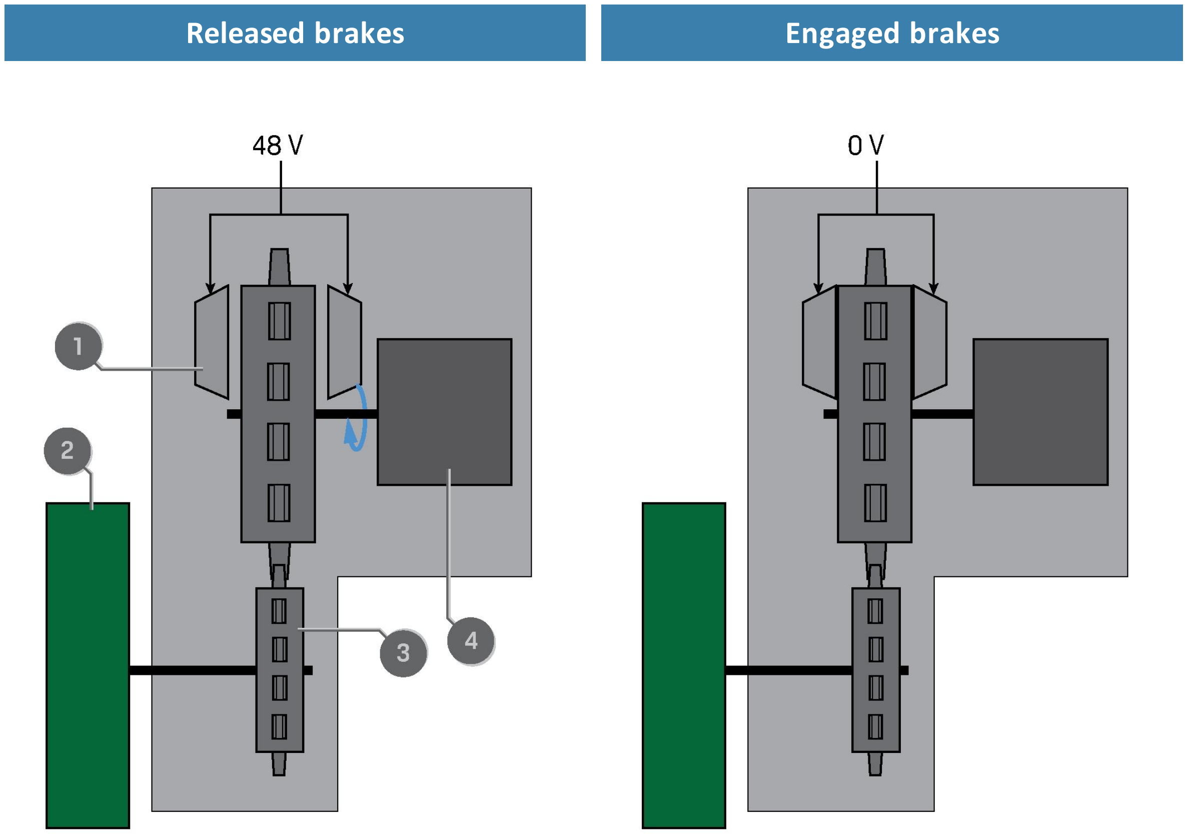


Figure 3.7. When the brakes (1) receive 48 V, they are released, and the motor (4) can rotate the gears (3) so the drive wheel (2) can move the robot forward. When the brakes do not receive enough power, they engage to stop the motor from rotating the gears.

Encoders

The encoders are electromagnetic devices that count the number of revolutions in the motor and in which direction the motors are rotating. This is used to indicate how quickly the motor is rotating and in which direction. Each motor has a magnetic disk that rotates with the motor. The encoders measure the magnetic field from the disk and uses this to determine how quickly, in which direction, and how many times the motor has rotated.

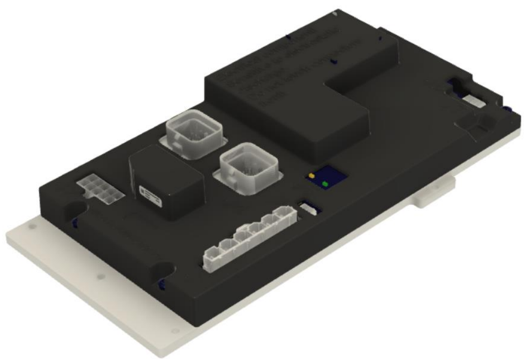
Common issues

- **The robot is reporting Hall sensor and encoder errors**
  The hall sensors and encoders have their own cable connections to the motor controller carrier board and safety PLC. Often if an error is reported regarding either of these, it is

worthwhile to investigate the cables. The error can also be a symptom of other faults in the motor and brake system, so after checking the encoder and hall sensor cables, inspect all other cables connecting the motor controller carrier board to the drive train.

