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C. Control and Signal Modules

VL1— EtherCAT Control/Signal Module

1. Product Overview

The VL1 modules enable the customer to control and communicate with the Tool Changer through a network using an EtherCAT interface. Control of the Tool Changer is realized through the Master along with the reporting of various Tool Changer I/O. The Tool module supports Tool-ID reported through the Master and functions as a pass-through for EtherCAT network and power to downstream equipment.

The VL1 module supports the use of an integrated single or double solenoid valve, which is provided on the valve adapter module (9121-Jxx), for Latch/Unlatch control of the Tool Changer. The user is required to provide a pneumatic supply source to the Tool Changer. Please refer to the appropriate manual for specific module and Tool Changer requirements.

In addition to supporting the standard Tool Changer input signals (Locked, Unlocked, and Ready-to-Lock proximity sensors) the modules also support advanced diagnostic and fault reporting. Refer to *Table 4.3.*

A standard 5-Pin Minifast connector is provided on the Master and Tool modules for interfacing with Auxiliary Power. The power source for US1 and US2 Power must be a 24VDC certified power supply or equivalent voltage controlled power supply. A standard M12 D-Coded 4-Pin connector is provided on the Master and Tool modules for interfacing with EtherCAT. When the Tool Changer is coupled, the Master and Tool modules pass signals via a spring-loaded pin block. A flexible rubber seal surrounds the pin block and is designed to be water resistant, but they are not waterproof (see *Figure 1.1*).

The VL1-M/VL1-T modules are designed with a Safety circuit to allow the Tool Changer to be operated in the safest manner possible. To avoid unintentional Tool release, the power for the unlatch valve is routed through a safety switch connector. A safety switch must be connected to support this function. Refer to *Section 2.5—Tool-side TSI* for detailed information regarding the safety features of the EtherCAT control/signal modules.

1.1 VL1 Master

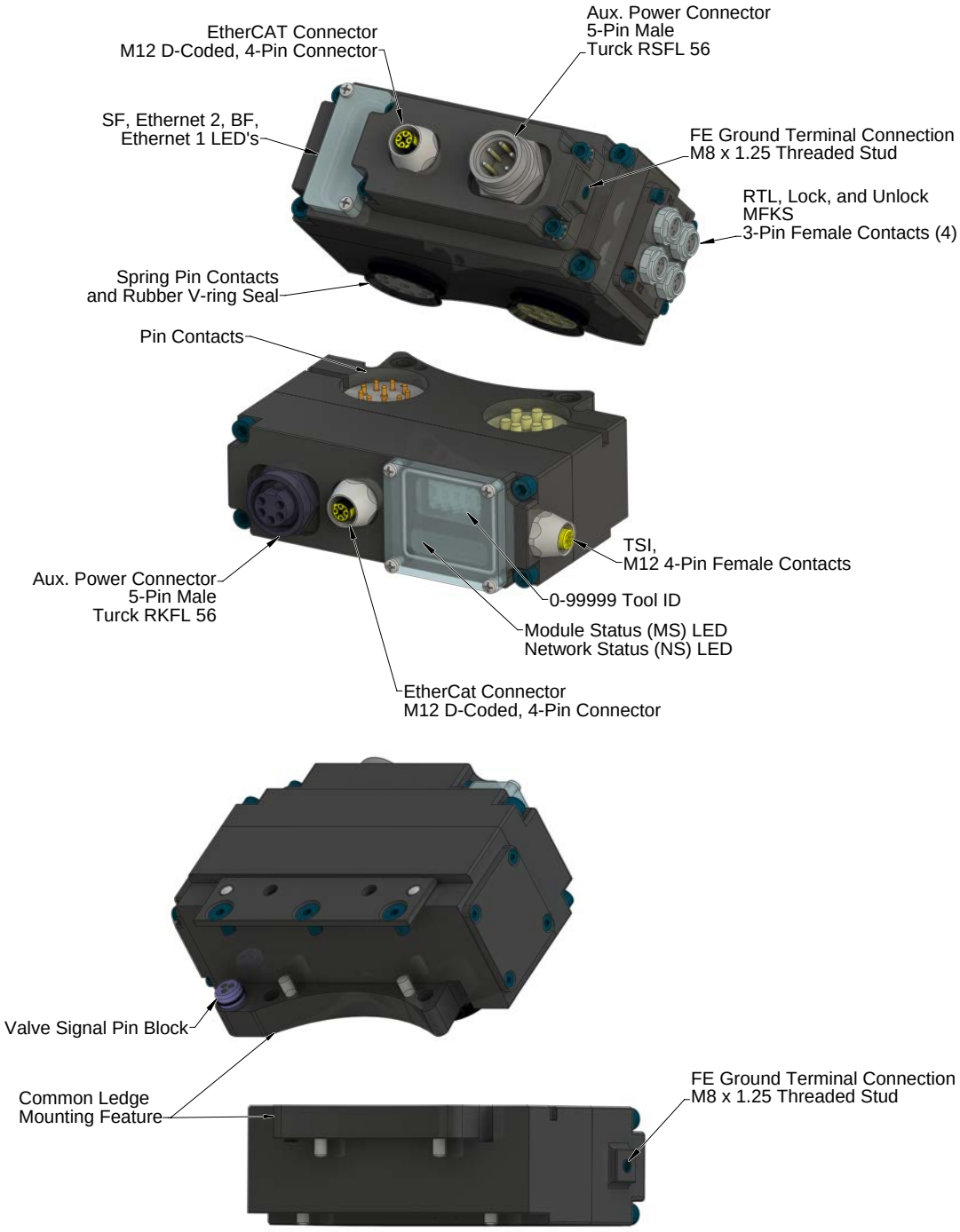
The VL1-M module has an integrated 3-Pin Valve signal pin block to provide the latch and unlatch signals to the solenoid valves. The master module is equipped with M8 3-Pin connectors for the RTL1, RTL2, Lock, and Unlock sensor connections.

The Master module also incorporates ATI's exclusive Arc Prevention Circuit which extends the life of all electrical power contacts by eliminating arcing caused by inductive loads and high inrush current during coupling/uncoupling. Refer to *Section 2.2—Arc Prevention Circuit* for additional information regarding the Arc Prevention Circuit.

The VL1-M module provides status LED's to visually indicate their operation.

An electrical interface is provided on the Master module for support of a solenoid valve (DC Voltage, sourcing-type). The integrated valve is supplied from ATI as part of the valve adapter block (9620-20-C-Jxx). Refer to the Valve Adapter Manual for more information (9620-20-C-Jxx Air and Valve Adapters with Valve Signal Pass Through). Electrical interface drawings and connector details are provided in drawings in *Section 9—Drawings*.

Figure 1.1—VL1 Modules



1.2 VL1 Tool

The VL1-T module requires a Spacer module to align the VL1 Master and Tool modules and mounts to the Tool body of the Tool Changer. A M12 4-Pin connector provides connection to the TSI safety switch that is integrated into the safety circuit.

The Tool module employs a series of thumbwheel switches for setting of the Tool-ID input. This allows the customer to distinguish between the different Tools that are being used in a robotic cell or on a production line. The Tool-ID is reported through the Master module bitmap. See *Section 2.1.1—EtherCAT Interface Information* for EtherCAT bitmap and detailed I/O information.

2. Product Information

The VL1 modules enable the customer to control and communicate with the Tool Changer through a network using an EtherCAT interface. An EtherCAT node is established on the Master module but not on the Tool. Control of the Tool Changer is realized through the Master Node along with the reporting of various Tool Changer I/O. The Tool module supports Tool-ID reported through the Master and functions as a pass-through for EtherCAT network and power to downstream equipment.

2.1 Master Module

2.1.1 EtherCAT Interface Information

Table 2.1 lists the EtherCAT interface parameters employed in the VL1 Master module.

Table 2.1—EtherCAT Interface Parameters

Parameter	Description
Hot Connect	supported
Baud rate	100 MBit/s
Data transport layer	Ethernet II, IEEE 802.3

2.2 Arc Prevention Circuit

The VL1 module incorporates ATI's exclusive Arc Prevention Circuit. The Arc Prevention Circuit extends the life of all electrical power contacts by eliminating arcing caused by inductive loads and high inrush current during coupling/uncoupling. The Arc Prevention Circuit makes it possible to couple/uncouple without switching power off and prevents damage to the contacts.

In the VL1 module, the Arc Prevention Circuit controls the ON/OFF status of the following (2) power signals:

-Input and Logic power US1+

-Output power US2+

The behavior of the Arc Prevention circuit is more fully described in the following sections.

