GACI

Accelerator Control Interface

for Particle Therapy System Integration

User Manual

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3 Safety Information

3.1 Standards

This unit is designed for compliance with harmonized electrical safety standard EN61010-1:2000. It must be used in accordance with its specifications and operating instructions. Operators of the unit are expected to be qualified personnel who are aware of electrical safety issues. The customer's Responsible Body, as defined in the standard, must ensure that operators are provided with the appropriate equipment and training.

3.2 Power and Grounding

The unit is designed to operate from +24VDC power, with a typical current requirement of 600 mA. A suitably rated power supply module is supplied as standard and is strongly recommended. Customers who make their own 24 V power provision should ensure that the supply cannot source more than 4200 mA, that it has the correct connector type, that it is rated for use in the environment, that it provides overcurrent and short circuit shutdown and that it has all necessary regulatory approvals.

A safety ground must be securely connected to the ground lug on the case.

3.3 Safety considerations for the intended application

The ACI is an associated component of an overall dose safety system for a proton therapy machine. By itself, it cannot ensure safe delivery of dose. It must be connected to relevant signals and interlock systems, the configuration must be subjected to risk analysis, and the connections must be checked and tested. If there is any reason to suspect the features are not working as described, the proton therapy system must not be used for medical treatments until the problem is identified and resolved.

3.3.1 Signal passthrough

The unit is equipped with a signal passthrough loop. Critical control signals can be gated via this passthrough by a safety device such as the Pyramid Interlock Control Interface (ICI). In particular the Beam Enable and Beam Intensity signals are part of this interlock.

3.3.2 Beam stops

The ACI can be used to control and monitor treatment room beamstops. The beam stops cannot be retracted unless all interlock conditions are met and the Scan/Dose host commands them open. In this way the beam stops will automatically close in the event an interlock triggers.

3.3.3 Control verification readbacks

Critical control signals have mirrored inputs that the application program can use to verify that the control signals have properly reached their destinations.

3.3.4 Selected room report

The selected room is reported by the ACI over a pair of digital relays. These can be sent to a safety PLC to be incorporated into the overall safety system logic.

3.4 Symbols

Some of the following symbols may be displayed on the unit and have the indicated meanings.

Direct current

Earth (ground) terminal

Protective conductor terminal

Frame or chassis terminal

Equipotentiality

Supply ON

Supply OFF

CAUTION – RISK OF ELECTRIC SHOCK

CAUTION – RISK OF DANGER – REFER TO MANUAL

4 Models

ACI-G	ACI accelerator control interface for general use.

5 Scope of Supply

ACI-G model.

PSU24-40-1R 24 VDC 40-watt power supply with Redel locking connector, rated for medical use.

USB memory stick containing:

- ACI User manual
- ACI Datasheet
- Manufacturing test results

OEM customers will receive only components relevant to their application.

6 Optional Items and Related Products

6.1 Interface units

X22 Bidirectional fiber optic to TTL converter. Allows TTL logic connections to ACI fiber optic ports.

6.2 Power Supplies

PSU24-40-1R +24 VDC 40W PSU (universal voltage input, plug receptacle for standard IEC C14 three-pin socket) with output lead terminated in two-pin Redel PAG connector.

CAB-LR-3-REDEL Cable Switchcraft LR 2.1mm jack to Redel PAG connector.

PD-8 Eight output +24 VDC power supply unit, 19” rack mounting.

6.3 Signal Cables and Cable Accessories

CAB-BNC-xx-BNC cable xx feet long BNC terminated both ends, RG-58.

6.4 Data Cables

CAB-RJ45-xxx-RJ45 Ethernet CAT5, xxx feet long.

CAB-ST-xxHCS-ST Fiber-optic cable pair 200 µm silica fiber ST terminated with color-coded sleeves, xx feet long.

7 Intended Use and Key Features

7.1 Intended Use

The ACI is intended to be used as an integration component of a particle therapy system where treatment nozzles in one up to three treatment rooms must communicate with a single beam production system. The accelerator type for the beam production system can be a cyclotron, synchrotron, synchrocyclotron or linac.

The device is expected to be used along with Pyramid Technical Consultants real time controllers and scan/dose software. It may be used in other contexts only after analysis of the proposed integrated system to ensure suitability.

The ACI has features that allow it to form part of a beam control and interlocking sub-system when used together with one or more Pyramid Technical Consultants Interlock Control Interfaces ("ICI"). Consult the user manual for the ICI as necessary when implementing and using a system with both units. The simple block schematic figure below shows the ACI as it is typically embedded in a multi-room proton therapy system.

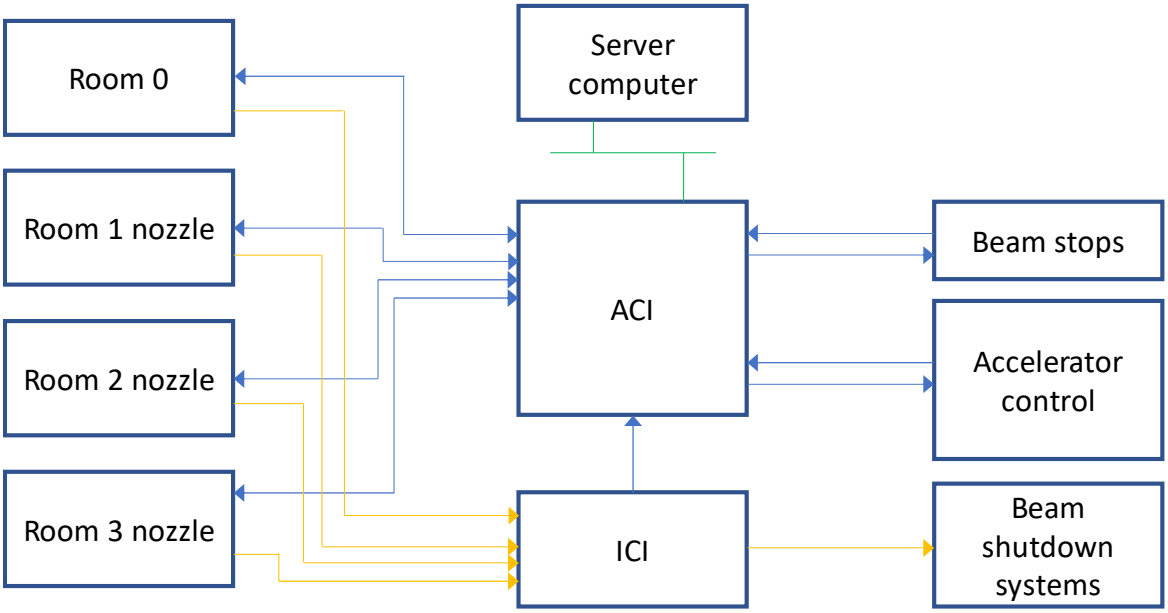


Figure 1 - ACI signal connections

The ACI uses fiber optic digital inputs and outputs to provide galvanic isolation. Users who need to interface to TTL logic lines at the accelerator electronics may use the Pyramid X22 bidirectional converter to make connections.

The ACI has capability to control and monitor pneumatically actuated beam stops which use 24 VDC solenoids. Some facilities may choose to do beam stop control through a separate

controller, in which case the ACI should monitor the beam stop positions via parallel limit switches.

7.2 Key Features

Designed in accordance with the requirements of IEC 60601-1 and related standards. Specifically designed to address requirements of IEC 60601-2-64:2014 and referenced standards therein.

Analog and digital interfaces to the accelerator to control beam enable and intensity, with confirmation readbacks.

Readback from synchrotron accelerators to report beam remaining.

Measurement of accelerator frequency for synchrotron accelerators that can be used for energy validation by the client control system.

Signal passthrough system that allows an external safety device such as the Pyramid Interlock Control Interface (ICI) to gate accelerator control signals.

Communication interfaces to Pyramid scan nozzle control system to receive desired beam settings from up to four rooms.

Control and readback of beam stops.

Illuminated LCD display to view device status.

Built-in self-diagnostics.

Ethernet connectivity via an EPICS interface to report ACI parameters.

8 Specification

Accelerator Interface		
	Beam enable command	Fiber optic digital output to accelerator (640 nm visible light) to command beam on. Configurable hardware logic option uses the readback "Beam ready" signal to force beam off when beam is not available.
	Beam enabled state	Fiber optic digital input to monitor the beam enabled state from the accelerator.
	Beam current command by current	Commands the beam intensity via a current level 0-20 mA (10 V compliance). Terminate with a low resistance (0 or 50 Ohm) resistor if the alternative 10V output is used.
	Beam current command by voltage	Alternate method of commanding the beam intensity by an analog voltage (0 to 10V); able to drive 5 kohm load.
	Beam current readback	Differential analog signal 0-10V, or 0-20mA from accelerator to readback the setting of the beam current. An internal dip-switch must be set to indicate whether the signal is 0-10V or 0-20mA.
	Beam ready status readback	Fiber optic digital input from accelerator indicating if beam is available.
	Beam remaining readback	Differential analog input 0-10V input from accelerator to monitor beam remaining in the accelerator.
	Frequency readback	Fiber optic digital input from accelerator to monitor frequency. Typical use for measuring synchrotron orbit frequency as an indication of beam energy.
Multiple room Support		
	Number of rooms	Up to three rooms maximum plus "room 0" to permit accelerator operation with no treatment room selected.
	Room select input	One of the following depending upon room selection mode settable via internal dip switch: - Two external bits input as digital levels - Requested over Ethernet EPICS interface
	Room selected readback	Both of the following: - Two bits externally output as contact closures

