HPS-1 Heated Pitot-Static Probe

HPS-1 of Simtec is a lightweight pitot-static probe with an integrated and regulated heating system and drainage system that prevents aggregation of ice, water and moisture.

The HPS-1 is the optimal solution if precise pitot and static pressure is needed on unmanned aerial vehicles (UAV), remotely piloted aircraft (RPA) or other flight vehicles. It can be used together with the ADC-10 Air Data Computer or with any other air data system.

Figure 1. HPS-1 L-Shape

Figure 2. HPS-1 Detached Heater Controller

Figure 3. HPS-1 Standard Version R9

The integrated heating electronics regulates the temperature of the probe within a narrow band of temperature. Using pulse width modulation of varying duty cycle, a stable probe temperature is achieved. At 100% duty cycle at least 40W of heating power is available. Both the maximum temperature and the maximum duty cycle are configurable by the factory and by the user. A status output signal indicates system normal operation. A discrete input signal allows the flight control computer (or autopilot) to switch the heater on and off during the flight. This can be used to conserve power during a long flight.

The static holes are located in the stainless-steel part of the probe for highest accuracy and best heating performance as well as mechanical and chemical resistance.

Key Features

- Small size and lightweight, very small probe diameter of only Ø9 mm
- Made of stainless steel, aircraft grade aluminum and carbon fiber tube
- Best solution for UAVs, RPAs and other flight vehicles
- Integrated and regulated heater
- 9-32 VDC Power Input (min. 40 Watt at 28VDC, 100% power)
- High accuracy

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- Designed and tested in the wind-tunnel Key Advantages
- Heated static holes
- Drainage system
- Small probe diameter and regulated temperature for lowest power consumption
- On/off function via 5V logic level
- Status indication via 5V logic level
- Electrical connector for easy installation and detachment
- Connector and pressure fitting in line with aircraft axis, allows slim fuselage design
- Reverse polarity protection

Specification

	40 W Version	60 W Version
Supply Voltage	9 V … 32 V	9 V … 28 V, Surge (<1 s) up to 32 V
Supply Current (100% Duty Cycle, 28V)	1.4 A … 2.0 A	2.1 A … 2.9 A
	The supply current I_{VS} at a given supply voltage VS is calculated as: $I_{VS} = I_{28\,V} \times V_S / 28\ V$	
Heater Temperature	The probe temperature is regulated by a microprocessor and a temperature sensor. Standard tip temperature is 80°C. The tip temperature is configurable via the status pin.	
Heater Power (100% Duty Cycle, 28V)	At 100% duty cycle a minimum of 40W of heating power is provided. The heating power is automatically reduced when the targeted probe temperature is reached.	At 100% duty cycle a minimum of 60W of heating power is provided. The heating power is automatically reduced when the targeted probe temperature is reached.
	The heater power P_{VS} at a given supply voltage V_S is calculated as: $P_{VS} = P_{28\,V} \times (V_S / 28\ V)^2$	
Electrical Connector	Binder 711 Female 4-Pole (09 0082 32 04) – Pin-1: 9 .. 32VDC (28VDC) – Pin-2: Ground – Pin 3: 5V On/Off (RX for configuration) – Pin 4: 5V Status Indication (TX for configuration)	
Accuracy	Calibrated in wind-tunnel, see aerodynamic properties for details.	
Materials	Stainless steel, aviation grade aluminum, carbon fiber tube	
Operating Temp.	-55°C .. +80°C (-40°C .. +80°C start-up))	
Mounting	Two to four M4 screws (M3 for L-Shape)	
Mass	0.095kg @ 300mm	

Function

The total pressure port is protected internally with a settling chamber so that no water and ice can enter the pressure lines. A drainage system drains water to the outside. The static pressure ports are drilled in the stainless steel tube to guarantee accurate static pressure.

The integrated electronic circuit board holds the microprocessor, the sensor electronics and the power electronics. The temperature in the probe tip is regulated with the help of a small temperature sensor. The power to the heater is regulated by a sophisticated control algorithm. To provide fine grained heater regulation and to minimize power fluctuation on the power system of the aircraft pulse-width modulation (PWM) is used to adjust the required power. Maximum power and maximum temperature is configurable by the factory or the user. As maximum power is configurable, the system can be used on smaller aircraft with limited maximum power capabilities.

