Icing Warning Sensor Manual

Airborne Innovations LLC

2170 Eugene Street
Hood River, OR 97031

info@airborneinnovations.com
Phone: 541-380-0928
Fax: 253-276-9765

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Revision	Date	Description
1.0.0	15 May 05	Created.
1.0.1	1 June 05	Algorithm update
2.0.0	30 Aug 05	CAN bus support added
2.1.0	19 Dec 06	Additional heat control, carb ice features added
2.1.2	5 Apr 09	Added rate commands, CAN change for compatibility with Piccolo CAN downlink
2.1.2	4 May 09	Documented cloud output

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1 Introduction

Airborne Innovations has just introduced new technology to aid in icing avoidance and situational awareness. This experimental sensor is designed to help detect potential icing conditions before ice accumulation becomes a problem.

In many icing situations the right thing to do is turn around and go back into icing free conditions. But pilots and UAV operators must keep situational awareness before they are out of options, since weather conditions can quickly change and eliminate options. Research flights have shown that icing conditions can form with ice accumulation rates that can quickly overwhelm most aircraft. A pilot may only have minutes to make a life saving decision to get out of those conditions. This sensor can provide a crucial head start in recognizing many conditions conducive to ice formation, even before ice accumulation has begun. In many cases, by the time true ice accumulation has begun (or is detectable), the situation may have already degraded to a dangerous level. Our goal is that the pilot / UAV operator be given the best possible advance warning information while there are still safe flight path options available. So our principle is to attempt to detect conditions conducive to ice formation, giving as much warning as possible about the situation before it becomes a problem.

The onboard computer in this miniature icing warning sensor runs an advanced algorithm which detects some potential icing conditions. Research and testing in this field continues and as we improve the algorithm we will provide user downloadable algorithm updates.

In some NTSB reports of in-flight icing events, aircraft crew were not aware of icing conditions before experiencing icing related performance or control degradation.

Airborne Innovations personnel have been involved with UAV operations in icing conditions and have seen how quickly a UAV can get into a difficult situation, with rapid ice accumulation quickly leading in a matter of minutes to degradation of performance, loss of control, or aerodynamic degradation which results in an inability to climb and potentially causes a descent under full engine power. If UAV operators are not situationally aware of potential icing conditions, they may not be able to respond in time. We have seen cases of UAVs developing control problems within minutes of entering icing conditions.

It is shocking that aircraft and lives are still lost due to flight in icing conditions and through poor awareness and bad piloting decisions. Several years of university research, postdoc work, and flight testing have culminated in this icing algorithm, and we feel a duty to release this product in the hopes that it will contribute to increased aircraft safety.

OEM Applications:

This sensor is ideal for unmanned aerial vehicle (UAV) applications. UAV's are routinely lost due to icing conditions. Integration of this sensor provides one more tool that can be used to improve UAV operator situational awareness.

This may also be applicable to small general aviation aircraft, although lack of certification limits it strictly to experimental installations.

This manual documents the technical features of the Airborne Innovations Icing Warning Sensor

Features and Benefits

Compact sensor solution

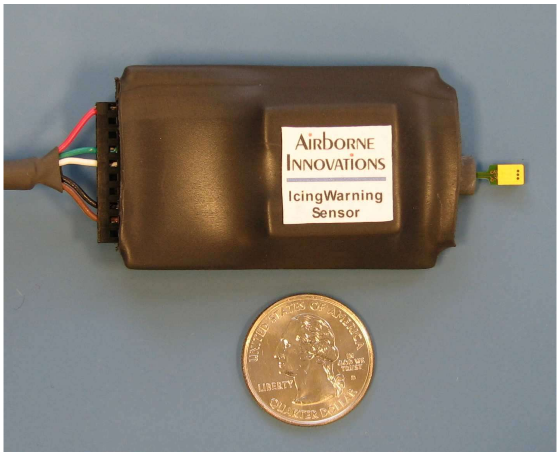
Low power

Slim form factor (install inside aircraft wing or fuselage)

