INSTRUCTION MANUAL

0871LP1

Freezing Rain Sensor

July 2020

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Section 1. Purpose

This document provides detailed information about the Collins Aerospace model 0871LP1 Freezing Rain Sensor for use in ground-based meteorological applications. Topics covered include requirements, qualification categories and methodology, and detailed design information.

Section 2. General

The Collins Aerospace 0871LP1 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-485 interface (RS-232 is available with a line level converter) and one discrete output which is the Status Output. The discrete Ice signal output is essentially non-functional in this model 0871LP1, and no external connection is required.

One freezing rain sensor is used on each station and provides the primary means of ice detection or an icing condition so that appropriate actions can be taken.

Section 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 0.020” (0.5 mm) 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.

Note: by default, the heater power is not automatic and is controlled in the programming of the sensor.

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 if the freezing rain sensor remains in an icing environment. The ice signal activates at 0.2 mm ice accretion and stays on until after the end of the icing encounter through a manual trigger of the heater declared in the datalogger programming and will remain on for 25 seconds. Each time 0.2 mm forms on the probe, the event count is captured.

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.

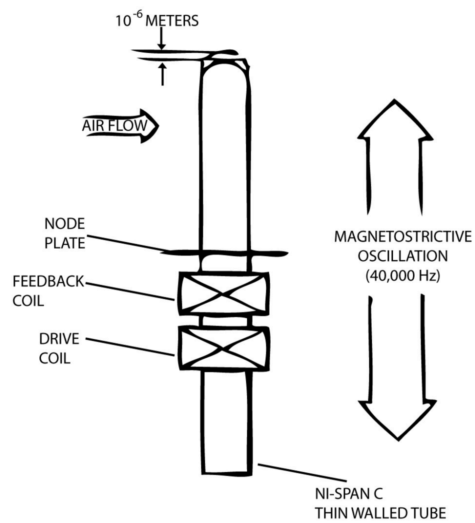

Figure 1. MSO Circuit Schematic

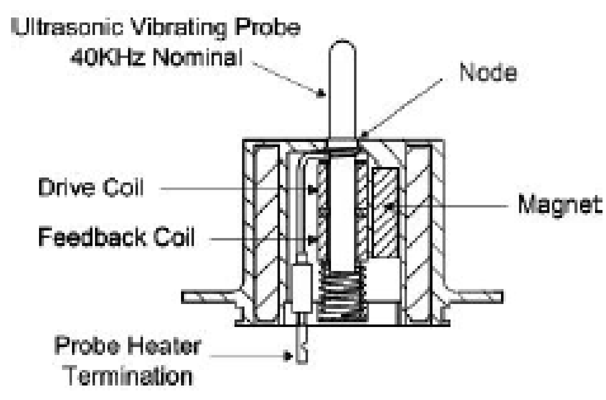

Figure 3.2-1: Sectional View of MSO Components

Figure 2. MSO Circuit Sectional View

Section 4. Physical Description

The freezing rain sensor is an integrated unit containing both the sensor and processing electronics. It contains a 2.9" (7.35 cm) square faceplate for mounting to the 0871LH1MNT and a 2.86" (7.28 cm) diameter housing containing the processing electronics. It uses a MS27474T10B99PN connector (MIL-C-38999, series II, jam nut), containing seven 20-gauge pins. The unit weighs 0.7 lbs. (318 grams), maximum.

