SENSOR USER GUIDES

REVISION 1

DHT22 Temperature and Humidity

The DHT22 sensor is a low cost combination temperature and humidity sensor manufactured by Aosong (Guangzhou) Electronics Co., Ltd.

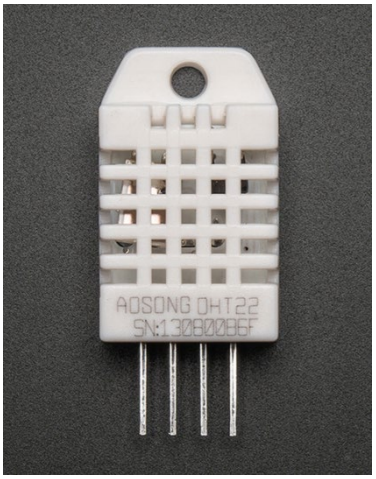


Figure 1. Picture of AOSONG DHT22 Sensor

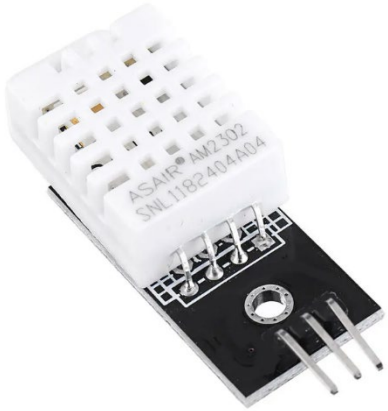


Figure 2. Picture of AOSONG DHT22 Sensor(PTC) with Soldered PCB

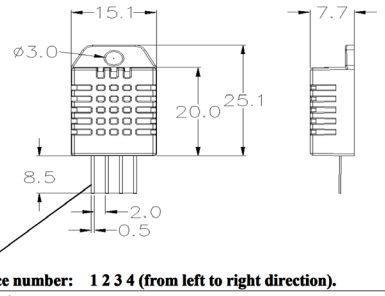
Also available as wired version (AM2302), the DHT22 Sensor belongs to the same product line as DHT11, which is a lower cost sensor with less accuracy and less range.

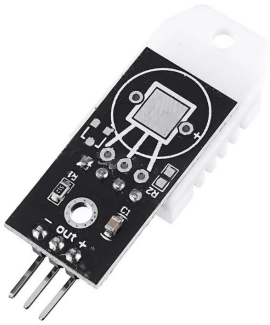
The model purchased by our team includes the Aosong sensor soldered onto a printed circuit board (PCB). See *Figure 2* above.

DHT22 Model Specifications

Model	**DHT22**
Power Supply	3-5V
Measuring Range	0-100% Relative Humidity -40 to 80° C
Accuracy	2-5% Humidity Accuracy ±0.5° C Temperature Accuracy
Sampling Rate	0.5 Hz (once every 2 seconds)
Transmission Distance	20m

DHT22 Wiring





Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD—power supply
2	DATA--signal
3	NULL
4	GND

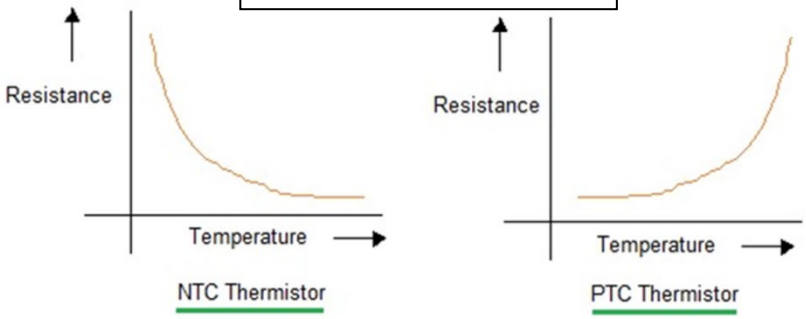
Sensing Element

The DHT22 sensing element is built includes three basic parts, a thermistor to measure temperature, a capacitive humidity sensor, and a chip that enables a single bus digital signal for both humidity and temperature.

The temperature element of the DHT22 is a negative temperature coefficient (NTC) thermistor. The NTC thermistor (DS18B20) is a resistor that measures increasing temperature with decreasing resistance. NTC thermistors are the most used thermistor as opposed to positive temperature coefficient (PTC) thermistors.

There is a non-linear relationship between resistance and temperature of the NTC, but this is rectified using digital circuits to map the and predict the NTC curve.

FIGURE 6. DEPICTION OF N NTC CURVE VS A PTC CURVE



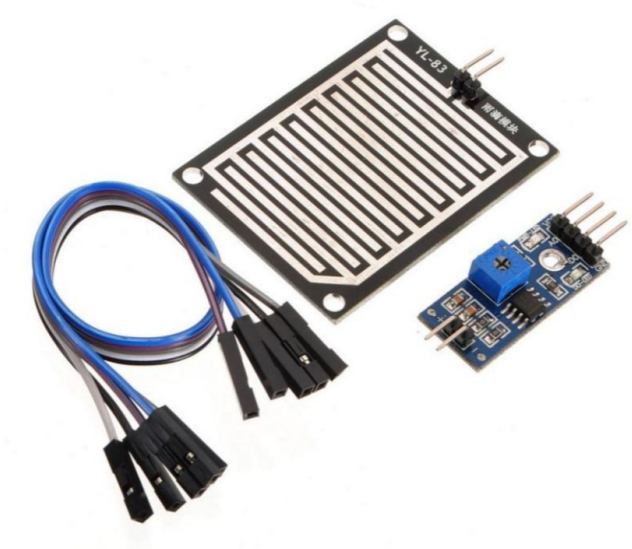
The humidity element of the DHT22 uses a polymer humidity capacitor. The humidity sensor is built by placing a polymer capacitor between a pair of electrodes. As the relative humidity of the environment increases, so does the capacitance of the sensor creating a direct relationship. Capacitive humidity sensors are generally more accurate and stable than those of resistive sensors.

YL-83 Rain Detector

The Yl-83 Rain detection sensor is a low cost sensor, that is capable of detecting both rain and snow. The circuitry within the sensor includes both a digital output that allows detection and an analog output that will estimate rain intensity.

In addition, the sensor also allows a two minute period between rain drops before the sensor sends an “OFF” state. It also contains a self heating element to ensure that the surface dries quickly and protects from condensation and the build up of water.

This product is manufactured by Aexit.



YL-83 Model Specifications

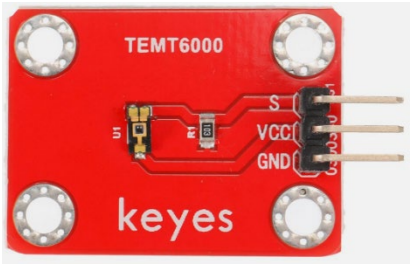
Model	**YL-83**
Power Supply	3-5V
Measuring Range	ON/OFF Rain Detection, Snow Detection
Sampling Rate	0.033 Hz (once every 2 minutes)

YL-83 Wiring

Pin	**Wiring to Arduino**
A0	Analog pins
D0	Digital pins
GND	GND
VCC	5V

TEMT6000 Ambient Light Sensor

The TEMT6000 is a photoresistor manufactured by Keyes. The sensor measures the illuminance in light with a unit of lux. It's wide angle of half sensitivity is 60 degrees and it uses a silicon NPN as its sensing element.



TEMT6000 Model Specifications

Model	**TEMT6000**
Power Supply	3-5V
Measuring Range	10-1000 Lux
Sampling Rate	Faster reacting (in nanosecond range)

TEMT6000 Wiring

Sensing Element

TEMT6000 Wiring

Pin	**Wiring to Arduino**
S	Analog pins
GND	GND
VCC	5V

SF-110-SS Radiation Frost Sensor

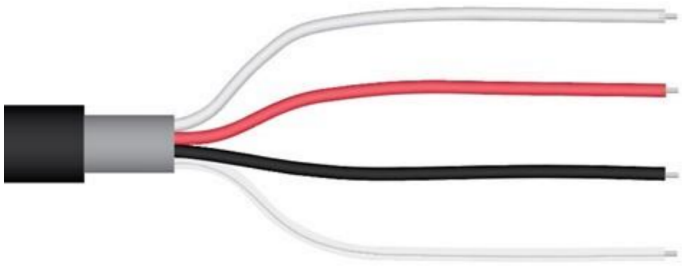
The SF-110-SS Radiation Frost Sensor is manufactured by Apogee and it provides close approximations to the temperature of leaves. This is important because the air temperature may not always accurately reflect the temperature of the plants, and lower radiation temperatures could lead to frost damage even when the air temperature is not at a freezing point.

SF-110-SS Model Specifications

Model	**TEMT6000**
Power Supply	2-5V
Measuring Range	-50 to 70 Degrees Celsius

SF-110-SS Wiring

Wiring for Radiation Frost Detectors (as of January 2022)



White: Therm 1 (positive leaf thermistor lead)

Red: Excitation channel (excitation for leaf thermistor)

Black: Therm 1 (negative leaf thermistor lead)

Clear: Shield/Ground

LM393 Soil Moisture Sensor

The LM393 is a Soil Moisture Sensor that is manufactured by HiLetGo. When the soil moisture is high, the sensor sends out a high voltage and when the moisture is low, the sensor sends out a low voltage to the microcontroller.

The sensor offers both a digital output and an analog output using a similar chip to the rainfall sensor.