2.2.1 Arc Prevention Circuit Behavior during Coupling

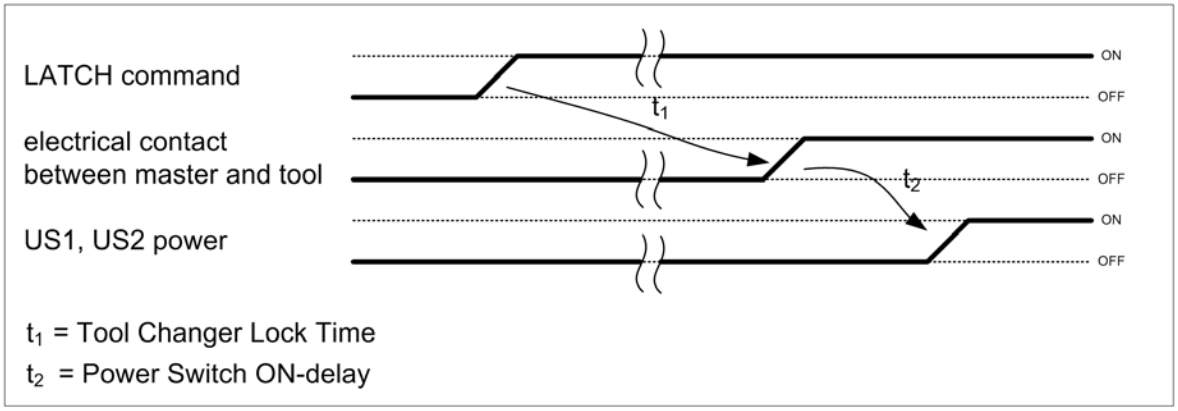
The behavior of the Arc Prevention circuit during coupling can be more clearly understood by referring to *Figure 2.1*, which shows the power-on timing diagram for the Arc Prevention Circuit. Starting at the top of the diagram, the LATCH command is issued thus initiating locking of the Master and Tool.

Soon after locking is initiated, electrical contact between Master and Tool Pin Contacts occurs (this time is designated t_1 in the diagram). The magnitude of time t_1 is a function of many factors including the weight of the EOAT, the distance between the Master and Tool when the LATCH command is issued, how well the Master and Tool are aligned during pick-up, etc.

As soon as electrical contact is made and the LATCH command is issued, the Arc Prevention Circuit will turn on US1 and US2 power. The time delay between when the electrical contacts become fully engaged to when power is actually available to the EOAT (time t_2 in the diagram) is less than 20 ms.

Important: The Arc Prevention Circuit will only allow power to pass to the Tool after the LATCH command has been issued and the Master and Tool module's electrical contacts are fully engaged.

Figure 2.1— Arc Prevention Circuit Power-On Timing



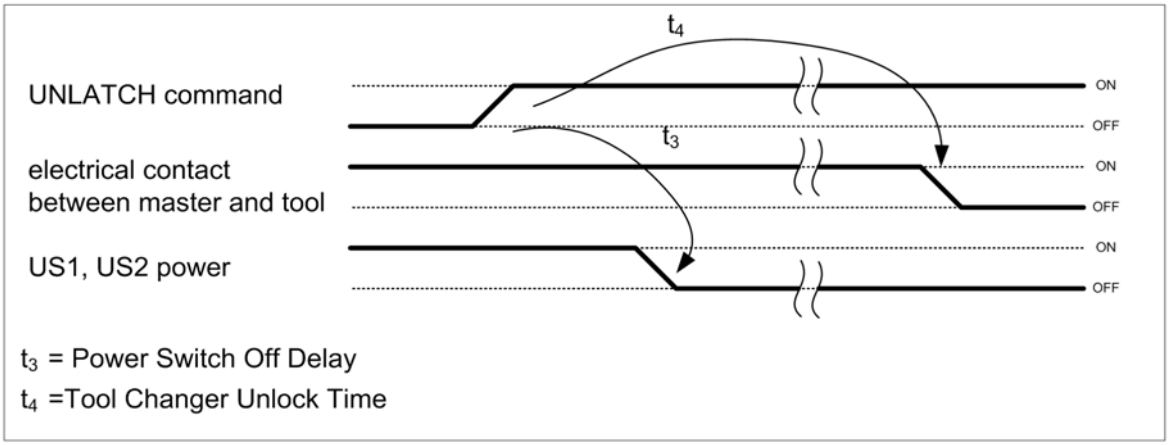
2.2.2 Arc Prevention Circuit Behavior during Uncoupling

The behavior of the Arc Prevention Circuit during uncoupling can be more clearly understood by referring to *Figure 2.2*, which shows the power-off timing diagram for the Arc Prevention Circuit. Starting at the top of the diagram, the UNLATCH command is issued thus initiating uncoupling of the Master and Tool.

Immediately after the UNLATCH command is issued, the Arc Prevention Circuit will turn off US1 and US2 power. The power-off time delay between the UNLATCH command and the switching off of power (designated t_3 in the diagram) is less than 50 ms.

Some time after power is turned off and the Master and Tool begin to separate, electrical contact between Master and Tool Pin Contacts will be lost. This occurs with a delay, designated t4 in the diagram, after the UNLATCH command is issued. The magnitude of time t_4 is a function of many factors, including the weight of the EOAT, the friction between Master and Tool alignment pins, etc. but is usually not shorter than 100 ms.

Figure 2.2—Arc Prevention Circuit Power-Off Timing



2.3 Software

A ESI file for the Master node is available from our website (www.ati-ia.com/download/edsfiles) or by e-mail. Reference the following Part Number:

(www.ati-ia.com/download/edsfiles) or by e-mail.

Reference the Part Number: 9031-20-1050

Robot input and output bitmaps for the Master node are provided in *Table 2.2* and *Table 2.3.*

Table 2.2—I/O Bitmap, Robot Outputs to 9121-VL1-M Module

Byte	Bit#	Name	Description/Function
1	0	Locked	Tool Changer is locked
	1	Unlocked	Tool Changer is unlocked
	2	US1_Power_Present	US1 supply voltage on robot side within the allowable range of 20.4 to 28.8V (20.4V <= US1<= 28.8V)
	3	US2_Power_Present	US2 supply voltage on robot side within the allowable range of 20.4 to 28.8V (20.4V <= US2<= 28.8V)
	4	RTL1	Ready-to-Lock Prox1 I/P
	5	RTL2	Ready-to-Lock Prox2 I/P
	6	TOOL_PRESENT	Master and Tool are in electrical contact.
	7	Tool Power Is On	Indicates that Arc Prevention Circuit is turned ON and power is provided to the Tool
2	0	Unlatch Enabled	Unlatch Enabled Status Information
	1	TSIV	TSI Switch Verify
	2	TSRV	TSI Relay Verify
	3	Reserved	unused input
	4	RTLV1	Ready-to-Lock Relay 1 Verify
	5	RTLV2	Ready-to-Lock Relay 2 Verify
	6	Reserved	
	7	Reserved	
3	0	ERROR_ON_ LATCH	Overload or short circuit on Latch Output
	1	ERROR_ON_ UNLATCH1	Overload or short circuit on Unlatch Output
	2	Reserved	Overload or short circuit on unused output
	3	Unsafe Unlatch	Unlatch Rejected Due to Unsafe Condition Present
	4	Lock/Unlock Sensor Fault	Lock & Unlock Inputs True at the same time
	5	COMM Error	Tool ID Communication Timeout
	6	Reserved	
	7	Reserved	
4	0 to 7	Reserved	

Table 2.2—I/O Bitmap, Robot Outputs to 9121-VL1-M Module			
5	0	Tool ID Switch1 Bit1	
	1	Tool ID Switch1 Bit2	
	2	Tool ID Switch1 Bit4	
	3	Tool ID Switch1 Bit8	
	4	Tool ID Switch2 Bit1	
	5	Tool ID Switch2 Bit2	
	6	Tool ID Switch2 Bit4	
	7	Tool ID Switch2 Bit8	
6	0	Tool ID Switch3 Bit1	
	1	Tool ID Switch3 Bit2	
	2	Tool ID Switch3 Bit4	
	3	Tool ID Switch3 Bit8	
	4	Tool ID Switch4 Bit1	
	5	Tool ID Switch4 Bit2	
	6	Tool ID Switch4 Bit4	
	7	Tool ID Switch4 Bit8	
7	0	Tool ID Switch5 Bit1	
	1	Tool ID Switch5 Bit2	
	2	Tool ID Switch5 Bit4	
	3	Tool ID Switch5 Bit8	
	4 to 7	Reserved	
8	Reserved		

Table 2.3—I/O Bitmap, Robot Outputs to 9121-VL1-M Module			
Byte	**Bit#**	**Name**	**Description/Function**
1	0	Latch	Request Lock
	1	Unlatch	Request Unlock
	2	Spare	Spare O/P (Reserved)
	3	Fault Reset	Reset errors, allow affected I/O to be reactivated
	4 to 7	Reserved	
2 to 8	(Reserved)		

2.3.1 RUN and ERROR LEDs

The RUN status LED is identified on the module as “SF”. It provides device status for power and proper operation. Refer to *Table 2.4* for an outline of this LED’s operation.

The ERROR status LED is identified on the module as “BF”. It provides EtherCAT status information. Refer to *Table 2.5* for an outline of this LED’s operation.