		- Ethernet EPICs PV
Beam Stop Interface		
	Control	Opto-isolated digital outputs to control beam stops for all rooms. For rooms 1-3 the room must be selected to effect control.
	Readback	Opto-isolated digital inputs to readback beam stop in and out states for all rooms.
Processors		
ACI	Type	TI Sitara AM335x (ARM Cortex A8) 1 GHz with dual PRU.
	Operating system	QNX.
	Automated self-test (POST)	Automated tests of relay function, RAM and flash memory, battery function, Ethernet connection. System operation prohibited if POST fails.
M40s	Type	PIC 18LF8722.
	Operating system	None.
Connectivity	Fiber optic channels to dosimetry system	Direct fiber optic communication channels for up to three treatment rooms plus room zero for control and monitoring. Implemented using individual Pyramid M40 interface devices, one per channel. Compatible with the Pyramid Scan/Dose system. Systems without the Pyramid Scan/Dose system can use the A560 or Q560 loop controllers to obtain equivalent control.
	Ethernet	Ethernet 10/100/1000 Mbps. Auto MDIX. Embedded EPICS channel access server allows client software to monitor and control device function.
	USB	USB port for device setup and diagnostics (qualified service technician access). Connecting to the USB port creates a virtual network to a host system and appears at static IP address 192.168.7.2.
Power	Power input	24 V (+/- 2V) DC, 600 mA typical, 1000 mA max. Note that the embedded M40 interface devices are

		powered directly by the ACI. It is not necessary to connect 24 V power the Power Monitor jacks on the front panel.
Case	Format and materials	1U 19” 250 mm deep rack mounting steel chassis with Al alloy front panel and polycarbonate decals. Fan-cooled.
	Protection rating	The case is designed to rating IP43 (protected against solid objects greater than 1mm in size, protected against spraying water).
	Weight	3.5 kg (7.7 lb)
	Dimensions	See figure.
Environment	Operating environment	10 to 35 C (15 to 25 C recommended), < 70% humidity, non-condensing, vibration < 0.2g all axes (1 to 100 Hz).
	Shipping and storage environment	-10 to 50 C, < 80% humidity, non-condensing, vibration < 1g all axes, 1 to 100 Hz.
Displays and Indicators	OLED display	2x16 character blue OLED to report device status.
	Power on light	Illuminate Pyramid logo on front panel.
	Device interface status LEDs	Each of the four rooms connect to the Scan/Dose control system via an M40 device interface. Each of these interfaces has 4 small status LEDs. When the device is operating correctly the first and fourth LEDs will be blinking.
Switches	Device interface status address switch	Each of the four M40 devices has an address switch which can be set from 0x01 to 0x0F.
	SW2 (internal)	Determines if the outgoing Beam Enable command is routed via hardware AND with the Beam Ready response from the accelerator before being sent out.
	SW3 (internal)	Determines if the room selection is performed internally via two digital input signals, or externally via an Ethernet command.

	SW6 (internal)	Determines the type of signal used for the I monitor signal, either 0-20mA or 0-10V.
	SW7 (internal)	Determines the type of signal used for the Q charge signal, either 0-20mA or 0-10V.

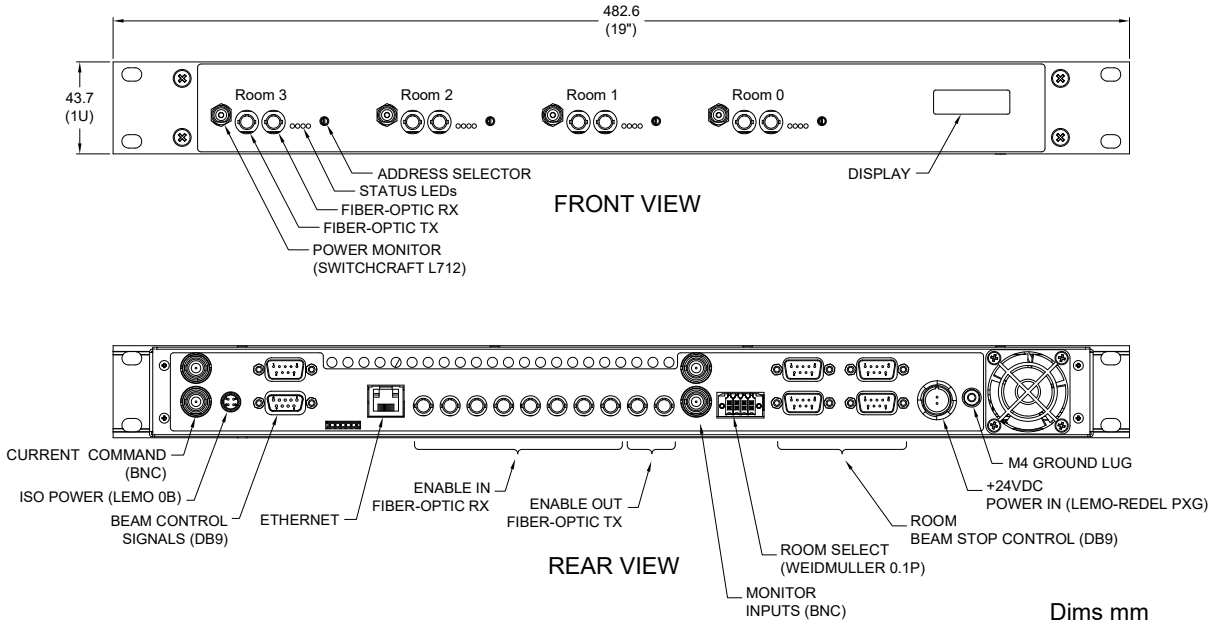


Figure 2 - ACI front and rear panels. Dimensions in mm.

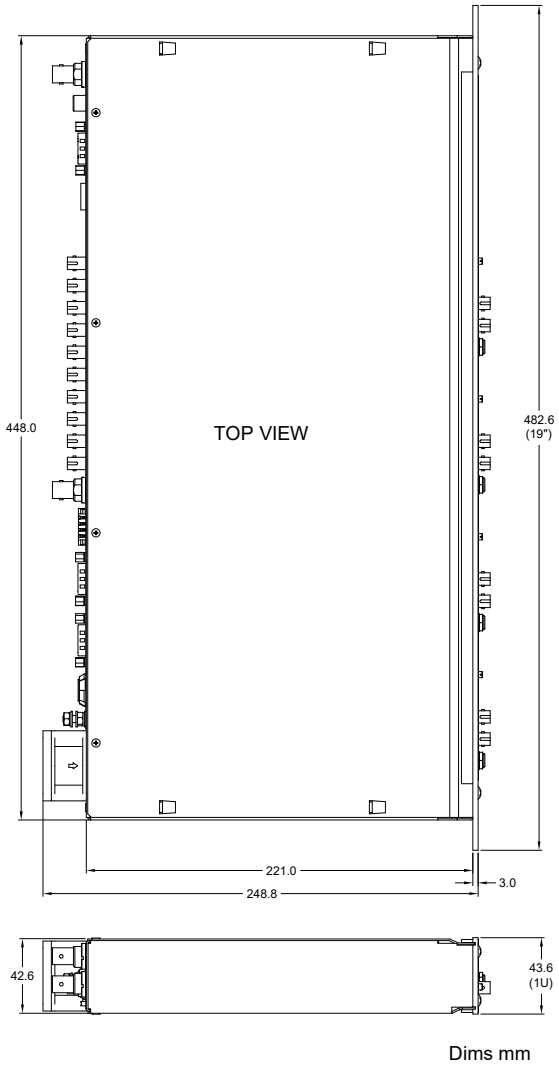


Figure 3 - ACI case plan and side views. Dimensions in mm.

9 Installation

9.1 Mounting

The ACI is intended for 19” rack mounting, but may be mounted in any orientation, or may be simply placed on a level surface. A fixed mounting to a secure frame is recommended in a permanent installation for best reliability. The mounting position should allow sufficient access to connectors and cable bend radii. 60 mm minimum clearance is recommended at front and back of the device.
Best performance will be achieved if the ACI is in a temperature-controlled environment. No forced-air cooling is required in addition to the unit’s built-in fan, but free convection should be allowed around the back and sides of the case.

9.2 Grounding and Power Supply

A secure connection should be made using a ring lug, from the M3 ground lug to local chassis potential. This is the return path for any high voltage discharge passing via the ACI.

+24 VDC power should be provided from a suitably-rated power supply with the following minimum performance:

Output voltage	+24 +/- 0.5 VDC
Output current	1500 mA minimum, 4200 mA maximum
Ripple and noise	< 1% pk-pk, 1 Hz to 1 MHz
Line and load regulation	< +/- 5%

The ACI includes an internal automatically re-setting PTC fuse rated at 1.1 A that protects the internal circuitry. However, the external supply should in no circumstances be rated higher than the connector limit of 10 A.

9.3 Signal Connections

A typical facility has multiple treatment rooms that must share a single accelerator. The ACI provides an interface between the Accelerator Control System (ACS) and up to 4 individual room controllers (three treatment rooms plus a room 0 to allow accelerator operation with no treatment room active). The room controllers themselves will be made up of multiple electronic units. The interface between the ACI and the room controllers is done through a combination of fiber-optic communication links and fiber optic digital levels.

Below is a typical block diagram of these connections for the case of a synchrotron accelerator.