- **The robot is reporting dynamic brake errors**
  The robot will report an error in the dynamic brakes if the robot does not stop before the set time limit. If the robot is not loaded according to the payload specifications, the robot may not stop within the expected time limit and will report an error in the dynamic brakes even though they are working as they should. Doing this repeatedly results in the mechanical brakes wearing down from being used in an unintended way.

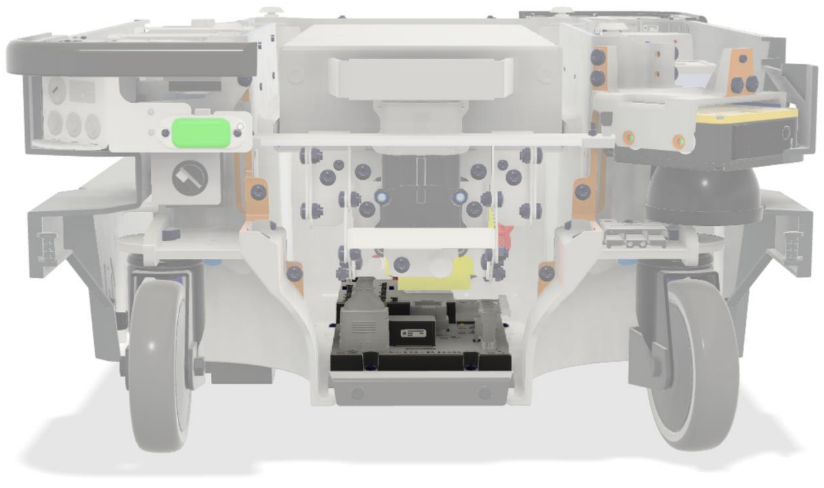
3.5 Power board



The power board is responsible for the overall power management of the system. It includes power supplies for individual subsystems as well as overload protection for the various interfaces. It also contains the inertial measurement unit (IMU).

Location and connection

The power board is located in the center of the robot and can be accessed by opening the rear maintenance cover, disconnecting the battery, and opening the battery hatch—see your robot's user guide. The power board is located beneath the safety PLC and can be unmounted by unscrewing the two front screws and releasing the side clasps.



The power board powers all electrical components in the robot. *Figure 3.8* shows which components the power board directly provides power to, and through which components it indirectly powers the remaining components.

