



iMAC[®]

Integrated Monitoring and Control System
iMAC2 User Manual

Version: 4 – October 2018

Designed and Manufactured in Australia by Ampcontrol Pty Ltd



WARNING!



The **warning** symbol highlights a potential risk of **injury or death**.
Please share these warnings with other operators.

CAUTION!



The **caution** symbol highlights a potential risk of **damage to equipment**.
Please share these cautions with other operators.

NOTE



The **note** symbol highlights **key information**.
Please share these notes with other operators.

ENVIRO



The **enviro** (environmental) symbol highlights areas which may have an impact on the surrounding **fauna and/or flora**.

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Before You Begin

Thank you for purchasing the Ampcontrol iMAC System.

WARNING!



In the interests of **safety and correct equipment operation**, please take the time to read and understand the content in this manual.

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1 INTRODUCTION

1.1 Document Scope

This document is intended to provide an overview of the functionality of the iMAC System. It also serves as a user manual for the general operation of the iMAC2 Controller.

This document is not intended to provide information on the operation of individual modules, instruction on programming the iMAC2 Controller or modules, or how to access the Modbus communication registers. Please refer to the relevant supplementary documents for this information.

1.2 Supplementary Documents

The iMAC2 System User Manual is intended to be read in conjunction with the following documents:

1.2.1 System Documentation

- IMAC2B010 iMAC2 Controller Ethernet Communications Manual
- IMAC2B011 iMAC2 Controller Web Interface Manual
- IMAC2B015 iMAC2 Controller Ethernet-IP (CIP) Communications Manual
- IMACB094 iMAC System Installation Requirements
- IMACB153 iMAC Controller Serial Communications Manual
- IMACB182 iMAC SIL Emergency Stop Qualification
- IMACB005 iMAC Module Programming Manual

1.2.2 Module Documentation

- IMACB003 iMAC RO4 Module Technical Datasheet
- IMACB018 iMAC LPU Module Technical Datasheet
- IMACB020 iMAC DI8 Module Technical Datasheet
- IMACB045 iMAC IIM Module Technical Datasheet
- IMACB046 iMAC DI4 Module Technical Datasheet
- IMACB047 iMAC EOL/MEOL Module Technical Datasheet
- IMACB060 iMAC LED4 Module Technical Datasheet
- IMACB061 iMAC SSW Module Technical Datasheet
- IMACB062 iMAC SQM Module Technical Datasheet
- IMACB066 iMAC AIM Module Technical Datasheet
- IMACB067 iMAC RTD1 Module Technical Datasheet
- IMACB141 iMAC ARM Module Technical Datasheet
- IMACB142 iMAC CRM Module Technical Datasheet
- IMACB143 iMAC EMM Module Technical Datasheet
- IMACB144 iMAC GRM Module Technical Datasheet
- IMACB146 iMAC IRK Keypad Technical Datasheet
- IMACB147 iMAC PIM Module Technical Datasheet
- IMACB148 iMAC SIM-G Module Technical Datasheet
- IMACB149 iMAC SIM-G2 Module Technical Datasheet
- IMACB150 iMAC SIM-T Module Technical Datasheet
- IMACB151 iMAC MLB Barrier Technical Datasheet
- IMACB152 iMAC SLB Barrier Technical Datasheet
- IMACB154 iMAC SIM-P Module Technical Datasheet
- IMACB172 iMAC LIM Module Technical Datasheet

1.3 Definitions

1.3.1 System Definitions

Term	Definition
<i>2-Wire System</i>	A 2-Wire iMAC system has a fieldbus that contains a Signal Line and a Common Line. The Signal Line is fed through all of the emergency stop contacts and terminated into the EOL module. In a 2-Wire System, all iMAC fieldbus modules communicate over the Signal Line. This means that if an emergency stop is activated, the Signal Line is broken and all modules downstream of the activated emergency stop will lose communication with the iMAC2 Controller.
<i>3-Wire System</i>	A 3-Wire iMAC system has a fieldbus that contains a Signal Line, Monitoring Line and a Common Line. The Signal Line is fed through all of the emergency stop contacts and terminated into the EOL module. The Monitoring Line is terminated into an MEOL module. In a 3-Wire System, all iMAC fieldbus modules communicate over the Monitoring Line. The advantage of the 3-Wire System, over the 2-Wire System, is that when the Signal Line is broken by an emergency stop, communication with all modules is still possible via the Monitoring Line.
<i>A-Line</i>	The Signal Line in a 3-wire system.
<i>AR</i>	The Auxiliary Relay (AR) of the iMAC2 Controller. The operation of the AR can be customised using the application (SLP) software.
<i>B-Line</i>	The Monitoring Line in a 3-wire system or the Signal Line in a 2-wire system.
<i>C-Line</i>	The Common Line for 3-wire and 2-wire systems
<i>Common Line</i>	The Common Line as the name suggests is the common return communications line of the L1 fieldbus. The Common Line is used in both 2-Wire and 3-Wire Systems.
<i>CR</i>	The Control Relay (CR) of the iMAC2 Controller. Provides emergency stop function via End-Of-Line module monitoring.
<i>Fieldbus</i>	The iMAC Fieldbus is the communications backbone for the iMAC system. Can be run as either a 2-Wire or 3-Wire System.
<i>iMAC</i>	Integrated Monitoring and Control
<i>Monitoring Line</i>	The Monitoring Line forms part of the L1 fieldbus in a 3-Wire system and is terminated into a MEOL module In 3-Wire Systems, all the modules communicate over the Monitoring Line. This allows communication to continue with all modules if an emergency stop is activated, which opens the Signal Line. The Signal Line is fed through the emergency stop contacts.
<i>Multi-drop</i>	The term multi-drop refers to a communications line that allows multiple communicating devices to be connected to the same line.
<i>Signal Line</i>	The Signal Line forms part of the L1 fieldbus in both 2-Wire and 3-Wire systems. The Signal Line is feed through the emergency stop contacts and is terminated into the EOL module. In a 3-Wire System, the Signal Line is used only for tripping and the modules communicate on the Monitoring Line. In a 2-Wire System, the Signal Line is used for both tripping and communication.
<i>SLP</i>	Supervisory Logic Program. The Ampcontrol proprietary programming language for the iMAC2 Controller's application software. Application (SLP) software must be written, compiled and installed in order for the iMAC2 Controller to perform intended operation.

1.3.2 Module Definitions

Term	Definition
<i>AIM</i>	Analogue Input Module that connects to the iMAC L1 fieldbus. There are two types available, a 0-10V model and a 4-20mA model.
<i>ARM</i>	Auxiliary Relay Module that connects to the iMAC L1 fieldbus. Provides a relay output that mimics the operation of the iMAC2 Controller's AR. Note: requires specific application (SLP) software for operation.
<i>CRM</i>	Control Relay Module that connects to the iMAC L1 fieldbus. Provides a relay output that mimics the operation of the iMAC2 Controller's CR. Note: requires specific application (SLP) software for operation.
<i>DI4</i>	Digital Input Module (4x digital inputs) that connects to the iMAC L1 fieldbus. Provides remote monitoring of four voltage free contacts.
<i>DI8</i>	Digital Input Module (8x digital inputs) that connects to the iMAC L1 fieldbus. Provides remote monitoring of eight voltage free contacts.
<i>EMM</i>	End of line Monitoring Module that connects to the iMAC L1 fieldbus. Provides a changeover relay output that de-energises if the Signal Line is unhealthy.
<i>EOL</i>	End Of Line Module that terminates the Signal Line of the iMAC L1 fieldbus.
<i>GRM</i>	General Relay Module that connects to the iMAC L1 fieldbus. Provides an output relay that can be remotely controlled by the iMAC2 Controller.
<i>IIM</i>	Input and Indication Module that connects to the iMAC L1 fieldbus. Provides five voltage free contact inputs and four LED outputs for indication.
<i>IRK</i>	iMAC Remote Keypad that connects to the iMAC L1 fieldbus. Allows the user to operate the iMAC2 Controller's interface remotely.
<i>LED4</i>	LED Output Module that connects to the iMAC L1 fieldbus. Provides four LED outputs for indication.
<i>LIM</i>	LED Indication Module which interfaces directly to the iMAC Fieldbus, providing a highly configurable remote indication module.
<i>LPU</i>	Lightning Protection Unit Module that connects to the iMAC L1 fieldbus. Provides surge protection for a multi-dropped iMAC module.
<i>MEOL</i>	Monitoring End Of Line Module that terminates the Monitoring Line of the iMAC L1 fieldbus in a 3-Wire System.
<i>MLB</i>	Master Line Barrier is an intrinsically safe barrier required for I.S. applications. It connects between the iMAC2 Controller and hazardous area L1 fieldbus.
<i>RO4</i>	Relay Output Module (4x relays) that connects to the iMAC L1 fieldbus. Provides four relay outputs that can be remotely controlled by the iMAC2 Controller, or linked to follow the states of an iMAC input module.
<i>RTD1</i>	Resistance Temperature Device Module that connects to the iMAC L1 fieldbus. Provides a remote temperature input using a PT100 RTD sensor.
<i>SIM-G</i>	Serial Interface Module (GasGuard) that connects to the iMAC L1 fieldbus. This module provides an interface between an Ampcontrol GasGaurd Controller and the iMAC L1 fieldbus.
<i>SIM-G2</i>	Serial Interface Module (GasGuard x2) that connects to the iMAC L1 fieldbus. This module provides an interface between two Ampcontrol GasGaurd Controllers and the iMAC L1 fieldbus.
<i>SIM-P</i>	Serial Interface Module (Programmable) that connects to the iMAC L1 fieldbus. This module provides an interface between a Modbus RTU RS485 slave device and the iMAC L1 fieldbus.

Term	Definition
<i>SIM-T</i>	Serial Interface Module (Trolex™) that connects to the iMAC L1 fieldbus. This module provides an interface between a Trolex™ TX94 Series Controller and the iMAC L1 fieldbus.
<i>SLB</i>	Slave Line Barrier that connects to the iMAC L1 fieldbus. This barrier allows the connection of non-intrinsically safe modules to an intrinsically safe iMAC L1 fieldbus.
<i>SQM</i>	Sequence Module that connects to the iMAC L1 fieldbus. This module allows sequenced control of equipment using the iMAC2 Controller's sequencing bits.
<i>SSW</i>	Speed Switch Module that connects to the iMAC L1 fieldbus. This module provides conveyer belt slip protection and speed indication.

1.4 Fieldbus System Configurations

The iMAC fieldbus can be configured as either a 2-wire or 3-wire system depending on the required application. Each of these configurations can be used within hazardous areas, provided that the fieldbus is correctly installed utilising an iMAC MLB intrinsically safe barrier.

1.4.1 2-Wire System

2-Wire systems are typically used for low cost emergency stop systems or for monitoring systems that don't require an emergency stop function such as a mine wide gas monitoring system. If the iMAC2 Controller emergency stop function is not required, the EOL module is not required, however an EOL module is still recommended for providing fieldbus diagnostic functions.

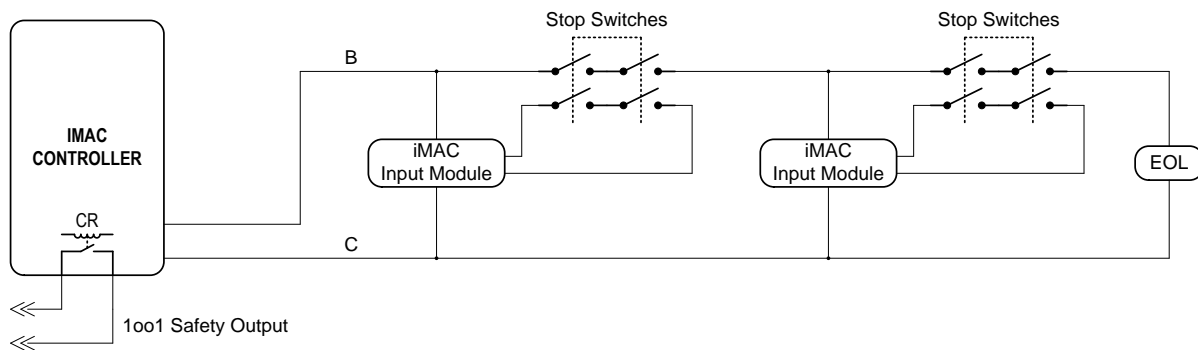


Figure 1.1: 2-Wire iMAC Fieldbus System Configuration

1.4.2 3-Wire System

3-Wire systems are typically used for emergency stop systems where constant monitoring of all modules is required, regardless of whether an emergency stop has been activated.

In a 2-Wire system, when an emergency stop is activated, all modules downstream of the activated switch go offline and cannot be monitored. The 3-Wire system addresses this shortcoming of the 2-wire system by using separate signal and monitoring lines.

The Signal Line (or A-line) is fed through all of the emergency stop contacts and terminated into the EOL module. The Monitoring Line (or B-line) is terminated into an MEOL module. All iMAC fieldbus modules are connected to and communicate across the Monitoring Line.

The A-line and B-line are separated using a resistor, the resistor value is typically 47 ohms and allows faults to be detected. Monitoring and comparing the EOL and MEOL module resistance readings allows the system to detect short circuit cabling faults between the A and B lines.

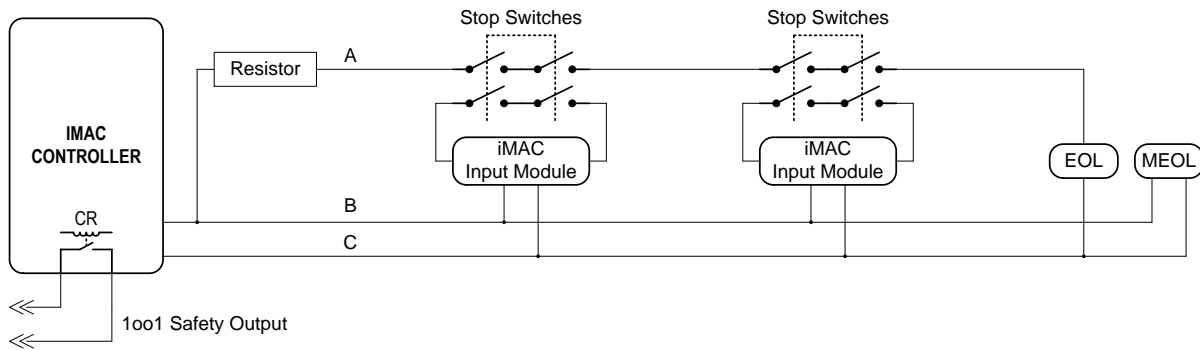


Figure 1.2: 3-Wire iMAC Fieldbus System Configuration

1.4.3 Intrinsically Safe Systems

If the iMAC fieldbus is required to be intrinsically safe, a Master Line Barrier (MLB) is required. The MLB barrier provides I.S. protection and incorporates the A-line resistor for three wire systems (i.e. there is no need for an additional external A-line resistor; the MLB provides this via its A-line connection).

