Guarantee

This equipment is guaranteed against defects in materials and workmanship. This guarantee applies for twelve months from date of delivery. We will repair or replace products which prove to be defective during the guarantee period provided they are returned to us prepaid. The guarantee will not apply to:

- Equipment which has been modified or altered in any way without the written permission of Campbell Scientific
- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific will return guaranteed equipment by surface carrier prepaid. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This guarantee and the Company’s obligation thereunder is in lieu of all other guarantees, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

Please inform us before returning equipment and obtain a Repair Reference Number whether the repair is under guarantee or not. Please state the faults as clearly as possible, and if the product is out of the guarantee period it should be accompanied by a purchase order. Quotations for repairs can be given on request.

When returning equipment, the Repair Reference Number must be clearly marked on the outside of the package.

Note that goods sent air freight are subject to Customs clearance fees which Campbell Scientific will charge to customers. In many cases, these charges are greater than the cost of the repair.
About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

**Area:**
- 1 in² (square inch) = 645 mm²

**Length:**
- 1 in. (inch) = 25.4 mm
- 1 ft (foot) = 304.8 mm
- 1 yard = 0.914 m
- 1 mile = 1.609 km

**Mass:**
- 1 oz. (ounce) = 28.35 g
- 1 lb (pound weight) = 0.454 kg

**Pressure:**
- 1 psi (lb/in²) = 68.95 mb

**Volume:**
- 1 UK pint = 568.3 ml
- 1 UK gallon = 4.546 litres
- 1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Recycling information

At the end of this product’s life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.
1. Purpose .................................................................................. 1
2. General ...................................................................................... 1
3. Detailed Principle of Operation ............................................. 1
4. Physical Description .............................................................. 3
5. Temperature Considerations .................................................. 3
6. Power Interruptions ................................................................. 3
7. Mounting Considerations ......................................................... 4
8. Wiring Diagram ......................................................................... 5
9. Program Examples ...................................................................... 6
   9.1 CR1000 .................................................................................. 6
   9.2 CR23X ................................................................................... 7

Figures
1. MSO Circuit Schematic ............................................................. 2
2. MSO Circuit Sectional View ....................................................... 2
3. Ice detector ............................................................................... 3
4. Mounting .................................................................................. 4
5. Power Supply Connections ....................................................... 5
6. General Hook-up Diagram ......................................................... 5
B1. Functional Block Diagram ..................................................... B-1

Tables
A1. BIT Information .................................................................... A-2
B1. 0871KB Ice Detector Qualification Capabilities .................. B-4
B2. Input/Output Pin Designations ............................................... B-5
Appendices

A. RS-422 Output Format.................................. A-1

B. Freezing Rain Sensor................................. B-1
0871LH1 Freezing Rain Sensor

1. Purpose

This document provides detailed information about the Goodrich model 0871LH1 Freezing Rain Sensor for use in ground-based meteorological applications. Topics covered include requirements, qualification categories and methodology, and detailed design information.

2. General

The Goodrich 0871LH1 Freezing Rain Sensor is a one-piece unit that detects the presence of icing condition. Twenty-four volts DC input power is provided to the freezing rain sensor. The freezing rain sensor outputs include ice detection indication and fault status indication. These outputs are provided through an RS-422 interface and discrete outputs. One freezing rain sensor is used on each station and provides the primary means of ice detection. The ice signal is used to indicate to the operator that an icing condition exists so that appropriate actions can be taken.

3. Detailed Principle of Operation

The freezing rain sensor uses an ultrasonically axially vibrating probe to detect the presence of icing conditions. The sensing probe is a nickel alloy tube mounted in the strut at its midpoint (node) with one inch exposed to the elements. This tube exhibits magnetostrictive properties: it expands and contracts under the influence of a variable magnetic field. A magnet mounted inside the strut and modulated by a drive coil surrounding the lower half of the tube provides the magnetic field.

A magnetostrictive oscillator (MSO) circuit is created with the above components and the addition of a pickup coil and an electronic comparator. The ultrasonic axial movement of the tube resulting from the activation of the drive coil causes a current to be induced in the pickup coil. The current from the pickup coil drives the comparator that, in turn, provides the signal for the drive coil.

