DIGITAL DIRECTIONAL
UAV AIR DATA PROBE

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.

Contents

Version Control

Version	Date	Summary of changes	Software vn.
1.0	11-2018	New document	
2.0	09-2019	Updated content and specifications, reformatted	
2.1	01-2020	Expansion of guidance on software and drivers.	
2.2	04-2020	Correction to serial comms pin connections. Updated checksum and serial comms.	1.2
3.0	07-2026	Revised for new product updates	

1 INTRODUCTION

Principle of operation

This probe system includes a seven-hole pressure-based directional velocity probe, referenced against local static pressure. The probe system also contains a pressure altimeter, a six-component inertial measurement unit, and one or two external temperature sensors for static temperature monitoring and/or heater temperature control, a case temperature sensor and a humidity sensor and an external comms/power module. The probe system can stream data over a network data line (with the comms/power adaptor module) once powered on, but may also be used together with a computer using the on-board USB terminal.

System description

Bespoke miniature multi-function air-data probe.

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.
1x Power/ comms module (optional)	This is a microcomputer module, providing a network link to the probe system as well as a voltage regulator for power.
1x Power/ comms cable assembly (optional)	

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

Standard sensor specifications (custom available on request)			
Product code	ID8HP-160P	ID8HP-1K0	ID8HP-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[1]	± 0.1 % FS		
Total error band after auto-zero[2]	± 0.5 % FS	± 0.25 % FS	± 0.25 % FS
1 x absolute (static) pressure transducer	Range 1 atm FS error band[2] ±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 non-condensing		
Storage temperature range	-40° to +65° C non-condensing		
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[3]	0°C - 65°C ± 0.5°C		
Ambient absolute pressure sensor specification	30-110 kPa FS, +/- 0.1 kPa		
Reference pressure	Integrated with static pressure ring on sting (available with external reference pressure input)		
Standard sting material	CFRP with AL-6061 inserts max. 970 mm long		
Sting diameter	12 mm		
Standard tip geometry	Hemispherical hole ID 1.5 mm		
Angular measurement range[4]	± 60°		
Sting heater (requires external control)	Optional film heater located between sting tip and static ring		
Sting tip temperature measurement	-80°C - 150°C ± 1°C		
Remote temperature probe	2x -80°C - 150°C ± 1°C		
Absolute temperature limits	-80° to +65° C (expected) non-condensing[5]		
Absolute pressure limits	10x P_{FS}		
Weight (approximate)	95 g		
Voltage	6-12 Vdc or via USB (6-28 Vdc with power/comms module)		
Power	min. 310 mW (excluding any heater power draw)		
Communications interface	UART and USB 2.0 CAN, RS232, RS485 & Ethernet with additional power/comms module		
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	Single-precision floats in SI units UART 3.3V serial output or via USB		

	UART serial ESD protected to ±25 kV
IMU specification	3 axis gyro, 125 °/s FS, ± 3.9 x10^{-3} °/s 3 axis accelerometer, 2g FS, ± 0.061 mg

[1] Includes errors due to pressure non-linearity, pressure hysteresis, non-repeatability and calibration uncertainty.
[2] Total residual error after auto-zero, excluding residual temperature sensitivity.
[3] Temperature is recorded at the location of the PCB. Waste heat from electronic components may distort temperature readings.
[4] Angular range specified for hemispherical tip; depends on tip geometry.
[5] Temperature limits are design limits, based on assumptions about heat transfer at high altitudes

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 connector. Data will then begin streaming serial data on the UART serial lines if streaming has been enabled. The system will stream data continuously while powered on, until commanded to stop.

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.

