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MICHELL INSTRUMENTS UK LTD

XTP601 PROCESS OXYGEN ANALYSER
&
XTC601 BINARY GAS ANALYSER

IEC 61511 PRIOR USE ASSESSMENT

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CHANGE HISTORY

Revision	Date of Issue	No. of Pages	Reasons for Change
1	02/10/2019	98	Initial issue.
2	07/02/2020	99	Updated to close out systematic capability actions.
3	28/07/2020	100	Reference to Test Summary reports ([35] & [36]) and User Manuals ([37] & [38]) added based upon stricter access controls implemented for the XTP601 and XTC601.
4	09/08/2022	83	Updates to report: • Change of value for IC20 within XTC601 FMEA (refer to Appendix A); • Addition of resistor R113 across C77 within XTC601 FMEA (refer to Appendix A); • Update to Warranty Return Assessment (refer to Section 8); • Update to Prior Use Assessment to amend document revisions (refer to Section 9).

CONTENTS

1 EXECUTIVE SUMMARY

1.1 General

This report provides a Prior Use Assessment of the Michell Instruments UK Ltd, XTP601 Process Oxygen Analyser and XTC601 Binary Gas Analyser, as defined in the Prior Use requirements in IEC 61511 (2nd Edition) Clause 11.5.3 and 11.5.4 [2] including an estimation of Probability of Failure on Demand (PFD), Safe Failure Fraction (SFF) and a review of the systematic capability as supporting evidence for avoidance and minimisation of systematic failures.

A Failure Mode Effects and Diagnostics Analysis (FMEDA) was conducted on the XTP601 and XTC601 to estimate the random hardware failure rate in order to assess suitability for use in a safety function with regards to the PFD and the architectural requirements in terms of Hardware Fault Tolerance (HFT) and SFF, using the approach detailed in Route 1_H in IEC 61508-2 [1].

IMPORTANT: It should be noted that this assessment does not include confirmation of the response time of the device. For response times (along with any relevant assumptions) reference should be made to the Safety Manual of each device and the total SIF response time **MUST** be compared against the process safety time for the specific application.

1.2 Hardware Reliability Verification

These devices will form part of the sensor element sub-system of a Safety Instrumented Function (SIF) and thus an assessment was conducted to demonstrate its capabilities in terms of PFD. The remaining sensing, logic solver and final element sub-systems were excluded from the assessment, in order to allow for their PFD contributions, the devices were assessed against 20% of Safety Integrity Level (SIL) 2 PFD band (e.g. SIL 2 band modified to 2.0E-03).

Results have been calculated for Proof Test Coverages (PTCs) of both 95% (testing capable of revealing 95% of undetected failures) and 90%, a Proof Test Interval (PTI) of 1 year (8,760 hours). The Mission Time before the analysers undergo a complete overhaul is assumed to be 10 years, with a Mean Time to Restoration (MTTR) of 168 hours.

The XTP601 Process Oxygen Analyser was assessed against the following safety function:

- Ability to detect oxygen presence within another gas stream and generate a 4-20mA output.

The XTC601 Binary Gas Analyser was assessed against the following safety function:

- Ability to detect target gas[1] in another gas stream and generate a 4-20mA output.

The full set of results for the hardware reliability verification are presented in Appendix A and the Reliability Block Diagrams (RBDs) are presented in Appendix B. Table 1 below shows a summary of the results of the XTP601 and XTC601 based on the data provided and the assumptions given in this report.

Table 1. Hardware Reliability Verification

Device	Proof Test Coverage (PTC)	PFD Target (20% of SIL 2 band)	PFD Achieved	Estimated Achieved PFD	SFF	Type	Estimated Achieved SIL (Arch)	Estimated Overall SIL Capability
XTP601	95%	2.0E-03	4.1E-04	2	94%	B	2	2
	90%		5.1E-04	2			2	2
XTC601	95%	2.0E-03	3.1E-04	2	96%	B	2	2
	90%		3.8E-04	2			2	2

It must be noted that the above assessment only covers the PFD capability of the XTP601 and XTC601. A full assessment covering the proof test and repair strategy and PFD contribution of other sub-systems must be carried out to justify any SIF PFD and SIL capability claim.

[1] Target gas is defined as the gas being targeted by the detector from the available detection spectrum.

1.3 Prior Use Assessment

1.3.1 Warranty Return Assessment

The results of the warranty return assessment are shown in Table 2. The results of the Prior Use assessment can be found in Section 8.

Table 2. XTP601 and XTC601 Warranty Return Results

Device	Random Hardware Dangerous λ (/hr) FMEDA	Warranty Return (Systematic + Random Hardware Failures) λ (/hr) Prior Use Assessment
XTP601	7.9E-07	3.9E-07
XTC601	7.4E-07	4.1E-07

Table 2 shows that the warranty return data broadly agrees with the FMEDA estimated failure rate.

1.3.2 Prior Use Systematic Capability Review

The results of the Systematic Capability Review can be found in Section 9.

1.4 Conclusion

The results of the assessment illustrate that based on the information provided and the stated assumptions, both units meet the requirements of the hardware capability assessment (i.e. random hardware failure and SFF) and systematic capability requirements in order to be deemed suitable for use in safety applications with a SIL 2 requirement:

The following conclusions apply:

- Hardware Capability:
  - XTP601 **meets** the random hardware reliability requirements and architectural constraints for use in a SIL 2 SIF in a simplex (i.e. HFT = 0) configuration with a PTC of 95% or 90% and a PTI of 1 year;
  - XTC601 **meets** the random hardware reliability requirements and architectural constraints for use in a SIL 2 SIF in a simplex (i.e. HFT = 0) configuration with a PTC of 95% or 90% and a PTI of 1 year;
- Systematic Capability:
  - The reviewed operational data (i.e. warranty return data) agrees with the estimated failure rate for both units;
  - The reviewed evidence for compliance with Prior Use requirements as defined in IEC 61511 [2] adequately demonstrates the necessary systematic capability.

2 RELATED DOCUMENTS

[1] IEC 61508, Functional Safety of Electrical/ Electronic/ Programmable Electronic Safety Related Systems, 2010 Edition.

[2] IEC 61511, Functional Safety of Safety Instrumented Systems for the Process Industry Sector, 2016 Edition.

[3] Michell Instruments, XTP601 Control PCB Alarm Relays / Cell Temp, Drawing Number: 80895C, Sheet 1 of 6, Issue: 06, Date: 24/03/2015.

[4] Michell Instruments, XTP601 Control PCB 4-20mA Analog Inputs, Drawing Number: 80895C, Sheet 2 of 6, Issue: 06, Date: 24/03/2015.

[5] Michell Instruments, XTP601 Control PCB 4-20mA Analog Outputs, Drawing Number: 80895C, Sheet 3 of 6, Issue: 06, Date: 24/03/2015.

[6] Michell Instruments, XTP601 Control PCB Microcontroller Circuit, Drawing Number: 80895C, Sheet 4 of 6, Issue: 06, Date: 24/03/2015.

[7] Michell Instruments, XTP601 Phase II Control PCB Power Supplies Contrast Circuit Diagram, Drawing Number: 80895C, Sheet 5 of 6, Issue: 06, Date: 24/03/2015.

[8] Michell Instruments, XTP601 Control PCB Sensor Bridge Drive / Conditioning, Drawing Number: 80895C, Sheet 6 of 6, Issue: 06, Date: 24/03/2015.

[9] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 1 of 6, Issue: 06, Date: 11/04/2022.

[10] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 2 of 6, Issue: 06, Date: 11/04/2022.

[11] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 3 of 6, Issue: 06, Date: 11/04/2022.

[12] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 4 of 6, Issue: 06, Date: 11/04/2022.

[13] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 5 of 6, Issue: 06, Date: 11/04/2022.

[14] Michell Instruments, XTC – Schematics Control PCB Assembly, Drawing Number: 81003-SCH, Sheet 6 of 6, Issue: 06, Date: 11/04/2022.

[15] Non-electronic Parts Reliability Data (NPRD), Reliability Information Analysis Center, Volume 1 & 2, 2011.

[16] Exida, Electrical & Mechanical Component Reliability Handbook, Third Edition (EMCRH) Electrical. ISBN-13: 978-1-934977-04-0. Dated: 2012.

[17] BT, Handbook of Reliability Data for Electronic Components used in Telecommunications Systems (HRD-5), Fifth Issue.

[18] Reliability, Maintainability and Risk, DJ Smith, Butterworth Heinemann, ISBN 0-7506-5168-7.

[19] Procedure Q021, Revision 13: Quality System Management Reviews, Date: 16/02/2021.

[20] Procedure M027, Revision 04: Software Control, Date: 24/01/2020.

[21] Procedure Q015, Revision 15: Quality System Documentation.

[22] Procedure Q001, Revision 04: Goods Received Inspection.

[23] Procedure T001, Revision 04: Software / Firmware Modification.

[24] XTC601 Firmware Change History: 37701.pdf.

[25] XTP601 Firmware Change History: 36217.pdf.

[26] XTC601 Firmware (37701) Changes Test Summary, Report No.: 2068/181, 24/02/2015.

[27] XTP601 Test Request Form, 11/01/2013.

[28] XTC601 Executive Test Summary, Report No.: 2001/134, Issue 1, 04/10/2013.

[29] XTP601 Application Software Test Report, Report No.: 7160-160, 20/03/2012.

[30] XTP601 Firmware Verification Test Report, Report No.: 7160-163, 19/03/2012.

[31] XTP601 and XTC601 Fault Detection Features, Document Reference: 97583, Issue: 1.00.

[32] IAR Settings for XTP601 and XTC601 Firmware Development (to ensure continued Functional Safety), Work Instruction 709, Issue A.

[33] SIL Function Safety Management (FSM) Policy, Document Reference: F0174, Issue 1.

[34] XTP / XTC 601 SIL Safety Manual, Document Reference: 97587, Issue 2.

[35] XTC Firmware 37701 V1.11, Report Number: DPT-0187, Date; 20/06/2022.

[36] XTP501/601 Firmware V1.13, Report Number: DPT-0182, Date: 05/005/2022.

[37] XTC601 Binary Gas Analyzer User's Manual, Document Reference: 97400, Issue 6.4, March 2022.

[38] XTP601 Process Oxygen Analyzer User's Manual, Document Reference; 97313, Issue 8.4, March 2022.

[39] XTP601 and XTC601 Invoiced Orders To Date.xlsx.

[40] XTC Service Detail.xlsx.

[41] XTP Service Detail.xlsx.

3 ABBREVIATIONS

λ	Failure Rate
λ_D	Dangerous Failure Rate
λ_{DD}	Dangerous Detected Failure Rate
λ_{DU}	Dangerous Undetected Failure Rate
λs	Safe Failure Rate
/hr	Per Hour
ADC	Analogue-To-Digital Converter
DAC	Digital-To-Analogue Converter
DC	Diagnostic Coverage
E/E/PE	Electrical / Electronic / Programmable Electronic
EMF	Electromotive Force
ESC	Engineering Safety Consultants
EUC	Equipment Under Control
FMEDA	Failure Mode Effect and Diagnostics Analysis
FMR	Failure Mode Ratio
FS	Functional Safety
FSM	Functional Safety Management
HFT	Hardware Fault Tolerance
HRD	Handbook of Reliability Data
MDT	Mean Down Time
MTTR	Mean Time To Restoration
NPRD	Non-Electronic Parts Reliability Data
oo	Out of (voting configuration)
O_2	Oxygen
O/C	Open Circuit
PFD	Probability of Failure on Demand
PFH	Average Frequency of a Dangerous Failure per Hour
PLC	Programmable Logic Controller
PTC	Proof Test Coverage
PTI	Proof Test Interval
QA	Quality Assurance
RBD	Reliability Block Diagram
S/C	Short Circuit
SFF	Safe Failure Fraction
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SR	Safety Related
T_p	Proof Test Interval

4 INTRODUCTION

4.1 Objectives

The objectives of this analysis were to conduct a FMEDA assessment of the Michell Instruments UK Ltd, XTP601 Process Oxygen Analyser and XTC601 Binary Gas Analyser in order to demonstrate its suitability for use in an up to SIL 2 rated safety system in accordance with IEC 61508 [1] and IEC 61511 [2].

This assessment was carried out in the following steps:

1. A FMEDA was carried out on the XTP601 and XTC601 in order to quantify the failure rate and determine the SFF;
2. PFD calculations were conducted for part of the sensing sub-system, using failure rates from the FMEDA;
3. Determination of maximum SIL capability for part of the sensing element sub-system, based on architectural constraints;
4. Prior use assessment to demonstrate systematic capabilities.

4.2 FMEDA Scope

The scope of the analysis was limited to the XTP601 and XTC601 as presented in the circuit diagrams [3]-[14].

IMPORTANT: This report is provided on the understanding that it forms part of the project functional safety documentation as defined in IEC 61508-1 Clause 5.2 and as such it will be verified in accordance with the project functional safety verification plan, IEC 61508-1 Clause 7.18.2. Evidence of verification should be available if required for any Functional Safety Assessment as per IEC 61508-1 Clause 8.2.

This FMEDA assessment addresses only the random hardware reliability (described in section 6); and architectural requirements (described in section 7) of IEC 61508 [1] and IEC 61511 [2].

The prior use assessment (described in section 9) addresses the systematic requirements of IEC 61511 [2].

IMPORTANT: It should be noted that this assessment does not include confirmation of the response time of the device. For response times (along with any relevant assumptions) reference should be made to the Safety Manual of each device and the total SIF response time **MUST** be compared against the process safety time for the specific application.

4.3 Meeting Records

The FMEDA team consisted of the following personnel:

Table 3. FMEDA Team

Name	Company	Title / Position
Chantal Sealey	Engineering Safety Consultants (ESC)	FMEDA Chair
Paulo Oliveira	ESC	FMEDA Co-Chair
Abdul Kadir	Michell Instruments UK Ltd	Electronic Engineer
Ray Hinkins	Michell Instruments UK Ltd	Development Manager

The FMEDA meeting for the XTP601 and XTC601 was held on the 23rd – 24th April 2019 at the Michell Instruments UK Ltd offices in Ely, Cambridge, United Kingdom, with the signed daily attendance sheets presented in Appendix C.

5 FAILURE MODE, EFFECT AND DIAGNOSTICS ANALYSIS (FMEDA)

5.1 General

A FMEDA was carried out to demonstrate capabilities and suitability of the XTP601 and XTC601 for use in a SIL rated SIF.

5.2 FMEDA Method

The FMEDA provides a stand-alone, bottom-up analysis of single-point failures of a single module. A description of the method and summary of the results are provided below. The FMEDA was based on the circuit diagrams [3]-[14] provided by Michell Instruments UK Ltd. The FMEDA was conducted on worksheets presented in Appendix A.

The boundary of the analysis are the devices under assessment itself. The FMEDA was conducted at a component level, which is judged to provide a depth of analysis that is adequately detailed for a first pass assessment of a SIL application.

The FMEDA worksheets presented in Appendix A details the functions considered, the failure modes postulated and the analysed effects. The worksheets also quantify the rate of occurrence of each failure effect based on the reliability assessment, and in each case, show the calculation of SFF.

5.3 Data Source

This assessment used the Non-electronic Parts Reliability Data (NPRD) [15], Exida [16] and BT's Handbook of Reliability Data (HRD)-5 [17] published sources of data, which generally gives a close comparison with field data, in order to determine a reasonable and conservative failure rate value from a traceable source to use in the analysis.

5.4 Failure Mode Ratio

The Failure Mode Ratios (FMRs) detailed in the FMEDA worksheets presented in Appendix A are from various sources of data and engineering judgment of the FMEDA team.

5.5 FMEDA Worksheets

5.5.1 Introduction

The following sub-sections describe the column headings in the FMEDA worksheets.

