**IECEx TEST REPORT**
**IEC 60079-11**
**Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"**

| | |
|---|---|
| ExTR Reference Number...............: | NO/DNV/ExTR21.0088/00 |
| ExTR Free Reference Number.......: | PRJN-313142-2021-PA-NOR |
| Compiled by + signature (ExTL).....: | Gunnar Nielsen |
| Reviewed by + signature (ExTL)....: | Bjørn Spongsveen |
| Date of issue.................................: | 2022-07-04 |
| Ex Testing Laboratory (ExTL) ........: | DNV |
| Address .........................................: | DNV Product Assurance AS<br>Veritasveien 1<br>1363 Høvik<br>Norway |
| Applicant's name ...........................: | RIKEN KEIKI Co., Ltd. |
| Address .........................................: | 2-7-6, Azusawa, Itabashi-ku,<br>Tokyo, 174-8744,<br>Japan |
| Standard ........................................: | IEC 60079-11:2011, 6th Edition |
| Test procedure ..............................: | IECEx System |
| Test Report Form Number .............: | ExTR60079-11_6B_DS (released 2021-10) |

***Instructions for Intended Use of Ex Test Report:***
*An Ex Test Report provides a clause-by-clause documentation of the initial evaluation and testing that verified compliance of an item or product with an IEC, ISO, ISO/IEC or IEC/IEEE Ex standard or technical specification. This Ex Test Report is part of an ExTR package that may include other Ex Test Report, Addendum, National Differences and Partial Testing documents, along with a single ExTR Cover. An Ex Test Report is to be compiled and reviewed by the ExTL. The Issuing ExCB indicates final approval of the Ex Test Report as part of the overall ExTR package on the associated ExTR Cover.*



**Possible test case verdicts:**

- test case does not apply to the test item ..................... :N / A

- test item does meet the requirement........................... :Pass

**General remarks:**
The test results presented in this Ex Test Report relate only to the item or product tested.

- "(see Attachment #)" refers to additional information appended to this document.
- "(see appended table)" refers to a table appended to this document.
- Throughout this document, a comma "," is used as the decimal separator.

The technical content of this Ex Test Report shall not be reproduced except in full without the written approval of the Issuing ExCB and ExTL.

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 1 | Scope | | |
| 2<br>DS 2010/006A | Normative references | | |
| 3 | Terms and definitions | | |
| 4 | Grouping and classification of intrinsically safe apparatus and associated apparatus | According to IEC 60079-0. | Pass |
| 5 | Levels of protection and ignition compliance requirements of electrical apparatus | | |
| 5.1 | General | Battery powered handheld equipment.<br>The EUT has a USB-C contact for charging of the single secondary cell. Um for the USB-C is 6,0V. Due to the low Um voltage the EUT is “X” marked. | Pass |
| 5.2 | Level of protection "ia" | Refer to Appendix A.1 for details. | Pass |
| 5.3 | Level of protection "ib" | Level of protection "ia". | N / A |
| 5.4 | Level of protection "ic" | Level of protection "ia". | N / A |
| 5.5 | Spark ignition compliance | Refer to Appendix A.2 for details. | Pass |
| 5.6 | Thermal ignition compliance | | |
| 5.6.1 | General | Refer to Appendix A.3 for details. | Pass |
| 5.6.2<br>DS 2015/009<br>DS 2015/016A | Temperature for small components for Group I and Group II | Refer to Appendix A.3.1 for details.<br>T4 @ +60°C | Pass |
| 5.6.3 | Wiring within intrinsically safe apparatus for Group I and Group II | Refer to Appendix A.3.2 for details. | Pass |
| 5.6.4 | Tracks on printed circuit boards for Group I and Group II | Refer to Appendix A.3.3 for details. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 5.6.5<br>**DS 2020/006** | Intrinsically safe apparatus and component temperature for Group III | Not for Group III. | N / A |

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|---|---|---|---|
| 5.7 | Simple apparatus | EUT is not a simple apparatus. | N / A |

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|---|---|
| 6 | Apparatus construction |

| | | | |
|---|---|---|---|
| 6.1 | Enclosures | | |
| 6.1.1 | General | Enclosure of EUT is ingress protection classified according to IEC 60529. | Pass |
| 6.1.2 | Enclosures for Group I or Group II apparatus | | |
| 6.1.2.1 | General | Table 5 is used. | Pass |
| 6.1.2.2 | Apparatus complying with Table 5 | ≥IP20<br>EUT is drop tested prior to IP test. | Pass |
| 6.1.2.3<br>**DS 2019/006** | Apparatus complying with Annex F | Table 5 is used instead of Annex F. | N / A |
| 6.1.3 | Enclosures for Group III apparatus | Not for Group III. | N / A |

| | | | |
|---|---|---|---|
| 6.2 | Facilities for connection of external circuits | | |
| 6.2.1 | Terminals | No terminals for connection of external circuits in EUT. | N / A |
| 6.2.2 | Plugs and sockets | USB-C socket for charging of the battery in non-hazardous area. | Pass |
| 6.2.3 | Determination of maximum external inductance to resistance ratio (*Lo/Ro*) for resistance limited power source | EUT is not a power source for other circuits. | N / A |
| 6.2.4 | Permanently connected cable | No permanently connected cables for external circuits. | N / A |
| 6.2.5 | Requirements for connections and accessories for IS apparatus when located in the non-hazardous area | USB-C socket for charging of the battery in non-hazardous area. Um: 6,0V. Internally this connection is named CN1.<br>The Um voltage will not take the safety components beyond 2/3 of their ratings. | Pass |

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| 6.3 | Separation distances | | |
| 6.3.1 | General | Alternative separation distances in Annex F are not used.<br>Distances according to Table 5 are considered. | Pass |
| 6.3.2 | Separation of conductive parts | Separation distances between different parts of the intrinsically safe circuit.<br>The requirements of this clause are considered during the evaluation of the circuit and layout. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 6.3.2.1 | Distances according to Table 5 | Separation distance requirements of Table 5 are considered and evaluated.<br>See Appendix B.1 for details. | Pass |
| 6.3.2.2 | Distances according to Annex F | Alternative separation distances are not used. | N / A |
| 6.3.3 | Voltage between conductive parts | Maximum voltage for the battery powered circuit are:<br>From single battery cell: 4,2V maximum open circuit voltage.<br>After step-up circuit to buzzer circuit: 4,2V x 3 = 12,6V<br>Zener diodes ZD1 to ZD4 from buzzer circuit: max. 4,8V. | Pass |
| 6.3.4 | Clearance | See Appendix B.1 for details. | Pass |
| 6.3.5 | Separation distances through casting compound | Casting compound is not used. | N / A |
| 6.3.6 | Separation distances through solid insulation | Solid insulation is not used. | N / A |
| 6.3.7 | Composite separations | Composite separations are not used. | N / A |
| 6.3.8 | Creepage distance | See Appendix B.1 for details. | Pass |
| 6.3.9 | Distance under coating | Coating is not used. | N / A |
| 6.3.10 | Requirements for assembled printed circuit boards | a) N / A<br>Coating is not used.<br>b) N / A<br>Coating is not used.<br>c) Considered in the evaluation of separation distances. | Pass |
| 6.3.11 | Separation by earthed screens | Earthed screens are not used. | Pass |
| 6.3.12 | Internal wiring | Internal wiring will not affect the separation distances due to its layout. | N / A |
| 6.3.13 | Dielectric strength requirement | Battery powered equipment with non-metallic enclosure. | N / A |
| 6.3.14 | Relays | Safety relays are not used. | N / A |

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| 6.4 | Protection against polarity reversal | The secondary battery cell is fixed and shall not be replaced by customer. | N / A |

| | | | |
|---|---|---|---|
| 6.5 | Earth conductors, connections and terminals | Battery powered equipment. | N / A |

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|---|---|---|---|
| 6.6 | Encapsulation | Encapsulation is not used. | N / A |
| 6.6.1 | General | | N / A |
| 6.6.2 | Encapsulation used for the exclusion of explosive atmospheres | | N / A |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |

| | |
|---|---|
| 7 | Components on which intrinsic safety depends |

| | | | |
|---|---|---|---|
| 7.1<br>**DS 2004/003**<br>**DS 2018/005A** | Rating of components | Resistors and zener diodes are used as safety components. The safety factor of at least 1,5 is satisfied.<br>Refer to Appendix A.4 for details. | Pass |

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| 7.2 | Connectors for internal connections, plug-in cards and components | Not possible with incorrect connections.<br> | Pass |

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| 7.3 | Fuses | The fuse, F1, is used in the charging circuit.<br>A current of 0,75A x 1,7 is considered to flow continuously when the equipment is located in the non-hazardous area.<br>The cold resistance of the fuse is not used.<br>The fuse is connected to the USB-C socket and will not carry current when the EUT is located in the hazardous area. Therefore encapsulation of the fuse is not required.<br>Thin film chip fuse not for replacement (soldered to the circuit board).<br>Um = 6,0V<br>Breaking capacity for the fuse: 50V / 63A.<br>In = 0,75A | Pass |

| | | | |
|---|---|---|---|
| 7.4 | Primary and secondary cells and batteries | | |
| 7.4.1 | General | One single cell of Panasonic NCR18650GA. This battery has been tested in NO/PRE/ExTR20.0043/00. Test data in this report are copies from the test data from NO/PRE/ExTR20.0043/00.<br>The battery shall not be replaced by the user or be charged in hazardous area. | Pass |
| 7.4.2<br>**DS 2010/003** | Battery construction | The battery is sealed. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 7.4.3 | Electrolyte leakage and ventilation | No electrolyte spillage. The battery has been tested according to clause 10.5.2. Encapsulation is not used.<br>EUT satisfy the requirements for “ia” and Group IIC. Requirement for hydrogen concentration does not apply.<br>The enclosure of the EUT is not sealed, but lid and enclosure is fixed together with four screws. Only one single cell inside enclosure.<br>The cell is sealed. | Pass |
| 7.4.4 | Cell voltages | According to table 14:<br>Type system: Lithium ion<br>Positive electrode: (NCA) Li(NiCoAl)$O_2$<br>Electrolyte: Liquid solution<br>Negative electrode: Carbon<br>Voltage: 3,6V<br>Maximum open circuit voltage: 4,2V | Pass |
| 7.4.5 | Internal resistance of cell or battery | Internal resistance: 24mΩ | Pass |
| 7.4.6 | Batteries in equipment protected by other types of protection | No other types of protection. Only intrinsic safety. | N / A |
| 7.4.7 | Batteries used and replaced in explosive atmospheres | The battery shall not be replaced. | N / A |
| 7.4.8 | Batteries used but not replaced in explosive atmospheres | The battery doesn’t need current-limiting devices to ensure the safety of the battery itself. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 7.4.9 | External contacts for charging batteries | a) The current from the battery to the external charging contact is limited by the safety resistors RS2, RS3, RS4 and RS5. These resistors are mounted in parallel.<br>Rp = (30 II 30 II 470 II 470) x 0,99Ω = 13,96Ω<br>Maximum voltage from EUT to charging contact is 4,8V (ZD1, ZD2, ZD3, ZD4 – buzzer circuit).<br>I = 4,8V / 13,96Ω = 344mA<br>According to Table A.1: 3,33A@12,1V is permitted.<br>344mA < 3,33A<br>If the current should be made from the maximum voltage in the buzzer circuit (4,2V x 3 = 12,6V) named VBZ it will be reduced by the serial safety resistors RS11 and RS12.<br>R = (8,2 + 8,2) x 0,99Ω = 16,2Ω<br>I = 12,6V / 16,2Ω = 776mA<br>According to Table A.1: 2,51A@12,6V is permitted.<br>776mA < 2,51A<br><br>In addition one parallel track has three serial connected blocking diodes (D1, D2 and D3). This is the buzzer circuit.<br><br>b) N / A<br>EUT satisfies sub-clause “a”. | Pass |

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|---|---|---|---|
| 7.5<br>**DS 2015/007** | Semiconductors | | |
| 7.5.1 | Transient effects | Battery powered equipment. No transient effects. | N / A |
| 7.5.2 | Shunt voltage limiters | a) D1, D2, D3 are diodes connected in series.<br>1,5 in safety factor is applied.<br>See appendix A.4.3 for details.<br><br>b) Zener diodes are used in the buzzer circuit to clamp the voltage to a maximum of 4,8V.<br>1,5 in safety factor is applied.<br>See appendix A.4.2 for details. | Pass |
| 7.5.3 | Series current limiters | See sub-clause 7.5.2.a above and appendix A.4.3 for details. | Pass |

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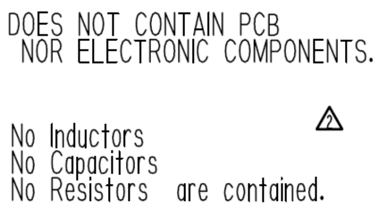
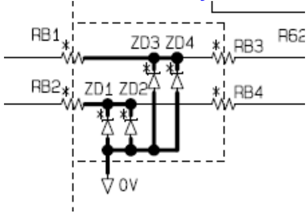
| 7.6<br>**DS 2012/009**<br>**DS 2016/002** | Failure of components, connections and separations | The information and requirements in this clause, including sub-clauses, are considered in the assessment of the circuits and layout for EUT. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 7.7 | Piezo-electric devices | There is one piezo-electric device in the circuit (BZ1). It's used as a buzzer. This device is tested according to clause 10.7.<br>E = 0,5 x 42,9nF x 18,9V2 = 7,67µJ<br>7,67µJ < 50µJ → IIC<br>See appendix B.2 for details. | Pass |