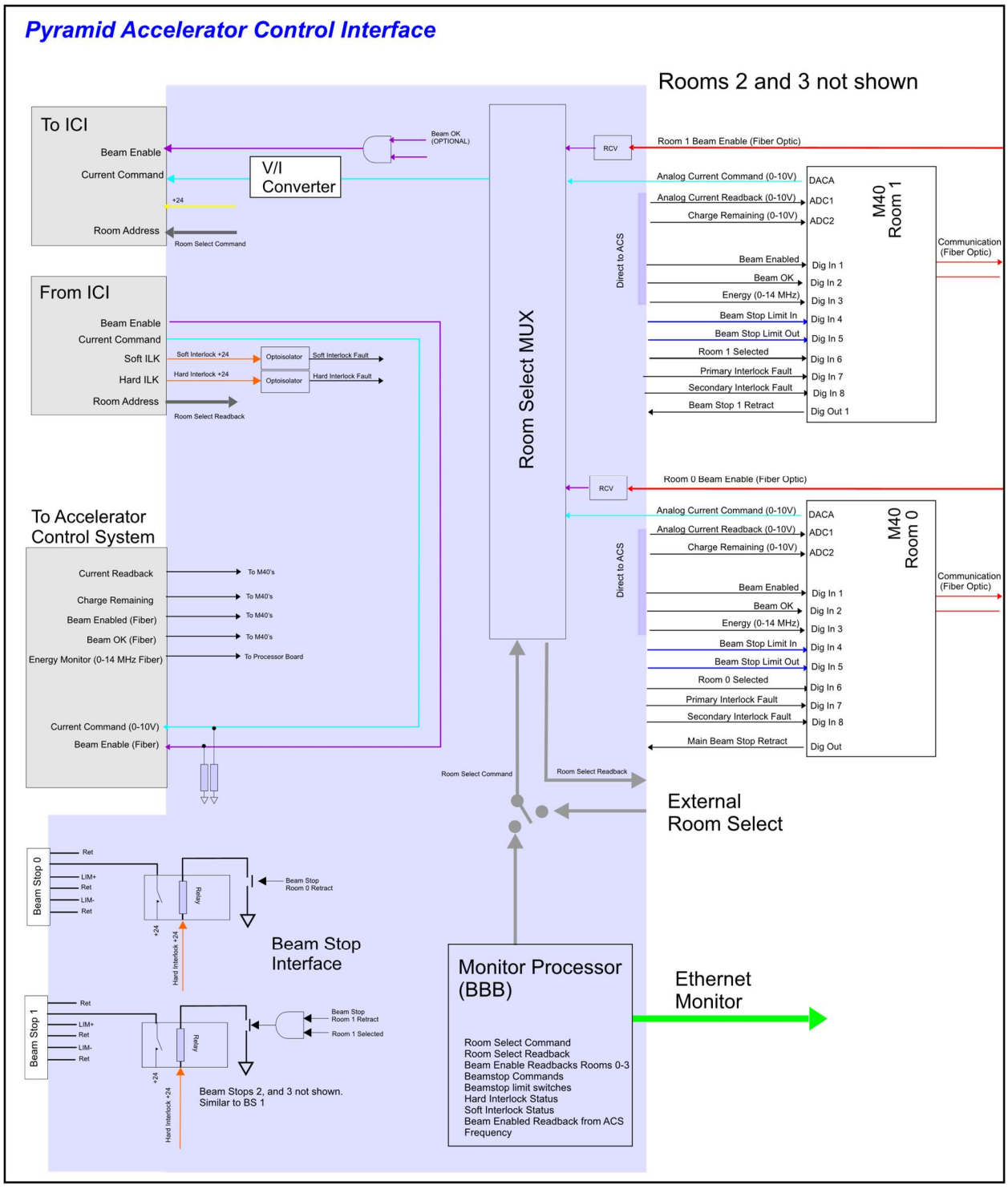


Figure 4 - ACI signal connections

The following connections are made to each subsystem.

9.3.1 Power

Function	Signal type	ACI connection	Termination	Cable type	Target connection	Comments
ACI power	24 VDC	Input +24V - 700mA	Redel PAG.M0.2 type or PFG.M0.2	PSU24-40-1R cable or CAB-LR-3-REDEL if using PD8	PSU24-40-1R	If the 0-10V signal is used, then the current-mode connector should be shorted using a zero or 50-ohm BNC terminator. The preferred type is 0-20mA for maximum isolation.
Isolated power output	24 VDC	ISO Power	Lemo EXG.0B.304	Twin core twisted pair insulated 24 or 22 AWG.	Remote device	Provides isolated power.
Power Monitor Room 0	N/A	N/A	N/A	N/A	N/A	Do not connect.
Power Monitor Room 1	N/A	N/A	N/A	N/A	N/A	Do not connect.
Power Monitor Room 2	N/A	N/A	N/A	N/A	N/A	Do not connect.
Power Monitor Room 3	N/A	N/A	N/A	N/A	N/A	Do not connect.

9.3.2 Accelerator

Function	Signal type	ACI connection	Termination	Cable type	Target connection	Comments
Beam intensity control	Analog voltage or current	Current Command, either 0-20mA or 10V	BNC	Coax RG58	Accelerator current demand input	If the 0-10V signal is used, then the current-mode connector should be shorted using a zero or 50-ohm BNC terminator. The preferred signal type is 0-20mA for maximum noise immunity.

Beam intensity readback used to verify control setting	Analog voltage or current	I Monitor Input	BNC	Coax RG58	Accelerator current output	Set SW6 internally to match the selected signal type, either 0-20mA or 0-10V. The preferred type is 0-20mA for maximum isolation.
Beam charge monitor to determine remaining beam in accelerator	Analog voltage or current	Q Monitor Input	BNC	Coax RG58	Accelerator beam remaining output	Set SW7 internally to match the selected signal type, either 0-20mA or 0-10V. The preferred type is 0-20mA for maximum isolation.
Enable beam on/off control to the accelerator	Light 640 nm digital comms	Enable Out	ST bayonet, white boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Accelerator beam command input	The Pyramid X22 can be used to convert to TTL if needed.
Enable beam on/off status reported back by accelerator	Light 640 nm digital comms	Enabled	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Accelerator beam enabled output	Use to confirm that beam is command on/off.
Beam is ready to be delivered	Light 640 nm digital comms	Beam Ready	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Accelerator beam ready output	Use to confirm that beam is available to extract.
Accelerator frequency	Light 640 nm digital comms	Frequency In	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Accelerator frequency output	Usually available from synchrotrons. Could also be

9.3.3 Scan/Dose System

Function	Signal type	ACI connection	Termination	Cable type	Target connection	Comments
Enable beam on/off control for room 0	Light 640 nm digital comms	Enable Room 0	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 0 I128_1 Enable Beam	Connect only if room 0 available.
Enable beam on/off control for room 1	Light 640 nm digital comms	Enable Room 1	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 1 I128_1 Enable Beam	Connect only if room 1 available.

Enable beam on/off control for room 2	Light 640 nm digital comms	Enable Room 2	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 2 I128_1 Enable Beam	Connect only if room 2 available.
Enable beam on/off control for room 3	Light 640 nm digital comms	Enable Room 3	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 3 I128_1 Enable Beam	Connect only if room 3 available.
Beam intensity control for room 0	Light 640 nm digital comms	Room0 Receive	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 0 I128_1 Channel 1 Out	Connect only if room 0 available.
ACI Status for room 0	Light 640 nm digital comms	Room0 Transmit	ST bayonet, white boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 0 I128_1 Channel 1 In	Connect only if room 0 available.
Beam intensity control for room 1	Light 640 nm digital comms	Room1 Receive	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 1 I128_1 Channel 1 Out	Connect only if room 1 available.
ACI Status for room 1	Light 640 nm digital comms	Room1 Transmit	ST bayonet, white boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 1 I128_1 Channel 1 In	Connect only if room 1 available.
Beam intensity control for room 2	Light 640 nm digital comms	Room2 Receive	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 2 I128_1 Channel 1 Out	Connect only if room 2 available.
ACI Status for room 2	Light 640 nm digital comms	Room2 Transmit	ST bayonet, white boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 2 I128_1 Channel 1 In	Connect only if room 2 available.
Beam intensity control for room 3	Light 640 nm digital comms	Room3 Receive	ST bayonet, black boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 3 I128_1 Channel 1 Out	Connect only if room 3 available.
ACI Status for room 3	Light 640 nm digital comms	Room3 Transmit	ST bayonet, white boot	HCS step index silica fiber, 200um core. OFS BC03597-10-BL	Room 4 I128_1 Channel 1 In	Connect only if room 3 available.

9.3.4 Other Connections

Function	Signal type	ACI connection	Termination	Cable type	Target connection	Comments
Ethernet interface	Ethernet 10/100/1000	Ethernet	RJ45 jack	CAT5	Treatment control system	1000kb recommended

Signal interlock outputs	Analog and digital TTL	Beam Control Signals – Signals Out	D9 male	9-pin ribbon cable	ICI or other suitable device	Terminate with loop back connector on inputs if interlocking not needed.
Signal interlock inputs	Analog and digital TTL	Beam Control Signals – Signals In	D9 female	9-pin ribbon cable	ICI or other suitable device	Terminate with loop back connector on outputs if interlocking not needed.
Room select command	5-24V digital level	Room Select, pins 5-8	Weidmuller 0.1P 8 pin	Twin core twisted pair insulated 24 or 22 AWG.	Safety PLC	SW3 must be set to “Internal” position.
Room selected readback	Contact closure relays	Room Select, pins 1-4	Weidmuller 0.1P 8 pin	Twin core twisted pair insulated 24 or 22 AWG.	Safety PLC	Always available.
Beam stop control for room 0			D9 female	Twin core twisted pair insulated 24 or 22 AWG.	Beam stop for room 0	Connect only if room 0 available.

9.4 Front panel configuration switches

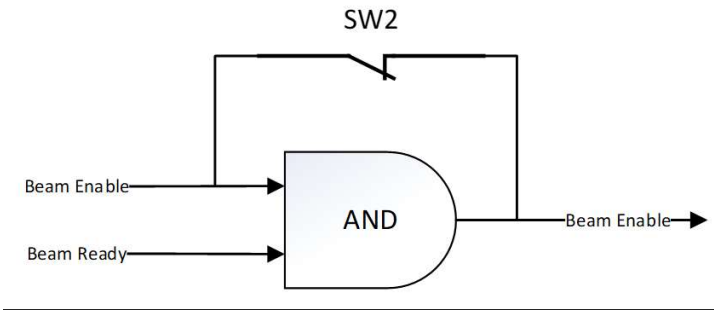
The ACI includes four embedded M40 high density I/O interfaces, one for each room. The fiber optic loop address switches for the M40s are accessible on the front panel.