Figure 4. Functional diagram of the HPS-1 heater system

Available Probe Models

To be able to meet all customers needs, there are several different models available:

Standard *SIM-D8C-4FE-R9*	Probe mounted on aluminum tube. Heater controller box directly attached to aluminum tube. Weight optimized Heater controller.
Mount *SIM-CC1-09A*	Probe mounted on carbon tube with aluminum mount. Heater controller box detached. Pig-tail cable with Binder connector.
L-Shape *SIM-304-695*	Probe mounted on L-shaped mast. Heater controller box detached. Pig-tail cable with Binder connector.
Boom *SIM-894-63D*	Probe mounted on carbon tube. Heater controller box detached. Pig-tail cable with Binder connector.

Available Probe Configurations & Options

Heater Power	The heater power can be increased to 60W instead of 40W. Note that the current consumption is increased by a factor of 1.5. If this option is chosen, the supply voltage must be limited to 28VDC maximum. Short duration surges up to 32V are acceptable.
Boom Length	Length of carbon/aluminum tube for Standard, Mount and Boom version
Installation Orientation	For the L-Shape probe the orientation of installation must be specified such that the drainage hole can be aligned accordingly.
Power Optimized Probe (PO)	On the power optimized probe, the shape of the tip is optimized to reduce power consumption, which is important in particular for high airspeed. In return, the accuracy of the pitot measurement is reduced at AoA and AoS above 18°.
Long Cable (LC)	The L-Shape probe can be ordered with an extended cable length of 1000mm instead of 250mm.

For guidelines on how to customize your part-number please refer to the drawings of the respective probe model.

Pitot and Static Pressure

The following diagram depicts the aerodynamic errors at large flow angles in relation to the true dynamic pressure Qc (correct reference pressure) for the Power Optimized (-PO) version:

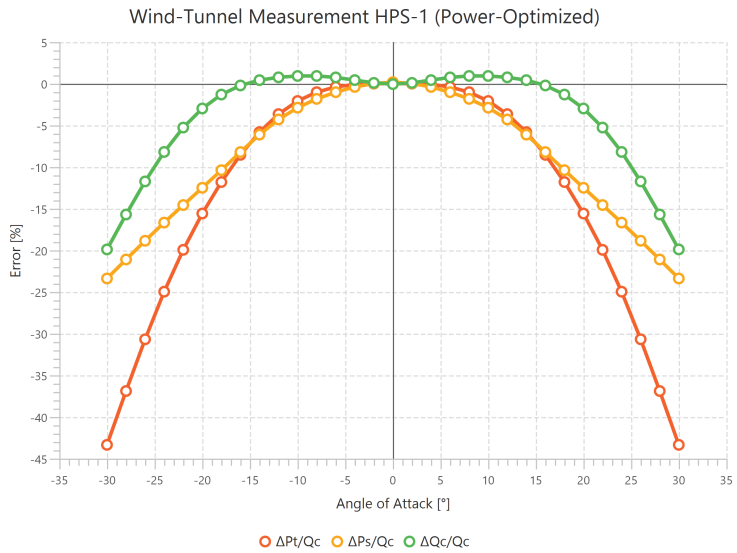


Figure 5. Aerodynamic properties of HPS-1-PO Version as measured in the wind-tunnel

The probe is designed to have small errors in dynamic pressure Qc which is important to get small errors in airspeed even at large angle of attack (AoA) and angle of side-slip (AoS). This is especially important for slow moving vehicles where gusts and crosswind have a strong effect.

The power optimized (-PO) version is optimized to reduce the required heater power at the cost of slightly reduced accuracy of the dynamic pressure Qc at AoA and AoS above 18°.

The probe has a symmetric behavior in all directions (AoA and AoS). On request Simtec can provide probes that are optimized in a certain direction (e.g. small errors at positive AoA).

The windtunnel calibration for the non Power Optimized version (Deprecated) is shown below.

