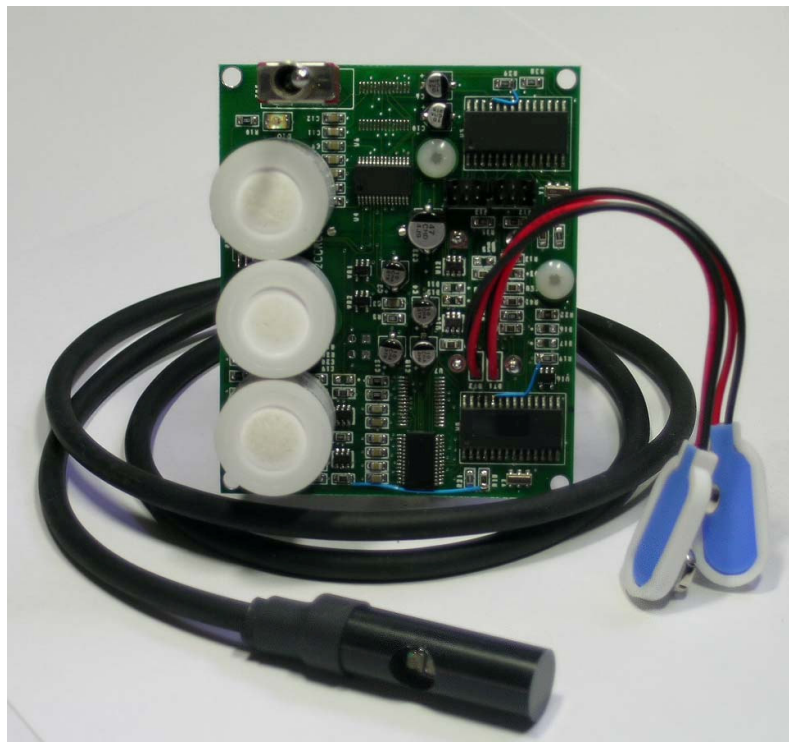




Features of the LRI Land Based ECCR Controller



LBC³

Land Based Closed Circuit Controller

Overview

This document presents the features and advantages of the LRI Land Based Rebreather Controller (LBC³). Our controller is specifically designed to assure continued operation in the event of electronic failures or system degradation and represents an extremely high level of commitment towards reliability and simplicity of operation.

Superior reliability is achieved through a combination of a safety first oriented design, reduction of failure points, functional redundancy and attention to the smallest operational detail as expressed through superior programming. In addition, such features as automatic diagnostics and an extremely simple user interface enables minimally trained or highly task loaded operators to operate an Electronic Closed Circuit Rebreather (ECCR) with safety and confidence.

Included for reference is the block diagram of the ECCR controller, shown in Figure 1.