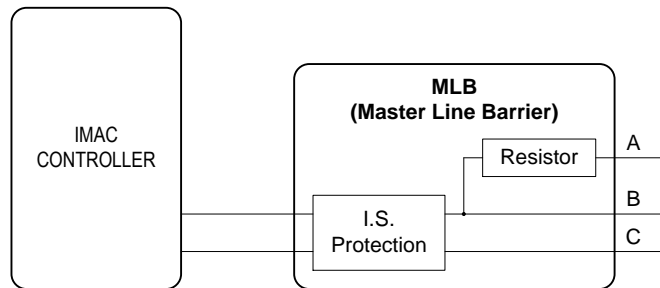


Figure 1.3: MLB Intrinsic Safety Barrier (Provides both 2-Wire and 3-Wire Terminal Connections)

WARNING!

**The MLB barrier must be installed in the safe area.
For full intrinsic safety requirements, please refer to the I.S. documentation.**

2 SAFETY AND OTHER WARNINGS

For safety reasons, the iMAC System must be installed, operated and serviced only by competent electrical personnel. Please read and understand this instruction manual completely before installing, operating or servicing this equipment. Failure to install or operate this system in accordance with the instructions contained in this manual may create hazardous operating conditions.

2.1 Safe Use of Equipment

The equipment supplied has been designed and manufactured to ensure safe operation. The equipment must only be used within the design parameters.

The instructions within this manual must be observed as an aid towards achieving the safest possible installation.

Persons responsible for installation, maintenance, or operation, must observe the following instructions:

2.1.1 Changes to Equipment

Changes in the design and modifications to the equipment are not permitted. Unauthorised changes made to the hardware or operating firmware will void the manufacturer's warranty, and may compromise the integrity of the system into which it is installed and other connected equipment.

2.1.2 Equipment Knowledge

Experience with, or understanding of, this equipment is essential for the safe installation and removal of the equipment. Therefore, please read and understand this manual prior to use. Competency based training courses are recommended and are available on request.

2.1.3 Manual Handling

Precautions have been taken to ensure all equipment is safe to handle and free from sharp edges. However, care should always be taken when handling enclosures.

2.1.4 Installation

Correct operation and safety depend on the iMAC System and associated equipment being installed correctly. Mechanical and or electrical installation and maintenance of plant and equipment must only be carried out by appropriately qualified personnel and must be tested thoroughly prior to operation.

WARNING!



When installing intrinsically safe equipment, the Conditions of Certification must be adhered to. Failure to comply with the Conditions of Certification may seriously compromise the integrity of the system and/or its components. The user must ensure that the "Conditions of Safe Use" outlined in the certificate are met or the certificate (and the I.S. rating) will not be valid.

2.1.5 Operation

As safety depends on the iMAC System functioning correctly it is highly recommended that all safety functions of the system be periodically tested to ensure correct operation.

3 RECEIVING AND STORAGE

3.1 Receiving

All possible precautions are taken to protect the equipment against damage or losses during shipment, however before accepting delivery, check all items against the packing list or bill of loading. If there are shortages or evidence of physical damage, notify Ampcontrol immediately.

Notify Ampcontrol within 7 days (maximum) in case of shortages or discrepancies, according to the packing list. This action will help ensure a speedy resolution to any perceived problems. Keep a record of all claims and correspondence. Photographs are recommended.

Where practicable do not remove protective covers prior to installation unless there are indications of damage. Boxes opened for inspection and inventory should be carefully repacked to ensure protection of the contents or else the parts should be packaged and stored in a safe place. Examine all packing boxes, wrappings and covers for items attached to them, especially if the wrappings are to be discarded.

3.2 Inspection

Equipment that is found to be damaged or has been modified away from its published specification must not be used. Please contact Ampcontrol if the equipment is suspected to be different than that ordered or if it does not match the published specifications.

3.3 Storage after Delivery

When the equipment is not to be installed immediately, proper storage is important to ensure protection of equipment and validity of warranty.

All equipment should be stored indoors, preferably on shelves and protected from the elements.

3.4 Unpacking of Equipment

The method of packing used will depend on the size and quantity of the equipment. The following cautions should be interpreted as appropriate.

CAUTION!



Take care when unpacking crates as the contents may have shifted during transport.

ENVIRO



The disposal of packaging materials, replaced parts, or components must comply with environmental restrictions without polluting the soil, air or water.

Ensure that any timber and cardboard used as **packaging is disposed of in a safe and environmentally responsible manner.**

Where possible, dispose of all waste products i.e. oils, metals, plastic and rubber products by using an approved recycling service centre.

4 iMAC SYSTEM OVERVIEW

The iMAC system is an Integrated Monitoring and Control system designed specifically for long line distributed monitoring and control in harsh hazardous areas such as mining and heavy industry. The system is IECEx Ex ia Group I certified allowing use in intrinsically safe underground mining applications.

The iMAC system is basically a configurable logic controller, with fieldbus connected I/O modules. Modules are simply multi-drop connected to the iMAC fieldbus which reach up 10km and beyond. Note: the maximum length possible depends on a number of factors such as the number and type of modules connected, the distribution of modules, and the fieldbus cable type. Ampcontrol has a number of optimised iMAC fieldbus cables available to cater for your specific system requirements. Please consult with a qualified Ampcontrol applications engineer whom will be able to discuss and advise the most cost effective cable to meet your requirements.

Key Features:

- Remote monitoring and control using a flexible range of I/O modules
- Digital input modules (most input modules are powered directly from the fieldbus)
- Relay output modules
- Analogue input modules
- Serial interface modules
- Fault tolerant fieldbus with high electrical noise immunity
- Advanced fieldbus diagnostics (including individual module loop resistance readings and individual module communications error counters)
- Fieldbus E/stop function qualifies for SIL2 or SIL3 applications
- Intrinsically Safe Certification (IECEx Ex ia Group I)

Typical Applications:

- Emergency Stop Systems
- Overland bulk material conveyors (E/stop, Pullkey monitoring, belt drift/wander, belt tear, blocked chute, sequencing, and remote isolation controls)
- Underground mining conveyors (E/stop, Pullkey monitoring, belt drift/wander, belt tear, blocked chute, sequencing, and remote isolation controls)
- Underground mine wide gas monitoring systems (NERZ/ERZ systems, CH₄, CO, CO₂, O₂, H₂S monitoring)
- Longwall monitoring and control (AFC, BSL, E/stop, sequencing and remote isolation controls)
- Coal prep-plant/washery monitoring
- Rail network traffic monitoring
- Any application that requires reliable monitoring and control of fieldbus I/O distributed over large distances. Up to 10km and beyond can be achieved, subject to system configuration and cable type.

4.1 Typical Installation

The iMAC system consists of a Controller which drives either a 2-wire or 3-wire fieldbus to which I/O modules are multi-drop connected; the fieldbus is terminated with specialised End-Of-Line (EOL) module(s) to ensure the integrity of the fieldbus.

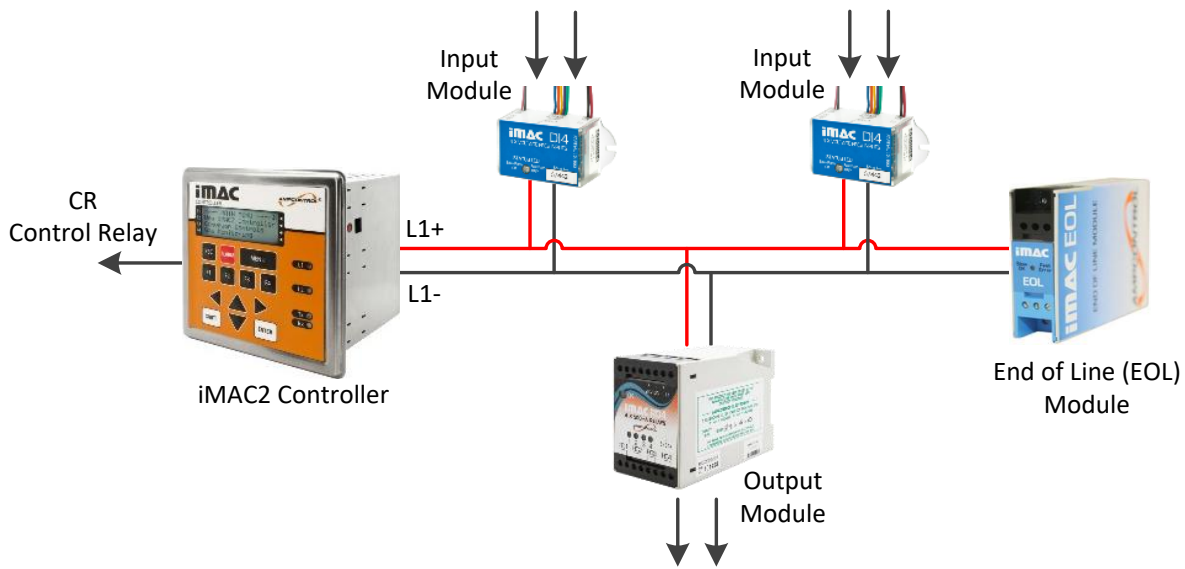


Figure 4.1: Block Diagram of a Simple iMAC 2-Wire System

The iMAC2 Controller is analogous to a mini-PLC. It communicates with I/O modules and can be programmed to process input data and affect output controls. The application program is known as SLP – Supervisory Logic Program. The SLP programming language is a proprietary Ampcontrol language with specialised control and monitoring functions.

The majority of iMAC input modules derive their power directly from the fieldbus line, whilst the majority of iMAC output modules require a local power supply to operate.

A host system (e.g. PLC) can communicate with the iMAC2 Controller via a configurable RS232/RS485 serial port using Modbus protocol. Data can be exchanged between iMAC2 Controller and host system via a read/write Modbus register map. The iMAC2 Controller provides an Ethernet TCP/IP port that allows read-only access to the iMAC2 Controller's Data Point Table. The Ethernet port also provides a Web Interface, allowing system data to be viewed in real time, as well as a viewing platform for the Controller's historical logs.

The Controller displays monitoring and control data on a four (4) line LCD screen. The user navigates the application software defined display screens via the unit's keypad, which also allows for user supervisory control messages.

Remote monitoring and control is implemented through modules connected to the fieldbus. Local control is implemented through the Controller's inputs and outputs. The Controller's critical safety relay is called the Control Relay (CR). The Controller also has an Auxiliary Relay (AR) output, which can be used for general control applications.

4.2 Application Software

Ampcontrol's qualified applications engineers can develop specific application (SLP) software that tailors the functionality of the iMAC2 Controller to the customer's individual requirements.

4.3 iMAC Modules

A wide range of iMAC fieldbus modules are available for designing flexible and expandable systems to meet your specific application requirements.

4.3.1 Input Modules

Digital input modules are available for monitoring switch contact devices such as e/stops, pullkeys, float switches, level switches, belt drift switches, belt wander switches, belt tear switches, blocked chute switches etc.

Analogue input modules are available for monitoring 4-20mA or 0-10V process devices such as pressure sensors, gas sensors, load sensors, level sensors etc.

Temperature input modules are available for monitoring temperature via PT100 RTD sensor elements.

4.3.2 Output Modules

Output modules can be controlled directly from input modules or indirectly via iMAC2 Controller application (SLP) software. In addition to general relay output modules, specialised output modules are available for duplicating the iMAC2 Controller Control and Auxiliary relays for redundancy and for passing belt sequence.

LED output modules are available for providing system status indication.

4.3.3 Serial Interface Modules

A number of serial interface modules are available, allowing Slave Modbus RTU devices such as Ampcontrol's GasGuard Controllers, Trolex™ Controllers and Ampcontrol's range of IS UPS (Uninterruptable Power Supplies) to communicate with the iMAC2 Controller over the fieldbus.

4.3.4 Specialty Modules

Specialty modules are available for monitoring conveyor speed/slip.

4.3.5 Protection Modules

Protection modules are available for providing intrinsic safety. For non-intrinsically safe applications lightning protection modules are available for providing a level of protection against nearby lightning strike transients.

4.3.6 End of Line Modules

End Of Line (EOL) modules are used to terminate the iMAC fieldbus and form part of the key safety function of the iMAC system.

4.4 iMAC Address Range

Each Controller can communicate and control 255 module data addresses.

All input modules must be given a unique address from 1 to 255. Output modules are also given an address from 1 to 255 but do not have to be unique. Output modules can share the same address as each other. Output modules with the same address will operate at the same time. Output modules can also be given the same address as an input module, in these cases the output module will respond directly to the input module's data.

Address 0 is reserved for specialised applications, for example CRM, ARM and GRM modules utilise Address 0. If a standard iMAC module is set to Address 0, the module will go offline and will not respond to fieldbus datascans. This can be a handy feature for fault finding. A module set to Address 0 will appear offline, but will still respond to rollcall scans allowing to its address to be set to a valid Address from 1 to 255.

Note: Non-addressable iMAC modules such as SQM, RKM and EOL rollcall as Address 0 even though they don't actually utilise Address 0, this is true for all non-addressable modules.

4.5 Fault Finding Statistics

The Controller records a number of statistics for every fieldbus address in the range 1-255. In addition to a DATA register, every fieldbus address has an associated STATUS register, RESISTANCE register and ERROR register. The module's **status** bits, fieldbus loop **resistance** and number of communication **errors** are recorded in these registers which are available to host systems via the Modbus interface.

4.6 Networking

The iMAC2 Controller is equipped with two fieldbus ports, the L1 driving port and the L2 listening port. Controllers can be networked together by connecting the listening L2 fieldbus port of one Controller to the parent driving L1 fieldbus of another Controller.

Controllers can be networked in a tree structure, with the Master Controller being at the top of the tree. The Master Controller drives a line, to which many Slave Controllers can be connected. Each Slave Controller can drive its own L1 fieldbus which may have many Slave Controllers connected to it. A maximum of 16 iMAC2 Controllers can be networked together on the iMAC system.