The oscillation frequency of the circuit is determined by the natural resonant frequency of the sensor tube, which is tuned to 40 kHz. With the start of an icing event, ice collects on the sensing probe. The added mass of accreted ice causes the frequency of the sensing probe to decrease in accordance with the laws of classical mechanics. A 0.5 mm (0.020") thickness of ice on the probe causes the operating frequency of the probe to decrease by approximately 130 Hz. Freezing Rain Sensor software monitors probe frequency, and detects and annunciates this frequency decrease. At the same time, the internal probe heater power is applied until the frequency rises to a predetermined set point plus an additional delay factor to assure complete de-icing.
Once de-iced, the sensing probe cools within a few seconds and is ready to sense ice formation again. When ice forms on the sensing probe again to the point where the MSO frequency decreases by 130 Hz, the sensor de-ices itself again. This cyclic process is repeated as long as the freezing rain sensor remains in an icing environment. The ice signal activates at 0.020” ice accretion and stays on for 60 seconds after the end of the icing encounter. Specifically, when the output is activated, a 60-second timer is started. Each time 0.020” forms on the probe, the 60-second counter is reset. In effect, the output stays on for 60 seconds after the beginning of the “last” icing encounter. The Status output indicates whether the freezing rain sensor is functioning correctly using tests that are described in more detail in following sections of this document.
4. Physical Description

The freezing rain sensor is an integrated unit containing both the sensor and processing electronics. It contains a 7.35 cm (2.9”) square faceplate for mounting to the 0871LH1MNT and a 7.28 cm (2.86”) diameter housing containing the processing electronics. The unit weighs 318 grams (0.7 lbs), maximum.

5. Temperature Considerations

In the case of unit malfunction causing strut heater lock-on, the probe temperature can exceed 204.4°C. Maintenance personnel should exercise caution when servicing the unit.

6. Power Interruptions

The freezing rain sensor is qualified to DO-160C power input category Z. The unit will remember status through a 200 ms power interruption, but the output string will cease during the interruption.

The freezing rain sensor uses a power fail monitor to verify the supply voltage. If a power fault is detected the freezing rain sensor is halted with a failure indication on the STATUS discrete output.
7. Mounting Considerations

![Figure 4 Mounting (part #0871LH1 MNT)](image)

The freezing rain sensor should be mounted to a sturdy crossarm located away from buildings or other obstacles that could shadow the sensing element from freezing rain. The sensor should be installed so that the sensing probe is a minimum 36 inches above the ground.

1. Remove the protective tube from strut.
2. Attach the freezing rain sensor to the mounting bracket using the supplied ¼ - 20 screws and lock washers. Position the freezing rain sensor on the mounting pole with the sensing probe pointing upward, with the bracket inclined at a 20° - 30° angle above horizontal to ensure proper drainage of melted ice.
3. Attach to a vertical or horizontal pipe using the supplied V bolts, nuts and washers. NOTE: The sensor should be mounted so as to be oriented into the prevailing wind.
4. Connect cable to connector.
5. Secure cable to bracket with cable ties.
6. Remove shipping cover and protective cap prior to powering on the unit.
8. Wiring Diagram - using cable Part # 0871LH1CBL-L

Datalogger Connections

<table>
<thead>
<tr>
<th>Description</th>
<th>Colour</th>
<th>CR3000/CR1000</th>
<th>CR10X/CR510</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>Blue</td>
<td>Control Port*</td>
<td>Control Port*</td>
</tr>
<tr>
<td>Status</td>
<td>Yellow</td>
<td>Control Port*</td>
<td>Control Port*</td>
</tr>
<tr>
<td>Power Reference</td>
<td>Black</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Case GND</td>
<td>Green</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>5V Power</td>
<td>Purple</td>
<td>5V</td>
<td>5V</td>
</tr>
<tr>
<td>Shield</td>
<td>Clear</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>

*cannot share control ports

Power Connections to Terminal Expander

<table>
<thead>
<tr>
<th>Power Connections</th>
<th>Colour</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 VDC</td>
<td>Red</td>
<td>V+</td>
</tr>
<tr>
<td>24V-</td>
<td>Black</td>
<td>V-</td>
</tr>
</tbody>
</table>

Figure 5 Power Supply Connections (part #C2155)

NOTE: Please contact a certified electrician to properly install the power supply.

