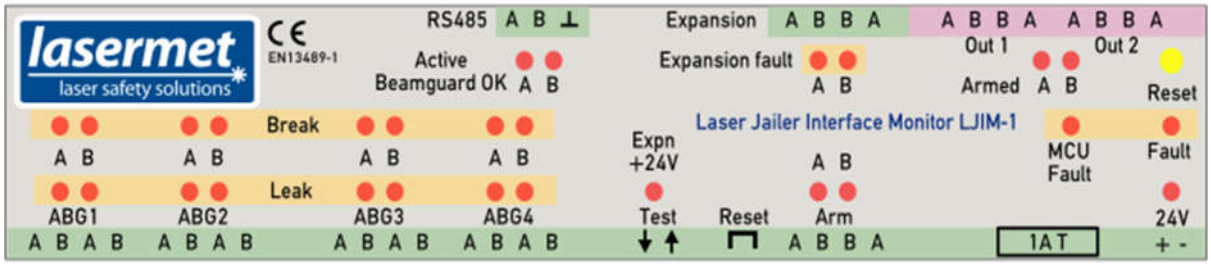
LASERMET
LASER JAILMASTER

INSTRUCTION MANUAL



FAIL SAFE LASER INTERLOCK CONTROLLER AND ACTIVE BEAMGUARD INTERFACE

LASERMET ICS-LJIM
Instruction Manual

Contents

1 Declaration of Conformity

LASERMET LIMITED

LASER JAILER INTERFACE MODULE

Part no. ICS-LJIM and ICS-LJIM-SO

DECLARATION OF CONFORMITY

This is to certify that the Laser Jail Master and Son of Laser Jail Master Expansion Board designated by Lasermet Part Number ICS-LJIM and ICS-LJIM-SO respectively has been tested in accordance with the following standards and found to comply.

Lasermet certifies that this product complies with the basic requirements for health and safety as provided by the following Standards:

Standards: EN ISO 13849-1:2015
Safety of Machinery – Safety-related parts of Control Systems
Part 1: General Principles for Design

Supplier:

Lasermet Limited
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137 Hankinson Road
Bournemouth
BH9 1HR
Dorset
United Kingdom

Country of Origin: England

Signed:

Paul Tozer
Managing Director

Date: 10 June 2019

2 Safety Warnings

This device is intended to be used as part of a safety system which may be used to protect personnel and equipment from possible injury, damage, or loss.

As such it must be installed and wired according to these instructions and tested by suitably qualified persons. No attempt may be made to tamper with the parts, open them, or use them outside of the parameters contained herein.

The units are only designed to be fixed to surfaces using their inbuilt fixing holes. They must not come into contact with each other or any other moving part when in use. The parts should never be subject to impact or mechanical strain.

Safety switches should never be defeated or bypassed. It is imperative that all steps are taken to ensure that any spare actuators are made unavailable, such that they cannot be used to defeat the switch or reduce the protection offered by the system in any way.

Glossary

EN	European Normalised (Standard)
ICS	Interlock Control System
ISO	International Standards Organisation
LED	Light-Emitting Diode
NC	Normally Closed
NO	Normally Open
OEM	Other Equipment Manufacturer
PL	Performance Level
PLC	Programmable Logic Controller
SIL	Safety Integrity Level
V	Volts
VDC	Volts (Direct Current)

3 Concept

The LJIM provides control of an interlock system intended to protect persons and equipment from accidental exposure to laser hazards caused by high power lasers. Its primary function is to actively monitor the walls and windows of the laser enclosure and to shut down the laser if these are compromised. This is achieved by using Lasermet's proprietary Active Beamguard (ABG) technology.

The LJIM system includes two modules, the main unit and the expansion unit. The main unit includes a laser interlock controller with two sets of interlock operator outputs and four separate ABG monitor circuits. The expansion unit can be connected to the master unit to add four more ABG monitor circuits to the system. Up to 31 expansion units can be connected to add more monitoring for complex systems.

Two external volt-free contacts are required to arm the system. These might be from a PLC, for example. When these contacts are both closed and all the necessary interlock input conditions are met (all ABG circuits valid), the controller will arm and enable the laser. If the Arm contacts are then opened the system will disarm.

If any ABG circuit is invalid (output contacts not closed) when the external Arm contacts are closed the controller will not arm. If the ABG output contacts then close, the controller will still not arm. This is to prevent an unexpected start-up of the laser. If the system fails to arm because of an ABG fault condition, the Arm request should be removed and the fault located before the laser can be reset.

The LJIM has a fully dual channel cross-checked architecture and when correctly wired can realise a system compliant with EN ISO 13849-1 up to performance level 'e'.

Two safety interlock outputs each rated at 4A resistive, 50VDC, are provided to enable the laser, operate door locks, or provide signals to a PLC. The interlock outputs are volt-free contacts. Each output comprises two contacts, one for each channel, operated by different relays. In the event of one contact failing to open, the other contact will open and the system is then disabled, preventing further use and maintaining safety.

The LJIM has a mismatch detector which disables the system in the event of a mismatch between the two safety circuits. This provides protection against single fault conditions that leave one channel stuck in the 'OK' state.

In addition to the safety-related circuitry, the LJIM has an RS485 serial connection intended for use in status and diagnostic monitoring. It functions as a Modbus RTU slave and can communicate with a Modbus master unit.

Lasermet provides a full range of equipment including interlock switches, illuminated warning signs, laser shutters, entry keypads with built-in fail-safe override timer, door locks, external power supplies etc. Some of these can be used to support the LJIM system. Full support, design and installation is available from Lasermet; please contact us for any queries. Contact details are given at the end of this manual

4 Summary of Evaluation of Compliance to EN ISO 13849-1:2015

To achieve a complete system performance level 'e' the system must be wired as described in this manual using suitably rated door sensors and measures taken to minimise the effects of common cause failures in the sensors and wiring which may be connected to the unit.

In service operation	365 days/year - 2 x eight-hour shifts
Functional demand on the controller	once per half hour

Main Unit Achieved Characteristics:

Architecture	Category 4
Performance Level (PL)	PL = e
PFH [1/h]	2.03×10^{-8}
MTTFd	126 years
Mission Time	20 years
Diagnostic Coverage (DC)	99% (HIGH)

Expansion Unit Achieved Characteristics:

Architecture	Category 4
Performance Level (PL)	PL = e
PFH [1/h]	9.81×10^{-9}
MTTFd	247 years
Mission Time	20 years
Diagnostic Coverage (DC)	99% (HIGH)

5 Installation

The LJIM is designed to be attached to a 35mm 'top-hat' style DIN rail inside a control cabinet. It should always be enclosed in a cabinet that requires use of a tool or key to open to prevent tampering and risk of touching live connections.