<table>
<tr>
<td>7.8</td>
<td>Electrochemical cells for the detection of gases</td>
<td>
Different types of electrochemical cells for the detection of different gases are used.
<table>
<tr><td>Detection Principle</td><td>Electrochemical</td><td>Electrochemical</td></tr>
<tr><td>Model</td><td>ESR-A1DP</td><td>ESR-X13P</td></tr>
<tr><td>Measured Gas</td><td>CO/H2S</td><td>O2</td></tr>
</table>
There are no circuit board or electronic components in these cells.<br>
Ref. document M4-4482-02-01K and M4-4488-19-01K<br>

<br>
Electrochemical evaluation:<br>
With reference to ExTAG DS 2002/001A 2007 09 25:<br>
Typical values under worst-case-condition have been reported) to be: 1,25V – 50mA – 1A (short circuit peak / capacitive) – 300mW<br><br>
Sometimes the maximum output values for sensors for toxic gases can only be reached with lethal concentrations. It is recommended to assess the characteristics only in the range of warning levels<br>
If the sensors are stand-alone-equipment they could be assessed to be simple apparatus.<br><br>
According to this clause the addition of power shall not be considered for thermal assessment.<br><br>
Voltage and current for 100% conditions (most servere condition) for these t wo cells are:<br>
Voltage: 0,1V<br>
Current 0,5mA<br>
No further evaluation for these cells are considered.
</td>
<td>Pass</td>
</tr>
</table>

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 8 | Infallible components, infallible assemblies of components and infallible connections on which intrinsic safety depends | | |
| 8.1 | Level of Protection “ic” | Level of protection “ia”. | N / A |
| 8.2 | Mains transformers | No mains transformers. Battery powered equipment. | N / A |
| 8.2.1 | General | | N / A |
| 8.2.2 | Protective measures | | N / A |
| 8.2.3 | Transformer construction | | N / A |
| 8.2.4 | Transformer type tests | | N / A |
| 8.2.5 | Routine test of mains transformers | | N / A |
| 8.3 | Transformers other than mains transformers | No transformers in the equipment. | N / A |
| 8.4 | Infallible windings | No infallible windings in EUT. | N / A |
| 8.4.1 | Damping windings | | N / A |
| 8.4.2 | Inductors made by insulated conductors | | N / A |
| 8.5 | Current-limiting resistors | Chip metal film resistors are used as safety components. They are all rated according to clause 7.1, with at least 1,5 safety factor.<br>See appendix A.4.1 for details. | Pass |
| 8.6<br>**DS 2003/003** | Capacitors | No capacitors are used as safety components. | N / A |
| 8.6.1 | Blocking capacitors | No blocking capacitors. | N / A |
| 8.6.2 | Filter capacitors | No filter capacitors. | N / A |
| 8.7 | Shunt safety assemblies | | |
| 8.7.1 | General | The Zener diodes ZD1, ZD2, ZD3 and ZD4 are used as safety components. These are coupled 2 and 2 in parallel on the two tracks to buzzer circuit.<br>Se appendix A.4.2 for details. | Pass |

<table>
<tr><th colspan="4">IEC 60079-11</th></tr>
<tr><th>Clause</th><th>Requirement – Test</th><th>Result – Remark</th><th>Verdict</th></tr>
<tr><td>8.7.2</td><td>Safety shunts</td><td>The Zener diodes ZD1, ZD2, ZD3 and ZD4 are used as safety shunts.<br>In the buzzer circuit it is a piezo driver, IC4, (charge pump) which multiplies the input voltage.<br>Ref. datasheet:<br>■RECOMMENDED OPEARATING CONDITION (Ta=25°C)
<table>
<tr><th>PARAMETER</th><th>SYMBOL</th><th>CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr>
<tr><td rowspan="2">Operating Voltage</td><td rowspan="2">VIN</td><td>1x Mode, 2x Mode</td><td>2.3</td><td>3.0</td><td>5.0</td><td rowspan="2">V</td></tr>
<tr><td>1x Mode, 2x Mode, 3x Mode</td><td>2.3</td><td>3.0</td><td>3.4</td></tr>
</table>
■ELECTRICAL CHARACTERISTICS<br>(Ta=25°C, $V_{IN}$=3V, $C_1$=100nF, $C_2$=100nF, $C_{OUT}$=100nF, $C_{PIEZO}$=15nF, DIN=4kHz)
<table>
<tr><th>PARAMETER</th><th>SYMBOL</th><th>CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr>
<tr><td rowspan="3">Output Voltage</td><td>$V_{OUT1}$</td><td>1x Mode</td><td>2.8</td><td>-</td><td>3</td><td>V</td></tr>
<tr><td>$V_{OUT2}$</td><td>2x Mode</td><td>5.2</td><td>-</td><td>6</td><td>V</td></tr>
<tr><td>$V_{OUT3}$</td><td>3x Mode</td><td>7.2</td><td>-</td><td>9</td><td>V</td></tr>
</table>
Maximum output voltage is 9V.<br>The Zener diodes limit the voltage to the circuits connected to the buzzer circuit, to a maximum voltage of 4,8V.</td><td>Pass</td></tr>
<tr><td>8.7.3</td><td>Shunt voltage limiters</td><td>No shunt voltage limiters.</td><td>N / A</td></tr>
</table>

<table>
<tr><td>8.8</td><td>Wiring, printed circuit board tracks, and connections</td><td>a) Wires are not used as infallible connections in EUT.<br>b) 2: Infallible tracks (single tracks) are used in the safety shunt assembly.<br>

See appendix B.3 for details.<br><br>3: Infallible vias (single) are used in the safety shunt assembly. The vias connect the anodes of the Zener diodes to GND layer.<br>See appendix B.4 for details.<br>c) 3: The soldered joints of the Zener diodes to the PCB are according to the component's manufacturer recommendations.</td><td>Pass</td></tr>
</table>

| | | | |
|---|---|---|---|
| 8.9 | Galvanically separating components | No galvanically separating components. | N / A |
| 8.9.1 | General | | N / A |
| 8.9.2 | Isolating components between intrinsically safe and non-intrinsically safe circuits | | N / A |
| 8.9.3 | Isolating components between separate intrinsically safe circuits | | N / A |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 9 | Supplementary requirements for specific apparatus | EUT is not a diode safety barrier, a FISCO apparatus or a handlight/caplight. | N / A |

| | | | |
|---|---|---|---|
| 9.1 | Diode safety barriers | | |
| 9.1.1 | General | | N / A |
| 9.1.2 | Construction | | |
| 9.1.2.1 | Mounting | | N / A |
| 9.1.2.2 | Facilities for connection to earth | | N / A |
| 9.1.2.3 | Protection of components | | N / A |

| | | | |
|---|---|---|---|
| 9.2 | FISCO apparatus | | N / A |

| | | | |
|---|---|---|---|
| 9.3 | Handlights and caplights | | N / A |

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| 10 | Type verifications and type tests |

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|---|---|---|---|
| 10.1<br>**DS 2013/002** | Spark ignition test | | |
| 10.1.1 | General | Spark ignition testing is not performed. EUT is assessed by using figures and tables in annex A of IEC 60079-11. 1,5 safety factor is considered in the assessment.<br>Refer to Appendix A.2 for details. | Pass |
| 10.1.2 | Spark test apparatus | Spark ignition testing is not performed. | N / A |
| 10.1.3 | Test gas mixtures and spark test apparatus calibration current | | |
| 10.1.3.1 | Explosive test mixtures suitable for tests with a safety factor of 1.0 and calibration current of the spark test apparatus | | N / A |
| 10.1.3.2 | Explosive test mixtures suitable for tests with a safety factor of 1.5 and calibration current of the spark test apparatus | | N / A |
| 10.1.4 | Tests with the spark test apparatus | | |
| 10.1.4.1 | Circuit test | | N / A |
| 10.1.4.2<br>**DS 2018/005A** | Safety factors | 1,5 | Pass |
| 10.1.5 | Testing considerations | | |
| 10.1.5.1 | General | | Pass |
| 10.1.5.2 | Circuits with both inductance and capacitance | Refer to Appendix A.2.4 for details. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 10.1.5.3 | Circuits using shunt short-circuit (crowbar) protection | Refer to Appendix A.2.5 for details. | N / A |
| 10.1.5.4 | Results of spark test | | N / A |

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|---|---|---|---|
| 10.2 | Temperature tests | See appendix B for temperature tests and appendix A for temperature assessment of small components. | Pass |

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| 10.3 | Dielectric strength tests | EUT is battery powered. No use of blocking capacitors, optocouplers or transformers. | N / A |

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| 10.4 | Determination of parameters of loosely specified components | No such components are used in safety assessment. | N / A |

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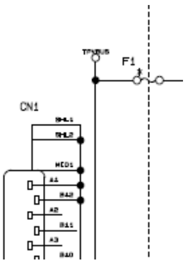
| 10.5 | Tests for cells and batteries | | |
| 10.5.1 | General | The battery cells are tested in IECEx test report NO/PRE/ExTR20.0043. Test results for electrolyte leakage test are copied from that report. | Pass |
| 10.5.2 | Electrolyte leakage test for cells and batteries | See appendix B.5 for details. | Pass |
| 10.5.3 | Spark ignition and surface temperature of cells and batteries | See appendix B5 and B6 for details. | Pass |
| 10.5.4 | Battery container pressure tests | The battery cell is sealed. | N / A |

| | | | |
|---|---|---|---|
| 10.6 | Mechanical tests | | |
| 10.6.1 | Casting compound | Casting compound is not used. | N / A |
| 10.6.2 | Determination of the acceptability of fuses requiring encapsulation | The fuse, F1, is mounted close to the USB-C charging contact (CN1), and is a part of the charging circuit. The fuse will only carry current when located in non-hazardous area.   | N / A |
| 10.6.3 | Partitions | EUT has no partitions. | N / A |

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| 10.7 | Tests for intrinsically safe apparatus containing piezoelectric devices | The buzzer, BZ1, is a piezo electric device.<br>See appendix B.2 for details. | Pass |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| 10.8 | Type tests for diode safety barriers and safety shunts | Battery powered equipment. No transients. | N / A |
| 10.9 | Cable pull test | No external cables. | N / A |
| 10.10 | Transformer tests | No transformers in EUT. | N / A |
| 10.11 | Optical isolators tests | No optical isolators in EUT. | N / A |
| 10.11.1 | General | | N / A |
| 10.11.2 | Thermal conditioning, dielectric and carbonisation test | | N / A |
| 10.11.2.1 | Overload test at the receiver side | | N / A |
| 10.11.2.2 | Overload test at the transmitter side | | N / A |
| 10.11.2.3 | Thermal conditioning and dielectric strength test | | N / A |
| 10.11.2.4 | Carbonisation test | | |
| 10.11.2.4.1 | Receiver side | | N / A |
| 10.11.2.4.2 | Transmitter side | | N / A |
| 10.11.3 | Dielectric and short-circuit test | | N / A |
| 10.11.3.1 | General | | N / A |
| 10.11.3.2 | Pre-test dielectric | | N / A |
| 10.11.3.3 | Short-circuit current test | | N / A |
| 10.11.3.4 | Current limited short-circuit current test | | N / A |
| 10.11.3.5 | Dielectric strength test | | N / A |
| 10.12 | Current carrying capacity of infallible printed circuit board connections | Tracks and vias are according to requirements in the standard. Tests are not necessary to perform. | N / A |
| 11 | Routine verifications and tests | EUT is not a diode safety barrier or incorporate a transformer. | N / A |
| 11.1 | Routine tests for diode safety barriers | | |
| 11.1.1 | Completed barriers | | N / A |
| 11.1.2 | Diodes for 2-diode “ia” barriers | | N / A |
| 11.2 | Routine tests for infallible transformers | | N / A |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |

| | | | |
|---|---|---|---|
| 12 | Marking | | |

| | | | |
|---|---|---|---|
| 12.1 | General | Marked according to IEC 60079-0.<br>No intrinsically safe parameters to be marked. | Pass |
| 12.2 | Marking of connection facilities | No connection facilities for use in hazardous area. | N / A |
| 12.3 | Warning markings | a) Secondary cells.<br>b) Battery is not to be replaced.<br>c) EUT satisfies sub-clause "7.4.9.a".<br>d) EUT do not require current limiting devices to ensure the safety of the battery itself. | N / A |
| 12.4 | Examples of marking | | Pass |

| | | | |
|---|---|---|---|
| 13 | Documentation | According to IEC 60079-0.<br>a) No parameters for entity concept.<br>b) N / A<br>c) Um: 6VDC.<br>d) The battery should be charged with the dedicated AC adapter or by power from IEC60950-certified SELV power source, or IEC62368-1-certified ES1 power source. The maximum voltage from the charger shall not exceed 6.0Vdc.<br>e) N / A (battery powered).<br>f) N / A<br>g) Ambient temperature is part of certification.<br>h) Annex F is not used. | Pass |

| | | | |
|---|---|---|---|
| Annex A (Normative) | Assessment of intrinsically safe circuits | | |
| A.1 | Basic criteria | | Pass |
| A.2 | Assessment using reference curves and tables | | Pass |
| A.3 | Examples of simple circuits | | Pass |
| A.4 | Permitted reduction of effective capacitance when protected by a series resistance | | Pass |

| | | | |
|---|---|---|---|
| Annex B (Normative) | Spark test apparatus for intrinsically safe circuits | Spark test apparatus is not used for this certification. | N / A |
| B.1 | Test methods for spark ignition | | |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| B.1.1 | Principle | | N / A |
| B.1.2 | Apparatus | | N / A |
| B.1.3 | Calibration of spark test apparatus | | N / A |
| B.1.4 | Preparation and cleaning of tungsten wires | | N / A |
| B.1.5 | Conditioning a new cadmium disc | | N / A |
| B.1.6 | Limitations of the apparatus | | N / A |
| B.1.7 | Modifications of test apparatus for use at higher currents | | N / A |