Figure 6 General Hook-up Diagram
9. Program Examples

9.1 CR1000

'Declare Public Variables
Public PTemp, batt_volt
Public TimeCount
Public IceSignal
Public StatusSignal
'ice signal: 1 = no ice, 0 = ice
'status signal: 0 = okay, 1 = fault

'Define Data Tables
DataTable (Stat,True,-1)
  Sample (1,StatusSignal,FP2)
EndTable

DataTable (Ice,True,-1)
  Sample (1,IceSignal,FP2)
EndTable

DataTable (Info,1,-1)
DataInterval (0,15,Sec,10)
Minimum (1,batt_volt,FP2,0,False)
Sample (1,PTemp,FP2)
EndTable

'Main Program
BeginProg
PortsConfig (&B11,&B00)

Scan (5,Sec,0,0)
  PanelTemp (PTemp,250)
  Battery (Batt_volt)

  TimeCount = Timer (1,Sec,0 )

  If TimeCount >= 61 then
    Portget (IceSignal,1 )
    PortGet (StatusSignal,2)
    If StatusSignal = 1 then
      CallTable Stat
    EndIf

    If IceSignal = 0 then
      CallTable Ice
      Timer (1,Sec,3)
    EndIf

  EndIf

  CallTable Info
NextScan
EndProg
9.2 CR23X

1: Timer (P26)
1: 3 Loc [ Timer ]

2: If (X<=F) (P89)
1: 3 X Loc [ Timer ]
2: 3 >=
3: 61 F
4: 30 Then Do

3: Set Port(s) (P20)
1: 9999 C8..C5 = nc/nc/nc/nc
2: 9988 C4..C1 = nc/nc/input/input

;This Section will read the status of the ports for comparison.
;********************************************************************

4: Read Ports (P25)
1: 1 Mask (0..255)
2: 2 Loc [ IceStat ]

5: Read Ports (P25)
1: 2 Mask (0..255)
2: 1 Loc [ FaultStat ]

;Check to see if there is a fault in the unit and output it.
;********************************************************************

6: If (X<=F) (P89)
1: 1 X Loc [ FaultStat ]
2: 1 =
3: 1 F
4: 30 Then Do

7: Do (P86)
1: 10 Set Output Flag High (Flag 0)

8: Set Active Storage Area (P80)^3085
1: 1 Final Storage Area 1
2: 10 Array ID

9: Real Time (P77)^1712
1: 1220 Year,Day,Hour/Minute (midnight = 2400)

10: Sample (P70)^23951
1: 1 Reps
2: 1 Loc [ FaultStat ]

11: End (P95)

;Check to see if there is Ice on the unit and output it.
;********************************************************************

12: If (X<=F) (P89)
1: 2 X Loc [ IceStat ]
2: 1 =
3: 1 F
4: 30 Then Do

13: Do (P86)
1: 10 Set Output Flag High (Flag 0)

14: Set Active Storage Area (P80)^10755
1: 1 Final Storage Area 1
2: 20 Array ID
15: Real Time (P77)*8112
  1: 1220 Year,Day,Hour/Minute (midnight = 2400)

16: Sample (P70)*5446
  1: 1 Reps
  2: 2 Loc [IceStat]

;If there is ice on the unit, start a looping sequence that ends only when ice is no longer detected.
;******************************************************************************

17: Timer (P26)
  1: 0 Reset Timer
  18: End (P95)

19: End (P95)
Appendix A. RS-422 Output Format

A.1 RS-422 Output Format for non-Campbell Datalogger Applications

This output operates at 9600 BAUD (One Start Bit, 8 Data Bits, No Parity, One Stop Bit). A 24-byte string is sent once per second. See section 10.2 for string definition.

A two-line output provides a bi-directional serial port, running at 9600 BAUD (8-bits, one Start Bit, one Stop Bit, no parity), to allow communication with aircraft electronics and external test equipment.

NOTE

If access to the digital RS422 data is required with a Campbell Scientific datalogger this is possible using an SDM-SIO1. Please contact Campbell Scientific for further details.

A.2 Built-In-Test (BIT)

Built-In-Test (BIT) capabilities of the freezing rain sensor consist of hardware, continuous, power-up, and operator-initiated tests.

Whenever a failure is detected and verified, the freezing rain sensor stops detecting and annunciating icing conditions and the heaters are disabled. Failures detected in Initiated and Continuous BIT are counted and enunciated once they have been verified. To eliminate nuisance errors, failures are verified by delaying (debouncing) the failure for a period of time. Failures detected in Initiated BIT are latched and power must be cycled on and off to remove a failure. If failures detected in Continuous BIT go away, the ice detector changes back to normal mode, and once again enables all ice detection functions.