While the unit itself operates on 24V it is possible that higher voltages fed from other equipment may be present on its output contacts.

5.1 Positioning

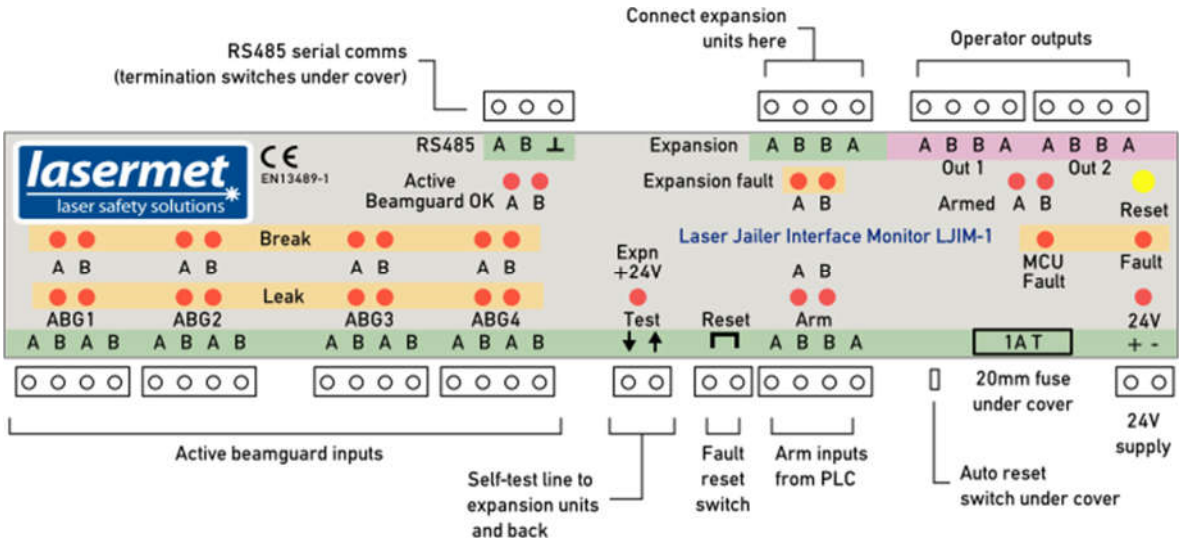
The LJIM should be mounted in a convenient position for wiring. It should be inaccessible by operators. It has indicator lights on its top surface which would normally only need to be observed by installation and maintenance personnel.

Provision should be made to prevent the unit from sliding along the DIN rail after fitting, for example by the use of end clamps or other equipment.

During installation, wired connections will need to be made from the LJIM to the monitored windows and wall panels required by the system. Allowance should be made for wire retention such as plastic slotted trunking running alongside both long sides of the unit.

5.2 Front Panel

The terminals are identified on the label on the top of the unit, as shown below. Holes in the label are shown in yellow and windows for LEDs are shown in red.



LJIM master top label showing terminal identification

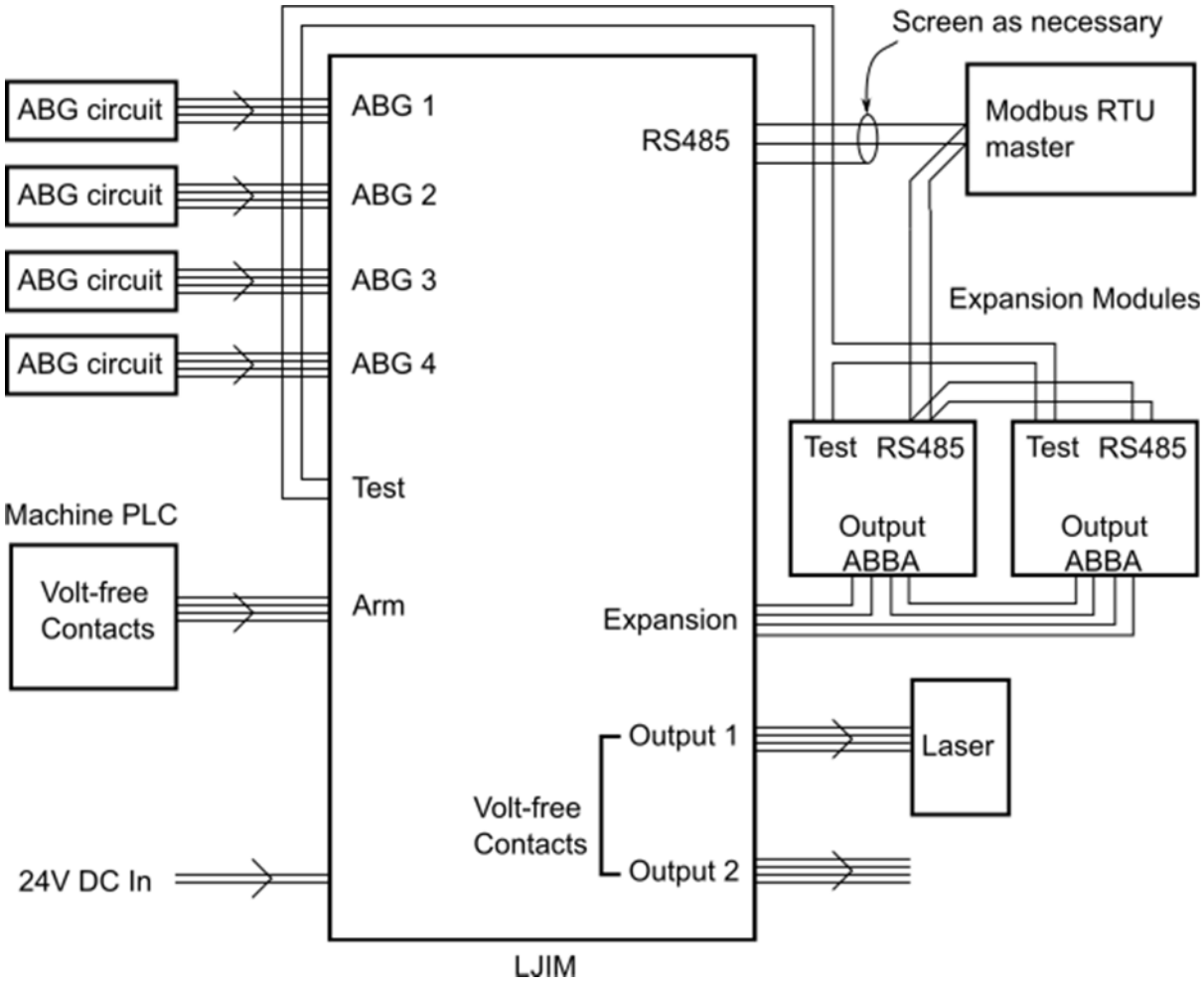
The ABG indicator LEDs show the status of each ABG monitor. The Break LEDs light when an ABG track has been broken. The Leak LEDs light when conduction has been detected from the track.

