

# DIGITAL 7-HOLE PROBE SYSTEM

## User Manual



### WARNING

**Read this document before using the product.**

This probe is an experimental prototype, for measurement purposes only.

This system is not certified for use on aircraft.

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## Version Control

| Version | Date    | Summary of changes                              |
|---------|---------|---|
| 1.0     | 05-2017 | New document                                    |
| 2.0     | 09-2019 | Updated content and specifications, reformatted |
|         |         |   |

# 1 INTRODUCTION

## Principle of operation

This probe system includes a seven-hole pressure-based directional velocity probe. The probe system also contains a pressure altimeter, a six-component inertial measurement unit, one or more fluid temperature sensors (which may be built into the probe sting), a case temperature sensor and a humidity sensor. The probe system will stream data over a serial data line once powered on, but may also be used together with a computer using the on-board USB terminal.

## System description

Bespoke miniature multi-function seven-hole probe system.

## System components

|                   |  |
|-------------------|--|
| 1x Probe assembly | The probe assembly consists of a seven-hole probe core with a local static sampling sleeve, a sensor package and an enclosure. |
| 1x USB cable      | A low-profile USB micro->A connector is bundled with the system.   |

Please ensure that all the system components listed above have been supplied, and that there is no apparent damage from shipping.

## System requirements

To interface with a computer, the probe system requires 64-bit Windows 7 (or newer) operating system (not included). Note that computer interface is not needed for stand-alone streaming operation. The probe has been pre-loaded with firmware; the computer software drivers and data logging software will be provided electronically. Additional drivers may be required to run the software on older Windows machines.

## 2 DETAILED SPECIFICATION

|   |   |              |              |
|---|---|--------------|--------------|
| 7 x differential pressure transducers                       | ID7HP-160P  | ID7HP-1K0    | ID7HP-6K9    |
| Standard pressure ranges                                    | 160 Pa FS   | 1 kPa FS     | 6.9 kPa FS   |
| Maximum overpressure  | 33.5 kPa  | 37.5 kPa     | 69 kPa       |
| Sensor accuracy <sup>1</sup>                                | ± 0.1 % FS  |              |              |
| Total error band after auto-zero <sup>2</sup>               | ± 0.5 % FS  | ± 0.25 % FS  | ± 0.25 % FS  |
| Compensated temperature range                               | -40° to +65° C  | 0° to +50° C | 0° to +50° C |
| Operating temperature range                                 | -40° to +65° C  |              |              |
| Storage temperature range                                   | -40° to +65° C  |              |              |
| Vibration   | Sensors rated to 15 g, 10 Hz to 2 Hz  |              |              |
| Maximum relative humidity                                   | 95 %  |              |              |
| Relative humidity sensor specification                      | 0 % to 100 % RH, +/- 3%   |              |              |
| Ambient temperature sensor specification <sup>3</sup>       | 0°C - 65°C ± 0.5°C  |              |              |
| Ambient absolute pressure sensor specification <sup>4</sup> | 30-110 kPa FS, +/- 0.1kPa   |              |              |
| Reference pressure  | Integrated with static pressure ring on sting or connectable to laboratory conditions   |              |              |
| Standard sting material                                     | Steel   |              |              |
| Sting diameter  | 3.7 mm  |              |              |
| Standard tip geometry                                       | Hemispherical   |              |              |
| Angular measurement range <sup>5</sup>                      | ± 45°   |              |              |
| Remote temperature probe                                    | -40°C - 150°C ± 0.5°C   |              |              |
| Absolute temperature limits                                 | 5° to +65° C non-condensing   |              |              |
| Absolute pressure limits                                    | 0.2 - 1.5 atm   |              |              |
| Weight (approximate)  | 45 g  |              |              |
| Voltage   | 6-24 VDC or via USB<br>Reverse-polarity protected<br>ESD protected to ±2 kV   |              |              |
| Power   | min. 290 mW   |              |              |
| Communications interface                                    | USB2.0, RS232 or UDP Ethernet available   |              |              |
| Data acquisition rate                                       | 1 kHz (equivalent)  |              |              |
| Digital resolution  | 24-bit pressure, 16-bit environmental and IMU   |              |              |
| System requirements   | Windows 7 or later, minimum 3GHz & 4Gb RAM  |              |              |
| Data output   | Continuous streaming, 100 Hz<br>Baud rate: 230400 BPS<br>Single-precision floats in SI units<br>TTL 3.3V serial output or via USB<br>TTL serial ESD protected to ±25 kV |              |              |
| IMU specification   | 3 axis gyro, 125 °/s FS, ± 3.9 x10 <sup>-3</sup> °/s<br>3 axis accelerometer, 2g FS, ± 0.061 mg   |              |              |

<sup>1</sup> Includes errors due to pressure non-linearity, pressure hysteresis, non-repeatability and calibration uncertainty.