A.3 Hardware Built-In-Test (BIT)

Hardware BIT is comprised of a watchdog timer that forces the microcontroller to re-initialize if it does not receive a strobe every 1.6 seconds. An internal voltage monitor forces the microcontroller to the reset state if the internal 5VDC power supply falls below 4.65 VDC and holds it there until the power supply returns above 4.65 VDC. When the microcontroller is reset, no output string is sent.
A.4 Continuous Built-In-Test (BIT)

Continuous BIT consists of verifying the following:

- The probe heater is in the correct state. The return leg of the heater is monitored.
- The ICE discrete output is in the correct state. The ICE discrete output is fed back to the microcontroller through a passive voltage divider and voltage comparator.
- The MSO is operating correctly. Frequencies between 39000 and 40150 Hz are valid.
- The probe heater is de-icing correctly. After turn-on, the probe heater must cause the MSO frequency to return to at least 39970 Hz within the 25 second timeout or it is considered failed.
- Probe is de-iced within 25 seconds. (De-Icing Fail).

A.5 BIT Failure That Disables Ice Output

The Ice output is disabled due to Continuous and Initiated BIT failures as shown in Table A1. BIT Information. Ice detection is disabled when these failures occur because the integrity of the ice detection capability has been compromised.

<table>
<thead>
<tr>
<th>Title</th>
<th>Disable Ice Detection 1</th>
<th>Initiated BIT</th>
<th>Continuous BIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSO Fail, High</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>MSO Fail, Low</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>EEPROM Fail</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RAM Fail</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ROM Fail</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Watchdog Fail</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Power Interrupt Timer Fail</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Power Fault Monitor Fail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probe Heater Always ON or OPEN</td>
<td>Active Test</td>
<td>Passive Test</td>
<td></td>
</tr>
<tr>
<td>Probe Heater Always OFF</td>
<td>Active Test</td>
<td>Passive Test2</td>
<td></td>
</tr>
<tr>
<td>Probe Heater ON w/ 1 Enable</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>De-Icing Fail</td>
<td>Clear Only</td>
<td>Set Only</td>
<td></td>
</tr>
<tr>
<td>Unknown Reset Failure</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ice Output (not contained in 0871KB1 model)</td>
<td>Active Test</td>
<td>Passive Test</td>
<td></td>
</tr>
</tbody>
</table>
Appendix A. RS-422 Output Format

Note 1: When the failure is enunciated, the software no longer provides ice detection capability.

Note 2: In Continuous BIT, the “Probe Heater Always OFF” failure is set when the heater is ON and a de-icing failure has been detected. If the frequency indicates that the ice has been removed within the expected time, the software will not annunciate the probe heater failure. The actual failure is most likely due to a problem in the heater feedback circuitry rather than heater control circuitry. The failure will be enunciated the next time IBIT is performed.

A.6 Operator-Initiated Tests

The operator can test the freezing rain sensor functionality by squeezing the tip of the probe between the index finger and thumb. This simulates icing by decreasing the frequency of the probe.

With the sensor wired to the datalogger use a digital voltmeter (DVM); measure DC voltage signal between the Ice signal (blue wire in control port) and the power reference ground (black wire in G terminal). The voltage reading should be 4500mVDC to 5000mVDC. When the probe tip of the ice detector is squeezed; thus changing the frequency and tripping the probe, the voltage reading will immediately drop to a reading below 500mVDC. Observing this will verify that the probe is operating properly and give the user enough time to release the probe before it reaches its full heating temperature.

CAUTION

Once initiated, the heating (de-icing) sequence will quickly heat the probe to 204.4°C. Though bare fingers must be used for a reliable test result, there is a danger that you will burn your fingers if you do not let go when heating has been verified.

A.7 Initiated Built-In-Test (BIT)

Initiated BIT is performed at initial power-up of the freezing rain sensor and following power interruptions of not less than 200 ms. Initiated BIT consists of the following tests:

- The ice and fault status outputs are set in the RS-422 string and on the discrete outputs so monitoring electronics or test equipment can verify activation.
- The freezing rain sensor heater is turned on for a short period of time to verify correct operation of the heater, heater control circuit, and heater feedback circuit.
- Correct operation of the watchdog timer is verified by simulating a microcontroller time-out and waiting for a reset input.
- Proper ROM operation is verified by computing a checksum of the ROM contents and comparing against a checksum stored in the ROM.
- RAM operation is verified by writing and reading test bytes.
• The Power Interrupt Timer is checked by verifying its transitions to a “warm” state after performing a “cold” start.