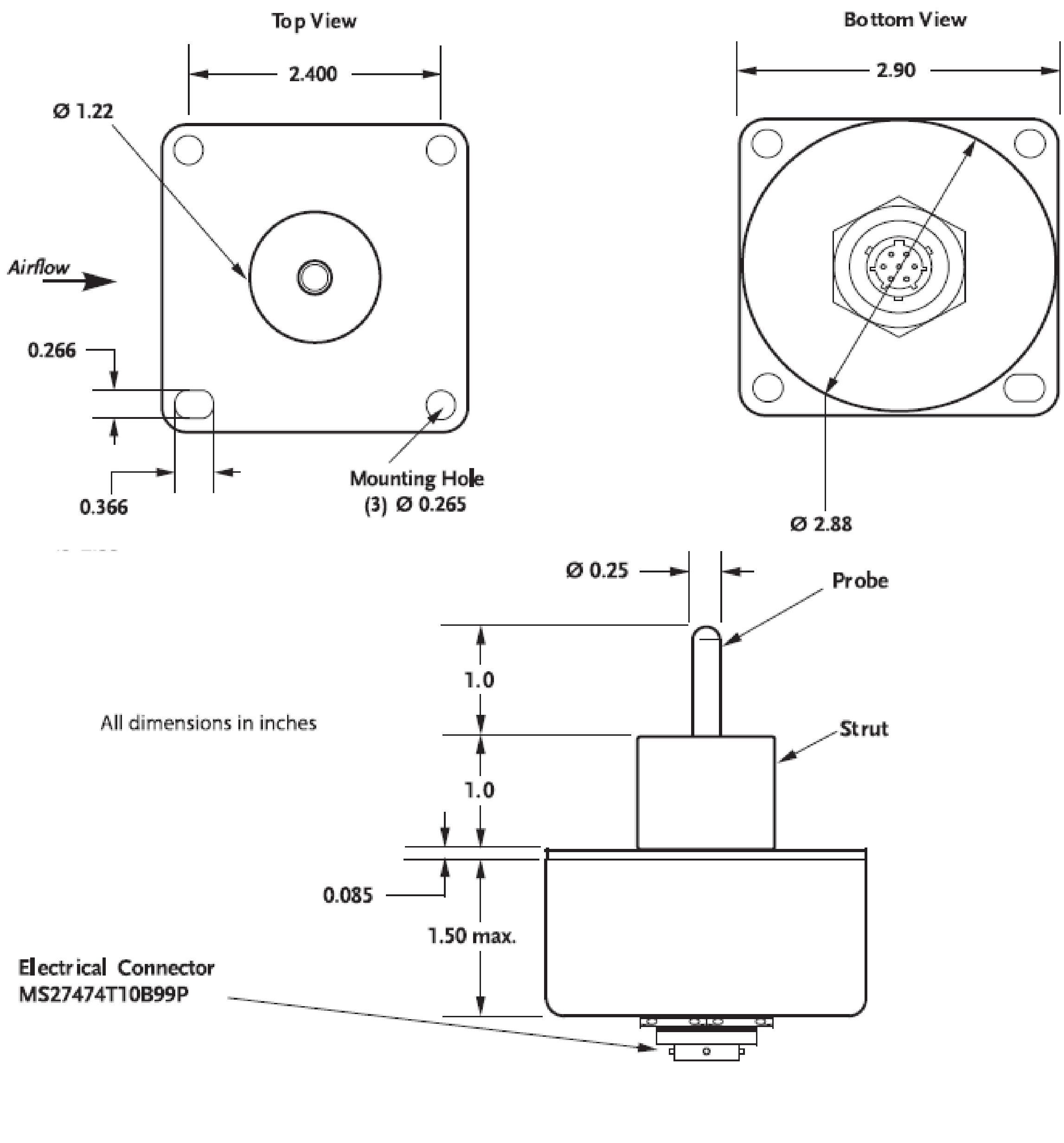

Figure 3. Physical Dimensions

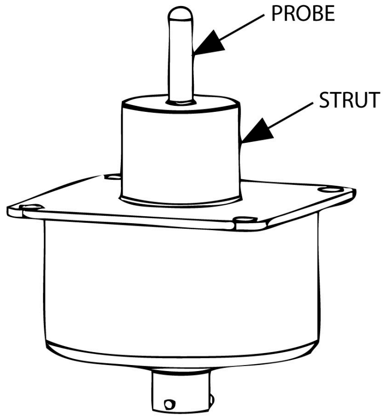

Figure 4. Ice Detector

Section 5. Temperature Considerations

In the case of unit malfunction causing strut heater lock-on, the probe temperature can exceed 204.4°C (400°F). Maintenance personnel should exercise caution when servicing the unit.

Section 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.

6.1 Disconnection from Supply Source

The ice detector does not have an integrated power switch. The installation shall provide a switch or circuit breaker near the ice detector, within easy reach of the operator, and marked as the disconnecting device for the ice detector. The current rating for this switch or circuit breaker should be at least 1.9 Amps but not greater than 5 Amps.

6.2 Protection Against Electric Shock – External Circuit Connections

All external circuits are contained in one connector (see Section 4), so are not accessible when the unit and cable connectors are mated. Further, the operating voltages on all pins are externally produced and externally limited to less than 33 V relative to 28 VDC Return, so are not considered hazardous in normal or single fault conditions. All external circuits other than the Case Ground pin shall be insulated from the Case Ground pin and unit enclosure according to the dielectric and insulation requirements specified in Table 7-1.

Section 7. Mounting Considerations

Figure 5. Mounting (part #0871LH1 MNT)

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.

NOTE: The "Hot Surface" safety label should be visible to the operator after the equipment is installed. Otherwise, if the unit is installed fully enclosed, the mounting apparatus should include the safety label in a visible location.