LM393 Model Specifications

Model	**TEMT6000**
Power Supply	3-5V
Measuring Range	0 to 100%

LM393 Wiring

Pin	**Wiring to Arduino**
A0	Analog pins
D0	Digital pins
GND	GND
VCC	5V

Aosong(Guangzhou) Electronics Co.,Ltd

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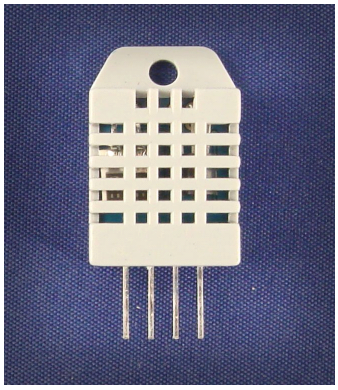
Digital-output relative humidity & temperature sensor/module

AM2303



Capacitive-type humidity and temperature module/sensor

1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

AM2303 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.
Small size & low consumption & long transmission distance(20m) enable AM2303 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

Model	AM2303
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer humidity capacitor & DS18B20 for detecting temperature
Measuring range	humidity 0-100%RH; temperature -40~125Celsius

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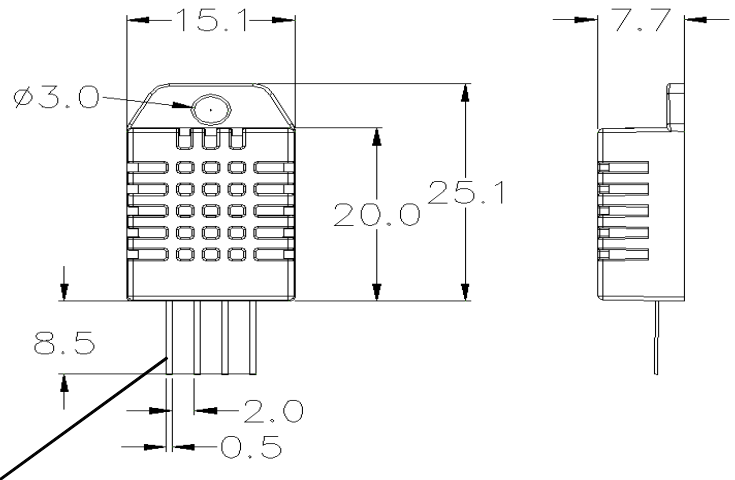
Accuracy	humidity +-2%RH(Max +-5%RH);	temperature +-0.2Celsius
Resolution or sensitivity	humidity 0.1%RH;	temperature 0.1Celsius
Repeatability	humidity +-1%RH;	temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH	
Long-term Stability	+-0.5%RH/year	
Sensing period	Average: 2s	
Interchangeability	fully interchangeable	

4. Dimensions: (unit----mm)



Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD----power supply
2	DATA--signal
3	NULL
4	GND

5. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Single-bus data is used for communication between MCU and AM2303, it costs 5mS for single time communication.

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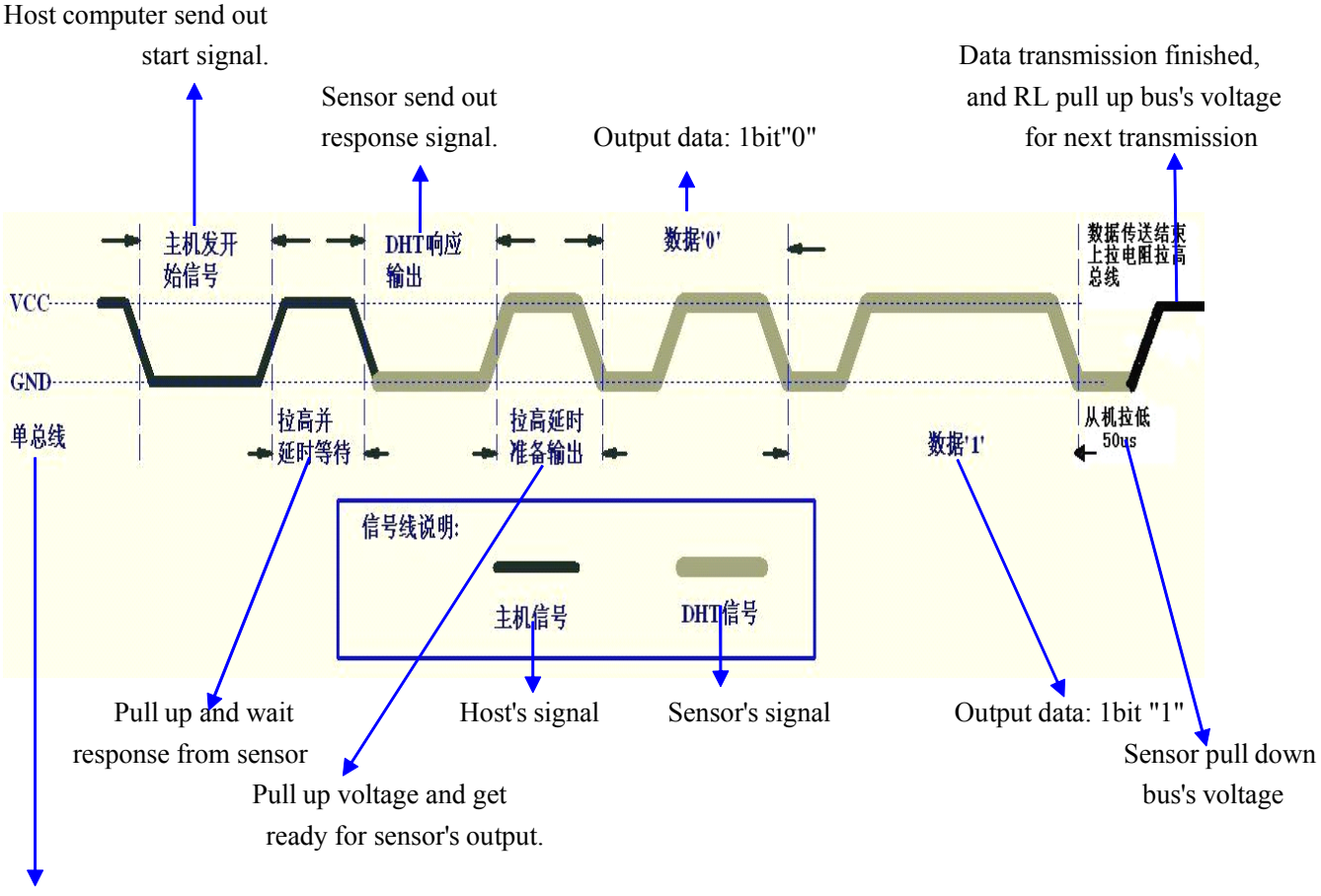
Data is comprised of integral and decimal part, the following is the formula for data.
AM2303 send out higher data bit firstly!

DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum

If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, AM2303 change from low-power-consumption-mode to running-mode. When MCU finishs sending the start signal, AM2303 will send response signal of 40-bit data that reflect the relative humidity and temperature information to MCU. Without start signal from MCU, AM2303 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from AM2303. AM2303 will change to low-power-consumption-mode when data collecting finish if it don't receive start signal from MCU again.

1) Check bellow picture for overall communication process:



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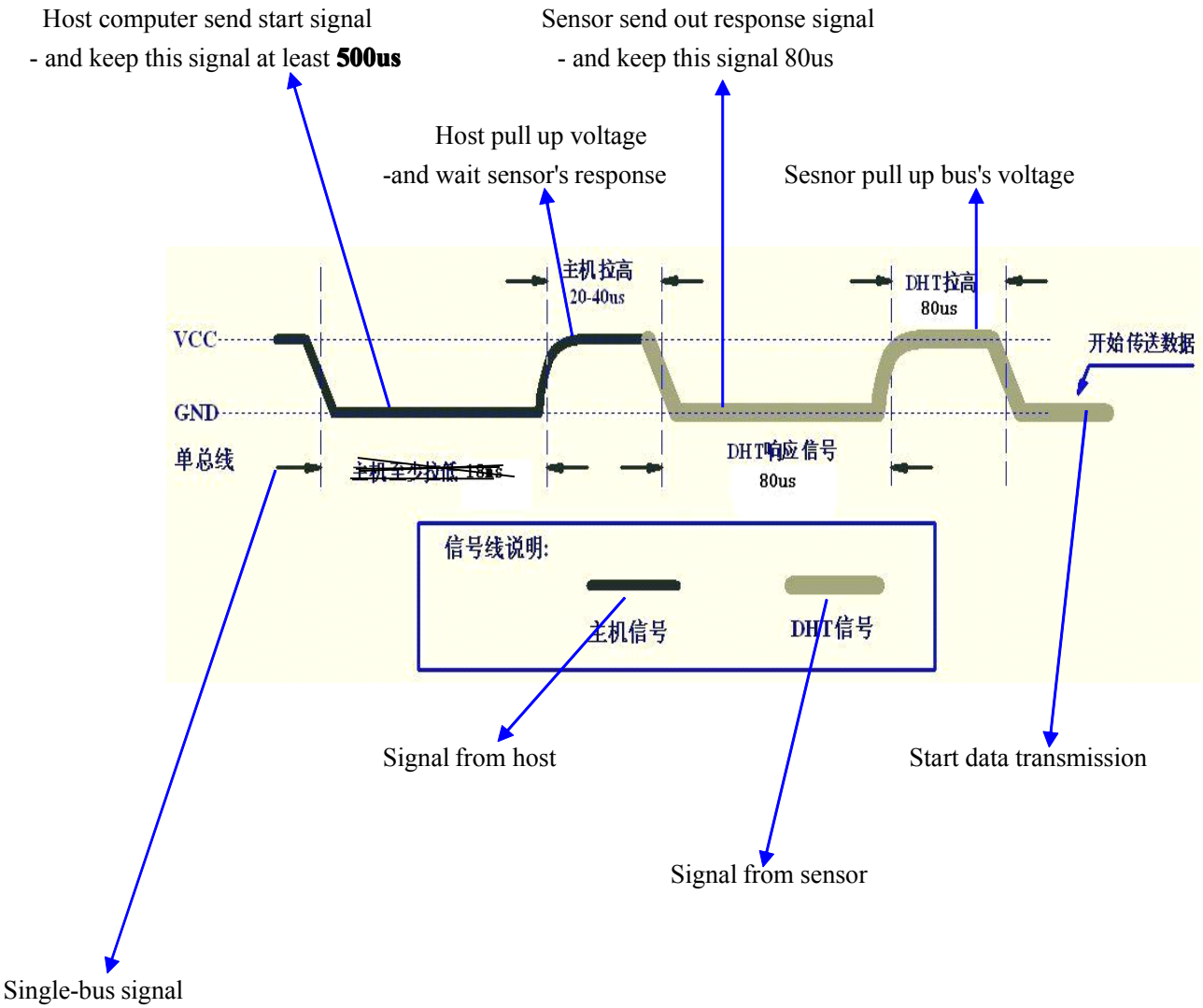
2) Step 1: MCU send out start signal to AM2303