• The power fail input is pulled down to verify a power failure is detected.

• Each time the critical data from the Serial EEPROM is read, a checksum is read and compared to the checksum computed from the contents. Each time critical data is written to the Serial EEPROM, a checksum is computed and stored with the data.

• Resets due to unknown reasons (such as reset from the watchdog timer) are detected.

Initiated BIT will examine the RESET EEPROM input. If the input is active, the STATUS output will be set to FAIL and the ICE output and probe heater will be disabled. (This feature allows a factory technician to perform the MSO capacitor selection process without activation of the probe heater.)

Activation of the Press-to-Test (PTT) input for greater than 100 ms also causes the ice detector to perform Initiated BIT. The PTT input is ignored when the ice output is active. After PTT is completed, the correlation count is restored to its pre-test value. Initiated BIT is complete within 3 ± seconds of initial power up.

### A.8 Correlation Counting

The freezing rain sensor tracks the amount of ice accumulation on the probe during an icing encounter. The correlation count is a value tracked by the freezing rain sensor that indicates the amount of ice that has accumulated on the probe during the icing encounter. Each correlation count equals 0.010 inches of ice.

The correlation count, ranging from 0 to 255, indicates the number of times the MSO frequency decreases by 65 Hz during an icing encounter. A decrease in frequency of 65 Hz correlates to an equivalent 0.25 mm of ice that would have formed on the ice detector probe, neglecting the change in collection efficiency caused by ice build-up. Upon reaching a correlation count of 255, the value is no longer incremented.

The freezing rain sensor compensates by adding a value (ranging from 0 to 6) to the correlation count when the ice detection cycle is completed, to account for the ice that would have accumulated if the heater had not been on.

The correlation count is in the serial string, Table A2. Serial String Format.

The correlation count is initialized to zero at unit power up.
Table A2. Serial String Format

<table>
<thead>
<tr>
<th>Byte</th>
<th>Bit</th>
<th>Definition</th>
<th>Comments/interpretation/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (First)</td>
<td>7</td>
<td>String ID</td>
<td>Presently defined as 00</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>May add additional strings in future</td>
</tr>
<tr>
<td>5 - 3</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Probe Heater State</td>
<td>1= Heater On; 0= Heater Off</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Ice Output</td>
<td>1 = Ice; 0 = No Ice</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>Status Output</td>
<td>1 = Fail; 0 = (OK) No Fail</td>
</tr>
<tr>
<td>1 - 2</td>
<td></td>
<td>MSO FREQUENCY</td>
<td>MSO Count in Hex; Frequency = 774060000/Dec (MSO)</td>
</tr>
<tr>
<td>3 - 7</td>
<td></td>
<td>ERRSTAT1</td>
<td>Unused; 1 = Active</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>MSA Fail, Too High</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>MSO Fail, Too Low</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>EEPROM Fail</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>RAM Fail</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>ROM Fail</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Watchdog Fail</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>Power Interrupt Timer Fail</td>
<td></td>
</tr>
<tr>
<td>4 - 7</td>
<td></td>
<td>ERRSTAT2</td>
<td>Probe Heater Failure; 00 = Probe Heater OK; 01 = Probe Heater Always ON or OPEN; 10 = Probe Heater Always OFF; 11 = Probe Heater ON with 1 Enable</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>De-Icing Fail</td>
<td>1 = Active</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>Unused</td>
<td></td>
</tr>
<tr>
<td>5 - 7</td>
<td></td>
<td>ON-TIME CNT</td>
<td>Power-On Time (In Hex) in 10-Minute Increments; 00 - 01FFFF</td>
</tr>
<tr>
<td>8 - 9</td>
<td></td>
<td>COLD START CNT</td>
<td>Cold Start Power-On Count; 00 - FFFF</td>
</tr>
<tr>
<td>10-11</td>
<td></td>
<td>ICE CNT</td>
<td>Ice Events; 00 - FFFF</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>FAIL CNT</td>
<td>Total Failures Encountered. This number is incremented each time the ice detector transitions from OK to fail; 00 - FF</td>
</tr>
<tr>
<td>13</td>
<td>7 - 4</td>
<td>FAIL DTL 1</td>
<td>MSO Frequency Fail Count; Heater Fail Count; 0 - F; 0 - F</td>
</tr>
</tbody>
</table>
### A.9 Electrostatic Discharge (ESD) Consideration

The freezing rain sensor internal components are ESD sensitive, class 1, so proper ESD precautions must be observed (wrist straps, conductive surfaces) when handling.