The dual-channel ABG inputs are wired A-B-A-B to maximise the detection of wiring errors. The other dual-channel inputs and outputs are wired A-B-B-A in line with Lasermet's normal practice.

Input signals are indicated by a green background, while the interlock outputs have a pink background. Fault status indications have an orange background.

6 Wiring

A typical wiring scheme for the LJIM is shown in the diagram. Be sure you know which configuration you require before you attempt to wire the unit. If you require further assistance, please call Lasermet technical help. Contact details are at the end of this manual.



Example overall wiring scheme

6.1 LJIM Inputs

Active Beamguard (ABG) inputs

Up to four dual-channel ABG circuits may be directly wired to the LJIM. These circuits consist of resistive tracking, either on wall panels or manufactured as part of enclosure windows.

A 4-way pluggable terminal block is provided for each circuit. One of the ABG tracks is wired to the 'A' terminals. The other track is wired to the 'B' terminals.

Circuits that are not used must be completed by wire links or resistors (e.g. a 4k7 resistor).

6.2 Interlock Operator Output Contacts

The LJIM has two dual-channel volt-free interlock operator output contacts (outputs 1-2) which may be used for various purposes including:

- Operating warning signs;
- Controlling beam shutters;
- Operating the laser's interlock input;
- Controlling door locks;
- Signalling the state of the controller to a PLC.

6.3 Beam Shutters

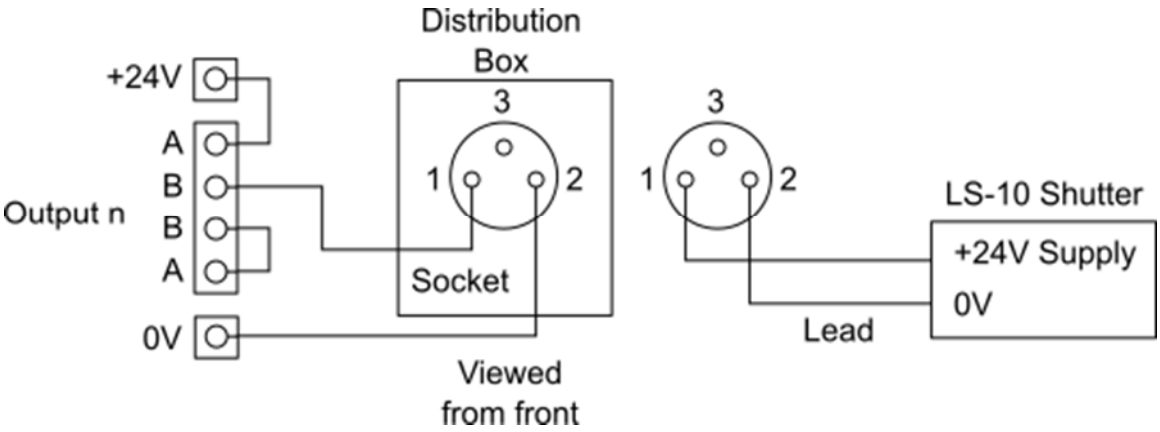
The LJIM may operate one or more beam shutters and one or more laser interlocks. For permanent fixed installations these may be directly wired to the LJIM. Where there is any possibility of the equipment being changed or moved it is often most convenient to be able to unplug the equipment.

Lasermet provide a range of small distribution boxes which allow for convenient positioning of wall or surface-mounted plugs for laser interlocks and sockets for shutters. The boxes are available with different combinations of plugs and sockets.

Modern industrial lasers are usually equipped with dual channel interlock inputs which may be directly connected to one of the dual channel outputs of the LJIM as described in this manual.

Many smaller lasers only have a single channel interlock input which can present problems if the safety system has to comply with ISO 13849 performance level 'e' since two methods of control are usually required. Some lasers have internal beam shutters which may be controlled by the LJIM. If the laser has two means of disabling, e.g. interlock and internal shutter, it is recommended that both are used. Otherwise it may be necessary to consider having an external shutter in addition to the laser's own interlock if a high safety integrity is required.

Lasermet's beam shutters are supplied with suitable leads to plug into the distribution boxes. Open-ended leads are provided for laser interlocks allowing the customer to fit the correct plug for his laser.



LS-10 Shutter

Use the above circuit. Note that older versions of LS-10 will only work off a 12VDC supply.

LS-20 and LS-200 Shutter

The LS-20 and LS-200 Shutters can use the above circuit. However, if monitoring of the shutter state is required it is recommended that the ICS-7-OEM controller, which has monitoring inputs, is used. Please contact Lasermet for further details.

6.4 Shutter with own Power Supply

For shutters that have their own power supply or are to be run from an existing supply, you can use one of the controller outputs to operate them. If the shutter requires a single contact to operate it, connect the A and B contacts of the controller output in series as shown in the wiring diagrams above for LS shutters, so that the shutter closes if either one or both output contacts open.

The connections should be arranged so that the shutter closes when the Interlock Operator contact opens. Any LJIM output used for shutters must not also be used for laser interlock control.

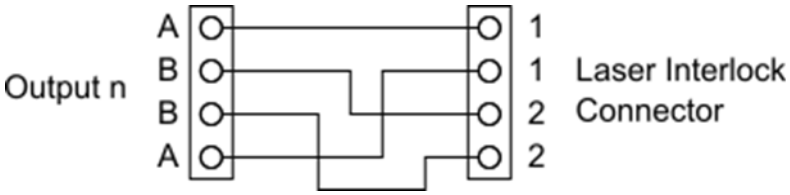
The contact is limited to 4A resistive load. If your shutter is solenoid-based it may need a protection diode fitted to prevent possible damage to the LJIM.

6.5 Interlock Connectors

Any of the LJIM output contacts may be used to operate a laser's interlock control, provided they haven't been used for any other purpose. The contacts are closed when the LJIM is armed. If there is more than one laser each must use its own output connector on the LJIM. Interlock sockets of several lasers must not be connected together.

