User Manual

Cobot Laser Welder

Model: THG-URW-2LF (THG-000357)

Version: en-US

Updated: 2024-11-18

Dear Reader,

Thank You

Congratulations on your purchase. We are grateful for the trust you have placed in our company, THG Automation. We are dedicated to *"welding for anyone"*, and we're here to help you unlock higher potential in your operations.

As you embark on your automation journey, these instructions will help you familiarize yourself with the product and ensure you make full use of its extensive features and achieve excellent results.

Request

Please take a moment to review the safety rules outlined in this manual. Careful handling and adherence to safety guidelines will provide you with years of safe and reliable operation.

Support

Thank you once again for choosing our product. We look forward to supporting you in achieving safe and successful operations.

If you encounter any issues please reach out to:

Contact

TSNA@thgautomation.com

+1 (317) 739-8457

Disclaimer

Please Before operating this equipment, it is crucial that you review the manuals from THG Automation, IPG Photonics, and Universal Robots.

Read the We emphasize the importance of thoroughly reading all the relevant operational manuals and completing a comprehensive safety assessment of your equipment and operational process. Our company is not responsible for any operation of the machine prior to fulfilling these requirements.

Manuals Physical copies of the manuals from Universal Robots and IPG Photonics accompany each unit. Should you need additional copies, they can be downloaded at the following links:

UNIVERSAL ROBOTS `https://www.universal-robots.com/download`

IPG PHOTONICS `https://gettingstarted.handheldlaserwelder.com`

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Chapter 1

Safety

1.1 Types of Safety Notices

⚠ DANGER!

Indicates immediate danger.
→ If not avoided, death or serious injury **WILL** result.

⚠ WARNING!

Indicates a potentially hazardous situation.
→ If not avoided, death or serious injury **MAY** result.

⚠ CAUTION!

Indicates a situation where damage or injury could occur.
→ If not avoided, minor injury and/or damage to property may result.

NOTE!

Indicates a risk of flawed results and possible damage to the equipment.

TIP!

Indicates tips for correct operation and other useful information.
This does not indicate a potentially hazardous situation.

1.2 Safety Review

Risk Assessment

To ensure the safe operation of this equipment, THG Automation requires purchasers and operators to complete a comprehensive safety assessment. This process is designed to identify potential hazards and implement risk reduction measures.

Assistance

If assistance is needed for conducting a safety assessment, the following organizations can provide support:

- **Robotic Industries Association**
  Access their risk assessment resources for industrial robots and collaborative systems:
  `https://www.automate.org/robotics/safety/robot-safety-software`

  RIA TR R15.606-2016 Technical Report
  Covers safety requirements for industrial robots and robot systems, including collaborative robots.

- **PILZ Risk Assessment**
  `https://www.pilz.com/en-US/services/risk-assessment`

- **OSHA Guidelines For Robotics Safety**
  `https://www.osha.gov/enforcement/directives/std-01-12-002`

- **Conversion Technology Inc.**
  Expertise in OSHA compliance consulting:
  `https://www.conversiontechnology.com/osha-compliance-consulting`

- **Sick - Collaborative Safety Guide**
  Access their guide for enhancing collaborative safety:
  `https://s.sick.com/us-en-Robotics-Safety-6`

These resources will help ensure that all safety standards are met, promoting a secure operational environment.

1.3 Robot Safety

⚠ DANGER!

- Verify the robot arm and tools/end effectors are properly and securely bolted in place.
- Verify the robot application has ample space to operate freely.

⚠ WARNING!

- Avoid using the robot if it is damaged.
- Avoid wearing loose clothing or jewelry when working with the robot. Tie back long hair.

⚠ CAUTION!

- Make sure tools/end effectors have no sharp edges or pinch points.

NOTE!

Very strong magnetic fields can damage the robot.
Do not expose the robot to permanent magnetic fields.

TIP!

Regularly test E-stop buttons to ensure proper and secure operation by disabling the robot for any reason.

1.4 Laser Safety

⚠ DANGER!

- **Invisible Laser Radiation**
  Welding beam laser light (1070 nm) cannot be seen and exposure can cause permanent eye damage as well as skin damage.
- **Eye Protection**
  Laser satefy rated glasses and helmet are **BOTH** required to provide sufficient protection for your eyes and face.
- **Skin Protection**
  Laser and heat resistant gloves, clothing, and aprons are required to protect skin from infrared and ultraviolet radiation, which can cause thermal burns and increased risk of skin cancer.

⚠ WARNING!

- **Laser Controlled Area**
  Only operate the laser within an area where the occupancy and activity of those within is controlled and supervised. All individuals in the area need to follow all safety procedures and guidelines.
- **Reflection**
  Lasers are highly reflective. The laser controlled area should prevent any stray beams from escaping, and spectators should never attempt to view the welding process without proper proctection.
- **Explosion**
  Never weld flammable or combustible materials.
  Store gas cylinders outside of the laser controlled area.

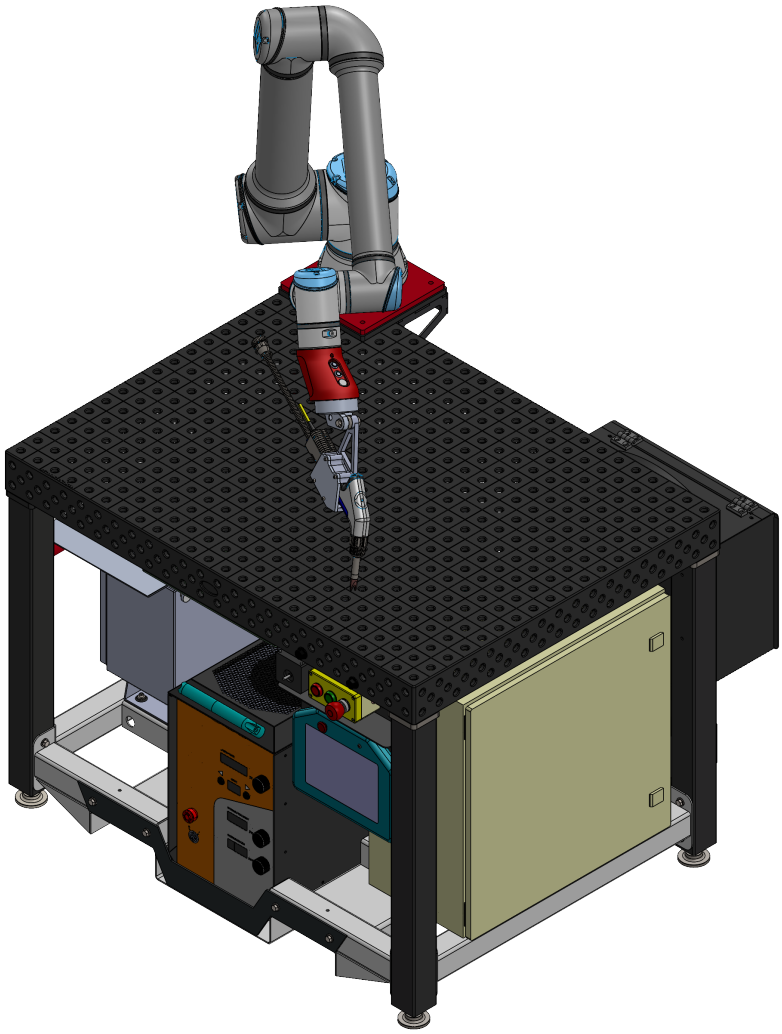
⚠ CAUTION!