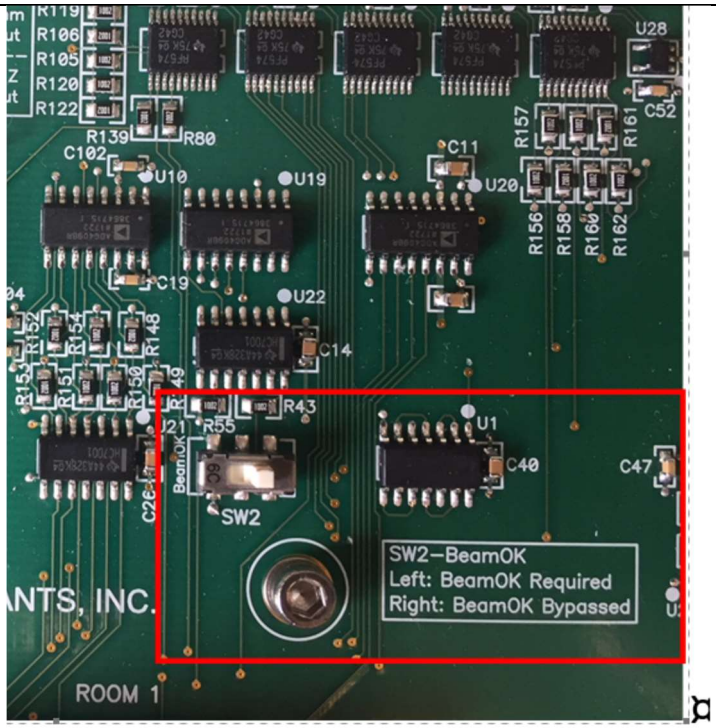
Figure 5 - Locations of M40 room interface loop address switches

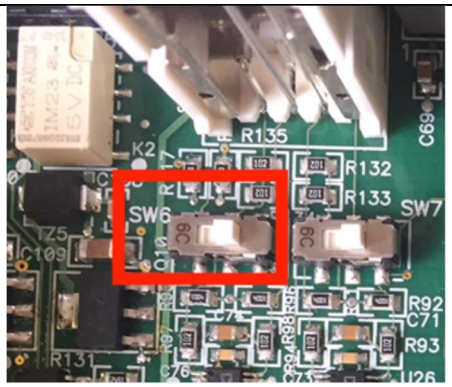
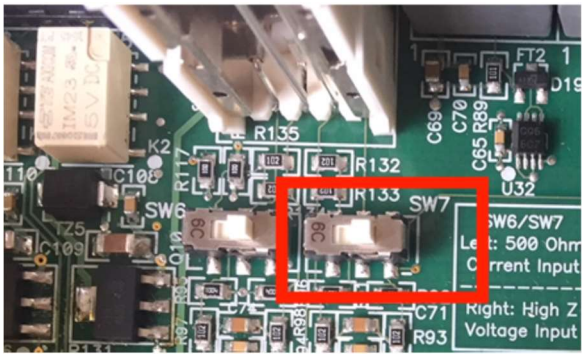
9.5 Internal configuration switches

The ACI has internal switches that govern certain behaviors of the system. They must be set to match the desired behaviors of the ACI. The configuration should be specified when the ACI is ordered and the unit will come pre-configured (recommended).

Alternately, the ACI can be field modified. Proper ESD procedures must be followed. Remove the top cover, locate the switch and place in the desired position. The silkscreen will indicate the relevant options. Reattach the top cover.

Name	Description
SW2	Determines if the Beam Ready (BEAM OK) signal must be high to allow the Beam Enable signal to ever go high. 

	
SW3	Determines whether room selection is done over the Ethernet interface or by using the digital input signals. Set the switch to “Internal” to use the connector, or “External” to use the Ethernet command. 
SW6	Determines if the Q monitor readback signal is 0-20mA (current input) or 0-10V (high Z).

	
SW7	Determines if the I monitor readback signal is 0-20mA or 0-10V (current input) or 0-10V (high Z). 

10 How the ACI Works and How to Use it - An Overview

A typical facility has multiple treatment rooms that must share a single accelerator. The ACI provides an interface between the Accelerator Control System (ACS) and up to 4 individual room controllers. The room controllers themselves will be made up of multiple electronic units. The interface between the ACI and the room controllers is done through a combination of fiber-optic communication links and fiber-optic digital levels. At any one time, only one of the room controllers (0,1,2, or 3) can have control over the accelerator.

Note that “Room 0” is typically used to control the beamline itself and may not be a treatment room. However, units 0,1,2 and 3 have similar I/O assignments. The one special aspect of the Room 0 controller is that it can control its associated beam stop even if it is not the “selected” room. For all other rooms, if the room is not selected, its beam stop is forced in.

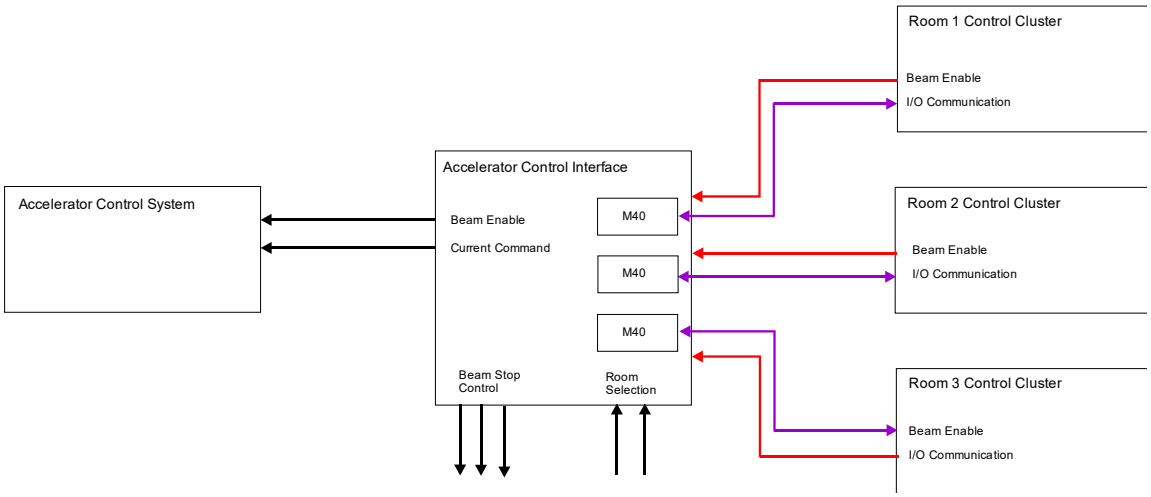


Figure 6 - Typical ACI implementation

The diagram below shows an example of connections to the ACI for one room. Other configurations are possible depending on details of the accelerator system and the number of treatment rooms.

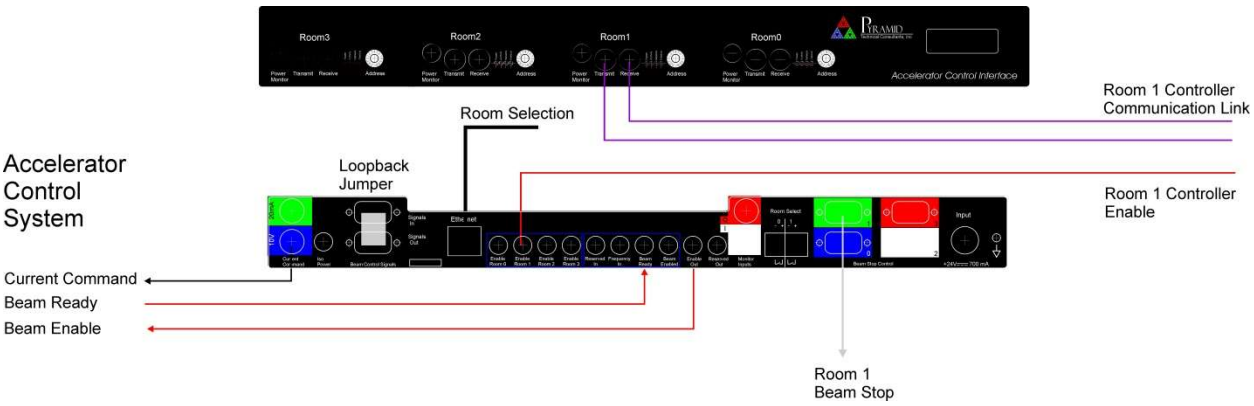


Figure 7 - Typical connections

10.1 Beam control signals

Critical beam control signals to the accelerator (beam enable, beam current command, room select) are passed out through the beam control signals out connector. There corresponding inputs on the pins of the beam control signals in connector. This allows these signals to be interrupted by an external interlock device such as the Pyramid ICI to provide an additional fast-acting level of safety. If there is no external interlock device, these signals must be looped round with a simple pin to pin pass-through cable from out to in to allow the ACI to operate.