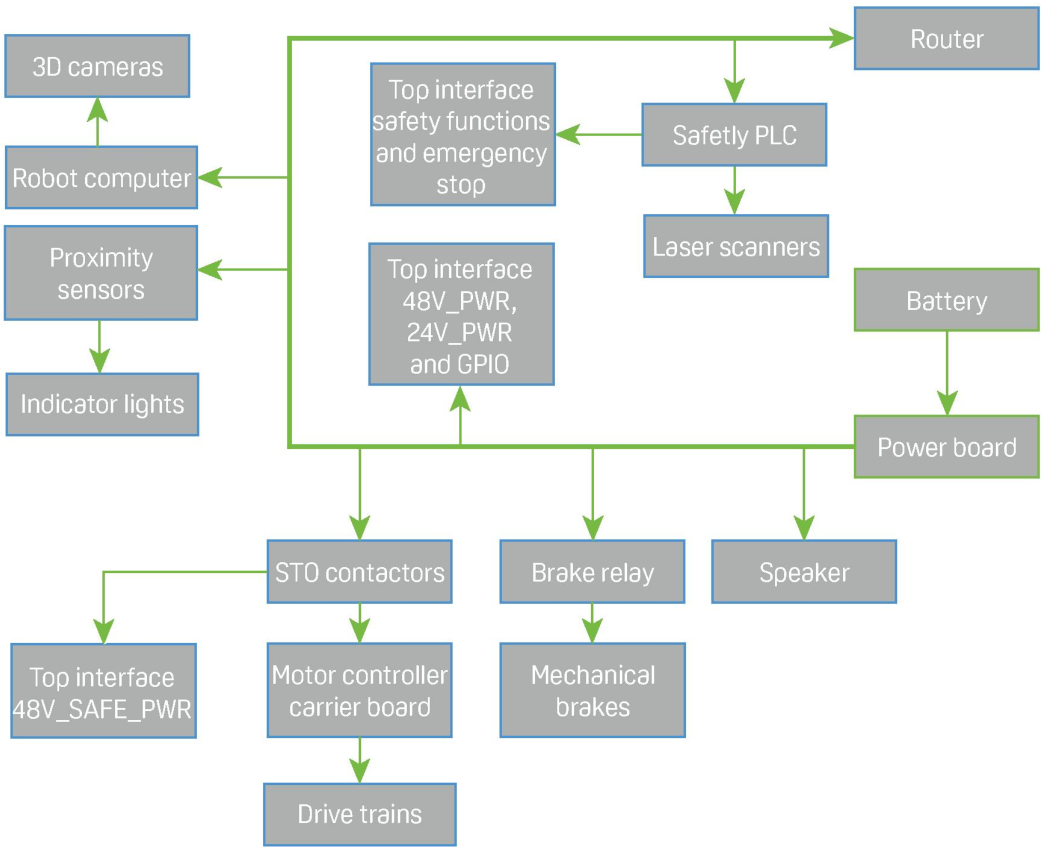


Figure 3.8. Overview of how power is delivered to the main robot components.

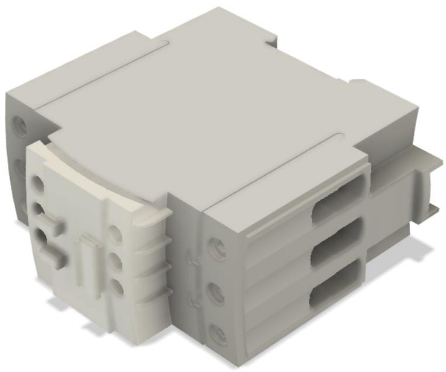
How it works

The power board has several power supply units within it to ensure that it can supply the correct amount of voltage and current to various robot components.

The power board is a closed component; if any connectors are not providing the appropriate power output, you must replace the entire power board.

To determine why a component is not receiving power, it is worthwhile to analyze from which component it directly receives power from—see *Figure 3.8*— and continue down the circuit to check whether the power supply is broken somewhere before the power board.

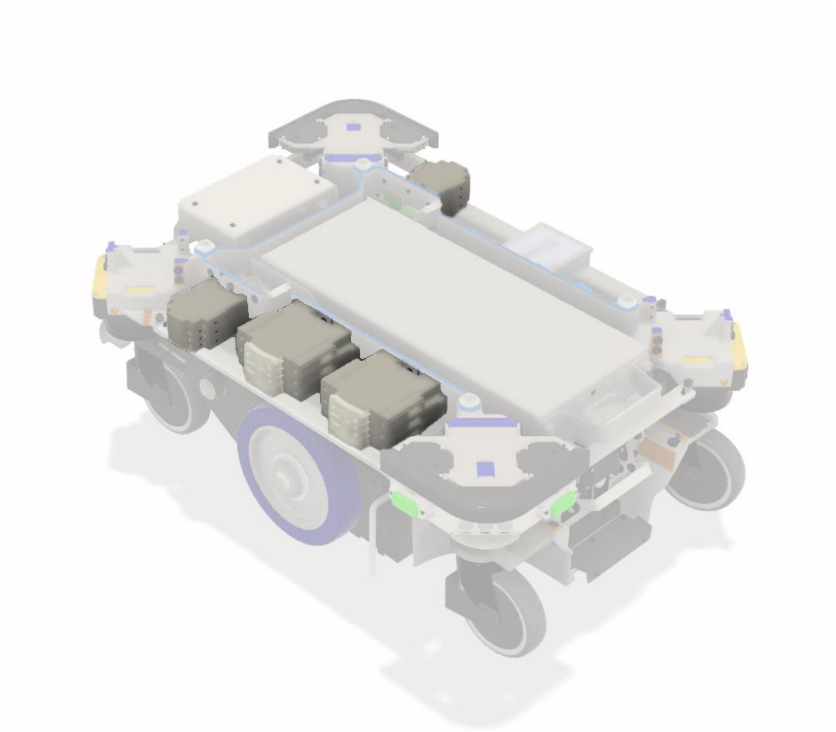
3.6 Safety contactors



The safety contactors are used to regulate the current to the actuators and top interface and to engage or release the brakes. Contactors can be either active or inactive. When they are active, they allow current to pass through one contact to another, and when they are inactive, the current cannot pass through. The contactors are controlled by the safety PLC, enabling it to cut power to all actuators and engage the brakes when a Protective or Emergency stop is triggered.

Location and connection

There are two pairs of contactors in MiR250: the STO contactors and the SS1 contactors. The STO contactors are located next to each other on the left side of the robot. The SS1 contactors are placed near the front on both sides of the robot.



The STO contactors are connected to the motor controller carrier board. When the STO contactors are deactivated, power is cut from the motors and the brake release, preventing the robot from moving.

The SS1 contactors are each connected to one of the motors. They are used to short circuit the motors to activate the dynamic brake function.