Section 8. Wiring Diagram - using cable Part # 0871LP1CBL-L

Table 1. Datalogger Connections

Description	Colour	CR1000X/CR1000	CR6
RS-485 High	White	Control Port*	U Port*
RS-485 Low	Brown	Control Port*	U Port*
Case GND	Green	G	G

*cannot share control ports

Table 2. Power Connections to C2673 (24VDC Power Supply)		
24 VDC +	Red	V+
24 VDC -	Black	V-

WARNING: Part C2673 must be installed by a certified electrician to local and national code.

Section 9. Program Example

9.1 CR1000X

```
Ice detector 0871LP1 Sensor
'==================Sensors and Peripherals=====================
'Sensor: , Ice detector 0871LP1, Output type RS485 ,
' Polling Data'  Baud rate: 9600, Data Bits: 8, Parity: None, Stop Bits: 1 The sensor will output Hex 24
Bytes string upon sending Command
' (S command to request current Satus and Command H to turn the heater ON)
'======================Wiring================================
' ---------  Ice detector 0871LP1 --------------------------
' All external circuits other than the Case Ground pin shall be insulated from the Case Ground pin and
unit enclosure.
'  RS485 port in the sensor:
' C5 ----------------------------- Brown (PIN E) RS-485 Low
' C6 ----------------------------- WHITE (PIN D) RS-485 High

' 24 V  Power ---------------------Red (PIN A)
' Power Return  ------------------ BLACK (PIN B)
' Earth Ground  ------------------ Green ( PIN C)
'========================Constants===========================
'Start of Constants Customization Section
'Program Scan Rate
Const Scan_Rate = 5
' Ice thickness in mm
Const Ice_mm_Threshold = 0.2
'End of Constants Customization Section
'====================== Declarations=========================
'Diagnostic Parameters
Public Battery_Voltage
Units Battery_Voltage = Volts
Public Panel_Temperature
Units Panel_Temperature  =Deg C

'0871LP1 Parameters
Public Read_LP1 As Boolean
Public Ice
Units Ice = inches
Public Ice_mm
Units Ice_mm = mm
Public Ice_Event_Count As Long

Public LP1_Serial_Error As Boolean
Dim LP1_Bytes(24) As Long
Public LP1_String(24)As String
Public LP1_Probe_Heater_State  As String *3
Public LP1_Ice_Output As String *6
```

```
Public LP1_status_Output As String *4

' ERRSTAT1 Parameters
Public LP1_ERR_MSO_TOO_HIGH As String *4
Public LP1_ERR_MSO_TOO_LOW As String *4
Public LP1_ERR_EEPROM As String *4
Public LP1_ERR_RAM As String *4
Public LP1_ERR_ROM As String *4
Public LP1_ERR_WATCHDOG As  String *4
Public LP1_ERR_PWR_INT_TIMER As String *4

' ERRSTAT2 Parameters
Public LP1_ERR_DE_ICING As String *4
Public LP1_ERR_PROBE_HEATER As String *4

Public Frequency As Float
Units Frequency = Hz
Public LP1_ON_Time_Days As Float
Public LP1_Cold_Start_Count As Float
Public LP1_ICE_Count As Float
Public LP1_FAIL_Count As Float
Public LP1_MSO_FAIL_Count As Float
Public LP1_Heater_FAIL_Count As Float
Public LP1_Software_Version As Float
Public LP1_ICE_Count_From_PWR_ON As Float
Public LP1_CHECKSUM  As Float
'===================== Data Tables========================
'Diagnostics Data Table (should be collected on a daily basis)
DataTable(Diagnostics,True,365)
  DataInterval(0,1440,Min,0)
  CardOut(0,365)
  Maximum(1,Battery_Voltage,FP2,False,False)
  Minimum(1,Battery_Voltage,FP2,False,False)
  Maximum(1,Panel_Temperature,FP2,False,False)
  Minimum(1,Panel_Temperature,FP2,False,False)
  Sample(1,Status.OSVersion,String)
  Sample(1,Status.SerialNumber,UINT2)
  Sample(1,Status.StartTime,String)
  Sample(1,Status.StationName,String)
  Sample (1,Status.ProgName,String)