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>FAIL DTL 2</td>
</tr>
<tr>
<td>15</td>
<td>LAST ERR 1</td>
</tr>
<tr>
<td>16</td>
<td>LAST ERR 2</td>
</tr>
<tr>
<td>17</td>
<td>2ND LAST ERR 1</td>
</tr>
<tr>
<td>18</td>
<td>2ND LAST ERR 2</td>
</tr>
<tr>
<td>19</td>
<td>PERM ERR 1</td>
</tr>
<tr>
<td>20</td>
<td>PERM ERR 2</td>
</tr>
<tr>
<td>21</td>
<td>Software Version</td>
</tr>
<tr>
<td>22</td>
<td>Correlation Count</td>
</tr>
<tr>
<td>23</td>
<td>CHECKSUM</td>
</tr>
<tr>
<td></td>
<td>7 - 4</td>
</tr>
<tr>
<td></td>
<td>3 - 0</td>
</tr>
<tr>
<td></td>
<td>0 - FF</td>
</tr>
<tr>
<td></td>
<td>0.01&quot; ice accretion increments since power-on</td>
</tr>
<tr>
<td></td>
<td>Summation (1-byte wide) of bytes 0 - 22</td>
</tr>
<tr>
<td></td>
<td>0 - FF</td>
</tr>
</tbody>
</table>

Appendix A. RS-422 Output Format
Appendix B. Freezing Rain Sensor

B.1 Freezing Rain Sensor Block Diagram

The block diagram in Figure B.1. Functional Block Diagram provides an understanding of the functionality of the freezing rain sensor.
B1.1 Microcontroller

The freezing rain sensor uses an Intel 87C51-type microcontroller to control the freezing rain sensor functions. This 8-bit microcontroller requires at least: 4 Kbytes of on-board ROM, 128 bytes of RAM, and 32 input/output ports. The freezing rain sensor uses about 75% of these resources. Upgraded microcontrollers that provide more resources are available. The microcontroller runs at 7.372 MHz.

B1.2 Watchdog/Reset Circuit

The watchdog timer/reset circuit monitors the microcontroller and provides a reset pulse if not periodically toggled. The watchdog also provides reset pulses on initial power-up and holds the microcontroller in the reset state if the internal power supply falls below an acceptable voltage. The watchdog indicates impending power loss so the ice detector can shut down in a known manner.

B1.3 Serial EEPROM

The Serial EEPROM stores unit status (icing state, failure state, heater state, correlation count) which is recovered after power interruptions of 200 ms or less. This allows the unit to meet the power interruption requirements of RTCA DC-160C, Section 16, Category Z. Additionally, the Serial EEPROM stores environmental and failure information such as unit elapsed-time, number of icing encounters, number of failures, and detailed information on types and quantities of each annunciated failure. This information is used by Rosemount Aerospace to confirm and repair failures reported by the end user and also to collect MTBF data. Each time the Serial EEPROM is written, a checksum is computed and written. Each time the Serial EEPROM is read, a checksum is computed and compared to the stored value.

B1.4 Probe Oscillator

The probe oscillator is the electronic control portion of the magnetostrictive oscillator (MSO) used to sense and detect ice. This circuit provides the drive and feedback of the ice sensing probe. The circuit drives the probe at a nominal 40kHz, and converts the feedback into a CMOS compatible square wave that is measured by the microcontroller. As ice accretes on the probe, the frequency decreases, and it is this frequency change that the microcontroller annunciates in the form of Ice Signal #1.

B1.5 Heater Control

The heater control turns the probe heater on and off as commanded by the microcontroller and monitors the actual heater state (ON or OFF) for verification by the microcontroller. Two outputs are required from the microcontroller to turn on the heater. This minimizes the possibility of an unintended heater ON condition. The heater control also monitors the state of the heater.
and provides feedback to the microcontroller so that it can be determined whether the heater is on or off.

B1.6 Drive Coil

The drive coil modulates the magnetic field of the magnetostrictive oscillator and causes an ultrasonic axial movement of the probe.

B1.7 Feedback Coil

The feedback coil senses the movement of the probe and when employed in the probe oscillator circuit, completes the feedback portion of the MSO.