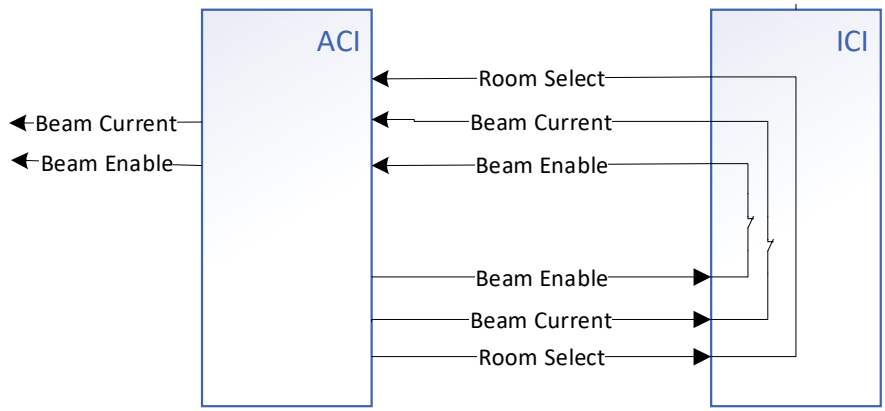


Figure 8 - Signal loop-round

10.2 Scan/Dose System

The ACI has been developed particularly to interface with the Pyramid Scan/Dose system. It contains four M40 device interfaces, each of which is assigned to a single room. These provide most of the analog and digital connection between the room controllers and the ACI. They are connected over a fiber-optic communication link between room loop controllers (A560 or I128 devices) and the M40s. For debugging purposes, these can be accessed through the PTC Diagnostic Software. The M40 addresses will appear as set by their individual address switches on the ACI front panel.

10.3 Room Selection

The ACI embodies the concept of "Selected Room". This is the room that has control of the accelerator. The room is selected from an external system and can be done in one two ways, depending on the setting of internal switch **SW3**

- Digital Bits: Two bits coming in to the ACI as digital levels
- Ethernet Command: A room select command from an external system sent over Ethernet

No matter which way the room is selected, the selection can be monitored in two ways, which are both available at all times:

- External Digital Bits: Two bits externally output as contact closures
- Ethernet Request: A room select readback request sent over Ethernet

10.4 Beam Stops

In a typical installation, there is a safety requirement to make sure that any non-selected room is prevented from delivering beam. This can be done through the installation of insertable beam stops, typically one per room, with an option for a single facility-level beam stop as well.

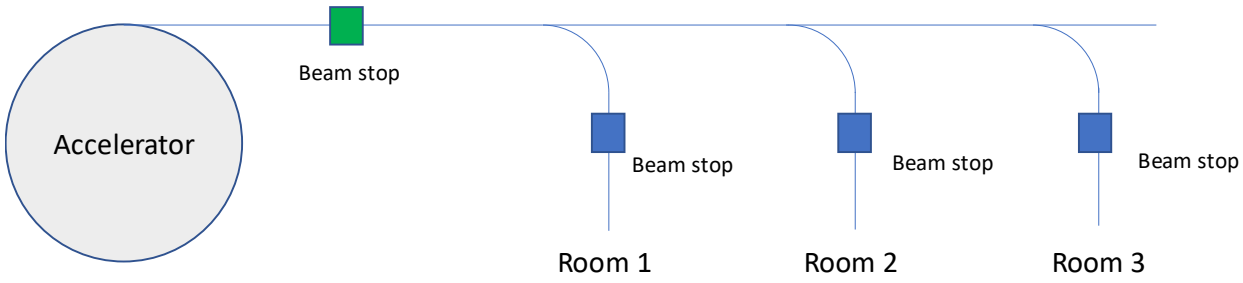


Figure 9 - Typical beam stop allocation

The ACI can control these beam stops if needed. The beam stops should be driven by 24 VDC solenoids controlling pneumatic actuators. The fail safe condition with solenoid power absent is for the beam stop to be in the beam path. The logic of the ACI allows only the selected room (of rooms 1, 2, and 3) to retract its beam stop by putting out a 24 VDC drive. All others are inserted (no 24 VDC). The ACI does this gating based on its room selection value. In the special case of a facility-level beam stop such as one located in the common branch of a high energy transfer line, before the room branches, this must be retractable no matter which room is selected. For this reason, Room 0 is allowed to retract this beam stop, even if it is not the selected room.

A relay exists in the ACI (referred to as K8) that must be energized for any beam stop to be retractable. This relay automatically energizes when the signal passthrough interlocks are

made. If this signal is routed via an external device like the Pyramid ICI, an interlock condition can be made to insert all beam stops via hardware logic. An example is to make a hard or facility-level interlock close all beam stops.

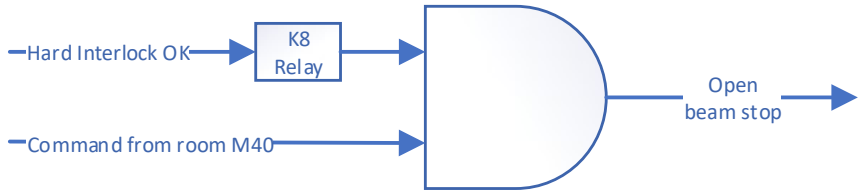


Figure 10 - Beam stop logic

10.5 Interface Signals to the Accelerator

10.5.1 Current Command

These analog outputs are used to command the beam current magnitude. These signals may be either current or voltage values, corresponding to the two connectors. Only one of the two outputs are active in a given system, depending on the needs of the accelerator controls. The choice between current mode and voltage mode control is selected internally. The value of these outputs is determined by the selected room M40 interface Analog Out #1 line.

- Current Command 0-20 mA This is a 0-20 mA current-mode command.
- Current Command 0-10V This is a 0-10V voltage-mode

Note that the beam current response of the accelerator must be monotonic over a good part of the control signal range, but is not necessarily linear. Some accelerators operate without dynamic current control, in which case these controls will be unused, and dose control will be achieved by an alternative current command method or simply by timing. Examples are slow extraction synchrotrons where the beam spill current may be fixed for given energy, or only adjustable from one spill to the next, and linacs where the pulse is too short to allow any dynamic current control except from pulse to pulse.

If the voltage-mode signal is to be used, the current-mode connector should be shorted using a zero or 50-ohm BNC terminator.

10.5.2 I Monitor

The accelerator should preferably acknowledge the current command value by reflecting it to this signal in the form of a 0-10V voltage. The value has no effect on the ACI. It is distributed to all the room embedded M40 units on the Analog In #1 line.

10.5.3 Q Remaining

A slow extraction synchrotron accelerator may indicate the percent of charge remaining in the ring in the form of a 0-10V signal. The value has no effect on the ACI. It is distributed to all room embedded M40 units on the Analog In #2 line.

10.5.4 Enable Out

This is the fast beam on/off signal from the ACI to the accelerator control which is the primary control for dose control in a standard "step and shoot" pencil beam scanning system. It reflects the state of the fiber optic enable signal from the selected room. In the case of the Pyramid nozzle system, the signal is created be the electrometer reading the integral plane of the primary ionization chamber (IC1). Optionally the signal can be hardware logic ANDed with the incoming Beam Ready signal by appropriate setting of **SW2** inside the unit.

10.5.5 Frequency In

This input allows the accelerator frequency to be measured, which is a useful check on beam energy with synchrotrons. The input can span 0-20 MHz. It is reported via the EPICS Ethernet interface. A typical workflow would be to request and energy and wait for the frequency to match the expected setting for that energy. Some real time monitoring can be performed also as the energy layer is delivered.

10.5.6 Beam Ready

This input from the accelerator indicates that the accelerator is presently able to provide beam. The signal is distributed to all the embedded room M40 units as Digital In #2. This signal can optionally be used to gate the Enable Command Output and can be selected using internal switch **SW2.**

10.5.7 Beam Enabled

The accelerator control system should preferably acknowledge the state of the Beam Enable command. If this function is not available, the ACI will still function. This signal is distributed to all room embedded M40 units as Digital Input #1.

10.6 Processor

A Beagle Bone Black (BBB) microprocessor card provides an Ethernet EPICS interface to the client via the IG2 service (channel access server). The BBB monitors many of the digital signals as well as providing a readout of the accelerator frequency if connected. The BBB also allows the active room to be selected if this option is enabled on the board using **SW3**.

10.7 Isolated Power

This connector can supply independent power levels to power a remote interface device. For best noise immunity, all analog signals are isolated at the ACI level. Ideally, the analog signals should also pass through isolation amplifiers at the accelerator control end.

11 Updating the ACI Firmware

The ACI maintains its program and various options in files on its SD memory card. These files should be changed only by qualified service personnel. The procedure is listed here in case a change should be necessary, but it is strongly recommended that you contact Pyramid before proceeding with any change.

ATTENTION

If the ACI is in use in a medical therapy system, then following any change to setup, it is mandatory that the system should be tested and re-certified as fit for its purpose by a qualified person.

11.1 Updating the Firmware

The firmware can be updated via two methods.

11.1.1 Changing the SD card.

The SD flash memory card can be changed, although this requires opening the unit by removal of the top panel. This will allow the operating system and running program to be updated. When this is done, it is important to preserve the System.xml file from the previous card and copy it to the appropriate location (see below). It is recommended that this procedure only be carried out at Pyramid.

11.1.2 Using the diagnostic program

The ACI firmware can be updated directly by connection to the Pyramid website. Please see the section User Interface->Config->Update Firmware for full information on how to do this.

11.2 Changing IP Address

The IP address can be changed by editing the ethernet communications file **/etc/network/interfaces**. In this file, you can change the primary network interface called **eth0**.

A static or dynamic IP can be set by using one of the following two lines:

```
iface eth0 inet dhcp                    // will give it a DHCP address.
iface eth0 inet static                  // will give it a static address.
```

If using a static IP, you must follow that line with the following lines:

```
address 192.168.100.123
netmask 255.255.255.0
gateway 129.168.100.1
```

To activate the new settings, SSH into the device and run

```
ifdown eth0
ifup eth0
```

Otherwise, restart the ACI by disconnecting and reconnecting the power cable.

11.3 Serial Number

The ACI serial number is kept in file **\opt\pyramid\aci\Debug\Serial.txt**. Do not modify this file.

11.4 Loopback Address

The ACI loopback address is kept in file **\opt\pyramid\aci\Debug\IPAdress.txt**. Do not modify this file.

11.5 M40 firmware

The M40 interface devices embedded in the ACI should not require firmware updates. If they do require updates, then both the FPGA code and the PIC microcontroller application code can be updated over the fiber optic interface. Refer to the M40 user manual for full details.