<sup>2</sup> Total residual error after auto-zero, excluding residual temperature sensitivity.

<sup>3</sup> Temperature is recorded at the location of the PCB. Waste heat from electronic components may distort temperature readings.

<sup>4</sup> Pressure is recorded inside the sensor package enclosure. Please ensure that the vents on the sides of the enclosure are clear to ensure correct readings

<sup>5</sup> Angular range specified for hemispherical tip; depends on tip geometry.

### 3 SERIAL COMMUNICATIONS

When the probe system is powered on, it will undergo a brief system diagnostic test; if the test is passed, then a green LED will illuminate at the rear of the probe near the cable connections. Data will then begin streaming serial data on the TTL lines. The system will stream data continuously while powered on.

The sensors are factory-calibrated, and the calibration data is held in on-board memory. Data are converted into SI units by the firmware and streamed as single-precision floats.

#### Commands

Each data packet consists of 70 bytes, beginning with an unsigned-integer frame character ("#") and terminating with a checksum (both inclusive); the UART configuration is the typical 8-N-1. The data order is shown below.

| Byte index | Description                     | Type    | Unit  |
|------------|---------------------------------|---------|-------|
| <b>0</b>   | Frame character '#'             | uint8   | -     |
| <b>1</b>   | Pressure 0                      | float32 | Pa    |
| 2          |                                 |         |       |
| 3          |                                 |         |       |
| 4          |                                 |         |       |
| <b>5</b>   | Pressure 1                      | float32 | Pa    |
| 6          |                                 |         |       |
| 7          |                                 |         |       |
| 8          |                                 |         |       |
| <b>9</b>   | Pressure 2                      | float32 | Pa    |
| 10         |                                 |         |       |
| 11         |                                 |         |       |
| 12         |                                 |         |       |
| <b>13</b>  | Pressure 3                      | float32 | Pa    |
| 14         |                                 |         |       |
| 15         |                                 |         |       |
| 16         |                                 |         |       |
| <b>17</b>  | Pressure 4                      | float32 | Pa    |
| 18         |                                 |         |       |
| 19         |                                 |         |       |
| 20         |                                 |         |       |
| <b>21</b>  | Pressure 5                      | float32 | Pa    |
| 22         |                                 |         |       |
| 23         |                                 |         |       |
| 24         |                                 |         |       |
| <b>25</b>  | Pressure 6                      | float32 | Pa    |
| 26         |                                 |         |       |
| 27         |                                 |         |       |
| 28         |                                 |         |       |
| <b>29</b>  | Atmospheric pressure            | float32 | Pa    |
| 30         |                                 |         |       |
| 31         |                                 |         |       |
| 32         |                                 |         |       |
| <b>33</b>  | External thermistor temperature | float32 | deg C |
| 34         |                                 |         |       |
| 35         |                                 |         |       |
| 36         |                                 |         |       |

|           |  |         |          |
|-----------|--|---------|----------|
| <b>37</b> | Internal case temperature (sensor die) | float32 | deg C    |
| 38        |  |         |          |
| 39        |  |         |          |
| 40        |  |         |          |
| <b>41</b> | Relative humidity                      | float32 | %        |
| 42        |  |         |          |
| 43        |  |         |          |
| 44        |  |         |          |
| <b>45</b> | Accelerometer x component              | float32 | <i>g</i> |
| 46        |  |         |          |
| 47        |  |         |          |
| 48        |  |         |          |
| <b>49</b> | Accelerometer y component              | float32 | <i>g</i> |
| 50        |  |         |          |
| 51        |  |         |          |
| 52        |  |         |          |
| <b>53</b> | Accelerometer z component              | float32 | <i>g</i> |
| 54        |  |         |          |
| 55        |  |         |          |
| 56        |  |         |          |
| <b>57</b> | Gyroscope x component                  | float32 | deg / s  |
| 58        |  |         |          |
| 59        |  |         |          |
| 60        |  |         |          |
| <b>61</b> | Gyroscope y component                  | float32 | deg / s  |
| 62        |  |         |          |
| 63        |  |         |          |
| 64        |  |         |          |
| <b>65</b> | Gyroscope z component                  | float32 | deg / s  |
| 66        |  |         |          |
| 67        |  |         |          |
| 68        |  |         |          |
| <b>69</b> | Checksum                               | uint8   | -        |