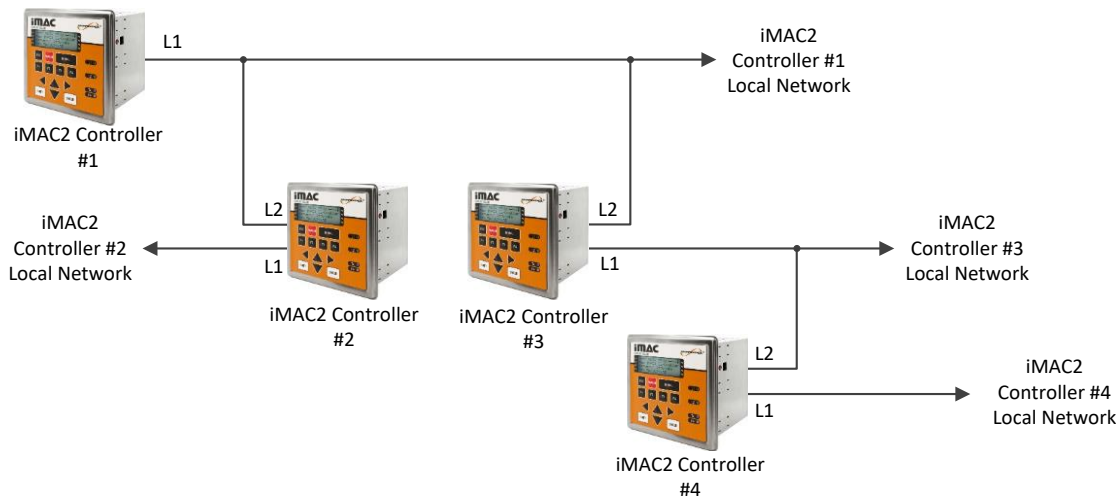



Figure 4.2: Tree Network of iMAC2 Controllers

WARNING!



The L1 fieldbus lines from two Controllers must **never be connected together**. This would **violate the Intrinsic Safety Approval** and may damage the drive circuits.

In a networked iMAC system, each individual Controller will drive its own fieldbus, via the L1 port.

The L2 fieldbus port shall only be used for connection to a 'Parent L1 Line' owned by a Controller further up the tree. The Controller's L2 connection terminals are electrically isolated and the Controller responds to parent L1 signals like any other module connected to the parent L1 fieldbus.

The iMAC2 Controller's application (SLP) software can be programmed to utilise the iMAC2 Controller's 16-position rotary switch to select the Controller's network address.

Networking can also be achieved by connecting each iMAC2 Controller to a PLC, which then allows communication over the site's PLC network.

4.7 Local and Global Data

An iMAC fieldbus address can be configured as LOCAL or GLOBAL. If the address is local, it is not passed around the network. A local address is only available at the Controller to which the module is connected.

To output local data, the output module must be connected to the same communication line as the local address. Local data can only be displayed on the Controller driving the L1 fieldbus to which the local modules are connected.

If the address is global it is passed throughout the network. A global address can have only one owner (input module or Controller) within the whole network. But a global address can be output in many places across the network.

Usually each Controller within a network has a range of local addresses, which are used for local monitoring and control. The results, or summary, of the monitoring information is published into a range of global addresses for display and control at other Controllers.

4.8 Sequence Control

The iMAC System provides four specialised control bits for sequence control. These are generally used for conveyor sequence control, but can be re-purposed for other applications. The sequence control bits are called:

- L1 Sequence Down Bit
- L1 Sequence Up Bit
- L2 Sequence Up Bit
- L2 Sequence Down Bit

The “L1 Sequence Down Bit” and the “L2 Sequence Up Bit” are used by the iMAC2 Controller to initiate downstream and upstream sequenced starts (respectively). These bits can be set and cleared by the Controller’s application (SLP) software. This is in contrast to the “L1 Sequence Up Bit” and the “L2 Sequence Down Bit” which are read only. These bits are set by other Controllers in the iMAC Network.

The “L1 Sequence Down Bit” is transmitted from the iMAC2 Controller’s L1 fieldbus port. Any iMAC2 Controller’s that are networked with this Controller, via their L2 fieldbus ports, will receive this bit and store it as the “L2 Sequence Down Bit”.

The “L2 Sequence Up Bit” is transmitted from the iMAC2 Controller’s L2 fieldbus port. The upstream iMAC2 Controller in the network will receive this bit and store it as the “L1 Sequence Up Bit”.

The Controller’s application (SLP) software can be customised to affect conveyor control via these sequence bits, Figure 4.3 and Figure 4.4 show typical upstream and downstream examples.

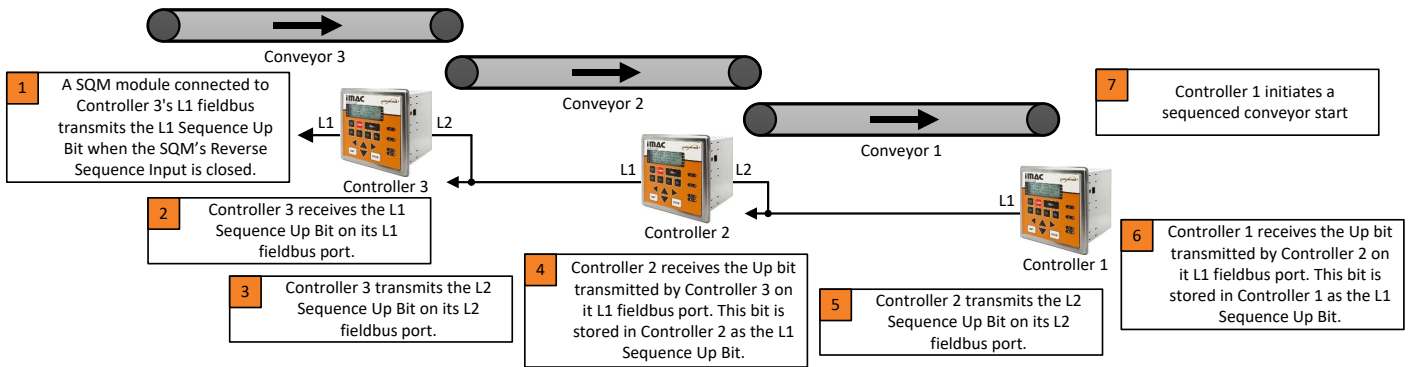


Figure 4.3: Example of the use of Upstream Sequence Bits for Conveyor Sequence Control

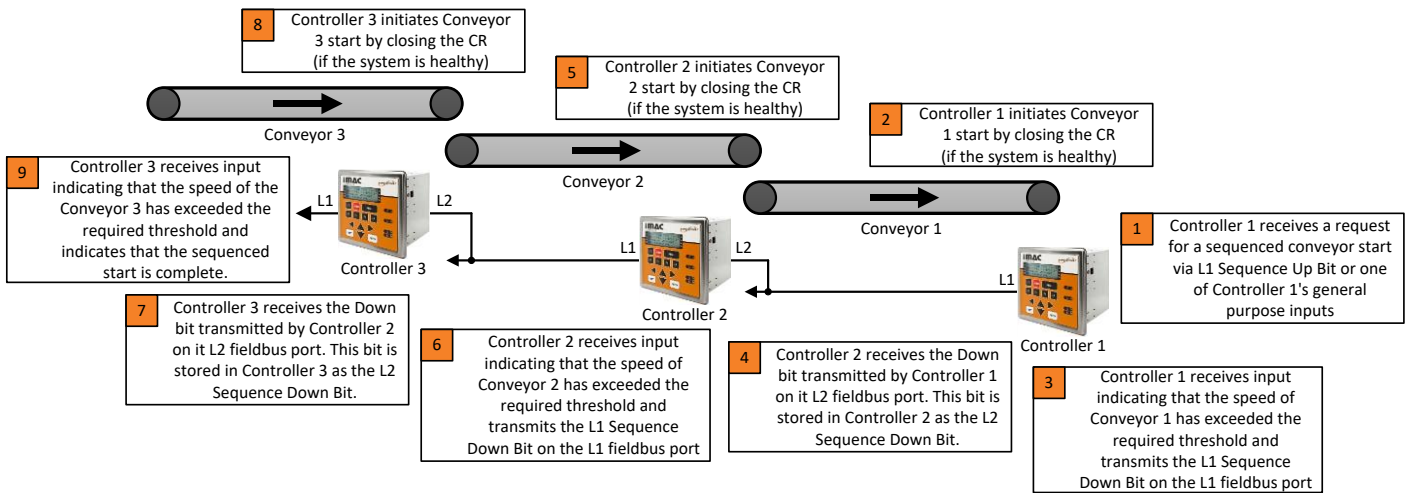


Figure 4.4: Example of the use of Downstream Sequence Bits for Conveyor Sequence Control

4.9 Emergency Stop SIL Qualification

The primary safety function of the iMAC2 Controller is that its Control Relay (CR) will de-energise on loss of communications with the iMAC EOL module. This allows an emergency stop system to be implemented simply by installing emergency stop switch contacts in series with the signal line that connects iMAC2 Controller to EOL module. When an emergency stop switch contact operates, the signal line connection between iMAC2 Controller and EOL module is open circuited causing a loss in communication between Controller and EOL which the Controller detects and forces its Control Relay (CR) to open (de-energise).

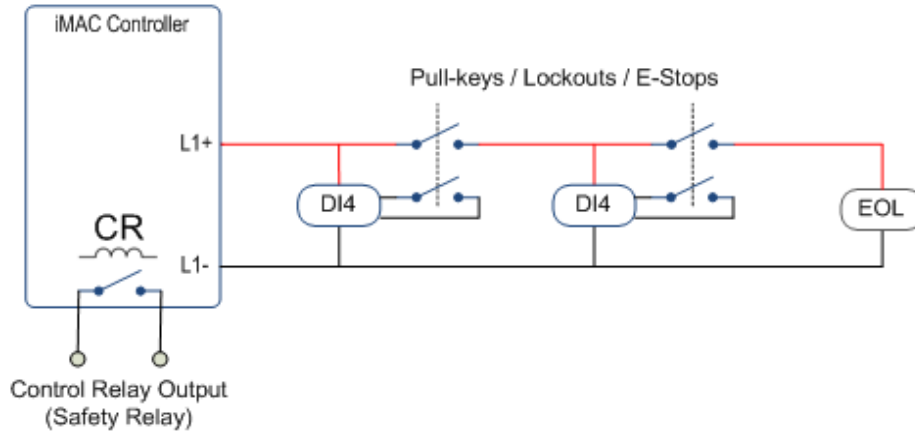


Figure 4.5: An Implementation of Emergency Stops on a 2-Wire iMAC Fieldbus

Refer to IMACB182 iMAC Emergency Stop SIL Qualification document for detailed safety information.

4.10 IECEx Certifications

The iMAC System has been Ex ia Group I certified for use in hazardous areas such as underground coal mines. Certification details are as follows:

Certification	Date Issued	Approved Module Types
IECEX ITA 07.0017X Issue 1 Certificate of Conformity	23/03/2018	MLB, GM1, GM1-D, GM2, SA16, AIM, SIM
IECEX ITA 07.0017X Issue 1 System Approval Overview Diagram (IMAC-Z-032)	The system approval overview drawing details how the system can be configured, how modules can be connected, the numbers of modules that can be connected, cable parameters and relevant entity parameters. Note the iMAC system is certified as a system, entity parameters are only used for connecting certain iMAC modules to other intrinsically safe systems. For example, iMAC AIM and SIM modules have entity parameters for connecting their 4-20mA, RS485 and Power Supply connections to other entity approved intrinsically safe devices.	

When interpreting iMAC IECEx approval documentation it is important to note the relationship between approved module hardware types and the actual module types. The following table illustrates the relationship between approved hardware types and module types:

IECEx Approved Hardware Type	iMAC Module Type
MLB	MLB
GM1	DI4, LED4, LIM, IIM, RTD1, IRK(RKM)
GM1-D	EOL, MEOL
GM2	SSW
SA16	ARM, CRM, EMM, GRM, SQM, SLB
AIM	AIM 4-20mA, AIM 0-10V
SIM	SIM-T, SIM-G, SIM-G2, SIM-P

CAUTION!



The user is responsible for ensuring that the Ex ia Intrinsic Safety certification is maintained by **complying with the “Conditions of safe use”** outlined in the certificate

5 FIELDBUS SIGNALLING PROTOCOL

The iMAC Integrated Monitoring and Control system uses a patented signalling system that utilises a robust combination of pulse width modulation techniques, together with 20mA current loop signalling.

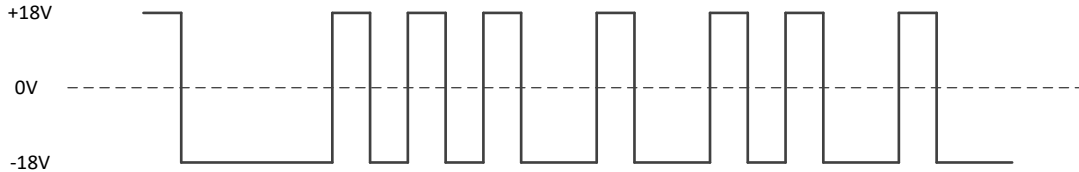


Figure 5.1: Bipolar Pulse Width Modulated iMAC Fieldbus Signal

The iMAC fieldbus signal uses a bi-polar 18 volt pulse width modulated waveform. This gives the iMAC signal a very large noise margin and allows the iMAC communication system to tolerate induced noise from outside sources.

The transmission speed is variable to accommodate the overall resistance and capacitance of the fieldbus. The iMAC system is not compromised by line capacitance or inductance because of a fixed transmission baud rate. The transmission speed is selectable so the data throughput can be optimised at commissioning for the particular system type. All iMAC modules are auto-bauding, automatically adapting to the iMAC2 Controller's selected baud rate.

Both voltage and current are sampled on module data replies. The Controller calculates the resistance and stores the value in a database with the module data and other variables including error counts. The loop resistance to every module provides invaluable maintenance information. The error count on every module gives the user instant indication of pending problems, which can be rectified during a planned maintenance shift.

All data points within the iMAC System are 16-bit data words. Each scan is verified with a 16-bit CRC checksum. Modules are always online and can force exception scans when data changes resulting in response times as short as 100ms. This structure was chosen to simplify the interface to 16-bit PLCs and allow analogue and digital data points to be handled in one systematic fashion.