| | |
|---|---|
| Annex C (Informative) | Measurement of creepage distances, clearances and separation distances through casting compound and through solid insulation |

| | | | |
|---|---|---|---|
| Annex D (Normative) | Encapsulation | Encapsulation is not used. | N / A |
| D.1 | Adherence | | N / A |
| D.2 | Temperature | | N / A |

| | |
|---|---|
| Annex E (Informative) | Transient energy test |

| | | | |
|---|---|---|---|
| Annex F (Normative) | Alternative separation distances for assembled printed circuit boards and separation of components | Annex F is not used. | N / A |
| F.1 | General | | N / A |
| F.2<br>**DS 2019/006** | Control of pollution access | | N / A |
| F.3 | Distances for printed circuit boards and separation of components | | |
| F.3.1 | Level of protection “ia” and “ib” | | N / A |
| F.3.2 | Level of protection “ic” | | N / A |

| | | | |
|---|---|---|---|
| Annex G (Normative) | Fieldbus intrinsically safe concept (FISCO) – Apparatus requirements | Not for FISCO certification. | N / A |
| G.1 | Overview | | N / A |
| G.2 | Apparatus requirements | | |
| G.2.1 | General | | N / A |
| G.2.2 | FISCO power supplies | | |
| G.2.2.1 | General | | N / A |

| IEC 60079-11 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| G.2.2.2 | Additional requirements of 'ia' and 'ib' FISCO power supplies | | N / A |
| G.2.2.3 | Additional requirements of 'ic' FISCO power supplies | | N / A |
| G.3 | FISCO field devices | | |
| G.3.1 | General | | N / A |
| G.3.2 | Additional requirements of 'ia' and 'ib' FISCO field devices | | N / A |
| G.3.3 | Additional requirement of 'ic' FISCO field devices | | N / A |
| G.3.4 | Terminator | | N / A |
| G.3.5 | Simple apparatus | | N / A |
| G.4 | Marking | | N / A |
| G.4.1 | Examples of marking | | N / A |

| | |
|---|---|
| Annex H (Informative) | Ignition testing of semiconductor limiting power supply circuits |

**Measurement Section, including Additional Narrative Remarks**

## APPENDIX A: Description of product

### A.1 General overview

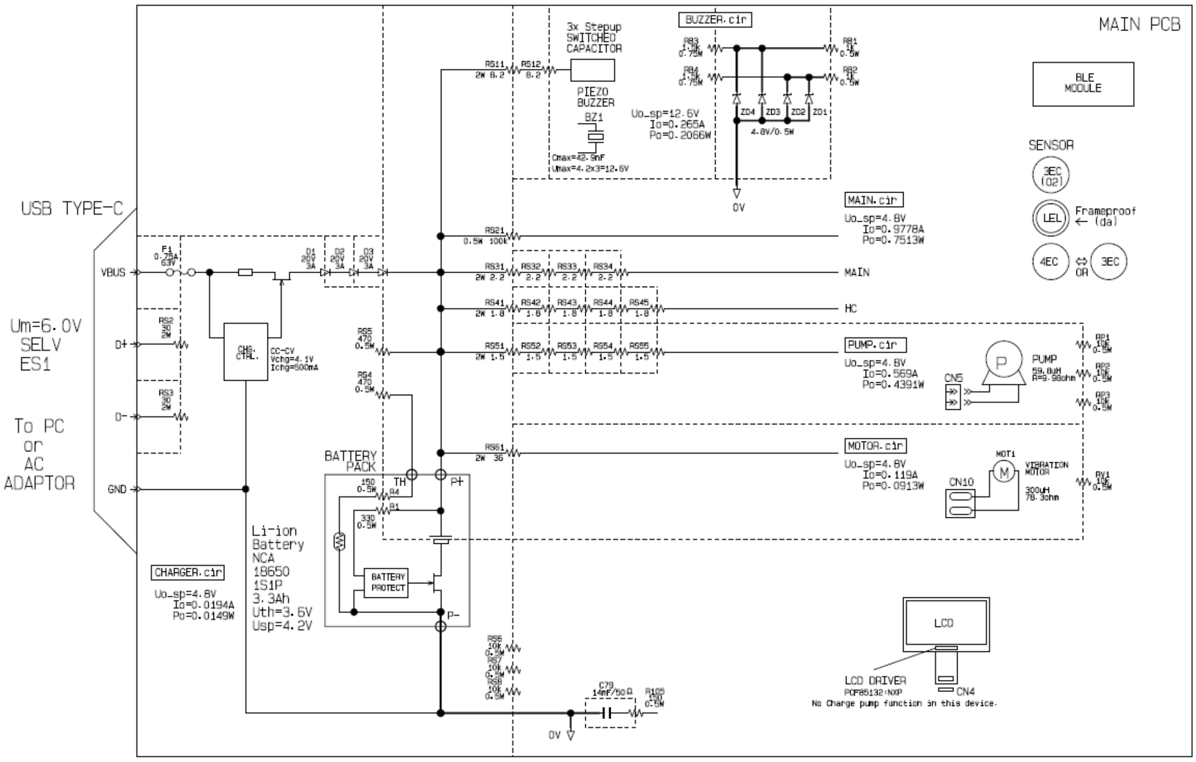
Equipment under test (EUT) is a gas detector named GX-Force. It is hand-held, powered by 1 secondary cell, and comes with three different gas detection cells. EUT is equipped with a buzzer (piezo-electric), pump, vibration motor, low energy Bluetooth module (BLE), LCD screen and LEDs for alarm.

Additional information:

- Pump, RIKEN KEIKI RP-12, is already certified in IECEx PRE 17.0070/Presafe 17ATEX11584.
- Battery, Panasonic NCR18650GA, is already tested in NO/PRE/ExTR20.0043.
- Vibration motor, LEXIN LE4A3GS1G4, is already certified in IECEx DEK 17.0050X/DEKRA 17ATEX0103X.

A detailed explanation for the different circuits below.

IS safety diagram (overview):




AC adapter:

This specific AC adapter (Mass Power Electronic Limited S018) can be used for charging the battery. Copy of certificates are stored in project folder at ExTL.

**2.5 Safety Standards**

The power supply shall be certified by following international regulatory standards.

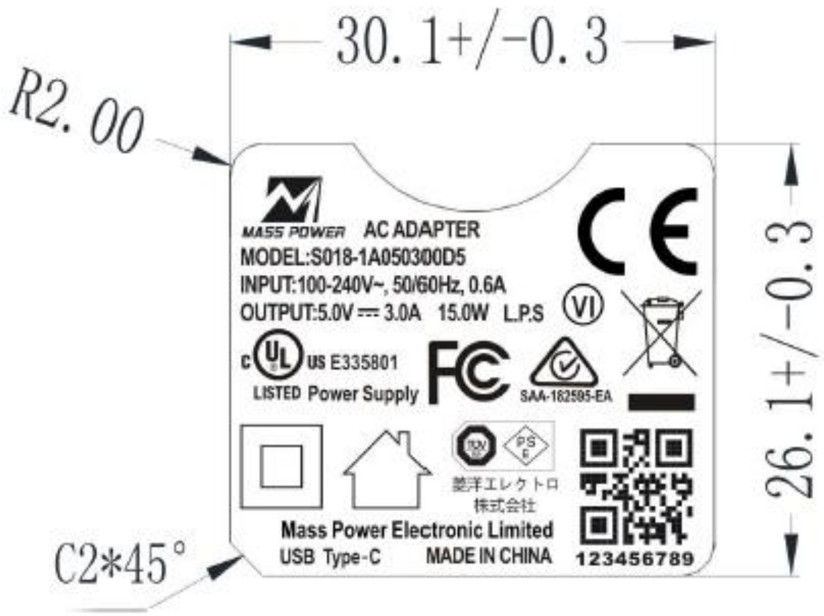
| Item | Country | Status | Safety standard |
|---|---|---|---|
| CE | Europe | Approved | EN62368-1 |
| GS | Germany | Approved | EN62368-1 |
| UL/cUL | America / Canada | Approved | UL 62368 and CAN/CSA |
| SAA | Australia/New Zealand | Approved | AS/NZS 62368.1 |
| CCC | China | Approved | GB4943 |
| TUV Mark | United Kingdom | --- | BS EN60950-1 |
| PSE | Japan | Approved | J60950-1 |
| KCC | Korea | --- | K60950 |
| CB | Global | Approved | IEC62368-1 |

### 2.2.1 Output voltage and current

| Rated output voltage (V) | Nominal output voltage (V) | Voltage range (V) | No load (A) | Min load (A) | Rated load(A) | Max. load (A) | Rated output power(W) |
|---|---|---|---|---|---|---|---|
| 5 | 5.2 | 4.9-5.5 | 0 | 0 | 3 | * | 15 |

The power supply output voltage must stay within the limits specified in table 2 when operating at steady state.

### 5.2 Label Drawing




Charging circuit:
The battery shall only be charged in non-hazardous area , and not replaced. It shall be charged with the dedicated AC adapter (Mass Power S018), by power from IEC 60950 (Information technology equipment – Safety) certified SELV power source or IEC 62368-1 (Audio/video, information and communication technology equipment - Part 1: Safety requirements) certified ES1 (ES1 equal to SELV) power source. The maximum voltage from the charger shall not exceed 6,0VDC (Um: 6,0VDC). The charging contact is USB-C. The charging circuit will only be operative in the non-hazardous area.
The USB-C contact is named CN1 by RIKEN KEIKI. It has 3 tracks going to the circuit in addition to GND. Track 1 is protected by fuse F1 (0,75A x 1,7 = 1,275A), track 2 protected by resistor RS2 (30Ω x 0,99 = 29,7Ω) and track 3 protected by resistor RS3 (30Ω x 0,99 = 29,7Ω). Track 4 is GND.
After the charging circuit there are 6 tracks going to the battery pack and the remaining circuits. So the non-active charging circuit in hazardous area is protected by the parallel coupled resistors RS4, RS5, RS6, RS7 and RS8. These resistors are also in parallel with three serial coupled blocking diodes, D1, D2 and D3. The current to the buzzer circuit, main circuit, pump circuit and motor circuit is further reduced with safety resistors. By this construction the USB-C contact is not capable of delivering hazardous spark energy to the environment in hazardous area.
See appendix A.2 for details.

Battery circuit/pack:
Contains one secondary cell. Maximum voltage is 4,2V. Nominal voltage is 3,6V. This circuit has its own pcb named protect pcb. Protect pcb is connected to main pcb with the contact CN2 (3 pins).
**Pin 1 (P+):** Connection to positive signal from charger, + polarity on battery and main circuit. The connection to the charger goes through the three diodes, D1, D2 and D3. There is also a connection to the protect IC through the resistor R1 (330Ω ± 1%).
**Pin 2 (TH):** Connection to negative signal from charger through R4 (150Ω ± 1%) and to the protect IC and negative polarity on battery. There is also a thermistor in series with R4 (RT1).
**Pin 3 (P-):** Connection to negative pole on battery and to the 0V on main pcb. It's connected to the same tracks as pin 2 (TH), but after the safety resistor and thermistor.
Maximum current between P+ and P- will be through the safety resistor R1.
See appendix A.2 for details.

Buzzer circuit:

Connection between Buzzer circuit (VBZ) and battery is through the resistors RS11 and RS12 (8,2Ω x 0,99 x 2 = 16,2Ω). Between buzzer and main circuit (IC12) there are connection named PB4 and PB5. These connections are protected by resistors (RB1 + RB3) II (RB2 + RB4) = 1kΩ x 0,99 x 2 II 1kΩ x 0,99 x 2= 990Ω, and parallel coupled Zener diodes ZD1, ZD2, ZD3 and ZD4, U = maximum 4,8V. The buzzer circuit include a step-up piezo driver (3 x U = 3 x 4,2V = 12,6V).

Pump circuit:
This circuit contains a pump (RP-12) for suction of gas in the surrounding atmosphere to be used in the gas analyse. The pump is connected to the pump circuit with the connection CN5.
Pump circuit is connected to the battery through the resistors RS51, RS52, RS53, RS54 and RS55 (R = 1,5Ω x 0,99 x 5 = 7,4Ω.
In addition the pump circuit is connected to the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ( R = (10kΩ x 0,995) / 3 = 3316Ω)
Pump, RIKEN KEIKI RP-12, is already certified in IECEx PRE 17.0070/Presafe 17ATEX11584. All results for the specific pump are copied from that project.

Motor circuit:
Vibration motor, LEXIN LE4A3GS1G4, is already certified in IECEx DEK 17.0050X/DEKRA 17ATEX0103X.
The circuit itself is powered by the battery through the resistor RS61 (36Ω x 0,99 = 35,64Ω). In addition the circuit is connected to main circuit through the resistor RV1 (10kΩ x 0,995 = 9950Ω).

LCD:
There is a LCD screen connected to the main board (CN4). There is none charge pump function in the LCD driver. The polarity is not reversed.

BLE Module (IC16): Bluetooth 5.0 low energy module. It uses the chip Nordic nRF52832 (512kB Flash, 64kB RAM). The chip itself contains maximum 1,5µF and negligible inductance. It’s connected to main circuit by CN9. The module itself is named IC16.