Data-bus's free status is high voltage level. When communication between MCU and AM2303 begin, program of MCU will transform data-bus's voltage level from high to low level and this process must beyond at least 18ms to ensure AM2303 could detect MCU's signal, then MCU will wait 20-40us for AM2303's response.

Check bellow picture for step 1:



Step 2: AM2303 send response signal to MCU

When AM2303 detect the start signal, AM2303 will send out low-voltage-level signal and this signal last 80us as response signal, then program of AM2303 transform data-bus's voltage level from low to high level and last 80us for AM2303's preparation to send data.

Check bellow picture for step 2:

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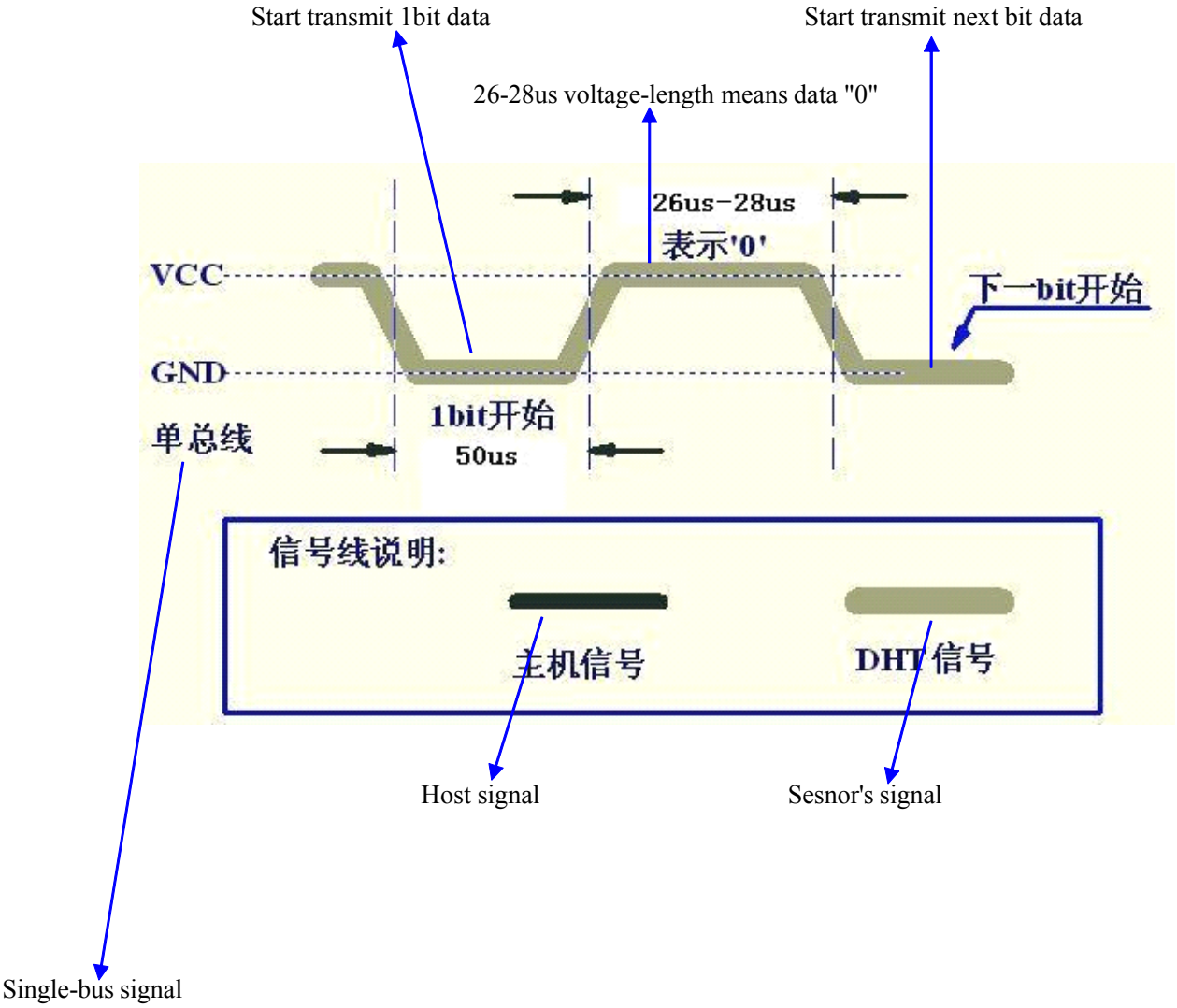

Step 3: AM2303 send data to MCU

When AM2303 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0".

Check bellow picture for step 3:

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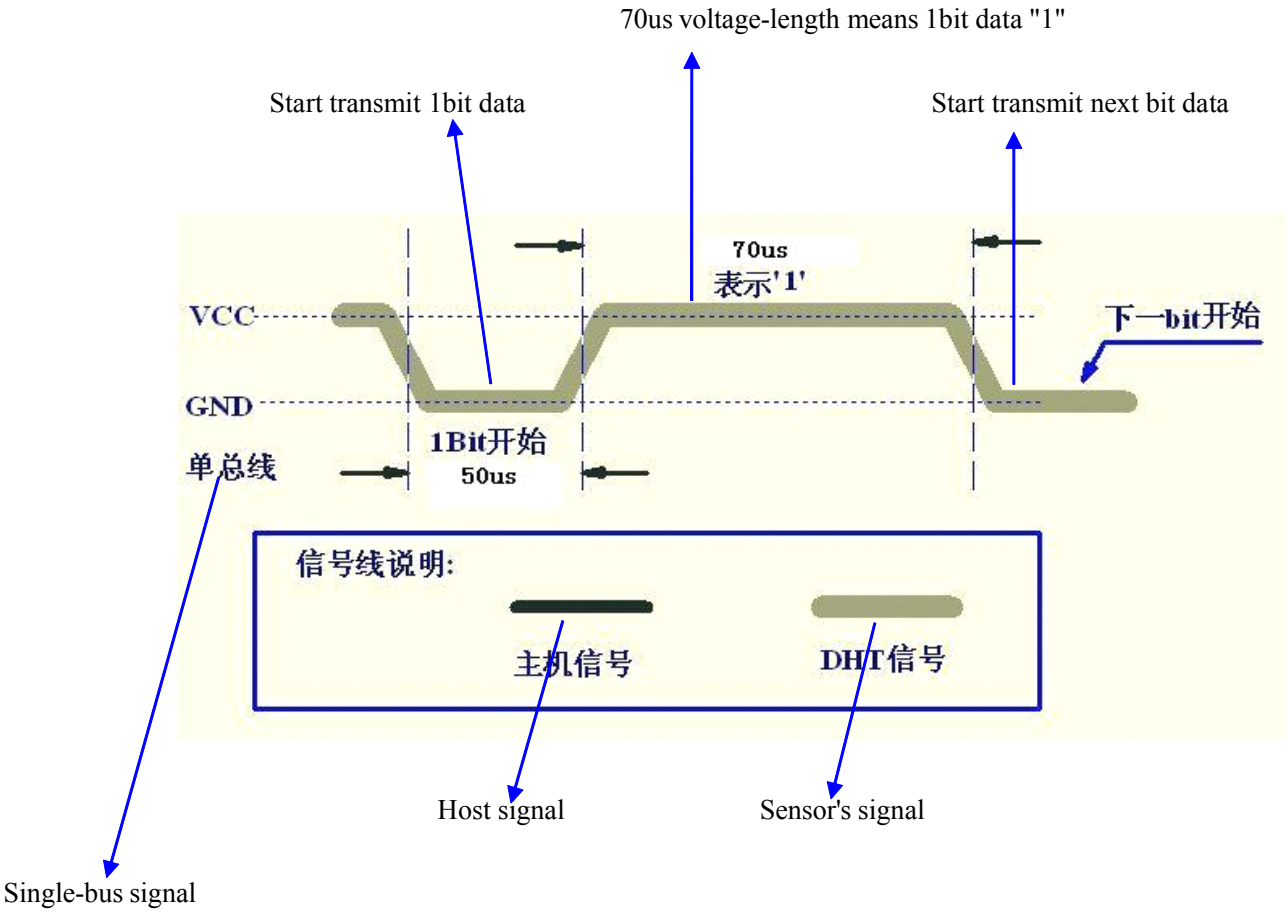

If signal from AM2303 is always high-voltage-level, it means AM2303 is not working properly, please check the electrical connection status.