6 iMAC2 SUPERVISORY CONTROLLER

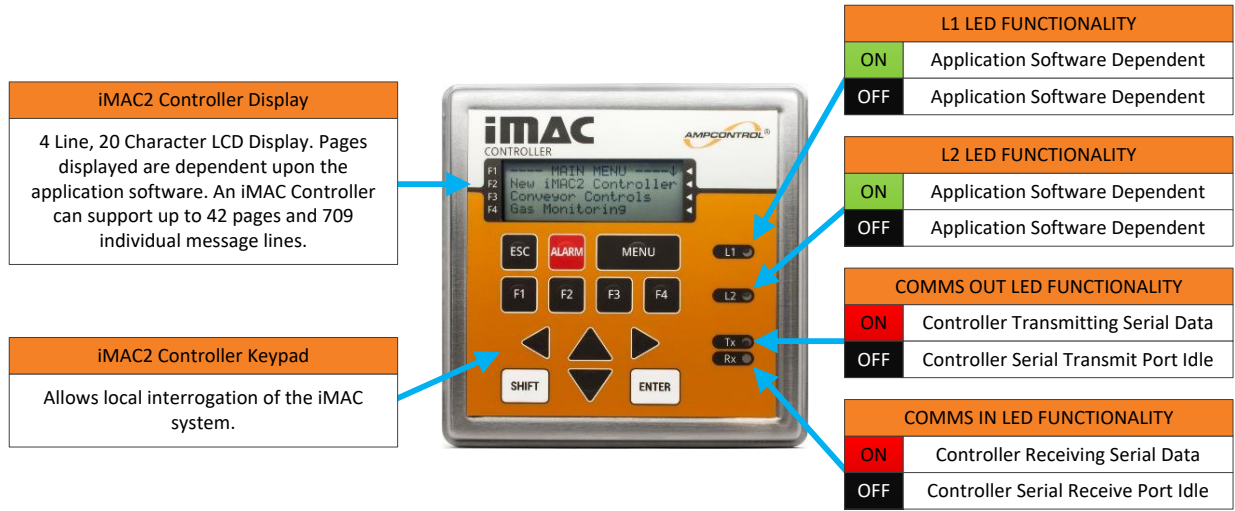


Figure 6.1: iMAC2 Controller (Front)

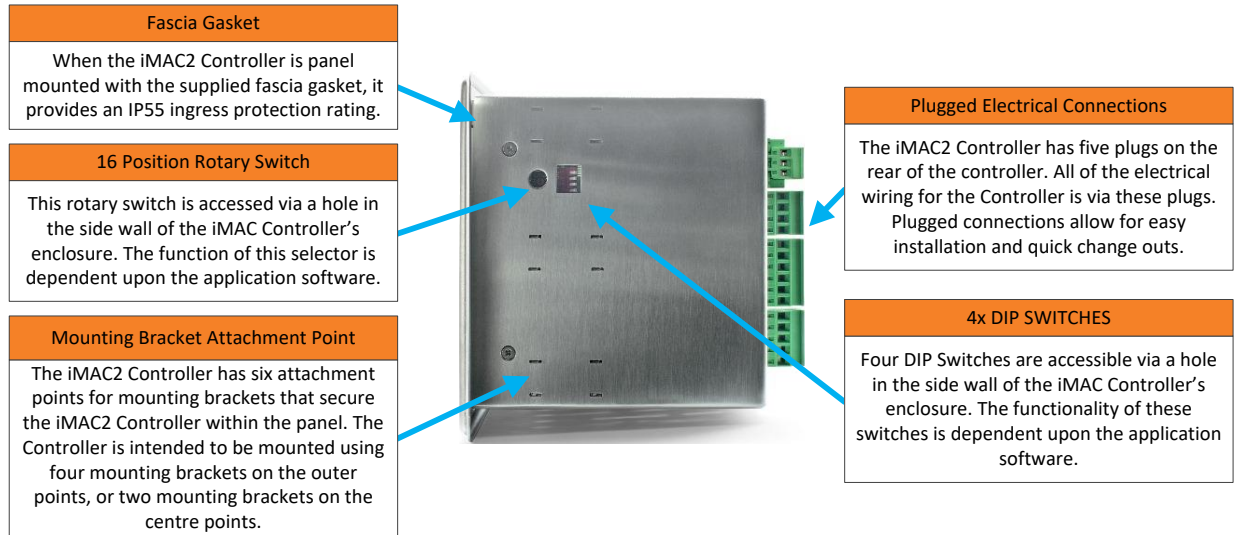


Figure 6.2: iMAC2 Controller (Right Side)

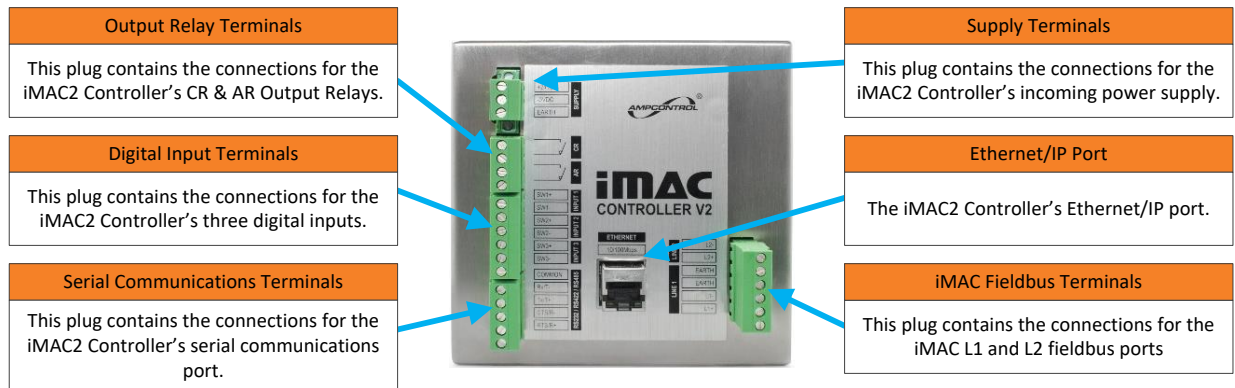


Figure 6.3: iMAC2 Controller (Rear)

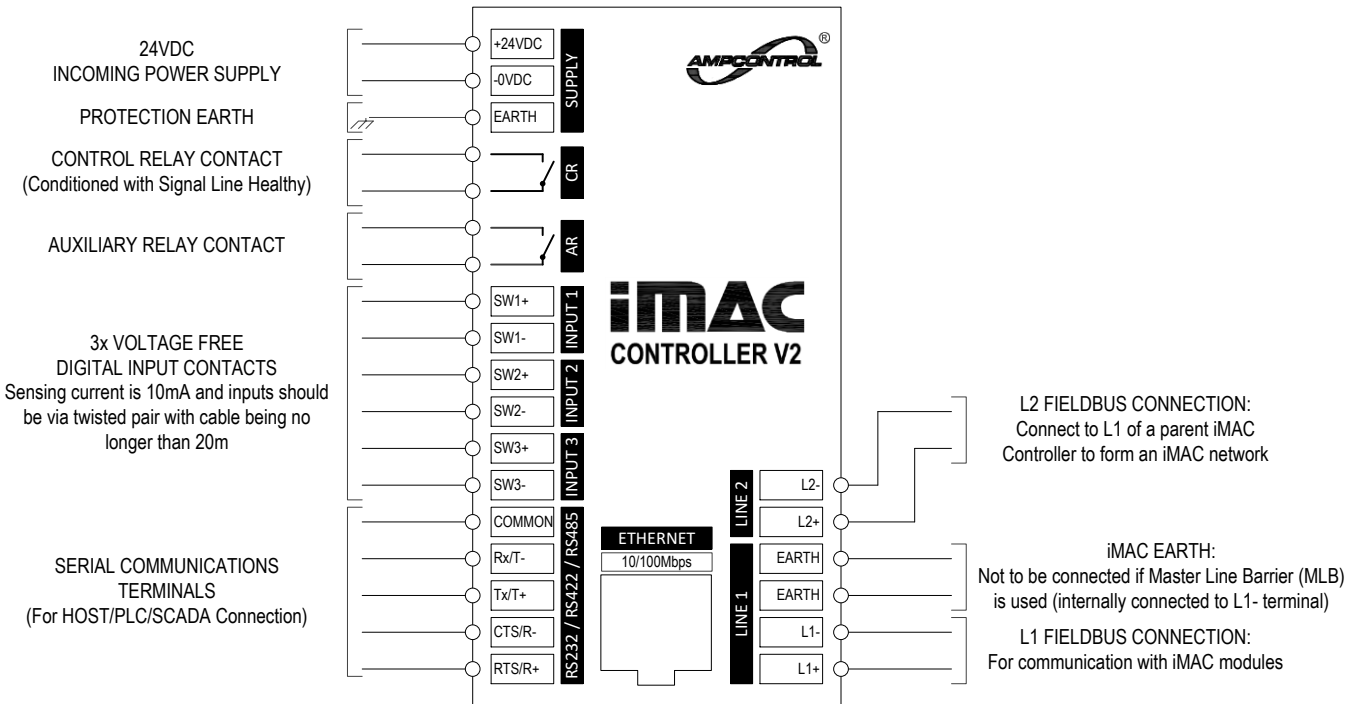


Figure 6.4: iMAC2 Controller Terminal Layout

6.1 Power Supply

The iMAC2 Controller requires a 24VDC power supply. Refer to Section 12 for further details.

6.2 Digital Inputs

There are three general purpose voltage free inputs on the rear on the Controller. These can be used as general purpose digital inputs to the application (SLP) software. Typical applications of these inputs are for sequence operation purposes: sequence in, speed switch and reverse sequence control.

The sensing current is 10mA on these inputs. The inputs are surge protected and are electrically isolated from the rest of the Controller circuitry. The cable connecting the Controller inputs to the voltage free contacts should be twisted pair, with a maximum length of 20m.

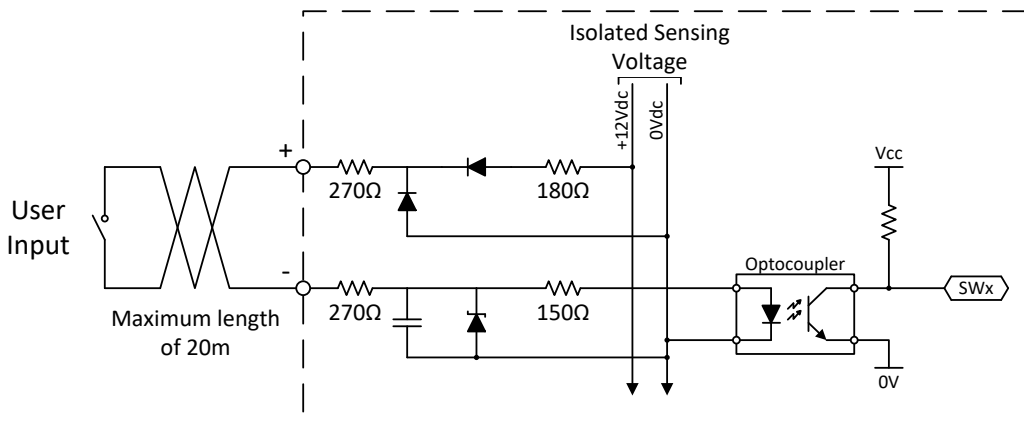


Figure 6.5: General Purpose Input Internal Circuitry

6.3 Relay Outputs

The Controller has two relay outputs: the Control Relay (CR) and the Auxiliary Relay (AR). These relays have one normally open 10A, 240VAC contact. The CR relay is conditioned with “Signal Line Healthy” and this cannot be overridden or disabled. With this exception, the CR relay can additionally be programmed using application (SLP) software to operate under any combination of the inputs and outputs in the iMAC System. The AR relay is also able to be programmed to operate under any combination of inputs and outputs. The AR relay is not conditioned with “Signal Line Healthy”.

6.4 Serial Communications Port

The serial communications port provides a host link to optional devices, such as a PLC, allowing transfer of information between systems. It is also used for downloading Controller application (SLP) software.

The serial communication port can be configured as RS232, RS422 or RS485 and supports a number of protocols. The supported protocols are briefly described in the following subsections. For detailed instruction on the use of the iMAC2 Controller’s communication port, refer to the IMACB153 iMAC Controller Serial Communications Manual.

6.4.1 Slave Modbus RTU Protocol (Recommended)

The iMAC2 Controller acts as a Modbus slave device, the slave address is selectable via the Serial Communications section of the iMAC2 Controller’s System Menu. The Controller supports a number of standard Modbus commands and data is accessed via the Controller’s Data Point Table.

6.4.2 Ampcontrol IP Protocol

The Ampcontrol IP Protocol reads data from the General Buffer area of the Controller’s Data Point Table. The application software of the iMAC2 Controller must move data into these registers in a specific format to allow transfer of information between systems. Refer to the IMACB153 iMAC Controller Serial Communications Manual for more details.

The Ampcontrol IP protocol is a single-drop (single point-to-point) protocol.

6.4.3 Ampcontrol IP2 Protocol

Like the Ampcontrol IP protocol, the Ampcontrol IP2 protocol reads data from the General Buffer area of the Controller’s Data Point Table. The difference between the two protocols is that the IP2 protocol is a multi-drop protocol, whereby one master host device can read and write up to 15 slave Controllers.

The Ampcontrol IP protocols maintain compatibility with legacy DNET IP, IP2 & SLIP systems and are intended for backwards compatibility only. Modbus Slave Protocol is recommended for new systems.

6.4.4 L1 Maintenance Protocol

This allows capture and processing of the L1 Maintenance data which is streamed out the iMAC2 Controller serial port in real-time, providing bit level diagnostic of the L1 communications. This protocol is typically only used by qualified Ampcontrol personnel.

6.4.5 Master Modbus RTU Protocol

Limited support is provided for existing legacy installations only. Modbus Slave Protocol is recommended for new systems.

6.5 Ethernet Communications Port

The iMAC2 Controller is equipped with a 10/100Mbps RJ45 Ethernet port that supports the Modbus TCP/IP Protocol and the Network Time Protocol (NTP).

In addition to these protocols, the iMAC2 Controller also provides a webserver for data viewing and diagnostic functions.

For detailed information regarding the Ethernet communications port, refer to the IMAC2B010 iMAC2 Controller Ethernet Communications Manual.

For detailed information regarding the operation of the iMAC2 Web Interface, refer to the IMAC2B011 iMAC2 Controller Web Interface Manual.

6.6 Fieldbus Ports

6.6.1 L1 Fieldbus Port

The L1 fieldbus port is the primary fieldbus port to which the iMAC modules are multi-drop connected.

The iMAC2 Controller is orderable in one of two L1 fieldbus operating voltage options: 18V and 21V. The 18V option must be used for intrinsically safe systems, the 21V option is only recommended for large > 7km non-intrinsically safe systems.

6.6.2 L2 Fieldbus Port

The L2 fieldbus port is used for networking the iMAC2 Controller to a parent Controller's L1 fieldbus.


The L2 port is optically isolated.

6.7 Memory

The iMAC2 Controller has 32k flash memory for storing application (SLP) software. This memory is retained when power is removed from the Controller. The Controller has an area of this memory reserved for storing non-volatile application software variables which are automatically saved and restored each time the Controller's power is cycled.

6.8 Intrinsically Safe Battery

The iMAC2 Controller contains an internal non-user replaceable intrinsically safe battery for maintaining the unit's real time clock functions.

	WARNING! The iMAC2 Controller contains a non-user replaceable intrinsically safe battery .
	The controller must be returned to an authorised Ampcontrol service centre for battery replacement.

The iMAC2 Controller shall be installed in a safe area (which may be inside a flameproof box). However, Issue 1 of Certificate IECEx ITA 07.0017X allows the iMAC2 Controller, under power withdrawn condition, to be located in an area that may lose ventilation and be classified as Zone 0. It also provides compliance for the iMAC2 Controller battery to be used within a flameproof enclosure according to IEC 60079-1:2014 Annex E. Refer to Certificate IECEx ITA 07.0017X Issue 1 for further details.