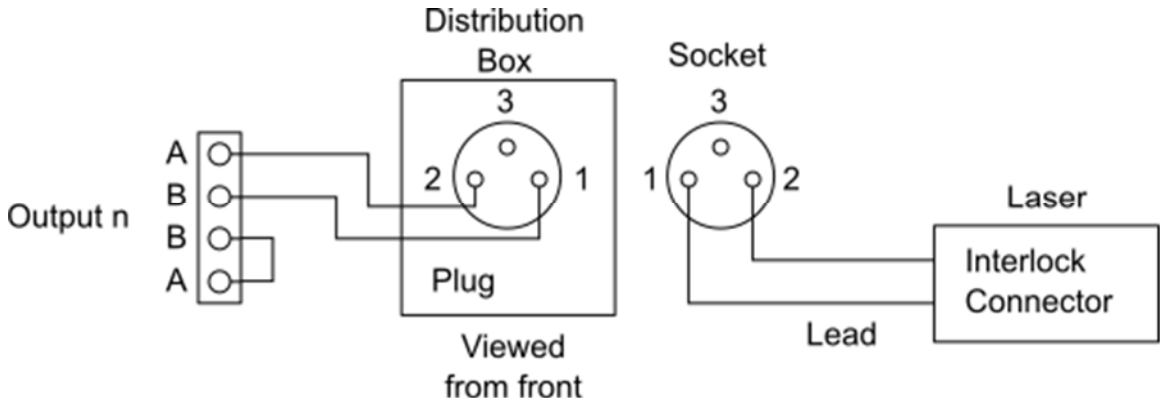
Where the controller is part of a fixed laser system it is usual to directly connect the two devices. For lasers with a single interlock channel use the following connections:

For lasers with dual channel interlocks use the following connections:



Where the laser may be removed from the system or exchanged, a Lasermet Distribution Box may be used to provide a connection point convenient to the laser. In this case for lasers with a single channel interlock, the A and B LJIM output channels are connected in series to pins 1 and 2 of the plug of the distribution box. See the diagram below.

Leads are available in various lengths to plug into the distribution box. The other end of the lead is unconnected to allow fitting of a plug suitable for the laser.

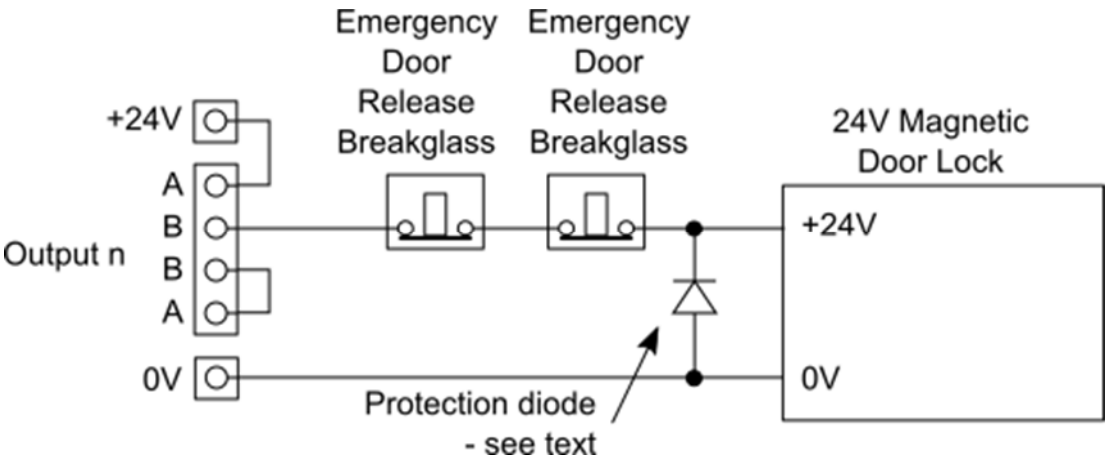


Most industrial lasers are now designed to be compliant with EN 13849-1 and feature two interlock input channels. This will require a distribution plug and socket with more connections.

6.6 Electromagnetic Door Locks

Use only fail-safe door locks provided by Lasermet (electric door strikes or maglocks). These will prevent access to the room while the laser is on while always allowing people to enter or leave the room in the event of a power loss. In order to ensure that people can always enter or leave the room in the event of an emergency it will be necessary to put an emergency stop or break glass switch near each door. If in doubt, call Lasermet technical help.

The door should be fitted with interlock switches so that the laser is disabled if a door is opened using the break glass switch.



Note that several maglocks can be wired in parallel from the same LJIM output provided the 4A maximum rating of the contact is not exceeded.

Some locks can be configured for 12V or 24V supply. They should be set for 24V operation and run off the 24V supply to reduce the current consumption to 0.25A per lock. To set the Maglock for 24V operation, open the terminal access cover on the lock. Remove the two black links from the circuit board and refit one of them across the middle two pins. Park the spare link with one side on one of the empty end pins so it is not lost. If in doubt, refer to the instructions supplied with the maglock.

In all cases a diode rated at 1A 50V or more must be wired directly across the terminals of each door lock. Lasermet's Maglocks usually have the diode fitted as standard, in which case it is essential that the supply is connected the right way round.

7 Expansion Units

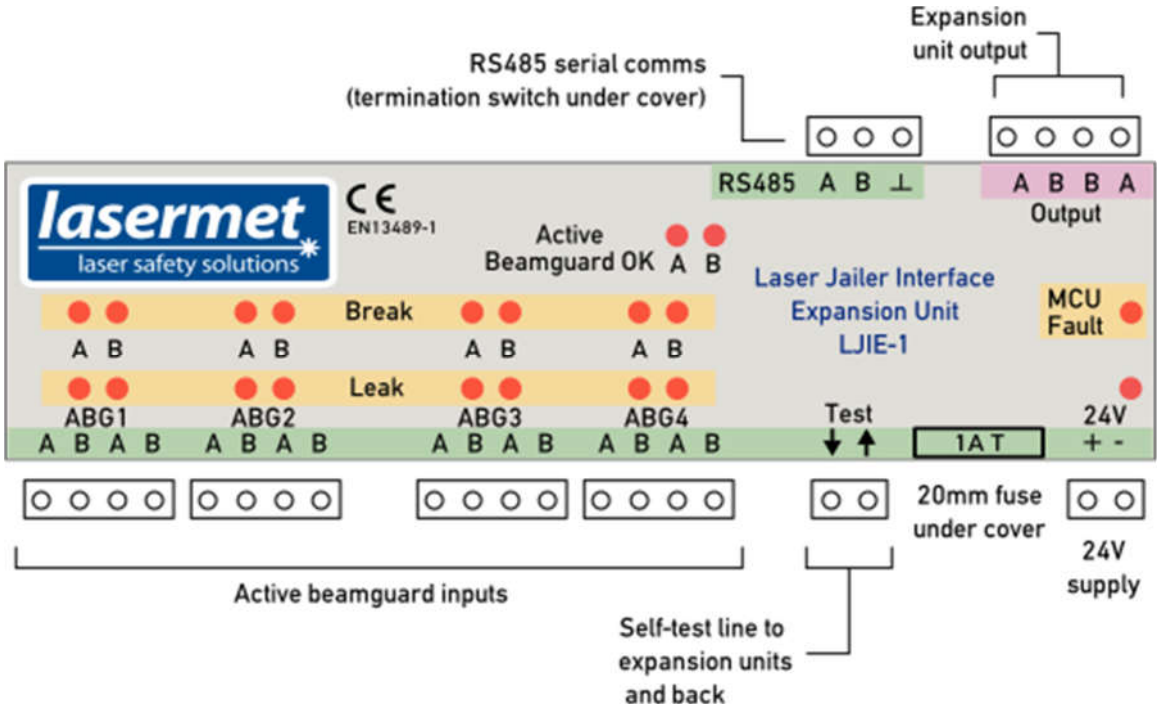
The LJIM can be connected to one or more Lasermet Laser Jailer Expansion Units which extend the main unit by providing more ABG monitor sections.