- Ensure proper ventilation and fume extraction.
  Welding smoke / vapor is comprised of very fine particles which can damage the lungs, heart, kidneys and central nervous system.

Chapter 2

Hardware Installation

2.1 Overview



2.1.1 Parts List

Part Numbers

- **Siegmund Fixture Table Kit → THG-000315**
- **Robot Arm**
  - **UR20 →**
  - **UR10 → THG-000262**
- **Control Box → THG-000269**
- **Teach Pendant → THG-000271**
- **Positioner Box → URP-2X1**
- **Offset adapter**
  - **UR20 → THG-001151** (w/ 3PE)
  - **UR10 → THG-001152** (no 3PE)
- **Operator Panel → THG-000332**
- **Power Source → IPG-LHW-1500-XR-10**
- **Wire Feeder → IPG-LJ-WF002**
- **Torch & Hosepack**
- **Cobot Integration Box**

2.2 Getting Started

Overview

1. **Mount** the robot arm to the fixture table.
2. **Connect** the electrical cables and grounding wires.
3. **Mount** the offset adapter to the robot arm.
4. **Mount** the torch and hosepack to the robot arm.
5. **Connect** the gas supply to the power source.

Robot Arm

1. **Locate** the robot mounting plate at the back left corner of the table.
2. **Remove** the provided bolts for securing the robot arm from the mounting plate.
3. **Remove** the robot arm from underneath the table and from its packaging.
4. **Locate** the robot power cable coiled within the interior of the robot base and uncoil it.
5. **Feed** this cable through the opening in the robot mounting plate.
    - **Ensure** that the cable is fully fed through the hole before securing the robot to the mounting plate.
6. **Rotate** the robot arm so that the black rubber tab, found along the edge of the robot base, is facing away from the front of the table.
    - This is crucial to ensure your robot does not run into any issues with exceeding movement parameters.
7. **Secure** the robot arm to the mounting plate using the bolts from step 2.
8. **Tighten** the bolts to 16 Nm (12 lb-ft).

Electrical

1. **Ground** the table to earth using customer supplied grounding wire.
2. **Ground** the power source to table using grounding clamp at the rear of the power source.
3. **Locate** and **connect** the following cables:
   - robot arm power cable (to control box)
   - control box power cable
   - power source power cable
   - wire feeder power cable
4. **Power ON** the robot, and **move** it into an accessible position for the next step.

Offset Adapter

1. **Remove** the backing plate.
2. **Locate** the pin and press the offset adapter onto the robot arm.
3. **Secure** the offset adapter with provided (4) M4 bolts.
4. **Reattach** the backing plate.
5. **Connect** the cable from the offset adapter to the robot arm.

Welding Torch

1. **Attach** the tool holder bracket to the offset adapter.
2. **Insert** welding torch into the tool holder.
3. **Secure** the tool holder bracket with provided M4 bolts.
4. **Insert** the 2 set screws, one for each trigger on the torch, just past the point where they press the triggers.

Hosepack

1. **Fasten** the hosepack to the robot arm with the provided straps.

Gas

1. **Connect** the gas supply to a customer supplied pressure regulator.
2. **Connect** the pressure regular to the power source gas outlet.

2.3 Electrical Setup

Setup

To ensure the safe operation of this equipment, THG Automation requires that all purchasers/operators establish proper grounding and use compatible plugs and power supplies for the robot and power source.

2.3.1 Power Requirements

Device	Voltage	Frequency	Max Draw
Robot	100-240 VAC	50/60 Hz Single phase	15A
LightWeld	200-240 VAC	50/60 Hz Single phase	24A
WireFeeder	100-240 VAC	50/60 Hz Single phase	3A

2.3.2 Proper Grounding Is Essential

NOTE!

Each welding table must have an independent grounding connection to prevent risks from unexpected power surges. Failure to ensure proper grounding may lead to equipment damage and could void your warranty.

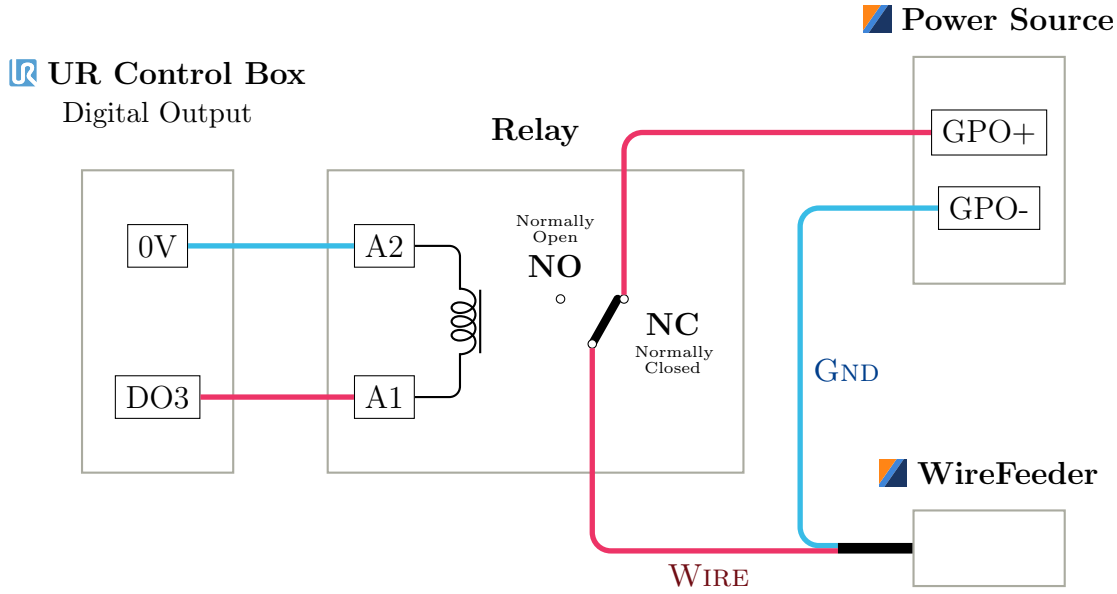
Resources

Proper grounding shields your system from external electrical interferences. Consult a certified electrician to verify that your power setup is adequate and safe for your collaborative robot welding system. For more information, consult these resources:

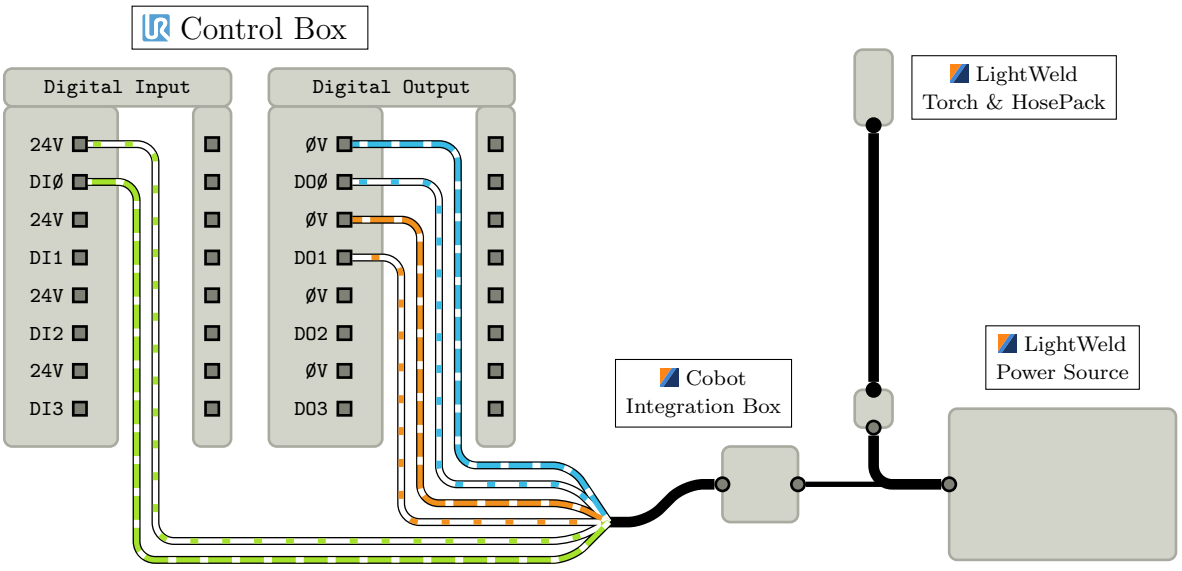
- **Electronics Hub - Grounding Tutorial**
  `https://www.electronicshub.org/electrical-grounding`
- **NFPA - Grounding and Bonding Resource**
  `https://www.nfpa.org/NEC/About-the-NEC/Grounding-and-bonding`

2.4 Electrical Schematics

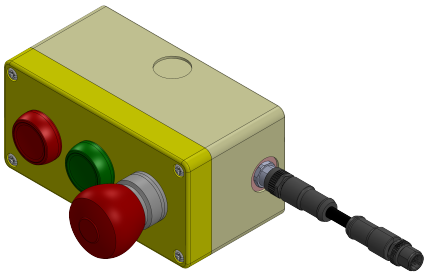
2.4.1 Schematic for Control Box + WireFeeder