5.5.2 Summary: Function Block.

This table presents the findings of the analysis for each block and quantifies the postulated failure modes.

5.5.3 Total λ_{DU} (/hr)

This column quantifies the dangerous undetected failures based on the diagnostic coverage of each block as discussed during the FMEDA.

5.5.4 Total λ_{DD} (/hr)

This column quantifies the dangerous detected failures based on the diagnostic coverage of each block as discussed during the FMEDA.

5.5.5 Total λ_S (/hr)

This column quantifies the safe failures based on the circuitry and application of each block as discussed during the FMEDA.

5.5.6 Total λ (No Effect) (/hr)

This column quantifies the failures which have no effects on the module based on the circuitry and application of each block as discussed during the FMEDA.

5.5.7 SFF

This column quantifies the SFF for the device under analysis based on the quantified failures described above.

5.5.8 Block Number / Function

These columns provide an identifier and a brief description of the function block under analysis.

5.5.9 Diagnostic Measures

The diagnostic measures are the means whereby the failure mode can be detected. This includes positive indications or signals generated by the module, or for example, errors in protocol or processes that could be detected if interrogated by appropriate external equipment.

5.5.10 Component Failure Rate, λB

This column details the failure rate of the components under analysis.

5.5.11 Failure Mode Ratio

The FMR provides a means of apportioning the component failure rate, between the failure modes of that function. In a functional level analysis, it is not possible to obtain failure mode ratios from published sources and therefore the apportionment was based on the complexity of technology employed by the function and engineering judgment applied during the FMEDA. Estimation of the failure mode ratio is detailed within Appendix A.

5.5.12 Failure Mode Failure Rate

The failure mode failure rate is the product of the Functional Failure Rate, and the Failure Mode Ratio, and represents the rate at which each postulated failure mode is expected to occur.

5.5.13 Interpretation of Failure Classification

- Safe failures are failures that cannot lead to the loss of the safety function but can lead to spurious alarm or trip action, ensuring that the process is placed in a safe state.
- Dangerous failures can lead to the loss of the safety function. In a redundant configuration, where a failure causes switchover from an active unit to a standby unit, this is considered to be a dangerous failure because loss of the safety function is only averted by the presence of the redundant channel and the diagnostics that allow the detection and changeover mechanism.
- Non Safety–related failures have no effect on the safety function in that for example, they relate to functions that are only used during maintenance.
- Detected failures are revealed by the documented detection methods. Undetected failures are not revealed by diagnostics.

5.5.14 Comments

The comments field has been used to provide any additional information not covered by the other worksheet fields.

6 HARDWARE RELIABILITY ASSESSMENT METHODOLOGY

6.1 Introduction

The hardware reliability analysis methodology of this study is in accordance with IEC 61508 [1].

6.2 Definition of SIL

The hardware reliability of a SIF is expressed in terms of either its PFD; or Average Frequency of a Dangerous Failure per Hour (PFH[2]), depending on the frequency of demands made upon it.

The frequency of demand ('mode of operation') on the SIF falls into three categories:

- Low demand mode (IEC 61508-4: 3.5.16 [1]) – where the safety function is only performed on demand, in order to transfer the Equipment Under Control (EUC) into a specified safe state, and where the frequency of demands is no greater than one per year, or;
- High demand mode (IEC 61508-4: 3.5.16 [1]) – where the safety function is only performed on demand, in order to transfer the EUC into a specified safe state, and where the frequency of demands is greater than one per year, or;
- Continuous mode (IEC 61508-4: 3.5.16 [1]) - where the safety function retains the EUC in a safe state as part of normal operation.

Thus, the four SILs are defined as presented in Table 4.

Table 4. SILs

SIL	Low Demand (PFD)	High Demand (PFH)
4	≥ 10^{-5} to < 10^{-4}	≥ 10^{-9} to < 10^{-8}
3	≥ 10^{-4} to < 10^{-3}	≥ 10^{-8} to < 10^{-7}
2	≥ 10^{-3} to < 10^{-2}	≥ 10^{-7} to < 10^{-6}
1	≥ 10^{-2} to < 10^{-1}	≥ 10^{-6} to < 10^{-5}

Based on the definitions given in (IEC 61508-4: 3.5.16 [1]), this study assumes the devices will be used in a LOW DEMAND safety system, thus the PFD SIL definitions presented in Table 4 apply.

6.3 Probability of Failure on Demand

For LOW DEMAND SIFs (refer to section 6.2), IEC 61508 [1] requires calculation of the PFD of each full SIF loop:

$$PFD_{sys} = PFD_s + PFD_L + PFD_{FE} \qquad \textbf{(IEC 61508-6: B.3.2.1 [1])} \qquad \textbf{(1)}$$

Where:

PFD_{sys} is the PFD of a safety function for the electrical/electronic/programmable electronic (E/E/PE) safety-related system;

PFD_s is the PFD for the sensor subsystem;

PFD_L is the PFD for the logic subsystem;

PFD_{FE} is the PFD for the final element or final element subsystem.

[2] The term "probability of dangerous failure per hour" is not used in IEC 61508 [1] but the acronym PFH was retained. When it is used, it means "average frequency of a dangerous failure [h]".

The overall PFD of the full SIF is cross-referenced with Table 4 in order to determine its SIL, in terms of hardware reliability.

6.4 Failure Rate, λ

6.4.1 General

To calculate PFD, it is first necessary to introduce the term 'failure rate.'

Failure rate is denoted by λ and defined as the *number of failures per unit time.* For the purposes of this analysis all failures rates are measured per hour.

6.4.2 Failure Modes

In order to calculate the PFD of the sensor, logic or final element sub-system using λ, its failure modes must first be examined. The number of failures is apportioned into safe and dangerous failure modes, where:

- A **dangerous failure** (IEC 61508-4: 3.6.7 [1]) is defined as a failure of an element and/or subsystem and/or system that plays a part in implementing the safety function that:
    a) prevents a safety function from operating when required (demand mode) or causes a safety function to fail (continuous mode) such that the EUC is put into a hazardous or potentially hazardous state, or;
    b) decreases the probability that the safety function operates correctly when required.
- A **safe failure** (IEC 61508-4: 3.6.8 [1]) is defined as a failure of an element and/or subsystem and/or system that plays a part in implementing the safety function that:
    a) results in the spurious operation of the safety function to put the EUC (or part thereof) into a safe state or maintain a safe state, or;
    b) increases the probability of the spurious operation of the safety function to put the EUC (or part thereof) into a safe state or maintain a safe state.

It follows that the total failure rate λ, is equal to the sum of the safe and dangerous failure rates:

$$\lambda = \lambda_D + \lambda_S \qquad (2)$$

Where:

λ_D is the dangerous failure rate per hour and;

λ_S is the safe (or spurious) failure rate per hour.

6.4.3 Diagnostic Testing

The dangerous failure rate is further apportioned into dangerous detected and undetected failures, where:

- A **detected** failure (IEC 61508-4: as defined in 3.8.6 [1]) is defined as the dangerous failures that are detected by automatic on-line diagnostic tests and;
- An **undetected** failure (IEC 61508-4: as defined in 3.8.5 [1]) is defined as the dangerous failures that are revealed through proof testing, allowing the system to be restored to an "as new" condition or as close as practical to this condition.

The relationship can therefore be described by:

$$\lambda_D = \lambda_{DD} + \lambda_{DU} \qquad (3)$$

Where:

λ_{DD} is the dangerous detected failure rate per hour and;

λ_{DU} is the dangerous undetected failure rate per hour.

Note that safe failures revealed by diagnostic testing are not considered since by definition (refer to section 6.4.2), they do not have the potential to put the SIF into a fail-to-function state and thus do not contribute to the PFD of a sub-system.

6.5 PFD and Mean Down Time (MDT)

6.5.1 General

The PFD of a single sub-system, for instance a single detector, is found by multiplying the dangerous failure rate, λD, (refer to section 6.4.2) by the Mean Down Time (MDT):

$$PFD = \lambda MDT \quad \textbf{(4)}$$

Where MDT is the time taken to repair a fault: the Mean Time to Restoration (MTTR), plus the time taken to detect it. It is assumed that, on average, a fault will occur at the mid-point of the test interval, thus the time taken to detect a fault is equal to half the test interval, $T/2$, therefore:

$$MDT = MTTR + T/2 \quad \textbf{(5)}$$

6.5.2 PFD Average for Detected Failures

In general, for failures which are detected by the diagnostic tests of a sub-system (refer to section 6.4.3), the test interval (termed as 'diagnostic test interval'), T_d, is typically less than 1 hour (refer to IEC 61508-6: Annex B [1]) and thus the time taken to detect a fault, $T_d/2$, is considered small in comparison with the MTTR, i.e.:

$$MDT_{(Detected)} \approx MTTR$$

Thus:

$$PFD_{(Detected)} = \lambda_{DD} MTTR \quad \textbf{(6)}$$

Where MTTR is the Mean Time to Restoration in hours.

6.5.3 PFD Average for Undetected Failures

For undetected failures (refer to section 6.4.3), i.e. failures revealed only by manual proof testing, the MTTR is considered small in comparison with the time taken to detect a fault, i.e. the mid-point of the proof test interval, $T_p/2$, therefore:

$$MDT_{(Undetected)} \approx T_p / 2$$

Thus:

$$PFD_{(Undetected)} = \lambda_{DU} T_P / 2 \quad \textbf{(7)}$$

Where T_p is the proof test interval in hours.

6.5.4 PFD for Sub-system

The overall PFD of a single sub-system (sensor, logic or final element sub-system), comprises the PFD for undetected faults and the PFD for detected faults:

$$PFD_{subsystem} = PFD_{(Undetected)} + PFD_{(Detected)} \quad \textbf{(8)}$$

7 ARCHITECTURAL ASSESSMENT METHODOLOGY

7.1 Hardware Fault Tolerance (HFT)

In addition to the hardware reliability assessment (refer to section 6), there are also minimum architecture requirements to be met. Each subsystem within a SIF must meet the minimum HFT for the required SIL. That is, the sensor, logic and final element subsystems must all individually meet the overall SIL requirement for the SIF.

To determine the level of HFT (or redundancy) required in a SIF using the Route 1_H approach detailed in IEC 61508-2: 7.4.4.2, the Safe Failure Fraction (SFF) must be calculated for each subsystem.

7.2 Safe Failure Fraction (SFF)

The SFF is essentially the proportion of random failures in a sub-system which either result in a safe state, or a dangerous state that is revealed by automatic diagnostic tests. SFF is calculated using the following formula:

$$SFF = \frac{\lambda_{DD} + \lambda_S}{\lambda_D + \lambda_S} \qquad \textbf{(IEC 61508-2: C.1.h [1])} \qquad \textbf{(9)}$$

Where:

λ_{DD} is the dangerous detected failure rate per hour;

λ_D is the sum of dangerous detected and dangerous undetected failures per hour;

λ_S is the safe (spurious) failure rate per hour.

Note that in calculating SFF, no credit is taken for the contribution of Non-Safety Related failures. The failure rates and calculated values of SFF are summarised in Section 11.2.

7.3 IEC 61508 Architectural Constraints (Route 1_H)

Table 5 present the minimum HFT for Type A and Type B components respectively. For a component to be considered Type A, all the following criteria must be met:

- Failure modes are well defined and;
- Behaviour under fault conditions is well defined and;
- Failure data is available.

If a component fails to meet any of these criteria, it is considered to be Type B. Type B components normally contain complex microelectronics, commonly found in Programmable Logic Controllers (PLCs) and smart sensors. Simple devices, such as valves, relays and devices using discrete electronic (non-programmable) are normally considered to be Type A.

Table 5. HFT for Type A and Type B Components [1]

SFF	Minimum HFT for Type A Components			Minimum HFT for Type B Components		
	SIL for simplex	SIL for m+1	SIL for m+2	SIL for simplex	SIL for m+1	SIL for m+2
	(HFT=0)	(HFT=1)	(HFT=2)	(HFT=0)	(HFT=1)	(HFT=2)
<60%	1	2	3	Not allowed	1	2
60-90%	2	3	4	1	2	3
90-99%	3	4	4	2	3	4
>99%	3	4	4	3	4	4

The architectural assessment of the devices, in terms of HFT, Type and SFF, is presented in Appendix B.

8 PRIOR USE

8.1 General

A prior use assessment as per the requirements of IEC 61511 (2nd Edition), Clause 11.5.3 and 11.5.4 [2] was carried out to demonstrate the XTP601 and XTC601 suitability for use in a SIL rated safety function/system.

8.2 Failure Rate Estimation

The intention of the failure rate estimation is to demonstrate that the rate of dangerous failures from operational experience is not greater than the rate of dangerous random hardware failures, identified by means of the FMEDA. The failure rate from operational experience includes random hardware and systematic failures and subsequently this data can be used to define the systematic capability of the device and validate the failure rates identified by the FMEDA.

The calculations were based on field data provided by Michell Instruments UK Ltd, stating the number of units that are operational against the hours of operation. The analysis considered the unit dangerous failures during the operation and thus the estimated failure rates are provided using the Chi-Square method.

Warranty return data was analysed by Michell Instruments UK Ltd to identify dangerous failure applicable to the XTP601 and XTC601, this analysis identified a total of 30 potentially dangerous failures for the XTP601 and 8 potentially dangerous failures for the XTC601.

An explanation of the Chi-Square Test technique can be found in many standard texts, for example Reliability, Maintainability and Risk, Chapter 5 [18]. Warranty return data was used for the estimation of the XTP601 and XTC601 failure rate.

It should be noted that any reassessment conducted on the FMEDA assessment will affect the suitability of the prior use assessment.

Table 6 presents the available warranty return data supplied by Michell Instruments UK Ltd.

Table 6. Warranty Return Data

Device	Items Shipped [39]	Operational Hours	Number of Dangerous Failures [40]-[41]
XTP601	944	82,694,400	30
XTC601	324	22,705,920	8

Table 7 presents a summary of the failure rate estimation.

Table 7. Prior Use assessment

Device	Confidence Level	Total λ (/hr)
XTP601	70%	3.9E-07
XTC601	70%	4.1E-07

The failure rate, λ (/hr), from Table 7 was estimated using the Chi-Square method with a confidence level of 70% in line with the recommendations in IEC61508 [1] (part 2, paragraph 7.4.9.5). Both random hardware and systematic failures were accounted for in the estimation.

Table 8 provides a comparison to the calculated failure rates from volume of operating experience and the FMEDA.

Table 8. Module Failure Rate

Device	Random Hardware Dangerous λ (/hr) FMEDA	Warranty Return (Systematic + Random Hardware Failures) λ (/hr) Prior Use Assessment
XTP601	7.9E-07	3.9E-07
XTC601	7.4E-07	4.1E-07

9 ASSESSMENT TO SHOW THAT A FIELD DEVICE MEETS UP TO SIL 2 BY PRIOR USE (AS PER REQUIREMENTS OF IEC 61511 (2ND EDITION), CLAUSE 11.5.3 AND 11.5.4)

(Para 11.5.2, 11.5.3, 11.5.4)

9.1 Field Experience

Requirement	Evidence	Actions
Demonstration that it is able to perform the required functions and that the previous use has shown there is a low enough probability that it will fail in a way which could lead to a hazardous event when used as part of the safety instrumented system, due to either random hardware failures or systematic faults in hardware or software in systems in similar operating profiles and physical environments, factors to consider: • Volume of the operating experience; • the complexity and functionality of the component or sub-system; • Any embedded software has a good history of use in application with safety type functions.	• Failure Modes Effect and Diagnostics Analysis (FMEDA) carried out for the XTP601 and XTC601 to determine failure modes and failure rates with respect to the intended safety function of the devices) – analysis provided justification for use in SIL 1 application (complex Type B devices) (refer to Appendix A). • A Prior Use assessment was carried out whereby the in service failures (random and systematic) were analysed and compared with the dangerous failures (detected and undetected) identified in the FMEDA to support the values claimed (refer to section 8). • Operation history provided by Michell Instruments UK Ltd, using warranty returns based on operating hours and number of recorded failures (refer to section 8). • Devices have not been used within a safety application yet, so no specific data available, however there is reported use in similar applications and profiles (albeit non-safety related).	No further action required.