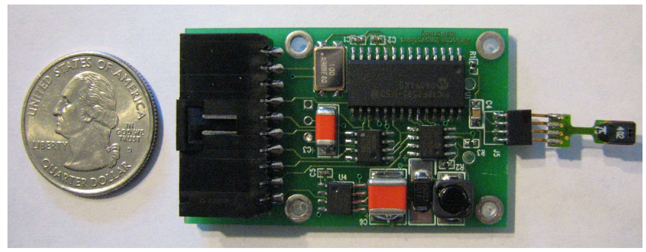
Cost effective

Variety of packaging options available (bare board / shrink wrap / potting)

Custom harness options available



Icing Warning Sensor (Sensor mounted directly on connector, MTE-10 connector on board option)



Icing Warning Sensor bare board

2 Specification

Characteristics	***Conditions***	***Min***	***Typ***	***Max***	***Units***
Electrical					
Input Voltage	Internal regulator, option for external regulator	9	12	30	Volts
Power			0.5		Watts
Digital Interface					
UART	ASCII 8N1, RS232 (DS276N) (TTL option if ordered)		9600		Baud
CAN Bus	CAN 2.0 Extended Identifiers		1		MBaud
Update rate	Continuous		2		Hz
Connections	MTE connector or bare wires		10		pins
Sensor lead	connector or up to 2' cable		4		pins
Physical					
Dimensions	Circuit board assembly			35x56	mm
Weight	Processor and sensor only			15	grams
Environmental					

Characteristics	*Conditions*	*Min*	*Typ*	*Max*	*Units*
Temperature	Operating (extended temp -40 to 120C available)	-40		85	deg C
	Storage	-55		130	deg C

3 Pinout

3.1 Standard 10 pin connector (MTE-10 pins)

Pin Number	*Pin Name*	*Description*
1	Vin	Power input, 9-30V
2	CANH	CAN Bus high
3	CANL	CAN Bus low
4	UART_RX	UART receive
5	UART_TX	UART transmit
6	DOUT1	Digital out 1
7	DOUT2	Digital out 2
8	Gnd	Ground
9	DOUT3	Digital out 3
10	NC	Reserved1

3.2 Serial only MTE-4F connector pinout (option)

MTE Pin Number	*Pin Name*	*Description*
1	Vin	Power input, 9-30V
2	UART_RX	UART receive
3	UART_TX	UART transmit
4	GND	Ground

3.3 CAN only MTE-5F connector pinout (option)

MTE Pin Number	Pin Name	Description
1	Vin	Power input, 9-30V
2	CANH	CAN Bus high
3	CANL	CAN Bus low
4	GND	Ground
5	Shield	Shield (NC)

4 Basic Device Operation

The Airborne Innovations IceWarning sensor includes sensors capable of detecting some environmental conditions conducive to ice formation.

The sensor combines digitally calibrated sensor elements with an advanced algorithm which has been shown under some conditions to provide warning of icing conditions before ice even begins to form. The current algorithm has been developed over several years, initially as part of a doctoral dissertation, and has been enhanced significantly under independent research.

The algorithm has been tuned with UAV flight data, and in some cases has shown a 5 minute advance warning over conventional ice detection sensors. Not all icing conditions can be detected with this sensor, but it is a useful addition to UAV situational awareness.

The current algorithm is called RAID9 (Robotic Aircraft Icing Detection algorithm #9).

A research paper is available which documents earlier work (RAID1-3). The RAID9 algorithm is much improved from the earlier work.

Disclaimer

This is an experimental sensor and is not certified. This sensor does not detect ice or supercooled liquid droplets (SLD) directly, but does detect some but possibly not all conditions conducive to ice formation. Airborne Innovations makes no guarantee as to its effectiveness, but we believe it is a useful addition to icing conditions situational awareness. Use of this product is entirely at the user's risk.

4.1 Sensor Mounting and Usage

The sensor element needs to be mounted with access to the air stream. It can be mounted inside a wing or fuselage, with the sensor element directly in the element. It should be kept out of engine exhaust, and the sensing element should not directly be touching a wing or fuselage surface.