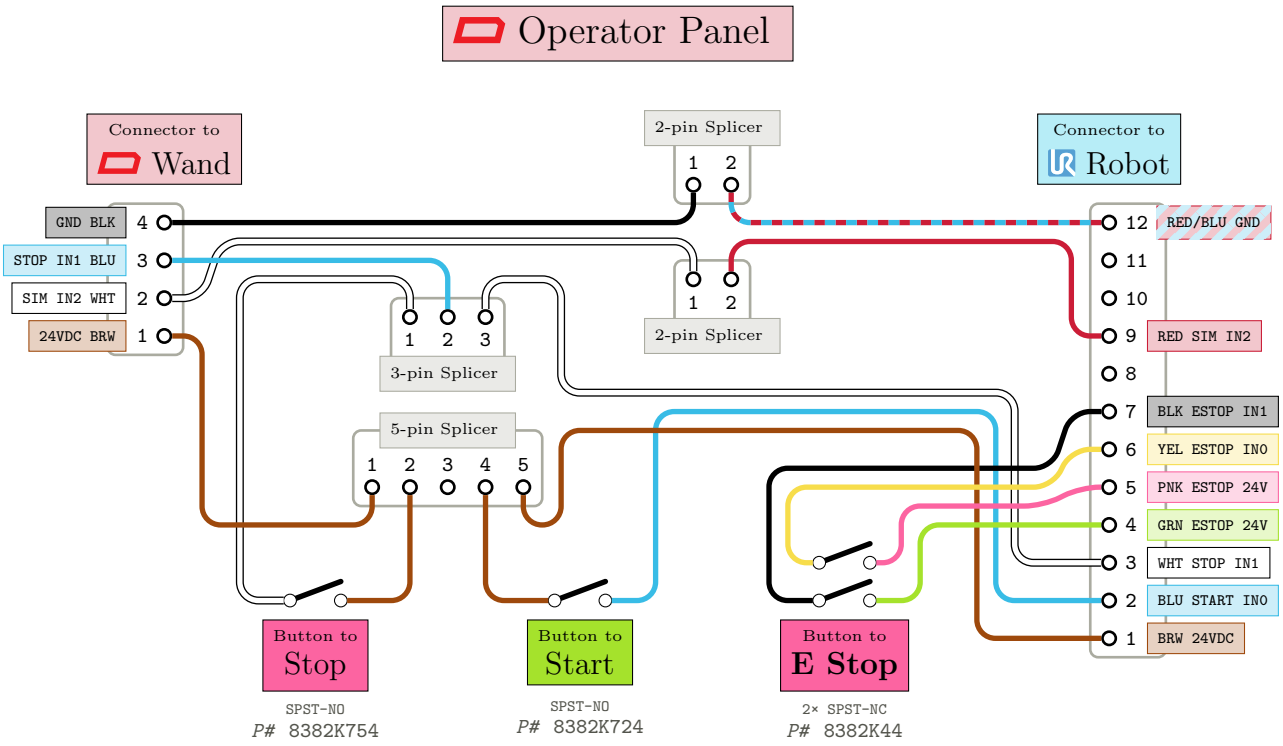


2.4.2 Schematic for Control Box + Cobot Integration Box



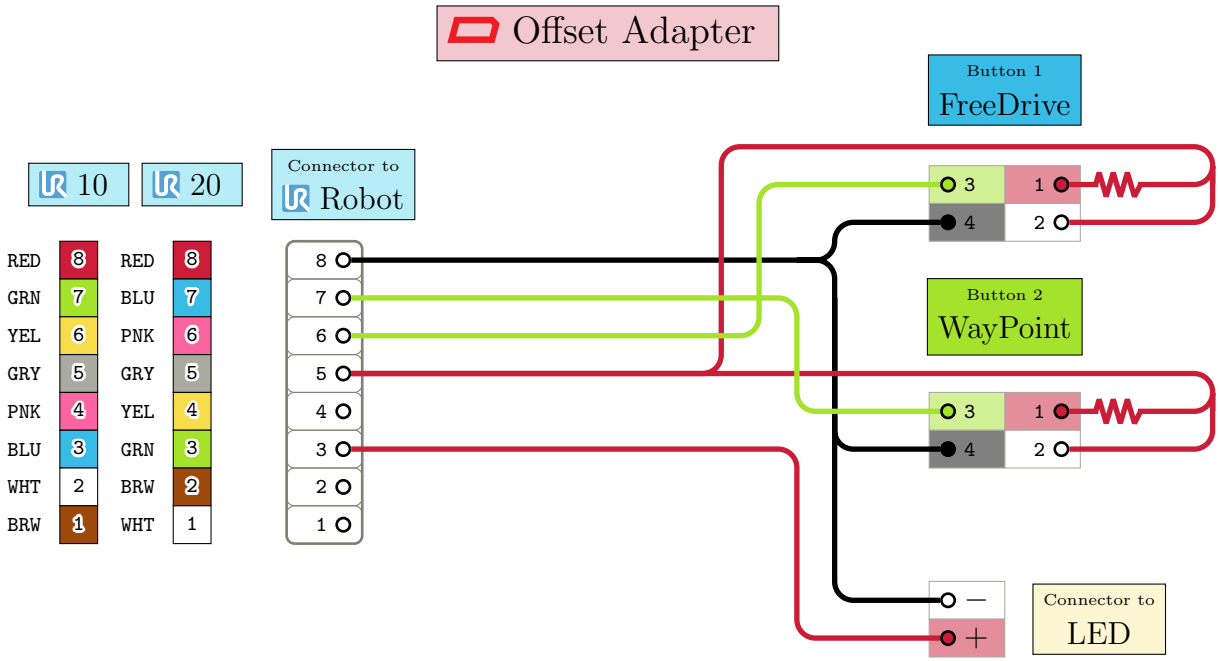
2.4.3 Schematic for Operator Panel





2.4.4 Schematic for Offset Adapter





2.5 Gas Setup

Connection Connect customer supplied 12mm (1/2 inch) OD flexible tubing from gas supply tank to rear panel gas input.

Pressure Pressure must be maintained at 1.0-2.0 bar (15-30 psi). Failure to regulate the gas pressure will cause low or high safety interlocks to trigger, interrupting welding processes.

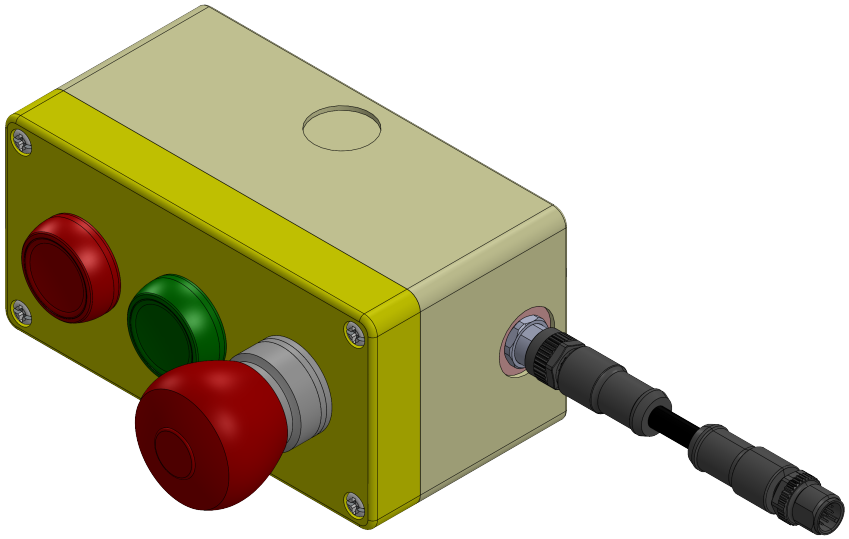
TIP!

We recommend using a regulator to control the gas pressure. Not having one will cause constant headaches and failed welds.

Type of Gas The type of gas is dependent on the material. Consult guidelines for more information.

Metal	Gas
Steel	Nitrogen
Nickel Alloys	Nitrogen
Copper	Nitrogen
Aluminum	Argon
Titanium	Argon

2.6 Operator Panel



Stop Button	This will stop the program, if it is running, the same as if you pressed stop program on the Teach Pendant.
Start Button	This will start the program, but only if the Teach Pendant is in Remote mode.
Emergency Stop Button	This will immediately stop everything, by sending an Emergency Stop signal to the robot.

2.7 Offset Adapter



Overview

The offset adapter comes equipped with 2 buttons on the front and an LED light on the bottom. The lights around the buttons will turn on when the robot arm is powered on.

Blue button
Top

The Free Drive button. Pressing this button will allow you to move the robot arm freely, provided it is allowed to.

Green button
Middle

The Set Waypoint button. Pressing this button will allow you to set a waypoint for the robot arm.

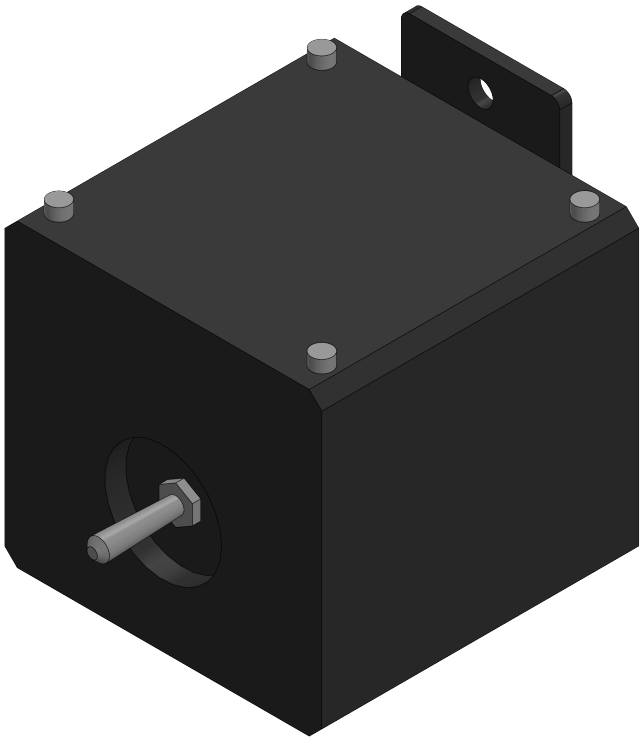
3PE button
Rear

The Three Position Enable button. If you have a 3PE button, usually found on UR20 robots, pressing this button will activate the robot arm's 3PE mode.

LED Light
Bottom

The bottom of the offset adapter has an LED light. The light can be toggled in the toolbar. The robot arm must be powered on for it to receive power.

2.8 Cobot Integration Box



Purpose

Also known as the Cobot Trigger Interface, this box allows for the the trigger signals sent by software to the laser welder.

There are 2 triggers:

1. **Gas Trigger** → intructs the power source to begin shielding gas flow.
2. **Emission Trigger** → acts as a start button for the laser. If all safety interlocks are satisfied, including 1.5 seconds of shield gas, the laser will fire.

Cobot Mode

In this mode, the triggers are managed by the software, while the physical triggers are pressed using set screws.

Manual Mode

This mode allows for the torch to be removed from the tool holder, in order to perform manually welds.

Chapter 3

Software Operation

3.1 Glossary

URCap → Universal Robots Capability. This is the software written by THG Automation that interfaces with the robot and controls the welding process.

Also known simply as a Cap.

TCP → Tool Center Point. The location of the welding tool tip, specified as a Pose in the robot's coordinate system.

Pose → (X, Y, Z, rX, rY, rZ). A position (X, Y, Z) and orientation (rX, rY, rZ) in the robot's coordinate system. The default units for position are meters and radians for orientation.