All contactors are controlled by the safety PLC. The STO contactors also send a feedback signal to the safety PLC to signal when the contactor has been switched successfully.

How it works

Contactors are electronically operated switches that either connect or disconnect the current between two contacts. The switch changes position using electromagnetism. Within a contactor, there is a coil that current passes through to create a small magnetic field that either pulls or pushes the switches so the contacts are connected.

When the coil does not receive current, the switches return to a default position where the contacts are not connected and current cannot pass through.

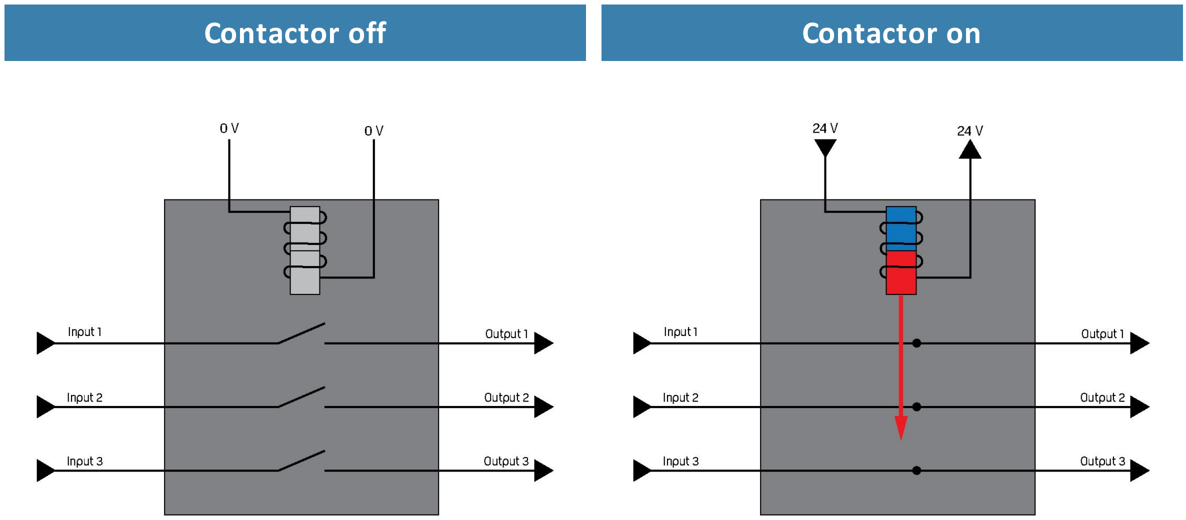


Figure 3.9. When the coil in a contactor receives 0 V, the contacts do no connect, and current can't pass through. If the coil receives 24 V, the magnetic field it creates pushes the switches to the contacts connect.

STO contactors

The STO contactors are connected to the safety PLC in two circuits.

One circuit is used to control the coil so the safety PLC can cut the power to the motor controllers and the brake release. The coil receives 24 V whenever the robot is in an operational state, allowing current to pass through to the motors. As soon as a Protective or Emergency stop is triggered, the coil does not receive any power, and the switch changes position so current cannot pass through. This cuts the power from the power board to the motor controller and the 48V Safe Power pin in the top power interface.

The other circuit is a feedback circuit that sends a constant 24 V until the contactor switches states where the signal briefly becomes 0 V. This signal only indicates whether the contactor switches states. It does not indicate the current state of the contactor.

When the robot starts up, the safety PLC runs a quick contactor check where it switches the state of the contactors and verifies that it receives the correct feedback.

There are two STO contactors located next to each other. They are connected in series to ensure redundancy in the safety system, meaning that if one of the STO contactor fails to switch to an inactive state, the other contactor works as a backup to cut the power connection.

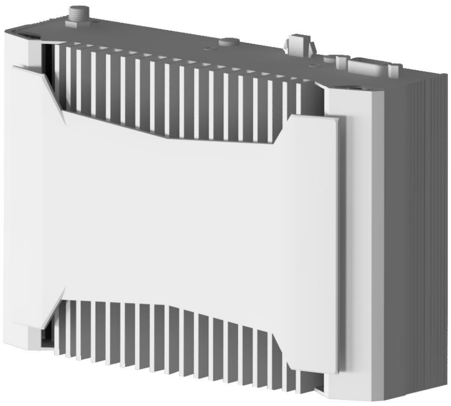
SS1 contactors

The SS1 contactors are only used in the circuit that connects the motor controller to the motors. They are used to engage the dynamic brake function in the motors by short circuiting the connection. They do not send any feedback signals to the safety PLC. Instead, the safety PLC monitors the safety motor encoders to check whether the SS1 contactors have engaged the dynamic brake function successfully to stop the robot.