9.2 Manufacturer's Quality Assurance (QA) & Procedures

Requirement	Evidence	Actions
Consideration of the manufacturer's quality management and configuration systems. Appropriate standards have been used for hardware as well as the embedded and utility software.	• Procedure Q021, Revision 13: Quality System Management Reviews [19] details that Michell Instruments UK Ltd's Quality System has been designed to comply with the requirements of ISO 9001. • Procedure M027, Revision 04: Software Control [20] describes the process on how copies of the Software / Firmware are kept. • Procedure Q021, Revision 13: Quality System Management Reviews [19] provides the process that is following within the organisation to ensure that the quality management system in place is still effective.	No further action required.

Requirement	Evidence	Actions
	• Procedure Q015, Revision 15: Quality System Documentation [21] provides the process on how the content, format, issue control, modification and distribution processes are followed with respect to the quality system documentation. • SIL Function Safety Management Policy [33], details how functional safety is managed through the lifecycle as per IEC 61508 [1], including competency requirements for staff.	

9.3 System Features

Requirement	Evidence	Actions
Adequate identification and specification of the components or sub-systems.	• The XTP601 and XTC601 FMEDA identifies all the components within the devices.	No further action required.
Unused features of the components and sub-systems shall be identified in the evidence of suitability, and it shall be established that they are unlikely to jeopardise the required safety instrumented functions.	• FMEDA carried out for the XTP601 and XTC601 identified any unused components and subsystems (refer to Appendix A). • SIL Function Safety Management Policy [33] defines both SR and non-SR elements.	No further action required.
Understanding of unsafe failure modes.	• Any unsafe failure modes have been identified in the XTP601 and XTC601 FMEDA analysis presented in Appendix A.	No further action required.
Protection against unauthorised or unintended modifications.	• Procedure T001, Revision 04: Software / Firmware Modification [23] provides the process that needs to be undertaken for any software or firmware modifications. • XTC601 Firmware Change History: 37701 [24] and XTP601 Firmware Change History: 36217 [25] provides firmware version numbers and the changes that have been made between previous versions. • Software / Firmware Product Release Permit is filled out once a new or modified version of Software / Firmware needs to be released. • XTP601 and XTC601 Test Summaries [35], [36] provides the testing conducted on the XTP601 and XTC601 based upon modifications to the firmware. • Section 3.3 of the XTP / XTC 601 Safety Manual [34], states after configuration that the menu codes will be changed to protect against unauthorised changes. • Opening note of the XTP / XTC 601 Safety Manual [34], indicates that the product design of the devices is strictly controlled, and unauthorised changes are not permitted and in doing so will negate the functional safety assessment.	No further action required.

Requirement	Evidence	Actions
Measures are implemented to detect faults during program execution and initiate appropriate reaction; these measures shall comprise all of the following: • Program sequence monitoring; • Protection of code against modifications or failure detection by online monitoring; • Failure assertion or diverse programming; • Range check of variables or plausibility check of values; • Modular approach.	• Procedure T001, Revision 04: Software / Firmware Modification [23] provides the process that needs to be undertaken for any software or firmware modifications. • XTC601 Firmware (37701) Changes Test Summary, Report No.: 2068/181, 24/02/2015 [26] provides the testing conducted on the XTC601 once modifications to the firmware were made to ensure that functionality of the device was not affected. • XTP601 Test Request Form, 11/01/2013 [27] details the firmware testing conducted for V1.03 for XTP601 and the results obtained based on this version of firmware's modification. • XTP601 and XTC601 Test Summaries [35], [36] provides the testing conducted on the XTP601 and XTC601 based upon modifications to the firmware. • XTP601 and XTC601 Fault Detection Features Document [31], details the fault measures that are in the XTP601 and XTC601, along with how they are detected and the measures in place to test the safety outputs.	No further action required.
It has been used or tested in typical configurations, with test cases representative of the intended operational profiles.	• XTC601 Executive Test Summary, Report No.: 2001/134, Issue 1, 04/10/2013 [28] provides evidence that the XTC601 has been tested against a different set of ranges and sample gases to evaluate of the product meets its design specification. • XTP601 Application Software Test Report, Report No.: 7160-160, 20/03/2012 [29] provides evidence that the application software for the XTP601 has been tested against the check list on Michell Instruments production release permit document. • XTP601 Firmware Verification Test Report, Report No.: 7160-163, 19/03/2012 [30] provides evidence that the XTP601 has been tested against the specification / description of all parameters in each block. • XTP601 and XTC601 Test Summaries [35], [36] provides the testing conducted on the XTP601 and XTC601 based upon modifications to the firmware.	No further action required.
Trusted verified software modules and components have been used.	• Work Instruction 709 [32], details the module and compiler tools used and why these tools have been selected. This document will be referred to by the firmware engineer before any changes are done to the firmware.	No further action required.

Requirement	Evidence	Actions
The system has undergone dynamic analysis and testing.	• XTC601 Executive Test Summary, Report No.: 2001/134, Issue 1, 04/10/2013 [28] provides evidence that the XTC601 has been tested against a different set of ranges and sample gases to evaluate of the product meets its design specification. • XTP601 Application Software Test Report, Report No: 7160-160, 20/03/2012 [29] provides evidence that the application software for the XTP601 has been tested against the check list on Michell Instruments production release permit document. • XTP601 Firmware Verification Test Report, Report No: 7160-163, 19/03/2012 [30] provides evidence that the XTP601 has been tested against the specification / description of all parameters in each block.	No further action required.
The system does not use artificial intelligence nor dynamic reconfiguration.	N/A	N/A

9.4 Formal assessment report

Requirement	Evidence	Actions
Formal assessment on both the field experience and manufactures QA and procedures.	• This report provides the formal assessment on both the experience, system features and manufacturer's QA and procedures.	No further action required.
Safety manual including constraints for operation, maintenance and fault detection shall be available covering the typical configurations of the device and the intended application profiles.	• XTC601 Binary Gas Analyzer User's Manual, Document Reference: 97400, Issue 6.4, March 2022 [37]. • XTP601 Process Oxygen Analyzer User's Manual, Document Reference; 97313, Issue 8.4, March 2022. [38]. • XTP / XTC 601 Safety Manual [34].	No further action required.

10 PROJECT DATA AND ASSUMPTIONS

10.1 General Assumptions

The following points summarise the general assumptions used in the analysis. Where possible, specific paragraph references provide the context of the assumption, indicating where it has been applied.

a) The devices under analysis are considered to be Type B as per IEC 61508-2 Clause 7.4.4.1.2, as it meets one or more of the following requirements due to the presence of complex devices (e.g. ASIC or microprocessor):

   a. The failure modes of at least one constituent components is not well defined, OR;

   b. The behaviour of the element under fault conditions cannot be completely determined, OR;

   c. There is sufficient dependable failure data to show that the claimed rates of failure for detected and undetected dangerous failures are met (see IEC 61508-2 clauses 7.4.9.3 to 7.4.9.5).

b) If a failure occurs, it is assumed that on average it will occur at the mid-point of the test interval. In other words, the fault will remain undetected for 50% of the test period (refer to 6.5.3);

c) Failure modes not detected by diagnostics or by fail-to-safe conditions, were assumed to be detected at proof test, (refer to section 6.4.3);

d) The analysis assumes constant failure rates and therefore the effects of early failures are expected to be removed by appropriate processes (refer to section 6);

e) The logic solver, final elements and any additional sensing subsystems have been excluded from this analysis and thus 80% of the SIL 2 band has been allocated for their contribution;

f) Components are not operated beyond their useful life thus ensuring that failures due to wear-out mechanisms do not occur;

g) It is assumed that the user's control system is configured to detect 'out of range' errors;

h) It is assumed that all diagnostic relay alarms are generated through the Modbus or relay.

10.2 Test & Overhaul Intervals

The assumed Proof Test Interval is 1 year (8,760 hours), which is based on the periodic test interval (full stroke test) being completed. A major overhaul is assumed to be conducted on the equipment, such that it is returned to the as-new condition, once every 10 years (87,600 hours).

11 RESULTS

11.1 Calculation of XTP601 & XTC601 Failure Rate (FMEDA)

Table 9 presents a summary of the FMEDA of XTP601 and XTC601 in terms of Dangerous Undetected (λ_{DU}), Dangerous Detected (λ_{DD}) and Safe (λ_S) failure rates.

Table 9. Results of XTP601 and XTC601 FMEDA

Device	λ_S (/hr)	λ_{DD} (/hr)	λ_{DU} (/hr)
XTP601	1.6E-07	7.4E-07	5.4E-08
XTC601	1.6E-07	7.0E-07	3.9E-08

11.2 Hardware Reliability Assessment

Table 10 presents the results of the assessment for the XTP601 and XTC601. These devices will form part of the sensor element sub-system of a SIF and thus an assessment was conducted to demonstrate its capabilities in terms of PFD. The remaining sensing, logic solver and final element sub-systems were excluded from the assessment, in order to allow for their PFD contributions, the devices were assessed against 20% of SIL 2 PFD band (e.g. SIL 2 band modified to 2.0E-03).

Results have been calculated for PTCs of both 95% (testing capable of revealing 95% of undetected failures) and 90%, a PTI of 1 year (8,760 hours). The Mission Time before the analysers undergo a complete overhaul is assumed to be 10 years, with a MTTR of 168 hours.

Table 10. Hardware Reliability Verification

Device	Proof Test Coverage (PTC)	PFD Target (20% of SIL 2 band)	PFD Achieved	Estimated Achieved PFD	SFF	Type	Estimated Achieved SIL (Arch)	Estimated Overall SIL Capability
XTP601	95%	2.0E-03	4.1E-04	2	94%	B	2	2
	90%		5.1E-04	2			2	2
XTC601	95%	2.0E-03	3.1E-04	2	96%	B	2	2
	90%		3.8E-04	2			2	2

11.3 Warranty Return Assessment

The results of the warranty return assessment are shown in Table 11. The results of the Prior Use assessment can be found in Section 9.

Table 11. XTP601 and XTC601 Warranty Return Results

Device	Random Hardware Dangerous λ (/hr) FMEDA	Warranty Return (Systematic + Random Hardware Failures) λ (/hr) Prior Use Assessment
XTP601	7.9E-07	3.9E-07
XTC601	7.4E-07	4.1E-07

Table 11 shows that the warranty return data broadly agrees with the FMEDA estimated failure rate.

12 CONCLUSION

The results of the assessment illustrate that based on the information provided and the stated assumptions, both units meet the requirements of the hardware capability assessment (i.e. random hardware failure and SFF) and systematic capability requirements in order to be deemed suitable for use in safety applications with a SIL 2 requirement:

The following conclusions apply:

- Hardware Capability:
  - XTP601 **meets** the random hardware reliability requirements and architectural constraints for use in a SIL 2 SIF in a simplex (i.e. HFT = 0) configuration with a PTC of 95% or 90% and a PTI of 1 year;
  - XTC601 **meets** the random hardware reliability requirements and architectural constraints for use in a SIL 2 SIF in a simplex (i.e. HFT = 0) configuration with a PTC of 95% or 90% and a PTI of 1 year;
- Systematic Capability:
  - The reviewed operational data (i.e. warranty return data) agrees with the estimated failure rate for both units;
  - The reviewed evidence for compliance with Prior Use requirements as defined in IEC 61511 [2] adequately demonstrates the necessary systematic capability.

Appendix A

Failure Mode, Effects Analysis Worksheets

Summary: Function Block (XTP601)					
Block	**Total Non-Safety Related Failure λ(NSR) (/hr)**	**Total λS (/hr)**	**Total λDU (/hr)**	**Total λDD (/hr)**	**SFF (%)**
Alarm Relays / Cell Temperature	2.52E-08	1.30E-07	5.34E-09	9.84E-08	97.72%
4-20mA Analog Inputs	Non Safety Related Block				
4-20mA Analog Outputs	1.37E-08	7.55E-09	7.55E-09	2.50E-07	97.15%
Microcontroller	1.74E-08	1.09E-08	2.84E-08	8.02E-08	76.23%
Power Supplies Contrast	4.37E-08	7.06E-09	7.06E-09	1.15E-07	94.55%
Sensor Bridge Drive / Conditioning	3.24E-08	1.22E-09	5.72E-09	1.96E-07	97.18%
Total	**1.32E-07**	**1.57E-07**	**5.41E-08**	**7.39E-07**	**94.31%**

Block:	XTP601 Process Oxygen Analyser
Safety Function:	Ability to detect oxygen presence within another gas stream and generate a 4-20mA output (resolution 0.038% of available span - informative only, not safety criteria)
Diagnostic Measures:	Watchdog for the microcontroller which will try to reset microcontroller Sensor cell temperature unstable error (50 °C required for accurate detection), which produces an alarm and forces the output to a safe state Pressure sensor circuit error, which will give warning on display and will be available as a warning to user via Modbus communications O_2 sensor circuit error, which will give warning on display and will be available as a warning to user via Modbus communications Internal temperature too high error, which will give warning on display and will be available as a warning to user via Modbus communications. Analogue output will indicate a fault condition % O_2 beyond calibration range error, which will output an alarm (internal to unit)
Safe Failure Mode:	Detection of oxygen without presence of oxygen in gas stream 4-20mA signal generated without O_2 detection Modbus signal generated without O_2 detection
Dangerous Failure Mode:	Failure to detect oxygen when oxygen is present Failure to generate 4-20mA / Modbus signal output
Environmental Profile (if applicable):	Operating Temperature: 5 - 55 °C