Main circuit:
The main circuit is connected to all of the other circuits, but the current is reduced by the use of safety resistors. There are mainly three tracks from the battery to the main circuit.
VBAT: RS21 → 100kΩ x 0,99 = 99000Ω
VMAIN: RS31, RS32, RS33, RS34 in series → 2,2Ω x 0,99 x 4 = 8,71Ω
VHC: RS41, RS42, RS43, RS44, RS45 in series → 1,8Ω x 0,99 x 5 = 8,91Ω
The three different tracks must be considered to be in parallel. Rp3 = 99000Ω II 8,71Ω II 8,91Ω = 4,4Ω
In addition the main circuit connection to the other circuits:
Buzzer circuit: RB1 II RB2 = 1kΩ x 0,99 II 1kΩ x 0,99 = 495Ω
Pump circuit: RP1, RP2 and RP3 ( R = (10kΩ x 0,995) / 3 = 3316Ω)
Motor circuit: RV1 (10kΩ x 0,995 = 9950Ω).
Rtotal = 4,4Ω II 495Ω II 3316Ω II 9950Ω = 4,35Ω
The connections to the other circuits (buzzer, pump and motor) are negligible.

**A.2 Spark ignition considerations**
A.2.1 Resistive spark ignition

Charging circuit:
(This evaluation is for the USB-C contact to not deliver delivering hazardous spark energy in Ex zone.)
Maximum voltage from battery is, U: 4,2V (maximum open circuit voltage).
Minimum resistance to limit the current is, R = RS4 II RS5 II RS6 II RS7 II RS8 = 470Ω x 0,99 II 470Ω x 0,99 II 10kΩ x 0,995 II 10kΩ x 0,995 II 10kΩ x 0,995 = 217,4Ω
Maximum current, I = 4,2V / 217,4Ω = 19,4mA.
In addition the current will be limited by the cold resistance of F1 in parallel with RS2 and RS3, but this resistance is negligible, and is not considered in this evaluation.
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 19,4mA
12,1V > 4,2V

Battery circuit/pack:
Maximum voltage from battery is, U: 4,2V (maximum open circuit voltage).
Minimum resistance to limit the current is, R = R1 = 330Ω x 0,99 = 326,7Ω
Maximum current, I = 4,2V / 326,7Ω = 12,9mA.
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 12,9mA
12,1V > 4,2V
Maximum voltage between P+ and Th is, U: 4,2V (maximum open circuit voltage).
Minimum resistance to limit the current is, R = R4 = 150Ω x 0,99 = 148,5Ω
Maximum current, I = 4,2V / 148,5Ω = 28,3mA.
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 28,3mA
12,1V > 4,2V
P + is limited by the resistors connected to the other circuits.

Buzzer circuit:
Maximum voltage to buzzer circuit from battery, U = 4,2V
Minimum resistance between buzzer circuit and battery, R = RS11 + RS12 = 8,2Ω x 0,99 x 2 = 16,2Ω
Maximum current to buzzer from battery, I = 4,2V / 16,2Ω = 260mA
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 260mA
12,1V > 4,2V
Maximum voltage due to the step-up driver, U = 4,2V x 3 = 12,6V.
Maximum current if 100% efficiency of step-up converter, I = 260mA / 3 = 8,7mA
According to table A.1 a current of 2,51 is permitted @12,6V and 1,5 safety factor.
2,51A > 86,7mA
Maximum voltage from buzzer to main circuit, U (ZD1, ZD2, ZD3 and ZD4) = 4,8V + 1,0V (VR) = 5,8V
Minimum resistance from buzzer to main circuit @ 5,8V, R = RB1 II RB2 = 1kΩ x 0,99 II 1kΩ x 0,99 = 495Ω
Maximum current from buzzer circuit and main circuit, I = 5,8V / 495Ω = 11,8mA
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 11,8mA
12,1V > 5,8V
Total current to the buzzer circuit will be current from battery + current from main circuit = 260mA + 4,2V / (495Ω x 2) = 260mA + 5mA = 265mA
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 265mA
12,1V > 4,2V

Pump circuit:
Maximum voltage to buzzer circuit from battery, U = 4,2V
Minimum resistance between pump circuit and battery is RS51, RS52, RS53, RS54 and RS55 in series (R = 1,5Ω x 0,99 x 5 = 7,4Ω). In addition current from the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ( R = (10kΩ x 0,995) / 3 = 3316Ω).
Rp = 7,4Ω II 3316Ω = 7,38Ω
Maximum current to the pump circuit, I = 4,2V / 7,38Ω = 569mA
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 569mA
12,1V > 4,2V

Motor circuit:
Maximum voltage to buzzer circuit from battery, U = 4,2V
Minimum resistance from battery and main circuit is, R = RS61 II RV1 = 36Ω x 0,99 II 10kΩ x 0,995 = 35,51Ω.
Maximum current, I = 4,2V / 35,51Ω = 119mA
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 119mA
12,1V > 4,2V

Main circuit:
Maximum voltage to buzzer circuit from battery, U = 4,2V

Minimum resistance, R = 4,35Ω
Maximum current, I = 4,2V / 4,35Ω = 966mA
Maximum current from buzzer circuit and main circuit, I = 5,8V / 495Ω = 11,8mA
Total, I = 966mA + 11,8mA = 977,8mA
(Current from motor and pump circuits are negligible.)6,4
According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 978mA
12,1V > 4,2V

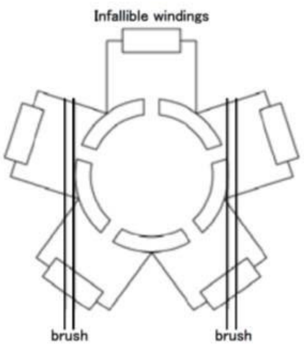
A.2.2 Inductive spark ignition

Charging circuit:
No inductors. Inductance from components such as ferrite bead, ICs and tracks is negligible @19,4mA and 1,5 safety factor.
Maximum inductance permitted according to figure A.6, L = 40μJ / (0,5 x (19,4mA x 1,5)$^2$) = 94,4mH.

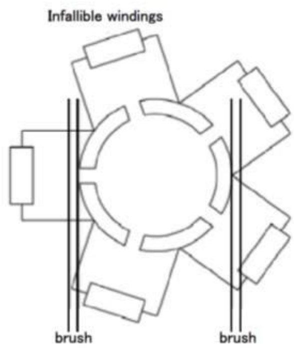
Battery circuit/pack:
No inductors. Inductance from components and tracks is negligible @28,3mA and 1,5 safety factor.
Maximum inductance permitted according to figure A.6, L = 40μJ / (0,5 x (28,3mA x 1,5)$^2$) = 44,4mH.

Buzzer circuit:
No inductors. Inductance from components and tracks is negligible @260mA and 1,5 safety factor.
Maximum inductance permitted according to figure A.6, L = 40μJ / (0,5 x (265mA x 1,5)$^2$) = 506μH.

Pump circuit:
No inductance in the pump circuit except for the inductance in the pump itself.
Pump motor:
Micro pump type RP-12: (Internal motor of pump is type A12B-09-SS). The pump type was used in other product from manufacturer whereof it was assessed in Presafe project D0001494-00.
The pump's motor has windings. The motor coil resistance is taken as an resistance to protect it' s inductance. The minimum motor coil resistance and maximum motor coil inductance of A12B-09-SS are as follows.
case1:one commutator segment active. case2:two commutator segments active.




Rmin 13.1Ω / Lmax 59.8μH




Rmin 11.0Ω / Lmax 49.8μH

The range of the motor coil resistance and the motor coil inductance are as follows.
Rmin = 11.0Ω - 13.1Ω, Lmax = 49.8μH - 59.8μH (9,98Ω stated by RIKEN KEIKI.)
The worst value is Rmin = 11.0Ω and Lmax = 59.8μH respectively.
The effective internal inductance of a pump motor coil is Lmax=59.8μH max. And the minimum resistance of a pump motor coil is Rmin = 9,98Ω .
Minimum resistance, R = 7,38Ω (pump circuit) + 9,98Ω = 17,36Ω
Maximum current in coil, I = 4,2V / 17,36Ω = 242mA.
Maximum inductance permitted according to figure A.6, L = 40μJ / (0,5 x (242mA x 1,5)2) = 607μH.
607μH > 59,8μH

Motor circuit:
No inductance in the pump circuit except for the inductance in the motor itself.
Vibration motor, LEXIN LE4A3GS1G4, is already certified in IECEx DEK 17.0050X/DEKRA 17ATEX0103X.

According to datasheet:

＊温度20℃，相対湿度65%の条件下にて測定のこと。

| | | | |
|---|---|---|---|
| 4−7 | Terminal Resistance 端子間抵抗 | +65℃ | 133 Ω ± 10% |
| | | +20℃ | 115 Ω ± 10% |
| | | −25℃ | 93 Ω ± 10% |
| | | −40℃ | 87 Ω ± 10% |
| 4−8 | Inductance インダクタンス | +65℃ | 240 μH以下 |
| | | +20℃ | 275 μH以下 |
| | | −25℃ | 295 μH以下 |
| | | −40℃ | 300 μH以下 |

Maximum inductance in the moter: 300µH.
Minimum cold resistance in motor: 78,3Ω
Total resistance in the circuit is, R = 78,3Ω + 35,51Ω = 113,81Ω
Maximum current through the motor coil, I = 4,2V / 113,81Ω = 36,9mA
Maximum inductance permitted according to figure A.6, L = 40µJ / (0,5 x (36,9mA x 1,5)$^2$) = 26,1mH.
26,1mH > 300µH

BLE module:
The BLE module has a inductance of 10,8nH (L3 and L4). Maximum current to the BLE module is, I = 978mA.
Maximum inductance permitted according to figure A.6, L = 40µJ / (0,5 x (978mA x 1,5)$^2$) = 37µH.
37µH > 10,8nH

Main circuit:
No inductance in the main circuit board except for ferrite beads (NF2, NF21, NF22, NF23, NF31, NF32, NF33 and NF41). In addition the inductance in BLE module, 10,8nH.
Maximum inductance permitted according to figure A.6, L = 40µJ / (0,5 x (978mA x 1,5)$^2$) = 37,2µH.
37µH > 10,8nH

A.2.3 Capacitive spark ignition

Charging circuit:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C1, C2, C3, C11, C12, C13, C14, C15, C16, C17, C18 | 120 | | | 0 | 1,20E-04 | 1,20E-04 |
| IC2 | | | 7 | 0 | 7,00E-12 | 7,00E-12 |
| IC3 | | | 26 | 0 | 2,60E-11 | 2,60E-11 |
| | | | | | 1,20E-04 | 1,20E-04 |

According to table A.2 a maximum capacitance of 136µF is permitted at a voltage of 4,8V x 1,5 = 7,2V.
136µF > 120µF

Battery circuit/pack:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C1, C2, C3 | 1,6 | | | 0 | 1,60E-06 | 1,60E-06 |
| | | | | | 1,60E-06 | 1,60E-06 |

According to table A.2 a capacitance of 420µF is permitted @ 4,2V x 1,5 = 6,3V.
420µF > 1,6µF.

Buzzer circuit:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C51, C52, C53 | 1 | | | 0 | 1,00E-06 | 1,00E-06 |
| BZ1 | | 42,9 | | 0 | 4,29E-08 | 4,29E-08 |
| | | | | | 1,04E-06 | 1,04E-06 |

According to table A.2 a capacitance of 1,15µF is permitted @ 12,6V x 1,5 = 18,9V.
1,15µF > 1,04µF

Pump circuit:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C31, C32, C33, C34, C35, C36 | 8 | | | 0 | 8,00E-06 | 8,00E-06 |
| | | | | | 8,00E-06 | 8,00E-06 |

According to table A.2 a capacitance of 47µF is permitted @ 4,8 x 1,5 = 7,2V.
136µF > 8µF

Motor circuit:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C54, C55 | 5 | | | 0 | 5,00E-06 | 5,00E-06 |
| | | | | | 5,00E-06 | 5,00E-06 |

According to table A.2 a capacitance of 47µF is permitted @ 4,8 x 1,5 = 7,2V.
136µF > 5µF

BLE module:
Maximum capacitance in the chip, C = 1,5µF.

Main circuit:

| Capacitor | Capacitance | | | Tolerance | Capacitance | Capacitance incl. tolerance |
|---|---|---|---|---|---|---|
| | Micro | Nano | Pico | | | |
| C21, C22, C23, C24, C25, C26, C41, C42, C43, C44, C45, C61, C62, C63, C64, C65, C66, C67, C68, C69, C71, C72, C73, C74, C75, C76, C77, C78, C81, C82, C83, C84, C85, C86, C87, C91, C92, C93, C94, C95, C96, C97, C98, C101, C102, C103, C104, C105, C106, C107, C110, C111, C112, C113, C114, C115, C116, C117, C118, C120, C121, C122, C123, C124, C125, C126, C130, C131, C132, C133, C134, | 120 | | | 0 | 1,20E-04 | 1,20E-04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| C135, C136, C140, C141, C142, C143, C144, C145, C151, C152, C153, C155, C160, C161, C162, C163, C164, C165, C166, C167, C171, C172, C173, C174 | | | | | | |
| | | | | | 1,20E-04 | 1,20E-04 |

In addition the capacitance from IC16 (BLE module), 1,5µF
According to table A.2 a capacitance of 136µF is permitted @ 4,8 x 1,5 = 7,2V.
136µF > 121,5µF
In addition there will be capacitance from other circuits. The current is reduced by safety resistors:
Buzzer circuit: RB1 II RB2 = 1kΩ x 0,99 II 1kΩ x 0,99 = 495Ω → I = 4,8V / 495Ω = 9,7mA
Pump circuit: RP1, RP2 and RP3 ( R = (10kΩ x 0,995) / 3 = 3316Ω) → I = 4,8V / 3316Ω = 1,5mA
Motor circuit: RV1 (10kΩ x 0,995 = 9950Ω) → I = 4,8V / 9950Ω = 0,5mA
Charger circuit: The current will be limited by the resistors to the main circuit, R = 4,4Ω → I = 4,8V / 4,4Ω = 1,091A
In addition C79 (14mF) that must be discharged through R105 → I = 4,8V / (150Ω x 0,99) = 4,8V / 148,5Ω = 32,4mA

Total, I = 9,7mA + 1,5mA + 0,5mA +1,091A + 32,4mA = 1,136A @4,8V. According to table A.1 a current of 3,33A is permitted @12,1V and 1,5 safety factor.
3,33A > 1,136A
12,1V > 4,8V

Information for C79: This is a small supercapacitor with a nominal and discharge capacity of 4,0µAh and a electrostatic capacity of maximum 14mF. The minimum internal resistance of the capacitor is 50Ω.
I = 4,8V / 50Ω = 96mA → 96mA < 3,33A. In addition the current will be reduced by safety resistor R105.
Due to the very small capacitance of the capacitor (4,0µAh) and the high impedance it is considered not necessary to do temperature measurements on the component. The unique ceramic packaging with superior air-tightness is used. As the result, it offers leakage resistance and humidity resistance. Total weight of the capacitor is 0,025g.