6. Electrical Characteristics:

Item	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	5.5	V
Current supply	Measuring	1.3	1.5	2.1	mA
	Average	0.5	0.8	1.1	mA
Collecting period	Second	1.7		2	Second

*Collecting period should be : >1.7 second.

7. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The DHT11 sensor

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can recover after working in non-normal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere AM2303's sensitive-elements and debase AM2303's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the AM2303 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the AM2303 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

AM2303 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase AM2303's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

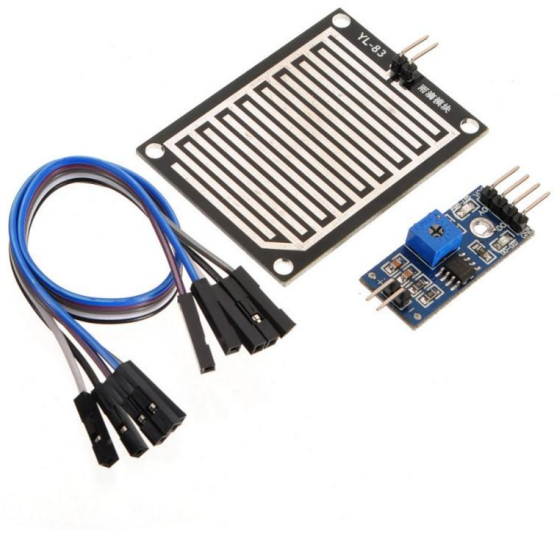
* Welding temperature should be bellow 260Celsius.

* Avoid using the sensor under dew condition.

* Don't use this product in safety or emergency stop devices or any other occasion that failure of AM2303 may cause personal injury.

VAISALA www.vaisala.com

Yl-83 Rain Detector



Vaisala YL-83 Rain Detector

Features/Benefits

- Fast and accurate precipitation detection (ON/OFF)
- Rain intensity measurement with processing unit
- Maintenance free
- Heating element for keeping sensor free of snow and condensed moisture, and for quick drying

Rain and snow are quickly and accurately detected with the YL-83 Rain Detector. The YL-83 operates via droplet detection rather than by signal level threshold.

A special delay circuitry allows about two-minute interval between raindrops before assuming an OFF (no rain) position. This enables the sensor to accurately distinguish between rain cessation and light rain.

The YL-83 also features an analog Rain Signal for estimating rain intensity. Since this signal is proportional to the percentage of moist or wet area on the sensor plate, rain intensity has a direct impact on the amplitude and variation of this analog signal.

The YL-83 sensor is positioned at a 30° angle. This design, together with the internal heating element, ensures that the surface dries quickly, an essential factor in calculating intensity. The same heating element also protects the surface from fog and condensed moisture, and is activated at low temperatures in order to melt snow, thus allowing snow detection. Sensor performance is not affected by reasonable amounts of dirt and dust due to droplet detection.

It is intended to be used in areas
with only rain or wet/moist snow precipitation.

Technical Data

Sensor

Capacitive principle, thick layer sensor
RainCap™ with a thin glass shield. Integrated heater element.

Sensitivity of Rain Detection

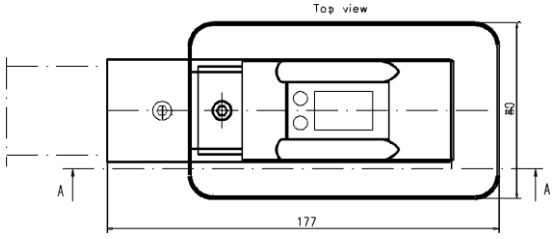
Minimum wet area	0.05 cm²
OFF-delay (active)	< 5 min

Physical

Sensor plate	
Sensing area	7.2 cm²
Angle	30°
Housing material	Polypropylene
Windshield and support bracket	Aluminum
Moisture shield	Polyurethane
Dimensions	(h × w × l)
With wind shield	110 × 80 × 175 mm
Without wind shield	90 × 46 × 157 mm
Weight	500 g
Cable length	4 m

Electrical

Supply voltage	12 VDC ± 10 %
Supply current	
Typical less than	150 mA
Maximum	260 mA
Heater OFF	25 mA
Sensor plate	
Heating power	0.5 ... 2.3 W



Output

Rain ON/OFF

Open collector, active low signal corresponds to rain	
Maximum voltage	15 V
Maximum current	50 mA
Analog output	1...3 V (wet...dry)
Frequency output	1500...6000 Hz, non-calibrated

Input

Control to switch heater OFF

Open circuit input enables the heater.	
Connection to GND disables the heater.	
Contact rating min.	15 V, 2 mA

Ground Wiring

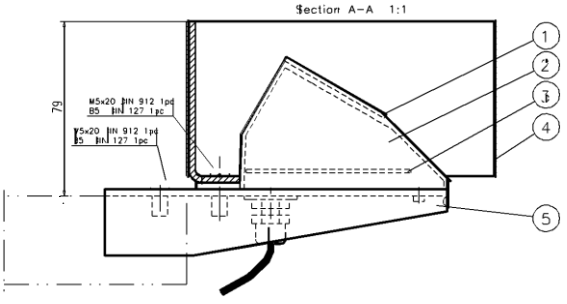
Separate ground wires for signal and heater

Temperature Range

Operating	-15...+55 °C (+5...+131 °F)
Storage	-40...+65 °C (-40...+149 °F)

Mounting

By one screw (M5 x 20 mm) to sensor arm



1. *Sensor, RainCap™*
2. *Polyurethane moisture shield*
3. *Component assembly*
4. *Wind shield*
5. *Mounting plate*

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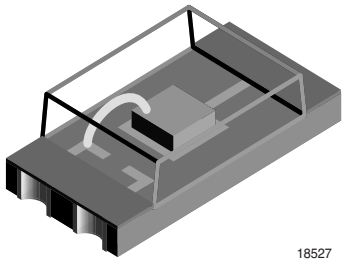
CE

Ambient Light Sensor

Description

TEMT6000 is a silicon NPN epitaxial planar phototransistor in a miniature transparent mold for surface mounting onto a printed circuit board. The device is sensitive to the visible spectrum.



Features

- Adapted to human eye responsivity
- Wide angle of half sensitivity φ = ± 60°
- SMD style package on PCB technology
- Suitable for IR reflow soldering

- Lead free component
- Component in accordance to RoHS 2002/95/EC and WEEE 2002/96/EC

Applications

Ambient light sensor for display backlight dimming in:
Mobile phones
Notebook computers
PDA's
Cameras
Dashboards

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Value	Unit
Collector Emitter Voltage		V_{CEO}	6	V
Emitter Collector Voltage		V_{ECO}	1.5	V
Collector current		I_C	20	mA
Total Power Dissipation	$T_{amb} \leq 55$ °C	P_{tot}	100	mW
Junction Temperature		T_j	100	°C
Operating Temperature Range		T_{amb}	- 40 to + 85	°C
Storage Temperature Range		T_{stg}	- 40 to + 85	°C
Soldering Temperature	t ≤ 3 s	T_{sd}	260	°C
Thermal Resistance Junction/ Ambient		R_{thJA}	450	K/W

Basic Characteristics

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector Emitter Breakdown Voltage	I_C = 0.1 mA	V_{CEO}	6			V
Collector dark current	V_{CE} = 5 V, E = 0	I_{CEO}		3	50	nA
Collector-emitter capacitance	V_{CE} = 0 V, f = 1 MHz, E = 0	C_{CEO}		16		pF
Collector Light Current	E_v = 20 lx, standard light A	I_{ca}	3.5	10	16	µA
	E_v = 100 lx, standard light A	I_{ca}		50		µA
Angle of Half Sensitivity		φ		±60		deg
Wavelength of Peak Sensitivity		λ_p		570		nm
Range of Spectral Bandwidth		$\lambda_{0.1}$		360 to 970		nm
Collector Emitter Saturation Voltage	E_v = 20 lx, 0.45 µA	V_{CEsat}		0.1		V

Typical Characteristics (T_{amb} = 25 °C unless otherwise specified)