**IMPORTANT NOTE:** Data are transmitted using the little-endian convention, so that the first byte transmitted for each quantity is the least significant.

|             |                                       |
|-------------|---------------------------------------|
| Baud        | 230400 bps                            |
| UART config | 1 start bit / 8 data bits/ 1 stop bit |
| Parity      | none                                  |

The data streams as 3.3V TTL output; this is not compatible with a 5V receiver. A unidirectional level translator (not included) may be used if signals are to be sent to a 5V receiver. The receiving board must also have at least a 70 byte receive buffer to prevent data overrun.

### Checksum & data corruption warning

A checksum byte is included with each data packet to provide a warning of data loss or corruption in transmission. To compute the checksum, add all the byte values in the array excluding the checksum byte at the end of the array, modulo 256. If the data has been transmitted correctly, this value will match the transmitted checksum. If the computed and transmitted checksums do not match, the entire data packet should be discarded.

An example function for computing the checksum is included below, where it has been assumed that the array and its length are global scope variables.

```
uint8_t CalcChecksum()
{
    uint8_t sum = 0;
    for (uint8_t i = 0; i < (Nbytes - 1); i++)
    {
        sum += ArrayOfBytes[i];
    }
    return sum;
}
```

By defining the sum variable as a `uint8_t` the addition will automatically be modulo 256. Otherwise more explicitly it would be

```
sum = (sum + ArrayOfBytes[i]) % 256
```

## 4 PHYSICAL CONNECTIONS

The probe system is supplied as a single integrated unit. The probe sting should be mounted so that the tip is facing axially in the direction of nominal mean flow. Note that the on-board IMU will enable the roll-alignment of the probe to be matched to calibration conditions.

**WARNING:** Do not apply local stresses to the probe casing, or the casing may crack. The probe should be held in place with a friction collet, or other circular clamping arrangement.

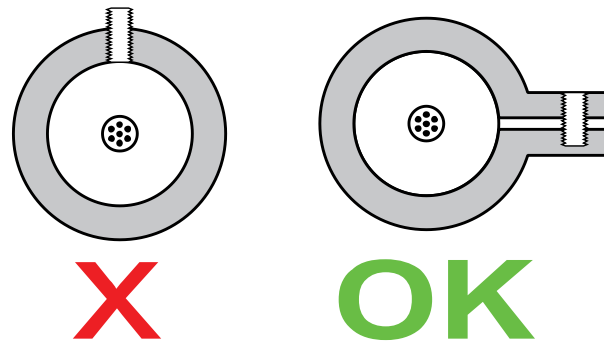


Figure 1: Correct probe mounting

### Probe assembly

The probe assembly consists of a seven-hole probe core surrounded by a static pressure sleeve, and has been machined with a hemispherical tip for maximum sensitivity to small flow angles.

The tip has been coated with a red damage-evident varnish. The static taps, if included, may have been drilled in slightly different axial locations on the sting, for structural reasons.

The hole arrangement, when viewed from upstream, is as illustrated below. Note that the roll alignment is arbitrary. Note that this may vary for some probes. Please check the documentation included with the probe.

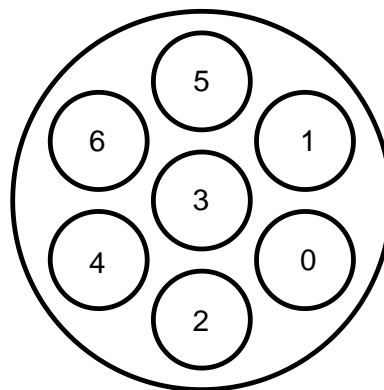


Figure 2: Hole numbering convention, looking at probe tip from upstream, with the probe body located behind.



## Sensor package

There are two user-accessible ports on the sensor package- a micro-USB port and a serial comms port.

*Micro-USB port:* This allows the user to access the sensing and diagnostic functions of the probe system using a PC (with the appropriate drivers and software installed).

*Comms port:* This is the serial communications connection. There are four pins- V+ (1), GND (2), Rx (3) and Tx (4), where pin 1 is on the left when the probe is oriented such that the serial port is below the micro-USB port. The length of the data cables should be limited to 1.8 m or less, and should be routed away from the board and any cables carrying electric motor currents.