A.2.4 Combination of inductive and capacitive spark ignition

Charging circuit:
No combination of inductance and capacitance.

Battery circuit/pack:
No combination of inductance and capacitance.

Buzzer circuit:
No combination of inductance and capacitance.

Main circuit:
No inductance in the main circuit board except for ferrite beads (NF2, NF21, NF22, NF23, NF31, NF32, NF33 and NF41). BLE module has an inductance of 10,8nH. Maximum permitted inductance is 37µH. 10,8nH is only 0,35% of permitted inductance.

Pump circuit:
Capacitance: 136µF > 8µF → 5,9%

Inductance: 607µH > 59,8µH → 9,9%
Both inductance and capacitance are below 50% of permitted values. No further assessment is necessary.

Motor circuit:
Capacitance: 136µF > 5µF → 3,7%
Inductance: 26,1mH > 300µH → 1,2%
Both inductance and capacitance are below 50% of permitted values. No further assessment is necessary.

A.2.5 Shunt short-circuit (crowbar) spark ignition
No crowbars in the circuit.

A.2.6 Other spark ignition considerations
N / A

**A.3 Thermal ignition consideration**
Maximum nominal voltage from the battery pack, U: 3,6V
Maximum open circuit voltage: 4,2V
Maximum voltage from the buzzer circuit, U: 5,8V. (As the charge pump does not have 100% efficiency this is not considered.)
Maximum ambient temperature, Ta = +60°C

A.3.1 Temperature for small components for Group I and Group II
Charging circuit:
The power to the charging circuit is limited by the resistors RS4, RS5, RS6, RS7 and RS8 in parallel.
R = 470Ω x 0,99 II 470Ω x 0,99 II 10kΩ x 0,995 II 10kΩ x 0,995 II 10kΩ x 0,995 = 217,4Ω
Voltage from battery is, U: 3,6V
Maximum power, P = (3,6V² / 217,4Ω) / 4 = 14,9mW
For components >20mm²: 14,9mW < 1,2W → T4
For components <20mm²: Rth = (275°C - 60°C) / 14,9mW = 14429K/W → Actual Rth for a component is much less than 14429K/W → T4

Battery circuit/pack:
Voltage from battery is, U: 3,6V
Minimum resistance to limit the current is, R = R1 = 330Ω x 0,99 = 326,7Ω
Maximum power, P = (3,6V² / 326,7Ω) / 4 = 10,0mW.

Voltage between P+ and Th is, U: 3,6V
Minimum resistance to limit the current is, R = R4 = 150Ω x 0,99 = 148,5Ω
Maximum power, P = (3,6V² / 148,5Ω) / 4 = 21,9mW.
For components >20mm²: 21,9mW < 1,2W → T4
For components <20mm²: Rth = (275°C - 60°C) / 21,9mW = 9818K/W → Actual Rth for a component is much less than 9818K/W → T4

P + is limited by the resistors connected to the other circuits.

Buzzer circuit:
Voltage to buzzer circuit from battery, U = 3,6V
Minimum resistance between buzzer circuit and battery, R = RS11 + RS12 = 8,2Ω x 0,99 x 2 = 16,2Ω
Maximum power to buzzer from battery, P = (3,6V² / 16,2Ω) / 4 = 200mW

Maximum power from buzzer circuit to main circuit, P = (3,6V² / (16,2Ω + 495Ω) / 4 = 6,4mW
or
Maximum power from main circuit to buzzer circuit, P = (3,6V² / 495Ω) / 4 = 6,6mW

Total power to the buzzer circuit will be power from battery + power from main circuit = 200mW + 6,6mW = 206,6mW
For components >20mm²: 206,6mW < 1,2W → T4

For components <20mm²: Rth = (275°C - 60°C) / 206,6mW = 1041K/W. Rth for R62 (0603) is 350K/W. → 350K/W < 1041K/W → T4

Pump circuit:
Voltage to buzzer circuit from battery, U = 3,6V
Minimum resistance between pump circuit and battery is RS51, RS52, RS53, RS54 and RS55 in series (R = 1,5Ω x 0,99 x 5 = 7,4Ω). In addition current from the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ( R = (10kΩ x 0,995) / 3 = 3316Ω).
Rp = 7,4Ω II 3316Ω = 7,38Ω
Maximum power to the pump circuit, P = (3,6V² / 7,38Ω) / 4 = 439,1mW
For components >20mm²: 439,1mW < 1,2W → T4
For components <20mm²: Rth = (275°C - 60°C) / 439,1mW = 490K/W. Rth for Q6 (1,6mm x 1,6mm > 0603) is approx. 350K/W. → 350K/W < 490K/W → T4

Motor circuit:
Voltage to buzzer circuit from battery, U = 3,6V
Minimum resistance from battery and main circuit is, R = RS61 II RV1 = 36Ω x 0,99 II 10kΩ x 0,995 = 35,51Ω.
Maximum power, P = (3,6V² / 35,51Ω) / 4 = 91,3mW
(Power from main circuit and RV1 (10kΩ) is negligible.)
For components >20mm²: 91,3mW < 1,2W → T4
For components <20mm²: Rth = (275°C - 60°C) / 91,3mW = 2354K/W. Rth for Q6 (1,6mm x 1,6mm > 0603) is approx. 350K/W. → 350K/W < 498K/W → Actual Rth for a component is much less than 9818K/W → T4

Main circuit:
Voltage to buzzer circuit from battery, U = 3,6V
Minimum resistance, R = 4,35Ω
Maximum power, P = (3,6V² / 4,35Ω) / 4 = 744,9mW
In addition power from the buzzer circuit, P = 6,4mW
(Power from pump and motor circuits are negligible.)
Total power, P = 744,9mW + 6,4mW = 751,3mW
For components >20mm²: 751,3mW < 1,2W → T4
For components <20mm²: Rth = (275°C - 60°C) / 751,3mW = 286K/W. Components in size 1206, 0805 and SOT-23 have Rth less than 286K/W → T4
R21, R22, R23, R24, R25, R26, R31, R32, R33, R34, R35, R36, R51, R52, R53, R54, R55, R56, R71, R72, R73, R74, R75, R76, R77, R75, R76, R77, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R101, R102, R103, R104, R106, R107, R108, R109, R111, R112, R121,R122, R123, R124, R125, R126, R127, R128, R129, R130, R131, R132, R141, R142, R143, R144, R145, R151, R152, R153, R154, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R169, R170, R171, R172, R173, R174, R175, R176, R178, R181, R182, R183, R184, R185, R186, R191, R192, R193, R194, R195, R196, R201, R202, R203, R204, R206, R211, R212, R213, R214, R215, R216, R217, R220, R221, R222, R223, R224, R225, R226, R227, R231, R232, R233, R234: 1608 /0603. See appendix B.6 for test details → T4
PS1: Pressure sensor. The measuring bridge resistors are >10kΩ each.
D5, D6, D7, D8, D8, D9, D10, D11: Schottky diode, VR 30V, VF 0,37V, 0,8mm x 1,2mm. Maximum power, P = 0,37V x (3,6V / 4,35Ω) = 307mW. Package size is between 0402 and 0603, Rth ≈ 600K/W. T = 60°C + 600K/W x 307mW = 245°C → T4
Q3: 1,6mm x 1,6mm is larger than a 0603 component, so the test in appendix B.6 will be representative.
Q4: 2,0mm x 2,0mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.
Q8, Q9, Q10, Q11, Q14, Q15, Q16: 2,0mm x 2,1mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.
Q13: 2,0mm x 2,0mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.
IC3, IC6, IC7, IC9, IC11: SOT-23
IC5: 2,9mm x 1,6mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.

IC10: 3,1mm x 3,1mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.
IC12: >20mm²
IC13: 3,9mm x 5,05mm (footprint) > 20mm² surface area.
IC14: 3,81mm x 4,8mm (footprint) > 20mm² surface area.
IC15: 27mm² > 20mm²
IC16: Hybrid circuit, including 0201 inductors. See appendix B.7 for temperature measurement test.
IC17: 5mm x 5mm (footprint) > 20mm² surface area.
IC18, IC22: larger than a SOT-23 package component, and will have a Rth less than 250K/W.
IC19, IC20: 3mm x 3mm (footprint) > 20mm² surface area.
IC21: 2,0mm x 2,0mm, this component is larger than a 0805 component, and will have a Rth less than 250K/W.
NF21, RF22, NF23, NF31, NF32, NF33, NF41: 0402, beads, jumper or resistors: Maximum supply to main circuit is 751,3mW and 3,6V. For beads DC resistance is 2,2Ω and current rating is 200mA@125°C. The component is already tested in RIKEN KEIKI project NO/PRE/ExTR15.0012/00. *The surface temperature of the small components <20mm² measured while dissipating 1.137W.*
*This resulted in a maximum temperature rise is 204°C (SENSOR_PCB – NF3 – BLM15HD182 - 0402). At ambient temperature of 60°C the maximum surface temperature would hence be 264°C which is below the 275°C limit.* Also 0402 resistor is tested in the same project @807mW → ΔT 105,9K.
TH1: 1608 = 0603 component, so the test in appendix B.6 will be representative.

A.3.2 Wiring within intrinsically safe apparatus for Group I and Group II
Maximum power to the different circuits:
Buzzer circuit: 206,6mW
Pump circuit: 439,1mW
Motor circuit: 91,3mW
Main circuit: 751,3mW
Maximum ambient temperature: +60°C.
According to NOTE 5 of Table 2: When the maximum power does not exceed 1,2W (ref. Table 4 of IEC 60079-0) the wiring can be assigned a temperature classification of T4.
Wiring from battery to pcb is AWG 22 = 0,34mm². According to table 2 a current of 7,7A is permitted @+40°C with a cross-sectional area of 0,196mm². Maximum current to all circuits added together is 978mA + 12,9mA + 28,3mA + 260mA + 569mA +119mA = 1,97A. 7,7A > 1,97A
Wiring to pump from pcb is AWG 28 = 0,08mm². According to table 2 a current of 3,7A is permitted @+40°C with a cross-sectional area of 0,0314mm². Maximum current to the pump is, I = 3,6V / 7,38Ω = 488mA.
488mA < 3,7A and 0,08mm² > 0,0314mm²

A.3.3 Tracks on printed circuit boards for Group I and Group II
Maximum power to the different circuits:
Buzzer circuit: 206,6mW
Pump circuit: 439,1mW
Motor circuit: 91,3mW
Main circuit: 751,3mW
Maximum ambient temperature: +60°C.
According to clause 5.6.4: When the maximum power does not exceed 1,2W (ref. Table 4 of IEC 60079-0) the wiring can be assigned a temperature classification of T4.
The current from the battery will be reduced by the current limiting resistors, and the track width is 1mm → 5,9A / 2 / 1,2 = 2,45A permitted current → 2,45A > 1,97A (see calculation in A.3.2 above).

A.3.4 Intrinsically safe apparatus and component temperature for Group III
N / A – no dust certification.