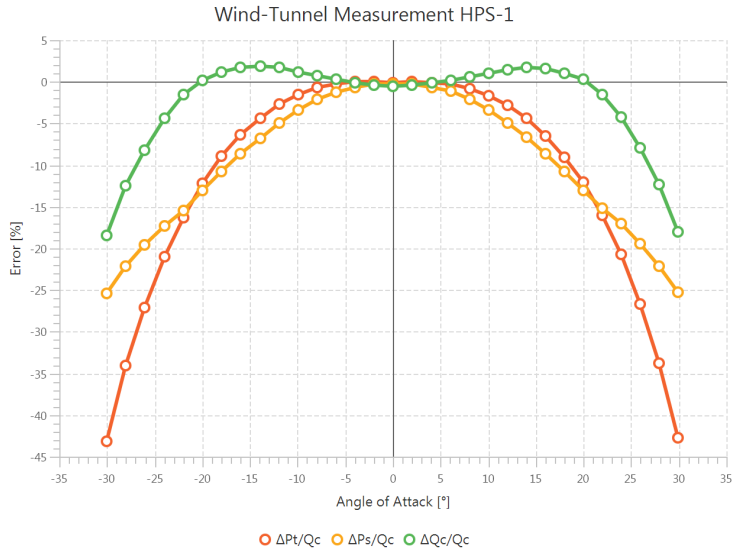


Figure 6. Aerodynamic properties of HPS-1 standard version as measured in the wind-tunnel

Heater Temperature and Power

The maximum temperature of the tip and maximum available power is configurable via the status pin. Standard tip temperature is factory-preset to 80°C. The heater of the 40W version is not designed to be operated above 30 V_{DC} for a prolonged time. The 60W version must not be operated above 28 V_{DC}.

The average power consumption during the flight depends on the airspeed, outside air temperature and the tip temperature and can be calculated from the formula below:

$$P_{tot} = p\,[T_{tip} - T_{oat}] + K$$

p has been measured in Simtec's windtunnel, where the results are shown in the graph below. An additional margin K should be accounted for melting and heating the water impacting the probe. Contact Simtec for additional information regarding the required margin K.

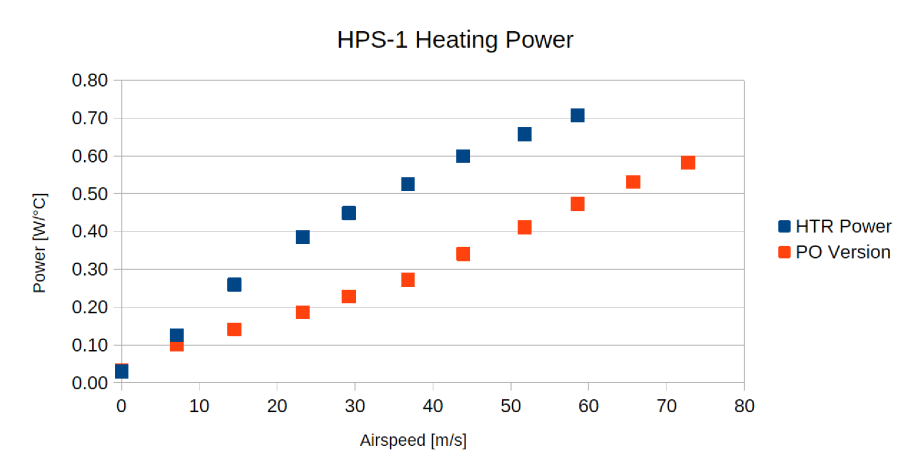


Figure 7. Heating Power

Table 1. Example Calculation

CAS	30	m/s	airspeed of UAV
p	0.23	W/°C	power per °Celsius according to diagram at 30 m/s (PO version)
Toat	-15	°C	ambient temperature at altitude
Ttip	80	°C	tip temperature according to configured value
Ptot	26.9	W	$P_{tot} = 0.23 \times [80 + 15] + K \cong 21.9\ W + K$

Status Indication

The status pin provides information concerning the probe temperature with a 5V TTL signal. As of revision R4 of the Heater Controller Box (SIM-B04-03A) and revision R7 of the HPS-1 Standard Version (SIM-D8C -4FE), there are two user-configurable manners of indicating the heater temperature: legacy or PWM. For older versions, only the legacy status indicator is available. Note that the revision is clearly marked on the device for R4/R7 and above. Older versions do not have their revision marked on the device.