  Sample(1,Status.RunSignature,UINT2)
  Sample(1,Status.ProgSignature,UINT2)
  Sample(1,Status.LithiumBattery,UINT2)
  Sample(1,Status.Low12VCount,UINT2)
  Sample(1,Status.SkippedScan,UINT2)
  Sample (1,Status.WatchdogErrors,UINT2)
  Sample (1,Status.VarOutOfBound,UINT2)
  Sample(1,Status.CPUDriveFree,UINT4)
```

```
  Sample(1,Status.USRDriveFree,UINT4)
  Sample(1,Status.CardBytesFree,UINT4)
EndTable

DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Minimum(1,Battery_Voltage,FP2,False,False)
  Average(1,Panel_Temperature,FP2,False)
EndTable

DataTable(LP1_Ice_Detector,True,-1)
  Sample (1,LP1_Raw_in_Buff,String)
  Sample (1,Frequency,IEEE4)
  Sample (1,Ice_Event_Count,IEEE4)
  Sample (1,Ice_mm,FP2)
  Sample (1,LP1_Ice_Output,String)
  Sample (1,LP1_status_Output,String)
  Sample (1,LP1_Probe_Heater_State,String)
  Sample (1,LP1_ERR_MSO_TOO_HIGH,String)
  Sample (1,LP1_ERR_MSO_TOO_LOW,String)
  Sample (1,LP1_ERR_EEPROM,String)
  Sample (1,LP1_ERR_RAM,String)
  Sample (1,LP1_ERR_ROM,String)
  Sample (1,LP1_ERR_WATCHDOG,String)
  Sample (1,LP1_ERR_PWR_INT_TIMER,String)
  Sample (1,LP1_ERR_DE_ICING,String)
  Sample (1,LP1_ERR_PROBE_HEATER,String)
  Sample (24,LP1_Bytes(),FP2)
  Sample (1,LP1_CHECKSUM,FP2)
EndTable

'===================== Subroutines=========================

' Error State Subroutine
Sub LP1_Error_State
  LP1_Probe_Heater_State  = "NAN"
  LP1_Ice_Output = "NAN"
  LP1_status_Output ="NAN"
  LP1_ERR_MSO_TOO_HIGH ="NAN"
  LP1_ERR_MSO_TOO_LOW ="NAN"
  LP1_ERR_EEPROM ="NAN"
  LP1_ERR_RAM ="NAN"
  LP1_ERR_ROM ="NAN"
  LP1_ERR_WATCHDOG ="NAN"
  LP1_ERR_PWR_INT_TIMER ="NAN"
  LP1_ERR_DE_ICING="NAN"
  LP1_ERR_PROBE_HEATER ="NAN"
  Frequency = NAN
```

```
  LP1_ON_Time_Days = NAN
  LP1_Cold_Start_Count =NAN
  LP1_ICE_Count =NAN
  LP1_FAIL_Count =NAN
  LP1_MSO_FAIL_Count =NAN
  LP1_Heater_FAIL_Count =NAN
  LP1_Software_Version =NAN
  LP1_ICE_Count_From_PWR_ON =NAN
  LP1_CHECKSUM =NAN
EndSub

' Get Data Subroutine
Sub LP1_GetData
  Public LP1_Raw_in_Buff As String *48
  Public String_Length
  Public i,J
  Public NBytesReturned

  LP1_Serial_Error = False
  If LP1_Serial_Error = False
    SerialFlush (ComC5)
    SerialOut (ComC5,"S",CHR(13),0,10)
    Delay (1,200,mSec)
    SerialInRecord (ComC5,LP1_Raw_in_Buff,0,48,&H0D0A,NBytesReturned,01)
    String_Length = Len (LP1_Raw_in_Buff)
    J=0
    For i = 1 To 24
      LP1_String(i)=Mid (LP1_Raw_in_Buff,1+J,2)
      J=J+2
    Next i
  EndIf

  LP1_CHECKSUM = 0
  For i = 1 To 24 Step 1
    LP1_Bytes(i)= HexToDec(LP1_String(i))
    If i < 24
      LP1_CHECKSUM = LP1_CHECKSUM+ LP1_Bytes(i)
    EndIf
  Next
  LP1_CHECKSUM=LP1_CHECKSUM AND &B11111111
  If LP1_CHECKSUM <> LP1_Bytes(24)Then LP1_Serial_Error = True
    If LP1_Serial_Error = True Then
      Call LP1_Error_State
    Else
      ' For LP1 Byte 1
      ' Bit 0 -Status Output
      If (LP1_Bytes(1) AND &B00000001) <> 0 Then
        LP1_status_Output = "Fail"
```

```
    Else
      LP1_status_Output = "OK"
    EndIf
    ' Bit 1 -Ice Output
    ' **The discrete Ice signal output is non-functional in the LP1 model, no external connection
is required**
    If (LP1_Bytes(1) AND &B00000010) <> 0 Then
      LP1_Ice_Output = "Ice"
    Else
      LP1_Ice_Output = "No Ice"
    EndIf

    ' Bit 2 - Probe Heater State
    If (LP1_Bytes(1) AND &B00000100) <> 0 Then
      LP1_Probe_Heater_State= "On"
    Else
      LP1_Probe_Heater_State= "Off"
    EndIf
    ' Bytes 2 and 3 concatenation for the MSO frequency
    Frequency = 774060000/((LP1_Bytes(2) << 8)+ LP1_Bytes(3))
