

## Mobile Robot LD

### Safety Guide



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## Revision History

Revision code	Date	Revised Content
01	January, 2017	Original release
02	January, 2018	<ul style="list-style-type: none"> <li>• Changed upper battery storage temperature from 60°C to 45°C.</li> <li>• Added LD-90x (with LD-130CT) as being difficult to move with brake released.</li> <li>• Added Revision History. Revised definitions for Danger, Warning, and Caution to align with Omron's standards.</li> <li>• Added Burn, Entanglement, and Explosion alerts, as well as Special Information.</li> </ul>
03	August, 2018	<ul style="list-style-type: none"> <li>• Added Chapter: Safety Function Description.</li> <li>• Added Fire Hazard, Tip Hazard, and ESD Risk to Alerts and Special Information chapter.</li> <li>• Removed Explosion Risk.</li> <li>• Replaced Explosion with Fire in Operational Safety chapter.</li> <li>• Minor typo fixes.</li> </ul>
04	February, 2019	<ul style="list-style-type: none"> <li>• Added Enterprise Manager 2100 whenever the Enterprise Manager 1100 was mentioned.</li> <li>• Replaced "AIV" with "AMR".</li> </ul>
05	June, 2019	<ul style="list-style-type: none"> <li>• Revised Fleet definition in Definitions section in Chapter 2.</li> <li>• Removed Enterprise Manager (1100 or 2100) from Definitions section in Chapter 2.</li> <li>• Added EM2100, FLOW Core, Fleet Operations Workspace (FLOW), and Fleet Manager to Definitions section in Chapter 2.</li> <li>• Replaced Enterprise Manager with Fleet Manager where applicable.</li> <li>• Added laser emitter icon and meaning to Chapter 1: Alerts and Special Information.</li> <li>• Replaced all "Omron Adept Technologies, Inc." with "Omron Robotics and Safety Technologies, Inc.", and where applicable only mentioned Omron instead of full "Omron Robotics and Safety Technologies, Inc.".</li> <li>• Updated Techpubs email address to Techpubs@omron.com. It was previously Techpubs@adept.com.</li> <li>• Replaced "Omron Support" with "Omron Representative" throughout the manual.</li> <li>• Revised the IMPORTANT note in Avoidance section in Chapter 2.</li> <li>• Replaced "LD Platform" with "AMR" in User's Responsibility section in Chapter 2.</li> <li>• Replaced "LD Platform" with "AMR" in Qualification of Personnel section in Chapter 2.</li> <li>• Added the word "Robot" to Table 3-2, row SF5, column "what is controlled".</li> </ul>

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Revision code	Date	Revised Content
		<ul style="list-style-type: none"><li>• Replaced Mobile Robot Software Suite with MobilePlanner in Configurable Warning Buzzer section in Chapter 2.</li></ul>

# Chapter 1: Alerts and Special Information

## Alert Levels

There are three levels of alert notation used in our manuals. In descending order of importance, they are:



**DANGER:** Identifies an imminently hazardous situation which, if not avoided, is likely to result in serious injury, and might result in death or severe property damage.



**WARNING:** Identifies a potentially hazardous situation which, if not avoided, will result in minor or moderate injury, and might result in serious injury, death, or significant property damage.



**CAUTION:** Identifies a potentially hazardous situation which, if not avoided, might result in minor injury, moderate injury, or property damage.

## Alert Icons

The icon that starts each alert can be used to indicate the type of hazard. These will be used with the appropriate signal word - Danger, Warning, or Caution - to indicate the severity of the hazard. The text following the signal word will specify what the risk is, and how to avoid it.

Icon	Meaning	Icon	Meaning
	This is a generic alert icon. Any specifics on the risk will be in the text following the signal word.		This identifies a hazardous burn risk.
	This identifies a hazardous electrical situation.		This identifies an entanglement risk.
	This identifies a hazardous fire risk.		This identifies an ESD risk.
	This identifies a tip hazard.		This identifies a laser emitter eye damage risk.

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## Special Information

There are several types of notation used to call out special information.

**IMPORTANT:** Information to ensure safe use of the product.

**NOTE:** Information for more effective use of the product.

**Additional Information:** Offers helpful tips, recommendations, and best practices.

**Version Information:** Information on differences in specifications or compatibilities of different versions of hardware or software.

## Chapter 2: Operational Safety

### 2.1 What to Do in an Emergency or Abnormal Situation

Press any E-Stop button (a red push-button on a yellow background) and then follow the internal procedures of your company or organization for an emergency or abnormal situation. If a fire occurs, use a type D extinguisher: foam, dry chemical, or CO<sub>2</sub>.