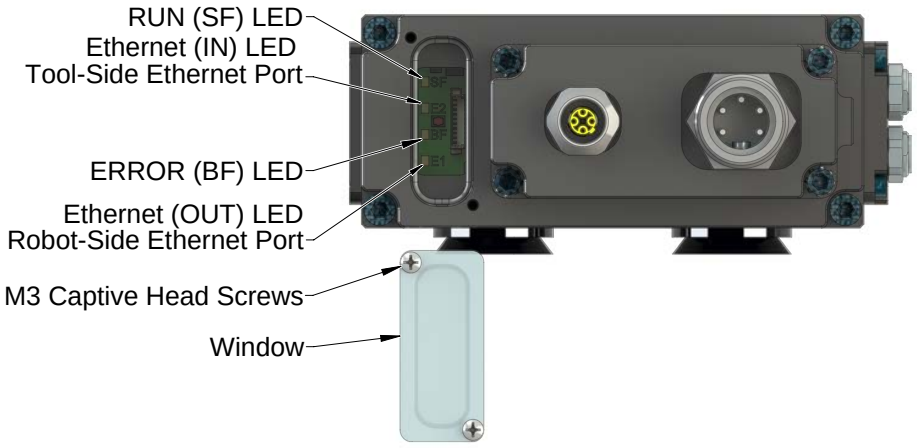
Table 2.4—Master Module RUN Status LED

LED	State	Note
RUN	Off	INIT: The device is in state INIT.
	Blinking	PRE-OPERATIONAL: The device is in PRE-OPERATIONAL state.
	Single Flash	SAFE-OPERATIONAL: The device is in SAFE-OPERATIONAL state.
	On	OPERATIONAL: The device is in OPERATIONAL state.

Table 2.5—Master Module ERROR Status LED

LED	State	Note
ERROR	Blinking	Invalid Configuration: General Configuration Error. Possible reason: State change commanded by master is impossible due to register or object settings.
	Single Flash	Local Error: Slave device application has changed the EtherCAT state autonomously. Possible Reason 1: A host watchdog timeout has occurred. Possible Reason 2: Synchronization Error, device enters Safe-Operational automatically.
	Double Flash	Process Data Watchdog Timeout: A process data watchdog timeout has occurred. Possible reason: Sync Manager Watchdog timeout.
	ON	Normal Operation

Figure 2.3—Master Module LED



2.3.2 Integrated Ethernet Switch

The VL1 Master module provides an integrated 2-port EtherCAT switch which supports the EtherCAT standard.

2.3.3 Ethernet IN and Ethernet OUT LEDs

The Ethernet LEDs provide information about link status and activity on the ports of the integrated Ethernet switch.

The Ethernet IN LED displays the status of the robot-side Ethernet port (refer to *Table 2.6*).

The Ethernet OUT LED displays the status of the Tool-side Ethernet port (refer to *Table 2.7*).

Table 2.6—Master Module Ethernet IN LED

Status	LED Function	Note
No Link	Off	The Master module has no connection to the Ethernet.
Link	Green	The Master is connected to the Ethernet but there is currently no data exchange activity.
Active RX/TX	Blinking Amber	There is sporadic data exchange activity with the Ethernet.
EtherCAT connection established	Amber	There is continuous data exchange activity with the Ethernet.

Table 2.7—Master Module Ethernet OUT LED

Status	LED Function	Note
No Link	Off	There is no Ethernet device connected to the tool module.
Link	Green	There are one or more Ethernet devices connected to the Tool module but there is currently no data exchange activity.
Active RX/TX	Blinking Amber	There is sporadic data exchange activity with the Ethernet.
EtherCAT connection established	Amber	There is continuous data exchange activity with the Ethernet.

2.4 Tool Module

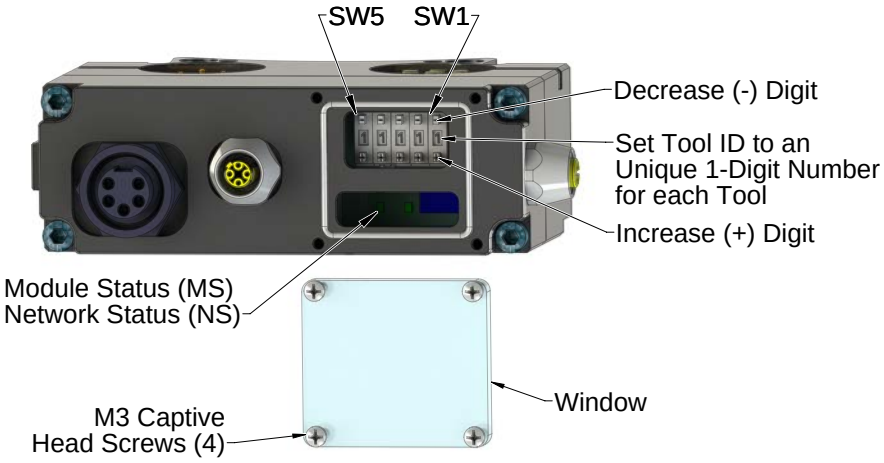
The Tool module utilizes a patented, rapid communication method to report the Tool-ID information from the push-button switches to the Master module as soon as the Tool Changer is coupled. Typically the Tool-ID information is available to the Master within 150 ms from the time the changer is coupled.

Five push-button switches are provided on the Tool module for setting of a Tool-ID number.

If the plastic window and seal above the Tool-ID switches are removed, ensure the seal and window are re-positioned correctly to prevent a leakage path to the module inside.

If the Tool ID is not communicated to the Master within 250 ms from the time the changer is coupled; then a Tool-ID_Error shall be set in the bit map. If a Tool is not present the Tool ID is set to FFFFF. If the Master and Tool are coupled and the Tool ID fails to be reported, a Tool-ID_Error shall be set.

Figure 2.4—VL1 Tool Module, Tool-ID Switch Settings



2.5 Tool-side TSI

The VL1-M module is designed with special features to afford the user the opportunity to operate the Tool Changer in the safest manner possible. The tool stand Interlock (TSI) circuit is provided to ONLY allow Tool release while in the stand or storage location as indicated by actuation of a customer-integrated switch.

The TSI feature provides a “hard-wired” interrupt of the Unlatch solenoid circuit and is intended to prevent release of the tool except when in the stand or storage location (See *Figure 2.5*).

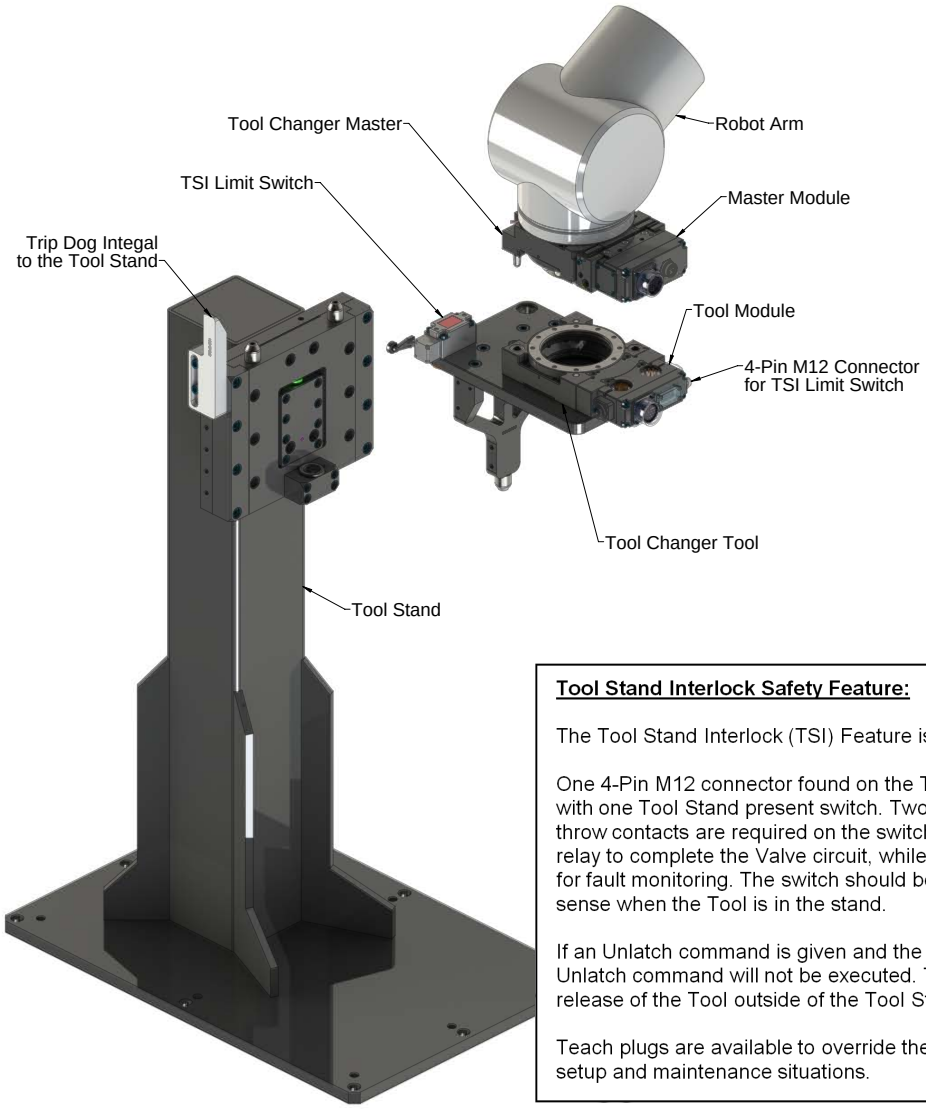
The interrupt for the Unlatch solenoid circuit is passed electrically down to the Tool Changer tool where it is wired into the TSI Relay. The second set of TSI Relay contacts sources US1 power and provides the TSRV input for health status monitoring of the TSI Relay.