Also referred to as a Point, or Waypoint.

Feature → A feature represents an object defined by a Pose relative to the robot base. There are 2 predefined features: the Base and Tool.

The Base feature is the origin of the robot's coordinate system, located in the center of the robot base.

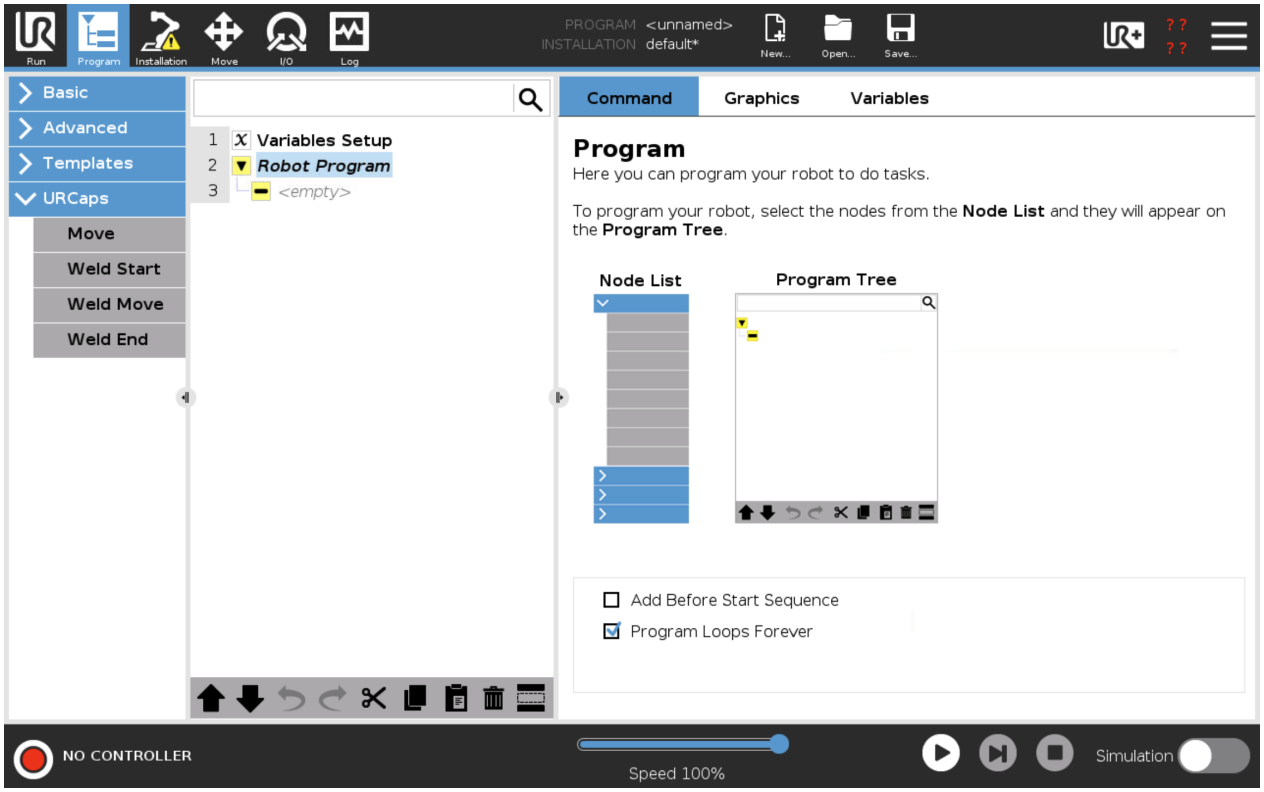
The Tool feature is located with origin in the center of the current TCP.

Also referred to as a Frame.

3.2 Programming

Purpose

Programs are how you tell the robot what to do. They consist of a series of nodes that are executed in order. Each node is a specific action that the robot will perform.



3.2.1 Node Overview

Overview

All robots come with a set of basic, advanced, and template nodes.

The URCap introduces the following nodes to assist with welding:

- **Air Moves** → move without welds.
- **Weld Moves** → execute welds.

Air Moves

Air Moves navigate the robot arm around obstacles **without** welding. There are 2 types of Air Moves:

- **Linear Move** → is a direct line from point A and point B.
- **Joint Move** → is a path from point A to point B that is optimal for the robot. It may not be a direct line between A and B, but requires the least movements for the robots joint positions.

TIP!

Unlike the standard Move node, Air Move offers greater flexibility, starting from any position to reach the specified waypoint.

TIP!

Joint moves work well for longer moves with few obstructions, because the robot arm calculates the most efficient path for all joints.

Welds

Weld nodes define the path for welding operations. They include Start, End, and optional MoveP or MoveC waypoints.

Each weld path begins with Approach and concludes with Retract waypoints, calculated from the start and end positions.

Weld Process

The full process follows these steps:

1. move to **Approach** waypoint
2. move to **Start** waypoint
3. **initiate** the Weld process
4. move to any number of **MoveP** or **MoveC** waypoints
5. move to **End** waypoint
6. **conclude** the Weld process
7. move to **Retract** waypoint

Weld Start — A Weld Start node initiates the welding sequence, and automatically includes a nested Weld Move and Weld End node.

Weld MoveP Process / Line — Directs the weld along a straight path with constant speed.

Weld MoveC Circle / Arc — Directs the weld along an arc path through an intermediate waypoint at constant speed.

Weld End — Terminates the welding sequence.

3.2.2 Node Waypoints

Purpose — Setting waypoints determines the robot's movement, and can be fixed, variable, or home positions. You can transform waypoints with offsets and features.

Fixed — Fixed waypoints are defined by positioning the robot and saving its pose.

TIP!

Use the Offset Adapter to quickly set a waypoint: select the node, hold the green button, and wait for the LED to flash.

Variable — Variable waypoints are advanced options, referencing previously defined waypoints for flexibility, especially in part checking (coming soon).

Home — Use Home positions, set in the Installation screen, as waypoints for Air Moves.

Offsets — Offsets adjust waypoints by a specified pose transformation.

Features — Every waypoints is defined in reference to a feature, defaulting to the Base. Set additional features for complex patterns, supported by a future dedicated node.

3.2.3 Node Configuration

Shared Parameters A Weld Start node sets shared parameters for the welding process.

Travel Speed Defines the speed at which the robot moves between waypoints. Linear movements are specified in system units. Joint movements are always specified in degrees per second.

Acceleration Sets the rate of acceleration and deceleration for air moves. Linear movements are specified in system units. Joint movements are specified in degrees per second squared.

Blend Radius A blend radius is for blending the robot arm's movement between waypoints. A smaller value will make the path turn sharper whereas a higher value will make the path smoother. The radius is always specified in millimeters.