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function **Comments**
Alarm Relays / Cell Temp																		
L1	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Noise filter.	Open Circuit. Short Circuit.	O/C: Cell temperature reading would be out of range but would be detected by the sensor cell unstable signal. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by Sensor cell temperature unstable error diagnostics.
L2	Ferrite Bead, 0603, 60ohms, 3A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Noise suppression inductor.	Open Circuit. Short Circuit.	O/C: No heater drive and the heater will go below its range. Sensor cell will no longer heat up, causing a 4-20mA alarm condition. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by Sensor cell temperature unstable error diagnostics.
R1	RES 100R 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage divider resistor. Drops voltage to 5v between the coil and supply.	Open Circuit. Short Circuit.	O/C: Relay will remain in its non-powered state preventing alarm 1 function (externally set by the user). S/C: Applies 15v to the relay. Relay will still function without issue according to manufacturers.	20%	0%	80%	0%	3.00E-11	0.00E+00	1.20E-10	0.00E+00	This will be used in a detection only function.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R2	RES 100R 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage divider resistor. Drops voltage to 5v between the coil and supply.	Open Circuit. Short Circuit.	O/C: Relay will remain in its non-powered state preventing alarm 2 function (externally set by the user). S/C: Applies 15v to the relay. Relay will still function without issue according to manufacturers.	20%	0%	80%	0%	3.00E-11	0.00E+00	1.20E-10	0.00E+00	This will be used in a detection only function.
R3	RES 10K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias for the cell temperature sensor.	Open Circuit. Short Circuit.	O/C, S/C: Temperature would be out of range but would be detected by the sensor cell unstable signal.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R4	RES 330R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Limits the current on the gate.	Open Circuit. Short Circuit.	O/C: Does not have a drive on the gate and therefore the heater would be off but would be detected by the sensor cell unstable signal. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by Sensor cell temperature unstable error diagnostics.
R93	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of a filter circuit.	Open Circuit. Short Circuit.	O/C: No temperature signal, causing temperature out of range error. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by Sensor cell temperature unstable error diagnostics.
D1	DIODE, SMT, SIGNAL, BAS2, 0, SOT-23 PACKAGE	1	Diode, Silicon Signal	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Conducts back Electromotive Force (EMF) on the coil.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Potential damage to TR2, causing alarm 1 to fail. S/C: Alarm 1 will not switch. High resistance, high impedance: No effect Low resistance, low impedance: Potential to cause alarm 1 not to switch.	7.5%	0%	92.5%	0%	5.25E-11	0.00E+00	6.48E-10	0.00E+00	
D2	DIODE, SMT, SIGNAL, BAS2, 0, SOT-23 PACKAGE	1	Diode, Silicon Signal	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Conducts back EMF on the coil.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Potential damage to TR2, causing alarm 2 to fail. S/C: Alarm 2 will not switch. High resistance, high impedance: No effect Low resistance, low impedance: Potential to cause alarm 2 not to switch.	7.5%	0%	92.5%	0%	5.25E-11	0.00E+00	6.48E-10	0.00E+00	
D3	Diode, Fast Recovery, 1A, 1000V, SMF	1	Diode, Si Rectifier, <3A	4.00E-09	4.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Resistive heater.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: No effect. S/C: Heater would always be off. High, Low resistance, Impedance: Indeterminate state.	10%	7.5%	7.5%	75%	4.00E-10	3.00E-10	3.00E-10	3.00E-09	Detected by Sensor cell temperature unstable error diagnostics.
C1	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Temperature would be out of range but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C2	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Heater would always be off but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C3	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Heater would always be off but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C66	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling on the power rail to IC25B.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 5v rail to ground and IC25B will malfunction, resulting in temperature out of range error. Drift: Indeterminate state. Major leak capable of causing short 5v rail to ground, resulting in temperature out of range error. Minor Leak: No effect.	28%	10%	10%	52%	1.68E-10	6.00E-11	6.00E-11	3.12E-10	Detected by Sensor cell temperature unstable error diagnostics.
C85	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of a filter circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No temperature signal, causing temperature out of range error. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
ZD1	Diode BZX84-C3V0 ZENER, 3V 5% 250mW SOT-23-3	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Clamps the voltage so that it does not go above the Vgs of the transistor.	Open Circuit. Short Circuit. Zener Voltage Drift.	All failure modes: No effect:	100%	0%	0%	0%	3.00E-09	0.00E+00	0.00E+00	0.00E+00	
TR1	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Alarm 1 relay switching transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Alarm 1 output will be inactive. S/C: Alarm 1 output will always be activated and not change state. Leakage, Low Gain: No effect.	20%	60%	20%	0%	1.60E-09	4.80E-09	1.60E-09	0.00E+00	
TR2	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Alarm 2 relay switching transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Alarm 2 output will be inactive. S/C: Alarm 2 output will always be activated and not change state. Leakage, Low Gain: No effect.	20%	60%	20%	0%	1.60E-09	4.80E-09	1.60E-09	0.00E+00	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
RL1	RELAY, PCB MOUNTING, SPC, O, 12VDC, 10A, 240V	1	Relay, Contact, Miniature	6.00E-08	6.00E-08	Nonelectronic Parts Reliability Data 2011, 2-717.	Alarm 1 relay output.	Contact Open. Contact Short. Coil Failure.	Contact stuck open, Coil Failure: Alarm 1 output will always be inactive (detected if does not match the Modbus signals). The user would have to compare the status of the relay as reported via the Modbus message with the status of the relay as read from the actual relay contacts. If both conditions do not match, then the user will be expected to detect that as a stuck relay failure and put the process into a safe condition via the users own fault relay. Contact stuck short: Alarm 1 output will always be active.	0%	100%	0%	0%	0.00E+00	6.00E-08	0.00E+00	0.00E+00	Component failure rate data assumed to be equivalent to standard miniature relay.
RL2	RELAY, PCB MOUNTING, SPC, O, 12VDC, 10A, 240V	1	Relay, Contact, Miniature	6.00E-08	6.00E-08	Nonelectronic Parts Reliability Data 2011, 2-717.	Alarm 2 relay output.	Contact Open. Contact Short. Coil Failure.	Contact stuck open, Coil Failure: Alarm 2 output will always be inactive (detected if does not match the Modbus signals). The user would have to compare the status of the relay as reported via the Modbus message with the status of the relay as read from the actual relay contacts. If both conditions do not match, then the user will be expected to detect that as a stuck relay failure and put the process into a safe condition via the users own fault relay. Contact stuck short: Alarm 2 output will always be active.	0%	100%	0%	0%	0.00E+00	6.00E-08	0.00E+00	0.00E+00	Component failure rate data assumed to be equivalent to standard miniature relay.
PL1	Socket, PCB, 6 Way, 3.5mm, Through hole, Blk	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL3	Header, PCB, RA, 3.9mm, 8 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
TR3	Transistor, SI4840BDY, MOSFET, 40V, 19A, 0.009R	1	Transistor, FET, Power >5W	5.00E-08	5.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Driving the heater.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Heater would be off but would be detected by the sensor cell unstable signal. S/C: Heater would always be on but would be detected by the sensor cell unstable signal. Leakage: No effect. Low Gain: No effect.	20%	0%	0%	80%	1.00E-08	0.00E+00	0.00E+00	4.00E-08	Detected by Sensor cell temperature unstable error diagnostics.
PL2	Header, 8 Way, RA, 2.54mm	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
IC25B	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Buffering the temperature signal to the Analogue-To-Digital Converter (ADC).	Open Circuit. Short Circuit.	O/C, S/C: No temperature signal output, causing temperature out of range error.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by Sensor cell temperature unstable error diagnostics.
4-20mA Analog Inputs																		
R5	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R6	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R7	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R8	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R9	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R10	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R11	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R12	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R13	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R14	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C15	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C39	CAP ELT 33uF C, 25V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C4	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C5	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C6	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C7	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C72	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL4	Socket, PCB, 6 way, 3.5mm, Through Hole	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP4	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC24A	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC24B	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4-20mA Analog Outputs																		
R15	RES 100R 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Current range resistor.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R16	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the output current levels.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R17	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protection for transistor, TR5.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R18	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the gain setting for IC2.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R19	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets up the analogue 4-20mA output.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R20	RES 100R 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Current range resistor.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R21	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the output current levels.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R22	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protection for transistor, TR7.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R23	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the gain setting for IC2.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R24	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets up the analogue 4-20mA output.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R101	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protecting transistor TR4 from being over driven.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R102	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protecting transistor TR6 from being over driven.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
C8	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of decoupling for IC2.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 15v rail to ground and IC2 will malfunction, resulting in no analogue output 1. Drift: Indeterminate state. Major leak capable of causing short 15v rail to ground, resulting in no analogue output 1. Minor Leak: No effect.	28%	10%	10%	52%	1.68E-10	6.00E-11	6.00E-11	3.12E-10	Detected by user's control system diagnostics.
C87	CAP TNT 10uF C, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of decoupling for IC2.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 15v rail to ground and IC2 will malfunction, resulting in no analogue output 1. Drift: Indeterminate state. Major leak capable of causing short 15v rail to ground, resulting in no analogue output 1. Minor Leak: No effect.	39%	2.5%	2.5%	56%	2.73E-10	1.75E-11	1.75E-11	3.92E-10	Detected by user's control system diagnostics.
C9	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Set the analogue output to minimum. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system diagnostics.
C11	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Set the analogue output to minimum. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system diagnostics.

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D15	Diode, Schottky, 30mA	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Analogue output will be fully off. S/C, Low Resistance: No effect. High Resistance, Impedance: Indeterminate effect.	75%	7.5%	7.5%	10%	3.75E-09	3.75E-10	3.75E-10	5.00E-10	Detected by user's control system diagnostics.
D16	Diode, Schottky, 30mA	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Analogue output will be fully off. S/C, Low Resistance: No effect. High Resistance, Impedance: Indeterminate effect.	75%	7.5%	7.5%	10%	3.75E-09	3.75E-10	3.75E-10	5.00E-10	Detected by user's control system diagnostics.
IC2A	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal conditioning.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
IC2B	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal drive.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
IC2C	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal conditioning.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
IC2D	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal drive.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
TR4	TRANSISTOR, SMT, BC850B, NPN, SOT23 PACKAGE	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the analogue 4-20mA output.	Open Circuit. Short Circuit. Leakage. Low Gain.	S/C: Analogue output fully on (load > 70mA) = Fully on. O/C: Analogue output = 8mA = Indeterminate. Leakage, Low Gain: No effect.	20%	10%	10%	60%	1.60E-09	8.00E-10	8.00E-10	4.80E-09	Detected by user's control system diagnostics.
TR6	TRANSISTOR, SMT, BC850B, NPN, SOT23 PACKAGE	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the analogue 4-20mA output.	Open Circuit. Short Circuit. Leakage. Low Gain.	S/C: Analogue output fully on (load > 70mA) = Fully on. O/C: Analogue output = 8mA = Indeterminate. Leakage, Low Gain: No effect.	20%	10%	10%	60%	1.60E-09	8.00E-10	8.00E-10	4.80E-09	Detected by user's control system diagnostics.
TR5	TRANSISTOR, SMT, FZT751, (2W), PNP	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Analogue output drive transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on. Leakage / Low Gain: Indeterminate state.	0%	2.5%	2.5%	95%	0.00E+00	2.50E-09	2.50E-09	9.50E-08	Detected by user's control system diagnostics.
TR7	TRANSISTOR, SMT, FZT751, (2W), PNP	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Analogue output drive transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on. Leakage / Low Gain: Indeterminate state.	0%	2.5%	2.5%	95%	0.00E+00	2.50E-09	2.50E-09	9.50E-08	Detected by user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
FIL2	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Analogue output will go to minimum. S/C, Drift, Leak: No effect.	50%	0%	0%	50%	1.00E-09	0.00E+00	0.00E+00	1.00E-09	Detected by user's control system diagnostics.
FIL3	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Analogue output will go to minimum. S/C, Drift, Leak: No effect.	50%	0%	0%	50%	1.00E-09	0.00E+00	0.00E+00	1.00E-09	Detected by user's control system diagnostics.
PL5	Socket, PCB, 3.5mm, 7 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Microcontroller																		
R26	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R27	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R28	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R42	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Optional termination resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R51	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	I2C pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: PCB Tempr sensor loss of communications will result in out of range internal temperature. This will flag as an alarm on the 4-20mA.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R53	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	I2C pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: PCB Tempr sensor loss of communications will result in out of range internal temperature. This will flag as an alarm on the 4-20mA.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R100	RES 115K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Over temperature shutdown output (Not used).	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R43	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R44	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R31	RES 4K3 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Providing biasing to the reference zener diode.	Open Circuit. Short Circuit.	O/C, S/C: No 5V reference, leading to pressure reading going off scale and generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by pressure sensor circuit error diagnostics.

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R34	RES 20K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Gain setting resistor.	Open Circuit. Short Circuit.	O/C, S/C: Pressure reading goes out of range and generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by pressure sensor circuit error diagnostics.
R37	RES 20K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Gain setting resistor.	Open Circuit. Short Circuit.	O/C, S/C: Pressure reading goes out of range and generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by pressure sensor circuit error diagnostics.
R35	RES 10K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Gain setting resistor.	Open Circuit. Short Circuit.	O/C, S/C: Pressure reading goes out of range and generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by pressure sensor circuit error diagnostics.
R94	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the filter circuit.	Open Circuit. Short Circuit.	O/C: No pressure signal and generates an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by pressure sensor circuit error diagnostics.
R36	RES 10K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Gain setting resistor.	Open Circuit. Short Circuit.	O/C, S/C: Pressure reading goes out of range and generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by pressure sensor circuit error diagnostics.
R45	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R46	RES 20K 0805, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R25	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Pull up resistor (believed to provide pull up function when watchdog is not in use / during programming).	Open Circuit. Short Circuit.	O/C: Watchdog o/p push pull so no effect (as pushed up to 3.3V internally). S/C: RST pin on processor forced high so no effect (although cannot reset).	90%	0%	10%	0%	1.35E-10	0.00E+00	1.50E-11	0.00E+00	
R29	RES 100R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Provides a filter to the analogue supply.	Open Circuit. Short Circuit.	O/C: Loss of microcontroller analogue power and subsequent loss of power to Digital-To-Analogue Converter (DAC). S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R32	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	2.5v reference to ADC/DAC.	Open Circuit. Short Circuit.	O/C: Loss of 2.5 reference to the DAC/ADC, leading to loss of analogue output. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R30	RES 2K2 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Digital potentiometer SPI comms pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R41	RES 1K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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R33	RES 10K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R112	RES 1K5 1206, 0.25W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C13	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C14	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C43	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C19	CAP CER 4.7nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Causes the Modbus comms to fail. Minor Leak: Indeterminate state. Major Leak: Could result in message corruption.	30%	9%	9%	52%	1.80E-10	5.40E-11	5.40E-11	3.12E-10	Detected by comms protocol.
C20	CAP CER 4.7nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Causes the Modbus comms to fail. Minor Leak: Indeterminate state. Major Leak: Could result in message corruption.	30%	9%	9%	52%	1.80E-10	5.40E-11	5.40E-11	3.12E-10	Detected by comms protocol.
C44	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC27.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC27 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by internal temperature too high error diagnostics.
C22	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C25	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C26	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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C27	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C28	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C86	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No pressure signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C68	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect S/C: Shorts the feedback resistor, leading to out of range message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C69	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the output, leading to out of range message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C23	CAP CER 470pF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the output, leading to out of range message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C24	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the output, leading to out of range message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C40	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of reference and loss of supply to pressure sensor. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C21	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of 15v supply, leading to pressure out of range error. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by pressure sensor circuit error diagnostics.
C41	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C42	CAP CER 1uF 0603, 25V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C18	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler for reset pin.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Would force the microcontroller to be constantly reset. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C16	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C12	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C35	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling the internal reference voltage.	Open Circuit. Short Circuit. Drift. Leak.	All failure modes: Loss of internal reference which is not used. No effect.	100%	0%	0%	0%	7.00E-10	0.00E+00	0.00E+00	0.00E+00	
C17	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling the internal reference voltage.	Open Circuit. Short Circuit. Drift. Leak.	All failure modes: Loss of internal reference which is not used. No effect.	100%	0%	0%	0%	6.00E-10	0.00E+00	0.00E+00	0.00E+00	
C37	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling 2.5v reference signal.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the reference, leading to analogue output going to minimum. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system diagnostics.
C38	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling 2.5v reference signal.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the reference, leading to analogue output going to minimum. Leak: Indeterminate state.	35%	5%	5%	55%	2.10E-10	3.00E-11	3.00E-11	3.30E-10	Detected by user's control system diagnostics.
C33	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
D14	LED, Blue, 20mA, 3.7V, PLCC-2	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
XT1	Crystal, 32.768KHz, 20ppm, 12.5pF	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
XT2	Crystal, 32.768KHz, 20ppm, 12.5pF	1	Crystal Unit	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Clock signal for the microcontroller.	Period Jitter. Incorrect Frequency.	Period Jitter / Incorrect Frequency: Could lead to message corruption or signal alteration - exact effect not quantified.	25%	50%	12.5%	12.5%	5.00E-09	1.00E-08	2.50E-09	2.50E-09	Detected by comms protocol.
BT1	BATTERY, NimH 2.4V,15mAH, RECHARGEABLE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
IC4	IC ds1340z-33 +, RTC Trickel Charge 12c	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP1	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP2	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP3	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC5	IC, SN65HVD12D, TxRx, 1Mbps, Half Duplex, SO8	1	Microprocessor, MOS, 10K Gates	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	RS485 interface IC. Logic converter between comms protocol RS485 and RS232.			0%	0%	10%	90%	0.00E+00	0.00E+00	8.00E-10	7.20E-09	Assumed comms DC = 90%.
IC27	IC, LM75BDP, Tempr Sens, I2C, -55/+125, +/-2C	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Temperature sensor IC.			0%	0%	50%	50%	0.00E+00	0.00E+00	6.00E-09	6.00E-09	Assumed comms DC = 50%.
IC7	IC, M25PE40, Flash, 4Mb, VFQFPN8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL8	Header, PCB, Shrouded, 2x13 Way, 2,54mm, SMT	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC8A	IC, AD8667ARZ, Dual Op-Amp, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Buffering the 5v reference voltage to the pressure sensor.	Open Circuit. Short Circuit.	O/C, S/C: No supply to pressure sensor.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by pressure sensor circuit error diagnostics.
IC8B	IC, AD8667ARZ, Dual Op-Amp, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Pressure signal conditioning.	Open Circuit. Short Circuit.	O/C, S/C: No pressure signal and go out of range.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by pressure sensor circuit error diagnostics.
IC9	IC, LM4050BIM3-5.0, Volt Ref, 5V, 50ppm	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reference voltage for the pressure sensor.	Open Circuit. Short Circuit. Zener Voltage Drift.	O/C, S/C: Potential damage to pressure sensor. Zener Voltage Drift: May give an incorrect pressure reading and subsequently an error in oxygen reading.	10%	0%	0%	90%	3.00E-10	0.00E+00	0.00E+00	2.70E-09	Detected by pressure sensor circuit error diagnostics.
IC10	Pressure Sen,15-115 kPa, 5V, 45mV/kPa, thru-hole	1	Microprocessor, Bipolar, 5K-50K Transistors	3.00E-08	3.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Pressure sensor IC.			0%	0%	50%	50%	0.00E+00	0.00E+00	1.50E-08	1.50E-08	Assumed comms DC = 50%.
TR11	TRANSISTOR, SOT-23 DIGIT, AL,	1					Not part of the safety	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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	SMT, MMUN2215LT1G						function of the device.											
TR10	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL10	CONNECTOR, PCB, 3 WAY, HEADER, VERTICAL	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC6	IC - MICR0-CONTROLLER, M, SP430FG4618IPZ, 16BIT MC	1	MOS FPGA	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Microcontroller.			0%	0%	10%	90%	0.00E+00	0.00E+00	2.00E-09	1.80E-08	Assumed comms DC = 90%.
PL7	Header, Through Hole,2.54, mm, 2x7Way, Vertical	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC3	IC, TPS3823-33, Watchdog, g 3.3V, SOT-23	1	Microprocessor, MOS, 10K Gates	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Microcontroller watchdog.	Open Circuit. Short Circuit.	O/C: No effect. S/C (to ground): Processor will hang and will not do anything. This would mean changes to detected input would not be processed and transmitted to output.	85%	0%	15%	0%	6.80E-09	0.00E+00	1.20E-09	0.00E+00	
Power Supplies Contrast																		
L5	Inductor, 220uH, 0.7A, 0.44R	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Output filter for IC23.	Open Circuit. Short Circuit.	O/C, S/C: No output from IC23, leading to subsequent loss of power rails and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	2.50E-08	Detected by user's control system and analogue input system diagnostics.
R39	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the grounds.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R49	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the grounds.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R47	RES 51K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the bias voltage for external shutdown pin of IC23.	Open Circuit. Short Circuit.	O/C: Turn IC23 output off and subsequent power rails and unit will shut down. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R48	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the bias voltage for external shutdown pin of IC23.	Open Circuit. Short Circuit.	S/C: Turn IC23 output off and subsequent power rails and unit will shut down. O/C: No effect.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by user's control system and analogue input system diagnostics.