Serial stream

Each data packet consists of 78 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, and is the same for both UART and USB.

byte index	*Description*	*Type*	*Unit*
0	Frame character '#'	uint8	-
1	Pressure 0 (absolute)	float32	Pa
2			
3			
4			
5	Pressure 1	float32	Pa
6			
7			
8			
9	Pressure 2	float32	Pa
10			
11			
12			
13	Pressure 3	float32	Pa
14			
15			
16			

17 18 19 20	Pressure 4	float32	Pa
21 22 23 24	Pressure 5	float32	Pa
25 26 27 28	Pressure 6	float32	Pa
29 30 31 32	Pressure 7	float32	Pa
33 34 35 36	External thermistor 0 temperature	float32	°C
37 38 39 40	External thermistor 1 temperature	float32	°C
41 42 43 44	Atmospheric pressure	float32	mbar
45 46 47 48	Internal board temperature	float32	°C
49 50 51 52	Relative humidity	float32	%
53 54 55 56	Accelerometer *x* component	float32	g
57 58 59 60	Accelerometer *y* component	float32	g
61 62 63 64	Accelerometer *z* component	float32	g
65 66 67 68	Gyroscope *x* component	float32	deg / s

69	Gyroscope *y* component	float32	deg / s
70			
71			
72			
73	Gyroscope *z* component	float32	deg / s
74			
75			
76			
77	CRC-16 CCITT	uint16	-
78			

*CRC16-CCITT 0x1021 polynomial. Initial value = 0x0000.

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

Baud	Configurable to 2 Mbps
UART config	1 start bit / 8 data bits/ 1 stop bit
Parity	none

The UART Tx has a 3.3V line level output; this may not be 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 79 byte receive buffer to prevent data overrun. The probe may receive 3.3V to 5V inputs.

A partial data packet, having only 42 bytes and excluding less critical data, is also available from the probe. The data order for this data packet is shown below.

byte index	*Description*	*Type*	*Unit*
0	Frame character '#'	uint8	-
1	Pressure 0 (absolute)	float32	Pa
2			
3			
4			
5	Pressure 1	float32	Pa
6			
7			
8			
9	Pressure 2	float32	Pa
10			
11			
12			
13	Pressure 3	float32	Pa
14			

15			
16			
17	Pressure 4	float32	Pa
18			
19			
20			
21	Pressure 5	float32	Pa
22			
23			
24			
25	Pressure 6	float32	Pa
26			
27			
28			
29	Pressure 7	float32	Pa
30			
31			
32			
33	External thermistor 0 temperature	float32	°C
34			
35			
36			
37	External thermistor 1 temperature	float32	°C
38			
39			
40			
41	CRC-16 CCITT	uint16	-
42			

*CRC16-CCITT 0x1021 polynomial. Initial value = 0x0000.

Checksum & data corruption warning

A CRC-16 checksum word (uint16) is included at the end of each data packet to provide a warning of data corruption in transmission. Example C++ code and DLL files to compute the CRC-16 checksum are available for download. If the computed and transmitted checksums do not match, the entire data packet should be discarded.

Note that additional details about the probe communications, including a summary of CRC16-CCITT implementation, are appended to the end of this document.

4 PHYSICAL CONNECTIONS

The probe system is supplied either as a single integrated unit or as a modular system containing 1 or more sting assemblies with a single sensor package. 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.

Additionally, a small dot may appear near the tip of the probe, adjacent to the hole that was oriented upwards during the calibration process.

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.

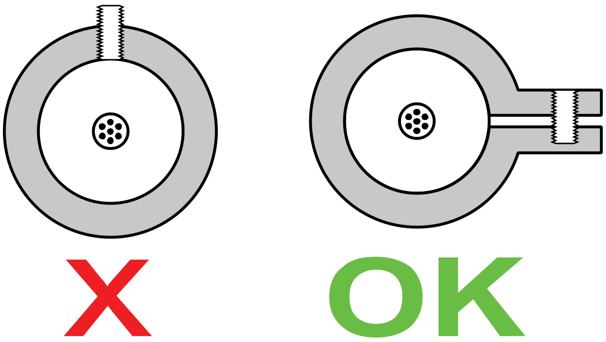


Figure 1: Correct probe mounting (sting geometry may vary)

It is recommended that the probe be fixed into the airframe by the sting, using a friction collet (see figure 1), so that there are minimal loads transferred between the carbon-fibre sting and the nylon sensor enclosure. The sensor enclosure-sting junction cannot withstand large bending moments.

Sting 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. A slight narrowing of the sting around the static ring is included to improve performance at nonzero incidence.