#### Releasing the Brakes

In case of an emergency or abnormal situation, the LD Platform AMRs can be manually moved. However, only qualified personnel who have read and understood this manual and the AMR user's guide should manually move the AMR. The brakes on the drive wheels can be released with the brake release button. This requires battery power, and an E-Stop must be pressed on the AMR.

**NOTE:** The LD-130CT and the LD-90x have a high gear ratio, and are very difficult to move, even with the brakes released.

#### Releasing an E-Stop



**WARNING: INJURY OR PROPERTY DAMAGE RISK:**  
If the AMR's E-Stop is triggered, ensure that the cause of the E-Stop is resolved, and all surrounding areas are clear and safe before releasing the E-Stop.

After the E-Stop button has been manually released, the AMR will wait until the motors are manually enabled.

Once the motors are enabled, the AMR will wait two seconds and then resume commanded motion, if there is adequate space to maneuver.

### 2.2 Definitions

**Platform:** The basic part of the robot, including the chassis, drive assemblies, suspension, wheels, battery, lasers, sonar, a core with gyroscope, navigation software, connectors for interfacing with and powering the payload structure, and platform covers.

**Payload Structure:** Anything you attach to the platform. This could be as simple as a box for holding parts or documents that you want transported, or as complicated as a robotic arm that will be used to pick up parts to transport.

**LD Platform OEM:** Either the LD-60 or LD-90 (or LD-90x) platform for 60 or 90 kg payloads.

**LD Platform Cart Transporter:** Either the LD-105CT or LD-130CT platform and cart. The platform has the HMI post (including extended arms) and the coupling plate attached, set up to transport a cart. This is also referred to as just a transporter.

**AMR (Autonomous Mobile Robot):** A platform with a payload structure attached to it. This is your complete mobile robot, which will transport your products, parts, or data.

**Fleet:** Two or more AMRs operating in the same area, and managed by the same Fleet Manager.

**EM2100:** Is a network appliance, with built-in processor, that runs the FLOW Core software.

**FLOW Core:** All of the software used by Fleet Operations Workspace. The software runs on a combination of the EM appliance(s), the AMRs, and the user's PC.

**Fleet Operations Workspace (FLOW):** Consists of one or more EM appliance(s), and the Flow Core.

**Fleet Manager:** The set of capabilities within the FLOW Core software that executes all fleet management activities. These include the management of maps, AMR configuration, job queue management, and traffic coordination. Fleet Manager runs on an EM2100 appliance.

## 2.3 User's Responsibilities

It is the end-user's responsibility to ensure that the AMRs are used safely. This includes:

- Reading the installation and operation instructions, as well as this Safety Guide, before using the equipment.
- Ensuring that the environment is suitable for safe operation of the AMR.  
If a fleet of AMRs (two or more) is installed, the a Fleet Manager must be used, unless no two AMRs will ever operate in the same area.
- Ensuring that anyone working with or near an AMR has been adequately trained, and is following the AMR user's guide and this guide for safe AMR operation.
- Maintaining the AMRs so that their control and safety functions are working properly.

### General Hazards

- Do not ride on the AMR.
- Do not exceed the maximum payload.  
Payload decreases as slope increases. Refer to the user's guide. The LD Platform Cart Transporter with a cart is not intended to operate on any slope.
- Do not exceed the maximum recommended speed, acceleration, deceleration, or rotation limits. See Center of Gravity in the AMR user's guide.  
Rotational speed becomes more significant when the payload's center of gravity is farther away (vertically and/or horizontally) from the platform's center of gravity.
- Do not drop the AMR, run it off a ledge, or otherwise operate it in an irresponsible manner.
- Do not allow the AMR to drive through an opening that has an automatic gate/door unless the door and AMR are configured correctly with the Call/Door Box option.  
Refer to the LD Platform Peripherals Guide for details on the Call/Door Box.
- Do not get the AMR wet, or expose the equipment to rain or moisture.

- Do not continue to run the AMR after hair, yarn, string, or any other items have become wound around the platform's axles, casters, or wheels.
- Do not use parts not authorized by Omron.
- Do not turn on the AMR without the antennas in place.
- Although the lasers used are Class 1 (eye-safe), we recommend that you not look into them.

### Falling Hazards



**WARNING: INJURY OR PROPERTY DAMAGE RISK:**

The AMR can cause serious injury to personnel or damage to itself or other equipment if it drives off of a ledge, such as a loading dock, or down stairs.