A double pole, single-throw limit switch (TSI Limit Switch) is integrated on the EOAT such that it is made when the tool is in the stand. One set of the TSI Limit Switch contacts sources US1 power and drives the TSI Relay, thus closing the Unlatch solenoid circuit. The second set of TSI Limit Switch contacts sources US1 power and drives the TSIV input.

On the Tool Changer master side a parallel path is required for the Unlatch solenoid circuit so that the Tool Changer can be Unlocked (for example: the locking mechanism can be fully retracted) prior to entering and coupling with the tool. This is necessary when there is no tool present because the Unlatch solenoid circuit is routed through the tool and the Tool Changer could not otherwise be Unlocked.

In order to achieve this parallel path an RTL Relay is integrated into the module and is driven by the RTL sensor. When there is no tool present (therefore the RTL sensor is low) the RTL Relay allows the Unlatch solenoid circuit to be completed and an Unlatch command is processed. When a tool is present (and therefore the RTL sensor is high) the RTL Relay is energized and the Unlatch solenoid circuit is diverted through to the tool side. The second set of RTL relay contacts sources US1 power and provides the RTLV input for health status monitoring of the RTL Relay.

Figure 2.5—Tool Stand Interlock (TSI)



Tool Stand Interlock Safety Feature:

The Tool Stand Interlock (TSI) Feature is provided with this Tool Changer.

One 4-Pin M12 connector found on the Tool module is designed for use with one Tool Stand present switch. Two sets of NO, double-pole single-throw contacts are required on the switch. One set energizes a Tool-side relay to complete the Valve circuit, while the second set provides an input for fault monitoring. The switch should be integrated onto the EOAT to sense when the Tool is in the stand.

If an Unlatch command is given and the Tool is not docked properly, the Unlatch command will not be executed. This prevents the accidental release of the Tool outside of the Tool Stand.

Teach plugs are available to override the TSI safety feature during initial setup and maintenance situations.

3. Installation

The control/signal modules are typically installed by ATI prior to shipment. The following steps outline the field installation or removal. For wiring information refer to *Section 9—Drawings*.

WARNING: Do not perform maintenance or repair(s) on the Tool Changer or modules unless the Tool is safely supported or placed in the tool stand, all energized circuits (for example: electrical, air, water, etc.) are turned off, pressurized connections are purged and power is discharged from circuits in accordance with the customer specific safety practices and policies. Injury or equipment damage can occur with the Tool not placed and energized circuits on. Place the Tool in the tool stand, turn off and discharge all energized circuits, purge all pressurized connections, and verify all circuits are de-energized before performing maintenance or repair(s) on the Tool Changer or modules.

CAUTION: Thread locker applied to fasteners must not be used more than once. Fasteners might become loose and cause equipment damage. Always apply new thread locker when reusing fasteners.

3.1 Master Module Installation

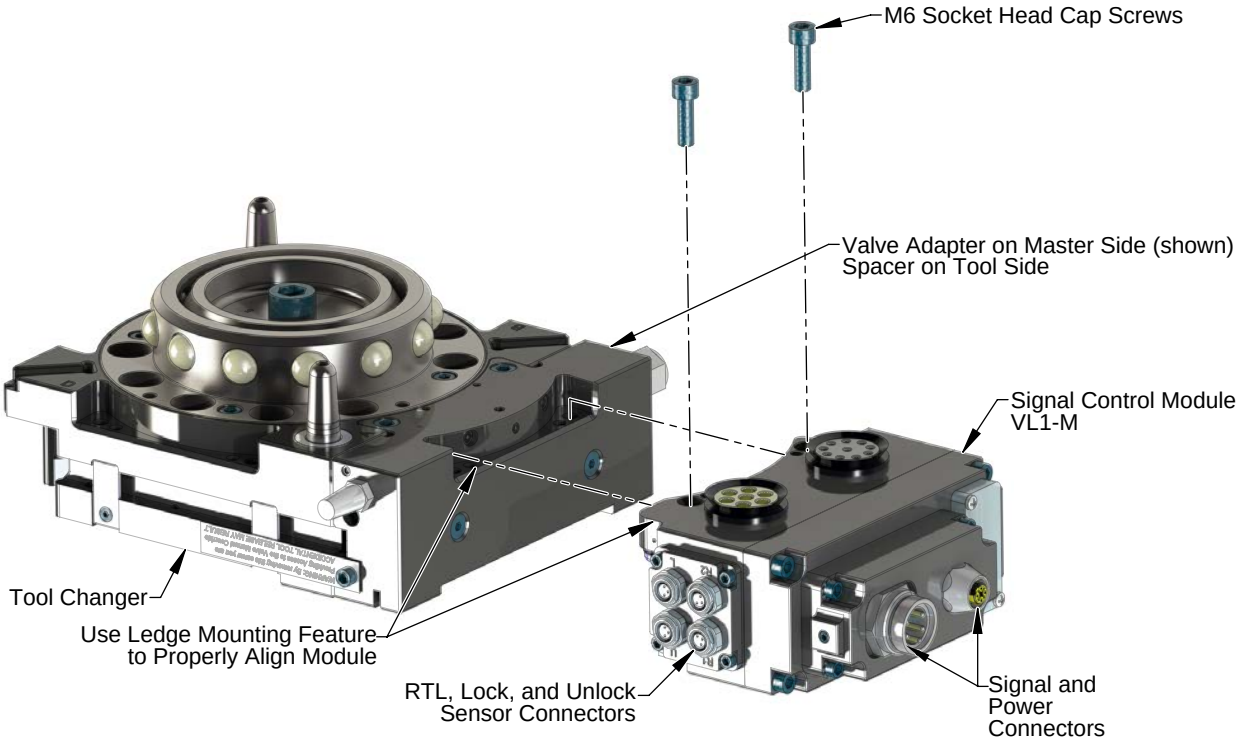
Refer to *Figure 3.1*

Tools required: *5 mm hex key*

Supplies required: *Clean rag, Loctite® 242*

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. Wipe down the mounting surfaces with a clean rag.
5. Using the ledge feature, place the module into the appropriate location on the valve adapter. Align the module with the valve adapter using the dowels in the bottom of the ledge feature.
6. Apply Loctite 242 to the supplied M6 socket head cap screws., install the (2) M6 socket head cap screws securing the module to the air adapter using a 5 mm hex key. Tighten to 70 in-lbs (7.9 Nm).
7. Power, signal, auxiliary, sensor cables and EtherCAT can be connected to the module after attaching the module to the Tool Changer body. Ensure that the connectors are cleaned prior to being secured as appropriate.
8. After a few seconds it should be operating on the network.
9. Safely resume normal operation.

Figure 3.1—VL1-M Module Installation



3.2 Master Module Removal

Tools required: *5 mm hex key*

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. Disconnect the (L) Lock, (U) Unlock, and (R1 and R2) RTL sensor cable connectors from the module.
5. Disconnect the EtherCAT and 5-Pin power cables from the VL1-M control/signal module.
6. Support the control/signal module and, remove the (2) M6 socket head cap screws using a 5 mm hex key. Lower the module until it clears the guide pin.

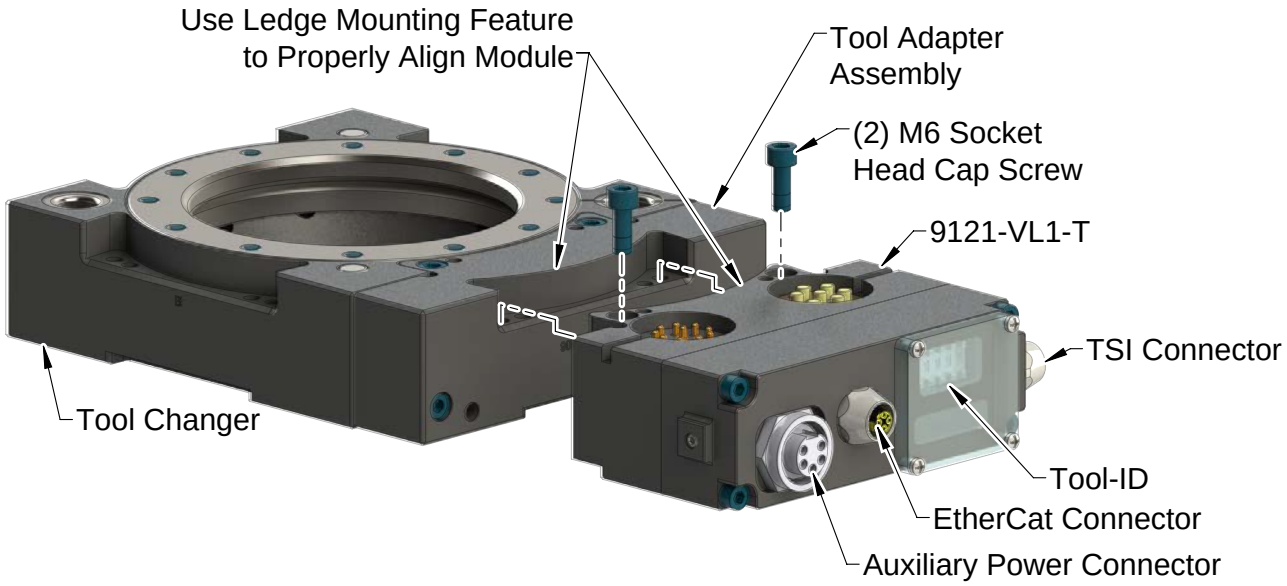
3.3 Tool Module Installation

Tools required: *5 mm hex key*

Supplies required: *Clean rag, Loctite 242*

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. Wipe down the mounting surfaces with a clean rag.
5. Using the ledge feature, place the module into the appropriate location on the valve adapter spacer. Align the module with the valve adapter spacer using the dowels in the bottom of the ledge feature.
6. Apply Loctite 242 to the supplied M6 socket head cap screws.
7. Install the (2) M6 socket head cap screws securing the module to the air adapter using a 5 mm hex key. Tighten to 70 in-lbs (7.9 Nm).
8. Connect the safety switch cables to the module.
9. Connect the power cable and EtherCat cable connectors to the module.
10. Set the Tool-ID. Refer to *Section 3.8—Setting the Tool-ID.*
11. Safely resume normal operation.