The sting can be removed for cleaning and maintenance. The threaded compression collet between the sting and the sensor enclosure should be tightened to a maximum torque of 1 Nm.

The hole arrangement, when viewed from upstream, is as illustrated in figure 2. Note that the roll alignment is arbitrary. Note that this may vary for some probes. Please check the documentation included with the probe.

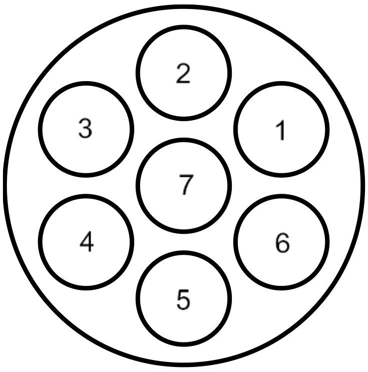


Figure 2: Hole numbering convention, looking at probe tip from upstream, with the probe body located behind.

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 UART 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 above the micro-USB port (see figure 3). Note that pin 1 on the matching plug is marked with a small recessed triangle.

IMPORTANT: UART configuration should always be tested with 5V initially: pins are reverse-polarity protected up to 5V only.

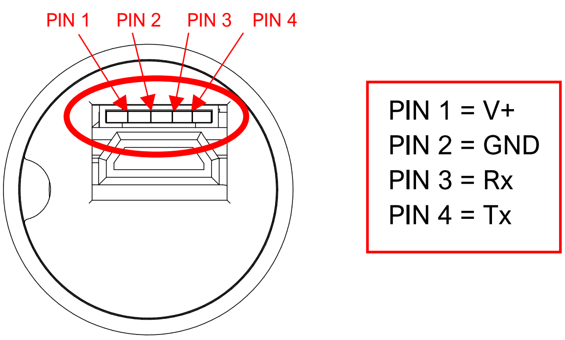


Figure 3: Serial comms pin assignment

Note that the pin numbering shown here is for the hardware end. Cable assemblies are not cross-linked: if a mating cable assembly is used, the pin order will be reversed on the cable end.

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. When used with the power/comms module, the serial communications will be via the module.

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.

Power/comms module

The power/comms module provides power conditioning as well as data conversion to the desired network protocol, and uses the probe's serial communications port (see figure 4). The power/comms module is supplied in OEM configuration for customer installation.

WARNING: Use extreme care in any soldering and connecting during customer installation. Damage from incorrect installation will invalidate the product warranty.

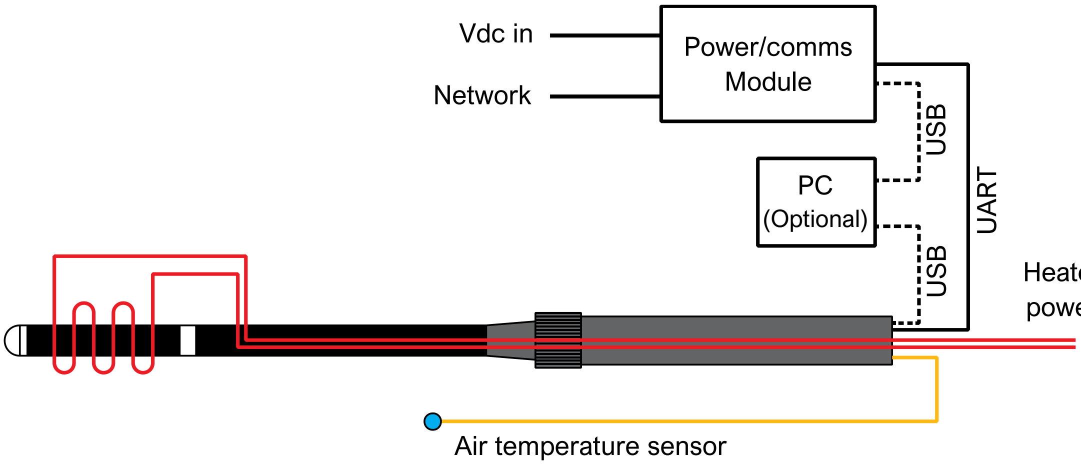


Figure 4: Schematic setup.