### Physical Barriers

The edge of a loading dock, the entrance to downward stairs, or any other substantial drop that is within the AMR's expected operating area should be physically marked so that the AMR's safety navigation laser will see the barrier, and stop before reaching it. The AMR is designed to detect objects 200 mm tall, so the barrier must be at least that tall. However, because of variations in floor flatness, we recommend a barrier that is 250 mm tall.

The barrier needs to be continuous at the site, so that the AMR can't drive around or through it to the dropoff.

### Logical Barriers

You should also use forbidden areas, sectors, or lines with several feet of safety zone (padding) before the actual dropoff, to ensure that the AMR will not try to drive there.

These need to be continuous at the site, so that the AMR can't plan a path to drive around or between them to the dropoff.

### Electrical Hazards



**WARNING: ELECTROCUTION RISK:**

The charging dock has AC power inside. Its covers are not interlocked.

- Do not use power extension cords with the charging dock unless properly rated.
- Never access the interior of the platform with the charger attached.
- Immediately disconnect the battery pack when removing the access cover.

Avoid shorting the battery terminals.

- Do not use any charging dock not supplied by Omron Robotics and Safety Technologies, Inc.
- If any liquid is spilled on the AMR, power off the AMR, clean up all possible liquid, and allow the AMR to air dry thoroughly before restoring power.

## Pinch Hazard

### Platform Covers



**CAUTION: PINCH RISK:**

The covers are held in place with strong magnets, which can pinch you if you are not careful. Follow the instructions in the AMR user's guide Maintenance chapter for handling covers.

## Magnetic Field Hazards

### Platform Covers



**WARNING: MAGNETIC FIELD, PERSONAL INJURY RISK:**

Magnetic fields can be hazardous to medical implant wearers. Medical implant wearers stay back 30 cm (12 inches) from the platform covers, which are held in place with strong magnets.

### Docking Funnel



**WARNING: MAGNETIC FIELD, PERSONAL INJURY RISK:**

Magnetic fields can be hazardous to medical implant wearers. Medical implant wearers stay back 30 cm (12 inches) from the underside of the platform, which is exposed during certain maintenance procedures for which the platform is tipped on its side.

## Other Hazards

**NOTE:** Hazards specific to maintenance are covered in Safety Aspects While Performing Maintenance on page 22.

## Qualification of Personnel

It is the end-user's responsibility to ensure that all personnel who will work with or near AMRs have attended an appropriate Omron training course and have a working knowledge of the system. The user must provide additional training as needed.

As noted in this and the AMR user guides, certain procedures should be performed only by **skilled** or **instructed** persons. For a description of the level of qualification, we use the standard terms:

- **Skilled persons** have technical knowledge or sufficient experience to enable them to avoid the dangers, electrical and/or mechanical
- **Instructed persons** are adequately advised or supervised by skilled persons to enable them to avoid the dangers, electrical and/or mechanical

All personnel must observe industry-prescribed safety practices during the installation, operation, maintenance, and testing of all electrically-powered equipment.



**WARNING:** Before working with the AMR, every entrusted person must confirm that they:

- Have the necessary qualifications
- Have received the guides (both this guide, and the AMR user's guide)
- Have read the guides
- Understand the guides
- Will work in the manner specified by the guides

### Payload Movement and Transfer

Monitoring and confirmation of the status of AMR payload movement and transfer to or from facility equipment is the user's responsibility.

Payload transfer problems must trigger an AMR E-Stop, preventing the AMR from moving until an Operator has resolved the problem and confirmed that the system is safe to use. This handling of payload transfer problems is the user's responsibility.

Providing an interlock between the AMR and facility equipment is the user's responsibility.

### Configurable Warning Buzzer

The LD Platforms have a configurable warning buzzer. It is the user's responsibility to configure this buzzer as appropriate for the facility in which the AMR will be operating. The buzzer will sound whenever the AMR is moving backwards or is turning. Other situations are configurable.

The buzzer is configured with MobilePlanner, using the following parameters:

**Version Information:** These parameters are only available with the MobilePlanner 5.0 and later.

- DriveWarningEnable

**NOTE:** If this parameter is set to False, the remaining parameters will not be displayed.



**WARNING:** Disabling the DriveWarningEnable parameter violates the JIS D 6802 standard. It is strongly recommended that you leave this set to True.