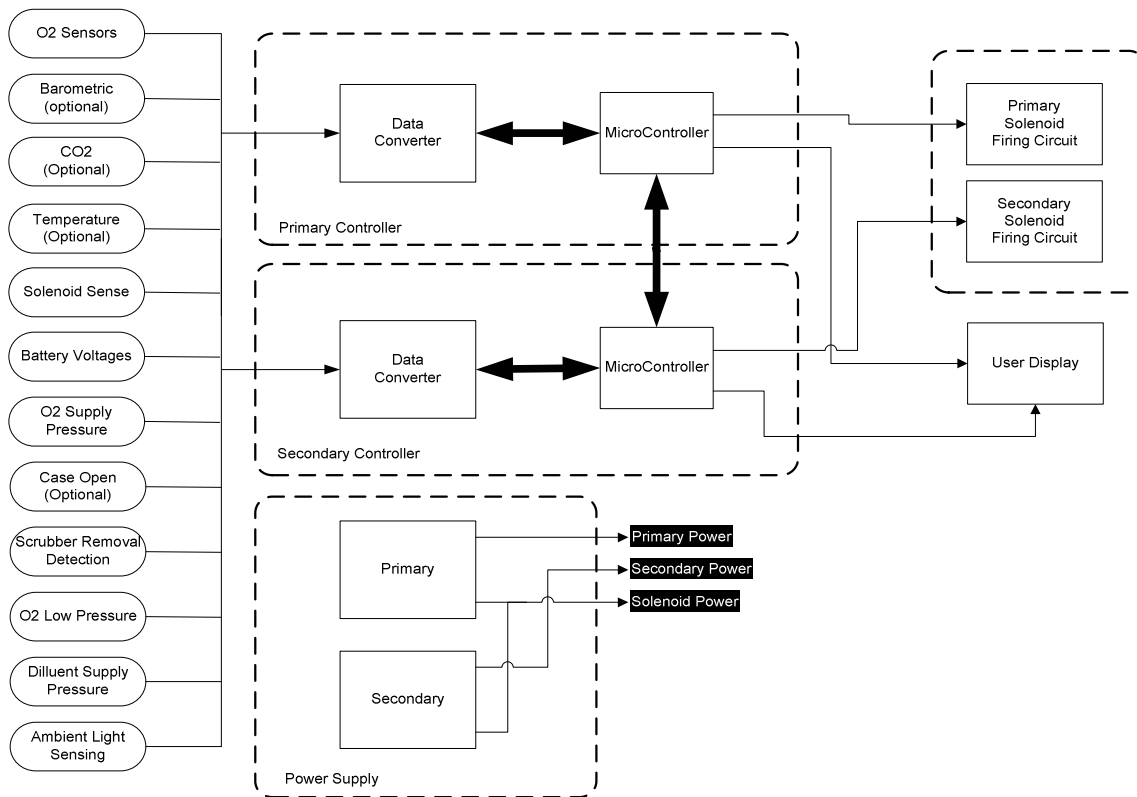


Figure 1 - Block Diagram of LPO₂CCRC



Hardware Features

- **Complete Integrated Design**

All of the electronics, excluding the user display, is located on one PCB and within one module. All gas porting is conducted within the module. All sensors, where practical, are located within the module.

This approach minimizes wiring and maximizes reliability through a number of factors including the significant reduction of single points of failure.

- **Redundancy**

It can be seen that the controller is completely redundant in every aspect. This level of system redundancy is imperative to assure mission completion in the event of hardware failures. The Primary processor, solenoid firing circuit, display, and power supply are all shadowed by the secondary backup systems.

In the event of controller failures, whether electronic or programmatic, the design of the system is such that it will failover to the shadow subsystem seamlessly and without the need for user interaction or even awareness that this has occurred. The failsafe design, redundant hardware and software enables continued use of the controller for the expected duration of the mission operation regardless of single failures and a significant number of multiple failures. In the event of multiple severe failures, the controller will continue to attempt to provide life support – however, the users expected operational time may be shorted. The user will be notified of the new shortened time via the User interface.

- **Battery Operation**

Off-the-shelf 9v alkaline batteries provide the controller with a sleep duration for the shelf life of the batteries and a runtime exceeding 100 hours.

- **Automatic On/Off**

The controller turns on automatically when the Oxygen supply is turned on and turns off when the system is no longer in use. No user operated controls are necessary to engage/disengage life support. These features will be described further in the Software Features section.



Software Features

- **Hardware Monitoring**

- *Primary and secondary processor function*

Each controller is actively monitored. Primary processor failure causes the secondary to assume control. Should the secondary processor be unavailable, the primary processor has a hard coded RAM independent program to inject 5 liters of Oxygen per minute. Secondary processor failure that occurs during the Operations Mode does not impact the normal use. Failures in either processor are reported during the automatic diagnosis which occurs during scrubber changes and prior to any use. Any pre-existing system failure will prevent the controller from entering the Operational mode and the user indication during Diagnostics will be a simple “replace module” alarm. The controller is prevented from being used while the “replace module” alarm is active.

- *Primary and secondary power supply function*

Each power supply is actively monitored and qualified. If there is not enough power to assure complete run time based on scrubber duration, the user is informed during startup. During Operational mode, if the primary power falls too low or fails, the controller seamlessly switches to the secondary power source. Since no user involvement is required in the subsystem switch and no functionality is lost, no failure status information is needed or displayed while in Operations Mode.. Power supply failures are detected during Diagnostics Mode and indicated with a “Replace Battery” alarm. The controller cannot enter Operations mode until the error condition is cleared.

- *Data acquisition circuitry function*

Each processor monitors its data acquisition subsystem. During operational mode, if the primary subsystem should fail, the processor will seamlessly fail over to the secondary processor and its data acquisition subsystem. Since no user involvement is required in the subsystem switch and no functionality is lost, no failure status information is needed or displayed during Operations Mode. Data acquisition failures are detected during Diagnostics Mode and indicated with a “Replace Module” alarm. The controller is prevented from being used while the “replace module” alarm is active.

- *Solenoid function*

Solenoid firing is monitored for failure. Upon failure, the secondary circuits are seamlessly switched to. Since no user involvement is required in the subsystem switch and no functionality is lost, no failure



status information is needed or displayed during Operations Mode. If the failure occurs while on the secondary processor during operations, the user is alerted to a “Very Short Time” condition which will then change to “Bailout” based on Oxygen levels. Solenoid failure is detected during Diagnostics Mode and indicated with a “replace module” alarm. The controller is prevented from being used while the “replace module” alarm is active.

- *User interface function*

The controller only uses a single LED for the user interface and has a backup redundant LED available for real-time failure replacement.

- **Software Monitoring**

- *Memory Errors*

Due to the internal design of the controller software, the system can tolerate and correct most data errors. Should the processor experience a high level of errors during operational mode, the processor is failed and control is reverted to the shadow processor. Diagnostic mode will display “replace module” alarm if memory errors have occurred.

- *Program Errors*

Program failure causes the processor to stop operating, or operate unpredictably. This in turn, causes the processor to fail and the secondary processor will assert control. Should this happen to the secondary processor while the primary is in operational mode, the controller is still functional and the user is not notified until Diagnostic mode. Both processors are also protected with failsafe devices to automatically restart the processor in the event of major malfunction.