Figure 3.2—VL1-T Module Installation



3.4 Tool Module Removal

Tools required: *5 mm hex key*

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. Disconnect the safety switch cables from the module.
5. Disconnect the power cable and EtherCat cable connectors from the module.
6. Support the control/signal module, remove the (2) M6 socket head cap screws using a 5 mm hex key and lift the module.

3.5 EtherCAT Interface

The EtherCAT interface parameters and I/O bitmaps employed in the VL1 modules are found in *Section 2.1.1—EtherCAT Interface Information* of the manual. These should be thoroughly understood prior to operating the Tool Changer. A detailed operational sequence is provided in *Section 4.4—Recommended Sequence of Operation.*

3.6 Utility Schematic

Refer to drawings in *Section 9—Drawings* of this manual for customer interface and wiring details for the VL1-M/VL1-T modules.

3.7 Electrical Connections

Refer to drawings in *Section 9—Drawings* of this manual for customer connections details for the VL1-M/VL1-T modules.

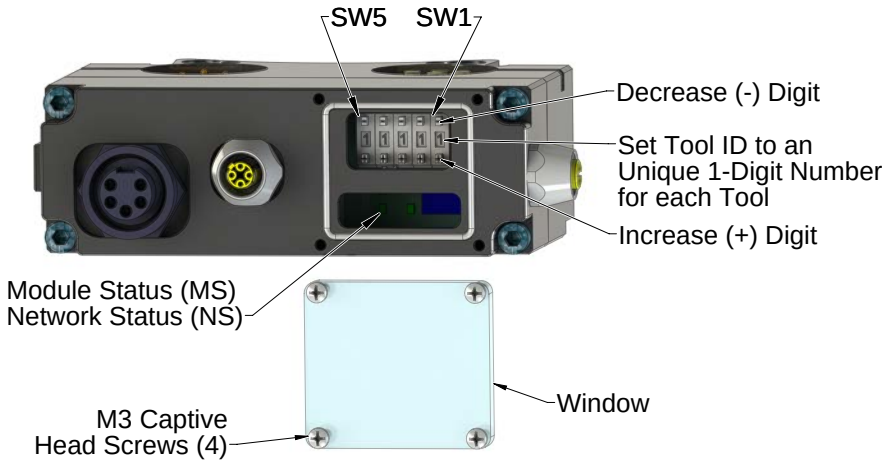
NOTICE: The power source for US1 and US2 Power must be a 24VDC certified power supply or equivalent voltage controlled power supply.

3.8 Setting the Tool-ID

Tools required: *Phillips screwdriver*

(5) push button switches are provided on the Tool module for setting of a Tool-ID number. Each Tool must have an unique 5 digit Tool-ID number.

Figure 3.3—Setting the Tool ID



1. Loosen the (4) M3 pan head captive screws and remove the Tool-ID window.
2. Use a non-conductive tool (e.g., plastic stylus) to press on the Tool-ID push buttons to increase (+) or decrease (-) the digit values.

NOTICE: When replacing the window, ensure that the seal is re-positioned correctly to prevent fluid ingress.

3. Re-install the Tool-ID window and tighten the M3 pan head captive screws.

4. Operation

A recommended Sequence of Operations is provided in *Section 4.4—Recommended Sequence of Operation* of this manual. This procedure is to be used as a general guide when programming a robot or PLC for use with a Tool Changer and control/signal modules. This procedure is intended for "automatic" modes used during normal application processes.

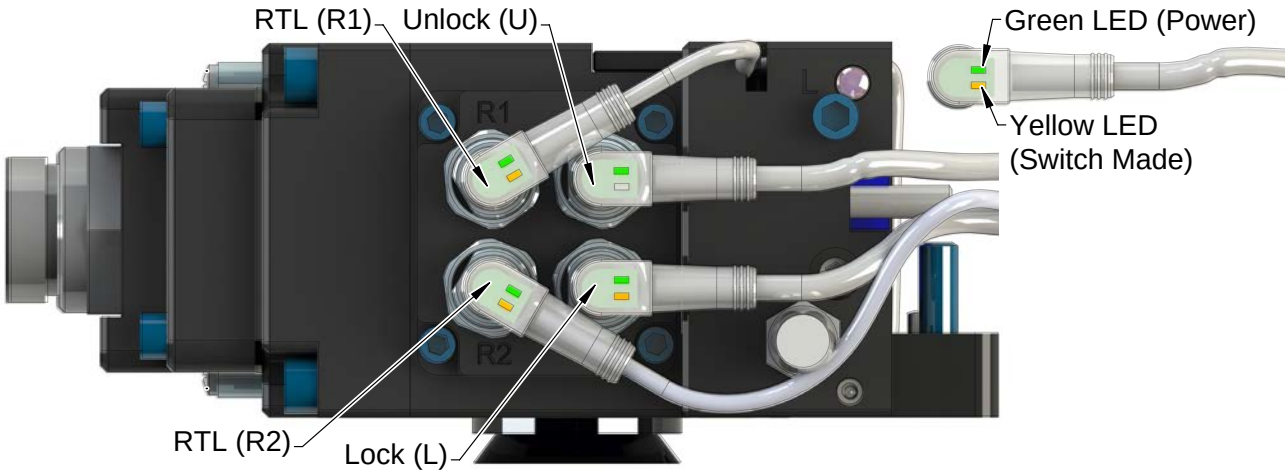
4.1 Lock, Unlock, and Read-To-Lock (RTL) Sensor Cable LED Behavior

The Lock, Unlock, and RTL sensor cables are equipped with two LEDs. The Green LED indicates the sensor has power and the yellow LED indicates the switch has been made. The LED behavior is affected by the control/signal module.

Table 4.1—Sensor Cable LED Behavior for Common Tool Changer Positions

Tool Changer Position	Sensor cable LED Behavior			
Unlocked (Tool Changer Master plate free of stand with no Tool plate attached)	RTL (R1) Sensor	ON OFF	ON ON	Unlock (U) Sensor
	RTL (R2) Sensor	ON OFF	ON OFF	Lock (L) Sensor
Ready to Lock (Tool Changer Master plate with Tool plate parallel and at a distance of 1.22 mm or less from each other)	RTL (R1) Sensor	ON ON	ON ON	Unlock (U) Sensor
	RTL (R2) Sensor	ON ON	ON OFF	Lock (L) Sensor
Locked (Tool Changer Master plate with Tool plate attached in fully locked position)	RTL (R1) Sensor	ON ON	ON OFF	Unlock (U) Sensor
	RTL (R2) Sensor	ON ON	ON ON	Lock (L) Sensor
Missed Tool (Tool Changer Master plate locked with no Tool plate attached)	RTL (R1) Sensor	ON OFF	ON OFF	Unlock (U) Sensor
	RTL (R2) Sensor	ON OFF	ON OFF	Lock (L) Sensor

Figure 4.1—Lock, Unlock, and RTL Sensor cable LED Behavior (Shown in Locked Position)



(Control module shown for reference only)

4.2 Inputs

The following describes the most critical inputs from the ATI Master module.

4.2.1 Unlatch Enabled

The Unlatch Enabled bit is set high when the module determines that the necessary preconditions for unlatching the Tool have been met (Tool is in the Tool Stand, etc.). A Tool can only be released if the "Unlatch Enabled" bit is high. Refer to *Section 2.5—Tool-side TSI.*

Table 4.2—UNLATCH Enable Logic and Truth Table

Inputs			Output	
Tool Present	**TSIV**	**Disable UNLATCH Error Condition (see *Table 4.3* for definition)**	**UNLATCH Enable**	**Status of Master Body**
0	0	0	1	No tool, positioned in free air
0	1	0	1	No tool, positioned in tool stand (this is a transient state which is only true just prior to RTL being made)
1	0	0	0	Tool is present, positioned in free air
1	1	0	1	Tool is present, positioned in tool stand
X	X	1	0	Error condition

4.3 Error Conditions

The following describes the reported error conditions and explains how to reset the condition.