**A.4 Rating of components**
A.4.1 Resistors
Um when charging: 6,0V

Charging circuit:
RS2, RS3: 30Ω, 1%, 2W, 200V → P = (6V² / (30Ω x 0,99)) x 1,5 = 1,82W → 2W > 1,82W
RS4, RS5: 470Ω, 1%, 0,5W, 200V → P = (6V² / (470Ω x 0,99)) x 1,5 = 116mW → 0,5W > 116mW
RS6, RS7, RS8: 10kΩ, 0,5%, 0,5W, 200V → P = (6V² / (10kΩ x 0,995)) x 1,5 = 6mW → 0,5W > 6mW

Buzzer circuit:
RS11, RS12: 8,2Ω, 1%, 2W, 200V → These two resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0,43V) maximum voltage will be, V = (6V – 0,43V) / 2 = 2,79V over each resistor. P = (2,79$V^2$ / (8,2Ω x 0,99)) x 1,5) = 1,44W → 2W > 1,44W
RB1, RB2: 1kΩ, 0,5%, 0,5W, 200V → P = (6$V^2$ / (1kΩ x 0,995)) x 1,5 = 55mW → 0,5W > 55mW
RB3, RB4: 1,5kΩ, 1%, 0,75W, 200V → P = (4,8$V^2$ / (1,5kΩ x 0,99)) x 1,5 = 8mW → 0,75W > 8mW

Pump circuit:
RS51, RS52, RS53, RS54, RS55: 1,5Ω, 1%, 2W, 200V → These five resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0,43V) maximum voltage will be, V = (6V – 0,43V) / 5 = 1,12V over each resistor. P = (1,12$V^2$ / (1,5Ω x 0,99)) x 1,5) = 1,27W → 2W > 1,27W
RP1, RP2, RP3: 10kΩ, 0,5%, 0,5W, 200V → P = (6$V^2$ / (10kΩ x 0,995)) x 1,5 = 6mW → 0,5W > 6mW

Motor circuit:
RS61: 36Ω, 1%, 2W, 200V → Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0,43V) maximum voltage will be, V = 6V – 0,43V = 5,57V over the resistor. P = (5,57$V^2$ / (36Ω x 0,99)) x 1,5) = 1,31W → 2W > 1,31W
RV1: 10kΩ, 0,5%, 0,5W, 200V → P = (6$V^2$ / (10kΩ x 0,995)) x 1,5 = 6mW → 0,5W > 6mW

Main circuit:
RS21: 100kΩ, 1%, 0,5W, 200V → P = (6$V^2$ / (100kΩ x 0,99)) x 1,5 = 0,5mW → 0,5W > 0,5mW
RS31, RS32, RS33, RS34: 2,2Ω, 1%, 2W, 200V → These four resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0,43V) maximum voltage will be, V = (6V – 0,43V) / 4 = 1,40V over each resistor. P = (1,40$V^2$ / (2,2Ω x 0,99)) x 1,5) = 1,35W → 2W > 1,35W
RS41, RS42, RS43, RS44, RS45: 1,8Ω, 1%, 2W, 200V → These five resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0,43V) maximum voltage will be, V = (6V – 0,43V) / 5 = 1,12V over each resistor. P = (1,12$V^2$ / (1,8Ω x 0,99)) x 1,5) = 1,06W → 2W > 1,06W
R105 (in series with capacitor C79): 150Ω, 1%, 0,5W, 200V → P = (6$V^2$ / (150Ω x 0,99)) x 1,5 = 364mW → 0,5W > 364mW

Battery circuit:
R1: 330Ω, 1%, 0,5W, 200V → P = (6$V^2$ / (330Ω x 0,99)) x 1,5 = 166mW → 0,5W > 166mW
R4: 150Ω, 1%, 0,5W, 200V → P = (6$V^2$ / (150Ω x 0,99)) x 1,5 = 364mW → 0,5W > 364mW

A.4.2 Shunt voltage limiters
Zener diodes are used in the buzzer circuit to clamp the voltage to a maximum of 4,8V (two and two parallel coupled).

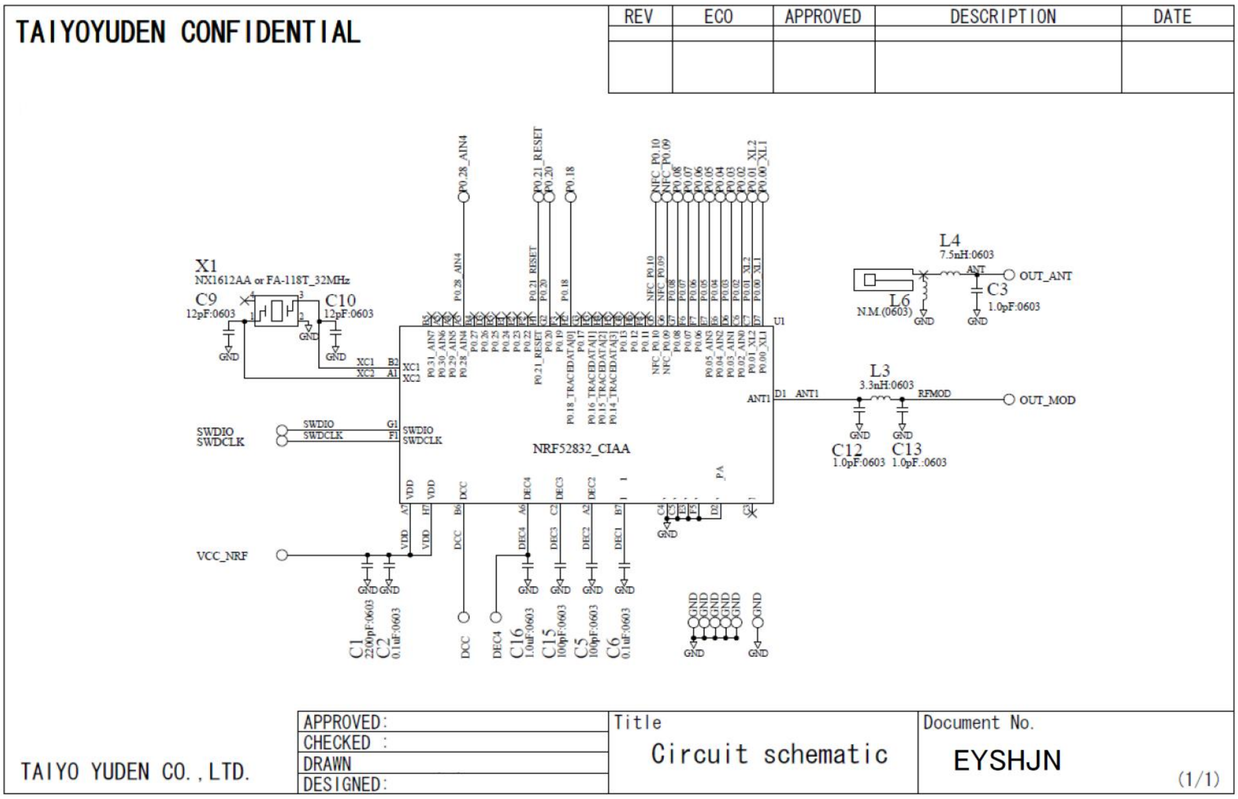
| P/N | Symbol | | | | | | |
|---|---|---|---|---|---|---|---|
| | Zener Voltage: $V_Z$(V) | | | Dynamic Impedance: $Z_Z$(Ω) | | Reverse Current: $I_R$(μA) | |
| | MIN. | MAX. | $I_Z$(mA) | MAX. | $I_Z$(mA) | MAX. | $V_R$(V) |
| TFZV 2.0B | 2.020 | 2.200 | 20 | 140 | 20 | 120 | 0.5 |
| TFZV 2.2B | 2.220 | 2.410 | 20 | 120 | 20 | 120 | 0.7 |
| TFZV 2.4B | 2.430 | 2.630 | 20 | 100 | 20 | 120 | 1.0 |
| TFZV 2.7B | 2.690 | 2.910 | 20 | 100 | 20 | 100 | 1.0 |
| TFZV 3.0B | 3.010 | 3.220 | 20 | 80 | 20 | 50 | 1.0 |
| TFZV 3.3B | 3.320 | 3.530 | 20 | 70 | 20 | 20 | 1.0 |
| TFZV 3.6B | 3.600 | 3.845 | 20 | 60 | 20 | 10 | 1.0 |
| TFZV 3.9B | 3.890 | 4.160 | 20 | 50 | 20 | 5 | 1.0 |
| TFZV 4.3B | 4.170 | 4.430 | 20 | 40 | 20 | 5 | 1.0 |
| TFZV 4.7B | 4.550 | 4.800 | 20 | 25 | 20 | 5 | 1.0 |
| TFZV 5.1B | 4.940 | 5.200 | 20 | [illegible] | 20 | 5 | 1.5 |

They are rated 0,5W. The current to the zener diodes are limited by safety resistors (RB1 II RB3 for ZD3 II ZD4 and RB2 II RB4 for ZD1 II ZD2) for one zener couple and RB2, RB3 and RB4. 1,5 in safety factor is applied.
ZD1, ZD2, ZD3, ZD4: 4,8V, 0,5W → P = ((6V / (1kΩ x 0,995 II 1,5kΩ x 0,99)) x UZ) x 1,5 = (6V / 595,7Ω) x 4,8V x 1,5 = 73mW → 0,5W > 73mW. Due to the large safety factor (SF = 500mW / 49mW = 10,3) rating test is considered not to be necessary.

A.4.3 Series current limiter
D1, D2, D3 are diodes connected in series. Maximum current in lead direction is secured by the fuse F1. 1,5 in safety factor is applied.
If diodes = 3A
Vr diodes = 20V
Ifuse = 0,75A x 1,7 = 1,275A
Maximum voltage in circuit = 12,6V

3A > 1,275A x 1,5 = 1,92A
20V > 12,6V x 1,5 = 18,9V

A.4.4 __________
IC16 (hybrid circuit) circuit diagram and bom:




| Parts No. | Description | Parts name and standard | Supplier | Remark |
|---|---|---|---|---|
| C1 | CAPACITOR | LMK063 BJ222 KP-F or Equivalent | TAIYO YUDEN or other supplier | |
| C2 C6 | CAPACITOR | JMK063 BJ104 KP-F or Equivalent | TAIYO YUDEN or other supplier | |
| C3 C12 C13 | CAPACITOR | GRM0334C1E or Equivalent | MURATA or other supplier | |
| C5 C15 | CAPACITOR | UMK063 CH101JT-F or Equivalent | TAIYO YUDEN or other supplier | |
| C9 C10 | CAPACITOR | TMK063 CH120 JP-F or Equivalent | TAIYO YUDEN or other supplier | |
| C16 | CAPACITOR | JMK063ABJ105MP-F or Equivalent | TAIYO YUDEN or other supplier | |
| L3 | INDUCTOR | HK 0603 or Equivalent | TAIYO YUDEN or other supplier | |
| L4 | INDUCTOR | HK 0603 or Equivalent | TAIYO YUDEN or other supplier | |
| X1 | CRYSTAL | FCX-07L (32MHz) or Equivalent | RIVER ELETEC or other supplier | |
| U1 | IC | nRF52832 | NORDIC | |
| PCB1 | PCB | PB-150197 | MEIKO | |
| CASE1 | CASE | GTC097-KFT | KOBAYASHI SPRING | |

**APPENDIX B: Tests**

### B.1 Separation distances (creepage and clearance)

| | |
|---|---|
| Equipment Tested: | Layout of circuit board |
| Date of Test (yyyy/mm/dd): | 2022/02/03 and 2022/02/28 |
| Clause and Standards: | 6.3.4 and 6.3.8 of IEC 60079-11: 2011 |

#### B.1.1 Test procedures

Separation distances are measured by the use of microscope and micrometers on circuit board.


#### B.1.2 Results

**Creepage and clearance separation distances**

| Designation | Distance [mm] | Requirement [mm] | | Designation | Distance [mm] | Requirement [mm] |
|---|---|---|---|---|---|---|
| Charging circuit: | | | | RV1 | 2,2 | ≥1,5 |
| RS2 | 1,8 | ≥1,5 | | | | |
| RS3 | 1,8 | ≥1,5 | | Main circuit: | | |
| RS4 | 2,4 | ≥1,5 | | RS21 | 2,2 | ≥1,5 |
| RS5 | 2,5 | ≥1,5 | | RS31 | 1,8 | ≥1,5 |
| RS6 | 2,4 | ≥1,5 | | RS32 | 1,8 | ≥1,5 |
| RS7 | 2,4 | ≥1,5 | | RS33 | 1,8 | ≥1,5 |
| RS8 | 2,4 | ≥1,5 | | RS34 | 1,8 | ≥1,5 |
| D1 | 1,5 | ≥1,5 | | RS41 | 1,7 | ≥1,5 |
| D2 | 1,5 | ≥1,5 | | RS42 | 1,7 | ≥1,5 |
| D3 | 1,5 | ≥1,5 | | RS43 | 1,7 | ≥1,5 |
| | | | | RS44 | 1,7 | ≥1,5 |
| Buzzer circuit: | | | | RS45 | 1,8 | ≥1,5 |
| RS11 | 1,9 | ≥1,5 | | R105 | 2,0 | ≥1,5 |
| RS12 | 2,7 | ≥1,5 | | | | |
| RB1 | 2,1 | ≥1,5 | | Battery/protect circuit: | | |
| RB2 | 2,2 | ≥1,5 | | R1 | 2,0 | ≥1,5 |
| RB3 | 2,4 | ≥2 | | R4 | 2,0 | ≥1,5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RB4 | 2,2 | ≥2 | | | | |
| | | | | | | |
| Pump circuit: | | | | | | |
| RS51 | 3,1 | ≥1,5 | | | | |
| RS52 | 2,0 | ≥1,5 | | | | |
| RS53 | 1,8 | ≥1,5 | | | | |
| RS54 | 1,8 | ≥1,5 | | | | |
| RS55 | 1,9 | ≥1,5 | | | | |
| | | | | | | |
| Motor circuit: | | | | | | |
| RS61 | 1,7 | ≥1,5 | | | | |

**Separation distances between tracks and components [mm]. Requirements ≥1,5 mm:**

Battery/protect circuit:
- Between R4 and RT1: 2,0

Charger circuit:
- Between D2 and RS42: 1,6

Buzzer circuit:
- Between RS11 and R22: 2,1

Pump circuit:
- Between RS54 and RS55: 1,5

Main circuit:
- Between RS31 and RS34: 1,6
- Between RS42 and RS43: 1,5
- Between RS43 and R16: 1,6