6.9 Data Point Table

The iMAC2 Controller’s data point table consists of 1617 16-bit registers. The registers contained within the address range 0-1535 are accessible via both the serial communications port and the Ethernet communications port. Registers in the address range 1536-1697 are accessible via the Ethernet communications port only.

The register map is arranged as follows:

iMAC2 Controller Data Point Table										
Modbus Address Block: 000h-0FFh	System Data Register	255x Module Data Registers (Modbus Table Address = iMAC Module's Address) Modbus Table Addresses: 001h-0FFh								
Decimal	0	1	2	3	4	5	-----	253	254	255
Hexadecimal	0h	1h	2h	3h	4h	5h	-----	FDh	FEh	FFh
Modbus Address Block: 100h-1FFh	System Status	255x Module Status Registers (Modbus Table Address = iMAC Module's Address + 256) Modbus Table Addresses: 101h-1FFh								
Decimal	256	257	258	259	260	261	-----	509	510	511
Hexadecimal	100h	101h	102h	103h	104h	105h	-----	1FDh	1FEh	1FFh
Modbus Address Block: 200h-2FFh	EOL Module Resistance	255x Module Resistance Registers (Modbus Table Address = iMAC Module's Address + 512) Modbus Table Addresses: 201h – 2FFh								
Decimal	512	513	514	515	516	517	-----	765	766	767
Hexadecimal	200h	201h	202h	203h	204h	205h	-----	2FDh	2FEh	2FFh
Modbus Address Block: 300h-3FFh	Line Shunt	255x Module Error Registers (Modbus Table Address = iMAC Module's Address + 768) Modbus Table Addresses: 301h – 3FFh								
Decimal	768	769	770	771	772	773	-----	1021	1022	1023
Hexadecimal	300h	301h	302h	303h	304h	305h	-----	3FDh	3FEh	3FFh
Modbus Address Block: 400h-4FFh	System Runtime Variables	OneShot	WORDBIT	WORD	Application Software General Buffer 480h – 4FFh					
Decimal	1024-1046	1047-1151			1152-1279					
Hexadecimal	400h-416h	417h-47Eh			480h-4FFh					
Modbus Address Block: 500h-5FFh	NVM System Variables	User NVM			Application Software General Buffer 580h – 5FFh					
Decimal	500h-51Fh	520h-57Fh			580h-5FFh					
Decimal	1280-1311	1312-1407			1408-1535					
Hexadecimal	500h-51Fh	520h-57Fh			580h-5FFh					
Modbus Address Block: 600h-651h	Controller Information (Ethernet Port Only)									
Decimal	600h-6A1h									
Hexadecimal	1536-1697 600h-6A1h									

Figure 6.6: iMAC2 Controller’s Data Point Table

Each iMAC2 Controller has an allowance for up to 255 16-bit data registers to be utilised by iMAC fieldbus modules. Each data register has an associated status register, resistance register, and error register.

iMAC I/O modules need to be configured with an iMAC address in the range of 1 to 255. The iMAC address maps directly to the corresponding Controller data register. The corresponding addresses of the status register, resistance register, and error register are +256, +512 and +768 offset respectively.

For example, consider a single address input module (e.g. DI4 module) that is programmed to fieldbus Address 5, the data register in the iMAC2 Controller’s data point table will be Address 5. The associated status register will be at Address 261 (5+256), the associated resistance register will be at Address 517 (5+512) and the associated error register will be at Address 773 (5+768).

For a complete range of data definitions, including system runtime variables, refer to the IMACB153 iMAC Controller Serial Communications Manual, or the IMACB2010 iMAC2 Controller Ethernet Communications Manual.

7 iMAC FIELDBUS MODULES

The iMAC System has a wide range of available I/O modules. This section provides an overview of each module type currently available (at the time of publishing this document). For detailed iMAC module information, refer to the module’s individual datasheet.

CAUTION!



For information on correct installation practices for iMAC modules, refer to the **iMACB094 iMAC Installation Requirements document**.

Module ordering part numbers can be found in the equipment list in Section 13.

7.1 Intrinsically Safe Barriers

There are two types of I.S. barriers available for the iMAC System: the Master Line Barrier (MLB) and the Slave Line Barrier (SLB).

The MLB is designed to restrict the transfer of energy from non-intrinsically safe circuits to intrinsically safe circuits by the limitation of voltage and current. The MLB allows approved modules to be connected to the iMAC L1 fieldbus within hazardous areas. The MLB is DIN rail mounted and does not require a power supply. The MLB **must** be located in the safe area, or in a suitable flameproof enclosure.

WARNING!



**The MLB is only to be connected to L1.
Only one MLB is to be connected per L1 Fieldbus.**

In order to connect non-approved modules to the Intrinsically Safe communication line they must be connected through a SLB. The SLB is DIN rail mounted and requires an 110V or 240V power supply (model dependent). The SLB **must** be located in the safe area, or in a suitable flameproof enclosure.

WARNING!



When installing intrinsically safe equipment, **the Conditions of Certification must be adhered to**. Failure to comply with the Conditions of Certification may **seriously compromise the integrity of the system and/or its components**. The user must ensure that the “Conditions of Safe Use” outlined in the certificate are met or the certificate (and the I.S. rating) **will not be valid**.

For further information on the MLB and SLB modules, refer to their respective technical datasheets.

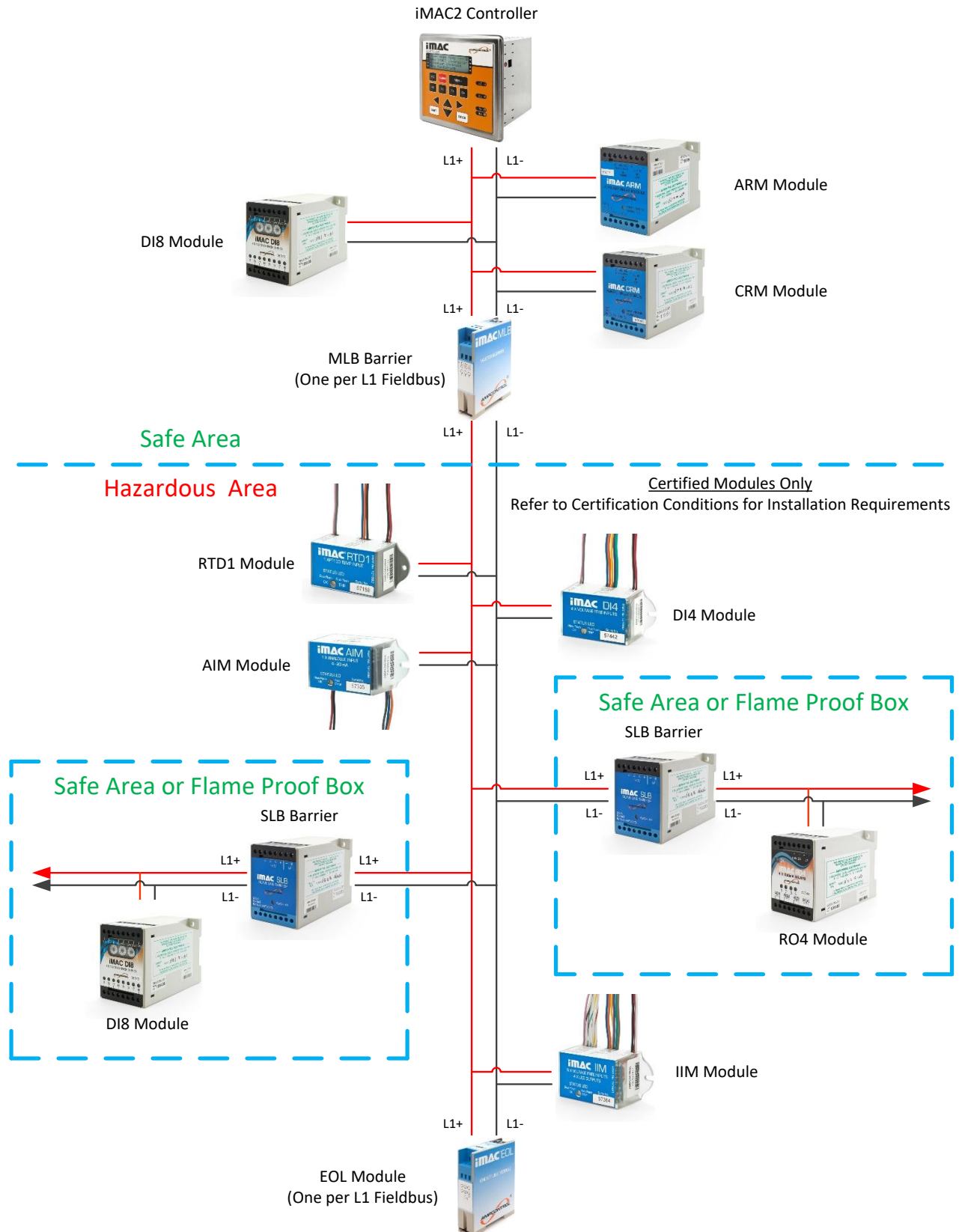


Figure 7.1: Utilisation of MLB and SLB Barriers in an Intrinsically Safe System

7.2 Intrinsically Safe Remote Keypad

The iMAC2 Controller cannot be mounted directly in a hazardous area. For these applications, the Controller is intended to be installed within a flameproof enclosure behind a viewing window. In order for the user to operate the Controller in these circumstances, an externally mounted Intrinsically Safe iMAC Remote Keypad (IRK) is required for each iMAC2 Controller. Pressing a keypad button on the IRK will perform the same function as pressing the corresponding button on the iMAC2 Controller. The IRK provides an exact functional mimic of the iMAC2 Controller’s keypad operation.

For further information on the IRK, including installation details, refer to the IRK’s technical datasheet.

7.3 Digital Input Modules

The iMAC System has three types of digital input modules available. These modules use voltage free contacts as inputs and store the state of these inputs in the module’s registers. These registers are available to be accessed by the iMAC2 Controller, and any output modules that have been set to the same address.

Type	Description	Function	Example Application
DI4	4 x Digital Input Module	Provides 4 x Digital Inputs	Allows remote inputs into the iMAC System via the module’s voltage free inputs. Can be used in hazardous areas.
DI8	8 x Digital Input Module	Provides 8 x Digital Inputs	Allows remote inputs into the iMAC System via the modules voltage free inputs.
IIM	Input and Indication Module	Provides 5 x Digital Inputs and 4 x LED Outputs	Voltage free inputs for the iMAC System with programmable output LEDs for system status indication. Can be used in hazardous areas.

7.4 Analogue Input Modules

The iMAC System has three types of analogue input modules available. These modules allow analogue inputs to be interfaced with the iMAC fieldbus. The analogue input data is stored in the module’s registers. These registers are available to be accessed by the iMAC2 Controller.

Type	Description	Function	Example Application
AIM 4-20mA	Analogue Input Module (4-20mA)	Provides 1 x 4-20mA Analogue Input	Analogue process control signal measurement. Can be used in hazardous areas.
AIM 0-10V	Analogue Input Module (0-10V)	Provides 1 x 0-10V Analogue Input	Analogue process control signal measurement. Can be used in hazardous areas.
RTD1	1 x Temperature Input Module	Provides 1 x input for a PT100 RTD temperature sensor	Remote temperature monitoring. Can be used in hazardous areas.

7.5 Output Modules

The iMAC System has seven types of output module available. The different types of output module provide different functions for the control systems that they are installed in.

Type	Description	Function	Example Application
RO4	4 x Relay Outputs Module	Provides 4 x relay outputs that mimic the state of an input module with the same address. Alternatively, relays can be remotely controlled by the iMAC2 Controller	Control outputs at different locations
ARM	Auxiliary Relay Module	Mimics the state of the iMAC2 Controller's AR	Provides an additional AR output for the iMAC2 Controller. Can be used to provide a control output at a remote location or as cross-checking for the iMAC2 Controller's AR Relay. <i>Note: requires specific application (SLP) software for operation.</i>
CRM	Control Relay Module	Mimics the state of the iMAC2 Controller's CR	Provides an additional CR output for the iMAC2 Controller. Can be used to provide a control output at a remote location or as cross-checking for the iMAC2 Controller's CR Relay. <i>Note: requires specific application (SLP) software for operation.</i>
GRM	General Relay Module	Provides 1 x relay output that can be remotely controlled by the iMAC2 Controller	Provides general purpose relay output.
EMM	End of Line Monitoring Module	Monitors the health of the iMAC EOL module/fieldbus and energises 1 x relay output if healthy	Allows implementation of control systems in remote locations. This module is used to ensure L1 fieldbus communications to EOL module is healthy. Relay output energises when system is healthy, de-energises when unhealthy.
SQM	Sequence Module	Provides 1 x Sequence Relay Output and 1 x Reverse Sequence Digital Input.	Provides remote sequence controls e.g. for hardwired I/O conveyor sequence controls.

Type	Description	Function	Example Application
LED4	4 x LED Output Module	Provides 4 x Output LEDs that mimic the state of an input module with the same address. Alternatively, LEDs can be remotely controlled by the iMAC2 Controller.	Control LED outputs at remote locations e.g. indicate remote isolation, status of conveyor signal lines etc. Can be used in hazardous areas.
LIM	LED Indication Module	Provides 7 selectable LED profiles for green, yellow or red flash sequences.	Responding to a 4-20mA Analogue Input with green, yellow or red LED indication.

7.6 Serial Interface Modules

The iMAC System allows certain external equipment to communicate with the iMAC2 Controller through the use of Serial Interface Modules. These modules form a communication bridge between the iMAC System and compatible RS485 Modbus devices, allowing up to 16 Modbus Holding Registers to be read from a Modbus Slave RTU device and be transmitted to an iMAC2 Controller across the iMAC Fieldbus.

Type	Description	Function	Example Application
SIM-G	Serial Interface Module – 1 x GasGuard Controller	Communications Bridge between the iMAC System and a single GasGuard Controller's RS485 Modbus interface.	Allows RS485 Communications from a GasGuard Controller installed in the field to be transmitted back to the iMAC2 Controller over the fieldbus. Can be used in hazardous areas.
SIM-G2	Serial Interface Module – 2 x GasGuard Controllers	Communications Bridge between the iMAC System and two GasGuard Controllers' RS485 Modbus interfaces.	Allows RS485 Communications from two GasGuard Controllers installed in the field to be transmitted back to the iMAC2 Controller over the fieldbus. Can be used in hazardous areas.
SIM-P	Serial Interface Module - Programmable Modbus RTU	Communications Bridge between the iMAC System and a compatible RS485 Modbus RTU device	Transfers up to 16 Modbus registers from a Modbus RTU slave device to the iMAC2 Controller over the fieldbus. Can be used in hazardous areas.
SIM-T	Serial Interface Module -Trolex™ 9042 Controller	Communications Bridge between the iMAC System and a Trolex™ 9042 Controller's RS485 Modbus interface	Allows RS485 Communications from a Trolex™ 9042 Controller installed in the field to be transmitted back to the iMAC2 Controller over the fieldbus. Can be used in hazardous areas.