The signalling from the expansion units is provided by dual relay contacts. Essentially there is no limit on the number of contacts that can be connected, since the resistance of each individual contact is so low.

In order to test the operation of the monitors, a test connection is also provided. This is normally at +24V. When lowered to 0V, the expansion unit performs a self-test on each of its channels. If the self-test is successful, the output contacts are re-enabled. If the self-test fails, one of the contacts will remain open. The self-test is requested by the LJIM every time the unit is armed.

7.1 Front Panel

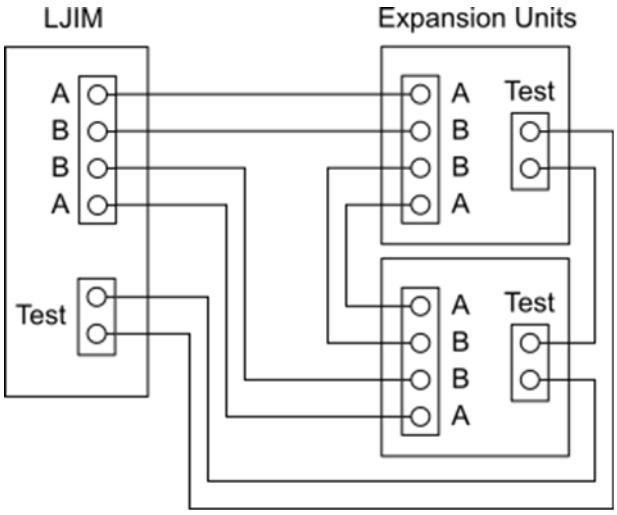
All of the terminals are identified on the label on the top of the unit, as shown below. Windows for LEDs are shown in red.



LJIE Laser Jailer Expansion Module

ABG input connections to the expansion unit are the same as for the main unit. The output connections are dual-channel volt-free contacts indicating that the ABG section is in the safe state.

7.2 Connections to Expansion Units



The diagram shows the connections for two expansion units. The dual-channel outputs are daisy-chained to the expansion input on the LJIM. Further expansion units can be added, keeping their output contacts in series. The test connections are made in the same manner. The two test terminals on the expansion units are actually connected together, but two terminals are provided to facilitate wiring as a continuous loop.

If no expansion units are used, the expansion inputs should be linked A-A and B-B, and the test terminals should also be linked.

7.3 Use of Expansion Units

Self-test Failures

The self-test function is included so that the LJIM and the expansion units can check the integrity of their own active beamguard monitoring circuitry. No faults would normally be expected. However, a fault on one channel of the active beamguard window or panel circuits may also lead to a self-test fail, which will lead to a mismatch indication even after the ABG fault has been cleared. In this case, cycling the test connection at the LJIM will clear the fault. When setting up the system for the first time, it may be desirable to put a switch in the test connection. Switching this off, then on, will re-run the self-test, clearing any fault indications for faults that have been fixed.

Monitoring Status of the Expansion Units

The expansion units have the same ABG status LEDs as the LJIM main unit, and also have LEDs to indicate the status of their output relay. In addition (see later section), the LJIM and expansion units can be connected to a Modbus master for centralised monitoring.

Extra Switches

Because the expansion connector requires volt-free contacts, extra switches can be included if required. This might be used, for instance to provide a key lock facility. Any switches used should be dual channel.

8 Mismatch Detector

The LJIM trips out and disables the laser when either of its two safety circuits opens. It is normal for both safety circuits to open more or less simultaneously.

If the second safety circuit does not open within a short time of the first (typically around 1.5 seconds), a mismatch is triggered and the 'Fault' light illuminates on the front panel. It is then not possible to arm the system.

Because the LJIM is intended for active beamguard systems, which are always dual channel, no provision has been made for disabling mismatch detection.

8.1 Configurable Options for Safety Circuit Mismatch Events

Mismatch Event Behaviour

In the event of a mismatch being detected either of the following two actions are available depending on the option switch settings:

a) Lock out, preventing further use, unless the system is reset by switching it off and on again;

b) Lock out, preventing further use, unless the system is attended to by a qualified technician.

Option a) is suitable for mission-critical applications where the inability to use the laser would be costly or inconvenient. Having detected and indicated that there is a fault it allows the system to be reset to operate on the one good safety circuit provided the faulty circuit has been closed. The need to manually reset the system before it can be used provides a clear indication to operators that there is a problem that needs to be addressed at the earliest opportunity and that other risk limitation steps may be required in the interim. An example might be to secure the affected door out of use until it can be repaired.

Option b) is the lowest risk option, as once a safety circuit fault has been detected the system cannot be used. The LJIM can only be reset by opening the cabinet in which it is mounted and operating the Fault Reset button. Procedures should indicate that this is only carried out by suitably trained technicians once the fault has been repaired.

By default, the mismatch detector is factory set to be enabled in option 'a' above.

Mismatch Detection Settings

The Safety Circuit Mismatch Detection behaviour is set by the option switch on the left-hand side of the fuse. When closed, this switch enables automatic mismatch to reset on cycling the power. The 'ON' position is indicated on the switch.

8.2 Clearing a Mismatch Fault Indication

In all cases the fact that a mismatch fault has been indicated warns users that the safety of the system may be compromised. Site-specific instructions should indicate the actions to be taken by users in such an event.

If the auto reset option has been selected, the system may be temporarily cleared by turning the power supply off, waiting for ten seconds, then turning it back on again. In this case the system should be attended to by a suitably qualified technician to identify and repair the fault at the earliest opportunity as a fault has been identified and the system may cease to provide protection without further warning.

If the LJIM has been configured to permanently lock out, it can only be reset by pressing the Fault Reset button. This should only be undertaken by suitably qualified technicians once the fault has been identified and repaired as otherwise the unit will just lock out again.