- DoNotWarnDrivingForwards  
Default: False

- DoNotWarnTurningInPlace  
Default: False
- DriveWarningLoudMilliseconds  
Default: 500. If DriveWarningQuietMilliseconds is 0, this parameter is irrelevant.
- DriveWarningQuietMilliseconds  
Default: 500. This is the length of time between warnings that the buzzer is silent. Setting this to 0 will cause a continuous warning.

## Multi-AMR Avoidance

When multiple AMRs are operating in the same operating space, they must be connected to a Fleet Manager via WiFi. The Fleet Manager helps prevent collisions by sharing AMRs' dynamic X, Y, Theta, size, and path-planning information with each other. AMRs then factor this data into their obstacle avoidance. This is not an interlocked method of preventing collisions. Ultimately, it is the end-user/integrator's responsibility to provide an interlocked method of preventing collisions.

**NOTE:** If two AMRs are approaching each other, neither will see the other because the incoming laser beams are interpreted as reflected beams. Because of this, any installation with more than one AMR working in the same operating space must be managed by the same Fleet Manager.

## Traffic Control

Use a *switchable forbidden area* on the map to prevent the AMR from entering an area based on the state of a discrete input. If this input is set from another vehicle, such as a forklift, while it is in that area, then the AMR will not be allowed to enter that area.

## Passing Lanes

Since the LD Platform technology does not use fixed tracks to guide the AMRs, the concepts of passing lanes and human safety areas are not relevant.

## 2.4 Risk Assessment

Safety standards in many countries require appropriate safety equipment to be installed as part of the system. Safeguards must comply with all applicable local and national standards for the location where the AMR is installed.

We have performed a Risk Assessment for Omron Robotics and Safety Technologies, Inc. AMRs, based on the intended applications of the AMR. The conclusions are summarized in this section.

### PL and PFH

The Performance Level (PL) calculation for safety functions of the Omron mobile robot products are based on the ISO 13849 standard. PL evaluation has been performed for the LD Platform OEM and LD Platform Cart Transporter including the supplied joystick.

The PL achieved and the Probability of Dangerous Failure per Hour (PFH) are calculated using SISTEMA as per ISO 13849-1, based on requirements of EN 1525 and UL 3100, for the following Safety Functions:

No.	LD Platform Function	PL Achieved	PFH [1/h]
1	ESTOP Logic - Speed Control. Forward and reverse control.	d	3.7E-7
2	Charge Contact Shutoff Circuit	b	1.1E-6
3	ESTOP Logic - Emergency Stop (HMI Front Panel)	d	3.4E-8
4	ESTOP Logic - User Emergency Stop (ESTOP)*	d	4E-7
	*The ESTOP pins on the User Interface connector are provided for use with a user-supplied external E-Stop. The user is responsible for calculating the overall PL and PFH, inclusive of user-supplied components, and performing a final risk assessment.		
5	LIDAR Velocity-Based Field Zone (Object Detection)	d	3.6E-8
6	ESTOP Logic - Manual (Joystick) Override	d	4.6E-8
The following safety function is applicable only to the Cart of the LD Platform Cart Transporter			
7	Cart Transporter Brakes*	b	1.1E-6
	*Cart Transporter brakes safety function not evaluated per UL 3100, only per EN 1525.		

### Exposure

Based on the risk assessment performed by Omron Robotics and Safety Technologies, Inc., the hazards associated with exposure to the AMR are minimal. However, these significantly rely on the awareness and training of the personnel around the AMR. Along with common sense, the following should be observed and practiced in order to avoid the minimal risks associated with exposure to the AMR.

- Do not ride on the AMR. Riding on the AMR or staying in the vicinity of the AMR for long periods (when ON or while charging) will expose you to the magnetic fields generated by the AMR.
- When the AMR is turning in place, while not moving forward, personnel must stay away from the AMR.

### Severity of Injury

The severity of injury depends on the type of payload and how the payload is integrated with the AMR. The severity of injury increases with the mass of the payload. Follow all industrial safety practices, such as use of steel-toe shoes around the AMR, and adding additional protection like side lasers, etc. depending on how the AMR is configured, to reduce any work-related injuries.

## Avoidance

The AMR will avoid obstacles unless modified or the safety systems are intentionally defeated. The AMR has a dual-channel, safety-rated laser to avoid obstacles.

**IMPORTANT:** The AMR observes safety navigation laser protection fields only at speeds greater than 300 mm/s (225 mm/s for LD-90 and LD-105CT models). Below this speed, the AMR still uses scanner data to detect and avoid obstacles. The safety bumper is active at all speeds. When the joystick is connected to the AMR, the operator must maintain control of the joystick and AMR at all times.