7.7 Specialty Modules

In addition to the above module types, the iMAC System also has a speciality module for monitoring conveyor belt speed, belt slip and belt sequencing. For detailed information on the installation and operation of this module, refer to the relevant technical datasheet.

Type	Description	Function	Example Application
SSW	Speed Switch Module	Monitors two proximity sensor heads, one on the conveyor drive roller and one on the free running idler roller.	Provides belt slip protection, speed indication and sequence control for conveyor belts using the iMAC System.

7.8 Protection Modules

The iMAC system has two lightning protection modules available. For detailed information on the installation and operation of these modules, refer to the relevant technical datasheet.

Type	Description	Function	Example Application
LPU2	Lightning Protection Module for 2-Wire Modules	Provides lightning protection for 2-wire iMAC modules	Sacrificial lightning transient protection for 2-wire modules e.g. DI4 module.
LPU3	Lightning Protection Module for 3-Wire Modules	Provides lightning protection for 3-wire iMAC Modules.	Sacrificial lightning transient protection for 3-wire modules e.g. IIM module.

7.9 End-of-Line Modules

iMAC End-of-Line modules form a key part of the safety feature of the iMAC System. In order for the iMAC2 Controller Control Relay (CR) to be energised, the Controller must be successfully communicating with the End-of-Line module.

There are two types of End-of-Line modules, the End-of-Line (EOL) module and the Monitoring-End-of-Line (MEOL) module. In 2-Wire systems, only the EOL module is required, 3-Wire systems require both an EOL and a MEOL to be installed and communication to be healthy before the Control Relay (CR) can be energised.

Type	Description	Function	Example Application
EOL	End of Line Module	Ensures healthy communications on the L1 fieldbus signal line.	Required in all iMAC Systems where the Control Relay (CR) safety function is required. Terminates L1 fieldbus signal line.
MEOL	Monitoring End of Line Module	Ensures healthy communications on the L1 fieldbus monitoring line.	Required in all 3-wire iMAC systems. Terminates L1 fieldbus monitoring line.

8 INSTALLATION

8.1 General Warnings

These instructions have been designed to assist users of the iMAC System with the installation of the iMAC2 Controller.

Before the iMAC2 Controller can be installed, there are a number of points that need to be considered and understood to prevent incorrect or unsafe operation of the iMAC2 Controller or the greater system into which it is installed.

Along with relevant competence, and an understanding of the target application, the following points should be considered:

8.1.1 Ensure that the information provided in this user manual is fully understood.

It is extremely important that the functionality and any limitations of the iMAC System are understood to prevent incorrect installation or misuse. If in doubt as to the nature of the limitations or their implication, consult a competent authority such as a site supervisor or Ampcontrol technical representative.

8.1.2 Ensure that the application into which the iMAC System is being installed has been properly defined, designed and approved.

Any system intended to mitigate the risk of injury needs to be properly designed and implemented. Such a system must be the result of structured risk analysis with the outcomes used to define the system requirements. These requirements, in turn, will guide the choice of all components needed to implement a safety system. Understanding the needs of the system will ensure proper selection of equipment.

8.1.3 Ensure that the iMAC System will properly perform the required functions within the system design.

It is important to understand how iMAC components are intended to interact with other equipment within a system. For safe and reliable use, it is crucial that neither the iMAC2 Controller nor its signalling be compromised by incompatibilities with connected or nearby equipment. For example, avoid running HV cables in close proximity to iMAC system cables.

8.1.4 Modifications of any form to the iMAC2 Controller and its associated modules are prohibited.

The iMAC2 Controller as supplied has been designed and manufactured to comply with the requirements of the relevant electrical standards. If modifications of any form are made, the equipment may no longer be fit for use. If any modifications or damage to the equipment is evident, do not use the equipment and contact Ampcontrol for advice.

8.2 Mandatory Installation Practices

The following information must be adhered to when installing the iMAC2 Controller. Failure to adhere to this information may give rise to unsafe operation.

Using the iMAC2 Controller in a manner that exceeds its electrical, functional or physical specifications, or in a way that is contrary to its operating restrictions, may increase risks to personnel and/or equipment resulting in injury or death.

- The iMAC2 Controller must be powered within the specified voltage range.
- The installation of the iMAC System must be carried out by suitably trained and qualified personnel (Refer to IMACB094 iMAC System Installation Requirements Document for further information).
- Identification labels fixed to the iMAC2 Controller must not be damaged, removed or covered before, during or after installation.
- The installation is to be in accordance with the relevant installation Standards/Codes of Practice.
- Modifications must not be made to any part of the iMAC2 Controller, or any of its associated modules. As supplied, the unit is built to, and complies with the relevant standards. Modifications to its construction will render the unit non-compliant.
- Complete, accurate and up to date records of the system must be kept as part of the site installation.
- For intrinsically safe installations, the Conditions of Use of the relevant certification must be adhered to.

8.3 Mechanical Arrangement

The iMAC2 Controller is housed in a metal enclosure and is intended to be panel mounted. When panel mounted correctly using the supplied mounting brackets, the fascia gasket provides an ingress protection rating of IP55. The iMAC2 Controller must be mounted with the supplied gasket to maintain this IP rating. Recommended panel cut-out is 135Hx135Wmm, overall dimensions of the enclosure are shown in *Figure 8.1*.

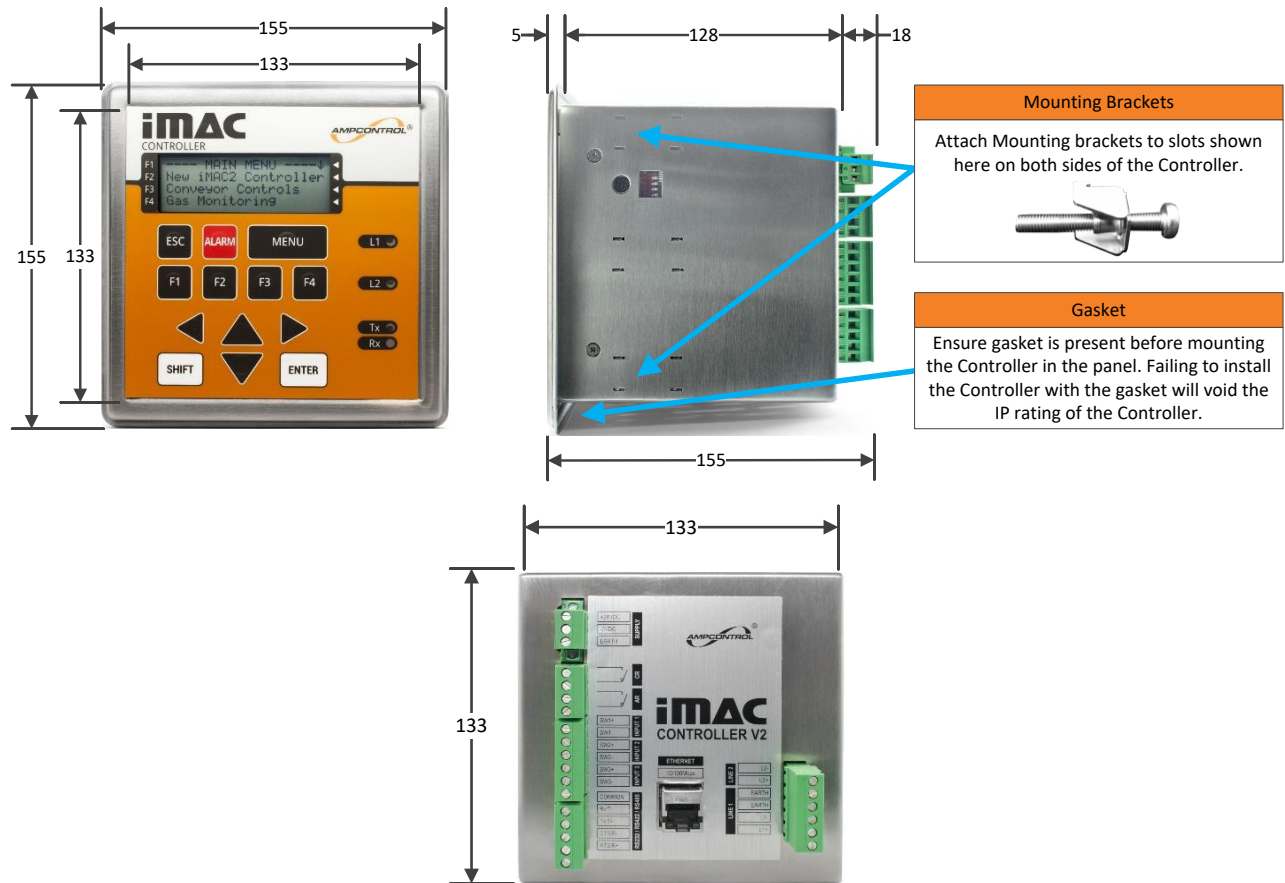


Figure 8.1: iMAC2 Controller Enclosure Dimensions

8.4 Electrical Connections

Due to the many configurations that the iMAC System can be installed in, the electrical installation requirements for the iMAC System are covered in a separate document. Please refer to the IMACB094 iMAC Installation Requirements document for detailed wiring diagrams.



9 COMMISSIONING AND CALIBRATION

Prior to being put into service, the iMAC System must be correctly commissioned. This manual does not cover system commissioning; the full scope of commissioning tests should be determined during the risk assessment or FMEA covering the design of the electrical protection system.

For assistance in installing and commissioning an iMAC System, contact Ampcontrol.

10 iMAC2 CONTROLLER OPERATION SUMMARY

This section provides an overview of the operational principles of the iMAC2 Controller. The topics covered include navigating the user interface, the user programmable L1/L2 LEDs and the communication status LEDs.

Topics not covered in this operation summary include the operation of individual modules, Modbus communication, iMAC2 Controller/Module programming, and detailed installation requirements. For information regarding these topics, please refer to the relevant separate documentation.

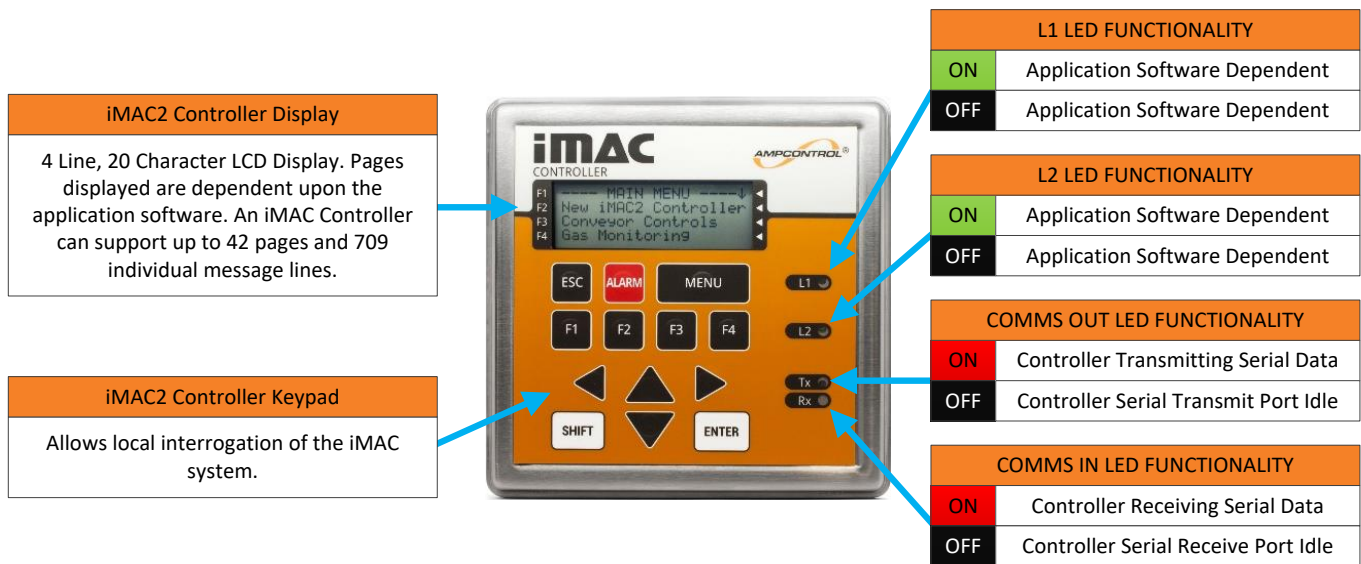


Figure 10.1: iMAC2 Controller Operational Interface (Front)

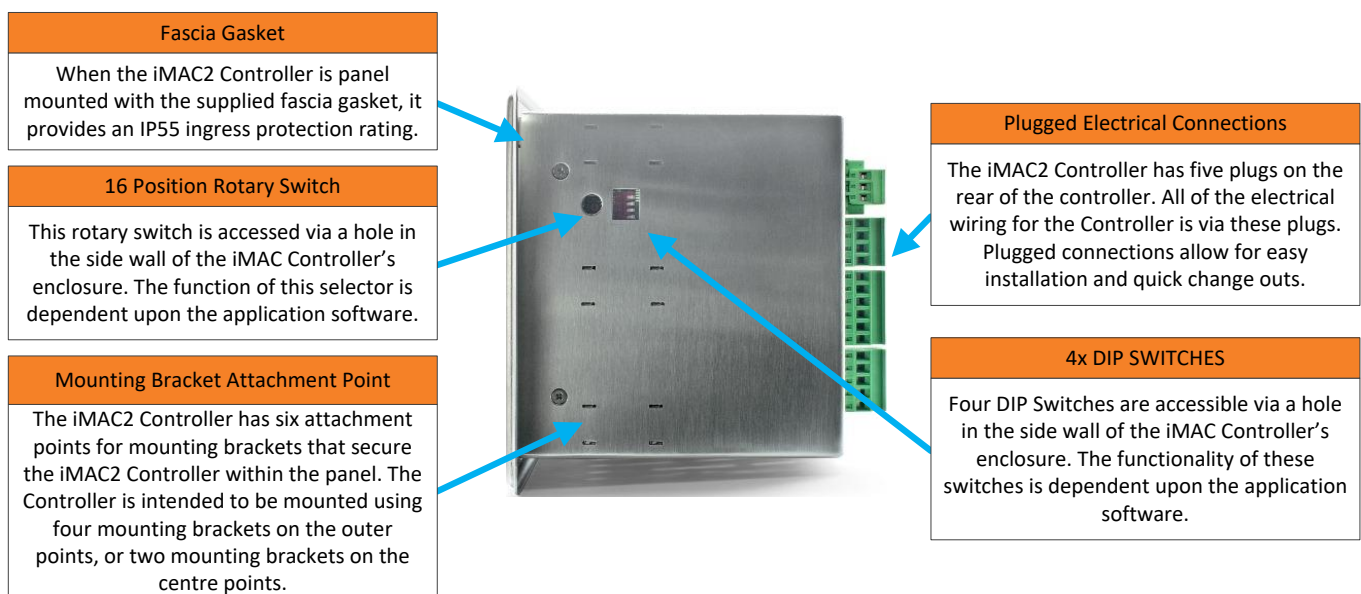


Figure 10.2: iMAC2 Controller Operational Interface (Right Side)

Ethernet Reset Pushbutton

The Ethernet Reset Button is located on the left side of the iMAC2 Controller's enclosure. Pressing and holding this button for a period of 5 seconds will reset the iMAC Controller's Ethernet Settings to the factory default. Refer to the IMAC2B010 iMAC2 Controller Ethernet Communications Manual for further details.