8.3 Mismatch Detector Remote Reset

Terminals are provided that allow for remote resetting of the mismatch detector if desired. The 'reset' switch should have a contact which closes to reset the detector. This could be provided by a switch or a volt-free output from a PLC.

Contact Lasermet or your local distributor for assistance if you wish to use this feature.

9 LED Indicators

ABG Status LEDs

Four LEDs are provided for each of the ABG monitors on the LJIM and expansion units. These indicate 'break' and 'leak' conditions for each channel respectively.

If a track on the ABG window or panel is broken, the corresponding 'break' LED will illuminate. This is the usual fault condition after a laser strike. It can also occur due to a disconnection in the circuit.

If conductance is detected between the A and B tracks on the ABG window or panel, the 'leak' LEDs on both channels will illuminate. The tracks are normally isolated from each other and held at different voltage levels, so this indicates a fault. This may be cause by a laser strike if the area between the tracks has become carbonised. It may also be caused by a wiring short.

If the 'leak' LED on the A channel illuminates while the corresponding B channel LED remains off, this probably indicates leakage from the tracks to ground. If the B channel 'leak' LED is illuminated, while the A channel LED remains off, this may indicate leakage into the circuits from a local power supply.

If just one channel has a fault, the mismatch detector will disable the LJIM until it is reset.

'Active Beamguard OK' A and B

These LED's will light in green when both ABG circuits on the LJIM are complete.

The system will not arm if either or both LED's are unlit. If the self-test has failed, one of the LEDs will be off even if there is no ABG status fault.

'Arm' A and B

The Arm indicators will illuminate blue when external contacts have closed in an attempt to arm the controller. The controller will not arm if only one channel is closed, indicated by only one light being illuminated.

'Mismatch Fault' LED

The LJIM continually monitors both safety circuits. If a mismatch occurs that lasts for more than about 1.5 seconds, the Mismatch Detector is triggered, which disables the system and illuminates a red 'Fault' light on the front panel.

The Mismatch Detector will detect a mismatch in the ABG circuits, the monitor inputs and its internal arming circuitry.

Site-specific procedures may be applicable in such an event, which cover actions to be taken to determine the cause of the fault, to have it rectified and to restore the system to operation. There may also be procedures to allow operation in degraded mode until normal operation can be restored.

'Armed' LED's

When the 'Active Beamguard OK' LEDs are lit and the external Arm contacts have been closed, the 'Armed' LEDs will light orange to warn that the LJIM has enabled the laser. If the 'Active Beamguard OK' LEDs are illuminated but the 'System Armed' LEDs do not illuminate when the external Arm contacts are closed, this could indicate that the internal checking circuitry of the LJIM has detected a fault condition.

'MCU Fault' LED

The ABG status LEDs, Arm status LEDs and serial interface are controlled by a microcontroller. If this has failed or has not been programmed, the 'MCU Fault' LED will illuminate. In this case, the ABG status LEDs will not be valid.

Power Supply LEDs

Green '24V' and 'Expn +24V' LEDs indicate that the main 24V power supply and the 24V switched power supply to the ABG units are on. If the '24V' LED is not illuminated, check the power supply connection and the main power supply fuse (1A T). The 'Expn +24V' LED will briefly turn off during the self-test phase. If it stays off, there is a fault in the LJIM circuitry.

'Expansion Fault' LEDs

The LJIM main unit has two red LEDs which light when the connections to the expansion input are not closed. They will light briefly during the self-test, but if illuminated at any other time, the cause should be investigated.

10 Operation

Once correctly wired, the LJIM is extremely easy to use. The following instructions cover the most common arrangements. For more complex customer-specific systems, additional procedures may apply.

10.1 Starting Up

1. Apply 24V power to the controller.
2. The unit will normally be operated as part of a PLC system that will have various other inputs that need to be satisfied. If the ABG inputs are all OK, and the expansion and test connections are all closed, the LJIM will be ready to arm on a signal from the PLC.
3. The PLC or manual operator will than close the contacts connected to the 'Arm' terminals. The unit will briefly run the self-test, during which the ABG status LEDs will flicker. If all is well the amber 'Armed' lights will be illuminated on the front panel of the unit.

N.B. Be aware that this action restores power to the shutters or the laser, and may result in accessible laser beams, depending on your system set up. This action should only be taken when everyone is ready and the necessary safety precautions have been taken e.g. protective eyewear etc.

If an attempt to arm the system is made while an input is invalid, the controller will not arm even if the input is restored. The external 'Arm' contacts must be opened, and a new arm attempt made.

10.2 Resuming Operation after ABG Fault

When a fault is detected by the ABG system, the LJIM will cut the power to the laser or the shutters and the 'Armed' lights will be extinguished. To resume laser operation:

1. Open the Arm contacts.
2. Investigate the fault condition. Note the ABG LED status display on the front panel. This may involve replacing an ABG panel or window if the fault was due to a laser strike, as these parts are sacrificial. If the fault was a loose connection this can be identified and repaired.
3. Reset the mismatch detector (where necessary).
4. When ready to restart, close the external Arm contacts.

N.B. Be aware that this action restores power to the shutters or the laser, and may result in accessible laser beams, depending on your system set up. This action should only be taken when everyone is ready and the necessary safety precautions have been taken e.g. protective eyewear etc.

11 Serial Interface

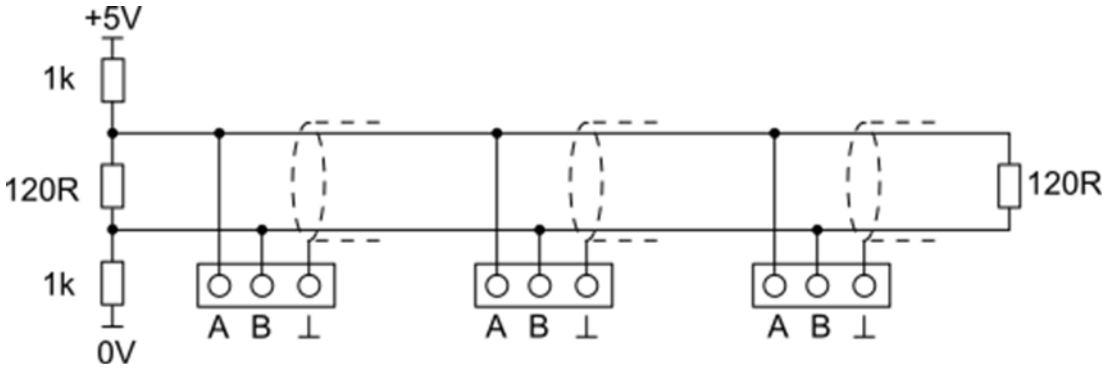
The LJIM is fitted with a serial interface to facilitate indication of the ABG and arm status. This takes the form of an RS485 physical interface configured to act as a Modbus RTU slave unit. The interface specification is as follows:

Physical Interface	RS485
Communication Speed	19200 bit/s
Data Bits	8
Stop Bits	1
Parity	None
Connections	A(+) and B(-) with common ground, plus screen

Note that A and B are the commonly used names for the two RS485 lines. When used in the context of the serial interface, they do not represent the two channels of the safety system.