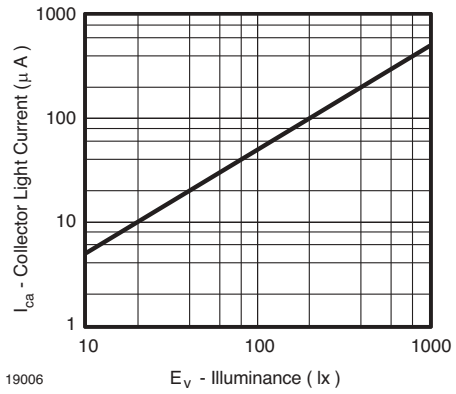


Figure 1. Collector Light Current vs. Illuminance

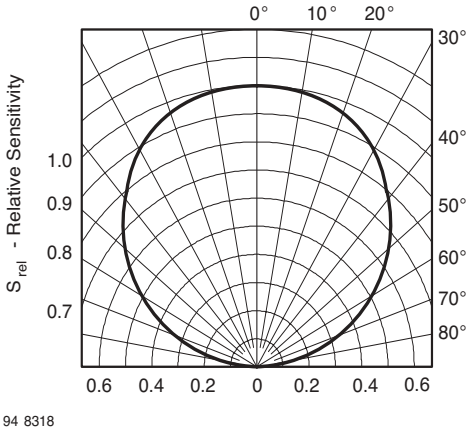


Figure 3. Relative Radiant Sensitivity vs. Angular Displacement

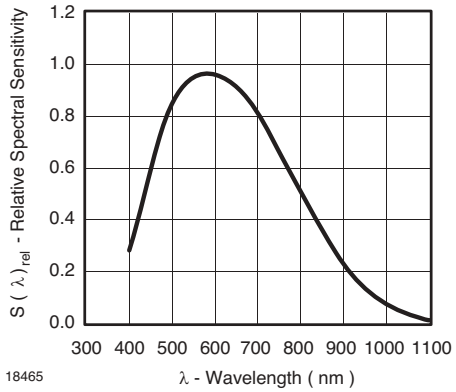


Figure 2. Relative Spectral Responsivity vs. Wavelength

Reflow Solder Profiles

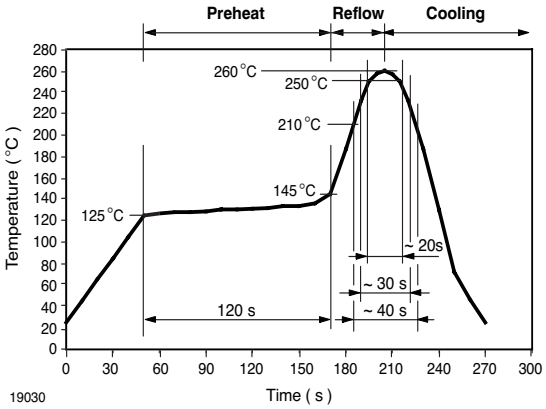


Figure 4. Lead-Free (Sn) Reflow Solder Profile

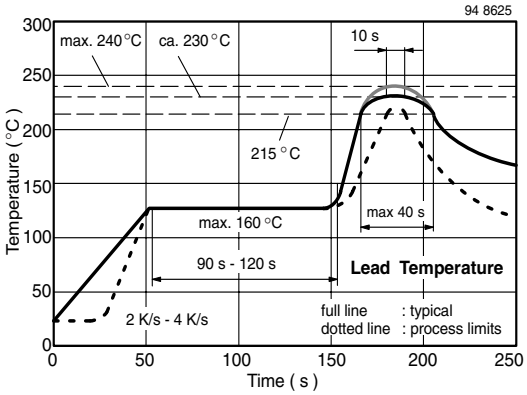


Figure 5. Lead Tin (SnPb) Reflow Solder Profile

Drypack

Devices are packed in moisture barrier bags (MBB) to prevent the products from moisture absorption during transportation and storage. Each bag contains a desiccant.

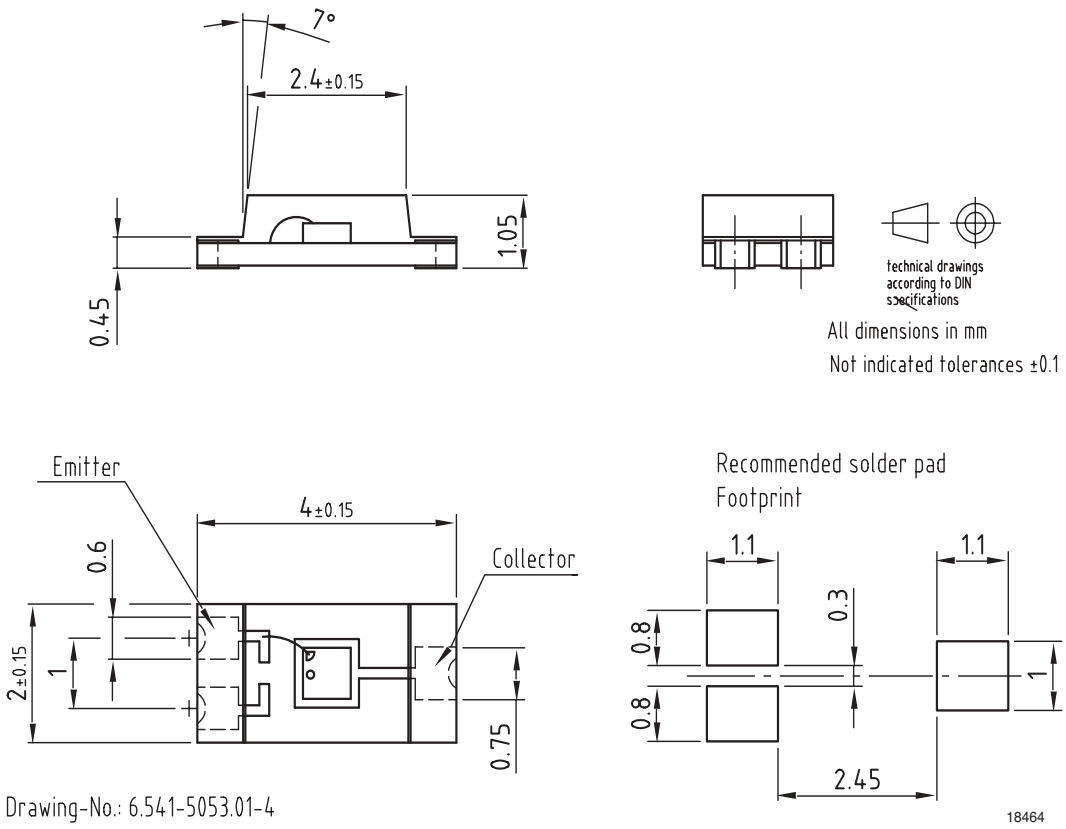
Floor Life

Floor life (time between soldering and removing from MBB) must not exceed the time indicated in J-STD-020. TEMT6000 is released for:
Moisture Sensitivity Level 4, according to JEDEC, J-STD-020
Floor Life: 72 h
Conditions: T_{amb} < 30 °C, RH < 60 %

Drying

In case of moisture absorption devices should be baked before soldering. Conditions see J-STD-020 or Label. Devices taped on reel dry using recommended conditions 192 h @ 40 °C (+ 5 °C), RH < 5 %

Package Dimensions in mm



Drawing-No.: 6.541-5053.01-4
Issue: 2; 21.06.04

Ozone Depleting Substances Policy Statement

It is the policy of **Vishay Semiconductor GmbH** to

1. Meet all present and future national and international statutory requirements.
2. Regularly and continuously improve the performance of our products, processes, distribution and operatingsystems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

Vishay Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively
2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA
3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

Vishay Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

Vishay Semiconductor GmbH, P.O.B. 3535, D-74025 Heilbronn, Germany
Telephone: 49 (0)7131 67 2831, Fax number: 49 (0)7131 67 2423

apogee®

INSTRUMENTS

OWNER'S MANUAL

RADIATION FROST DETECTOR

Model SF-110

Rev: 31-Aug-2022

APOGEE INSTRUMENTS, INC. | 721 WEST 1800 NORTH, LOGAN, UTAH 84321, USA
TEL: (435) 792-4700 | FAX: (435) 787-8268 | WEB: APOGEEINSTRUMENTS.COM

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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: SF-110
Type: Radiation Frost Detector

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Hazardous Substances (RoHS 2) Directive
2015/863/EU	Amending Annex II to Directive 2011/65/EU (RoHS 3)

Standards referenced during compliance assessment:

EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1 % lead concentration are RoHS 3 compliant using exemption 6c.

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but we rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, August 2022

Bruce Bugbee
President
Apogee Instruments, Inc.

CE

CERTIFICATE OF COMPLIANCE

UK Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: SF-110
Type: Radiation Frost Detector

The object of the declaration described above is in conformity with the relevant UK Statutory Instruments and their amendments:

2016 No. 1091	The Electromagnetic Compatibility Regulations 2016
2012 No. 3032	The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Standards referenced during compliance assessment:

BS EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
BS EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1 % lead concentration are RoHS 3 compliant using exemption 6c.

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but we rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, August 2022

Bruce Bugbee
President
Apogee Instruments, Inc.