Figure 10.3: iMAC2 Controller Operational Interface (Left Side)

10.1 iMAC2 Controller User Interface

The user navigates through the iMAC2 Controller's menu structure using the Controller's keypad. The operation of the keypad's buttons is as follows:

10.1.1 Function Keys: [F1], [F2], [F3] and [F4]

The four function keys initiate an action from the Controller. This can be a jump to another screen, a control function (e.g. resetting a trip, start conveyor, stop conveyor etc.), modifying a parameter, programming an iMAC module or setting up the Controller.

Each of the four function keys are assigned to each of the four display lines. The function key adjacent to the display line can be used to execute that display line function.

10.1.2 [MENU] Key

The [MENU] key allows the user to navigate directly to the main menu of the iMAC2 Controller application (SLP) software. From here it is possible for the user to navigate to a number of sub-menus using the [UP] and [DOWN] arrow keys, in combination with the function keys [F1] to [F4]. The available sub-menus are defined by the Controller's application (SLP) software and vary from one application software to another.

10.1.3 [ALARM] Key

The [ALARM] key allows the user to navigate directly to the alarm page, which displays any alarms or important status messages. Arrows will appear on the left of the text, if any further information on this particular alarm is available. This information can be accessed by pressing the relevant function key. The alarm page messages are defined by the Controller's application (SLP) software and vary from one application software to another.

10.1.4 [ESC] Key

The [ESC] key allows the user to navigate backwards to the previous sub-menu. It can also be used to exit-without-save when modifying parameters.

10.1.5 [ENTER] Key

The [ENTER] key allows the user to save-and-exit when modifying parameters e.g. for accepting changes to the serial communications settings.

10.1.6 [SHIFT] Key

The [SHIFT] key can be used as a key modifier, it can be pressed in conjunction with other keys to perform alternate key functions e.g. while on the Maintenance page modifying the [UP] and [DOWN] keys performs fast searches: pressing [SHIFT+UP] will jump to the next online address; pressing [SHIFT+DOWN] will jump to the preceding online address. Pressing [SHIFT+MENU] will navigate directly to system menu. Note: the system menu is only accessible using this method if permitted by the application software, this feature may, or may not, be enabled depending on application (SLP) software.

10.1.7 [UP], [DOWN], [LEFT] and [RIGHT] Arrow Keys

The [UP] and [DOWN] arrow keys are used to navigate up and down the menu screens (not between screens) and for modifying parameters when they are selected.

The [LEFT] and [RIGHT] arrow keys are used for modifying parameters when they are selected.

10.2 System Menu

The user can usually access the System Menu by pressing [SHIFT+MENU]. In some cases, the application (SLP) software may have disabled this function, in these cases the System Menu will be assessable according to an application software defined procedure, refer to the specific application software documentation for instructions on accessing the System Menu in these cases.

The System Menu allows access to the following pages:

- Maintenance Page
- Serial Communications Page
- Version Page

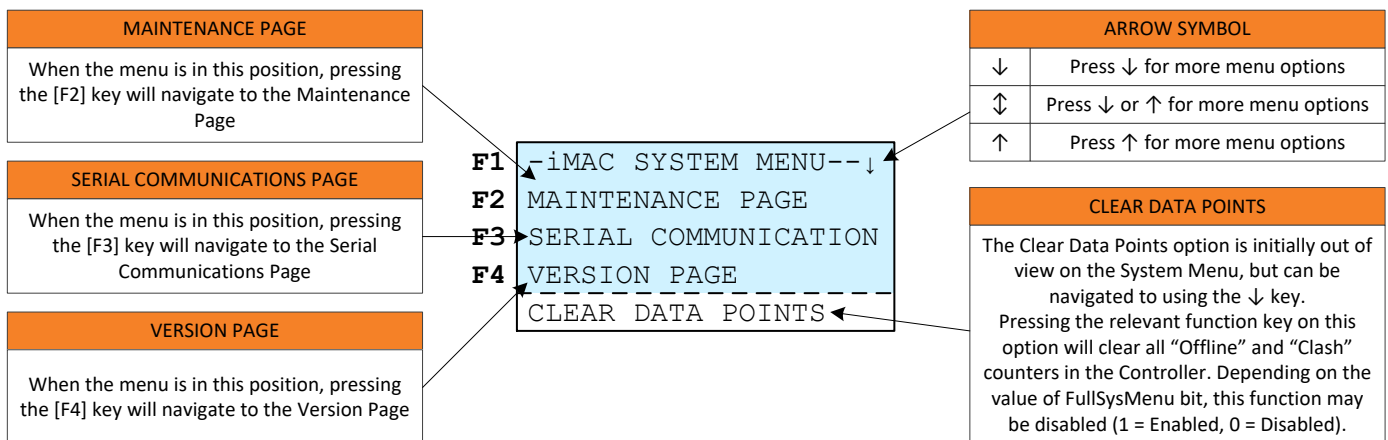


Figure 10.4: iMAC System Menu –Home Page

10.2.1 Maintenance Page

From the System Menu, press [F2] to navigate to the Maintenance page:

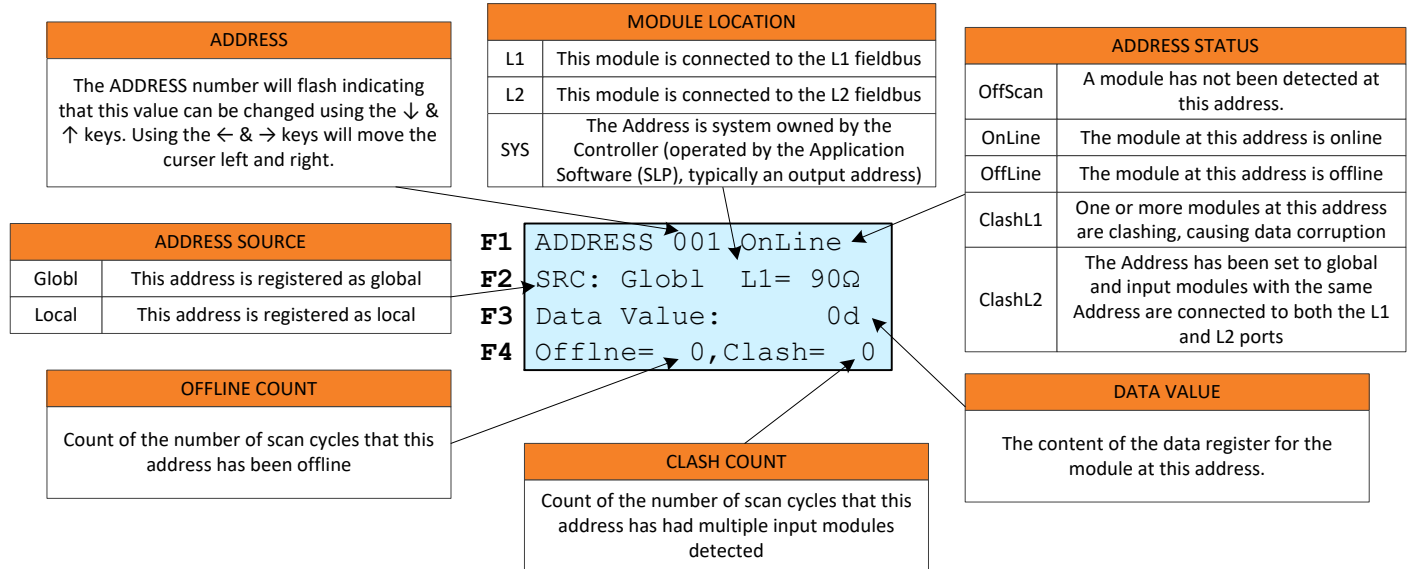


Figure 10.5: iMAC System Menu (Maintenance Page)

[F1] First Line

The Maintenance Page provides the user with a means of interrogating individual addresses on the fieldbus. The cursor flashes on the Address parameter, indicating that the user can change the interrogated address using the arrow keys.

Each Address can be classified as OffScan, OnLine, OffLine, ClashL1 or ClashL2. Refer to Figure 10.5 for descriptions of these classifications.

Pressing the [F1] key within the Maintenance Page will clear the OnScan bit, thus forcing the interrogated Address OffScan. An Address that is set to OffScan will not report an Offline flag when it is removed from the fieldbus. This can be used to remove a module from the fieldbus without causing an offline trip on the system. An address that is set to OffScan will automatically reset to OnLine when a module is detected at this address again.

[F2] Second Line

The second line of the Maintenance Page provides information about the installation location of the interrogated Address. Information includes whether the Address is a global or local address, whether the module is being detected on the L1 or L2 fieldbus, and the value of the fieldbus loop resistance to the installed module on the L1 fieldbus (note that resistance will appear as 0Ω if the address is System Owned or is detected on the L2 fieldbus).

[F3] Third Line

The third line contains the value that is stored in the data register of the module that is registered to the interrogated Address. It is possible to change the way that the value within the data register is displayed by pressing the [F3] key. Possible display options are decimal (d), binary (b), hexadecimal (x) & octal (o).

[F4] Fourth Line

The Offline and Clash counters are incremental counters that provide an indication of the number of times that the interrogated Address has registered as offline or as having an address clash during a fieldbus scan. The counters range from 0 to 255 and wrap back around to zero once 255 is reached. Pressing the [F4] function key while on the Maintenance Page will reset these counters, depending on the value of MinSysMenu bit, this function may be disabled (1 = Enabled, 0 = Disabled).

10.2.2 Serial Communications Page

From the System Menu, press [F3] to navigate to the Serial Communications page:

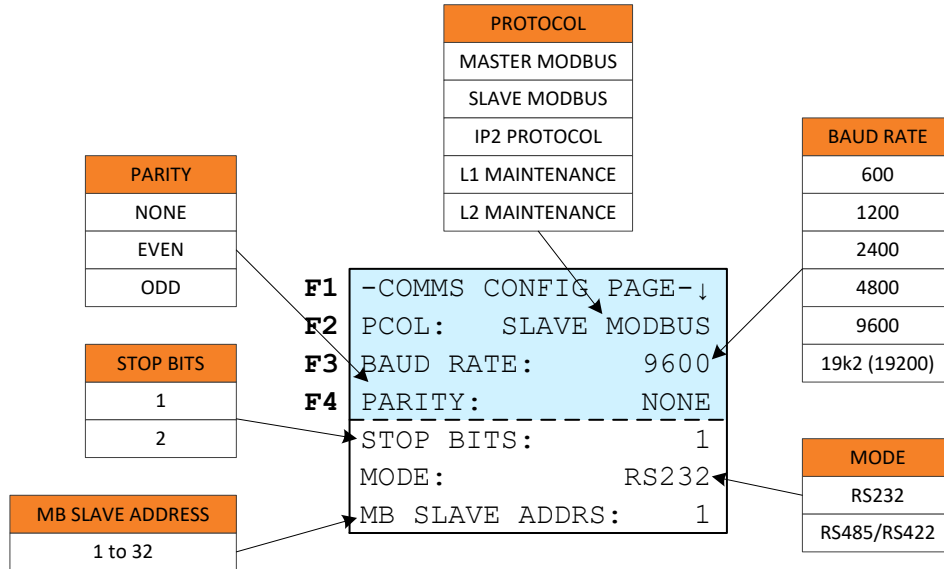


Figure 10.6: iMAC System Menu (Serial Communications Page)

Pressing the corresponding function key allows settings to be adjusted using the [UP] and [DOWN] keys. To save changes, press [ENTER] or the corresponding function key. To cancel changes, press the [ESC] key.

10.2.3 Version Page

From the System Menu, press [F4] to navigate to the Version page:

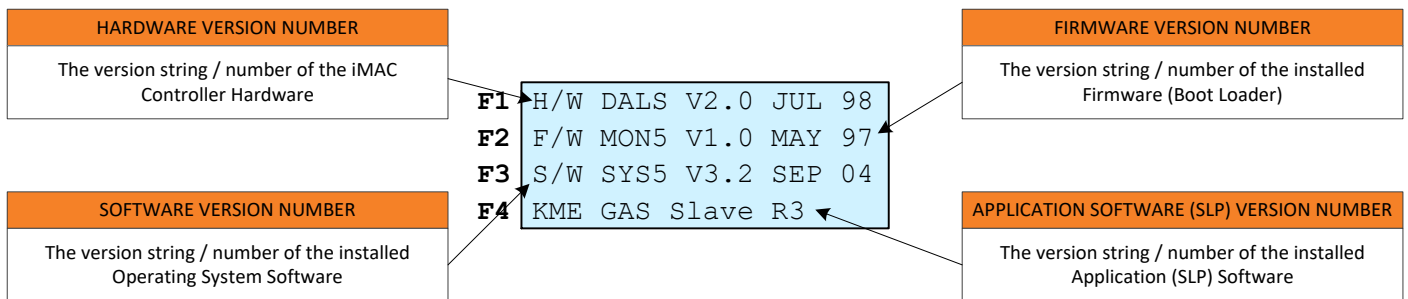


Figure 10.7: iMAC System Menu (Version Page)

10.3 iMAC2 Controller LEDs

The iMAC2 Controller has four LEDs. There are two green LEDs (L1/L2) that are user programmable and two red LEDs (COMMS IN/OUT) that are used to display serial communication activity.

10.3.1 User Programmable LEDs

The L1 and L2 LEDs are green in colour and their operation is determined by the application (SLP) software. The application software can turn the LEDs on, off, fast flash or slow flash under any logical combination of I/O data e.g. L1 open or short circuit, EOL fault or L2 Active etc.

The typical L1 and L2 LED operation is L1 on with CR and L2 on with AR, while a fast flash usually indicates the L1 fieldbus is short circuited.

10.3.2 Communications LEDs

The COMMS IN and OUT LEDs are red in colour and indicate that the Controller is receiving and transmitting serial communications data. The corresponding LEDs flash whenever serial data is being transmitted or received.