- *Calibration Data Protection*

The controller periodically validates the calibration data. If the data is not valid, the system will first attempt to retrieve the data from permanent memory. If the failure persists, the controller will fail over to the secondary processor which will take over operations with a redundant set of calibration data. Both processors also have the ability to fall back to generic factory default values which will sustain life support – although it will be a less accurate Oxygen set-point. As with all other controller failures, no one failure will affect the operational capability of the rebreather.

Set-Point maintenance is only affected in the event of multiple failures. Intelligent diagnosis enables the controller to assess such multiple failures in terms of a simple change of remaining operational duration as indicated to the user.



The controller is further protected from calibration data loss, by re-calibrating at every scrubber change. Attitude is compensated for during calibration. If calibration is unable to be achieved during diagnostic mode, the display indicates “Replace Module”, “Replace Sensors”, or “Stabilize Environment” depending on the situation diagnosis.

- *Continuous Performance Sampling*

The controller continuously samples and stores an 8 hour historical log of system parameter data. The stored data is able to be recalled for performance monitoring or failure assessment.

- **Intelligent Oxygen Sensor Assessment**

The level of Oxygen in the breathing loop is measured by three Oxygen sensors and interpreted by the controller’s processors. Evaluating these sensors for the actual level of Oxygen is of paramount importance. In our methodology, the controller assesses the reported Oxygen level from three perspectives; Solenoid firing, User display, and Alarm functions. For each of these perspectives the system determines how to assess the information the sensors are delivering and what must be acted upon as each of these perspectives have their own rules. Using this method of sensor analysis, the controller achieves a significant capability increase in both maintaining a given Oxygen set-point and responding to sensor deviations or failures.

- **Self Calibrating**

The controller must accurately maintain a specific Oxygen percentage in the breathing circuit. The precision of the system is dependant upon maintaining the calibration of the Oxygen sensors. These sensors drift over time and therefore the controller must be periodically re-calibrated. The Laguna Research LBC³ achieves this by automatically performing a complete calibration each time the scrubber is changed. Altitude variation is compensated automatically as well.

- **Simplified User Interface**

All information and conditions are translated into a “duration based” display to the user. This allows the rebreather to be operated with only a simple time indication to the user and is the key to the usability of this controller. The “duration translation” represents a unique and dramatic decrease in the user workload associated with failure management in a closed circuit rebreather by eliminating the confusion of trying to interpret lower level information such as individual sensor or environmental readings.

Controller errors are also translated into “duration remaining” information. However, due to the system redundancy, all but multiple significant failures are handled automatically and seamlessly enabling the system to continue to support life. This approach requires no notification to the user nor do is there any effect on operations or duration . In the rare event of multiple significant failures, the



effects of the failures are accessed in terms of the amount of time the system can still support life. The only information the user is then required to process is simply a change in the “duration remaining” indication.

The following levels of duration are used in the Laguna Research LBC3 controller.

- **“Long Time Remaining”** All systems are functioning normal, use the device according to specified operational duration – typically scrubber time limited.
- **“Short Time Remaining”** Normally considered to be the time at which the user should start planning and executing a normal exit from the operation. This is considered to be either 20% of total operational time or 10 to 20 minutes absolute depending on requirements specified by the customer/field of use.
- **“Very Short Time Remaining”** This is typically a 5 minute warning used to indicate that system failure is eminent. Evacuation must proceed immediately and if necessary, preparations must be made to use the open circuit bailout system.
- **“Bailout”** In most cases, the system will in fact still be attempting to maintain some level of breathable gas but the controller can no longer guarantee that it is sufficient to maintain life support. The user must, if at all possible, cease using the unit and use other means for life support. Bailout condition, other than for a scrubber timeout, is only indicated as the Oxygen level actually drops or if there are sufficient measurement failures such that the Oxygen levels can no longer be reliably measured.

- **Intelligent On/Off**

The controller will startup upon detection of the presence of Oxygen pressure or scrubber removal/insertion. The current status of the system is assessed and the controller will enter either the Operational Run state (scrubber inserted) or the Diagnostic state (scrubber removed). In either mode, Oxygen levels are continuously assessed and maintained. This is a failsafe design that will ensure a proper breathing gas at all times. Automatic shutdown is initiated either by removing the scrubber from the system, or after a period of 10 minutes of non-use in which no Oxygen consumption is detected. As a failsafe feature, turning off the Oxygen supply does NOT turn off the controller.

- **Automatic Diagnostic Mode**

Diagnostic mode is entered into automatically when the scrubber is either removed or replaced in the system. Additionally, this mode is also entered if the system is started without the scrubber installed.

It is in this mode that the controller is fully qualified itself BEFORE use. All failures are categorized into three action alarms:

- Replace Sensors



- Replace Batteries
- Replace Module

Further, complete Oxygen sensor calibration is performed and qualified during this mode.

- **Automatic Operational Mode**

The system will automatically enter the Operational (run) mode when the Oxygen supply is turned on AND the scrubber is installed. Both conditions must be met in order to enter this state. This is the normal life support mode.