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R83	RES 1K43 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage programming resistor for IC23.	Open Circuit. Short Circuit.	O/C: Vout ~ 1.21V instrument will not work and will be detected as error on the 4-20mA which will go to ~0mA. S/C: Vout ~ 24V Indeterminate behaviour.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R84	RES 16K5 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage programming resistor for IC23.	Open Circuit. Short Circuit.	S/C: Sensor cell supply voltage would be 24v instead of 18v, giving an indeterminate state. O/C: Output would go down to 1.21v and the subsequent power supplies will go down to 0v and unit will shut down.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R50	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the +5v digital and +5V analogue.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R38	RES 243R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage output programming resistor.	Open Circuit. Short Circuit.	O/C: Output would go down to 1.25v and the sensor supply would be too low and generate an alarm. S/C: Sensor cell supply voltage would be 24v instead of 18v but would have no effect on the safety function.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R40	RES 3K3 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage output programming resistor.	Open Circuit. Short Circuit.	O/C: Sensor cell supply voltage would be 24v instead of 18v but would have no effect on the safety function. S/C: Output would go down to 1.25v and the sensor supply would be too low and generate an alarm.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R59	RES 24K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the voltage divider circuit.	Open Circuit. Short Circuit.	O/C, S/C: Out of range O2 offset signal, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R60	RES 1K 0603, 0.063W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the voltage divider circuit.	Open Circuit. Short Circuit.	O/C, S/C: Out of range O2 offset signal, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R54	RES 510K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R52	RES 33K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R103	RES 0R0 0603, 0.1W 1%	1					Not part of the safety	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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							function of the device.											
R55	RES 15K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R56	RES 15K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R57	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R58	RES 34K8 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C31	CAP ELT 220uF G, 50V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 24v rail and shuts down the unit. Leak: Indeterminate state.	55%	7.5%	7.5%	30%	1.10E-08	1.50E-09	1.50E-09	6.00E-09	Detected by user's control system and analogue input system diagnostics.
C79	CAP ELT 68uF D, 35V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the +24v rail and shuts down the unit. Leak: Indeterminate state.	55%	7.5%	7.5%	30%	1.10E-08	1.50E-09	1.50E-09	6.00E-09	Detected by user's control system and analogue input system diagnostics.
C80	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Boost capacitor to generate the voltage at the output of the regulator.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Indeterminate state. Leak, Drift: No effect.	50%	25%	25%	0%	3.00E-10	1.50E-10	1.50E-10	0.00E+00	
C78	CAP TNT 47uF D, 20V 10%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Smoothing filter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: Ground the output of IC23 to 0V and all other subsequent power rails will fail, and unit will shut down. Drift: No effect.	5%	20%	20%	55%	3.50E-11	1.40E-10	1.40E-10	3.85E-10	Detected by user's control system and analogue input system diagnostics.
C81	CAP TNT 2.2uF B, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC21.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Ground input to IC21 and all subsequent power supplies will go to 0v and the unit will shut down. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system and analogue input system diagnostics.
C82	CAP TNT 2.2uF A, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC21.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Ground input to IC21 and all subsequent power supplies will go to 0v and the unit will shut down. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system and analogue input system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C83	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC22.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of +5v rail and subsequent power supplies and unit will shut down. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system and analogue input system diagnostics.
C84	CAP TNT 2.2uF A, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC22.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of +5v rail and subsequent power supplies and unit will shut down. Leak: Indeterminate state.	30%	10%	10%	50%	2.10E-10	7.00E-11	7.00E-11	3.50E-10	Detected by user's control system and analogue input system diagnostics.
C34	CAP ELT 33uF C, 25V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of negative voltage converter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Drift: No effect. Leak: Indeterminate state.	5%	7.5%	7.5%	80%	1.00E-09	1.50E-09	1.50E-09	1.60E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C36	CAP ELT 33uF C, 25V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of negative voltage converter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Drift: No effect. Leak: Indeterminate state.	5%	7.5%	7.5%	80%	1.00E-09	1.50E-09	1.50E-09	1.60E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C29	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 24v rail and shuts down the unit. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system and analogue input system diagnostics.
C30	CAP TNT 2.2uF B, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the sensor supply voltage, which generates an alarm. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C48	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor to IC16.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the +5v supply and loses the 2.5v reference. Leak: Indeterminate state.	10%	20%	20%	50%	6.00E-11	1.20E-10	1.20E-10	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C47	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor to IC16.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 2.5v reference, which generates an alarm. Leak: Indeterminate state.	10%	20%	20%	50%	6.00E-11	1.20E-10	1.20E-10	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C46	CAP ELT 10uF B, 16V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C64	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C70	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C71	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C65	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C67	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
D12	Diode, Schottky, 4A, 40V, SMB	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse polarity protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C, High Resistance: Disconnects the 24v rail and shuts down the unit. S/C, Low Resistance, Impedance: No effect.	82.5%	0%	0%	17.5%	4.13E-09	0.00E+00	0.00E+00	8.75E-10	Detected by user's control system and analogue input system diagnostics.
D13	Diode, Schottky, 2A, 40V, DO-214AC	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Catch diode for IC23.	Open Circuit. Short Circuit. High/Low resistance/impedance.	All failure modes: Potential for damage to IC23 and potential to lose +15v rail, leading to loss of subsequent power rails and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	5.00E-09	Detected by user's control system and analogue input system diagnostics.
FIL1	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Noise filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Disconnects the 24v rail and shuts down the unit. S/C, Drift: No effect. Leak: Indeterminate state.	30%	10%	10%	50%	6.00E-10	2.00E-10	2.00E-10	1.00E-09	Detected by user's control system and analogue input system diagnostics.
PL9	Socket, PCB, 3.5mm, 3 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
F1	Fuse with holder, SMT, 2A, fastblow, miniature	1	Fuse	1.00E-09	1.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Over current protection fuse.	Open Circuit. Short Circuit.	O/C: Disconnects the 24v rail and shuts down the unit. S/C: No effect.	50%	0%	0%	50%	5.00E-10	0.00E+00	0.00E+00	5.00E-10	Detected by user's control system and analogue input system diagnostics.
Z6	PCB Test Points, Through	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Z7	PCB Test Points, Through	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC23	IC, LM2675M-ADJ, Vreg, Adj, Switching	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Switching voltage regulator IC.	Open Circuit. Short Circuit. Incorrect Switching Frequency.	O/C, S/C: Loss of +15v rail, which will shut down the unit. Incorrect Switching Frequency: No effect.	50%	0%	0%	50%	6.00E-09	0.00E+00	0.00E+00	6.00E-09	Detected by user's control system and analogue input system diagnostics.

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IC21	IC, MC78M05BDTG, VReg, 5V, 0.5A, Linear	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	5v linear regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No 5v rail and subsequent power supplies will fail and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by user's control system and analogue input system diagnostics.
IC22	IC - +3.3V REGULATOR, L4, 931CD33, SMD	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	3.3v linear regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No 3.3v rail and subsequent power supplies will fail and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by user's control system and analogue input system diagnostics.
IC12	IC, TC7662BEOA, V Conver, -15V, 40mA, Switching	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage regulator IC.	Open Circuit. Short Circuit. Incorrect Switching Frequency.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Incorrect Switching Frequency: No effect.	50%	0%	0%	50%	6.00E-09	0.00E+00	0.00E+00	6.00E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC11	IC, LM317AMDT, V Reg, Linear, Adj, 0.5A	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No voltage supply to sensor cell and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC16	IC, LM4132CMF-2.5, Vref, 2.5V, 20ppm, SOT23	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage reference IC.	Open Circuit. Short Circuit.	O/C, S/C: Gives no 2.5v reference, which generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by Sensor cell temperature unstable error diagnostics.
IC25A	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Op amp for buffering the O2 offset signal.	Open Circuit. Short Circuit.	O/C, S/C: No O2 offset signal and generate and alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by % O_2 beyond calibration range error diagnostics.
IC15A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC15B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC14A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC14B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Sensor Bridge Drive / Conditioning																		
L3	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter.	Open Circuit. Short Circuit.	O/C: Loss of negative input to IC18, which generates an alarm. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by % O_2 beyond calibration range error diagnostics.

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L4	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter.	Open Circuit. Short Circuit.	O/C: Loss of negative input to IC18, which generates an alarm. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by % O_2 beyond calibration range error diagnostics.
R61	RES 1K 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Provides a start-up current to the sensor.	Open Circuit. Short Circuit.	O/C: No effect. S/C: Would over drive the circuit, leading to a very high O2 signal.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R64	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Biases transistor TR8.	Open Circuit. Short Circuit.	O/C: Indeterminate state. S/C: Would over drive the circuit, leading to a very high O2 signal.	0%	40%	40%	20%	0.00E+00	6.00E-11	6.00E-11	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R66	RES 4K99 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Biases transistor TR8.	Open Circuit. Short Circuit.	O/C: Would go fully on. S/C: Indeterminate state.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R85	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Will saturate op amp IC19A. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R68	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Set the gain of op amp IC19A.	Open Circuit. Short Circuit.	O/C, S/C: Will saturate op amp IC19A.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R74	RES 4K99 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Set the gain of op amp IC19A.	Open Circuit. Short Circuit.	O/C, S/C: Will saturate op amp IC19A.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R73	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Input bias for IC19B.	Open Circuit. Short Circuit.	O/C: Would give 0v on output of IC19B and generate alarm. S/C: Would generate error message.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error diagnostics.

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R71	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the gain on op amp IC19A.	Open Circuit. Short Circuit.	O/C: Sensor thermistors would be over driven, which would generate an alarm. S/C: Sensor thermistors would be under driven, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R75	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Sensor would go over range. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R98	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the gain on op amp IC19A.	Open Circuit. Short Circuit.	O/C: Sensor thermistors would be over driven, which would generate an alarm. S/C: Sensor thermistors would be under driven, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R76	RES 13K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Input bias for IC19B.	Open Circuit. Short Circuit.	O/C: Would give 0v on output of IC19B and generate alarm. S/C: Would generate error message.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error diagnostics.
R63	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias O2 signal from sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: O2 signal would swing low and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R70	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias O2 signal from sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: O2 signal would swing high and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R82	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: No O2 signal, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R78	RES 510K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of input to IC19B. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.
R79	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: IC19B output would saturate. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.
R81	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: No O2 sensor condition signal. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R65	RES 4K02 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of O2 signal into IC18, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R67	RES 4K02 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of O2 signal into IC18, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R87	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R88	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R89	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R90	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R91	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R99	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Over range gain, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
C52	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No drive to sensor, which would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C32	CAP TNT 10uF C, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No drive to sensor, which would generate an alarm. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C57	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v, leading to error message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C60	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Indeterminate state. S/C: Would over drive the circuit, leading to an over range O2 signal and therefore will be detected as an alarm condition on the 4-20mA o/p. Leak, Drift: No effect.	40%	5%	5%	50%	2.40E-10	3.00E-11	3.00E-11	3.00E-10	
C61	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of one of the supplies, which would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C49	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15 supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C50	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15 supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C55	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of IC17 decoupling.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: IC17 may malfunction and generate an alarm. Drift: No effect.	20%	15%	15%	50%	1.20E-10	9.00E-11	9.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C62	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the input to op amp IC19B and would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error diagnostics.
C76	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No sensor condition signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error diagnostics.
C77	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No O2 signal and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C63	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of IC20 decoupling.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: IC20 may malfunction and generate an alarm. Drift: No effect.	20%	15%	15%	50%	1.20E-10	9.00E-11	9.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function **Comments**
C58	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on +15v supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C59	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C56	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on +15V supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C54	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Zero output of IC18 and generated an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C75	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on -15v supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the -15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C51	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the negative input to IC18 and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C53	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the positive input to IC18 and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
ZD2	Zener Diode, MMSZ6V2T1G, 6.2V, 0.5A	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Limits the voltage on the base of TR8.	Open Circuit. Short Circuit. Zener Voltage Drift.	O/C: No control signal to TR8, leading to the sensor to be under driven and therefore will be detected as an alarm condition on the 4-20mA o/p. S/C: Over range control signal to TR8, leading to the sensor to be over driven and therefore will be detected as an alarm condition on the 4-20mA o/p. Zener Voltage Drift: No effect.	10%	0%	0%	90%	3.00E-10	0.00E+00	0.00E+00	2.70E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
TR8	Transistor, PNP, MJD32CG, 3A, 1.5W, DPAK	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Drives the sensor thermistors.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: No / very little O2 signal. S/C: Would over drive the system. Leakage, Low Gain: No effect.	20%	0%	0%	80%	2.00E-08	0.00E+00	0.00E+00	8.00E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function **Comments**
IC17	IC, AD5293BRUZ-20, 1%, Digipot, 20K, 10bit, SPI	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Zero the O2 signal output from sensor.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%. for
IC20	IC, AD5293BRUZ-20, 1%, Digipot, 20K, 10bit, SPI	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Digital gain setting potentiometer.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%. for?
IC18	IC, AD8221ARMZ, Instrum Amp, high CMRR	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Instrumentation amplifier.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%.
IC19A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Control op amp for the sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: No control to the sensor, leading to alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC19B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	O2 sensor signal condition buffer.	Open Circuit. Short Circuit.	O/C, S/C: No O2 sensor condition signal, leading to alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by O_2 sensor circuit error diagnostics.