Table 4.3—Error Conditions

Error Condition	Report update freeze immediately after UNLATCH command	Disable Unlatch and turn off Unlatch immediately	Reset with
Output POWER failure	No	No	"Clear Errors" - Bit
LATCH output overload	No	Yes	"Clear Errors" - Bit
UNLATCH output overload	No	Yes	"Clear Errors" - Bit
SPARE output overload	No	No	"Clear Errors" - Bit
UNSAFE UNLATCH COMMAND	Yes	Yes	Cycle UNLATCH output bit or "Clear Errors" - Bit
Input/Logic Power Failure	No	Yes	"Clear Errors" - Bit
RTL/RTLV Mismatch	No	Yes	"Clear Errors" – Bit
TSIV/TSRV Mismatch	No	Yes	"Clear Errors" – Bit
Lock/Unlock Sensor Fault	No	No	Correct error
Comm. Error	No	No	"Clear Errors" – Bit or Cycle Tool Changer (unlock and lock again)

4.4 Recommended Sequence of Operation

1. **Start**→ The robot and Tool Changer Master are free of the stand or storage location, the Tool Changer is uncoupled and the Tool Changer locking mechanism is fully retracted (unlocked condition). The tool is by itself in the tool stand. No error or fault conditions exist.

   a. The **RTL1 and RTL2** inputs are OFF.
   b. The **RTLV1 and RTLV2** are OFF.
   c. The **TSIV and TSRV** are OFF.
   d. The ATI tool and any downstream EtherCat device(s) are OFFline.
   e. The Input/Logic Power Good and Output Power Available inputs are ON and must remain so at all times.
   f. The **US1_Power_Present (Input Power)** and **US2_Power_Present (output Power)** inputs are ON and must remain so at all times.
   g. Tool-ID invalid (all 1→ 0xFFFF)
   h. Unlatch Enabled is ON.

2. Unlock the Master (This must be done prior to the Master entering the tool to prevent the ball bearings from impinging on the tool bearing race.)Robot and Master move within 0.06” of the tool and safety switch is within range.

   a. The **Latch** output command is made OFF and the **Unlatch** output command is made ON.
   b. The **Unlocked** input goes ON, indicating that the Tool Changer locking mechanism is fully retracted and the **Unlatch** operation is complete.
   c. Unlatch Enabled is ON.

3. Robot and Master move into the tool, are parallel and within 0.15” to 0.06” of the tool (for example: the module contact pins are touching but the **RTL** sensors have not yet sensed the targets on the tool).

   a. Unlatch Enabled is ON

4. Robot and Master move within 0.06” of the tool.

   a. The **RTL1** and **RTL2** inputs are ON, indicating that it is ok to couple the tool.
   b. The **RTLV1** and **RTLV2** are ON.
   c. The **Tool Present** and **TSIV** and **TSRV inputs** go ON, indicating that the Master and tool are in close proximity of each other and verifying the operation of the **TSI Limit Switches**.
   d. Communication is initiated with the ATI tool and downstream nodes. When the Tool Present input goes ON **Tool-ID** becomes available within 100–150ms.
   e. Shortly thereafter, communications should be established with the downstream devices.
   f. Unlatch Enabled is ON.

5. Couple the Tool Changer.

   a. The **Unlatch** output is made OFF and the **Latch** output is made ON.
   b. The **Unlocked** input goes OFF a short time later, indicating piston travel. Subsequently, the **Locked** input goes ON, indicating that the coupling operation is complete.
   c. Power becomes available on the Tool and the **Tool Power is On** bit becomes ON.
   d. Unlatch Enabled is ON.

6. Robot moves away from the tool stand with the Tool Changer coupled.

   a. The **TSI Limit Switch** becomes deactivated, and the **TSIV** and **TSRV** inputs go OFF.
   b. Unlatch Enabled is ON.

7. Normal operation

    a. The following inputs are ON:
        i. Locked
        ii. Input/Logic Power Good
        iii. Output Power Available
        iv. RTL1 and RTL2
        v. Tool Present
        vi. RTLV1 and RTLV2

    b. The following inputs are OFF:
        i. Unlocked
        ii. TSIV
        iii. TSRV
        iv. Unlatch Enabled

    c. The following output is ON:
        i. Latch

    d. The following output is OFF:
        i. Unlatch

8. Robot moves into the tool stand with the Tool Changer coupled.

    a. When the tool is returned to the stand, the **TSI Limit Switch** becomes activated and the **TSIV** and **TSRV** inputs go ON, indicating that it is safe to uncouple the Tool Changer.

    b. Unlatch Enabled becomes ON, indicating that it is safe to uncouple the Tool Changer.

9. Uncouple the Tool Changer.

    a. The **Latch** output is made OFF and the **Unlatch** output is made ON.

    b. The **Tool Power is On** bit becomes OFF.

    c. Communication is lost with downstream device(s).

    d. The **Locked** input goes OFF a short time later and subsequently the **Unlocked** input goes ON, indicating that the uncoupling operation is complete.

    e. Unlatch Enabled is ON.

10. Robot and Master move away from the tool, are parallel and between 0.15” to 0.06” of the tool.

    a. The **RTL1** and **RTL2** inputs become OFF.

    b. RTLV1 and **RTLV2** are OFF.

    c. The Tool Present and **TSIV** and **TSRV** are OFF.

    d. Tool-ID invalid (all 1→ 0xFFFF)

    e. Unlatch Enabled is ON.

11. Normal operation

    a. The following inputs are ON:
        i. Unlocked
        ii. Input/Logic Power Good
        iii. Output Power Available
        iv. Unlatch Enabled

    b. The following inputs are OFF:
        i. Locked
        ii. RTL1 and RTL2
        iii. RTLV1 and RTLV2
        iv. TSIV and TSRV
        v. Tool Present
        vi. Tool-ID invalid (all 1→ 0xFFFF)

5. Maintenance

The modules are not designed to be field serviced as all point-to-point wiring connections are soldered. Component replacement is limited to the V-ring seal on the Master.

WARNING: Do not perform maintenance or repair(s) on the Tool Changer or modules unless the Tool is safely supported or placed in the tool stand, all energized circuits (for example: electrical, air, water, etc.) are turned off, pressurized connections are purged and power is discharged from circuits in accordance with the customer specific safety practices and policies. Injury or equipment damage can occur with the Tool not placed and energized circuits on. Place the Tool in the tool stand, turn off and discharge all energized circuits, purge all pressurized connections, and verify all circuits are de-energized before performing maintenance or repair(s) on the Tool Changer or modules.

If the Tool Changer is used in dirty environments (for example: welding or deburring applications), limit the exposure of the Tool Changer. Idle Tool assemblies should be covered to prevent debris from settling on the mating surface. Also, the Master assembly should be exposed for only a short period of time during Tool change and down time.

Under normal conditions, no special maintenance is necessary; however, perform periodic inspections to assess for unexpected damage and assure long-lasting performance. Perform the following visual inspection monthly:

- Inspect mounting fasteners to verify they are tight and if loose, then tighten to the proper torque. Refer to *Section 3—Installation*.
- Cable connections should be inspected during maintenance periods to ensure they are secure. Loose connections should be cleaned and re-tightened. Inspect cable sheathing for damage, repair or replace damaged cabling. Loose connections or damaged cabling are not expected and may indicate improper routing and/or strain relieving.
- Inspect the Master and Tool pin blocks for any pin damage, debris or darkened pins. Refer to *Section 5.1—Pin Block Inspection and Cleaning*.
- Inspect V-ring seals for wear, abrasion, and cuts. If worn or damaged, replace. Refer to *Section 6.3.3—Seal Replacement*.

5.1 Pin Block Inspection and Cleaning

Tools required: *Nylon Brush (ATI part number 3690-0000064-60)*

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. Inspect the Master and Tool pin blocks for debris or darkened pins.

Figure 5.1—Inspect Master and Tool Pin Blocks



5. If debris or darkened pins are present, use a vacuum to remove the debris, and clean using a nylon brush (ATI part number 3690-0000064-60).

NOTICE: Do not use an abrasive media and/or cleaners or solvents to clean the contact pins. Using abrasive media and/or cleaners or solvents will cause damage to the contact surface or cause pins to stick. Clean contact surfaces with a vacuum or non-abrasive media such as a nylon brush (ATI part number 3690-0000064-60).

Figure 5.2—Clean Pin Blocks with a Nylon Brush



6. Inspect the Master and Tool pin blocks for stuck pins or pin block damage.

Figure 5.3—Stuck Pin and Pin Block Damage



7. If pins become stuck or if there is damage to the pin block, contact ATI for either a possible pin replacement procedure or module replacement.
8. Safely resume normal operation.

6. Troubleshooting and Service Procedures

The following section provides troubleshooting information to help diagnose conditions with the Tool Changer and service procedures to help resolve these conditions.

WARNING: Do not perform maintenance or repair(s) on the Tool Changer or modules unless the Tool is safely supported or placed in the tool stand, all energized circuits (for example: electrical, air, water, etc.) are turned off, pressurized connections are purged and power is discharged from circuits in accordance with the customer specific safety practices and policies. Injury or equipment damage can occur with the Tool not placed and energized circuits on. Place the Tool in the tool stand, turn off and discharge all energized circuits, purge all pressurized connections, and verify all circuits are de-energized before performing maintenance or repair(s) on the Tool Changer or modules.

6.1 Troubleshooting

Troubleshooting information is provided in the following table.