Common issues

- **The contactors will not switch even though they receive the correct signal for switching states**
  Mechanical contactors can occasionally get stuck and may just require you to gently tap the contactor on the side to release the switch. If this fixes the issue, but the issue recurs often, consider replacing the contactor.
- **The safety system reports a feedback issue with the contactors**
  This issue may occur if either the contactors or the connections to the contactors are faulty. Check the cable running from the safety PLC to the faulty contactor. If they appear fine, and measure 24 V to and from the safety PLC, you may need to replace the PLC module. If 24 V is delivered to the contactor but does not return to the safety PLC, you must replace the contactor.
- **The robot does not brake fast enough and reports an issue with the SS1 contactors or dynamic brakes**
  This error occurs if the robot does not stop in the expected time limit. This can happen if you have exceeded the total payload or if the center of mass of the payload is outside the specifications.

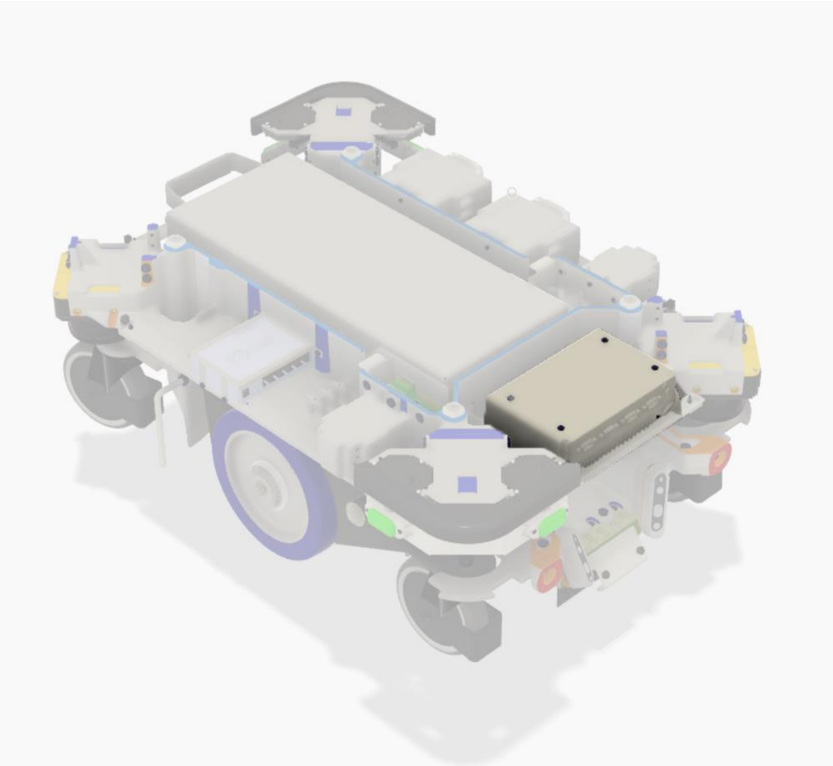
3.7 Robot computer



The robot computer is the main processing unit of the robot. It is responsible for collecting data from other robot components and propagating it to the robot interface or a connected MiR Fleet, for calculating global and local paths for the robot to follow based on sensor data and user input, and for distributing data correctly to other robot components.

Location and connection

The robot computer is located behind the front cover of the robot.



It connects to the motor controller carrier board and safety PLC to both send and receive data.

The computer also connects to all of the sensors on the robot (except the encoders) to receive environmental data.

How it works

The robot computer runs a Linux system where MiR's software package is installed. MiR's software is created on a ROS framework, consisting of various nodes for different software tasks. When the robot is turned on, the robot computer immediately begins running the necessary nodes to start up the robot components correctly.

Common issues

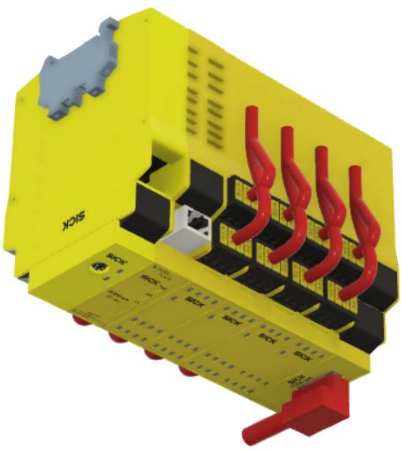
If the computer is not working or cannot be connected to, you cannot access the robot interface. This can either caused by be a problem with the connection from the router to the computer, the computer, or the router. You can check that both components are receiving power, since they have diodes that light up when they are turned on and are receiving power. If they are not receiving power, there is likely an issue with the power board. If both components are powered, check the connection between them.