10.4 Selectors & DIP Switches

The iMAC2 Controller has a 16 position rotary selector switch and a set of 4 DIP switches accessible from the side wall of the enclosure. These can be used as inputs into the application (SLP) software to perform user defined functions. A typical function of the rotary switch is to set the network address for the iMAC2 Controller when it is installed in an iMAC network. The DIP switches can be used to activate certain functions in the application software, such as changing the iMAC fieldbus communications line speed.

11 SERVICE, MAINTENANCE & DISPOSAL

11.1 Equipment Service

The iMAC2 Controller and iMAC Modules do not require internal servicing during their normal operating life. A number of external system based checks should however be completed on a regular basis. These 'routine inspections' must be carried out by suitably trained technicians. Routine inspections may take the form of either visual-only checks, or visual and 'hands-on' checks.

11.1.1 Visual Only Inspections

A basic visual inspection focuses on looking at the system installation for signs of physical damage, water or dust ingress and the condition of cables and labels. This type of inspection may involve opening cabinets to gain access to the iMAC2 Controller, iMAC Modules and other equipment. This level of inspection may also include cleaning display windows that have become obscured by dust/debris.

Observations would typically be:

- Check that equipment enclosures, cable trays, conduits, etc. are in good order with no physical damage.
- Check that sealed wall boxes are free from water and dust ingress internally. Door seals are in good condition.
- Check that connected cables are free from cuts, abrasions and obvious signs of damage. Cable restraints are in good order and correctly fitted.
- Check that labels on equipment, wall boxes and cables are present and in good condition (especially certification labels).
- Check that no modifications have been carried out to installed equipment.


11.1.2 Hands-On (Detailed) Inspections

A more detailed inspection would include all of the elements of a visual inspection, with additional checks that cover the integrity of connections, fixtures, fittings, configuration and operation.


In addition to basic visual observations, more detailed integrity checks would typically be:

- Verify equipment housings, wall boxes and other mechanical fixtures are secured in place. This includes terminal box lids, tightness of cable glands, integrity of wall-box mountings, security of equipment fixing to walls/DIN rails etc.
- Verify all electrical connections are secure with no loose screw terminals or DIN rail terminals not fitted to rails etc.
- Verify iMAC2 Controller has correct application (SLP) software and is correctly configured.
- Verify iMAC Modules are correctly addressed and programmed with correct parameters.
- Proof test safety functions
- Verify operation of Pullkey devices
- Verify operation of Lockout devices
- Verify belt sequencing devices
- Verify belt tracking devices (belt wander, belt tear)
- Verify blocked chute devices

11.2 Equipment Maintenance

WARNING!	iMAC2 Controllers and Modules have no user-serviceable parts . All repairs must be carried out by an authorised Ampcontrol service department/agency only .
	If a fault develops, return the equipment to an authorised Ampcontrol service department/agency for repair. It is essential that no attempt be made to repair the equipment as any attempt to dismantle or repair the equipment will void the warranty and certification of the unit or system .

11.3 Disposal

ENVIRO	The electronic equipment discussed in this manual must not be treated as general waste . By ensuring that this product is disposed of correctly you will be helping to prevent potentially negative consequences for the environment which could otherwise be caused by incorrect waste handling of this product.
	

12 iMAC2 CONTROLLER SPECIFICATIONS

Supply Voltage (+, - & E Terminals)	
<i>Voltage</i>	24VDC ($\pm 20\%$)
<i>Power Consumption</i>	< 15VA
<i>Inrush Current</i>	2.6A for 175ms
<i>Operating Temperature</i>	0 to +60°C
<i>Storage Temperature</i>	-20 to +80°C

L1 Fieldbus (L1+, L1- Terminals)	
<i>Surge Protection</i>	90V Lightning Arrestor
<i>Maximum Series Resistance to EOL</i>	800Ω
<i>Minimum Shunt (Insulation) Resistance</i>	1000Ω
<i>Minimum Baud Rate</i>	300
<i>Maximum Baud Rate</i>	1000 (dependant on cable type/length and module quantity/type/distribution)

L2 Fieldbus (L2+, L2- Terminals)	
<i>Optically Isolated</i>	10kV _{rms}
<i>Minimum Baud Rate</i>	300
<i>Maximum Baud Rate</i>	1000

Switches & Selectors		
Type	Location	Function
<i>16 Position Selector</i>	Access via right side of enclosure	Application software (SLP) dependent
<i>4x DIP Switches</i>	Access via right side of enclosure	Application software (SLP) dependent
<i>Ethernet Reset Switch</i>	Access via left side of enclosure	Reset IP settings to defaults

General Purpose Inputs (SW1+ & SW1-, SW2+ & SW2-, SW3+ & SW3- Terminals)	
<i>Quantity</i>	3 (Self Wetting)
<i>Self-Wetting Voltage</i>	12V (Nominal)
<i>Self-Wetting Current</i>	10mA (Nominal)
<i>Wiring</i>	Twisted pair, <20m (per input)
<i>Function</i>	Application software (SLP) dependant
<i>Optically Isolated</i>	1kV

Output Relay Contacts (CR, AR Terminals)	
<i>Contacts</i>	1 x NO Control Relay (CR) Contact 1 x NO Auxiliary Relay (AR) Contact
<i>Ratings (Resistive)</i>	10A, 250VAC, 30VDC (min 10mA, 5VDC)

Serial Communications (COMMON, Rx/T-, Tx/T+, CTS/R-, RTS/R+ Terminals)	
<i>Available Interfaces</i>	RS232 / RS422-RS485 (Selectable)
<i>Supported Protocols</i>	Modbus RTU Slave Protocol Ampcontrol IP2 Protocol Ampcontrol L1 Maintenance Protocol Ampcontrol L2 Maintenance Protocol
<i>Baud Rate</i>	2400, 4800, 9600
<i>Optically Isolated</i>	2.5kV

Ethernet TCP/IP Port	
<i>Available Interfaces</i>	RJ45 10/100Mbps Auto Negotiation
<i>Applicable Standards</i>	IEEE 802.3u, IEEE 802.3x
<i>Cable Requirements</i>	10BASE-T: UTP category 3, 4, 5 cable (maximum 100m) 100BASE-TX: UTP category 5, 5e cable (maximum 100m)
<i>Supported Protocols</i>	MODBUS TCP/IP (Port 502) NTP (for time synchronisation) Webserver (for configuration, data viewing and diagnostic functions)
<i>Maximum Request Rate</i>	100ms
<i>Recommended Response Timeout</i>	100ms
<i>Maximum Concurrent Web Connections</i>	The iMAC2 Controller allows four users to access the web server simultaneously

Real Time Clock	
<i>I.S. Battery</i>	3V Lithium
<i>Certification</i>	IECEX TSA 11.0064X
<i>Battery Life Expectancy</i>	10 years (typical)
<i>Accuracy</i>	±3 mins per year (typical)

Mechanical	
<i>Dimensions (mm) (see Figure 8.1)</i>	Overall 155H x 155W x 155D with connector plugs (x 140D excluding connector plugs) Panel Mount Cut Out 135H x 135W
<i>Weight</i>	1.8 kg
<i>IP Rating</i>	IP55 (when correctly panel mounted using supplied gasket)

13 EQUIPMENT LIST

13.1 iMAC2 Controllers & Accessories

13.1.1 iMAC2 Controllers

The iMAC2 Controller is available in two different models: Standard Controllers and Long Controllers. Standard Controllers use an 18V fieldbus voltage and are recommended for all systems less than 7km in overall length. Long Controllers use a 21V fieldbus voltage and are recommended for systems larger than 7km.

CAUTION!



Long Controllers are not compatible with intrinsically safe installations as the higher fieldbus voltage will blow the protection fuses of the iMAC MLB I.S. barrier.

Part Number	Description	Certification
171571	iMAC2 Controller (Standard) 24VDC	N/A
173552	iMAC2 Controller (Long) 24VDC	N/A

13.1.2 Accessories

Part Number	Description	Certification
171010	Replacement Mounting Clip (1 Only) (Suitable for iMAC2 Controllers and iMAC Remote Keypads)	N/A

13.2 Intrinsically Safe Barriers

iMAC Intrinsically Safe barriers are required to segregate non-IS components from the fieldbus.

Part Number	Description	Certification
121923	iMAC Master Line Barrier (MLB) Module (IS)	IECEX
100333	iMAC Slave Line Barrier (SLB) Module (IS) 110VAC Model	IECEX
100347	iMAC Slave Line Barrier (SLB) Module (IS) 240VAC Model	IECEX

13.3 Intrinsically Safe Remote Keypads

The iMAC Remote Keypad is an intrinsically safe keypad that can be installed in the hazardous area to remotely control an iMAC2 Controller which must be installed in a flameproof enclosure.

Part Number	Description	Certification
142084	iMAC Remote Keypad (IRK) (IS)	IECEX

13.4 Digital Input Modules

The iMAC System has a number of digital input modules available, including IS and non-IS modules.

Part Number	Description	Certification
121892	iMAC DI4 Module (4 x Digital Inputs) (IS) (Fieldbus Powered) (c/w LED)	IECEX
121894	iMAC DI4 Module (4 x Digital Inputs) (IS) (Fieldbus Powered)	IECEX
120942	iMAC DI8 Module (8 x Digital Inputs) Rotary Address, Plugged Type (Fieldbus Powered)	N/A
101495	iMAC DI8 Module (8 x Digital Inputs) Rotary Address, Terminal Type (Fieldbus Powered)	N/A
121891	iMAC IIM Module (5 x Digital Inputs & 4 x LED Outputs) (IS) (Fieldbus Powered)	IECEX

13.5 Analogue Input Modules

The iMAC System has a number of analogue input modules available for voltage, current or temperature inputs.

Part Number	Description	Certification
121881	iMAC AIM Module 0-10V Analogue Input (1 Analogue Input) (IS)	IECEX
121882	iMAC AIM Module 4-20mA Analogue Input (1 Analogue Input) (IS)	IECEX
121889	iMAC RTD1 Module (IS) (Fieldbus Powered) (c/w External LED) RTD PT100 Temperature Sensor	IECEX
121890	iMAC RTD1 Module (IS) (Fieldbus Powered) RTD PT100 Temperature Sensor	IECEX

13.6 Output Modules

The iMAC System has a number of output modules for both general and specialised use.

Part Number	Description	Certification
101498	iMAC RO4 V2 Module (4 x Relay Outputs)	N/A
115150	iMAC ARM Module (1 x Relay Output) (IS) 110VAC Model Mimics iMAC2 Controller AR Status*	IECEEx
144327	iMAC ARM Module (1 x Relay Output) (IS) 240VAC Model Mimics iMAC2 Controller AR Status*	IECEEx
115149	iMAC ARM Module (1 x Relay Output) (IS) 24VDC Model Mimics iMAC2 Controller AR Status*	IECEEx
115152	iMAC CRM Module (1 x Relay Output) (IS) 110VAC Model Mimics iMAC2 Controller CR Status*	IECEEx
144326	iMAC CRM Module (1 x Relay Output) (IS) 240VAC Model Mimics iMAC2 Controller CR Status*	IECEEx
115151	iMAC CRM Module (1 x Relay Output) (IS) 24VDC Model Mimics iMAC2 Controller CR Status*	IECEEx
115156	iMAC GRM Module (1 x Relay Output) (IS) 110VAC Model General Relay Module Controlled by iMAC2 Controller	IECEEx
115146	iMAC GRM Module (1 x Relay Output) (IS) 240VAC Model General Relay Module Controlled by iMAC2 Controller	IECEEx
115155	iMAC GRM Module (1 x Relay Output) (IS) 24VDC Model General Relay Module Controlled by iMAC2 Controller	IECEEx
115153	iMAC EMM Module (1 x Relay Output) (IS) 110VAC Model End of Line Monitoring Module, Output Closed if Healthy	IECEEx
115154	iMAC EMM Module (1 x Relay Output) (IS) 240VAC Model End of Line Monitoring Module, Output Closed if Healthy	IECEEx
144325	iMAC EMM Module (1 x Relay Output) (IS) 24VDC Model End of Line Monitoring Module, Output Closed if Healthy	IECEEx
115160	iMAC SQM Module (1 x Relay Output) (IS) 110VAC Model Sequencing Module	IECEEx
115158	iMAC SQM Module (1 x Relay Output) (IS) 240VAC Model Sequencing Module	IECEEx
115157	iMAC SQM Module (1 x Relay Output) (IS) 24VDC Model Sequencing Module	IECEEx
140213	iMAC LED4 Module (4 x LED Indication Outputs) (IS) (Fieldbus Powered)	IECEEx
178890	iMAC LIM Modules (7 x Selectable LED Profiles) (IS) (Fieldbus Powered)	IECEEx

*Requires specific application (SLP) software for operation

13.7 Serial Interface Modules

The iMAC system has a number of Serial Interface Modules available for allowing iMAC fieldbus connection to Modbus slave devices.

Part Number	Description	Certification
121915	iMAC SIM-G Module (IS) Allows connection to a single Ampcontrol GasGuard Controller	IECEX
121916	iMAC SIM-G2 Module (IS) Allows connection to two Ampcontrol GasGuard Controllers	IECEX
143646	iMAC SIM-P Module (IS) Allows connection to a generic Modbus RTU Slave Device	IECEX
121917	iMAC SIM-T Module (IS) Allows connection to a single Trolex™ 9042 Controller	IECEX

13.8 Specialty Modules

The iMAC Speed Switch module allows monitoring for conveyor belt speed, belt slip and belt sequencing.

Part Number	Description	Certification
121910	iMAC SSW Module (IS) (Fieldbus Powered) Speed Switch Module for Conveyors	IECEX

13.9 Protection Modules

The iMAC system has lightning protection modules available.

Part Number	Description	Certification
118911	iMAC LPU2 Module Lightning Protection for a 2-Wire Module (e.g. DI4)	N/A
142326	iMAC LPU3 Module Lightning Protection for a 3-Wire Module (e.g. IIM)	N/A



13.10 EOL and MEOL Modules

iMAC End-of-Line modules form a key part of the safety feature of the iMAC System. In order for the iMAC2 Controller Control Relay (CR) to be energised, the Controller must be successfully communicating with the End-of-Line module.

There are two types of End-of-Line modules, the End-of-Line (EOL) module and the Monitoring-End-of-Line (MEOL) module. In 2-Wire systems, only the EOL module is required, 3-Wire systems require both an EOL and a MEOL to be installed and communication to be healthy before the Control Relay (CR) can be energised.

Part Number	Description	Certification
121905	iMAC EOL Module (IS) (Fieldbus Powered)	IECEX
118702	iMAC EOL Module (Non-IS) (Fieldbus Powered)	N/A
121908	iMAC MEOL Module (IS) (Fieldbus Powered)	IECEX

APPROVED FOR EXTERNAL DISTRIBUTION – PROPERTY OF AMPCONTROL PTY LTD – NOT TO BE REPRODUCED IN PART