The power/comms module will output network communications in the selected format (RS232, RS485, CAN 2B and Ethernet are available). The module dimensions and connections will vary depending on the type. The probe can still be accessed via USB, and the power/comms module can likewise be independently accessed and configured via USB as needed.

If the sting is equipped with a heater, the tip temperature signal for heater control will be included in the data stream; this should be used to control switching of the heater lines.

WARNING: Heaters necessarily need active control: if powered without sufficient heat transfer from the tip, the heater is sufficiently powerful to destroy the probe. For carbon fibre stings, tip temperature must not exceed 65° C.

Modular system components
The modular probe system consists of a sensor package, gasket, sting assembly and retainer as shown in figure 5.

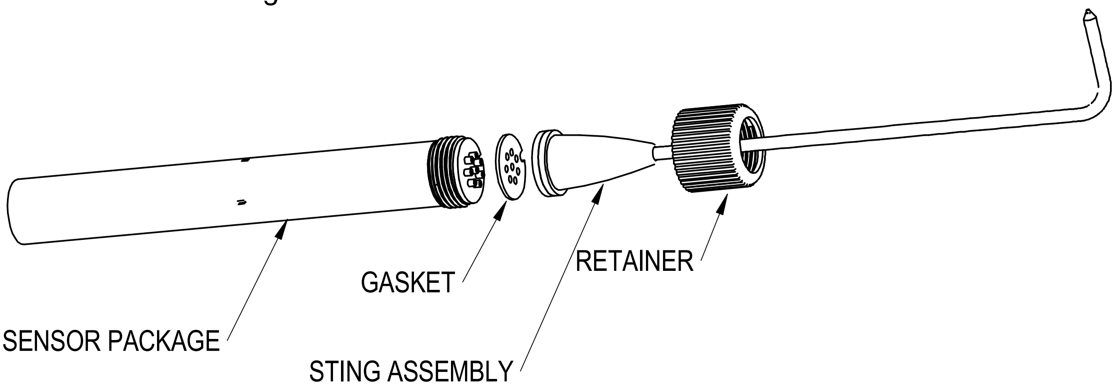


Figure 5: Modular probe system components (sting geometry may vary)

To assemble the probe, ensure the gasket and sting assembly are both fitted onto the barbs on the sensor package such that the cut-outs on all 3 components are aligned as shown in figure 6. Failure to do this will not prevent assembly and effective sealing of the probe components, but it will result in disagreement between pressure sensor channel numbers and hole numbering.

To secure the probe assembly, slide the retainer over the sting and screw by hand onto the sensor package. Tighten to no more than 1 Nm torque; the unit may be damaged by overtightening.

Figure 6: Correct alignment of modular system components (sting geometry may vary)

5 CARE AND HANDLING

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

Do not hot-plug any of the probe or power/comms module connectors. This may result in damage to the probe system, and will void the product warranty.

- The probe system is a precision measurement instrument and should be handled and stored with care when not in use. Prolonged storage of the system is possible; this will not affect the calibration of the unit. For prolonged storage, cover the probe tip and keep in a sealed case with dessicant pouch. The probe system is not user-serviceable.
- The low-mass 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.
- The sting heater should only be used under low temperature conditions, with high heat transfer. Tip temperature must be actively monitored when the heater is in use, noting that there is a time lag between activating the heater and registering a temperature change on the tip temperature sensor. Care must be taken to ensure that the temperature of the sting tip does not exceed 65°C, or internal damage may result.
- Do not polish or abrade the probe tip or static pressure ring, as this will alter the calibration of the sensor. It is recommended that the probe sting be covered during ground handling operations.
- 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.
- In the event of water ingress, the probe may be dried by heating to 40°C in a dessicant environment. Water entering the sting will not damage the system, but will result in incorrect readings.
- The probe sting can be removed and cleared with compressed air if necessary. Ensure that the sting is dry before reassembling.
- 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 can function independently of a PC by continuously streaming data (when configured to do so), it is possible to interface with a PC via the included USB port for data logging, conversion, 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. Ensure that the 64-bit version of the NI LabVIEW Run Time Engine is selected (note this is not the default option), and restart the computer following each installation. Correct download settings for each driver are shown in figures 7 and 8 below.