Legacy status indicator

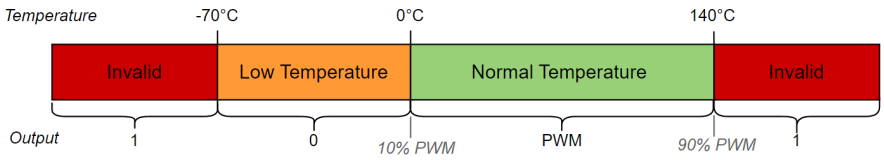
If the HPS-1 Heater Controller Box is configured with the legacy status indicator, the probe temperature is indicated with three distinct states.

Low-Temp	5	VDC	The tip is below reference temperature. There are three reasons the LOW-TEMP warning can happen: 1. during power-up until the heater reaches the correct temperature 2. Due to low outside temperature and high airspeed, the heater power becomes insufficient. 3. if the heater is not working correctly or broken and the correct tip temperature is not reached at all
High-Temp	0/5	VDC	The tip temperature is above the reference temperature of the tip. The status indication alternates between 0 and 5 V_{DC} at a rate of about 2 Hz. There are two reasons the HIGH-TEMP warning can happen: 1. at power-up or during a fast temperature change the heater can overshoot the reference temperature for a small amount of time 2. if the heater is not working correctly
Normal-OP	0	VDC	The system is working properly. The heater works at the configured temperature.

PWM status indicator

This option is only available on revision R4 of the Heater Controller Box (SIM-B04-03A) and revision R7 of the HPS-1 Standard Version (SIM-D8C-4FE) or above.

There are three distinct states: Invalid, Low Temperature or Normal Temperature.



Invalid	5	VDC	The tip temperature is below -70°C or above +140°C. This is due to a temperature sensor failure or a heater failure.
Low Temp	0	VDC	The tip temperature is between -70°C and 0°C. In this state the tip of the probe will get clogged when flying in icing conditions. There are three reasons the LOW-TEMP warning can happen: 1. during power-up until the heater reaches the correct temperature 2. Due to low outside temperature and high airspeed, the heater power becomes insufficient. 3. if the heater is not working correctly or broken and the correct tip temperature is not reached at all

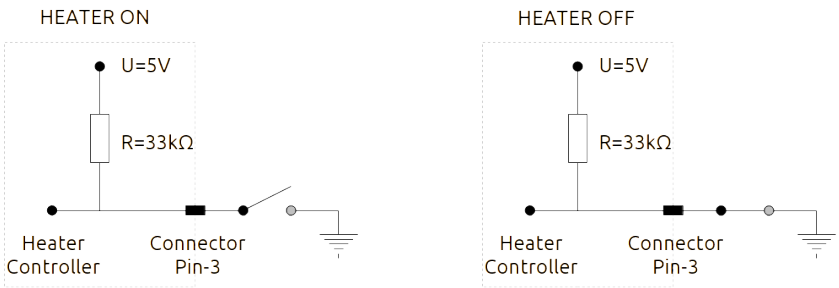
Normal Temp	5V	PWM	The tip temperature is between 0°C and 140°C. In this case, the PWM duty cycle is proportional to the tip temperature. Thus, the user can read the temperature with the following formula: $Temp = (Duty - 10\%) \times 175$ Where *Temp* is the probe temperature in °C and *Duty* is the duty cycle of the PWM in %. Here are some example of duty cycle and corresponding temperature: 10% → 0°C 28% → 31.5°C 72% → 108.5°C 90% → 140°C The frequency of the PWM can be 0.2Hz or 100Hz depending on the configuration. Please note that the frequency is not very accurate, however the duty cycle is precise.

On/Off Function

The heater can be shut off and on via the on/off pin:

On	5	VDC	If the on/off pin is not connected the heater works
Off	0	VDC	If 0 VDC is applied to the on/off pin the heater will be shut off.