Often, there are no issues with the computer itself. In most cases, you should check the cable connection to the robot computer to ensure that all devices are connected correctly. If you can access the robot interface, you will receive any errors regarding missing data or lost communication, if there is a faulty connection to a component.

If you can turn on the robot, but the status lights continue to show a wavering yellow light indicating that the robot is starting up, there is an issue with the software startup process. Try turning the robot off and then on again. Otherwise, USB restore your robot as described in the how-to guides *How to USB restore MiR100/MiR200* or *How to USB restore MiR500/MiR1000*.

If your robot has important data that has not been saved to other robots or MiR Fleet, contact Technical Support for assistance in retrieving the data before USB restoring.

3.8 Safety PLC

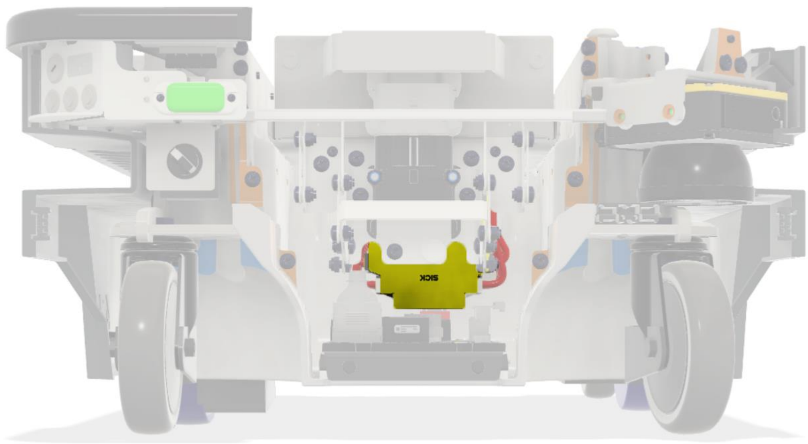


The safety PLC monitors and processes several inputs and outputs to ensure that the robot is only running when it is in a safe state. The safety PLC is responsible for registering the following:

- Triggering a Protective stop if the safety laser scanners detect an object within the active protective field.
- Triggering a Protective stop if any discrepancies are registered from the encoders relative to the expected response.
- Triggering a Protective stop if the relays or contactors are not functioning correctly.
- Triggering an Emergency stop if any Emergency stop button is pressed.

Location and connection

The safety PLC is located in the center of the robot and can be accessed by opening the rear maintenance cover, disconnecting the battery, and opening the battery hatch. The safety PLC is located above the power board and can be unmounted from the DIN rail by hand.



How it works

A PLC (Programmable Logic Computer) is a device that processes inputs to control certain outputs. In this case, the safety PLC consists of five modules: a CPU module, two modules for handling inputs and outputs, one motion controller module, and a gateway module for connecting devices.

CPU module

The CPU module contains the processing unit where the MiR safety software runs. The software dictates the output signals from the safety PLC based on the input signals.

Input and output modules

In this case, the safety PLC is connected to several I/O circuits that connect to the top module GPIO interface that can either send 24 V or 0 V to indicate either an active or inactive signal respectively. Certain signals result in the robot entering Protective or Emergency stop.

Signal name	Circuit description	Triggers
Test output 1	Provides 24 V test pulses to pin 1 in the Auxiliary safety function interface A.	NA
Test output 2	Provides 24 V test pulses to pin 1 in the Auxiliary safety function interface B.	NA
Safe guarded stop 1	Connects to pin 2 in the Auxiliary safety function interface A. Input for Safeguarded stop function.	Protective stop
Safe guarded stop 2	Connects to pin 2 in the Auxiliary safety function interface B. Input for Safeguarded stop function.	Protective stop
Shared E-stop in 1	Connects to pin 3 in the Auxiliary safety function interface A. Input for Shared emergency stop function.	Emergency stop
Shared E-stop in 2	Connects to pin 3 in the Auxiliary safety function interface B. Input for Shared emergency stop function.	Emergency stop
Reduced speed 1	Connects to pin 4 in the Auxiliary safety function interface A. Input for Reduced speed function.	Reduces speed to 0.3 m/s
Reduced speed 2	Connects to pin 4 in the Auxiliary safety function interface B. Input for Reduced speed function.	Reduces speed to 0.3 m/s
Locomotion 1	Connects to pin 5 in the Auxiliary safety function interface A. Output for Locomotion function.	NA

Signal name	Circuit description	Triggers
Locomotion 2	Connects to pin 5 in the Auxiliary safety function interface B. Output for Locomotion function.	NA
Shared E-stop out 1	Connects to pin 6 in the Auxiliary safety function interface A. Output for Shared emergency stop function.	NA
Shared E-stop out 2	Connects to pin 6 in the Auxiliary safety function interface B. Output for Shared emergency stop function.	NA

Table 3.1. I/O connections to the Auxiliary safety functions interface—see Safety system on page 22.