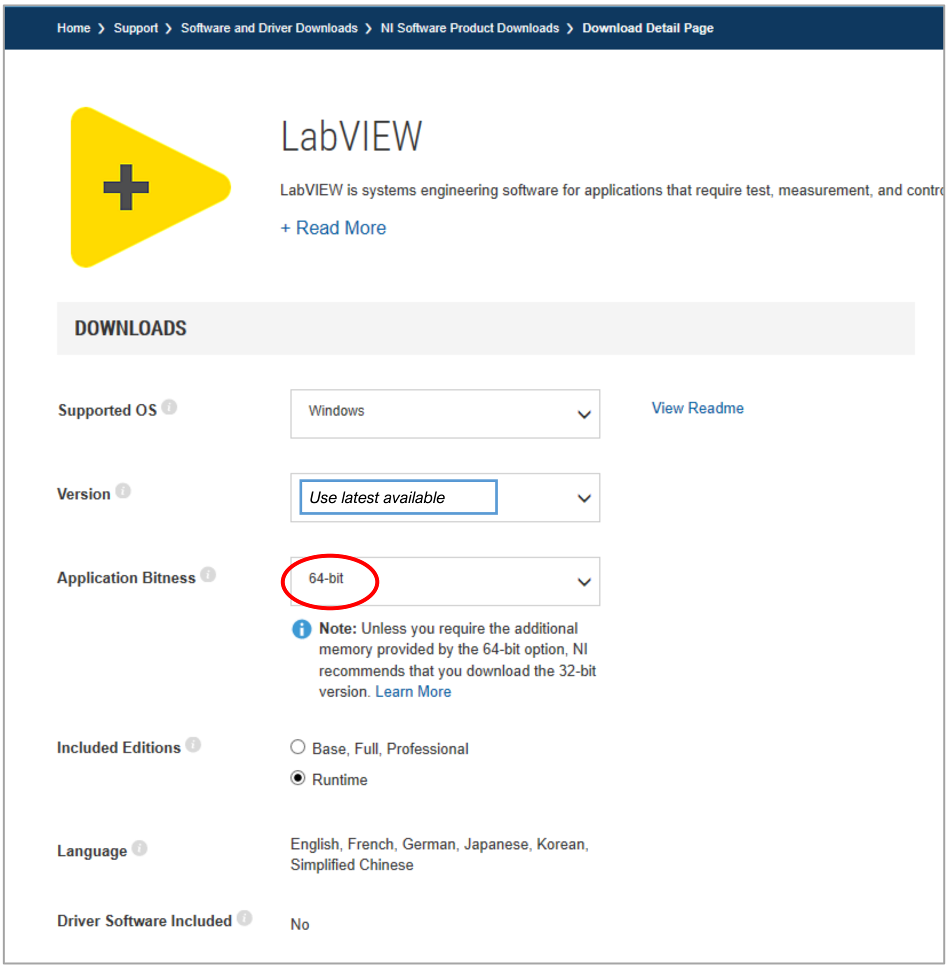


Figure 7: Download settings for NI LabVIEW Runtime Engine

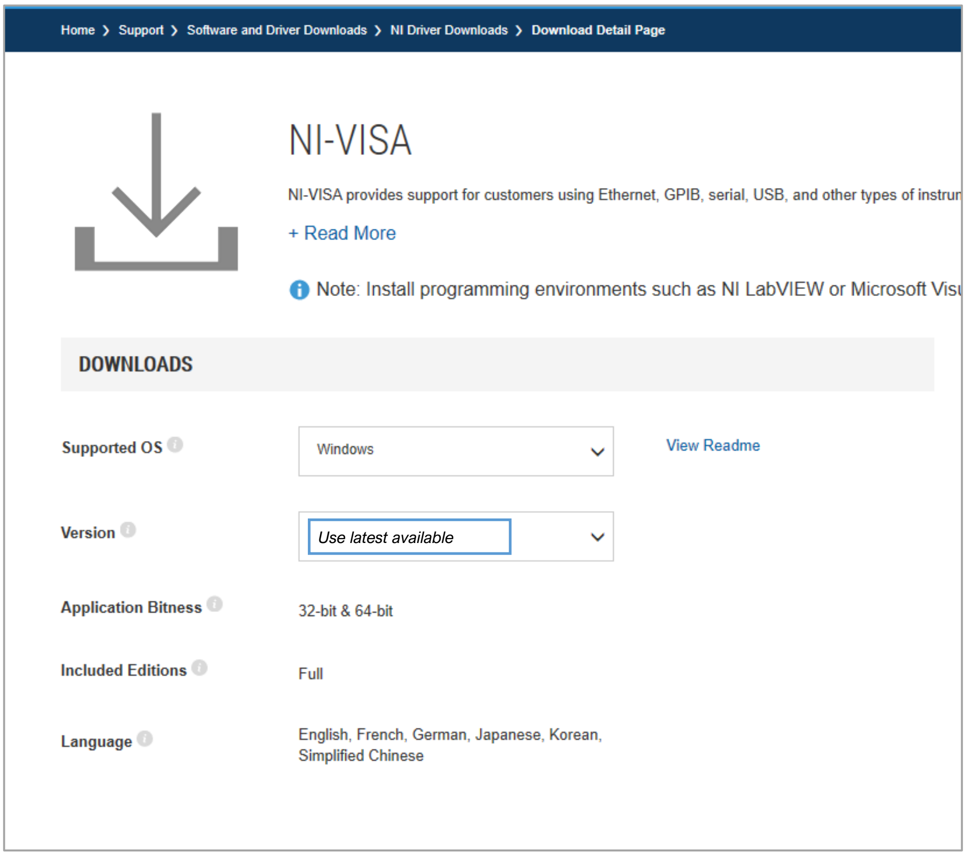


Figure 8: Download settings for NI VISA Runtime Engine

Additionally, a further USB driver install may be required for some older versions of Windows (not required for Windows 10).

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 9).

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. If using an older Windows version this may alternatively be a compatibility error requiring the additional installation described above.