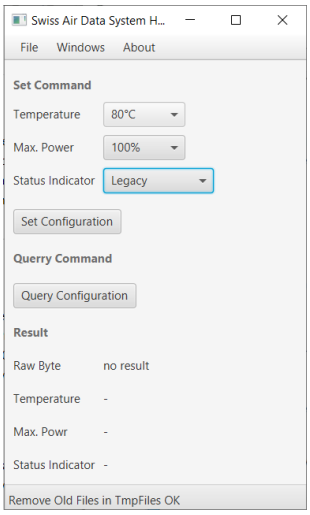
The on/off-pin on the HPS-1 is at 5VDC. If nothing is connected to the pin, the heater will be in the ON state (heater controller on). If the pin is connected to ground, the heater will be in the OFF state (heater off). The following diagram clarifies this behavior:



If the on/off functionality is not needed the on/off pin can be left unconnected. The heater starts working as soon as power is provided on the power pins.

In dry air and if no ice is anticipated the flight control computer (FCC) may decide to shut down the heater to conserve power. However it is recommended to keep the heater in the on state during all critical flight phases to prevent the accumulation of moisture and ice crystals.

Software Configuration



The heater can be configured via connector pin 3 and pin 4. A 5 VDC TTL signal at 1'200 baud is used to configure the heater. To re-program the tip temperature and the power, pin 4 is used as the TX-pin and pin 3 is used as the RX-pin. A USB TTL Serial cables (e.g. from http://www.ftdichip.com) can be used together with the HPS-1 configuration software. USB cables and the PC-software is available from Simtec on request.

A single command byte of data with the below bit-format has to be sent to the RX-pin of the HPS-1 to configure the heater. On success the heater stores the new values in non-volatile EEPROM and answers with a response byte of the same format on the TX-pin.

Byte Format (8 bits):	Description
`0pppttt1`	`ppp`: Max. Power Setting, values 0…7 `ttt`: Tip Temperature, values 0…7
`1xxxsss1`	`xxx`: Reserved bytes, not used `sss`: Status Indicator Configuration

Max. Power Setting (ppp)	Tip Temperature (ttt)	Status Indicator (sss)
`000`: Querry power	`000`: Querry temperature	`000`: Querry status
`001`: 10%	`001`: 5°C	`001`: Legacy status
`010`: 25%	`010`: 20°C	`010`: PWM 0.2Hz
`011`: 40%	`011`: 35°C	`011`: PWM 100Hz
`100`: 55%	`100`: 50°C	`100`: Stop status (always “5V”)
`101`: 70%	`101`: 65°C	`101`: Start status indicator
`110`: 85%	`110`: 80°C	`110`: Reserved for future used
`111`: 100%	`111`: 110°C	`111`: Reserved for future used

If the heater receives `0b00000001` it returns the configured temperature and power values. If the heater receives `0b10000001` it returns the configured status indicator.

Warnings

WARNING

The electronics feature a reverse polarity protection to prevent the damage of the internal electronics like the microprocessor or the temperature circuitry. Note however that during reverse polarity operation the heater is not controlled and full power is applied to the heater. The probe can get very hot and operation for more than a few seconds will destroy the probe!

WARNING

The 60W version must not be operated above the nominal voltage of 28 VDC. Short surges (<1s) up to 32V are acceptable.

WARNING

Do not apply pressure above 1500 hPa. Overpressure can destroy the internal tubing.

WARNING

The tip of the probe can get very hot.

Part-Numbers Probes

SIM-D8C-4FE-R9	HPS-1 Heated Pitot-Static Probe (Standard) Heated pitot-static probe, L=200/300/400mm. Includes probe, mount, heater controller and Binder-connector 4pole. Assembled and leakage tested.
SIM-CC1-09A	HPS-1 Heated Pitot-Static Probe Mount Heated pitot-static probe mount excl. detached heater controller. Includes probe, carbon tube, mount and connector mounted on pig-tail cable. Assembled and leakage tested. Heater controller *SIM-B04-03A* must be ordered separately.
SIM-304-695	HPS-1 Heated Pitot-Static Probe L-Shaped L-shaped heated pitot-static probe excl. detached heater controller . Includes probe, mast and connector mounted on pig-tail cable. Assembled and leakage tested. To improve resistance to saltwater corrosion, the probe mast is electroless nickel-plated starting with revision *R9*. Heater controller *SIM-B04-03A* must be ordered separately.
SIM-894-63D	HPS-1 Heated Pitot-Static Probe Boom Heated pitot-static probe boom excl. detached heater controller. Includes probe, carbon tube and connector mounted on pig-tail cable. Assembled and leakage tested. Heater controller *SIM-B04-03A* must be ordered separately.