In addition, there are side lasers (standard on the LD Platform Cart Transporter and optional for the LD Platform OEM), bumpers on the LD Platform OEM, and SONAR that are used to prevent the AMR from driving into an object or person.

The LD Platform OEM and LD Platform Cart Transporter are fully-autonomous AMRs that, once configured, work around people in industrial settings with no intervention needed. Risks associated with integrating the AMR in the industry can be avoided, with a few basic steps.

- Only trained personnel, who understand what the AMR does, should be in the vicinity of the AMR.
- Audio and visual alarms are built into the AMR. Do not modify these unless necessary.
- Additional safety measures may be implemented as deemed necessary by the integrator after risk assessment is completed.

The AMR will come to a complete stop when the bumpers are hit with a force of at least 67 N.

## Safety System Behavior

The standard control system is fully-hardened to all EMI influences. In addition, software monitors and controls all dual redundancy safety-rated features for certainty.

## 2.5 Environment

It is the end-user's responsibility to ensure that the operating environment of the AMR remains safe for the AMR. If there are areas that are not safe for the AMR to travel in, those areas should be physically blocked off so that the AMR's scanning laser will detect the barriers, and the AMR will not attempt to drive there. These areas can also be blocked off with forbidden zones in the MobilePlanner software, but that should be in addition to physical barriers.

## Public Access

The LD Platform is designed for operating in indoor industrial or professional environments. It must be deployed in a manner that takes into account potential risks to personnel and equipment. The product is not intended for use in uncontrolled areas without risk analysis, for example, areas open to general public access. Use in such areas may require deployment of additional safety measures.

### Clearance

The LD Platform is designed to operate in an environment that is generally level and has no narrow doors or other restricted areas that are too narrow for the AMR to pass through. It is the user's responsibility to ensure that adequate clearance is maintained on each side of the AMR, so that a person cannot get trapped between the AMR and a wall or other fixed object. You should consult the applicable standards for your area. An exception to side clearance can exist at pickup and dropoff locations where the AMR must get close to conveyors or other fixed facility objects.

The primary direction of travel of the LD Platform is forward. When the AMR is turning in place, with no forward movement, the detection of an obstacle in its path of rotation will not trigger an E-Stop.



**WARNING: IMPACT INJURY RISK:**

Personnel who work with or around the AMR should not stand close to the AMR when it is turning in place (with no forward motion).

### Obstacles

If the AMR will be entering high-traffic areas, the user must take appropriate precautions to alert people in those areas that an AMR might enter. If the traffic consists of other machines, the user must adjust the AMR's and/or the other machine's parameters to reduce the risk of a collision.

## 2.6 Intended Use

The LD Platform is not intended for use in any of the following situations:

- In hazardous (explosive) atmospheres
- Uncontrolled areas, for example, areas open to general public access

Use in such areas may require additional safety measures, and a risk analysis

The LD Platform is designed for operating in industrial or professional environments. They must be deployed in a manner that takes into account potential risks to personnel and equipment.

- In the presence of ionizing or non-ionizing radiation
- In life-support systems
- In residential installations
- Where the equipment will be subject to extremes of heat or humidity
- In mobile, portable, marine, or aircraft systems

**NOTE:** The gyroscope used to assist in navigation in LD Platforms requires a stationary environment for optimum accuracy. Therefore, we do not recommend the LD Platform for use on a ship, train, aircraft, or other moving environment.



**WARNING:** The instructions for operation, installation, and maintenance given in this guide and the AMR user's guide must be strictly observed.

### **Non-intended Use**

Non-intended use of LD Platform AMRs can:

- Cause injury to personnel
- Damage the AMR or other equipment
- Reduce system reliability and performance

LD Platforms are intended for use on generally level floors, in wheelchair-accessible areas. Some LD Platforms, and any LD Platform Cart Transporter, will not fit through a standard-width ADA door or opening.

The body of the AMR must not come into contact with liquids. The drive wheels can tolerate damp floors, but the body of the AMR must remain dry.

If there is any doubt concerning the application, ask your local Omron Representative to determine if it is an intended use or not.

### **AMR Modifications**



**WARNING: INJURY OR PROPERTY DAMAGE RISK:**

Any change to the AMR can lead to loss in safety or functionality. It is the user's responsibility to perform a risk assessment for the whole (modified) AMR after any such changes and to confirm that all safety features of the AMR are operational.