    ' Byte 4 is the ERRSTAT1
    If (LP1_Bytes(4) AND &B00000001) <> 0 Then
      LP1_ERR_PWR_INT_TIMER = "Fail"
    Else
      LP1_ERR_PWR_INT_TIMER  = "OK"
    EndIf

    If (LP1_Bytes(4) AND &B00000010) <> 0 Then
      LP1_ERR_WATCHDOG= "Fail"
    Else
      LP1_ERR_WATCHDOG  = "OK"
    EndIf

    If (LP1_Bytes(4) AND &B00000100) <> 0 Then
      LP1_ERR_ROM= "Fail"
    Else
      LP1_ERR_ROM  = "OK"
    EndIf

    If (LP1_Bytes(4) AND &B00001000) <> 0 Then
      LP1_ERR_RAM= "Fail"
    Else
      LP1_ERR_RAM  = "OK"
    EndIf

    If (LP1_Bytes(4) AND &B00010000) <> 0 Then
      LP1_ERR_EEPROM= "Fail"
    Else
```

```
  LP1_ERR_EEPROM  = "OK"
EndIf

If (LP1_Bytes(4) AND &B00100000) <> 0 Then
  LP1_ERR_MSO_TOO_LOW= "Fail"
Else
  LP1_ERR_MSO_TOO_LOW = "OK"
EndIf

If (LP1_Bytes(4) AND &B01000000) <> 0 Then
  LP1_ERR_MSO_TOO_HIGH= "Fail"
Else
  LP1_ERR_MSO_TOO_HIGH= "OK"
EndIf

' Byte 5 is the ERRSTAT2
If (LP1_Bytes(5) AND &B11000000) = &B00000000 Then
  LP1_ERR_PROBE_HEATER= "OK"
ElseIf (LP1_Bytes(5) AND &B11000000) = &B01000000 Then
  LP1_ERR_PROBE_HEATER= "Always On"
ElseIf (LP1_Bytes(5) AND &B11000000) = &B10000000 Then
  LP1_ERR_PROBE_HEATER= "Always Off"
ElseIf (LP1_Bytes(5) AND &B11000000) = &B11000000 Then
  LP1_ERR_PROBE_HEATER= "On"
EndIf

If (LP1_Bytes(5) AND &B00100000) <> 0 Then
  LP1_ERR_DE_ICING= "Fail"
Else
  LP1_ERR_DE_ICING= "OK"
EndIf

' LP1 output ON in 10 Minute Increments
LP1_ON_Time_Days = ((LP1_Bytes(6)<< 16 )+(LP1_Bytes(7)<<8)+LP1_Bytes(8))/144
' Cold Start Power-On Count
LP1_Cold_Start_Count = (LP1_Bytes(9)<<8)+LP1_Bytes(10)
' Ice Event
' Ice Count Bit won't update in this model LP1. It will be always Zero
LP1_ICE_Count = (LP1_Bytes(11)<<8)+ LP1_Bytes(12)
LP1_FAIL_Count = LP1_Bytes(13)

' MSO frequency Fail Count
LP1_MSO_FAIL_Count =      LP1_Bytes(14) >> 4
' Heater Fail Count
LP1_Heater_FAIL_Count = LP1_Bytes(14) AND &B00001111
' Software Version
LP1_Software_Version = LP1_Bytes(22)
' Correlation Count
```

```
    LP1_ICE_Count_From_PWR_ON = LP1_Bytes(23)
  EndIf
EndSub

SequentialMode

'=======================Main Program=======================
BeginProg
  'Open port COMC5 for the 0871LP1 Ice Sensor
  SerialOpen (ComC5,9600,3,0,50,4)

  '=======================Main Scan==========================

  Scan(Scan_Rate,Sec,1,0) 'scan rate is set as a constant

    '===================Diagnostics Information=====================
    'Datalogger Battery Voltage measurement
    Battery(Battery_Voltage)
    'Wiring Panel Temperature measurement
    PanelTemp(Panel_Temperature,_60Hz)
    Read_LP1 = true
    If Read_LP1 = true
      Call LP1_GetData
      Read_LP1 = false
    EndIf

    ' Formula to convert the frequency into Ice Thickness (inches)
    Ice = -0.00015*Frequency + 6
    If Ice < 0 Then Ice = 0
    ' Convert the accumulation from inches to Millimimeters
    Ice_mm = Ice*25.4
    ' If the Ice > Ice_mm_Threshold  turn the heater ON
    If Ice_mm > Ice_mm_Threshold
      Read_LP1 = false
      SerialFlush (ComC5)
      ' Turn the heater ON if the Ice accumulation is above the threshold
      SerialOut (ComC5,"H","",0,100)
      ' Increment the Ice_Event_Count every time the heater turns ON
      Ice_Event_Count = Ice_Event_Count +1
    EndIf

    '=====================Call Data Tables========================
    CallTable (LP1_Ice_Detector)
    CallTable Table1
    CallTable (Diagnostics)
    ' Reset the Ice_Event_Count counter at midnight
    If TimeIntoInterval (0,1440,Min) Then Ice_Event_Count = 0
  NextScan
```