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Customization of Probe Part-Numbers

The following options are available (eg. *SIM-D8C-4FE-R9-60W-400mm-PO*):

-40W *-60W*	Heater Power Optionally the heater power can be increased to 60W instead of 40W.
-200mm *-300mm* *-400mm*	Probe Length For *SIM-D8C-4FE*, *SIM-CC1-09A* and *SIM-894-63D*, different lengths are available. Standard lengths are 200mm/300mm/400mm. Custom lengths are available on request.
-TOP / -BTM *-RGT / -LFT*	Installation Orientation For *SIM-304-695*, the orientation of installation must be specified such that the drainage hole can be aligned accordingly.
-PO	Power Optimized Version (PO) For this version, the shape of the probe tip is optimized to reduce power consumption, which is important in particular for high airspeed. In return, the accuracy of the pitot measurement is reduced at AoA and AoS above 18°.
-LC	Long Cable (LC) For *SIM-304-695* the cable length can be extended to 1000mm.

For guidelines on how to customize your part-number please refer to the drawings of the respective probe part-number. If the kit is ordered, please add the configuration/option to the kit part-number following the guidelines presented for the corresponding probe part-number.

Part-Numbers Heater Controller

SIM-B04-03A	HPS-1 Heater Controller Detached Heater Controller Box required for *SIM-CC1-09A* and *SIM-304-695*.

Part-Numbers Kits

SIM-4C8-02D	HPS-1 Heated Pitot-Static Probe Mount - Kit Heated pitot-static probe mount with detached heater controller. Includes probe, carbon tube, mount, heater controller and Binder-connectors 4pole. Assembled and leakage tested.
SIM-4BE-4C2	HPS-1 Heated Pitot-Static Probe L-Shaped - Kit L-shaped heated pitot-static probe, detached heater controller. Includes probe, mast, heater controller and Binder-connectors 4pole. Assembled and leakage tested. To improve resistance to saltwater corrosion, the probe mast is electroless nickel-plated starting with revision *R9*.
SIM-24F-5FF	HPS-1 Heated Pitot-Static Probe Boom - Kit Heated pitot-static probe boom, detached heater controller. Includes probe, carbon tube, heater controller and Binder-connectors 4pole. Assembled and leakage tested.

Part-Numbers Ground Support Equipment (GSE)

SIM-97B-130	**HPS-1 Tip Cover** Used to protect HPS-1 pitot-static probe on ground. Includes "Remove Before Flight" flag.
SIM-4E1-7B8	**HPS-1 Pressure Test-Adapter Ps/Pt** Pressure test adapter which can be used for all HPS-1 base part-numbers.
SIM-EFD-E2B	**TTL-to-USB Converter Cable** Includes Binder connector, USB-connector and open-ended power cable, approx. 1.8m.

RoHS and REACH

RoHS: Simtec's safety critical aerospace products are excluded from the scope of the RoHS Directive.

REACH: Simtec PCBs (printed circuit boards) are soldered with leaded solder. Lead (CAS-No. 7439-92-1) is listed as a substance of very high concern (SVHC). When used as intended, these products are not hazardous to health.

Price, Availability and Lead Time

Call factory for details. The pitot-static system is built on order. Depending on user requirements, it takes between 6 to 8 weeks to build, calibrate and test the system.

Service and Support

Service and Repair: Should any damage occur during shipping, handling, or misuse by the user, Simtec is able to service it.

Consultation: Technical consultation can be obtained from Simtec if expertise is needed for the integration of the air data system into the aircraft, during flight-testing or post processing of data.

Contact Information

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