B1.8 Heater

The probe heater de-ices the probe. It is activated when the nominal icing trip point of 0.020” is reached and is turned off five seconds after the MSO has returned to at least 39,970 Hz (the additional five seconds allows the strut probe time to shed the de-bonded ice). The maximum heater ON time is 25 seconds. If the probe frequency has not returned at least 39,970 Hz by that time, a de-ice failure is declared and the heaters are turned off. An open circuit of the heater is detected by the microcontroller.

B1.9 DC Power Supply

The DC power supply provides 24 VDC for the heater circuitry. Internal circuitry converts the 24 VDC input power to 5 VDC for use by the microcontroller and associated circuits. It employs a large input capacitor to provide enough time between detection of input power loss and actual loss of DC power, for the microcontroller to store the current unity status in the non-volatile memory. The DC power supply provides input transient protection to meet RTCA DO-160C power input, voltage spike, and lightning requirements.

B1.10 Status Output

The status output provides a ground output when the freezing rain sensor is operating correctly, and high impedance (200 KΩ minimum) when the unit has detected a failure. Failures are detected through continuous and initiated tests. The Status output is capable of sinking 50 mA and is guaranteed to be no more than 1.5 VDC with respect to Signal Return when active. This output is transient protected to meet RTCA DO-160C lightning requirements and to prevent stray high-voltage from coupling into the unit and damaging the output transistor.

B1.11 Ice Signal Output

The Ice Signal output provides a ground output for 60 ± 6 seconds when the ice detector has detected the presence of ice.
Appendix B. Freezing Rain Sensor

(frequency drop of 130 Hz, equivalent to approximately 0.020” ice formation). If the frequency subsequently decreases by 130 Hz while the Ice Signal output timer is non-zero, the timer is reinitialized to 60 seconds.

The output is transient protected to meet RTCA DO-160C lightning requirements and to prevent stray high-voltage from coupling into the unit and damaging the output transistor.

The ice output has feedback to the microcontroller for software to verify it is in the correct state for more built in test coverage. The software in the 0871KB2 model uses this feedback to verify that the ice output is operating correctly. However, in the 0871KB1 model, the software does not use this input.

To interface to the 0871 KB, the power supply must provide a pull-up to 5 to 28 volts. When the ice output is inactive (open), the nominal resistance to ground is 13.4 KΩ. The power supply should source at least 0.250 mA to provide the proper signal to the Ice Signal feedback circuitry. When the output is active (closed), it is capable of sinking 50 mA and is guaranteed to be no more than 1.5 VDC with respect to Signal Return.

Table B.1 0871KB Ice Detector Qualification Capabilities

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Audio Freq Susc:</td>
<td>Cat Z</td>
</tr>
<tr>
<td>Induced Signal:</td>
<td>Cat Z</td>
</tr>
<tr>
<td>Susc: Chg Notice 3, Cat R</td>
<td></td>
</tr>
<tr>
<td>RF Susceptibility:</td>
<td>Cat Z</td>
</tr>
<tr>
<td>RF Emissions:</td>
<td>Cat Z</td>
</tr>
<tr>
<td>Lightning Induced Susceptibility</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Multiple Burst: Waveform 3 &amp; 4: Level 3</td>
<td></td>
</tr>
<tr>
<td>Multiple Stroke: Waveform 3: Level 3</td>
<td></td>
</tr>
<tr>
<td>Temperature Variation</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat A</td>
<td></td>
</tr>
<tr>
<td>Temperature/Altitude</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat D2 (-40°C to +71°C)</td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat E (Random, 7.9 grms)</td>
<td></td>
</tr>
<tr>
<td>Operation Shock, Crash Safety</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Shock</td>
<td></td>
</tr>
<tr>
<td>Salt Spray</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat S</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat B</td>
<td></td>
</tr>
<tr>
<td>Icing Performance</td>
<td>Rosemount Aerospace, Inc. Test Procedure</td>
</tr>
<tr>
<td>Power Input</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat Z, 18 - 29.5 VDC</td>
<td></td>
</tr>
<tr>
<td>Voltage Spike</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat A</td>
<td></td>
</tr>
<tr>
<td>Magnetic Effect</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat A (1 deflection at 0.5m)</td>
<td></td>
</tr>
<tr>
<td>Bonding</td>
<td>2.5 mΩ Max. Mounting Plate to Aircraft Structure</td>
</tr>
<tr>
<td></td>
<td>10 mΩ Max. Connector Shell to Mounting Plate</td>
</tr>
<tr>
<td>Dielectric Withstanding</td>
<td>MIL-STD 202, 500 VAC, 60 Hz, EMI Filters Disconnected</td>
</tr>
<tr>
<td>Insulation Resistance</td>
<td>MIL-STD 202, 500 VDC, 1000 MΩ, EMI Filters Disconnected</td>
</tr>
<tr>
<td>Fluid Susceptibility</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat F</td>
<td></td>
</tr>
<tr>
<td>Waterproofness</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat W</td>
<td></td>
</tr>
<tr>
<td>Fungus Resistance</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat F</td>
<td></td>
</tr>
<tr>
<td>Sand and Dust</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat D</td>
<td></td>
</tr>
<tr>
<td>Direct Lightning Strike</td>
<td>DO-160C:</td>
</tr>
<tr>
<td>Cat 1A</td>
<td></td>
</tr>
<tr>
<td>Software</td>
<td>DO-178B used as a guideline</td>
</tr>
</tbody>
</table>
### Table B.2 Input/Output Pin Designations