INTRODUCTION

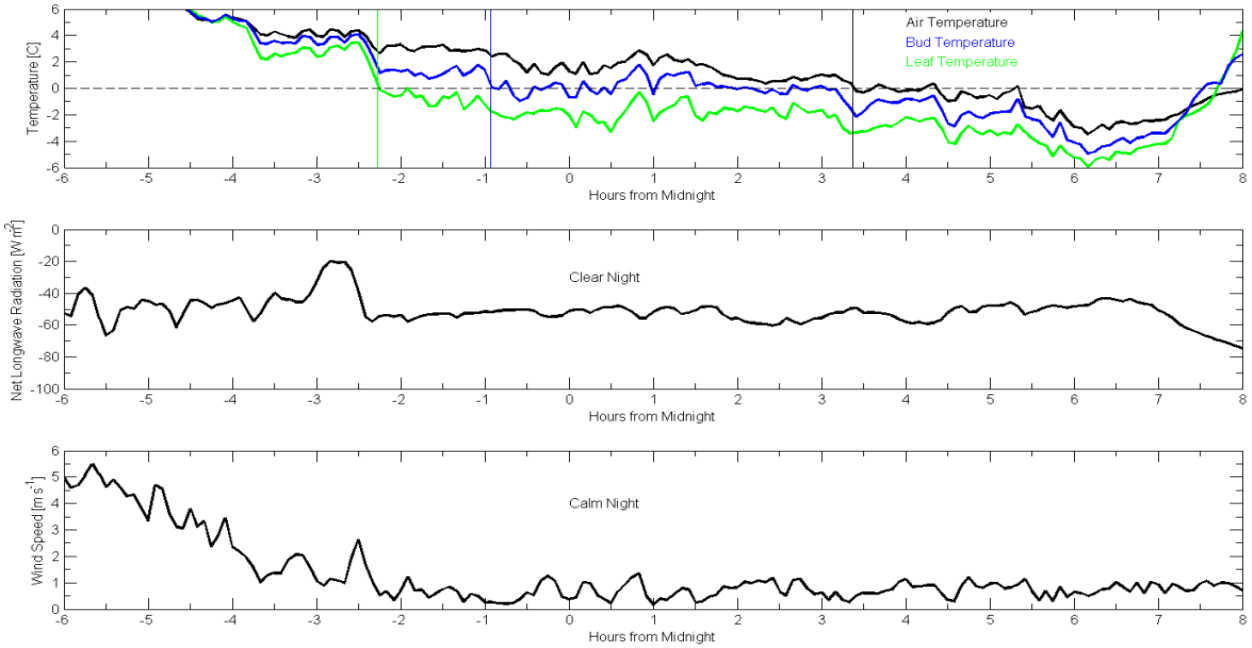
In January 2022, the SF-110 (formerly called the leaf and bud temperature sensor) underwent a redesign to improve performance and ruggedness. As part of this redesign, the bud temperature sensor was removed, as it was determined the leaf measurement was most critical. The SF-110 was renamed the radiation frost detector.

Frost damage to plants can have a large impact on crop yield and quality. Protection of crops during frost events is dependent on the accuracy of plant temperature predictions. Often, air temperature is not a reliable predictor of timing, duration, and severity of frost events because plant canopy temperatures can be significantly different than air temperature under certain environmental conditions.

On clear, calm nights, plant leaf temperature can drop below freezing even if air temperature remains above 0 C (see figure on page 6). This is called a radiation frost and is caused by the lack of air mixing (wind) near the surface and a negative net longwave radiation balance at the surface (more longwave radiation is being emitted from the surface than what the surface is absorbing from the clear sky). Under cloudy and/or windy conditions, radiation frost events do not occur.

Apogee model SF-110 radiation frost detectors are designed to approximate plant leaf temperatures for prediction of frost events. SF-110 radiation frost detectors are intended for applications in cropped fields and orchards when air temperatures will be near freezing and where air temperature measurements are not a good predictor of frost formation.

Apogee Instruments SF-110 radiation frost detectors consist of a precision thermistor combined with a simulated leaf. The sensor is designed to mimic a plant leaf. SF-110 radiation frost detectors provide close approximations of leaf temperature and can be used to predict frost on leaves. The detector is weatherproof and designed for continuous temperature measurement in the same environmental conditions to which plants are exposed. The SF-110 detector outputs one analog voltage signal (when supplied with an input voltage) that is related to the resistance of a thermistor. The resistance is directly related to simulated leaf temperature.



Simulated leaf (green trace in top panel) temperature from an Apogee model SF-110 compared to air temperature (black trace in top panel) and simulated bud (blue trace in top panel) temperature throughout a clear (net longwave radiation is plotted in middle panel), calm (wind speed is plotted in bottom panel) night during spring in Logan, Utah. Simulated leaf temperatures reached the freezing point approximately 5.5 hours before air temperature.

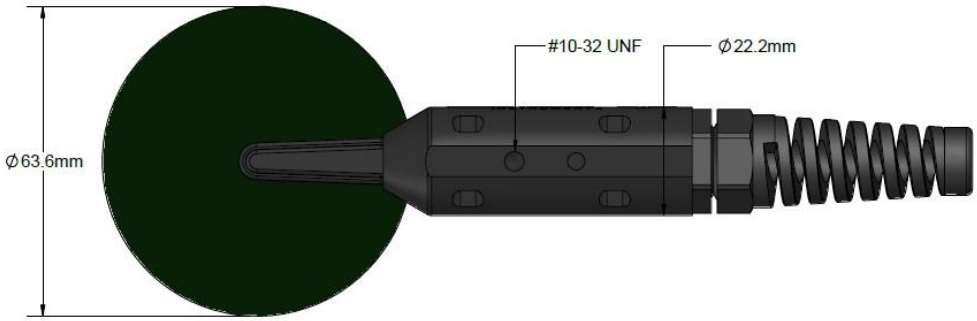
SENSOR MODELS

SF-110 radiation frost detectors use the same precision thermistors as Apogee ST series thermistor temperature sensors, but the thermistor is mounted into a simulated leaf. SF-110 detectors are rugged and weatherproof and are designed to be exposed to ambient environmental conditions.

A sensor's model number and serial number are located on a label near the cable connector. If you need the manufacturing date of your sensor, please contact Apogee Instruments with the serial number of your sensor.

SPECIFICATIONS

	SF-110
Measurement Range	-50 to 70 C
Measurement Uncertainty	0.1 (from 0 to 70 C); 0.2 C (from -25 to 0 C); 0.4 C (from -50 to -25 C)
Measurement Repeatability	Less than 0.05 C
Long-term Drift (Non-stability)	Less than 0.02 C per year (when used in non-condensing environments where the annual average temperature is less than 30 C; continuously high temperatures or continuously humid environments increase drift rate)
Equilibration Time	10 s
Self-Heating	Less than 0.01 C (typical, assuming pulsed excitation of 2.5 V DC); 0.08 C at 5 C (maximum, assuming continuous input excitation of 2.5 V DC)
Operating Environment	-50 to 70 C; 0 to 100 % relative humidity
Input Voltage Requirement	2.5 V DC excitation (recommended, see Operation and Measurement section)
Output Voltage Requirement	2.5 V DC
Current Draw	0.1 mA DC at 70 C (maximum, assuming continuous input excitation of 2.5 V DC)
Dimensions	17.5 cm length, 2.2 cm pipe diameter, 6.0 cm disk diameter (see diagram below)
Mass	75 g
Cable	5 m of three conductor, shielded, twisted-pair wire; cable is available in 5, 10, and 20 m lengths (custom lengths available by request); TPR jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires



DEPLOYMENT AND INSTALLATION

Apogee SF-110 radiation frost detectors should be mounted within—or very near—the plant canopy where frost detection is desired. This ensures the simulated leaf is in the same environment as the actual leaves.

An Apogee Instruments model AM-260 mounting bracket can be used to mount the detector to a cross arm or pole. The AM-260 allows adjustment of the angle of the detector. Mounting the detector with a slight downward slope, or tilt to one side, is recommended to minimize moisture/debris build-up on the simulated leaf.

CABLE CONNECTORS

Apogee sensors offer cable connectors to simplify the process of removing sensors from weather stations for calibration (the entire cable does **not** have to be removed from the station and shipped with the sensor).

The ruggedized M8 connectors are rated IP68, made of corrosion-resistant marine-grade stainless-steel, and designed for extended use in harsh environmental conditions.

Inline cable connectors are installed 30 cm from the head (pyranometer pictured)

Instructions

Pins and Wiring Colors: All Apogee connectors have six pins, but not all pins are used for every sensor. There may also be unused wire colors inside the cable. To simplify datalogger connection, we remove the unused pigtail lead colors at the datalogger end of the cable.

If a replacement cable is required, please contact Apogee directly to ensure ordering the proper pigtail configuration.

A reference notch inside the connector ensures proper alignment before tightening.

Alignment: When reconnecting a sensor, arrows on the connector jacket and an aligning notch ensure proper orientation.

Disconnection for extended periods: When disconnecting the sensor for an extended period from a station, protect the remaining half of the connector still on the station from water and dirt with electrical tape or other method.

When sending sensors in for calibration, only send the short end of the cable and half the connector.

Tightening: Connectors are designed to be firmly finger-tightened only. There is an O-ring inside the connector that can be overly compressed if a wrench is used. Pay attention to thread alignment to avoid cross-threading. When fully tightened, 1-2 threads may still be visible.

Finger-tighten firmly

OPERATION AND MEASUREMENT

Connect the detector to a measurement device (meter, datalogger, controller) capable of inputting 2.5 V DC, and measuring and displaying or recording a millivolt (mV) signal (an input measurement range of 0 to 2500 mV is required to cover the entire temperature range of the detector). In order to maximize measurement resolution and signal-to-noise ratio, the input range of the measurement device should closely match the output range of the thermistor.

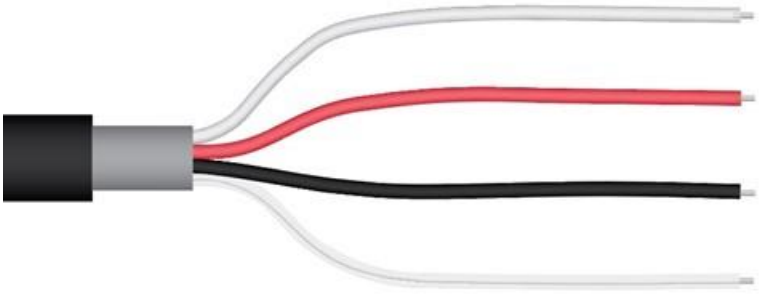
VERY IMPORTANT: In January 2022, the SF-110 (formerly called the leaf and bud temperature sensor) underwent a redesign to improve performance and ruggedness. As part of this redesign, the bud temperature sensor was removed, as it was determined the leaf measurement was most critical. The SF-110 was renamed the radiation frost detector.