Setup options

Within the [ACTION] tab, the user can select some options for data collection and processing.

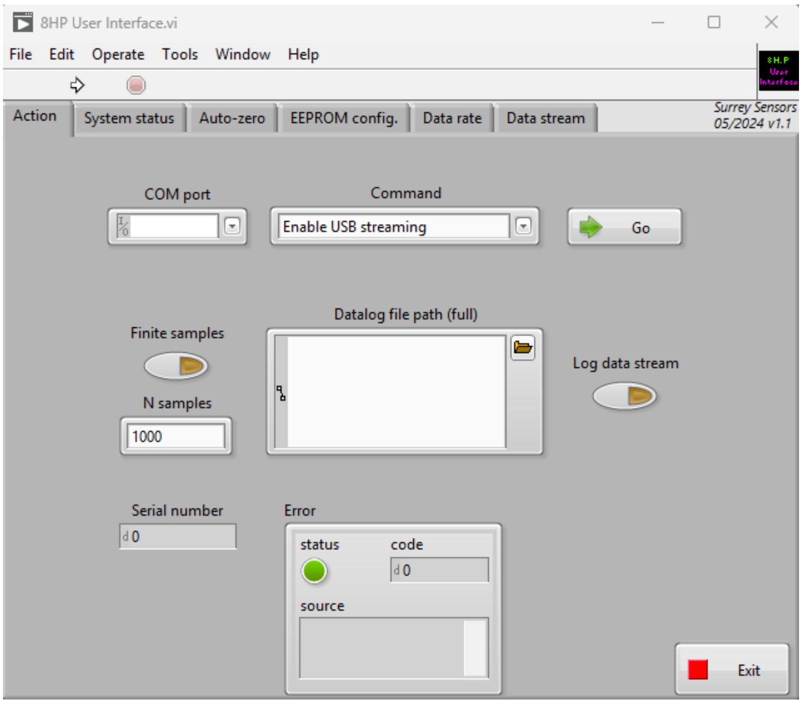


Figure 9: Probe system companion software screen-shot

- **Finite samples:** The probe can be instructed to collect a specified number *N* samples only. If this option is disabled, the probe will collect samples until manually stopped using the [DISABLE USB STREAMING] command.