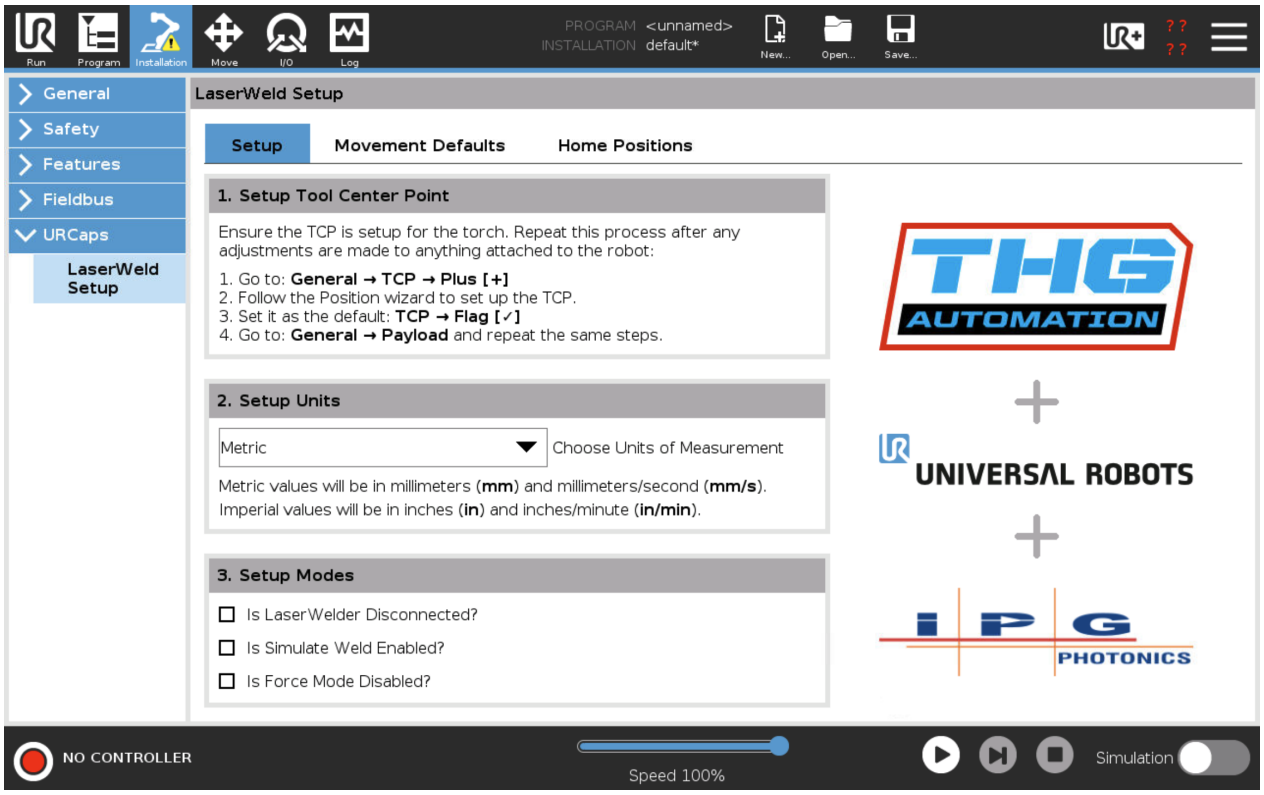
Approach & Retract Controls the entry and exit paths of the welding process. The speed and distance may be configured.

Process Name Allows naming of specific welding processes for easy identification.

Disable Wirefeed Option to disable the wire feed during specific operations as needed.

3.3 Installation

Purpose The Installation screen is used to configure global settings for the URcap.



Network The Cobot communicates to the LightWeld power source via ethernet cable. Your system is pre-configured by THG to:

Device	IP Address
UR Control Box	10.0.0.10
IPG Power Source	10.0.0.20
Subnet Mask	255.255.255.0
Default Gateway	10.0.0.1

3.3.1 Setup

TCP Your system is pre-configured by THG with a calibrated TCP and Payload.

NOTE!

Reconfigure the TCP whenever adjustments are made to the torch, and update the Payload if there are modifications to components attached to the robot arm.

Even minor changes, such as tightening straps on the hosepack, can shift the center of mass. This requires recalibration of the payload for maintaining optimal performance.

TIP!

Mastering the configuration of the TCP and Payload is crucial for achieving optimal results. Inaccurate setup is the leading cause of poor weld quality.

Units Units are set by default to Metric, but can be changed to Imperial.

Metric Measures distance in millimeters (**mm**) and speed in millimeters per second (**mm/s**).

Imperial Measures distance in inches (**in**) and speed in inches per minute (**in/min**).

TIP!

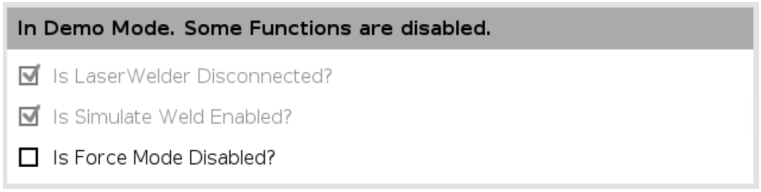
Learning and adopting the Metric System will increase the efficiency of your organization and improve the quality of your life. Guaranteed.

3.3.2 Modes

Demo Mode

If the panel below appears, your URCap is running in Demo Mode. This indicates a mismatch between the robot's serial number and the URCap license.

Please contact THG Automation support for assistance.



Disconnected Mode

If Is LaserWelder Disconnected? is checked, the robot operates in Disconnected Mode.

This mode allows the robot to run programs without the power source being connected or powered on.

Simulation Mode

By checking Is Simulate Weld Enabled?, you activate Simulation Mode. This mode runs the program without sending the enable trigger signals the power source.

This is used for testing parameters like pathing and pressure without initiating the welding process.