### ***Payload Structure***

Attaching a payload that is larger than the footprint of the top of the platform or is outside the recommended CG may impact safety and functionality. It is the user's responsibility to perform a risk assessment and declare compliance for the whole (modified) AMR.

### ***Reprogramming or Reconfiguration***

Reprogramming or reconfiguration of the AMR safety components or parameters may impact safety and functionality. It is the user's responsibility to perform a risk assessment and declare compliance for the whole (modified) AMR.

### ***Sharp Edges, Protrusions***

Adding a payload can introduce sharp edges, corners, or protrusions to the AMR. It is the user's responsibility to perform a risk assessment and declare compliance for the whole (modified) AMR.

### **Manufacturer's Declaration**

The manufacturer's declaration applies to the AMR as it was placed on the market. It is the responsibility of the end user to verify compliance of the system in the final application inclusive of any modifications or additions.

## **2.7 Safety Aspects While Performing Maintenance**

### **Electrical Safety**



**DANGER: ELECTROCUTION RISK:**

During maintenance of the charging dock, disconnect the AC power cord to the charging dock. Keep it locked up until you are done with maintenance.



**WARNING: SHOCK RISK:**

During maintenance and repair, disconnect the battery of the AMR as soon as possible. Avoid shorting the terminals of the battery.

### **Other Risks**



**WARNING: BURN RISK:**

Parts of the drivetrain can get hot during operation. Allow the platform to cool down before servicing.



**CAUTION: ENTANGLEMENT RISK:**

Keep all body parts and clothing away from moving parts. E-Stop and power-down the robot before maintenance.

### **Battery Safety Information**



**WARNING: FIRE RISK:**

The mobile robots use lithium ion batteries. If a battery is ruptured and exposed to water, it may ignite or explode.

If the battery is found to be leaking, do not expose to water. If possible, submerge in mineral oil and contact your local Omron Representative.

Effective April 1, 2016, IATA regulations (UN 3480, PI 965) require that air-shipped lithium ion batteries must be transported at a state of charge not exceeding 30%. To avoid total discharge, fully charge the battery immediately upon receipt.

### **Safety Precautions**

- Store batteries upright at 5 to 45°C (41 to 113°F) for up to one month.  
Store at 20 to 25°C (68 to 77°F) for up to one year.
- Do not expose to water.
- In case of fire, use a type D extinguisher: foam, dry chemical, or CO<sub>2</sub>.

### **Maintenance**

Every six months:

- Inspect battery for damage or leaks.
- Place battery on a charger and allow to fully charge.