Summary: Function Block (XTC601)					
Block	**Total Non-Safety Related Failure λ(NSR) (/hr)**	**Total λS (/hr)**	**Total λDU (/hr)**	**Total λDD (/hr)**	**SFF (%)**
Alarm Relays / Cell Temperature	2.52E-08	1.30E-07	5.34E-09	9.84E-08	97.72%
4-20mA Analog Inputs	Non Safety Related Block				
4-20mA Analog Outputs	1.37E-08	7.55E-09	7.55E-09	2.50E-07	97.15%
Microcontroller	1.58E-08	1.05E-08	1.30E-08	3.75E-08	78.70%
Power Supplies Contrast	4.37E-08	7.06E-09	7.06E-09	1.15E-07	94.55%
Sensor Bridge Drive / Conditioning	3.24E-08	1.27E-09	5.72E-09	1.99E-07	97.20%
Total	**1.31E-07**	**1.57E-07**	**3.87E-08**	**7.00E-07**	**95.68%**

Block:	**XTC601 Binary Gas Analyser**
Safety Function:	**Ability to detect target gas in another gas stream and generate a 4-20mA output (resolution 0.038% of available span - informative only, not safety criteria)**
Diagnostic Measures:	**Watchdog for the microcontroller which will try to reset microcontroller** **Sensor cell temperature unstable error (50 degC required for accurate detection), which produces an alarm and forces the output to a safe state** **O_2 sensor circuit error, which will give warning on display and will be available as a warning to user via Modbus communications** **Internal temperature too high error, which will give warning on display and will be available as a warning to user via Modbus communications. Analogue output will indicate a fault condition** **External sensor signal out of range error, which will output an alarm (internal to unit) - Not Safety Related** **% O_2 beyond calibration range error, which will output an alarm (internal to unit)**
Safe Failure Mode:	**Detection of target gas without presence of target gas in gas stream** **4-20mA signal generated without gas detection** **Modbus signal generated without gas detection**
Dangerous Failure Mode:	**Failure to detect target gas when target gas is present** **Failure to generate 4-20mA / Modbus signal output**
Environmental Profile (if applicable):	**Operating Temperature: 5 - 55 degC**

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function **Comments**
Alarm Relays / Cell Temp																		
L1	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Noise filter.	Open Circuit. Short Circuit.	O/C: Cell temperature reading would be out of range but would be detected by the sensor cell unstable signal. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by Sensor cell temperature unstable error diagnostics.
L2	Ferrite Bead, 0603, 60ohms, 3A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Noise suppression inductor.	Open Circuit. Short Circuit.	O/C: No heater drive and the heater will go below its range. Sensor cell will no longer heat up, causing a 4-20mA alarm condition. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by Sensor cell temperature unstable error diagnostics.
R1	RES 100R 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage divider resistor. Drops voltage to 5v between the coil and supply.	Open Circuit. Short Circuit.	O/C: Relay will remain in its non-powered state preventing alarm 1 function (externally set by the user). S/C: Applies 15v to the relay. Relay will still function without issue according to manufacturers.	20%	0%	80%	0%	3.00E-11	0.00E+00	1.20E-10	0.00E+00	This will be used in a detection only function.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R2	RES 100R 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage divider resistor. Drops voltage to 5v between the coil and supply.	Open Circuit. Short Circuit.	O/C: Relay will remain in its non-powered state preventing alarm 2 function (externally set by the user). S/C: Applies 15v to the relay. Relay will still function without issue according to manufacturers.	20%	0%	80%	0%	3.00E-11	0.00E+00	1.20E-10	0.00E+00	This will be used in a detection only function.
R3	RES 10K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias for the cell temperature sensor.	Open Circuit. Short Circuit.	O/C, S/C: Temperature would be out of range but would be detected by the sensor cell unstable signal.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R4	RES 330R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Limits the current on the gate.	Open Circuit. Short Circuit.	O/C: Does not have a drive on the gate and therefore the heater would be off but would be detected by the sensor cell unstable signal. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by Sensor cell temperature unstable error diagnostics.
R93	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of a filter circuit.	Open Circuit. Short Circuit.	O/C: No temperature signal, causing temperature out of range error. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by Sensor cell temperature unstable error diagnostics.
D1	DIODE, SMT, SIGNAL, BAS2, 0, SOT-23 PACKAGE	1	Diode, Silicon Signal	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Conducts back EMF on the coil.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Potential damage to TR2, causing alarm 1 to fail. S/C: Alarm 1 will not switch. High resistance, high impedance: No effect Low resistance, low impedance: Potential to cause alarm 1 not to switch.	7.5%	0%	92.5%	0%	5.25E-11	0.00E+00	6.48E-10	0.00E+00	
D2	DIODE, SMT, SIGNAL, BAS2, 0, SOT-23 PACKAGE	1	Diode, Silicon Signal	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Conducts back EMF on the coil.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Potential damage to TR2, causing alarm 2 to fail. S/C: Alarm 2 will not switch. High resistance, high impedance: No effect Low resistance, low impedance: Potential to cause alarm 2 not to switch.	7.5%	0%	92.5%	0%	5.25E-11	0.00E+00	6.48E-10	0.00E+00	
D3	Diode, Fast Recovery, 1A, 1000V, SMF	1	Diode, Si Rectifier, <3A	4.00E-09	4.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Resistive heater.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: No effect. S/C: Heater would always be off. High, Low resistance, Impedance: Indeterminate state.	10%	7.5%	7.5%	75%	4.00E-10	3.00E-10	3.00E-10	3.00E-09	Detected by Sensor cell temperature unstable error diagnostics.
C1	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Temperature would be out of range but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.

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C2	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Heater would always be off but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C3	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Heater would always be off but would be detected by the sensor cell unstable signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C66	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling on the power rail to IC25B.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 5v rail to ground and IC25B will malfunction, resulting in temperature out of range error. Drift: Indeterminate state. Major leak capable of causing short 5v rail to ground, resulting in temperature out of range error. Minor Leak: No effect.	28%	10%	10%	52%	1.68E-10	6.00E-11	6.00E-11	3.12E-10	Detected by Sensor cell temperature unstable error diagnostics.
C85	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of a filter circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No temperature signal, causing temperature out of range error. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
ZD1	Diode BZX84-C3V0 ZENER, 3V 5% 250mW SOT-23-3	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Clamps the voltage so that it does not go above the Vgs of the transistor.	Open Circuit. Short Circuit. Zener Voltage Drift.	All failure modes: No effect:	100%	0%	0%	0%	3.00E-09	0.00E+00	0.00E+00	0.00E+00	
TR1	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Alarm 1 relay switching transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Alarm 1 output will be inactive. S/C: Alarm 1 output will always be activate and not change state. Leakage, Low Gain: No effect.	20%	60%	20%	0%	1.60E-09	4.80E-09	1.60E-09	0.00E+00	
TR2	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Alarm 2 relay switching transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Alarm 2 output will be inactive. S/C: Alarm 2 output will always be activate and not change state. Leakage, Low Gain: No effect.	20%	60%	20%	0%	1.60E-09	4.80E-09	1.60E-09	0.00E+00	

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RL1	RELAY, PCB MOUNTING, SPC, O, 12VDC, 10A, 240V	1	Relay, Contact, Miniature	6.00E-08	6.00E-08	Nonelectronic Parts Reliability Data 2011, 2-717.	Alarm 1 relay output.	Contact Open. Contact Short. Coil Failure.	Contact stuck open, Coil Failure: Alarm 1 output will always be inactive (detected if does not match the Modbus signals). The user would have to compare the status of the relay as reported via the Modbus message with the status of the relay as read from the actual relay contacts. If both conditions do not match, then the user will be expected to detect that as a stuck relay failure and put the process into a safe condition via the users own fault relay. Contact stuck short: Alarm 1 output will always be active.	0%	100%	0%	0%	0.00E+00	6.00E-08	0.00E+00	0.00E+00	Component failure rate data assumed to be equivalent to standard miniature relay.
RL2	RELAY, PCB MOUNTING, SPC, O, 12VDC, 10A, 240V	1	Relay, Contact, Miniature	6.00E-08	6.00E-08	Nonelectronic Parts Reliability Data 2011, 2-717.	Alarm 2 relay output.	Contact Open. Contact Short. Coil Failure.	Contact stuck open, Coil Failure: Alarm 2 output will always be inactive (detected if does not match the Modbus signals). The user would have to compare the status of the relay as reported via the Modbus message with the status of the relay as read from the actual relay contacts. If both conditions do not match, then the user will be expected to detect that as a stuck relay failure and put the process into a safe condition via the users own fault relay. Contact stuck short: Alarm 2 output will always be active.	0%	100%	0%	0%	0.00E+00	6.00E-08	0.00E+00	0.00E+00	Component failure rate data assumed to be equivalent to standard miniature relay.
PL1	Socket, PCB, 6 Way, 3.5mm, Through hole, Blk	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL3	Header, PCB, RA, 3.9mm, 8 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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TR3	Transistor, SI4840BDY, MOSFET, 40V, 19A, 0.009R	1	Transistor, FET, Power >5W	5.00E-08	5.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Driving the heater.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Heater would be off but would be detected by the sensor cell unstable signal. S/C: Heater would always be on but would be detected by the sensor cell unstable signal. Leakage: No effect. Low Gain: No effect.	20%	0%	0%	80%	1.00E-08	0.00E+00	0.00E+00	4.00E-08	Detected by Sensor cell temperature unstable error diagnostics.
PL2	Header, 8 Way, RA, 2.54mm	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC25B	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Buffering the temperature signal to the Analogue Digital Converter (ADC).	Open Circuit. Short Circuit.	O/C, S/C: No temperature signal output, causing temperature out of range error.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by Sensor cell temperature unstable error diagnostics.
4-20mA Analog Inputs																		
R5	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R6	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R7	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R8	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R9	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R10	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R11	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R12	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R13	RES 16K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R14	RES 18K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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C15	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C39	CAP ELT 33uF C, 25V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C4	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C5	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C6	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C7	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C72	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL4	Socket, PCB, 6 way, 3.5mm, Through Hole	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP4	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC24A	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC24B	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4-20mA Analog Outputs																		
R15	RES 100R 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Current range resistor.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R16	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the output current levels.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R17	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protection for transistor, TR5.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R18	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the gain setting for IC2.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R19	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets up the analogue 4-20mA output.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R20	RES 100R 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Current range resistor.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R21	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the output current levels.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R22	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protection for transistor, TR7.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R23	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the gain setting for IC2.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully on. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R24	RES 470R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets up the analogue 4-20mA output.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by user's control system diagnostics.
R101	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protecting transistor TR4 from being over driven.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R102	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Protecting transistor TR6 from being over driven.	Open Circuit. Short Circuit.	O/C: Analogue output will be fully off. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C8	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of decoupling for IC2.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 15v rail to ground and IC2 will malfunction, resulting in no analogue output 1. Drift: Indeterminate state. Major leak capable of causing short 15v rail to ground, resulting in no analogue output 1. Minor Leak: No effect.	28%	10%	10%	52%	1.68E-10	6.00E-11	6.00E-11	3.12E-10	Detected by user's control system diagnostics.
C87	CAP TNT 10uF C, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of decoupling for IC2.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Shorts the power supply 15v rail to ground and IC2 will malfunction, resulting in no analogue output 1. Drift: Indeterminate state. Major leak capable of causing short 15v rail to ground, resulting in no analogue output 1. Minor Leak: No effect.	39%	2.5%	2.5%	56%	2.73E-10	1.75E-11	1.75E-11	3.92E-10	Detected by user's control system diagnostics.
C9	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Set the analogue output to minimum. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system diagnostics.
C11	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Set the analogue output to minimum. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system diagnostics.
D15	Diode, Schottky, 30mA	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Analogue output will be fully off. S/C, Low Resistance: No effect. High Resistance, Impedance: Indeterminate effect.	75%	7.5%	7.5%	10%	3.75E-09	3.75E-10	3.75E-10	5.00E-10	Detected by user's control system diagnostics.
D16	Diode, Schottky, 30mA	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C: Analogue output will be fully off. S/C, Low Resistance: No effect. High Resistance, Impedance: Indeterminate effect.	75%	7.5%	7.5%	10%	3.75E-09	3.75E-10	3.75E-10	5.00E-10	Detected by user's control system diagnostics.
IC2A	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal conditioning.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
IC2B	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal drive.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
IC2C	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal conditioning.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
IC2D	IC, LMC6484, Quad Op-Amp, Rail to Rail, SIOC-14	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	4-20mA signal drive.	Open Circuit. Short Circuit.	O/C, S/C: Analogue output will be fully off.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by user's control system diagnostics.
TR4	TRANSISTOR, SMT, BC850B, NPN, SOT23 PACKAGE	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the analogue 4-20mA output.	Open Circuit. Short Circuit. Leakage. Low Gain.	S/C: Analogue output fully on (load > 70mA) = Fully on. O/C: Analogue output = 8mA = Indeterminate. Leakage, Low Gain: No effect.	20%	10%	10%	60%	1.60E-09	8.00E-10	8.00E-10	4.80E-09	Detected by user's control system diagnostics.
TR6	TRANSISTOR, SMT, BC850B, NPN, SOT23 PACKAGE	1	Transistors, Silicon Bipolar Small Signal (< 5OOmW)	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the analogue 4-20mA output.	Open Circuit. Short Circuit. Leakage. Low Gain.	S/C: Analogue output fully on (load > 70mA) = Fully on. O/C: Analogue output = 8mA = Indeterminate. Leakage, Low Gain: No effect.	20%	10%	10%	60%	1.60E-09	8.00E-10	8.00E-10	4.80E-09	Detected by user's control system diagnostics.
TR5	TRANSISTOR, SMT, FZT751, (2W), PNP	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Analogue output drive transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on. Leakage / Low Gain: Indeterminate state.	0%	2.5%	2.5%	95%	0.00E+00	2.50E-09	2.50E-09	9.50E-08	Detected by user's control system diagnostics.
TR7	TRANSISTOR, SMT, FZT751, (2W), PNP	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Analogue output drive transistor.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: Analogue output will be fully off. S/C: Analogue output will be fully on. Leakage / Low Gain: Indeterminate state.	0%	2.5%	2.5%	95%	0.00E+00	2.50E-09	2.50E-09	9.50E-08	Detected by user's control system diagnostics.
FIL2	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Analogue output will go to minimum. S/C, Drift, Leak: No effect.	50%	0%	0%	50%	1.00E-09	0.00E+00	0.00E+00	1.00E-09	Detected by user's control system diagnostics.
FIL3	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Analogue output will go to minimum. S/C, Drift, Leak: No effect.	50%	0%	0%	50%	1.00E-09	0.00E+00	0.00E+00	1.00E-09	Detected by user's control system diagnostics.
PL5	Socket, PCB, 3.5mm, 7 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Microcontroller																		
R26	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R27	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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R28	RES 47K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R42	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Optional termination resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R51	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	I2C pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: PCB Tempr sensor loss of communications will result in out of range internal temperature. This will flag as an alarm on the 4-20mA.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R53	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	I2C pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: PCB Tempr sensor loss of communications will result in out of range internal temperature. This will flag as an alarm on the 4-20mA.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by Sensor cell temperature unstable error diagnostics.
R100	RES 115K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Over temperature shutdown output (Not used).	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R43	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R44	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R45	RES 100R 0603, 0.1W 0.1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R46	RES 20K 0805, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R25	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Pull up resistor (believed to provide pull up function when watchdog is not in use / during programming).	Open Circuit. Short Circuit.	O/C: Watchdog o/p push pull so no effect (as pushed up to 3.3V internally). S/C: RST pin on processor forced high so no effect (although cannot reset).	90%	0%	10%	0%	1.35E-10	0.00E+00	1.50E-11	0.00E+00	
R29	RES 100R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Provides a filter to the analogue supply.	Open Circuit. Short Circuit.	O/C: Loss of microcontroller analogue power and subsequent loss of power to Digital Analogue Converter (DAC). S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.