Disable Force Mode

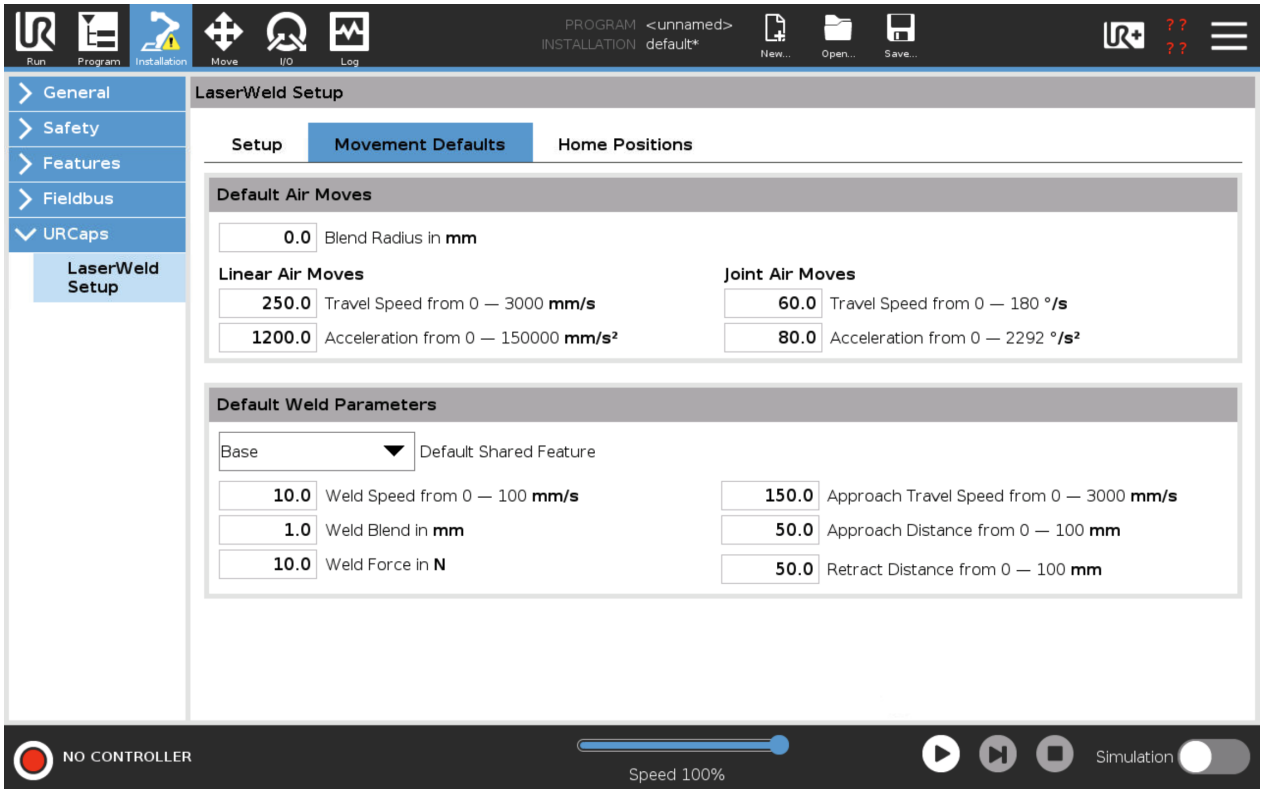
The LightWeld nozzle safety interlock requires a constant electrical connection. If contact with the material is broken, the interlock will engage, interrupting the welding process.

Force Mode is enabled to maintain nozzle pressure, to keep the nozzle interlock satisfied.

Checking Is Force Mode Disabled? will deactivate this functionality.

3.3.3 Defaults

Purpose The Movement Default panel is used to configuring the default values when creating new nodes.

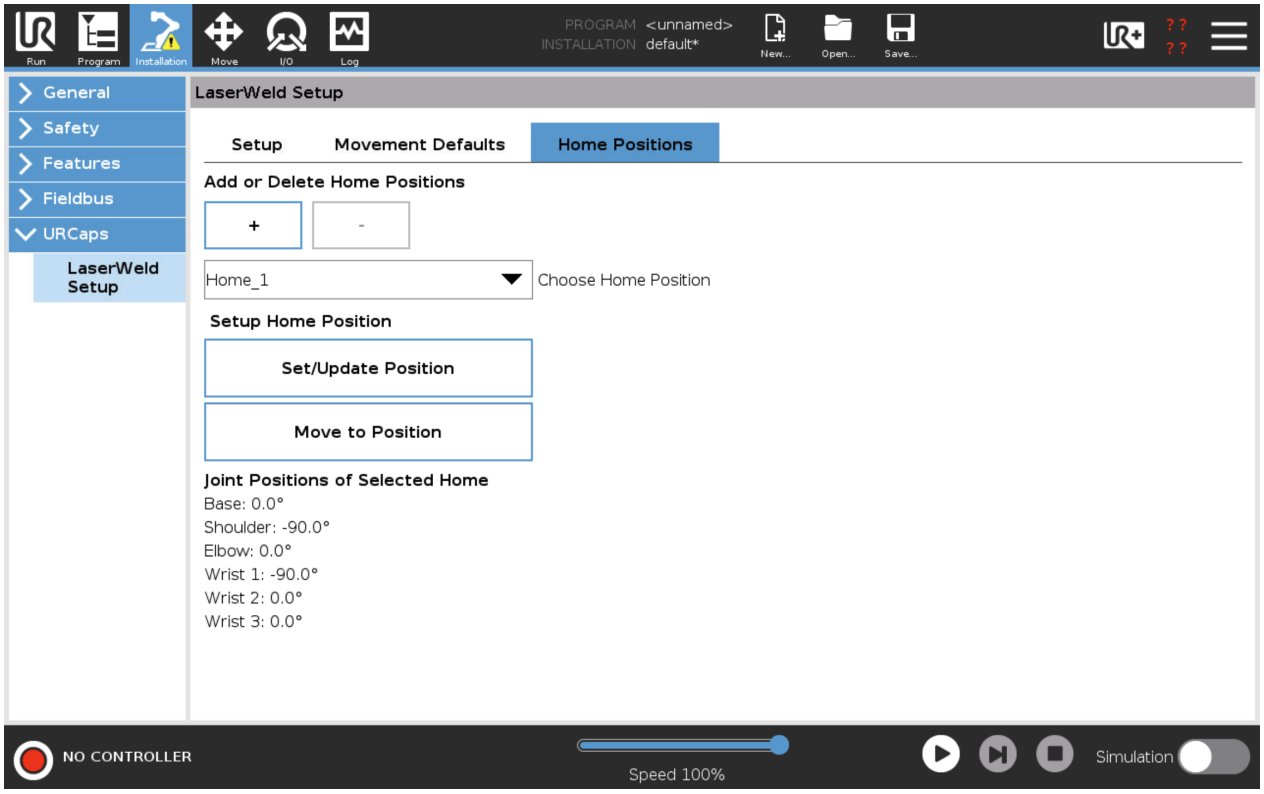


Air Moves When new Air Move nodes are created, they will default to the values set in this panel.

Welds When new Weld nodes are created, they will default to the values set in this panel.

3.3.4 Home Positions

Purpose Home positions are used for setting common positions for the robot to reuse in the program. They are managed in this panel.



3.4 Toolbar

Purpose The toolbar is used for quick access to controlling the system's state. It is located at the top of the screen, by tapping on the UR+ button in the top bar.

LED light The LED light can be toggled in the toolbar. The robot arm must be powered on for it to receive power.

3.4.1 System State

Interface	Meaning
Robot is Powered OFF	Indicates that the Robot arm is powered off
Welder is DISCONNECTED	Indicates that Disconnected Mode is enabled in the Installation screen
Welding will SIMULATE	Indicates that Simulation Mode is enabled in the Installation screen, and when the program runs, it will not send the enable trigger signals to the power source
Welding is SIMULATING	Indicates that Simulation Mode is enabled for the currently running program. Note the lock icon, this state cannot be changed while running a program.
Welding will be LIVE	Indicates that when the program runs, it will send the enable trigger signals to the power source. If all safety interlocks are satisfied, the laser will emit.
Welding is LIVE	Indicates that the welding process is currently running. Note the lock icon, this state cannot be changed while running a program.