Radiation Frost Detector

Leaf and Bud Temperature Sensor

RADIATION FROST DETECTORS WIRING

Wiring for Radiation Frost Detectors (as of January 2022)



White: Therm 1 (positive leaf thermistor lead)

Red: Excitation channel (excitation for leaf thermistor)

Black: Therm 1 (negative leaf thermistor lead)

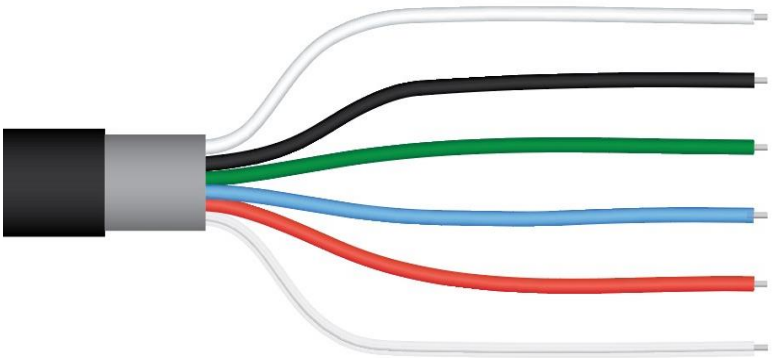
Clear: Shield/Ground

Measurement devices (e.g., datalogger, controller) do not measure resistance directly, but determine resistance from a half-bridge measurement, where an excitation voltage is input across the thermistor and an output voltage is measured across the bridge resistor (circuit diagram shown on page 13 is for simulated leaf thermistor).

LEAF AND BUD TEMPERATURE SENSORS WIRING (OLD DESIGN)

VERY IMPORTANT: Apogee changed all wiring colors of our bare-lead sensors in March 2018. To ensure proper connection to your data device, please note your serial number then use the appropriate wiring configuration below.

Wiring for Leaf and Bud Temperature Sensor Serial Numbers 1138 and above



White: Therm 1 (positive leaf thermistor lead)

Black: Therm 1 (negative leaf thermistor lead)

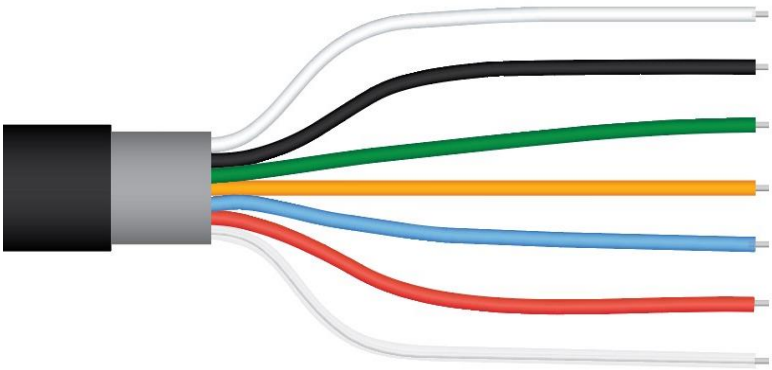
Green: Therm 2 (positive bud thermistor lead)

Blue: Therm 2 (negative bud thermistor lead)

Red: Excitation channel (excitation for leaf and bud thermistor)

Clear: Shield/Ground

Wiring for Leaf and Bud Temperature Sensor Serial Numbers range 0-1137



White: Excitation channel (excitation for bud thermistor)

Black: Single-ended channel (positive leaf thermistor lead)

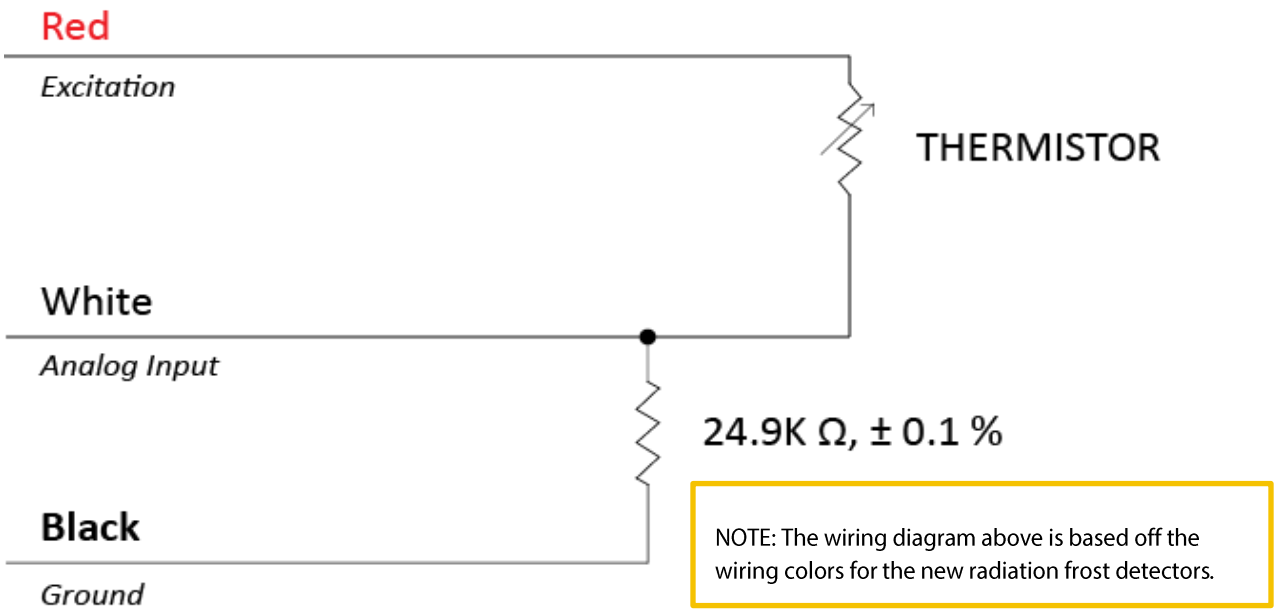
Green: Single-ended channel (positive bud thermistor lead)

Orange: Analog ground (negative bud thermistor lead)

Blue: Analog ground (negative leaf thermistor lead)

Red: Excitation channel (excitation for leaf thermistor)

Clear: Analog ground (shield wire)



An excitation voltage of 2.5 V DC is recommended to minimize self-heating and current drain, while still maintaining adequate measurement sensitivity (mV output from thermistor per C). However, other excitation voltages can be used. Decreasing the excitation voltage will decrease self-heating and current drain but will also decrease thermistor measurement sensitivity. Increasing the excitation voltage will increase thermistor measurement sensitivity but will also increase self-heating and current drain.

Conversion of Thermistor Resistance to Temperature

The thermistor in the simulated leaf has a resistive element where resistance changes with temperature. Thermistor resistance (R_T, in Ω) is measured with a half-bridge measurement, requiring an excitation voltage input (V_{EX}) and a measurement of output voltage (V_{OUT}):

$$R_T = 24900\left(\frac{V_{EX}}{V_{OUT}} - 1\right) \qquad (1)$$

where 24900 is the resistance of the bridge resistor in Ω. From resistance, temperature (T_K, in Kelvin) is calculated with the Steinhart-Hart equation and thermistor specific coefficients:

$$T_K = \frac{1}{A + B\ln(R_T) + C(\ln(R_T))^3} \qquad (2)$$

where A = 1.129241 x 10^{-3}, B = 2.341077 x 10^{-4}, and C = 8.775468 x 10^{-8} (Steinhart-Hart coefficients). If desired, measured temperature in Kelvin can be converted to Celsius (T_C):

$$T_C = T_K - 273.15 \qquad (3)$$

MAINTENANCE AND RECALIBRATION

Apogee SF-110 radiation frost detectors are weatherproof and are designed to be continuously deployed in outdoor conditions. When detectors are not is use, it is recommended that they be removed from the measurement environment, cleaned, and stored. SF-110 detectors deployed in the field should be periodically cleaned to remove all dust and debris.

The thermistor in SF-110 detectors is not factory calibrated, but it comes with a generic calibration (see Steinhart-Hart coefficients in OPERATION AND MEASUREMENT section). A custom calibration can be derived by comparing the temperature from the simulated leaf thermistor to a reference temperature measurement. Often, a simple offset can be used to make the measured temperature match the reference temperature.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Independent Verification of Functionality

Apogee SF-110 radiation frost detectors yield an independent resistance that is proportional to simulated leaf temperature. A quick and easy check of functionality of the thermistor can be accomplished with an ohmmeter.

To check the simulated leaf circuit, connect the lead wires of the ohmmeter to the red and white wires from the detector. The resistance should read 10 kΩ (10,000 ohms) at 25 C. If detector temperature is less than 25 C, resistance will be higher. If detector temperature is greater than 25 C, resistance will be lower. Connect the lead wires of the ohmmeter to the white and black wires from the detector. The resistance should read 24.9 kΩ and should not vary. Connect the lead wires of the ohmmeter to the red and black wires from the sensor. The resistance should be the sum of the resistances measured across the red and white wires, and white and black wires (e.g., 10 kΩ plus 24.9 kΩ at 25 C).

Compatible Measurement Devices (Dataloggers/Controllers/Meters)

Measurement of thermistor resistance requires an input excitation voltage, where 2.5 V DC is recommended. A compatible measurement device should have the capability to supply the necessary voltage.