Section 10. RS-485 Output Format for non-Campbell Datalogger Applications

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.

10.1 Valid Request Codes

All communications are initiated by the external serial communications program. Table 3 lists the valid request commands, which are single ASCII characters. Each character should be sent at least 100 ms apart. If commands are not spaced at 100 ms, they may be ignored.

To identify the beginning of a response string from the ice detector (presently only required for command "S"), a leading ASCII character is transmitted. To identify the end of the response string, a carriage return and line feed are transmitted. All responses will be transmitted in ASCII format.

Table 3. Valid Request Codes

Request Code	Description
"T" or "t"	Request self test
"S" or "s"	Request current status information
"H" or "h"	Request Heater Activation

Command "T" – Request a Self Test:
If an ASCII "T" or "t" is sent to the ice detector, the ice detector will run a self test. The results of the self test can be retrieved by requesting the current status information.

Command "S" – Request for Status Information:
If an ASCII "S" or "s" is sent to the ice detector, the ice detector will respond with the data string described in Table 5 under Section 12. The response will be transmitted in an ASCII format but will represent hexadecimal values. In this document, hexadecimal values are denoted by a "0x" followed by the value.

Command "H" – Request Heater Activation:
The probe heater is activated by sending an ASCII "H" or "h" to the ice detector after a predetermined icing trip point is reached, as indicated by the Ice Output bit or MSO frequency in the serial data string (see Table 5). The ice detector turns off the heater five seconds after the MSO has returned to at least 39,970 Hz (the additional five seconds allows the probe time to shed the de-bonded ice). The maximum heater ON time is 25 seconds. If the probe frequency has not returned to at least 39,970 Hz by that time, a de-ice failure is declared, and the heater is turned off. The ice detector will not accept any

other commands while the heaters are active. See section 15.5 for other information about the heater and control/feedback function.

Section 11. 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.

11.1 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.

11.2 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).

11.3 BIT Failure That Disables Ice Output

The Ice output is disabled due to Continuous and Initiated BIT failures as shown in Table 4. BIT Information. Ice detection is disabled when these failures occur because the integrity of the ice detection capability has been compromised.

Table 4. BIT Information

Title	Disable Ice Detection [1]	Initiated BIT	Continuous BIT
MSO Fail, High	X		X
MSO Fail, Low	X		X
EEPROM Fail		X	
RAM Fail	X	X	
ROM Fail	X	X	
Watchdog Fail		X	
Power Interrupt Timer Fail		X	
Power Fault Monitor Fail		X	
Probe Heater Always ON or OPEN		Active Test[3]	Passive Test[4]
Probe Heater Always OFF		Active Test[3]	Passive Test[2]
Probe Heater ON w/ 1 Enable		X	
De-Icing Fail		Clear Only	Set Only
Unknown Reset Failure		X	

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

Note: 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.

Note: Active test means actual triggering of the function in all states to verify response of the freezing rain sensor

Note: Passive test means a status check/verification that the function is in the state command

11.4 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.

11.5 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-485 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.

Section 12. 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 5. Serial String Format.

The correlation count is initialized to zero at unit power up.

Section 13. 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.

Section 14. Ice Detector RS-485 String Format

Table 5. Serial String Format

Byte	Bit	Definition	Comments/Interpretation/Range
0 (First)	7 (MSB)	String ID	Presently defined as 00
	6		May add additional strings in future
	5 - 3	Unused	
	2	Probe Heater State	1- Heater On
			0- Heater Off
	1	Ice Output	1- Ice
			0- No Ice
	0	Status Output	1- Fail
			0- (OK) No Fail
1 -2 MSO FREQUENCY		MSO Count in Hex	Frequency = 774060000/Dec (MSO)
3 - ERRSTAT1	7	Unused	1 = Active
	6	MSO Fail, Too High	
	5	MSO Fail, Too Low	
	4	EEPROM Fail	
	3	RAM Fail	
	2	ROM Fail	
	1	Watchdog Fail	
	0	Power Interrupt Timer Fail	
4 - ERRSTAT2	7 - 6	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
	5	De-Icing Fail	1 = Active
	4	Unused	
	3	Unused	
	2	Unused	