11.1 Connections

RS485 is a bus system in which the A and B terminals of all units on the bus are connected to two wires, which can be inputs (high impedance) or outputs.



Only one unit can be active at a time. All other units must be in the high impedance state. To ensure clean signals, the bus is terminated with its characteristic impedance, which depends on the cable, but 100-120R is normally used. This is essential at high communication speeds, but at the more modest speeds used here, it is still useful for reliability. The LJIM and expansion units include 120R resistors which may be connected as bus terminators by closing the switches next to the RS485 terminals. Depending on the installation, the bus termination may be provided in this way or may be situated elsewhere. It is normal to place the two terminators at the very ends of the bus.

When the bus is idle, all the units are in the high impedance state, so the A and B voltages float. It is normal to bias the bus with two resistors so that the A line is slightly positive with respect to the B line, as shown. These resistors are included in the LJIM master unit and are switched in when the two jumper switches are closed to connect the bus termination.

The cable used is normally a screened twisted pair with low capacitance (about 60pF per metre) and characteristic impedance of 100-120R. This can be a dedicated RS485 cable or low-capacitance microphone cable. Category 5 network cable is also suitable and may be used where more than pair

is required. If the cable is screened, the screen should be grounded at one end. Screened data cable may have a drain wire which makes the screen connection easier to wire, while microphone cable will require a wire to be soldered to the screen braid.

The connections assume a common ground, although RS485 will accommodate a degree of ground bounce. RS485 is capable of communicating over hundreds of metres, but more care is required for longer runs.

11.2 Modbus Operation

The RS485 bus is used in this product to implement a Modbus protocol. The method used is Modbus RTU, which uses communication in raw binary, with a 16-bit CRC error checking code at the end of each message. Only a small subset of the Modbus command set is required to read the required status values.

Master and Slave

In the Modbus protocol there is one master unit and all others connected on the bus are slaves. All communications are started by a message from the master and concluded by either a response from the slave, or a blank period if the message has not been recognised by any slave.

In this system, the LJIM and expansion units are all slaves, and the device reading the status is the master. This can be a dedicated Modbus master, a PLC with Modbus master capability, a PC with a USB-to-RS485 adapter, running Modbus master software, or a custom status display. For further details of master options, please contact Lasermet. A PC example is given in a later section.

Device Address

Each slave device has a device address, which is used by the master to select a slave. This can be in the range 1-247. The LJIM is shipped with the address set to 247. When setting up the system, the address should be re-configured so that the LJIM and expansion units all have different addresses. The units should be connected one by one and a message sent to slave address 247, as described below, to set a unique address. This will be stored in non-volatile memory. All subsequent communications for that slave must be directed to the new address.

The address 0 is used by Modbus for broadcast messages, but no broadcast messages apply to this system.

Reading Data

The Modbus protocol can read data in the form of 16-bit words. The LJIM and expansion units present their data in two words. One contains the overall status bit and two bits indicating the armed status for each channel. The other contains the 16 status bits corresponding to the 16 status LEDs on the front panel. The master unit needs only to poll the general status register at regular intervals, and then examine the ABG status register if there is a fault.

The status data from the expansion units are in the same format as the main unit, but the two output bits now indicate the status of the output relays of the expansion unit.

11.3 Register Access

Reading Status Registers

The two status registers are mapped as input registers 30000 and 30001, and also duplicated as holding registers 40000 and 40001. This should enable all the available master devices to read the registers.

Register 30000/40000: ABG status bits

High byte – ABG channel A

7	6	5	4	3	2	1	0
BR4A	BR3A	BR2A	BR1A	LK4A	LK3A	LK2A	LK1A
1	1	1	1	1	1	1	1

Low byte – ABG channel B

7	6	5	4	3	2	1	0
BR4B	BR3B	BR2B	BR1B	LK4B	LK3B	LK2B	LK1B
1	1	1	1	1	1	1	1

The normal values are shown in the bottom row. A zero indicates a fault and will be accompanied by a red LED on the front panel. BRxx = 0 indicates a track break or open circuit and LKxx = 0 indicates a leakage fault.

Register 30001/40001: General status bits

High byte – Not used

7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-
0	0	0	0	0	0	0	0

Low byte – General status

7	6	5	4	3	2	1	0
-	-	-	-	-	OK	OPB	OPA
0	0	0	0	0	1	0	0

OK 1 = no faults are present, 0 = fault detected by LJIM

Main Unit
OPB 1 = channel B output relay is on, 0 = relay is off
OPA 1 = channel A output relay is on, 0 = relay is off

Expansion Unit
OPB 1 = channel B has fault, 0 = channel B OK
OPA 1 = channel A has fault, 0 = channel A OK

The registers are read by sending a 'read input registers' or 'read holding registers' command. This is an example query (the base address offset of 30000 or 40000 is implicit, and all numbers are hexadecimal):

Slave Address	addr
Function	04
Starting address high	00
Starting address low	00
Number of points high	00
Number of points low	02
Error check code	CRC
	CRC

This command will read both registers in the same reply. It is also possible to read them one at a time. The slave will respond:

Slave Address	addr
Function	04
Byte count	04
Data high (30000)	FF
Data low (30000)	FF
Data high (30001)	00
Data low (30001)	04
Error check code	CRC
	CRC

In this case, there are no faults and the outputs are not armed (or if the addressed unit is an expansion unit, the output status is OK). To use the 'read holding registers' command, function code 03 is used.

Writing the Address

This is implemented as a write to holding register 40000. This example sets the address of a factory-default unit to 1:

Slave address	F7
Function	06
Register address high	00
Register address low	00
Preset data high	00
Preset data low	01
Error check code	CRC
	CRC

The response from the slave is a copy of the query. This reply is sent with the original slave address field, so that the master will recognise it as a reply to the command, but all subsequent transactions must use the new address.