The sensitivity (mV output from thermistor per C) of the temperature measurements varies with the excitation voltage and varies as a function of temperature. With an excitation voltage of 2.5 V DC, the sensitivity is lowest near the ends of the measurement range, -50 and 70 C. A compatible measurement device (e.g., datalogger or controller) should have resolution of at least 0.6 mV, in order to produce temperature resolution of less than 0.1 C across the entire temperature measurement range (less than 0.05 C from -35 to 45 C).

An example datalogger program for Campbell Scientific dataloggers can be found on the Apogee webpage at http://www.apogeeinstruments.com/content/Radiation-Frost-Detection-Sensor.CR1.

Modifying Cable Length

When the detector is connected to a measurement device with high input impedance, detector output signals are not changed by splicing on additional cable in the field. Tests have shown that if the input impedance of the measurements device is 1 mega-ohm or higher then there is negligible effect on the SF-110 leaf and bud temperature sensor, even after adding up to 100 m of cable. See Apogee webpage for details on how to extend sensor cable length (http://www.apogeeinstruments.com/how-to-make-a-weatherproof-cable-splice/). For cable extensions, shielded, twisted pair cable is recommended, in order to minimize electromagnetic interference. This is particularly important for long lead lengths in electromagnetically noisy environments.

The precision bridge resistors are located at the pigtail end of the cable. Thus, the SF-110 cable should not be shortened, otherwise the bridge resistor will be removed.

RETURN AND WARRANTY POLICY

RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

WARRANTY POLICY

What is Covered
All products manufactured by Apogee Instruments are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated by Apogee.

Products not manufactured by Apogee (spectroradiometers, chlorophyll content meters, EE08-SS probes) are covered for a period of one (1) year.

What is Not Covered
The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation, use, or abuse.

2. Operation of the instrument outside of its specified operating range.

3. Natural occurrences such as lightning, fire, etc.

4. Unauthorized modification.

5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered
This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What Apogee Will Do
At no charge Apogee will:

1. Either repair or replace (at our discretion) the item under warranty.

2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.

How To Return An Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by submitting an online RMA form at www.apogeeinstruments.com/tech-support-recalibration-repairs/. We will use your RMA number for tracking of the service item. Call (435) 245-8012 or email techsupport@apogeeinstruments.com with questions.

2. For warranty evaluations, send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration. ***Note:*** *When sending back sensors for routine calibration that have Apogee's standard stainless-steel connectors, you only need to send the sensor with the 30 cm section of cable and one-half of the connector. We have mating connectors at our factory that can be used for calibrating the sensor.*

3. Please write the RMA number on the outside of the shipping container.

4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.

Apogee Instruments, Inc.
721 West 1800 North Logan, UT
84321, USA

5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

PRODUCTS BEYOND THE WARRANTY PERIOD

For issues with sensors beyond the warranty period, please contact Apogee at techsupport@apogeeinstruments.com to discuss repair or replacement options.

OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of data, loss of wages, loss of time, loss of sales, accruement of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot by transferred or assigned. If any provision of this limited warranty is unlawful, void, or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

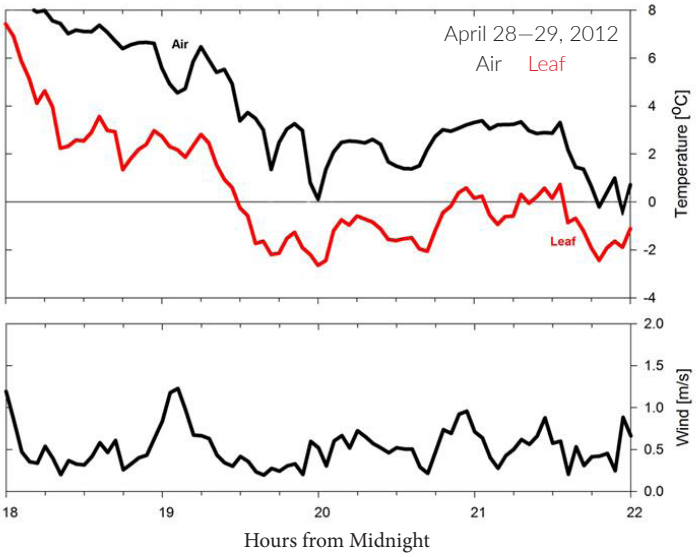
This warranty cannot be changed, assumed, or amended by any other person or agreement

RADIATION FROST DETECTORS

SF-110-SS & SF-421-SS

Effective prediction of leaf temperatures for orchards

Temperature Response



Leaf temperature approximations measured with an Apogee SF-110 compared to air temperature (top panel) and wind speed (bottom panel) on the evening of April 28, 2012. Leaf temperatures were below air temperature after 8 P.M. and reached freezing 6 hours before the air temperature.

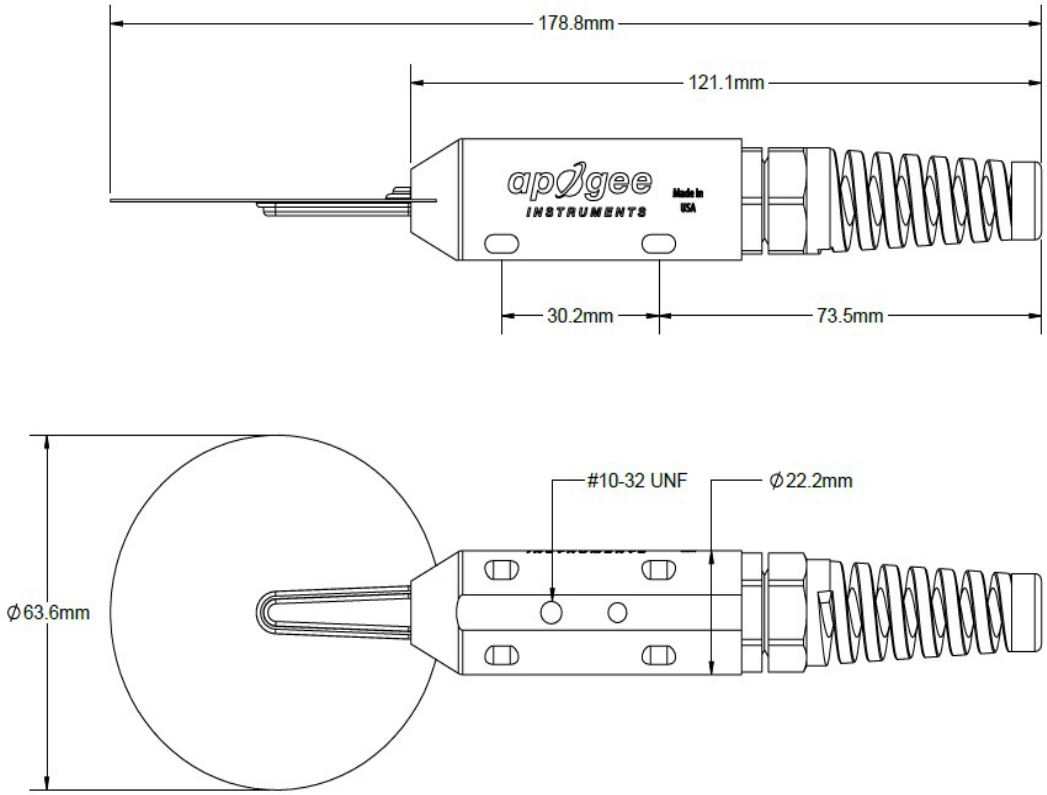
Product Specifications

Measurement Range	-50 to 70 C	
Measurement Uncertainty	0.1 C (from 0 to 70 C), 0.2 C (from -25 to 0 C), 0.4 C (from -50 to -25 C)	
Measurement Repeatability	Less than 0.05 C	
Long-term Drift (Non-stability)	Less than 0.02 C per year (when used in non-condensing environments where the annual average temperature is less than 30 C; continuously high temperatures or continuously humid environments increase drift rate)	
Equilibration Time	10 s	
Self-heating	Less than 0.01 C (typical, assuming pulsed excitation of 2.5 V DC), 0.08 C at 5 C (max. assuming continuous input excitation of 2.5 V DC	Less than 0.01 C
Operating Environment	-50 to 70 C; 0 to 100 % relative humidity	
Input Voltage Requirement	2.5 V DC excitation	5.5 to 24 V DC
Output Voltage Range	0 to 2.5 V DC (assuming input excitation of 2.5 V DC)	—
Current Draw	0.1 mA DC at 70 C (max. assuming continuous input excitation of 2.5 V DC)	1.56 mA (quiescent), 1.93 mA (active)
Dimensions	17.5 cm length, 2.2 cm pipe diameter, 6.0 cm disk diameter	
Mass	75 g	
Warranty	4 years against defects in materials and workmanship	

Monitor Radiation Frost Events

On calm, clear nights leaf temperatures can drop well below air temperature. A radiation frost occurs when frost forms on the surface before the air temperature reaches freezing. The Apogee radiation frost dectector contains a high accuracy thermistor mounted in a rugged housing. The thermistor mimics a leaf, which provides estimates of leaf temperatures when monitoring radiation frost events.

Dimensions



Features

Wide Range, Accurate Measurements
Thermistor accuracy is ± 0.1 C across a range of 0 to 70 C, providing accurate measurements at temperatures near zero where frost damage is likely to occur.

Output Options
Analog and digital output options include an unamplified voltage output or SDI-12 communication protocol.

Typical Applications
Applications include leaf temperature estimates in crop fields, orchards, and vineyards. Leaf temperatures returned by the detector can then be used to alert growers to the potential of frost damage to crops.

Rev: 4-Aug-2022