The sensor can be plugged into a connector on the processor board, or the sensor can be provided without the connector and a short cable can be installed with the sensor element extending up to 2 feet away from the processor board.

The sensor polarity is important. A small '+' is indicated on the left side of the sensor (also highlighted in red). This must be plugged into the processor board connector with the same polarity (marked on the processor unit). Be careful with the sensor contacts, the sensor leads can be fragile.

Locking zip ties, epoxy or self adhesive, or quick release surface contact mounts can be used to fix the sensor. The bare board option can be mounted with 4 small screws / standoffs. Contact us for other options and requirements.

Leukoflex tape (see photo) or silicone can be used to form a moisture tight seal allowing the sensor element only to be in the freestream.

Leukoflex tape seal

Be careful to keep the 4 contact wires and area from the sensor connector and sensor wires to the thin temperature isolation peninsula to the sensor free of moisture. If necessary heat shrink or silicone / RTV can be applied to the wires and bottom portion of the sensor.

Ideally the sensor should be mounted in a location which will minimize contact with liquid water, i.e. in the airstream under a wing). In practice this should not be a problem, but if moisture gets past the moisture seal and onto the sensor element's circuit board it may require a replacement of the sensor element (the element itself can tolerate liquid water but this may momentarily interfere with operation and/or require a heat cycle).

Also it may be necessary to replace the sensor element after approximately 6 months of use or if exposed to chemical contamination (e.g. fuel / exhaust). In practice we have seen the sensors last much longer without any apparent detrimental effects.

5 Output and Communication Protocol

The sensor outputs serial data using an ASCII output format with the '*' character as a start byte, and <cr> as a stop byte. The baud rate is fixed at 9600 baud.

For development we recommend using the free Realterm terminal program

(http://realterm.sourceforge.net or http://www.i2cchip.com/realterm/).

5.1 Powerup message

The sensor will output a short message at powerup:

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Icing Warning Sensor v2.1.2 5 April 2009

Airborne Innovations Copyright 2003-2009
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5.2 Periodic Output

The sensor will output a periodic message via the UART in the following format:

*ICE,<STATUS1>,<STATUS2>,<ICEWARN1>,<ICEWARN2>,<ICINGPOTENTIAL>,<CARBICEWARN>, <OAT>,<RH><cr><lf>

where

STATUS1 is a status message containing the health status of the sensor, output as an integer. If bit 0 (LSB) of this status integer is 0 the sensor is ok, if 1 the sensor has a problem.

STATUS2 is a status message, if bit 0 (LSB) is 1 then the heater is currently on, 0 it is off.

ICEWARN1 is the 1st stage ice warning (YELLOW caution warning).

0 for no warning, 1 for warning.

ICEWARN2 is the 2nd stage ice warning (RED critical warning)

0 for no warning, 1 for warning.

Note that ICEWARN1 and ICEWARN2 are two independent algorithms which are not mutually exclusive and each may be on or off. Currently ICEWARN2 is a subset of ICEWARN1 but this may not be the case for future iterations of the algorithms.

ICINGPOTENTIAL is an experimental output which ranges between 0 for no icing potential, and 100 for maximum icing potential. This is a relative icing potential indicator (it should not be interpreted as percentage chance of icing).

CARBICEWARN is a warning for potential carburetor icing conditions

0 for no warning, 1 for warning

Note that carburetor icing depends on many factors, and can be a problem particularly at low power settings (if this warning is on then for example be careful during full idle descents).

OAT is outside air temperature in degrees C (floating point value)

RH is % relative humidity (floating point value)

5.3 Heat Cycle

Sending the command *H to the sensor will cause a heating cycle. This will last for about 10 seconds and the sensor will continue to output data during this time (though the validity of the output is affected by the heating cycle). This can be used as a BIT sensor test, and may help to clear the sensor of moisture.

The heat cycle can be terminated earlier if desired using the *X command.

5.4 Sample Period

The sample rate can be set using one of 3 RS232 commands (or the CAN bus command below).

The sample period is stored in EEPROM and will be remembered after a power cycle.

The default sample period is 2 seconds (slow mode).