**IMPORTANT:** The Tx line described is the transmit bus for the sensor package. This should be connected to the Rx of the unit receiving the data.

## 5 CARE AND HANDLING

**WARNING:** Do not allow any liquids to come into contact with the sensor package, or the system may be permanently damaged.

- Place protective covers over the probe when not in use, and handle the probe with care.
- Protect the sensor package from moisture and dust, and store in an ESD-safe sleeve when not in service.
- The probe enclosure is made from sintered Nylon, and is susceptible to solvents. The probe sting is not commoned to the system ground. Sensible ESD precautions should be taken before handling.
- Ensure that no dust, dirt or liquid enters the probe. This will alter the system performance. Any foreign material introduced into the sensors themselves may permanently damage the sensors.
- Do not use the probe in wet or condensing conditions. In the event of clean water ingress, the probe can be dried by heating to 40°C.
- Care must be taken to avoid damage to the probe sting or the probe tip. If the damage-evident coating is chipped, it is likely that the calibration of the probe has changed.
- Probes may be cleaned using a mild detergent solution and a fibre-free cloth. Do not use solvents or alcohol on the probe, and take care not to get any cleaning solution in the holes.
- Do not apply any bending moments on the probe sting, as the junction between the probe and the sensor package may be damaged.
- Connect cables to the probe with care, as the socket mountings are fragile. Ensure that appropriate strain relief is used: cable strain may cause erroneous sensor readings. Excessive cable bending will damage the probe.

## 6 SOFTWARE AND DRIVERS

Although this probe system was designed to function independently of a PC by continuously streaming data, it is possible to interface with a PC via the included USB port for data logging, diagnostics and visualization.

### Drivers

There are two external drivers which must be downloaded and installed on the computer in order for the PC to be able to interface with the probe system, in addition to the specific system driver for your probe.

- [National Instruments LabView Run Time Engine \(LVRTE\)](#)
- [National Instruments VISA Run-Time Engine \(NIVISA\)](#)

These drivers are freely available for download from National Instruments. Compatible versions of both of these drivers have been bundled with your software package.

### Executable

An executable software package is provided with your probe system, which facilitates direct communication between your PC and your probe using the probe's micro-USB connector. After launching the software, you should see the window reproduced below (Figure 4).

### Starting procedure

- 1) Connect the computer to the probe's micro-USB socket.
- 2) The probe will perform a power-on self-test, lasting a couple of seconds. If all tests pass, the rear of the probe will illuminate with a green LED.
- 3) Load the program. It will start in the [ACTION] tab.
- 4) Using the [COM PORT] drop down menu, select the appropriate COM port.
- 5) Press the white arrow near the top left corner of the window to run the application.
- 6) Ensure that there are no errors in the [ERROR] dialogue box. If an error has occurred at this stage, it is most likely an invalid COM port selection.

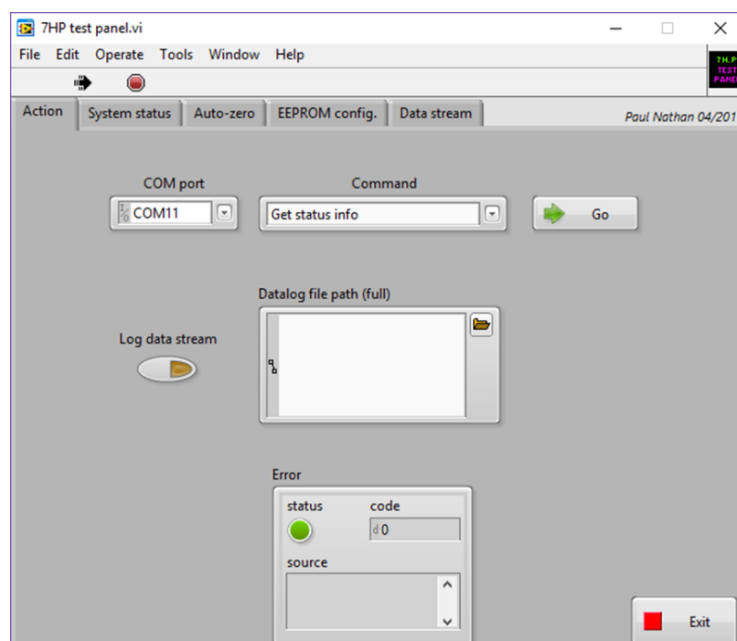


Figure 3: Probe system companion software screen-shot

## Available commands

The [COMMAND] drop-down menu in the [ACTION] tab contains the following commands. A command is run by pressing the [GO] button to the right of the [COMMAND] menu. The application will automatically switch to the relevant tab. Once finished, return to the [ACTION] tab to select another command and run as desired.