Motion controller module

The motion controller module is connected to the motor encoders. It registers the current speed of the robot, determining which protective field should be active, and monitors whether the data from the encoders are consistent with the expected data and are below the predefined safety limits.

If the data received from the encoders indicates that the robot has lost traction, is driving too fast, or that the encoders are faulty, the robot enters Protective stop.

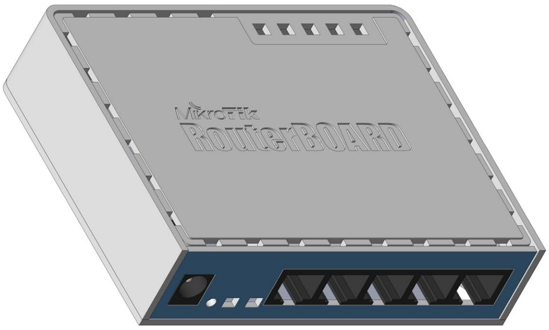
Gateway module

The gateway module enables data from the safety laser scanners to be interpreted by the safety PLC. Is also hooks up the PLC to the router to send data to the robot computer regarding errors displayed in the robot interface.

Common issues

Many errors in the safety PLC are displayed in the robot interface as en error in the safety system. These can be viewed under **Monitoring > Hardware health > Safety system**.

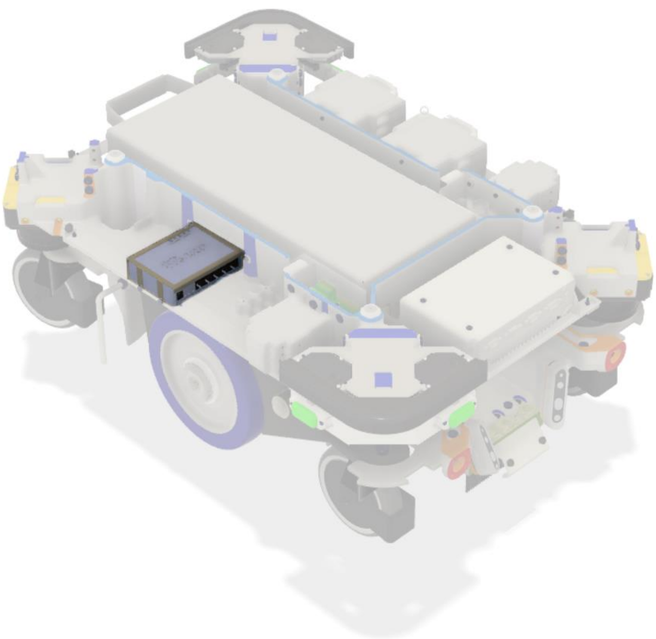
3.9 Router and access point



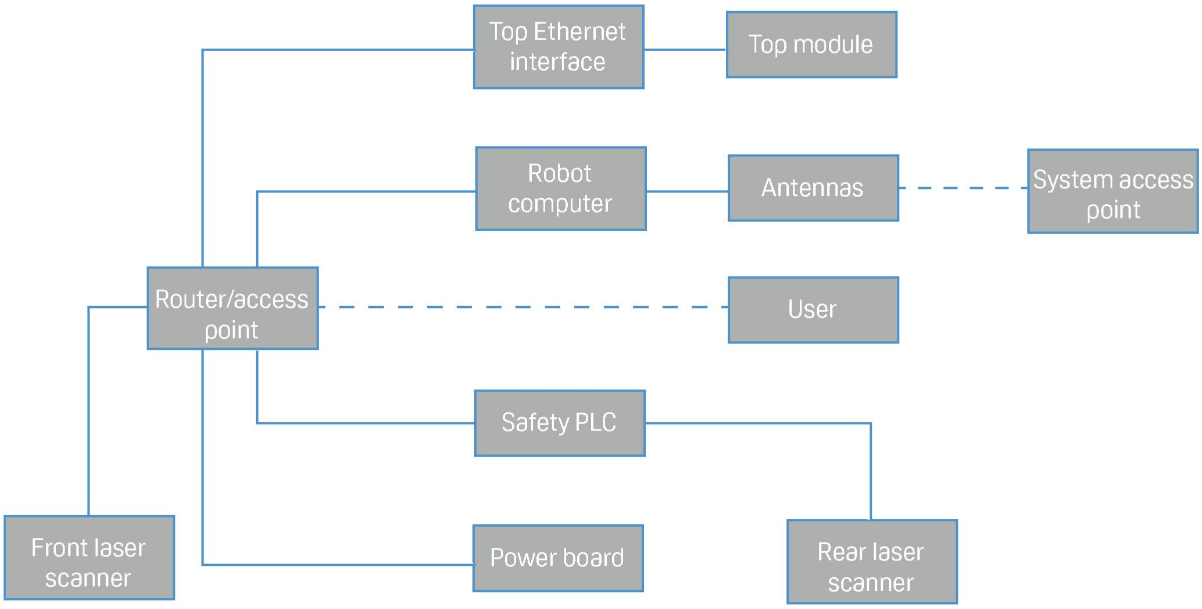
The router enables communication through Ethernet between various robot components and also contains a wireless access point that users can use to connect to the robot interface and robot components wirelessly.