	1	Unused	
	0	Unused	
5 - 7 ON-TIME CNT		Power-On Time (In Hex) in 10-Minute Increments	00 - 01FFFF
8 - 9 COLD START CNT		Cold Start Power-On Count	00 - FFFF
10-11 ICE CNT		Ice Events	00 - FFFF
12 - FAIL CNT		Total Failures Encountered. This number is incremented each time the ice detector transitions from OK to fail.	00 - FF
13 - FAIL DTL 1	7 - 4	MSO Frequency Fail Count	0 - F
	3 - 0	Heater Fail Count	0 - F
14 - FAIL DTL 2	7 - 4	Not Used	Not Used
	3 - 0	Not Used	Not Used
15 - LAST ERR 1		See ERRSTAT1 Above	
16 - LAST ERR 2		See ERRSTAT2 Above	
17 - 2ND LAST ERR 1		See ERRSTAT1 Above	
18 - 2ND LAST ERR 2		See ERRSTAT2 Above	
19 - PERM ERR 1		See ERRSTAT1 Above	
20 - PERM ERR 2		See ERRSTAT2 Above	
21 - Software Version	7 - 0	Software Version per VDD/SC1	0 - FF
22 - Correlation Count	7-0	0.01" ice accretion increments since power-on	0 - FF
23 - CHECKSUM		Summation (1-byte wide) of bytes 0 - 22	0 - FF

Section 15. Functionality Descriptions

15.1 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.

15.2 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.

15.3 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 Collins Aerospace to confirm and repair failures reported by the end user and 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.

15.4 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.

15.5 Heater and Heater Control

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.

The probe heater is activated by sending an ASCII “H” or “h” to the ice detector after a predetermined icing trip point is reached, as indicated by the Ice Output bit or MSO frequency in the serial data string (see Table 5). The ice detector turns off the heater five seconds after the MSO has returned to at least 39,970 Hz (the additional five seconds allows the probe time to shed the de-bonded ice). The maximum heater ON time is 25 seconds. If the probe frequency has not returned to at least 39,970 Hz by that time, a de-ice failure is declared and the heater is turned off. The ice detector will not accept any other commands while the heaters are active.

The probe heater de-ices the probe. The heater control turns the probe heater ON as commanded by the external serial communications program and OFF as commanded by the microcontroller (embedded software). 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, off or open circuit

15.6 Drive and Feedback Coil

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

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

15.7 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.

15.8 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 can sink 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.

15.9 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 (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 0871LH1 model uses this feedback to verify that the ice output is operating correctly. However, in the 0871LP1 model, the software does not use this input.

Appendix A Freezing Rain Sensor Block Diagram

The block diagram provides an understanding of the functionality of the freezing rain sensor.