This command can also be sent using function 16 (10 hex). This command is normally used to write multiple registers but is enabled to allow a wider range of master devices. The above example, implemented as function 16, would look like this:

Slave address	F7
Function	10
Starting address high	00
Starting address low	00
Number of registers high	00
Number of registers low	01
Byte count	02
Preset data high	00
Preset data low	01
Error check code	CRC
	CRC

11.4 Example using Python

A PC or Raspberry Pi with a USB to RS485 adapter can be used to access the units. For test purposes, the Python Minimal Modbus library may be useful. To use this, you will need:

- Python
- The pySerial library
- The MinimalModbus library

These can be easily downloaded and installed under Windows or Linux. You will need to install any drivers required for the USB to RS485 adapter and identify which serial port corresponds to your adapter. Once this has been done, run Python at a command prompt or use the Python console available on a Python IDE, and enter a command to import the MinimalModbus library. This will make all its functions available for this session.

```
>>>   import minimalmodbus
>>>
```

Then create an instrument using the port number and the current address of your unit:

```
>>>   lj = minimalmodbus.Instrument('COM4',247)
>>>
```

We can now test the system by reading the general status register:

```
>>>   lj.read_register(1,0,4)
>>>   4
>>>
```

The unit has responded with a value indicating that the outputs are off and there are no faults. Similarly, we can read the ABG status register:

```
>>>   lj.read_register(0,0,4)
>>>   65535
>>>
```

The result (returned here in decimal) indicates that all status bits are 1. To set a new slave address:

```
>>>   lj.write_register(0,1,0,6)
>>>
```

This sets the address to 1. We will now need to set the address for the Python instrument to the address we have just set, so that we can continue to communicate:

```
>>>   lj.address = 1
>>>
```

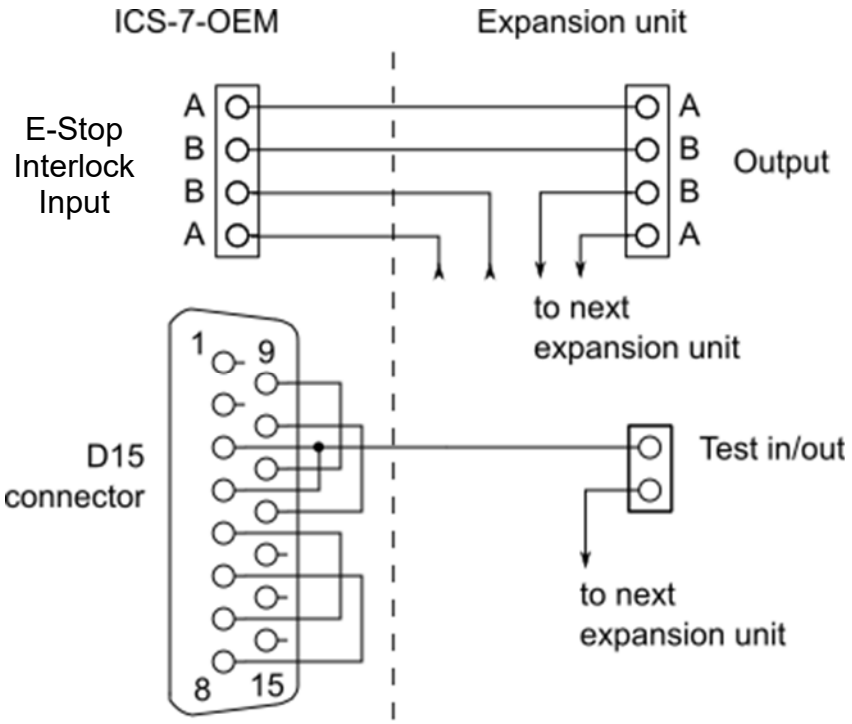
If there are problems, it may be useful to have more debug information. We can enable extra diagnostics as follows:

```
>>>   lj.debug = True
>>>
```

The Python library can also be used as a basis for GUI applications to display system status.

12 Connecting Expansion Units to ICS-7-OEM

The LJIM expansion units, ICS-LJIM-SO, can be used with the ICS-7-OEM interlock controller. Connections are as shown in the following diagram.



The outputs of the expansion units are daisy-chained and connected to the E-stop interlock input on the ICS-7-OEM. It is not recommended to connect the ICS-LJIM-SO outputs to an interlocked door input. In this case, the 'doors closed' output from the ICS-7-OEM will open contact when the LJIM-SO does its self-checking. This causes the system to trip and remove the arming signal to the ICS-7-OEM.

The test inputs on the expansion units are connected to the switched +24V power supply available from the D15 expansion connector on the ICS-7-OEM. The units must have a common ground connection.

The self-test function of the expansion units is operated whenever the ICS-7-OEM arms. Note that if the test connection is not made, the output relays of the expansion unit will not operate.

13 Fuses

The LJIM has a protection fuse which might blow if there is a fault or wiring error. This is indicated on the label and has a removable plastic cover for protection. Its rating is as follows:

Main 24V power supply fuse	1A T 20 x 5mm

The expansion units have separate power supply fuses.

14 Specifications

14.1 Main Unit

Safety Performance	Up to PL'e' to EN ISO 13849-1:2008 see section 4.
Shutdown Time	13.5ms typical. Measured from opening of ABG circuits to opening of interlock operator contacts.
Supply Voltage	24V DC (21.5 – 26.5V).
Power Consumption	6W typical
No. of Output Contacts	2 dual channel (NO).
Output Contact Rating	4A 50VDC resistive load.
Ingress Protection	IP20
Operating Conditions	0° to 55°C, 0% - 95% relative humidity non-condensing.
Size	210mm wide X 90mm high X 55mm over DIN rail
Weight	0.4kg

14.2 Expansion Unit

As for main unit except for the following:

Shutdown Time	13-15ms typical. Measured from opening of ABG circuits to opening of interlock operator contacts on main unit.
Power Consumption	4.5W typical
Size	210mm wide X 90mm high X 55mm over DIN rail
Weight	0.26kg

Dimensions are approximate. Values given as 'typical' are average values measured across a number of samples and are not guaranteed. Lasermet reserve the right to alter any specification without prior notice.

15 Warranty

Lasermet provide a 12-month warranty for defects in materials and manufacture, from the date of installation or delivery. Installations completed by Lasermet are covered against defects in workmanship for 12 months.

Damage or defects caused by other factors are not covered. For example, industrial contamination, incorrect cleaning, storm damage. Consequential loss is not covered under warranty. Compensation for indirect or direct loss or damage is expressly excluded. Rectification of the defects or a replacement does not initiate a new warranty period.

For all deliveries, payments and other legal transactions, English law takes precedence for any litigation.

16 Contact Details

Lasermet provide a full range of laser interlock equipment including interlock switches, illuminated warning signs, laser shutters, entry keypads with built-in fail-safe override timer, door locks, external power supplies etc. which can be interconnected to provide a complete system. We also supply equipment and consultancy covering all aspects of laser safety. Full support, design, and installation is available from Lasermet, please contact us for any queries.

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