12 User Interface

The ACI user interface can be accessed directly from any browser (Microsoft Explorer or Edge recommended). Simply type the IP address of the ACI in the address line:

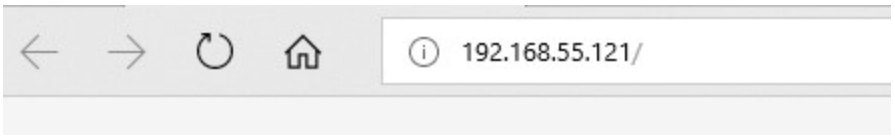


Figure 11 - Invoking the ACI diagnostic GUI

12.1 Panel

This tab shows the ACI I/O in table format. All inputs are displayed by function and by room. The outputs can be directly changed on this screen, including the room select bits and the spare fiber optic output.

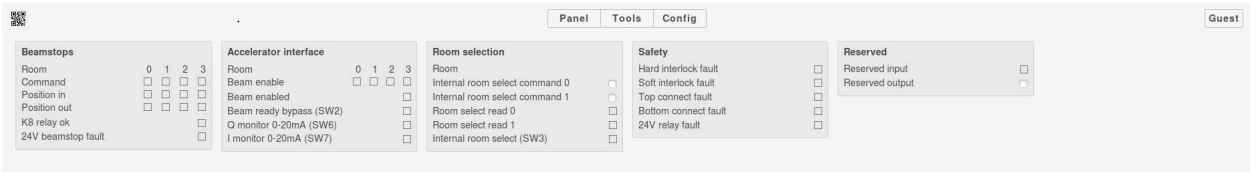


Figure 12 - ACI GUI home screen

The large white boxes allow the outputs to be controlled, in this case the internal room select bits and the spare fiber optic output.

The inputs are all displayed as smaller boxes, which are filled in when the input is high (active).

Separate categories are available for Beam stops, Accelerator Interface, Room Selection, Safety, and Reserved.

12.2 Tools

For factory use only.

12.3 Config

This tab allows basic configuration tasks to be performed.

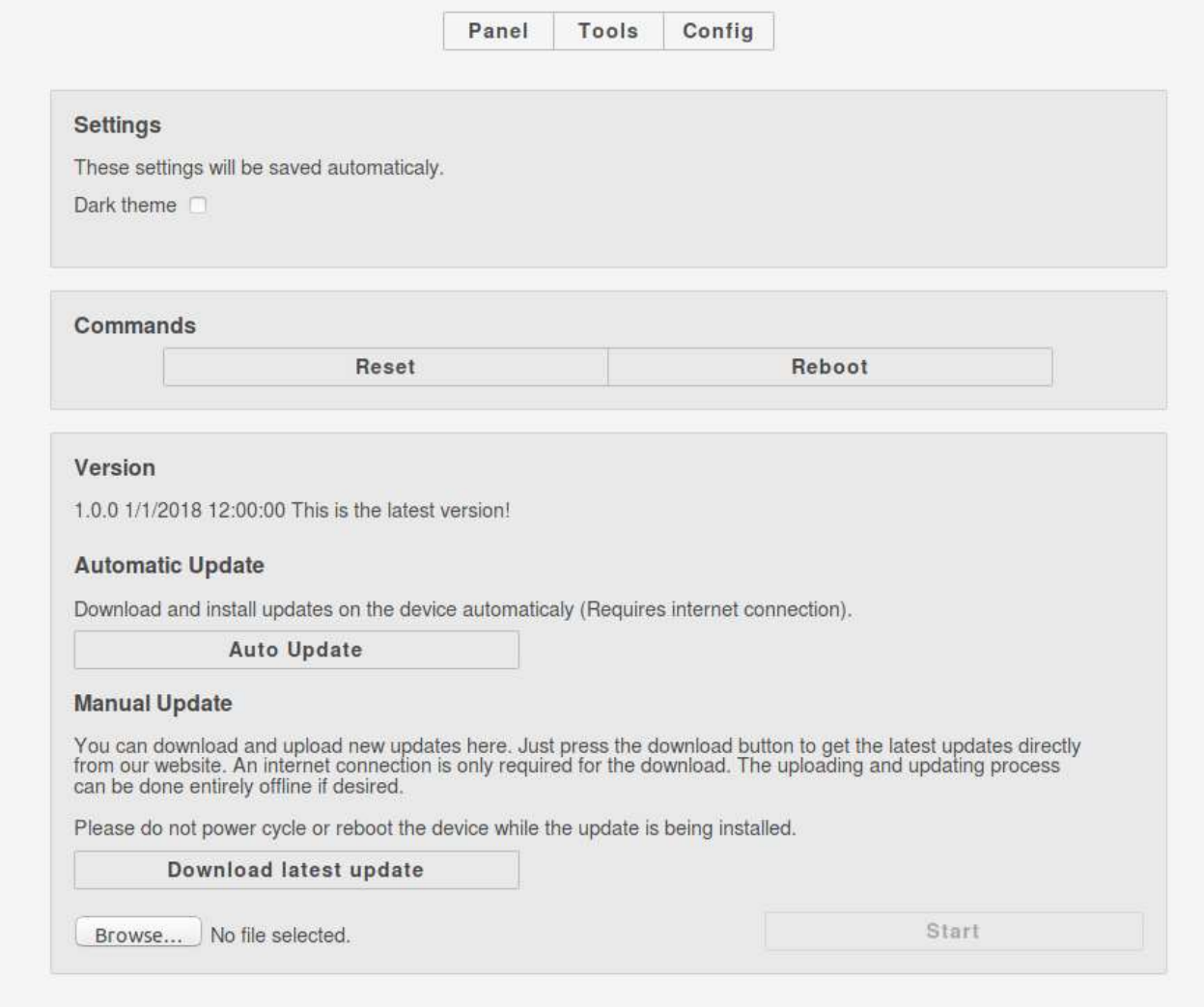


Figure 13 - User interface Config tab

12.3.1 Settings

Checking the “Dark Theme” button changes the background look of the displays. This parameter should be remembered by your browser.

12.3.2 Commands

Pressing the “Reset” button resets the BBB processor card. Pressing the “Reboot” button reboots the BBB.

12.3.3 Version

The current version of firmware is displayed in this section. A note is provided to indicate if this is the latest version available.

12.3.4 Automatic update

This feature allows the latest firmware to be automatically updated to the ACI device. The firmware will be downloaded directly from the Pyramid website, www.ptcusa.com, so an internet connection will be required to perform the update.

12.3.5 Manual update

Manual updates can be performed in this section. The latest version can be loaded and saved directly from the website (an internet connection is required). Alternately you may already have a firmware package from a previous download. When you have the firmware file, press browse to select it, then press the “Start” button to begin the update.

12.4 Guest

Reserved for future use.

13 Connectors

13.1 Rear Panel

The ACI real panel is shown in the diagram below.

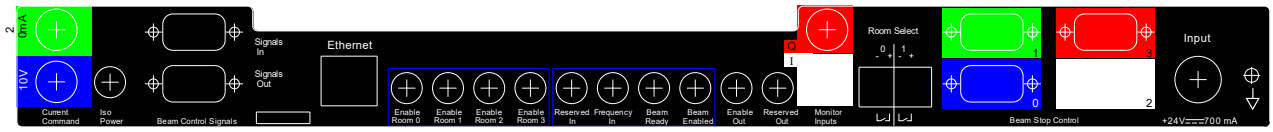
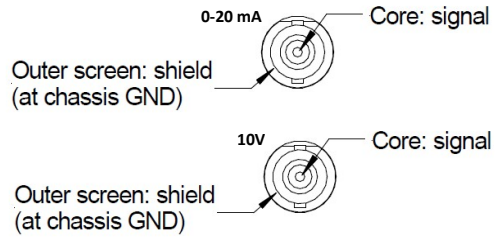


Figure 14 - ACI rear panel

The connectors are described from left to right.

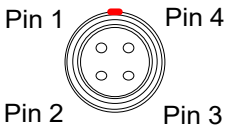
13.1.1 Current Command, 0-20mA and 10V



Dual- isolated BNC.

13.1.2 ISO Power

One four pin Lemo EXG.0B.304 female. Suitable mating connectors Lemo FGG.0B.304.CLCD52Z (crimp) or FGG.0B.304.CLAD52Z (solder).

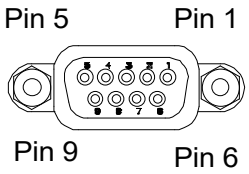


(External view on connector / solder side of mating plug)

1	+ 15V ISO
2	- 15V ISO
3	Common
4	Power OK Opto Out (no resistor)

13.1.3 Beam Control Signals

One D-Sub 9 pin female and one D-Sub male.



(External view on connector / solder side of mating plug)

1	Beam enable	6	Current command
2	Digital ground	7	Hard interlock +24V
3	Soft interlock +24V	8	24 V return
4	Room select bit 0	9	Digital ground
5	Room select bit 1		

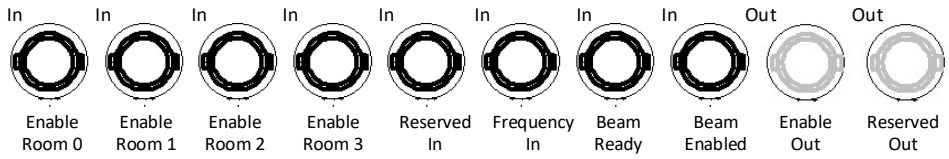
13.1.4 Ethernet

RJ-45 jack. To mate with standard RJ-45 plug.

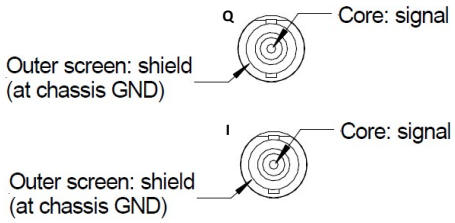
Auto MDIX facility - cable can be direct or crossover type.