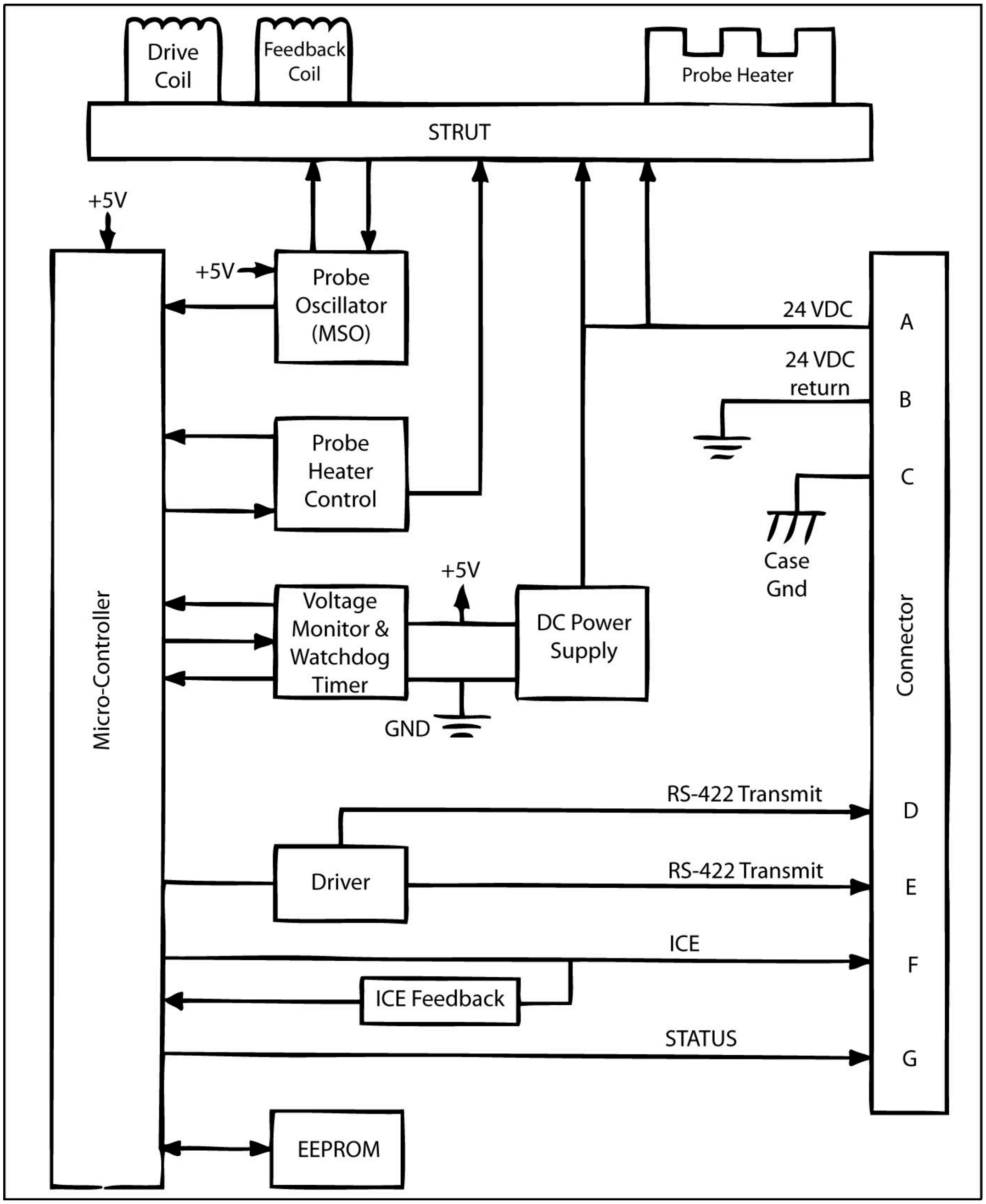

Figure 6 Functional Block Diagram

Appendix B. Input/Output Pin Designations

Table 6. Input/Output Pin Designations					
Signal Name	Con-nector Pin	Input or Output	Definition	Current	Wire Gauge
24VDC	A	Input	18-29.5 VDC**	1.5 Amp Max at 28VDC	20
24VDC Return	B	Input	----	1.5 Amp Max	20
Case Ground	C	Input	----	----	20
RS-485 High	D	Output	Per TIA-485-A Spec	Per TIA-485-A	20-24
RS-485 Low	E	Output	Per TIA-485-A Spec	Per TIA-485-A	20-24
Ice	F	Output	Non-Functional, no connection require***		
			Open Inactive		
Status	G	Output	Ground Active (1.5 VDC Max) [OK]	0.5 - 50 mA	20-24
			Open Inactive [Unit Failed]		

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

*** Toggles +5V/ground during PBIT but does not annunciate ice.

Appendix C Qualification Capabilities

Table 7. Qualification Capability Levels		
Test Name	Test Requirement	
EMC	DO-160C:	
	Audio Freq Susc:	Cat Z
	Induced Signal:	Cat Z
	Susc:	Chg Notice 3, Cat R
	RF Susceptibility:	Cat R
	RF Emissions:	Cat Z
Lightning Induced Susceptibility	DO-160C:	
	Multiple Burst:	Waveform 3 & 4: Level 3
	Multiple Stroke:	Waveform 3: Level 3
Temperature Variation	DO-160C:	Cat B
Temperature/Altitude	DO-160C:	Cat D2 (-40°C to +71°C)
Vibration	DO-160C:	Cat E and L(Random, 7.9 grms)
Operation Shock, Crash Safety	DO-160C:	Shock
Salt Spray	DO-160C:	Cat S
Humidity	DO-160C:	Cat B
Icing Performance	Collins Aerospace, Inc. Test Procedure	
Power Input	DO-160C:	Cat Z, 18 - 29.5 VDC
Voltage Spike	DO-160C:	Cat A
Magnetic Effect	DO-160C:	Cat A (1 deflection at 0.5m)
Bonding	2.5 mΩ Max. Mounting Plate to Aircraft Structure	
	10 mΩ Max. Connector Shell to Mounting Plate	
Dielectric Withstanding	MIL-STD 202, 500 VAC, 60 Hz, EMI Filters Disconnected	
Insulation Resistance	MIL-STD 202, 500 VDC, 1000 MΩ, EMI Filters Disconnected	
Fluid Susceptibility	DO-160C:	Cat F
Waterproofness	DO-160C:	Cat W
Fungus Resistance	DO-160C:	Cat F
Sand and Dust	DO-160C:	Cat D
Direct Lightning Strike	DO-160C:	Cat 1A
Software	DO-178B used as a guideline	