# Chapter 3: Safety Function Description

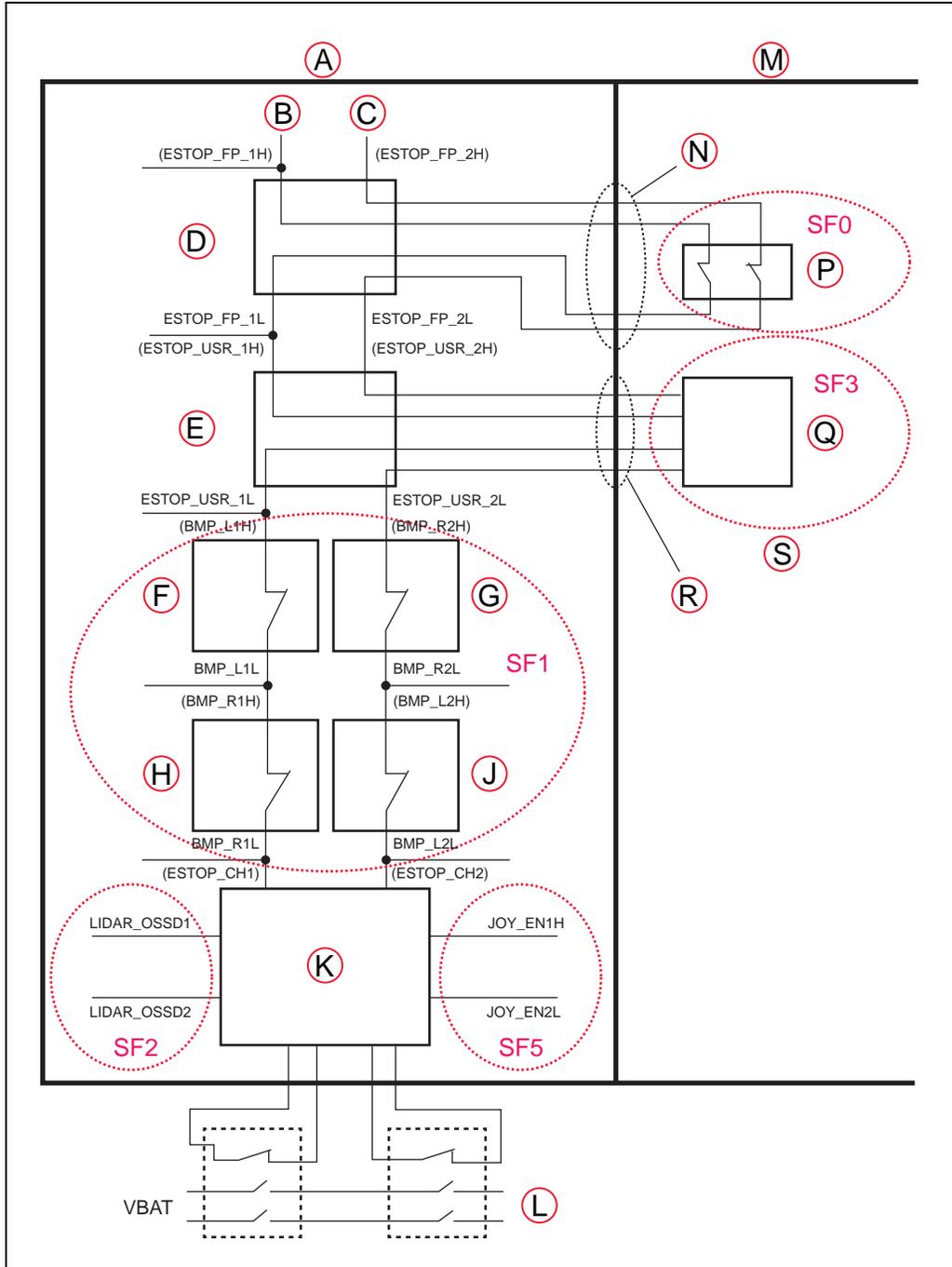


Figure 3-1. E-Stop Circuitry

Key	Meaning	Key	Meaning
A	Standard Circuits	K	E-Stop Relay Control Logic
B	E-Stop Source	L	High Power Amplifiers
C	Ground	M	User-Supplied Circuits
D	Front Panel E-Stop	N	HMI Connector
E	User E-Stop	P	Front Panel E-Stop
F	Bumper Left	Q	User E-Stop
G	Bumper Right	R	User Interface Connector
H	Bumper Right	S	Jumper closed when not used. MUST open both channels independently if used.
J	Bumper Left		

Table 3-1. Compliance, UL 3100, and ISO 13849-1 Functional Safety Information

Function #	Safety Function	PL	Cat	PFHd
SF0	ESTOP Logic - Emergency Stop	d	3	3.4E-8
SF1	ESTOP Logic - Safety Bumpers	d	3	3.6E-8
SF2	LIDAR Velocity-Based Field Zone (Object Detection)	d	3	4E-7
SF3	ESTOP Logic - User ESTOP	d	3	3.6E-8
SF4	ESTOP Logic - Speed control. Forward and reverse control.	d	3	3.7E-7
SF5	ESTOP Logic - Manual (Joystick) Override	d	3	4.6E-8

NOTE: SF4 is internal to the core, and is not shown in the preceding figure.

Table 3-2. Safety Function (SF) Descriptions

SF #	Internal?	Safety Function	Description	What is controlled
SF0	Internal	Emergency Stop	Pressing front panel Estop results in Cat 1 stop according to IEC 60204-1(NFPA 79) <sup>1</sup> . The vehicle will decelerate at a constant rate to complete stop, power will be removed from the left/right motor after a time delay and holding brakes will be engaged. SF0 has functional safety rating of Pld Category 3 <sup>2</sup> .	Robot
SF1	Internal	Safety Bumpers	The robot has left and right bumper switches, that are part of movable bumper, located in front of the robot. If the robot hits an obstacle the movable bumper will trigger E-stop condition, Cat 1 stop according to IEC 60204-1 (NFPA 79) <sup>1</sup> . When the vehicle is moving	Robot