13.1.5 Fiber Optic Channels

Six HFBR ST bayonets suitable for 1 mm plastic or 200 µm silica fiber. 664 nm (visible red) light. Dark casing = receiver, light casing = transmitter.



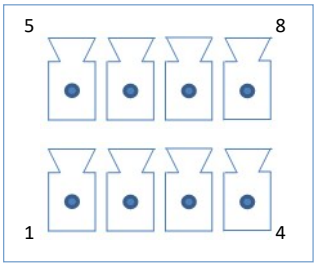
13.1.6 Monitor Inputs, Q and I



Dual isolated right-angle BNC.

13.1.7 Room Select

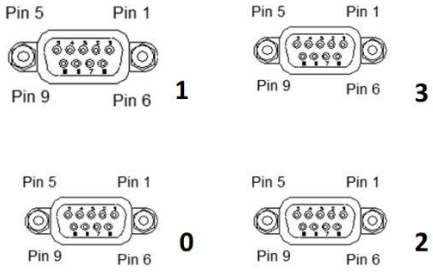
3.5 mm discrete Weidmuller 1289470000.



1	Room selected bit 1 10K impedance, 5-24VDC	5	Room select bit 1 contact closure
2	Room selected bit 1 return	6	Bit select bit 1 contact closure
3	Room selected bit 2 10K impedance, 5-24VDC	7	Room select bit 2 contact closure
4	Room selected bit 2 return	8	Bit select bit 2 contact closure

13.1.8 Beam Stops

Four D-Sub 9 pin female.

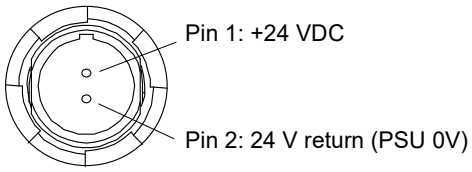


Each beam stop connection has the following signals:

1	Beam stop Insert	6	PS Ground
2	Limit Switch (BS In)	7	PS Ground
3	Limit Switch (BS Out)	8	PS Ground
4	NC	9	NC
5	NC		

13.1.9 Power Input, 24 VDC

Two-pin Redel PXG.M0.2GG.NG female. To mate with Redel PAG.M0.2 type or PFG.M0.2 type free plugs. Suitably terminated 24 V power supplies and leads are available from Pyramid Technical Consultants, Inc.



13.1.10 Ground lug

M4 threaded stud. To mate with M4 ring lug.

13.2 Front Panel

The ACI front panel is shown in the diagram below.

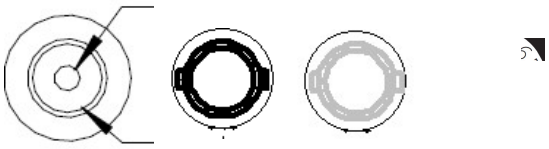
Figure 15 - ACI front panel

The connectors are described from left to right.

13.2.1 Room Monitor

Each room has a fiber message interface to the Scan/Dose system using an M40 device interface.

Room 3



Two HFBR ST bayonets suitable for 1 mm plastic or 200 µm silica fiber. 640 nm (visible red) light. Dark casing = receiver, light casing = transmitter.

The power monitor should not be used for 24 V power input. Power is supplied to the M40 devices by internal ACI connections.

14 Communications Interface

14.1 EPICS Server

14.1.1 Network Configuration

HTTP

The primary mode of communication for the ACI data is using HTTP. The process variable names can be used to access the data.

EPICS

The ACI can optionally use EPICS communication over standard local area network hardware. Addressing is using the IP4 standard, and it supports static and dynamic (DHCP) address assignment. The device can be configured via the serial interface, or by your own host software using the appropriate procedure calls. For more information on EPICS please go to the EPICS website at http://www.aps.anl.gov/epics/index.php.

Most control and data acquisition systems are set up with fixed addresses assigned by the network administrator. It is also typical to isolate such networks from the internet to prevent unauthorized access, and to allow operation without firewalls which can disrupt communications.

In order for the host computer and the ICI to communicate, they must be within the same subnet. It is typical to limit a local network to 256 addresses by setting the IP4 subnet mask to 255.255.255.0. Then the ICI and the host must have the first three bytes of their addresses common and must differ in the last byte. For example, the host could be 192.168.100.11 and the I128 at 192.168.100.20. The last byte must also not conflict with any other devices on the same subnet. Addresses with last byte 0 and 255 are reserved for special functions in TCP/IP. See the section on “File Setups” for information on changing the IP address of the unit.

To establish EPICS communication, open the ACI using a program such as WINCP. Navigate to the root/config directory, and modify file system.xml as follows:

```
<root>
  <aci/>
  <epics_server/>
</root>
```

14.1.2 Process variables

The ACI supports a series of process variable (PVs) that can be used to exchange information with the ACI over the EPICS interface. Each process variable can be address by using the assigned PV name as needed. In the unlikely case that more than one ACI is used on the system, then the PV name must be preceded by the ACI IP address and a colon in order to make the address unique.

For example, to address the room select command 0, the PV name is /aci/gpio/room_select_command_0. If the IP address of the ACI is 192.168.100.20, then the proper full name of the PV would be

```
192.168.100.20:/aci/gpio/room_select_command_0
```

Below is a list of all PV names:

PV Name	Description	Readonly	Type
/aci/faults/1	24V relay fault	TRUE	bool
/aci/faults/2	24V beamstop fault	TRUE	bool
/aci/faults/4	Top connect fault	TRUE	Bool
/aci/faults/5	Bottom connect fault	TRUE	bool
/aci/faults/6	K8 relay ok	TRUE	bool
/aci/faults/7	Hard interlock fault	TRUE	bool
/aci/faults/8	Soft interlock fault	TRUE	bool
/aci/gpio/beam_enable_room_0	Beam enable room 0	TRUE	bool
/aci/gpio/beam_enable_room_1	Beam enable room 1	TRUE	bool
/aci/gpio/beam_enable_room_2	Beam enable room 2	TRUE	bool
/aci/gpio/beam_enable_room_3	Beam enable room 3	TRUE	bool
/aci/gpio/beam_enabled	Ideally the accelerator sends this signal to indicate it is extracting beam, but not required	TRUE	bool
/aci/gpio/beam_ready	Used by the accelerator to indicate that it is ready to extract beam	TRUE	bool
/aci/beam_stop_pos/1	Beam stop position IN 0	TRUE	bool
/aci/beam_stop_pos/3	Beam stop position IN 1	TRUE	bool
/aci/beam_stop_pos/5	Beam stop position IN 2	TRUE	bool
/aci/beam_stop_pos/7	Beam stop position IN 3	TRUE	bool
/aci/beam_stop_pos/2	Beam stop position OUT 0	TRUE	bool
/aci/beam_stop_pos/4	Beam stop position OUT 1	TRUE	bool
/aci/beam_stop_pos/6	Beam stop position OUT 2	TRUE	bool
/aci/beam_stop_pos/8	Beam stop position OUT 3	TRUE	bool
/aci/beam_stop/1	Beam stop room 0	TRUE	bool
/aci/beam_stop/2	Beam stop room 1	TRUE	bool
/aci/beam_stop/3	Beam stop room 2	TRUE	bool
/aci/beam_stop/4	Beam stop room 3	TRUE	bool
/aci/beam_stop_room_0/state	Beam stop room 0 state, error, stopped, open, opening, or stopping.	TRUE	string

/aci/beam_stop_room_1/state	Beam stop room 1 state, error, stopped, open, opening, or stopping.	TRUE	string
/aci/beam_stop_room_2/state	Beam stop room 2 state, error, stopped, open, opening, or stopping.	TRUE	string
/aci/beam_stop_room_3/state	Beam stop room 3 state, error, stopped, open, opening, or stopping.	TRUE	string
/aci/beam_stop_relay_state	Beam stop relay state, open or closed.	TRUE	string
/aci/connector_state	Signal connection state, disconnect, top_disconnect, bottom_disconnect, or connected.	TRUE	string
/aci/power_24v_relay_state	+24V relay state, open or weld_closed.	TRUE	string
/aci/power_24v_beam_stop_state	Beam stop +24 power state, fault or ready.	TRUE	string
/aci/switches/1	Q monitor 0-20mA (SW6)	TRUE	bool
/aci/switches/2	I monitor 0-20mA (SW7)	TRUE	bool
/aci/switches/3	Beam ready bypass (SW2)	TRUE	bool
/aci/switches/4	Internal room select (SW3)	TRUE	bool
/aci/gpio/internal_room_select_command_0	Internal room select command 0	TRUE	bool
/aci/gpio/internal_room_select_command_1	Internal room select command 1	TRUE	bool
/aci/room/room_select_mode	Room select mode, internal or external	TRUE	string
/aci/gpio/room_select_command_0	Room select command 0	FALSE	bool
/aci/gpio/room_select_command_1	Room select command 1	FALSE	bool
/aci/gpio/room_select_readback_0	Room select read 0	TRUE	bool
/aci/gpio/room_select_readback_1	Room select read 1	TRUE	bool
/aci/hard_interlock_state	Hard interlock state, fault or ok	TRUE	string
/aci/soft_interlock_state	Soft interlock state, fault or ok	TRUE	string

14.2 Scan/Dose Message Interface

A fiber optic message interface is maintained between the ACI and each Scan/Dose room instance using an M40 device interface per room. The signals are documented below for reference.