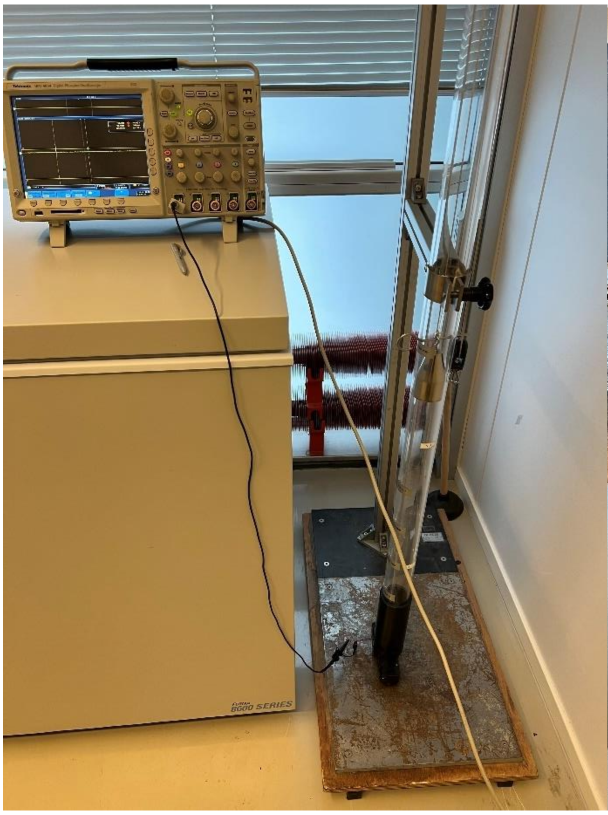
### B.2 Piezo-electric device (buzzer)

| | |
|---|---|
| Equipment Tested: | BZ1 |
| Date of Test (yyyy/mm/dd): | 2022/02/03 |
| Clause and Standards: | 7.7 and 10.7 of IEC 60079-11: 2011 |

#### B.2.1 Test procedures

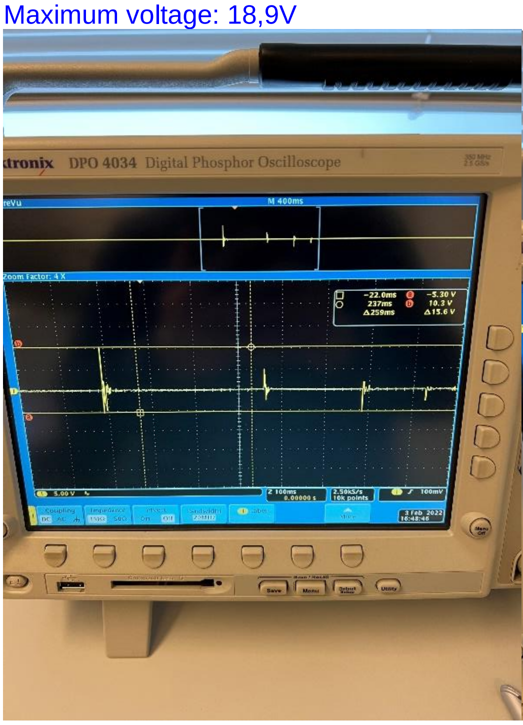
The piezoelectric devize (BZ1) was isolated from the other components in the circuit (IC4 was removed). Wires were soldered to the + and – soldering pads on the pcb.

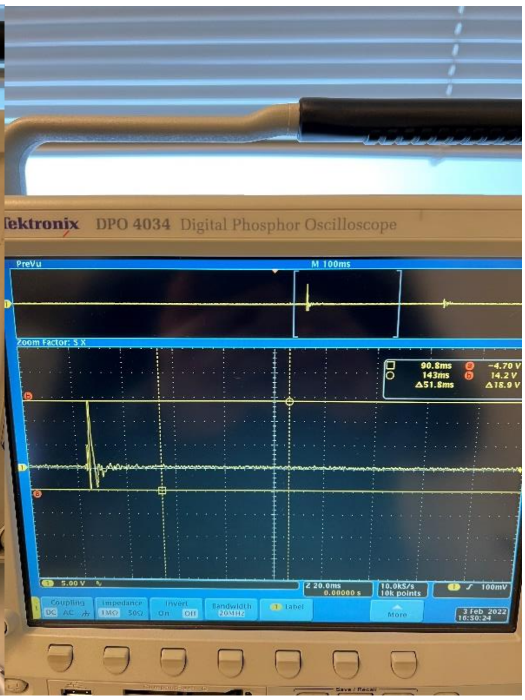
2 resistance to impact tests were performed on the surface of the enclosure. The impacts hit as close as possible to BZ1. Maximum voltage was measured by the use of a oscilloscope.



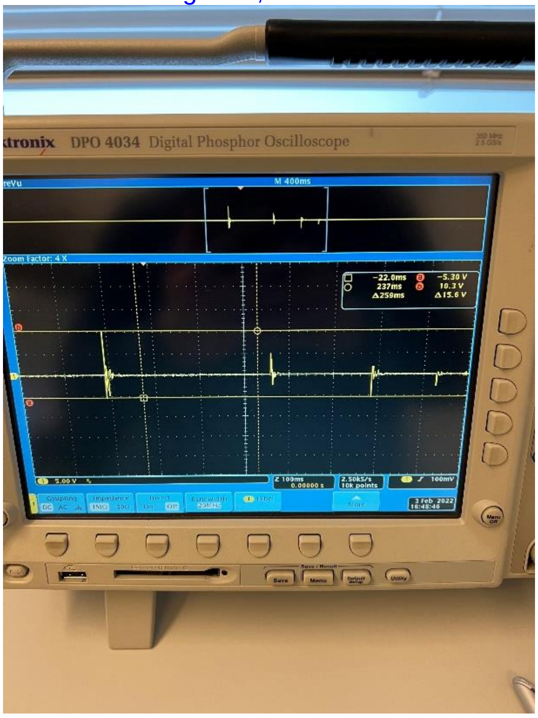

**B.2.2 Results**
Measured capacitance: 34,37nF
Claimed maximum capacitance in bom: 42,9nF


Test 1:
Maximum voltage: 18,9V



Test 2:
Maximum voltage: 15,6V

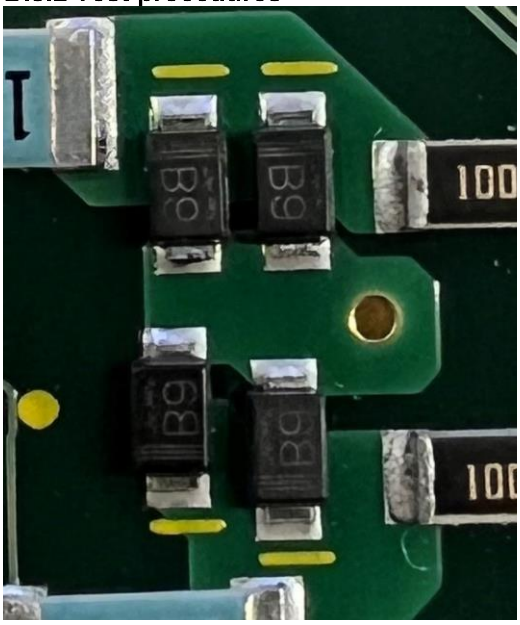



Result:
E = 0,5 x 42,9nF x 18,9V2 = 7,67µJ
7,67µJ < 50µJ → IIC

### B.3 Measurement of infallible tracks

| | |
|---|---|
| Equipment Tested: | Safety shunt assembly tracks, ZD1-ZD4 |
| Date of Test (yyyy/mm/dd): | 2022/06/21 |
| Clause and Standards: | 8.8.b.2 of IEC 60079-11:2011 |

#### B.3.1 Test procedures




Track is measured on the most narrow by the use of a microscope and micrometer.

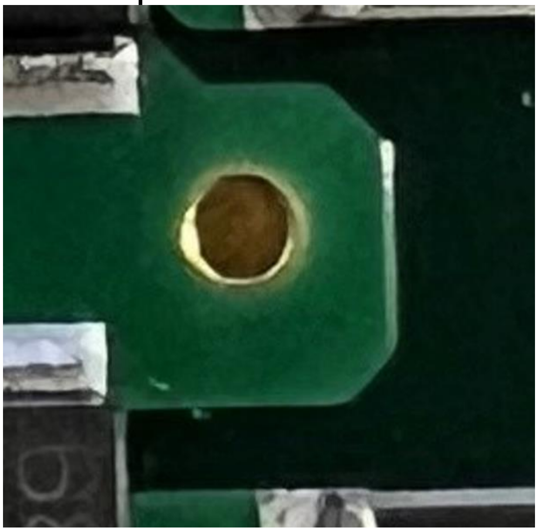
#### B.3.2 Results

Minimum = 2,2mm
Requirement: ≥2,0mm

### B.4 Measurement of infallible vias

| | |
|---|---|
| Equipment Tested: | Safety shunt assembly vias, ZD1-ZD4 anodes to GND |
| Date of Test (yyyy/mm/dd): | 2022/06/21 |
| Clause and Standards: | 8.8.b.3 of IEC 60079-11:2011 |

#### B.4.1 Test procedures



Internal diameter is measured on the most narrow by the use of a microscope and micrometer.

#### B.4.2 Results

Internal diameter = 0,7mm
Circumference = 3,14 x 0,7mm ≈ 2,2mm
Requirement: ≥2,0mm

### B.5 Battery testing

| | |
|---|---|
| Equipment Tested: | Panasonic NCR18650GA (single cell) |
| Date of Test (yyyy/mm/dd): | Date of issue for ExTR: 2020-03-30 |
| Clause and Standards: | 10.5.2, 10.5.3.a and 10.5.3.b of IEC 60079-11: 2011 |

#### B.5.1 Test procedures

Tested according to 10.5.3.a and 10.5.3.b and 10.5.2. Test results are copied from IECEx TR NO/PRE/ExTR20.0043/00.

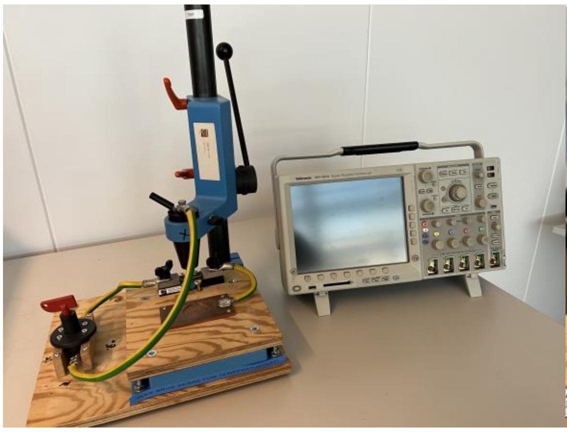
#### B.5.2 Results

Panasonic NCR18650GA:

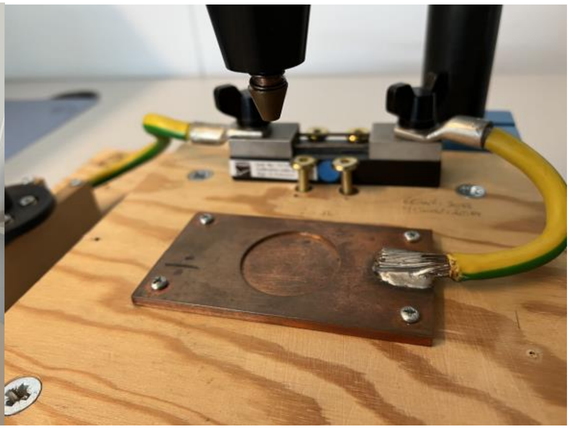
Spark ignition testing, clause 10.5.3. a:

| No. | Open circuit voltage [V] | Resistance of short circuit link [mΩ] | Measured voltage over short circuit link [mV] | Short circuit current (I = U / R) [A] | Internal resistance (R = U / I) [mΩ] |
|---|---|---|---|---|---|
| 1 | 4,139 | 2 | 300 | 150 | 28 |
| 2 | 4,127 | 2 | 324 | 162 | 25 |
| 3 | 4,127 | 2 | 320 | 160 | 26 |

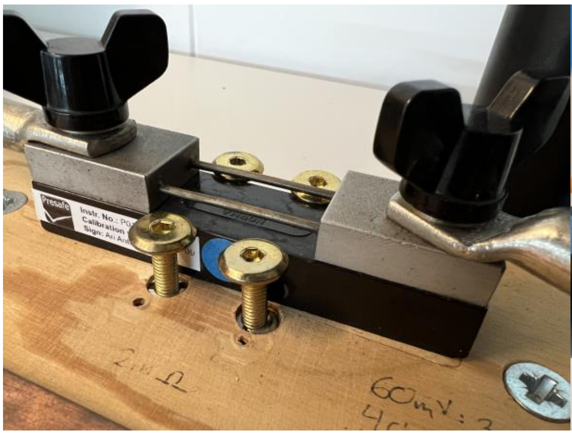
| | | | | | |
|---|---|---|---|---|---|
| 4 | 4,128 | 2 | 334 | 167 | 25 |
| 5 | 4,139 | 2 | 328 | 164 | 25 |
| **6** | **4,137** | **2** | **340** | **170** | **24** |
| 7 | 4,138 | 2 | 320 | 160 | 26 |
| 8 | 4,126 | 2 | 324 | 162 | 25 |
| 9 | 4,143 | 2 | 322 | 161 | 26 |
| 10 | 4,132 | 2 | 324 | 162 | 25 |



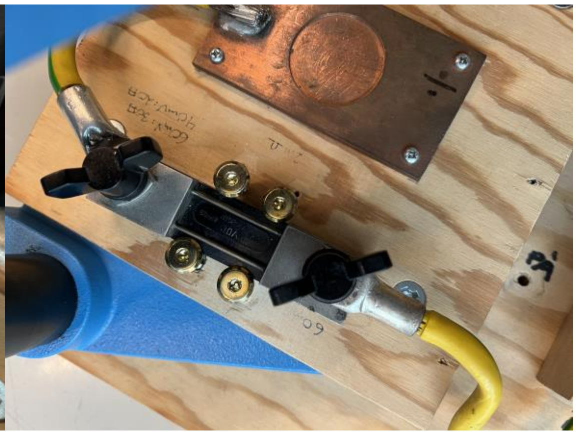
Overview.