Table 6.1—Troubleshooting

Symptom	Possible Cause	Correction
Unit will not lock or unlock	Debris caught between the Master and Tool plates.	Clean debris from between Master and Tool plates. Verify mounting fasteners is secure and does not protrude above the mating surfaces.
	Ball bearings are not moving freely.	Verify the ball bearings are moving freely. Clean and lubricate as needed. Refer to the Maintenance section of the Tool Changer manual for instructions.
	Air supply not to specifications.	Check air supply. Refer to the Installation section of the Tool Changer manual for specifications.
	Valve adapter exhaust muffler clogged.	The valve adapter exhaust muffler may be clogged. Refer to the valve adapter manual for more information.
	TSI switch not functioning properly.	Verify the TSI switch is functioning and properly adjusted.
	Input power outside limits.	Verify the input power is within limits (Valve Power Available is ON).
	Unlocked bit	Verify the Unlocked bit is ON.
	Signals are mapped incorrectly.	Verify signals are mapped and are communicating properly. Refer to *Section 9—Drawings* for electrical schematic.
	Master and Tool are within the specified No-Touch zone.	Verify the Master and Tool are within the specified No-Touch zone when attempting to lock. Refer to the Installation – tool stand Design Section of the Tool Change manual for specifications.
	Solenoid valve not functioning.	The valve adapter exhaust muffler may be clogged. Refer to the valve adapter manual for more information.
	Unlatch conditions have not been met.	Verify the Unlatch Enabled input is ON, refer to Section 4.2.3 Unlatch Enabled for conditions.

Table 6.1—Troubleshooting		
Symptom	**Possible Cause**	**Correction**
Sensors not operating properly (but EtherCAT is operating correctly).	Tool plate is not secured properly or debris is trapped between surfaces.	Ensure that the Tool plate is securely held to the Master plate, that nothing is trapped between their surfaces.
	Valve adapter exhaust muffler clogged.	The valve adapter exhaust muffler may be clogged. Refer to the valve adapter manual for more information.
	Sensor cables damage or incorrectly connected.	Verify the cables are connected correctly and not damaged, replace if damaged. Refer to the Troubleshooting Section of the Tool Changer manual.
	Sensors are not set correctly or not functioning.	Verify the sensors are set correctly and functioning. Refer to the Troubleshooting Section of the Tool Changer manual.
Loss of Communication	Damaged signal cabling	Check/Replace signal cabling up- and down-stream of Tool Changer modules.
	Worn or damaged contact pins	Inspect module contact pins for debris/wear/damage.
	Product upstream and downstream of Tool Changer failed or damaged	Check product upstream and downstream of Tool Changer for failure. This failure can “appear” to be caused by the Tool Changer or affect Tool Changer performance.
No Power on the Tool side	Latch command not issued	Verify the Latch command has been issued by the robot.
	Tool Power ON bit	Verify the Tool Power ON bit is ON.
	Tool Present bit	Verify the Tool Present bit is ON.

6.2 Service Procedures

The following service procedures provide instructions for inspection, adjustment, test or replacement of components.

6.3 VL1 Device Replacement Procedures

The device replacement procedures are based on the following assumptions:

- The topology of the EtherCAT network was properly defined with the EtherCAT engineering tool.
- The EtherCAT controller supports automatic device replacement.

6.3.1 VL1 Master Module Replacement Procedures

1. Remove the “old” module from the Tool Changer, refer to *Section 3.2—Master Module Removal* for removal procedure.
2. Install new module on Tool Changer, refer to *Section 3.1—Master Module Installation* for installation procedure.

6.3.2 Replace VL1 Module with an Already-Commissioned VL1 Module

1. Remove the “old” module from the Tool Changer, refer to *Section 3.1—Master Module Installation* for removal procedure.
2. It may be necessary to clean the mounting surface on the JR4 valve adapter prior to installing the module in order to remove any debris that may be present.
3. Using the ledge feature as a guide place the VL1-M control/signal module to the JR4 Valve Adapter mounting surface. Align the control/signal module with the valve adapter using the dowels in the bottom of the ledge feature.
4. If fasteners do not have pre-applied adhesive, apply Loctite 242 to the supplied M6 socket head cap screw fasteners., install the (2) M6 socket head cap screws securing the control/signal module to the valve adapter and tighten to 70 in-lbs (7.91 Nm).
5. Connect the pressure sensor and proximity sensor cables to the connectors on the VL1-M module.
6. Connect the RTL1, RTL2, Lock, and Unlock sensor cables to the connectors on the VL1-M module.

Figure 6.1—Module Installation and Removal VL1-M Control/Signal Module

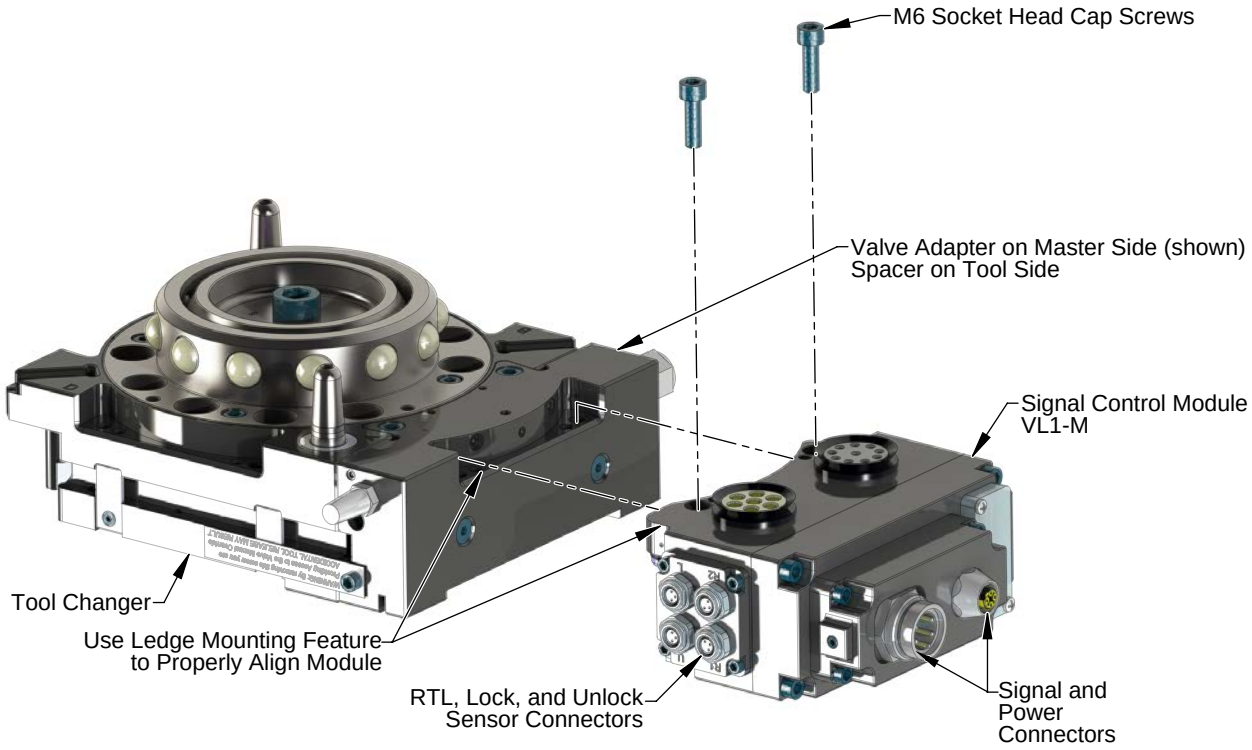
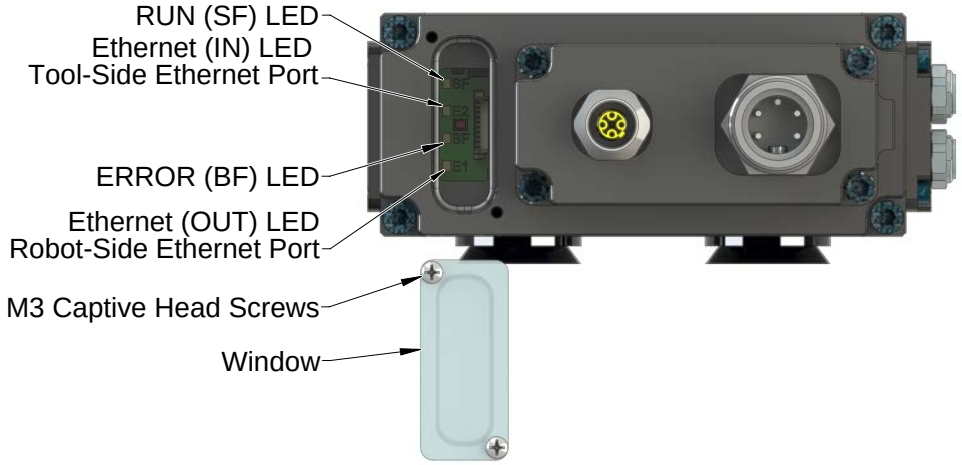


Figure 6.2—LED's



7. Connect the RJ45 Ethernet cable and the 5-Pin Power cable to the connectors on the VL1-M module.
8. After a few seconds it should be operating on the network.
9. The RUN LED should be GREEN.