3.5 Variables

3.5.1 THG

Movement

Name	Default	Units	Description
thg_speed	10.0	mm/s	robot travel speed
thg_accel	50.0	mm/s^2	robot travel acceleration
thg_blend	0.0	mm	robot blend radius
thg_speed_appr	150.0	mm/s	robot travel speed during approach
thg_dist_appr	50.0	mm	distance to move in the negative Z (TCP) for calculating approach
thg_dist_retr	50.0	mm	distance to move in the negative Z (TCP) for calculating retract
thg_is_arc_end	False		True if process is ending on a moveC
thg_tcp_pose	p[0,0,0,0,0,0]		current TCP Pose
thg_dist_arc	0.0	mm	distance to end of arc
thg_is_arc_adj	False		True if arc is being adjusted (starting in the middle of an arc)
thg_move_type	0		0 - None, 1-4 Process, 5-6 Non-Process
thg_moving	False		True if robot arm is currently moving
thg_wp_approach	p[0,0,0,0,0,0]		approach waypoint
thg_wp_arc_to	p[0,0,0,0,0,0]		arc to waypoint
thg_wp_arc_via	p[0,0,0,0,0,0]		arc via waypoint
thg_wp_line	p[0,0,0,0,0,0]		line waypoint
thg_jp_line	[0,0,0,0,0,0]		joint positions for calculation of line waypoint
thg_wp_retract	p[0,0,0,0,0,0]		retract waypoint

Process

Name	Default	Units	Description
thg_enable	True		True if process can be enabled (PowerSource is Not Disconnected)
thg_start	False		True if process has started (Laser is Emitting)
thg_process	""		Process Name, configured in the WeldStart Shared tab
thg_simulate	True		True if process is simulated
thg_timer	0		Timer used for calculating timeouts
thg_force	0.0	*N*	Current TCP pressure force
thg_force_down	10.0	*N*	Pressure to apply during process
thg_force_mode	False		True if force will be applied, False if no force will be applied

3.5.2 IPG

Name	Default	Units	Description
ipg_do_trig_1	1		Digital Output (on I/O) for Trigger 1, where High = Triggered
ipg_do_trig_2	2		Digital Output (on I/O) for Trigger 2, where High = Triggered
ipg_do_wire	3		Digital Output (on I/O) for Wirefeeding, where High = Disable Wirefeed
ipg_di_enable	3		Digital Input (on I/O) for Cobot Enable, where High = Cobot Enabled
ipg_delay_trig	2.5	*sec*	delay between when the software enables Trigger 1 (gas) and Trigger 2 (emission)
ipg_delay_start	1	*sec*	delay after the software enables Trigger 2
ipg_delay_stop	1	*sec*	delay at the end of a weld, between Trigger 2 (emission) and Trigger 1 (gas)
ipg_ip	10.0.0.20		IP address of the Power Source
ipg_socket			Socket for communication with Power Source
ipg_raw_sta	0		raw binary list of alarm statuses
ipg_raw_stg	0		raw binary list of general statuses
ipg_raw_sti	0		raw binary list of interlock statuses
ipg_raw_stw	0		raw binary list of warning statuses
ipg_rea_sta	[ ]		list of alarm statuses
ipg_rea_stg	[ ]		list of general statuses
ipg_rea_sti	[ ]		list of interlock statuses
ipg_rea_stw	[ ]		list of warning statuses
ipg_wirefeed	True		True if Wirefeed is enabled

Chapter 4

Troubleshooting

4.1 Error Messages and Codes

4.1.1 THG

Code	Description
`SerialNumber`	This Robot's Serial Number does not match the Software License.
`StartHasStart`	There should not be a Weld Start Node as a child of a Weld Start Node.
`StartNeedsEnd`	Need to add Weld End Node as child of Weld Start Node.
`HasUnknownChild`	Only Weld Movement and Non-Move type Nodes should be child of Weld Start Node.
`EndHasMultiple`	Weld End Node should be last child of Weld Start Node.
`EndIsNotLast`	Too many Weld End Nodes Set. There should only be one per Weld Start Node.
`DoubleCheck`	Please ensure the selected node will properly work inside the Weld Process.
`InvalidVariable`	Invalid Variable Name or Variable is not defined.
`NoConnection`	Please check the Ethernet cable to the Power Source.
`Force Mode`	Surface not found. Try placing it closer.
`Lost Contact`	Nozzle interlock not satisfied. Try adding more force.
`Trigger Interlock`	Triggers never fully triggered.
`IPG Interlock`	Please check: List of Interlocks that are not satisfied.

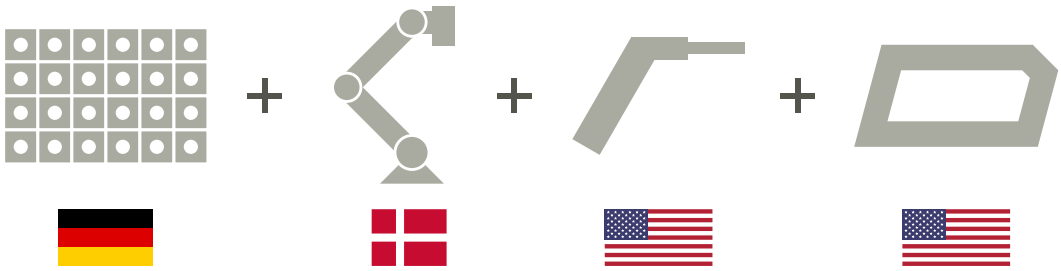
4.1.2 Common Errors

Code	Description
`04 NoPlasma`	Plasma detection feature did not detect plasma during welding. There are 2 independent conditions that can cause this: 1. **Normal** → No plasma detected during welding (light detected was below material threshold). 2. **Ambient** → Ambient light surrounding the material is interfering with the plasma detector operation. This is always paired with the Ambient Light Warning. If Ambient Light Warning is active with `04`, then error was due to ambient.
`08 BackReflection`	Internal back reflection photodiode reading exceeded its threshold. Light is reflecting back into fiber.
`21 NozzleShutdown`	While emission was ON, the nozzle to workpiece clamp interlock opened which resulted in the laser being shutdown (e.g. During welding the operator lifted nozzle off part while still pressing Trigger 2).
`22 Trigger1Shutdown`	While emission was ON, the Trigger 1 interlock opened which resulted in the laser being shutdown (e.g. During welding the operator released the Trigger 1 gas control on the weld head).
`30 GasShutdown`	Gas pressure was not detected while emission was ON or the laser tried to fire before gas delay was met.

4.1.3 Interlocks

Interlock	Description
`Nozzle`	This safety loop ensures the laser only fires when the head nozzle is electrically connected (touching) to the work piece.
`External`	This dual-channel system ensures laser emission is disabled unless both channels are closed, integrating with external safety measures for compliance and redundancy.
`Fiber`	This interlock ensures the laser shuts down or prevents emission if the optical fiber connector is not properly connected to external components, monitoring the interlock signal in the fiber cable.
`Key`	This front-panel keyswitch restricts access to the laser by requiring insertion and turning to the ON position, preventing removal until switched OFF.
`Trigger 1`	Trigger 1 has been physically closed or sent an enable signal.
`Trigger 2`	Trigger 2 has been physically closed or sent an enable signal.
`FPGA`	This hardware-based safety check verifies that all physical interlock conditions are met before allowing laser emission.
`Software`	This ensures all software conditions are met, monitoring for errors before permitting laser emission when trigger 2 is activated.

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