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Connector Pin</th>
<th>Input or Output</th>
<th>Definition</th>
<th>Current</th>
<th>Wire Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>24VDC</td>
<td>A</td>
<td>Input</td>
<td>18-29.5 VDC**</td>
<td>1.5 Amp Max at 28VDC</td>
<td>20</td>
</tr>
<tr>
<td>24VDC Return</td>
<td>B</td>
<td>Input</td>
<td>----</td>
<td>----</td>
<td>20</td>
</tr>
<tr>
<td>Case Ground</td>
<td>C</td>
<td>Input</td>
<td>----</td>
<td>----</td>
<td>20</td>
</tr>
<tr>
<td>RS-422 High</td>
<td>D</td>
<td>Output</td>
<td>Per RS-422 Spec</td>
<td>Per RS-422 Spec</td>
<td>20-24</td>
</tr>
<tr>
<td>RS-422 Low</td>
<td>E</td>
<td>Output</td>
<td>Per RS-422 Spec</td>
<td>Per RS-422 Spec</td>
<td>20-24</td>
</tr>
<tr>
<td>Ice</td>
<td>F</td>
<td>Output</td>
<td>Ground Active (1.5 VDC Max)</td>
<td>0.5 - 50 mA</td>
<td>20-24</td>
</tr>
<tr>
<td>Status</td>
<td>G</td>
<td>Output</td>
<td>Ground Active (1.5 VDC Max)</td>
<td>0.5 - 50 mA</td>
<td>20-24</td>
</tr>
</tbody>
</table>

**Ice will be correctly detected between these voltages. Proper probe de-icing, however, is only guaranteed when input voltage is 24VDC or greater.
CAMPBELL SCIENTIFIC COMPANIES

Campbell Scientific, Inc. (CSI)
815 West 1800 North
Logan, Utah 84321
UNITED STATES
www.campbellsci.com
info@campbellsci.com

Campbell Scientific Africa Pty. Ltd. (CSAf)
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za
sales@csafrica.co.za

Campbell Scientific Australia Pty. Ltd. (CSA)
PO Box 444
Thuringowa Central
QLD 4812 AUSTRALIA
www.campbellsci.com.au
info@campbellsci.com.au

Campbell Scientific do Brazil Ltda. (CSB)
Rua Luisa Crapsi Orsi, 15 Butantã
CEP: 005543-000 São Paulo SP BRAZIL
www.campbellsci.com.br
suporte@campbellsci.com.br

Campbell Scientific Canada Corp. (CSC)
11564 - 149th Street NW
Edmonton, Alberta T5M 1W7
CANADA
www.campbellsci.ca
dataloggers@campbellsci.ca

Campbell Scientific Ltd. (CSL)
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk
sales@campbellsci.co.uk

Campbell Scientific Ltd. (France)
Miniparc du Verger - Bat. H
1, rue de Terre Neuve - Les Ulis
91967 COURTABOEUF CEDEX
FRANCE
www.campbellsci.fr
info@campbellsci.fr

Campbell Scientific Spain, S. L.
Psg. Font 14, local 8
08013 Barcelona
SPAIN
www.campbellsci.es
info@campbellsci.es

Campbell Scientific Ltd. (Germany)
Fahrenheitstrasse13, D-28359 Bremen
GERMANY
www.campbellsci.de
info@campbellsci.de

Please visit www.campbellsci.com to obtain contact information for your local US or International representative.