- **Get status info:** running this command will activate the [SYSTEM STATUS] tab. The system will be queried for the status of the last self-test. Green indicators indicate the test was passed, while red indicates a fault. Descriptive text beside each indicator is provided.
- **Run self-test:** the system will be made to perform the power-up self-test again, and then query for the result. This allows the user to easily check any changes made without having to disconnect and reconnect the USB cable.
- **Perform temporary auto-zero:** this command should not be used under normal operating circumstances, and is included for development purposes only. It activates the [AUTO ZERO] tab and begins collecting samples from each pressure sensor to estimate the zero pressure reading. An offset is then temporarily stored in volatile memory that will remain until the system is powered down. During this procedure, ensure that the sensors are subjected to zero differential pressure.
- **Perform permanent auto-zero:** this command repeats the above, but this time writing the offsets permanently to non-volatile memory. **WARNING** – *this will overwrite the existing offsets that were used during probe calibration. Carrying out this procedure will invalidate your calibration!*
- **Get EEPROM values:** displays the [EEPROM CONFIG] tab and read off all the EEPROM values from the system.
- **Set EEPROM values:** this command should not be used under normal operating circumstances, and is included for development purposes only. To make changes to the EEPROM values, first run [GET EEPROM VALUES] to populate the table with the current values. Then, change the values as desired; return to the [ACTION] tab and run the [SET EEPROM VALUES] command. Finally, return to the [ACTION] tab and run the [GET EEPROM VALUES] command again to check the values are as desired and, importantly, that the EEPROM checksum indicator is green. A red indicator means the data has become corrupt in transit and should be re-transmitted. **WARNING** – *this will overwrite the existing EEPROM values that were used during probe calibration. Carrying out this procedure will invalidate your calibration!*
- **Set data rate:** This command allows the user to set the system sampling rate using a drop-down menu.
- **Get data rate:** This command allows the user to retrieve the current setting of the system sampling rate.
- **Enable USB streaming:** this command activates the USB data stream. The [DATA STREAM] tab is activated and a running plot of all seven pressure sensor values is displayed, along with values for all the other on-board sensors. This will continue indefinitely until the user presses the [STOP] button or selects another tab, or exits the

program by closing the window. Note that the data stream from the TTL serial output is not affected by enabling USB streaming.

- **Disable USB streaming:** this command stops data transmission over USB.
- **Get serial number:** Each probe is encoded with its own unique serial number, which is displayed in the window below the [COM PORT] drop-down menu. This function will retrieve the probe's serial number and display it in the [ACTION] tab. Note that the serial number is also retrieved as part of the normal startup operations. The serial numbers are decimal values; the probe having serial number "1234" will display as [d1234].
- **Exit:** this command stops the program from running, but leaves the window open so as to preserve settings for later use. This has the same functionality as pressing the [EXIT] button.

### Data logging option:

A tab-delimited ASCII text output of a time history of all the sensor values can be saved to disk by enabling the [LOG DATA STREAM] switch on the [ACTION] tab prior to running the [ENABLE USB STREAMING] command. If the [DATA LOG FILE PATH] box is left empty, the user will be prompted where to save the file. It is helpful to put a known extension on the file such as ".txt". Data is written to disk every second and stopped upon disabling USB streaming. If streaming is resumed and the filename is not changed, the user will be prompted to either replace the file or cancel. If cancel is chosen, a prompt will appear to allow a new filename to be chosen. If this is also cancelled, data streaming will begin but no log file will be created and the [LOG DATA STREAM] switch will be disabled.

### Notes on data reduction

The probe outputs seven pressures and a static pressure for use in resolving the three components of velocity. There are a number of open-source techniques for data conversion, offering various levels of trade-off between accuracy and speed. Examples and advice on implementing this process for your application are available from your Surrey Sensors Ltd. representative. A directional calibration service is also available on request.

## 7 TECHNICAL SUPPORT

Full technical support is available for this product and its associated software.

If you experience any difficulty in installation or use, or if you need additional support in the operation of the system, please contact your Surrey Sensors Ltd. account manager or technical representative.