The cell is placed between the contact points.



Probe for oscilloscope measures voltage drop over shunt resistor. Short circuit current is then calculated (I = U / R).



Calibrated shunt resistor of 2mΩ.

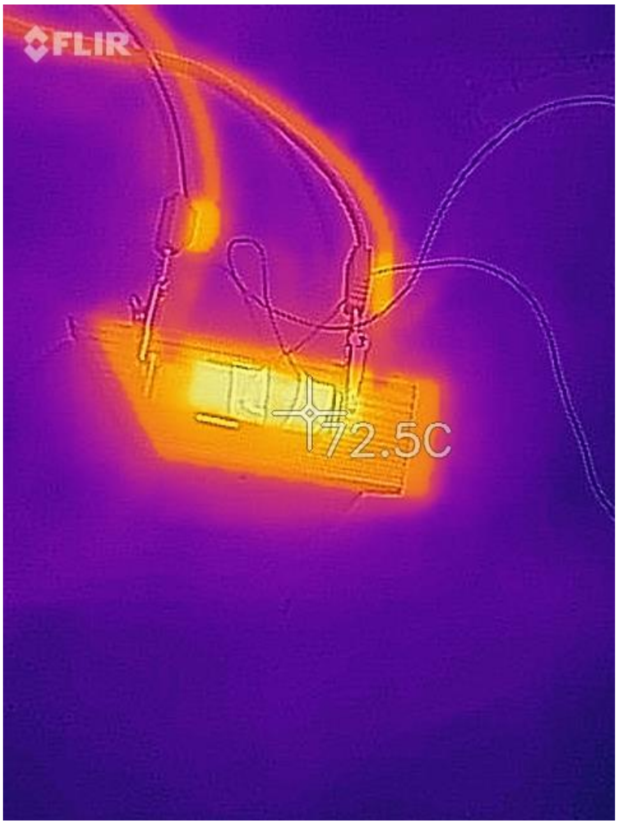
Surface temperature testing, clause 10.5.3.b (single cell, see also appendix B.6):

| No. | Ambient temperature [°C] | Measured temperature [°C] | Delta temperature [K] | Max. ambient temperature [°C] | Temperature class |
|---|---|---|---|---|---|
| 1 | 60 | 89 | 29 | 60 | T5 |
| **2** | **60** | **103** | **43** | **60** | **T4** |
| 3 | 60 | 96 | 36 | 60 | T5 |
| 4 | 60 | 89 | 29 | 60 | T5 |
| 5 | 60 | 87 | 27 | 60 | T5 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 60 | 91 | 31 | 60 | T5 |
| 7 | 60 | 93 | 33 | 60 | T5 |
| 8 | 60 | 90 | 30 | 60 | T5 |
| 9 | 60 | 85 | 25 | 60 | T5 |
| 10 | 60 | 89 | 29 | 60 | T5 |

NOTE: the temperature tests are done without an enclose upon customer request. Due to the large safety margin (32K) T4 is accepted.

A thermal camera is used to find the hottest point on the cell, so the thermal couple can be placed at the correct area. The thermal couple is fixed to the cell and temperature rise is measured by temperature meter.




Note: the temperature rise is measured by thermal couple and not the thermal camera.

Electrolyte leakage testing, clause 10.5.2:
The ten test cells are placed over a piece of blotting paper.
Test duration ≥12 hours.

Results:

Maximum short circuit current (if required): 170A

Minimum internal resistance: 24mΩ

Maximum temperature rise: 43K

Visible sign of electrolyte on the blotting paper or on the external surfaces of the test samples: No

Comments:

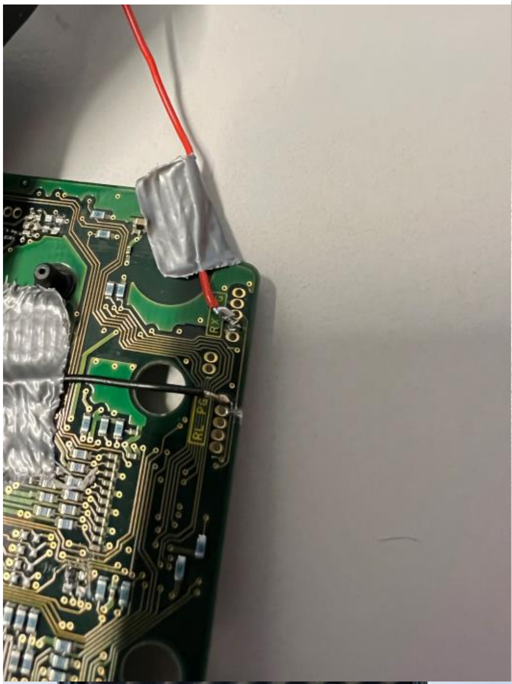
Discharged with 2,5A, and a cut off voltage of 2,5V.
Rated capacity: 3300mAh

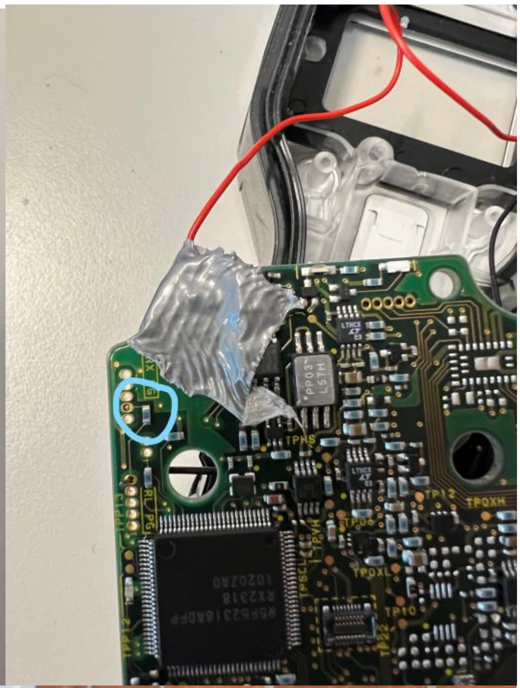
**B.6 Temperature test of 0603 component**

| | |
|---|---|
| Equipment Tested: | R73 (0603 - 33Ω) |
| Date of Test (yyyy/mm/dd): | 2022/03/09 |
| Clause and Standards: | 10.2 of IEC 60079-11: 2011 |

**B.6.1 Test procedures**

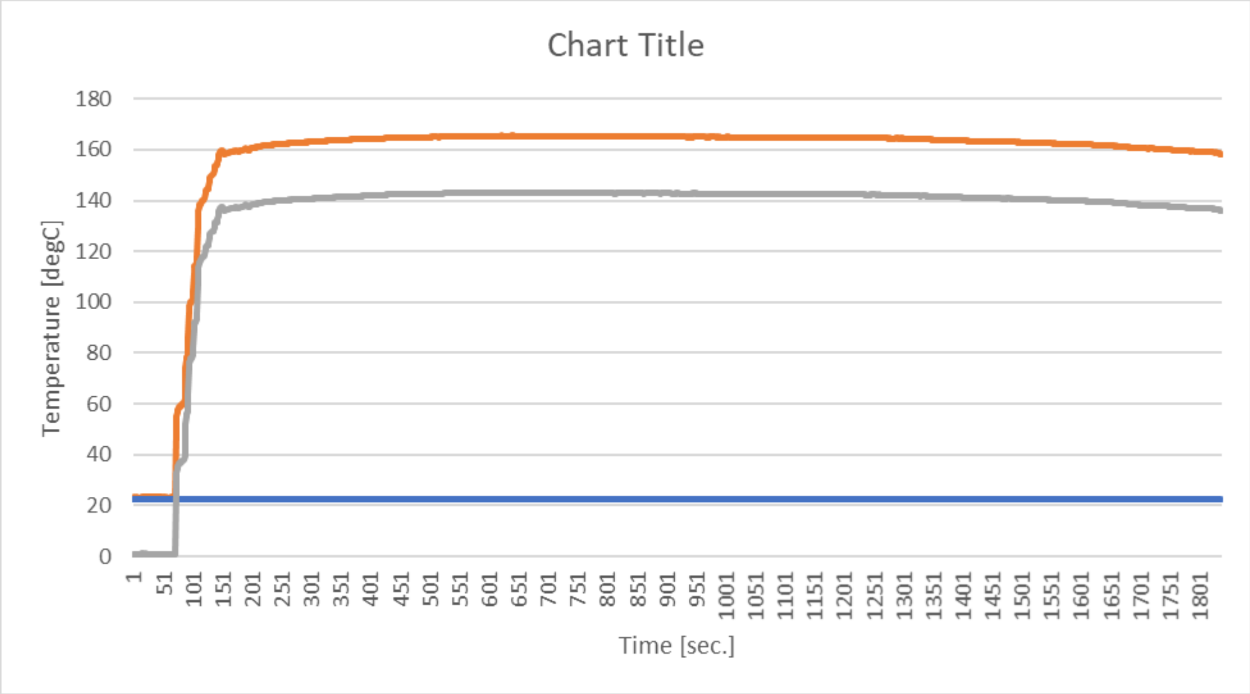
Component tested: R73 (33Ω). The component was isolated so all current supplied to it will float through this specific component. Connection wires were attached to CN6 and CN8 on the opposite site. Tracks had to be cut to isolate the component.
R73 was chosen to be tested as it has less cooling area connected to the soldering pads (very thin tracks).
Thermocouple attached to the component had a diameter of 0,08mm.






**B.6.2 Results**
Power dissipated of R73, P = 825mW
Ta: 22,3°C
Tmeasured = 165,6°C
ΔT = 143,3K
143,3K + 60°C = 203,3°C

203,3°C < 275°C → T4

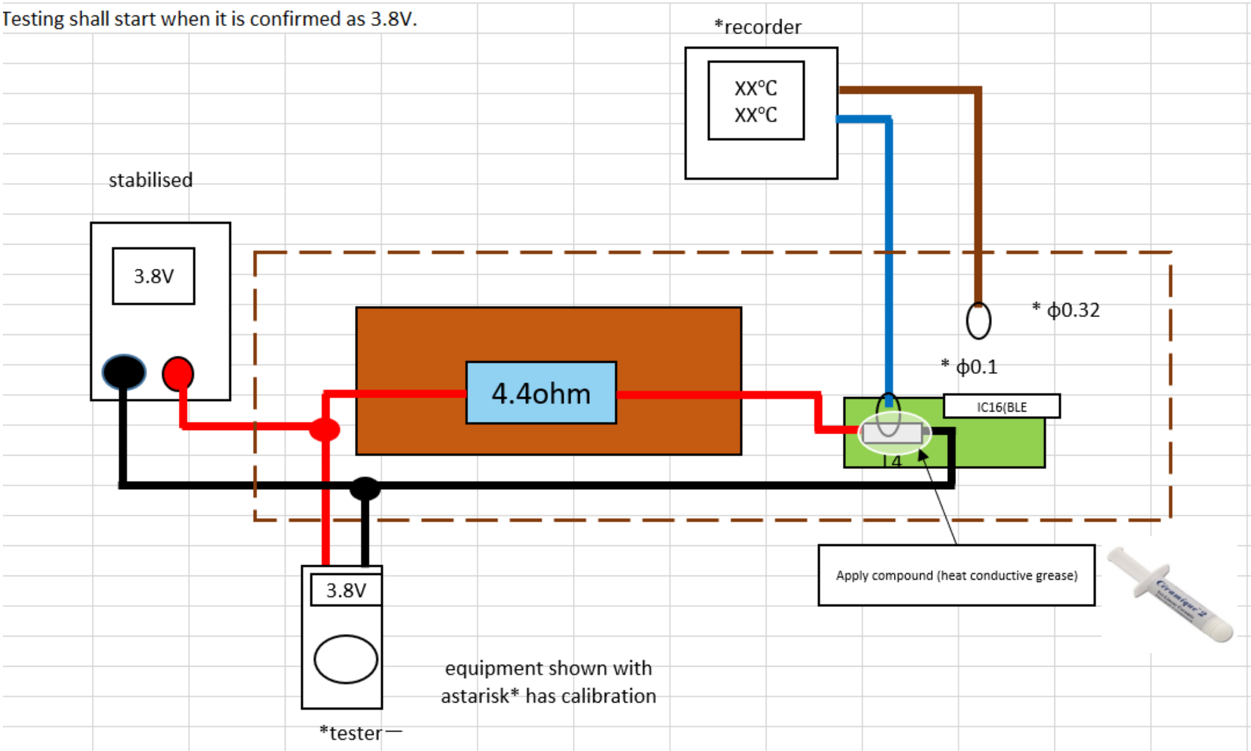



**B.7 Test conducted Temperature test of L4 (part of IC16 / BLE module)**

| | |
|---|---|
| Equipment Tested: | L4 (inductor) as a bart of the hybrid component IC16 |
| Date of Test (yyyy/mm/dd): | 2022/05/19 |
| Clause and Standards: | 10.2 of IEC 60079-11: 2011 |

**B.7.1 Test procedures**

According to clause 7.6.h of IEC 60079-11: 2011 the resistance of an inductor at failure shall be between nominal value (0,34Ω) and 0.
The inductor L4 was isolated on the circuit board.




R = 4,37Ω U = 3,8V

**B.7.2 Results**

Tmeasured = 171°C    Ta-max = 60°C    Ta = 26°C    ΔT = 145K
Tmax = 145K + 60°C = 205°C
205°C < 275°C → T4