Commands:

*S Slow mode, 2 second period

*F Fast mode, 1 second period

*U Fastest mode, 0.5 sec period. Note there may be some self heating in this mode unless there is any airflow.

5.5 Digital Outputs

The ICEWARN1 signal is output on DOUT1 (active high).

The CARBICE signal is output on DOUT2 (active high).

Another icing warning signal is output as a TTL level digital signal on DOUT3. This is a frequency output, designed to be connected to an LED panel display. Under critical icing conditions (ICEWARN2) it will output a ~10 Hz pulse. Under ICEWARN1 conditions it will output a ~1 Hz pulse. Under no icing conditions it will pulse briefly once every 3 seconds. This signal is active low.

If there is a problem with the sensor it will flash twice in quick succession, once every 3 seconds.

5.6 CAN bus output

The CAN bus is a robust two wire differential bus designed for use in high EMI environments which is well suited for UAV applications.

The sensor's CAN output is configured to use CAN 2.0 Extended Identifiers at 1 megabaud.

The CAN bus must be properly terminated. Typically this is done with a 120 ohm resistor across the CANH and CANL lines at both ends of the harness, or if there are more than two nodes, at each end of the chain. There are also termination schemes for a star network topology which is typical of a vehicle harness. Termination is left up to the user.

For R&D CAN bus work we recommend the Systec USB CAN module

at http://www.systec-electronic.com/html/index.pl/en_product_usb_canmodul

The 29-bit Message ID is encoded in the following format:

MSB Message Group (5 bits)	*Message type (8 bits)*	*Serial Number (16 bits) LSB*
always hex 0x14 (decimal 20)	See message types below	Device serial number, currently always 1

The downlink Message ID is hex 0x14 (decimal 20) for compatibility with the DATA_DOWN_GROUPID of the Piccolo avionics version 2.1.0 and later. Data with this groupID will automatically be downlinked.

The uplink (control) Message ID is hex 0x15 (decimal 21) equivalent to the Piccolo DATA_UP_GROUPID.

5.7 Group 0x14, CAN Message type 0x1C (decimal 28) : Icing warning output message

Byte	*Data*
0	STATUS1 output Bits 7..1: reserved Bit 0 (LSB): Sensor health (1=problem, 0=ok)
1	STATUS2 output Bits 7..1: reserved Bit 0 (LSB): Current heater status (1=on, 0=off)
2	ICEWARN output Bits 7..4 reserved Bit 3: Cloud output (1 for 80-100% cloud present) Bit 2: Carb ice warning (1 for warning) Bit 1: ICEWARN2 (1 for warning) Bit 0 (LSB): ICEWARN1 (1 for warning)
3	ICINGPOTENTIAL, uint8 0-100%
4	OAT, tenths of deg C, sint16H
5	OAT, tenths of deg C, sint16L
6	RH, hundredths %, uint16H
7	RH, hundredths %, uint16L

OAT is encoded as a signed 16 bit integer in tenths of a degree C.

RH is encoded as an unsigned 16 bit integer in hundredths of a %RH.

5.8 Group 0x15, CAN Message type 0x1D (decimal 29): (Sent to sensor) Trigger heat cycle / Set sample rate

Byte	***Data***
0	Heat control (1 to enable heating, 0 to disable heating)
1	Sample rate (0xFF for 2 sec period, 0x00 for ~0.5 sec period, 0x1 for ~1 sec period

The heat cycle may be triggered by sending a message type 0x1D to the sensor, with a one byte data length. The byte controls the heating element.

If no command is given to turn off the heater, it will automatically shut off after about 10 seconds.

6 Ordering Information

The standard sensor is shrink wrapped with a 10 pin right angle MTE connector (mating part Digikey A28382-ND) and a 4 position connector which plugs directly into the sensor.

Contact us for customization options including: bare board, potting, removing power regulator, extended temperature range, TTL UART output, serial only or CAN only harness if desired (4 or 5 pin MTE connector can be used), bare wire or MTE wire mounted interface.

An evaluation kit is available (part # 650-90000-01) which includes a bench test cable, sensor element, and the sensor processor .