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R32	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	2.5v reference to ADC/DAC.	Open Circuit. Short Circuit.	O/C: Loss of 2.5 reference to the DAC/ADC, leading to loss of analogue output. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system diagnostics.
R30	RES 2K2 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Digital potentiometer SPI comms pull up resistor.	Open Circuit. Short Circuit.	O/C, S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R41	RES 1K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R33	RES 10K 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R112	RES 1K5 1206, 0.25W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C13	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C14	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C43	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C19	CAP CER 4.7nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Causes the Modbus comms to fail. Minor Leak: Indeterminate state. Major Leak: Could result in message corruption.	30%	9%	9%	52%	1.80E-10	5.40E-11	5.40E-11	3.12E-10	Detected by comms protocol.
C20	CAP CER 4.7nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Causes the Modbus comms to fail. Minor Leak: Indeterminate state. Major Leak: Could result in message corruption.	30%	9%	9%	52%	1.80E-10	5.40E-11	5.40E-11	3.12E-10	Detected by comms protocol.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C44	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC27.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC27 to malfunction. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by internal temperature too high error diagnostics.
C22	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C25	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C26	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C27	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C28	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C41	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C42	CAP CER 1uF 0603, 25V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C18	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler for reset pin.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Would force the microcontroller to be constantly reset. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C16	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.
C12	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling to IC6.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v rail and cause IC6 to malfunction. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by analogue output going low, which can be detected by the user's control system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C35	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling the internal reference voltage.	Open Circuit. Short Circuit. Drift. Leak.	All failure modes: Loss of internal reference which is not used. No effect.	100%	0%	0%	0%	7.00E-10	0.00E+00	0.00E+00	0.00E+00	
C17	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling the internal reference voltage.	Open Circuit. Short Circuit. Drift. Leak.	All failure modes: Loss of internal reference which is not used. No effect.	100%	0%	0%	0%	6.00E-10	0.00E+00	0.00E+00	0.00E+00	
C37	CAP TNT 10uF A, 6.3V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling 2.5v reference signal.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the reference, leading to analogue output going to minimum. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system diagnostics.
C38	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupling 2.5v reference signal.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the reference, leading to analogue output going to minimum. Leak: Indeterminate state.	35%	5%	5%	55%	2.10E-10	3.00E-11	3.00E-11	3.30E-10	Detected by user's control system diagnostics.
C33	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
D14	LED, Blue, 20mA, 3.7V, PLCC-2	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
XT1	Crystal, 32.768KHz, 20ppm, 12.5pF	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
XT2	Crystal, 32.768KHz, 20ppm, 12.5pF	1	Crystal Unit	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Clock signal for the microcontroller.	Period Jitter. Incorrect Frequency.	Period Jitter / Incorrect Frequency: Could lead to message corruption or signal alteration - exact effect not quantified.	25%	50%	12.5%	12.5%	5.00E-09	1.00E-08	2.50E-09	2.50E-09	Detected by comms protocol.
BT1	BATTERY, NimH 2.4V,15mAH, RECHARGEABLE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC4	IC ds1340z-33 +, RTC Trickel Charge 12c	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP1	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP2	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
JMP3	SOCKET, JUMPER, 0.1" PITCH, BLUE	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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IC5	IC, SN65HVD12D, TxRx, 1Mbps, Half Duplex, SO8	1	Microprocessor, MOS, 10K Gates	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	RS485 interface IC. Logic converter between comms protocol RS485 and RS232.			0%	0%	10%	90%	0.00E+00	0.00E+00	8.00E-10	7.20E-09	Assumed comms DC = 90%.
IC27	IC, LM75BDP, Tempr Sens, I2C, -55/+125, +/-2C	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Temperature sensor IC.			0%	0%	50%	50%	0.00E+00	0.00E+00	6.00E-09	6.00E-09	Assumed comms DC = 50%.
IC7	IC, M25PE40, Flash, 4Mb, VFQFPN8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL8	Header, PCB, Shrouded, 2x13 Way, 2,54mm, SMT	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
TR11	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
TR10	TRANSISTOR, SOT-23 DIGIT, AL, SMT, MMUN2215LT1G	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
PL10	CONNECTOR, PCB, 3 WAY, HEADER, VERTICAL	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC6	IC - MICR0-CONTROLLER, M, SP430FG4618IPZ, 16BIT MC	1	MOS FPGA	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Microcontroller.			0%	0%	10%	90%	0.00E+00	0.00E+00	2.00E-09	1.80E-08	Assumed comms DC = 90%.
PL7	Header, Through Hole,2.54, mm, 2x7Way, Vertical	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC3	IC, TPS3823-33, Watchdog, g 3.3V, SOT-23	1	Microprocessor, MOS, 10K Gates	8.00E-09	8.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Microcontroller watchdog.	Open Circuit. Short Circuit.	O/C: No effect. S/C (to ground): Processor will hang and will not do anything. This would mean changes to detected input would not be processed and transmitted to output.	85%	0%	15%	0%	6.80E-09	0.00E+00	1.20E-09	0.00E+00	
Power Supplies Contrast																		
L5	Inductor, 220uH, 0.7A, 0.44R	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Output filter for IC23.	Open Circuit. Short Circuit.	O/C, S/C: No output from IC23, leading to subsequent loss of power rails and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	2.50E-08	Detected by user's control system and analogue input system diagnostics.

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R39	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the grounds.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R49	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the grounds.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R47	RES 51K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the bias voltage for external shutdown pin of IC23.	Open Circuit. Short Circuit.	O/C: Turn IC23 output off and subsequent power rails and unit will shut down. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R48	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the bias voltage for external shutdown pin of IC23.	Open Circuit. Short Circuit.	S/C: Turn IC23 output off and subsequent power rails and unit will shut down. O/C: No effect.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by user's control system and analogue input system diagnostics.
R83	RES 1K43 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage programming resistor for IC23.	Open Circuit. Short Circuit.	O/C: Vout ~ 1.21V instrument will not work and will be detected as error on the 4-20mA which will go to ~0mA. S/C: Vout ~ 24V Indeterminate behaviour.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R84	RES 16K5 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage programming resistor for IC23.	Open Circuit. Short Circuit.	S/C: Sensor cell supply voltage would be 24v instead of 18v, giving an indeterminate state. O/C: Output would go down to 1.21v and the subsequent power supplies will go down to 0v and unit will shut down.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by user's control system and analogue input system diagnostics.
R50	RES 0R 1206, 0.25W 5%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Separate the +5v digital and +5V analogue.	Open Circuit. Short Circuit.	O/C: No effect. S/C: No effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R38	RES 243R 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage output programming resistor.	Open Circuit. Short Circuit.	O/C: Output would go down to 1.25v and the sensor supply would be too low and generate an alarm. S/C: Sensor cell supply voltage would be 24v instead of 18v but would have no effect on the safety function.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.

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R40	RES 3K3 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage output programming resistor.	Open Circuit. Short Circuit.	O/C: Sensor cell supply voltage would be 24v instead of 18v but would have no effect on the safety function. S/C: Output would go down to 1.25v and the sensor supply would be too low and generate an alarm.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R59	RES 24K 0603, 0.1W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the voltage divider circuit.	Open Circuit. Short Circuit.	O/C, S/C: Out of range O2 offset signal, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R60	RES 1K 0603, 0.063W 0.1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of the voltage divider circuit.	Open Circuit. Short Circuit.	O/C, S/C: Out of range O2 offset signal, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R54	RES 510K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R52	RES 33K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R103	RES 0R0 0603, 0.1W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R55	RES 15K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R56	RES 15K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R57	RES 115K 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
R58	RES 34K8 0603, 0.063W 1%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C31	CAP ELT 220uF G, 50V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 24v rail and shuts down the unit. Leak: Indeterminate state.	55%	7.5%	7.5%	30%	1.10E-08	1.50E-09	1.50E-09	6.00E-09	Detected by user's control system and analogue input system diagnostics.
C79	CAP ELT 68uF D, 35V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the +24v rail and shuts down the unit. Leak: Indeterminate state.	55%	7.5%	7.5%	30%	1.10E-08	1.50E-09	1.50E-09	6.00E-09	Detected by user's control system and analogue input system diagnostics.

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C80	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Boost capacitor to generate the voltage at the output of the regulator.	Open Circuit. Short Circuit. Drift. Leak.	O/C: No effect. S/C: Indeterminate state. Leak, Drift: No effect.	50%	25%	25%	0%	3.00E-10	1.50E-10	1.50E-10	0.00E+00	
C78	CAP TNT 47uF D, 20V 10%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Smoothing filter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: Ground the output of IC23 to 0V and all other subsequent power rails will fail, and unit will shut down. Drift: No effect.	5%	20%	20%	55%	3.50E-11	1.40E-10	1.40E-10	3.85E-10	Detected by user's control system and analogue input system diagnostics.
C81	CAP TNT 2.2uF B, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC21.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Ground input to IC21 and all subsequent power supplies will go to 0v and the unit will shut down. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system and analogue input system diagnostics.
C82	CAP TNT 2.2uF A, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC21.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Ground input to IC21 and all subsequent power supplies will go to 0v and the unit will shut down. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by user's control system and analogue input system diagnostics.
C83	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC22.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of +5v rail and subsequent power supplies and unit will shut down. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system and analogue input system diagnostics.
C84	CAP TNT 2.2uF A, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor for IC22.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of +5v rail and subsequent power supplies and unit will shut down. Leak: Indeterminate state.	30%	10%	10%	50%	2.10E-10	7.00E-11	7.00E-11	3.50E-10	Detected by user's control system and analogue input system diagnostics.
C34	CAP ELT 33uF C, 25V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of negative voltage converter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Drift: No effect. Leak: Indeterminate state.	5%	7.5%	7.5%	80%	1.00E-09	1.50E-09	1.50E-09	1.60E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C36	CAP ELT 33uF C, 25V 20%	1	Capacitor, Electrolytic Aluminium Foil	2.00E-08	2.00E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of negative voltage converter.	Open Circuit. Short Circuit. Drift. Leak.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Drift: No effect. Leak: Indeterminate state.	5%	7.5%	7.5%	80%	1.00E-09	1.50E-09	1.50E-09	1.60E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C29	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 24v rail and shuts down the unit. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by user's control system and analogue input system diagnostics.
C30	CAP TNT 2.2uF B, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the sensor supply voltage, which generates an alarm. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C48	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor to IC16.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the +5v supply and loses the 2.5v reference. Leak: Indeterminate state.	10%	20%	20%	50%	6.00E-11	1.20E-10	1.20E-10	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C47	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor to IC16.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 2.5v reference, which generates an alarm. Leak: Indeterminate state.	10%	20%	20%	50%	6.00E-11	1.20E-10	1.20E-10	3.00E-10	Detected by Sensor cell temperature unstable error diagnostics.
C46	CAP ELT 10uF B, 16V 20%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C64	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C70	CAP CER 10nF 0603, 50V 10% X7R	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C71	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C65	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
C67	CAP 100nF 0603, 50V 10%	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
D12	Diode, Schottky, 4A, 40V, SMB	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Reverse polarity protection diode.	Open Circuit. Short Circuit. High/Low resistance/impedance.	O/C, High Resistance: Disconnects the 24v rail and shuts down the unit. S/C, Low Resistance, Impedance: No effect.	82.5%	0%	0%	17.5%	4.13E-09	0.00E+00	0.00E+00	8.75E-10	Detected by user's control system and analogue input system diagnostics.
D13	Diode, Schottky, 2A, 40V, DO-214AC	1	Diode, Si, Schottky	5.00E-09	5.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Catch diode for IC23.	Open Circuit. Short Circuit. High/Low resistance/impedance.	All failure modes: Potential for damage to IC23 and potential to lose +15v rail, leading to loss of subsequent power rails and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	5.00E-09	Detected by user's control system and analogue input system diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
FIL1	CAPACITOR, 3 TERMINAL WI, TH FERRITE BEADS, SMD	1	EMC Filter, Signal	2.00E-09	2.00E-09	Electrical & Mechanical Component Reliability Handbook, Third Edition - Volume 1: Electrical.	Noise filter. Part of the signal transducer circuit.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Disconnects the 24v rail and shuts down the unit. S/C, Drift: No effect. Leak: Indeterminate state.	30%	10%	10%	50%	6.00E-10	2.00E-10	2.00E-10	1.00E-09	Detected by user's control system and analogue input system diagnostics.
PL9	Socket, PCB, 3.5mm, 3 Way	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
F1	Fuse with holder, SMT, 2A, fastblow, miniature	1	Fuse	1.00E-09	1.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Over current protection fuse.	Open Circuit. Short Circuit.	O/C: Disconnects the 24v rail and shuts down the unit. S/C: No effect.	50%	0%	0%	50%	5.00E-10	0.00E+00	0.00E+00	5.00E-10	Detected by user's control system and analogue input system diagnostics.
Z6	PCB Test Points, Through	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Z7	PCB Test Points, Through	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC23	IC, LM2675M-ADJ, Vreg, Adj, Switching	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Switching voltage regulator IC.	Open Circuit. Short Circuit. Incorrect Switching Frequency.	O/C, S/C: Loss of +15v rail, which will shut down the unit. Incorrect Switching Frequency: No effect.	50%	0%	0%	50%	6.00E-09	0.00E+00	0.00E+00	6.00E-09	Detected by user's control system and analogue input system diagnostics.
IC21	IC, MC78M05BDTG, VReg, 5V, 0.5A, Linear	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	5v linear regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No 5v rail and subsequent power supplies will fail and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by user's control system and analogue input system diagnostics.
IC22	IC - +3.3V REGULATOR, L4, 931CD33, SMD	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	3.3v linear regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No 3.3v rail and subsequent power supplies will fail and unit will shut down.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by user's control system and analogue input system diagnostics.
IC12	IC, TC7662BEOA, V Conver, -15V, 40mA, Switching	1	Microprocessor, MOS, 5K-50K Transistors	1.20E-08	1.20E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage regulator IC.	Open Circuit. Short Circuit. Incorrect Switching Frequency.	O/C, S/C: Loss of -15v rail, leading to sensor conditioning circuitry failure. Incorrect Switching Frequency: No effect.	50%	0%	0%	50%	6.00E-09	0.00E+00	0.00E+00	6.00E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC11	IC, LM317AMDT, V Reg, Linear, Adj, 0.5A	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage regulator IC.	Open Circuit. Short Circuit.	O/C, S/C: No voltage supply to sensor cell and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC16	IC, LM4132CMF-2.5, Vref, 2.5V, 20ppm, SOT23	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Voltage reference IC.	Open Circuit. Short Circuit.	O/C, S/C: Gives no 2.5v reference, which generates an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by Sensor cell temperature unstable error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function **Comments**
IC25A	IC, AD8602ARMZ, Quad, Opamp, Precision, MSOP8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Op amp for buffering the O2 offset signal.	Open Circuit. Short Circuit.	O/C, S/C: No O2 offset signal and generate and alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by % O_2 beyond calibration range error diagnostics.
IC15A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC15B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC14A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
IC14B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1					Not part of the safety function of the device.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Sensor Bridge Drive / Conditioning																		
L3	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter.	Open Circuit. Short Circuit.	O/C: Loss of negative input to IC18, which generates an alarm. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by % O_2 beyond calibration range error diagnostics.
L4	Ferrite Bead, 30ohms, 0603, 1A, SMT	1	Inductor, Ferrite Core, Power	2.50E-08	2.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter.	Open Circuit. Short Circuit.	O/C: Loss of negative input to IC18, which generates an alarm. S/C: No effect.	15%	0%	0%	85%	3.75E-09	0.00E+00	0.00E+00	2.13E-08	Detected by % O_2 beyond calibration range error diagnostics.
R61	RES 1K 0805, 0.25W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Provides a start-up current to the sensor.	Open Circuit. Short Circuit.	O/C: No effect. S/C: Would over drive the circuit, leading to a very high O2 signal.	80%	0%	0%	20%	1.20E-10	0.00E+00	0.00E+00	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R64	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Biases transistor TR8.	Open Circuit. Short Circuit.	O/C: Indeterminate state. S/C: Would over drive the circuit, leading to a very high O2 signal.	0%	40%	40%	20%	0.00E+00	6.00E-11	6.00E-11	3.00E-11	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R66	RES 4K99 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Biases transistor TR8.	Open Circuit. Short Circuit.	O/C: Would go fully on. S/C: Indeterminate state.	0%	10%	10%	80%	0.00E+00	1.50E-11	1.50E-11	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.