Location and connection

The router is located on the right side of the robot.



It connects to the robot computer, safety PLC, safety laser scanners, power board, and the top module Ethernet interface.



How it works

The router acts as a communication hub between devices that routes data packets between the devices correctly. This is done using the IP addresses of the various devices.

This means that if any of the components connected to the router are unable to send and receive data to and from the other components, the router may be failing to correctly route the data.

Wireless access points and antennas

The wireless access point and antenna inside the router enable users to communicate with all the devices connected to the router. The access point emits a WiFi hotpot that users can connect to.

The two antennas on top of the robot connect directly to the robot computer. The antennas are used to connect the robot to an external wireless network, enabling the MiR robot to communicate with other devices connected to the same network.

The antennas translate electrical signals from the robot components into electromagnetic waves that propagate through the air and are measured and translated back into electrical signals by another antenna and access point.

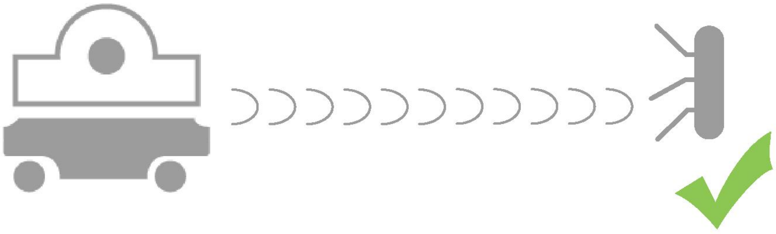


Figure 3.10. When the area between a robot and an access point is clear, the connection is better.

If the electromagnetic waves are blocked, the data cannot be picked up by the receiving antenna. For this reason, it is important to avoid too many solid objects between the robot's antennas and the user or network access point antenna.

Dense materials are often better a blocking WiFi signals.

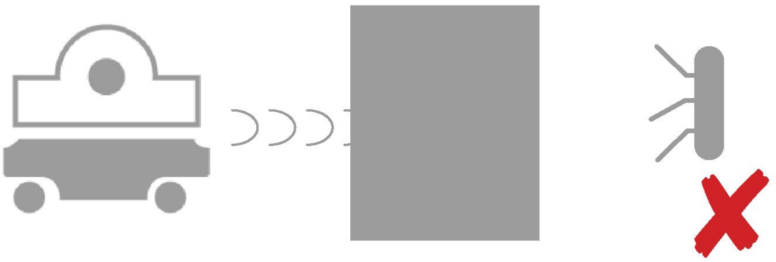


Figure 3.11. Obstacles between the robot and an access point will block the signal between them.

Other devices that emit WiFi signals at the same frequency as the robots can also interfere with the communication signal between the robot and the access point. If possible, make access points in the same area use different WiFi channels, and avoid installing devices that emit radio frequency in the areas where the robot is operating.

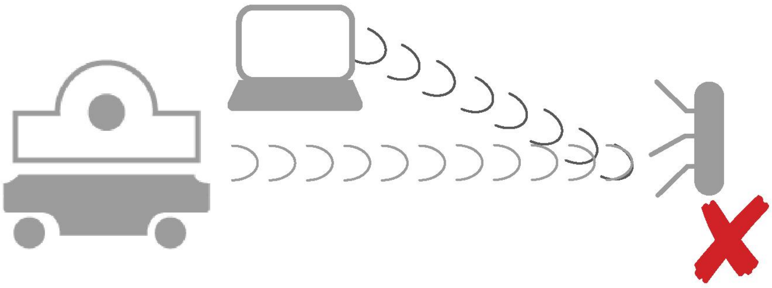


Figure 3.12. Other devices that also send WiFi signals on the same frequency or generate radio waves can interfere with the signal, also causing communication failure.

Common issues

- **Often losing connection to the robots**
  If the robots often disconnect from the network they are supposed to be connected to, it is often due to a poor network setup. We have collected many of the best practices you can apply to improve your wireless network in the *MiR Network and WiFi Guide* which can be found on the MiR website with the manuals for our robots and MiR Fleet.