SF #	Internal?	Safety Function	Description	What is controlled
			slower than 300 mm/s, the bumper signals will be ignored by the safety circuit (but react via software). SF1 has functional safety rating of Pld Category 3 <sup>2</sup> .	
SF2	Internal	LIDAR Velocity-Based Field Zone	The safety LIDAR has a total of 8 field sets. The field sets <sup>3</sup> correspond to field zones consisting of protective fields and warning fields. If the robot is driving faster than 300 mm/s with an active field set and an obstacle (like a person) intrudes into that field set, the LIDAR will trigger the LD E-STOP circuitry. This mechanism starts a controlled ESTOP event on the LD robot. SF2 has functional safety rating of Pld Category 3 <sup>2</sup> .	Robot
SF3	Logic and outputs INTERNAL	User E-Stop <sup>5</sup>	User supplied E-STOP button can be attached to the USER interface connector robot controller. Pressing the USER connected ESTOP results in Cat 1 stop according to IEC 60204-1 (NFPA 79) <sup>1</sup> . The vehicle will decelerate at a constant rate to complete stop, power will be removed from the left/right motor after a time delay and holding brakes will be engaged. SF3 has functional safety rating of Pld Category 3 <sup>2</sup> . If no user ESTOP is wired to the core then an ESTOP jumper must be attached to the connector. See user guide for specific information.	Robot
SF4	Internal	Speed control. Forward and reverse control.	The LD robot core <sup>4</sup> calculates robot speed from redundant wheel sensors (rotary encoders). Robot reverse speed is limited to 300 mm/s and forward speed is limited to 2100 mm/s. If the calculated speed exceeds the forward or reverse speed limits, the LD E-STOP circuitry is triggered. SF4 has functional safety rating of Pld Category 3 <sup>2</sup> .	Robot
SF5	Internal	Manual (Joystick) Bypass Detection	An external joystick is used in manual mode to drive the robot under operator control. A dual-channel trigger on the joystick bypasses the LIDAR safety zone detection allowing operation at speed under operator control. SF5 has functional safety rating of Pld Category 3 <sup>2</sup> .	Robot

<sup>1</sup> Stop Categories according to IEC 60204-1 (NFPA79)

- Category 0 and 1 result in the removal of drive power, with Cat 0 being IMMEDIATE and Cat 1 being a controlled stop (decelerate, then removal of power). E-Stop is either Cat 0 or Cat 1.

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<sup>2</sup> The PL achieved and the Probability of Dangerous Failure per Hour (PFH) are calculated using SISTEMA as per ISO 13849-1, based on requirements of EN 1525 and UL 3100, for the Safety Functions listed in Table 3-1. .

<sup>3</sup> According to EN 1525, the field sets only need to be active when the robot is driving faster than 300 mm/s.

<sup>4</sup> Robot core is a safety logic core designed per ISO 13849-1 recommendations for SRESW (Safety Rated Embedded Software, Clause 4.6.2).

<sup>5</sup> The ESTOP pins on the User Interface connector are provided for use with a user-supplied external E-Stop. The user is responsible for calculating the overall PL and PFH, inclusive of user-supplied components, and performing a final risk assessment.

**NOTE:** According to EN 1525, personnel detection means (example LIDARs) are not required or may be deactivated when a truck is working in a restricted zone or in the manual mode operation.

**NOTE:** According to EN 1525, when the truck is removed from the charging points, the charging connections shall be deactivated. The safety related parts of these systems shall be in accordance with EN 954-1 category 1.



**OMRON Corporation Industrial Automation Company**  
Kyoto, JAPAN

Contact: [www.ia.omron.com](http://www.ia.omron.com)

**Regional Headquarters**

**OMRON EUROPE B.V.**

Wegalaan 67-69, 2132 JD Hoofddorp  
The Netherlands  
Tel: (31)2356-81-300/Fax: (31)2356-81-388

**OMRON ASIA PACIFIC PTE. LTD.**

No. 438A Alexandra Road # 05-05/08 (Lobby 2),  
Alexandra Technopark,  
Singapore 119967  
Tel: (65) 6835-3011/Fax: (65) 6835-2711

**OMRON ELECTRONICS LLC**

2895 Greenspoint Parkway, Suite 200 Hoffman Estates,  
IL 60169 U.S.A.  
Tel: (1) 847-843-7900/Fax: (1) 847-843-7787

**OMRON ADEPT TECHNOLOGIES, INC.**

4550 Norris Canyon Road, Suite 150, San Ramon, CA 94583 U.S.A.  
Tel: (1) 925-245-3400/Fax: (1) 925-960-0590

**OMRON (CHINA) CO., LTD.**

Room 2211, Bank of China Tower, 200 Yin Cheng Zhong Road,  
PuDong New Area, Shanghai, 200120, China  
Tel: (86) 21-5037-2222/Fax: (86) 21-5037-2200

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Cat. No. I616-E-04

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