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R85	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Will saturate op amp IC19A. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R68	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Set the gain of op amp IC19A.	Open Circuit. Short Circuit.	O/C, S/C: Will saturate op amp IC19A.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC13	IC, LM4050BIM3-4.1, Vref, 4.1V, 50ppm	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Set the gain of op amp IC19A.	Open Circuit. Short Circuit.	O/C, S/C: Will saturate op amp IC19A.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	3.00E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R73	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Input bias for IC19B.	Open Circuit. Short Circuit.	O/C: Would give 0v on output of IC19B and generate alarm. S/C: Would generate error message.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error diagnostics.
R71	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the gain on op amp IC19A.	Open Circuit. Short Circuit.	O/C: Sensor thermistors would be over driven, which would generate an alarm. S/C: Sensor thermistors would be under driven, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R75	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Sensor would go over range. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R98	RES 120R 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Sets the gain on op amp IC19A.	Open Circuit. Short Circuit.	O/C: Sensor thermistors would be over driven, which would generate an alarm. S/C: Sensor thermistors would be under driven, which would generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
R76	RES 13K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Input bias for IC19B.	Open Circuit. Short Circuit.	O/C: Would give 0v on output of IC19B and generate alarm. S/C: Would generate error message.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by O_2 sensor circuit error diagnostics.

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R63	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias O2 signal from sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: O2 signal would swing low and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R70	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Bias O2 signal from sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: O2 signal would swing high and generate an alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.50E-10	Detected by % O_2 beyond calibration range error diagnostics.
R82	RES 20K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: No O2 signal, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R78	RES 510K 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of input to IC19B. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.
R79	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: IC19B output would saturate. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.
R81	RES 10K 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: No O2 sensor condition signal. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by O_2 sensor circuit error diagnostics.
R65	RES 4K02 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of O2 signal into IC18, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R67	RES 4K02 0603, 0.063W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of filter circuit.	Open Circuit. Short Circuit.	O/C: Loss of O2 signal into IC18, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
R87	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R88	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R89	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
R90	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R91	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C, S/C: In normal operation, no effect.	100%	0%	0%	0%	1.50E-10	0.00E+00	0.00E+00	0.00E+00	
R99	RES 0R0 0603, 0.1W 1%	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Select on test resistor (unused).	Open Circuit. Short Circuit.	O/C: Over range gain, which would generate an alarm. S/C: No effect.	20%	0%	0%	80%	3.00E-11	0.00E+00	0.00E+00	1.20E-10	Detected by % O_2 beyond calibration range error diagnostics.
C52	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No drive to sensor, which would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C32	CAP TNT 10uF C, 25V 20%	1	Capacitor, Electrolytic Tantalum Foil	7.00E-10	7.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No drive to sensor, which would generate an alarm. Leak: Indeterminate state.	35%	5%	5%	55%	2.45E-10	3.50E-11	3.50E-11	3.85E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C57	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v, leading to error message. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C60	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C: Indeterminate state. S/C: Would over drive the circuit, leading to an over range O2 signal and therefore will be detected as an alarm condition on the 4-20mA o/p. Leak, Drift: No effect.	40%	5%	5%	50%	2.40E-10	3.00E-11	3.00E-11	3.00E-10	
C61	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Loss of one of the supplies, which would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
C49	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15 supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C50	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15 supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C55	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of IC17 decoupling.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: IC17 may malfunction and generate an alarm. Drift: No effect.	20%	15%	15%	50%	1.20E-10	9.00E-11	9.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C62	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the input to op amp IC19B and would generate an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error diagnostics.
C76	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No sensor condition signal. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by O_2 sensor circuit error diagnostics.
C77	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: No O2 signal and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
R113	RES 20K 1% 0603	1	Resistor Fixed, Thick Film	1.50E-10	1.50E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Used in a potential divider	Open Circuit. Short Circuit.	O/C: Sensor signal could either be over-range or still be within range, but in error. S/C: Sensor signal will be under-range	0%	30%	30%	40%	0.00E+00	4.50E-11	4.50E-11	6.00E-11	A over or under-range sensor signal, will be detected by the system diagnostics
C63	CAP CER 1uF 0603, 25V 20%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Part of IC20 decoupling.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Leak: Indeterminate state. S/C: IC20 may malfunction and generate an alarm. Drift: No effect.	20%	15%	15%	50%	1.20E-10	9.00E-11	9.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C58	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on +15v supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C59	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 3.3v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C56	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on +15V supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the 15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
C54	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Zero output of IC18 and generated an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C75	CAP 100nF 0603, 50V 10%	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Decoupler on -15v supply.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the -15v supply and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C51	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the negative input to IC18 and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
C53	CAP CER 10nF 0603, 50V 10% X7R	1	Capacitor, Ceramic Single (chip) and Multilayer	6.00E-10	6.00E-10	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Filter capacitor.	Open Circuit. Short Circuit. Drift. Leak.	O/C, Drift: No effect. S/C: Grounds the positive input to IC18 and generates an alarm. Leak: Indeterminate state.	30%	10%	10%	50%	1.80E-10	6.00E-11	6.00E-11	3.00E-10	Detected by % O_2 beyond calibration range error diagnostics.
ZD2	Zener Diode, MMSZ6V2T1G, 6.2V, 0.5A	1	Diode, Voltage Regulator (Zener)	3.00E-09	3.00E-09	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Limits the voltage on the base of TR8.	Open Circuit. Short Circuit. Zener Voltage Drift.	O/C: No control signal to TR8, leading to the sensor to be under driven and therefore will be detected as an alarm condition on the 4-20mA o/p. S/C: Over range control signal to TR8, leading to the sensor to be over driven and therefore will be detected as an alarm condition on the 4-20mA o/p. Zener Voltage Drift: No effect.	10%	0%	0%	90%	3.00E-10	0.00E+00	0.00E+00	2.70E-09	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
TR8	Transistor, PNP, MJD32CG, 3A, 1.5W, DPAK	1	Transistors, Silicon Bipolar Power (= or > 5OOmW)	1.00E-07	1.00E-07	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Drives the sensor thermistors.	Open Circuit. Short Circuit. Leakage. Low Gain.	O/C: No / very little O2 signal. S/C: Would over drive the system. Leakage, Low Gain: No effect.	20%	0%	0%	80%	2.00E-08	0.00E+00	0.00E+00	8.00E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC17	IC, AD5293BRUZ-20, 1%, Digipot, 20K, 10bit, SPI	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Zero the O2 signal output from sensor.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%. for
IC20	IC, Digipot 100kohm, 14pin,10bit, SPI	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Digital gain setting potentiometer.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%. for?

Ref. #	Description	Qty	Component Type	λB (/hr)	λTotal	Data Source	Function	Potential Failure Modes	Description of Failure Effect, for each failure mode	Non-Safety Related Failure λNSR (%)	Safe Failure λs (%)	Dangerous Failure - Undetected λDU (%)	Dangerous Failure - Detected λDD (%)	Non-Safety Related Failure λNSR (/hr)	Safe Failure λs (/hr)	Dangerous Failure - Undetected λDU (/hr)	Dangerous Failure - Detected λDD (/hr)	Any comments or if it is not part of the safety function Comments
IC18	IC, AD8221ARMZ, Instrum Amp, high CMRR	1	Linear/Digital IC, MOS 400-4000 Transistors	1.50E-08	1.50E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Instrumentation amplifier.			0%	0%	10%	90%	0.00E+00	0.00E+00	1.50E-09	1.35E-08	Assumed comms DC = 90%.
IC19A	IC, LM258ADT, Dual Opamp, General purpose, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	Control op amp for the sensor cell.	Open Circuit. Short Circuit.	O/C, S/C: No control to the sensor, leading to alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by O_2 sensor circuit error and % O_2 beyond calibration range error diagnostics.
IC19B	IC, LM258ADT, Dual Opamp, General purpose, SO8	1	Linear/Digital IC, MOS 1-400 Transistors	1.10E-08	1.10E-08	Handbook of Reliability Data for Electronic Components Used In Telecommunication Systems, HRD5.	O2 sensor signal condition buffer.	Open Circuit. Short Circuit.	O/C, S/C: No O2 sensor condition signal, leading to alarm.	0%	0%	0%	100%	0.00E+00	0.00E+00	0.00E+00	1.10E-08	Detected by O_2 sensor circuit error diagnostics.

Appendix B

Reliability Block Diagrams

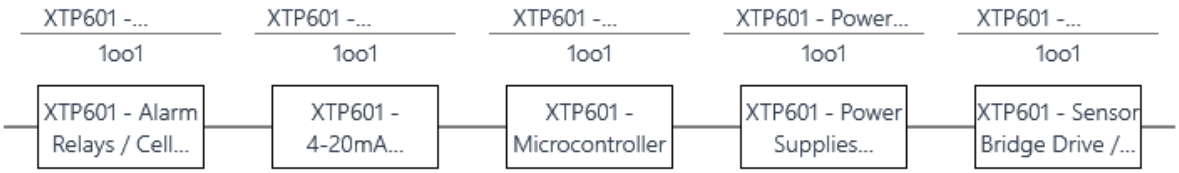
XTP601 Process Oxygen Analyser - 95% PTC

Note that the 4-20mA Analog Inputs Function Block is Non-Safety Related and has therefore been excluded from the calculations.

	Alarm Relays / Cell Temperature	4-20mA Analog Outputs	Microcontroller	Power Supplies Contrast	Sensor Bridge Drive / Conditioning
Configuration	1oo1	1oo1	1oo1	1oo1	1oo1
PFD Achieved - Proposed	4.2E-5	6.9E-5	1.9E-4	5.6E-5	5.3E-5
PFD Achieved - Proposed (Total)	4.1E-4				
Max Allowable SIL (Architectural Constraints)	SIL 2				

XTP601 Process Oxygen Analyser - 90% PTC

	Alarm Relays / Cell Temperature	4-20mA Analog Outputs	Microcontroller	Power Supplies Contrast	Sensor Bridge Drive / Conditioning
Configuration	1oo1	1oo1	1oo1	1oo1	1oo1
PFD Achieved - Proposed	5.3E-5	8.4E-5	2.4E-4	7.0E-5	6.5E-5
PFD Achieved - Proposed (Total)	5.1E-4				
Max Allowable SIL (Architectural Constraints)	SIL 2				



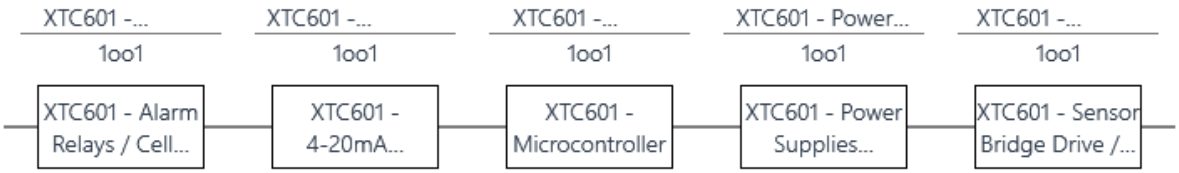
XTC601 Binary Gas Analyser - 95% PTC

Note that the 4-20mA Analog Inputs Function Block is Non-Safety Related and has therefore been excluded from the calculations.

	Alarm Relays / Cell Temperature	4-20mA Analog Outputs	Microcontroller	Power Supplies Contrast	Sensor Bridge Drive / Conditioning
Configuration	1oo1	1oo1	1oo1	1oo1	1oo1
PFD Achieved - Proposed	4.3E-5	7.0E-5	8.7E-5	5.5E-5	5.4E-5
PFD Achieved - Proposed (Total)	3.1E-4				
Max Allowable SIL (Architectural Constraints)	SIL 2				

XTC601 Binary Gas Analyser - 90% PTC

	Alarm Relays / Cell Temperature	4-20mA Analog Outputs	Microcontroller	Power Supplies Contrast	Sensor Bridge Drive / Conditioning
Configuration	1oo1	1oo1	1oo1	1oo1	1oo1
PFD Achieved - Proposed	5.3E-5	8.4E-5	1.1E-4	7.0E-5	6.6E-5
PFD Achieved - Proposed (Total)	3.8E-4				
Max Allowable SIL (Architectural Constraints)	SIL 2				



Appendix C

Meeting Attendance List

Session Attendance

Companies: MICHELL INSTRUMENTS LTD, ESC **Meeting:** FMEDA & FSA

Date: 23/04/2019

ESC

London, Warrington, Humberside & Abu Dhabi

Attendees:

Name	Company	Title	Signature
CHANTAL SEALEY	ESC LTD	FMEA CHAIR	CSealey.
PAULO OLIVEIRA	ESC LTD	CO-CHAIR/ASSESSOR	
ABDUL KADIR.	MICHELL	ELECTRONICS ENGINEER	
RAY HINKINS	MICHELL INSTRUMENTS	DEVELOPMENT MANAGER	

Session Attendance

Companies: MICHELL INSTRUMENTS LTD, ELY **Meeting:** FMEDA & FSA.

Date: 24/04/2019.

ESC

London, Warrington, Humberside & Abu Dhabi

Attendees:

Name	Company	Title	Signature
CHANTAL SEALEY	ESC LTD	FMEA CHAIR	
ABDUL KADIR.	MICHELL.	ELECTRONIC ENGINEER	
RAY HINKINS	MICHELL INSTRUMENTS	DEVELOPMENT MANAGER	
PAULO OLIVEIRA	ESC LTD	FMEA CO-CHAIR	