Pin	M40	DI0	DI1	DI2	DI3
1	ADC7_BUFIN	NC	NC	NC	NC
2	ADC5_BUFIN	NC	NC	NC	NC
3	ADC3_BUFIN	NC	NC	NC	NC
4	ADC1_BUFIN	Current Readback	Current Readback	Current Readback	Current Readback
5	Ground	Ground	Ground	Ground	Ground
6	Ground	Ground	Ground	Ground	Ground
7	Ground	Ground	Ground	Ground	Ground

8	Ground	Ground	Ground	Ground	Ground
9	Ground	Ground	Ground	Ground	Ground
10	Ground	Ground	Ground	Ground	Ground
11	Ground	Ground	Ground	Ground	Ground
12	DACG_OUT	NC	NC	NC	NC
13	DACE_OUT	NC	NC	NC	NC
14	DACC_OUT	NC	NC	NC	NC
15	DACA_OUT	I_CmdRoom0	I_CmdRoom1	I_CmdRoom2	I_CmdRoom3
16	Ground	Ground	Ground	Ground	Ground
17	Ground	Ground	Ground	Ground	Ground
18	ADC4_BUFIN	ICmdReadback	ICmdReadback	ICmdReadback	ICmdReadback
19	ADC2_BUFIN	ChargeRemaining	ChargeRemaining	ChargeRemaining	ChargeRemaining
20	DIG_IN2	BeamOK	BeamOK	BeamOK	BeamOK
21	DIG_IN4	BStopPosRdIn0	BStopPosRdIn1	BStopPosRdIn2	BStopPosRdIn3
22	DIG_IN6	Room0Selected	Room1Selected	Room2Selected	Room3Selected
23	DIG_IN8	HardInterlock Fault	HardInterlock Fault	HardInterlock Fault	HardInterlock Fault
24	DIG_OUT2	NC	NC	NC	NC
25	DIG_OUT4	NC	NC	NC	NC
26	DIG_OUT6	NC	NC	NC	NC
27	DACH_OUT	NC	NC	NC	NC
28	DACF_OUT	NC	NC	NC	NC
29	DACD_OUT	NC	NC	NC	NC
30	DACB_OUT	NC	NC	NC	NC
31	Chassis	Chassis	Chassis	Chassis	Chassis
32	24 Return	24 Return	24 Return	24 Return	24 Return
33	24V	24V_0	24V_1	24V_2	24V_3
34	DIG_IN1	BeamEnabled	BeamEnabled	BeamEnabled	BeamEnabled
35	DIG_IN3	Frequency	Frequency	Frequency	Frequency
36	DIG_IN5	BStopPosRdOut0	BStopPosRdOut1	BStopPosRdOut2	BStopPosRdOut3
37	DIG_IN7	SoftInterlockFault	SoftInterlockFault	SoftInterlockFault	SoftInterlockFault
38	DIG_OUT1	BStopCMDRoom0	BStopCMDRoom1	BStopCMDRoom2	BStopCMDRoom3
39	DIG_OUT3	NC	NC	NC	NC
40	DIG_OUT5	NC	NC	NC	NC
41	DIG_OUT7	NC	NC	NC	NC
42	DIG_OUT8	NC	NC	NC	NC
43	DIG_OUT8	Ground	NC	NC	NC
44	+5VD	NC	NC	NC	NC

15 Fault Finding

Symptom	Possible Cause	Confirmation	Solution
Device will not boot or communicate as seen on the OLED display.	Damage to ACI.		Contact Pyramid Technical Consultants, Inc.
	Failed firmware update.		Contact Pyramid Technical Consultants, Inc.
	Network IP addresses between ACI and client not compatible.	Check network addresses and IP masks are compatible.	Change addresses or configuration as needed.
	Duplicate Ethernet address of ACI.		Change ACI address.
Beam stops can be controlled even if hard interlock is not OK.	K8 safety relay welded shut	Using diagnostic GUI, examine the state of K8. Disconnect the passthrough connector to the ICI and see if the state changes.	Contact Pyramid Technical Consultants, Inc.
Beam stops cannot be opened	Passthrough cable broken or not properly connected.	Check that the Passthrough Top and Bottom LEDs are lit on the diagnostic GUI. Otherwise check the cable.	Properly attach or fix the passthrough cable.
	Hard interlock is not OK.	Check that the hard interlock is OK on the diagnostic GUI.	Fix condition preventing hard interlock from closing or fix wiring.

	Room is not selected (rooms 1-3 only).	Check if the room for the beam stop is selected.	Select the room.
Accelerator does not respond to beam enable command.	Broken fiber optic	Check if part is loose on the PCB.	Contact Pyramid Technical Consultants, Inc.
	Passthrough cable broken or not properly connected.	Check that the Passthrough Top and Bottom LEDs are lit on the diagnostic GUI. Otherwise check the cable.	Properly attach or fix the passthrough cable.
	Beam Present not TRUE and SW2 is set to require it.	Check that the Beam Ready signal is properly functioning if it is needed.	Fix the Beam Ready signal or change the setting of SW2.
Accelerator does not respond to beam intensity command.	Using the wrong output connector for the signal type in use.	Check that you are connected properly to the 0-20mA or 10V connector depending upon the output signal needed by the accelerator.	Switch cable to the correct connector.
	Passthrough cable broken or not properly connected.	Check that the Passthrough Top and Bottom LEDs are lit on the diagnostic GUI. Otherwise check the cable.	Properly attach or fix the passthrough cable.
Accelerator beam enabled command does not match the enable command from the ACI.	Broken fiber optic	Check if part is loose on the PCB. Flash an LED into the connector and examine the state of the input on the diagnostic GUI.	Contact Pyramid Technical Consultants, Inc.
	Accelerator not responding properly.		Fix accelerator logic.

Current monitor readback from the accelerator does not match the output.	Improper setting of SW6 to match expected signal input type.	Verify signal input type.	Change the switch setting.
	Accelerator not responding properly.		Fix accelerator logic.
Charge monitor readback from the accelerator does not match the output.	Improper setting of SW7 to match expected signal input type.	Verify signal input type.	Change the switch setting.
	Accelerator not responding properly.		Fix accelerator logic.
Room cannot be selected using the Ethernet command.	Improper setting of SW3.	Check that the switch is set to “External”.	Change the switch setting to “External”.
	Ethernet cable not plugged in.	Check the Ethernet connection using the diagnostic GUI.	Fix Ethernet connection.
Room cannot be selected using the bits on the input connector.	Improper setting of SW3.	Check that the switch is set to “Internal”.	Change the switch setting to “Internal”.
	Digital levels not properly supplied.	Verify the digital inputs to the ACI.	Fix input digital levels.

16 Maintenance

16.1 User Serviceable Parts

There are no user-serviceable parts inside the ACI.

16.2 Cooling Fan Maintenance

If there is buildup of dust in the filter, you should clear this by vacuum cleaning in situ, or by removing the filter element and cleaning it separately with an air jet. Note that detaching the filter element also detaches the fan from the case.

Figure 16 - Fan filter removal

If the fan fails, it is necessary to open remove the lid of the case to access the power connector. Due to risk of contamination or electrostatic discharge damage, we recommend that you consult Pyramid Technical Consultants, Inc. before attempting this.

To remove the lid of the case, remove four M2.5 cross-head screws from the rear top surface, and slide the cover backwards to disengage from the front panel.

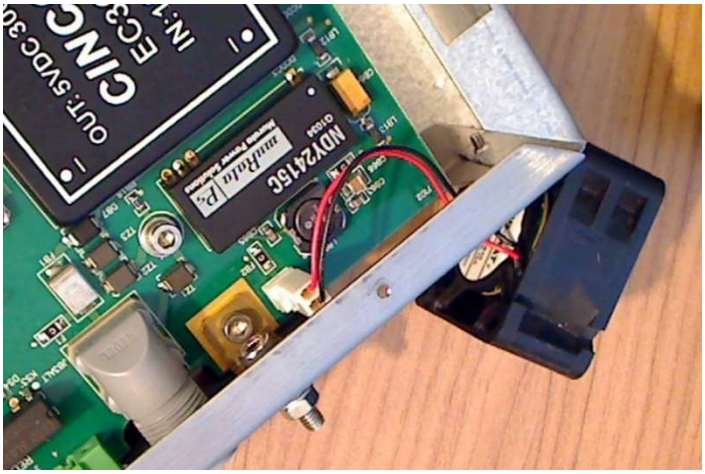


Figure 17 - Fan power connector example (2 pin Molex)

The ACI is fitted with a 1.1 amp automatically resetting positive temperature coefficient (PTC) fuse in the 24 VDC input. No user intervention is required if the fuse operates due to overcurrent. The fuse will reset when the overcurrent condition ends.

17 Returns Procedure

Damaged or faulty units cannot be returned unless a Returns Material Authorization (RMA) number has been issued by Pyramid Technical Consultants, Inc. If you need to return a unit, contact Pyramid Technical Consultants at support@ptcusa.com, stating

- model
- serial number
- nature of fault

An RMA will be issued, including details of which service center to return the unit to.

18 Support

Manual and software driver updates are available for download from the Pyramid Technical Consultants website at **www.ptcusa.com**. A secondary site can be found at **www.ptceurope.com**. Technical support is available by email from support@ptcusa.com. Please provide the model number and serial number of your unit, plus relevant details of your application.

19 Disposal

We hope that the ACI gives you long and reliable service. The ACI is manufactured to be compliance with the European Union RoHS Directive 2002/95/EC, and as such should not present any health hazard. Nevertheless, when your ACI has reached the end of its working life, you must dispose of it in accordance with local regulations in force. If you are disposing of the product in the European Union, this includes compliance with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC. Please contact Pyramid Technical Consultants, Inc. for instructions when you wish to dispose of the device.

20 Revision History

The release date of a Pyramid Technical Consultants, Inc. user manual can be determined from the document file name, where it is encoded YYMMDD. For example, ACI_UM_180502 would be a ACI manual released on p2 May 2018.

Version	***Changes***
ACI_UM_180612	First general release.
ACI_UM_180614	Small modification for missing photographs.
ACI_UM_230309	Modified process variable names.