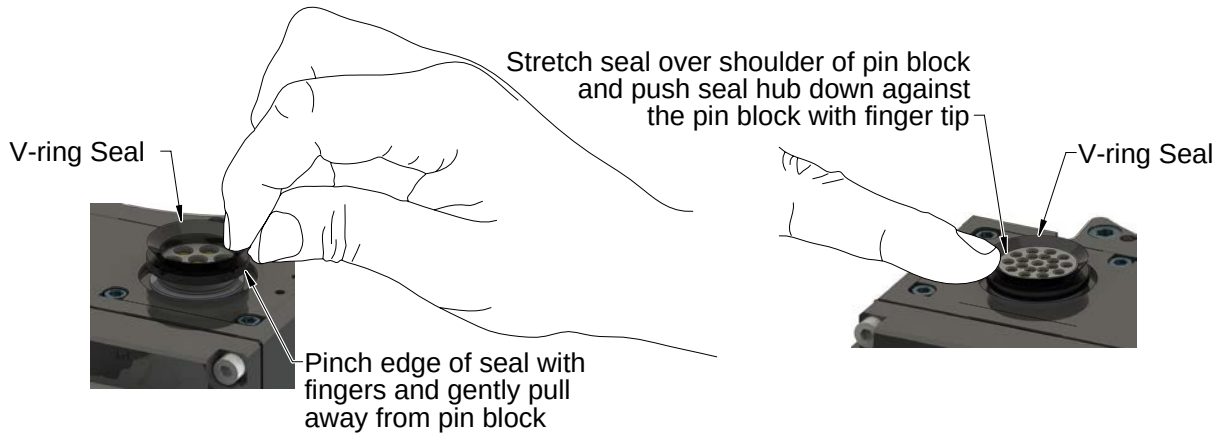
6.3.3 Seal Replacement

Part Required: *Refer to Section 9—Drawings.*

The seal protects the electrical connection between the Master and Tool module. Replace the seal if it becomes worn or damaged.

1. Place the Tool in a secure location.
2. Uncouple the Master and Tool plates.
3. Turn off and de-energize all energized circuits (for example: electrical, pneumatic, and hydraulic circuits).
4. To remove the existing seal, pinch the edge of the seal and pull the seal away from the pin block on the Master module.
5. To install a new seal, stretch the new seal over the shoulder of the pin block.
6. Push the seal hub down against the pin block.
7. Safely resume normal operation.

Figure 6.3—V-ring Seal Replacement



7. Serviceable Parts

7.1 Master Module Serviceable Parts

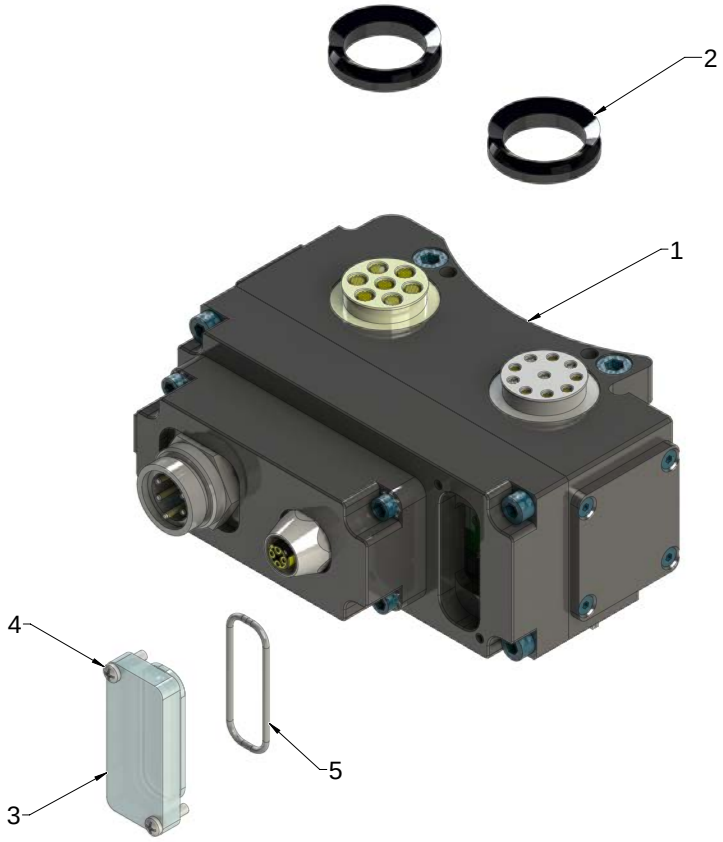


Table 7.1—Master Module			
Item No.	**Qty**	**Part Number**	**Description**
1	1	9121- VL1-M	VL1 Master EtherCAT module Assembly
2	2	4010-0000030-01	V-Ring Seal V-22A Nitrile
3	1	3700-20-4820	Window, DJ Master
4	2	3500-9957012-21	Pan Head M3 Captive Screw M3 X 12 1812-12-SS-PP-1
5	1	3410-0001201-01	O-Ring

7.2 Tool Module Serviceable Parts

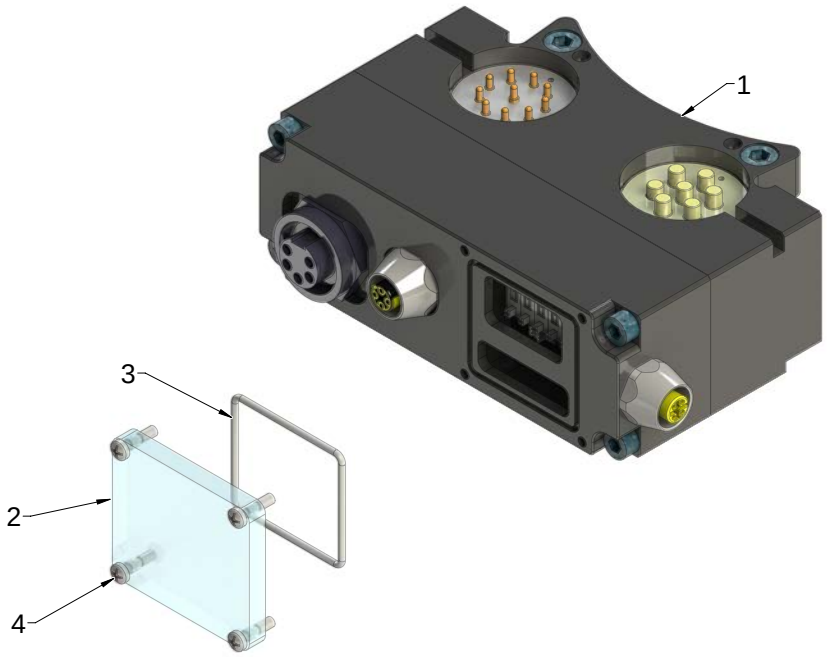


Table 7.2—Tool Module			
Item No.	**Qty**	**Part Number**	**Description**
1	1	9121- VL1-T	VL1 Tool module Assembly
2	1	3700-20-3058	Thick Window for Tool Side control/signal module, Polycarbonate
3	1	3410-0001021-01	O-Ring
4	4	3500-9957012-21	Pan Head M3 Captive Screw M3 X 12 1812-12-SS-PP-1

7.3 Accessories

Table 7.3—Accessories			
Item No.	**Qty**	**Part Number**	**Description**
*	*	3690-0000064-60	Brush, Blue Nylon All Purpose (Contact Pin Cleaning)

8. Specifications

Table 8.1—Master Module	
9121-VL1-M	VL1 EtherCAT Control Master module Assembly
Connector(s)	Auxiliary Power: 5-Pin Male Mini RSFL 56 EtherCAT: 4-Pin Female M12 D-Coded FKDD 44 Integrated Tool Changer I/O: (4) M8, 3-pin female connectors supporting Tool Changer Locked, Unlocked, and Ready-to-Lock proximity sensors. Integrated Connection to valve adapter: (1) 3-Pin Pin Block supporting Latch and Unlatch signals
EtherCat Port	US1+ and US2+ Power: 10A, 20–29VDC Note: Arc prevention is applied to US1 and US2 power.
Pass-Through Signals	3A, 30VDC maximum
Current Draw	US1 Power: 220mA @ 24VDC: Master and Tool with Locked, RTL1, and RTL2 sensors “on” and Safety Switch activating Relay. US2 Power: 250mA @ 24VDC (Solenoid Valve) (only when locking or unlocking Tool Changer). **Note:** Power source for US1 and US2 Power must be a 24VDC certified power supply or equivalent voltage controlled power supply.
Temperature	32°F to 120°F (0 to 49°C).
Weight	2.17 lbs (0.98 kg)

Table 8.2—Tool Module	
9121-VL1-T	VL1 EtherCAT Control Tool module Assembly
Factory Default Configuration	(5) Independent Tool-ID switches, each reading a (0–9) position (all factory set to Tool Position 1)
Connector(s)	Auxiliary Power: 5-Pin Female Mini RKFL 56 EtherCAT: 4-Pin Female M12 D-Coded FKDD 44 Connection to TSI Switch: (1) M12, 4-Pin female connector supporting connection to Limit Safety Switch
Pass-Through Power	US1+ and US2+ Power: 10A, 12-30VDC
EtherCat Port	3A, 30VDC maximum
Temperature	32°F to 120°F (0 to 49°C).
Weight	1.62 lbs (0.73 kg)

9. Drawings

Drawings are available on the *ATI website* or by contacting an ATI representative.