- **Log data stream:** 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. If the [DATALOG 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.

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.

- **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 UART serial output is not affected by enabling USB streaming.

- **Set HW Trig:** This command enables hardware triggering. Hardware triggering allows the probe's UART port to be used for synchronization, with specific EEPROM settings. See appendix for details.

- **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 actives 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 function should not be used under normal operation. This command is similar to temporary auto-zero, but the zero values are written permanently to the EEPROM. ***WARNING*** *– this will overwrite the existing offsets that were used during probe calibration. Carrying out this procedure my invalidate your calibration.*

- **Get EEPROM values:** displays the [EEPROM CONFIG] tab and read off all the EEPROM values from the system.

- **Set EEPROM values:** The EEPROM is the probe's on-board memory, and is factory-set for normal operation. To make changes to the EEPROM values, first run [GET EEPROM VALUES] to populate the table with the current values. These values should be recorded separately to ensure that the probe can be returned to factory settings. To make changes, alter 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. Note that probes typically ship with UART data streaming disabled; to enable this, the [UART STREAMING] setting in the EEPROM needs to be changed to [1] (for 'ON').

- **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.

- **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.

- **Disable USB streaming:** this command stops data transmission over USB.
- **Disable HW Trig:** This command disables hardware triggering.
- **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 [DATALOG 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.

Appendix 1: Additional communications details

Status bytes map

Byte num.	Bit	Description	Info		Byte default value
0	0	Pressure sensor 0 checksum okay	1 yes, 0 no	0	0
	1	Pressure sensor 1 checksum okay	1 yes, 0 no	0	
	2	Pressure sensor 2 checksum okay	1 yes, 0 no	0	
	3	Pressure sensor 3 checksum okay	1 yes, 0 no	0	
	4	Pressure sensor 4 checksum okay	1 yes, 0 no	0	
	5	Pressure sensor 5 checksum okay	1 yes, 0 no	0	
	6	Pressure sensor 6 checksum okay	1 yes, 0 no	0	
	7	Pressure sensor 7 checksum okay	1 yes, 0 no	0	
1	0	Pressure sensor 0 temperature in range	1 yes, 0 no	0	0
	1	Pressure sensor 1 temperature in range	1 yes, 0 no	0	
	2	Pressure sensor 2 temperature in range	1 yes, 0 no	0	
	3	Pressure sensor 3 temperature in range	1 yes, 0 no	0	
	4	Pressure sensor 4 temperature in range	1 yes, 0 no	0	
	5	Pressure sensor 5 temperature in range	1 yes, 0 no	0	
	6	Pressure sensor 6 temperature in range	1 yes, 0 no	0	
	7	Pressure sensor 7 temperature in range	1 yes, 0 no	0	
2	0	Pressure sensor 0 value in range	1 yes, 0 no	0	0
	1	Pressure sensor 1 value in range	1 yes, 0 no	0	
	2	Pressure sensor 2 value in range	1 yes, 0 no	0	
	3	Pressure sensor 3 value in range	1 yes, 0 no	0	
	4	Pressure sensor 4 value in range	1 yes, 0 no	0	
	5	Pressure sensor 5 value in range	1 yes, 0 no	0	
	6	Pressure sensor 6 value in range	1 yes, 0 no	0	
	7	Pressure sensor 7 value in range	1 yes, 0 no	0	
3	0	BME280 ident pass	1 yes, 0 no	0	128
	1	BMI160 ident pass	1 yes, 0 no	0	
	2	BMI160 acc self test pass	1 yes, 0 no	0	
	3	BMI160 gyr self test pass	1 yes, 0 no	0	
	4	External thermistor 0 value in range	1 yes, 0 no	0	
	5	External thermistor 1 value in range	1 yes, 0 no	0	
	6	MCU EEPROM checksum okay	1 yes, 0 no	0	
	7	1	-	128	

USB Command list

After
@

Cmd. Byte	Description	Return	Additional information	Comments
s	Retrieve status bytes	4x uint8	P_chk_ok, P_tmp_ok, P_val_ok, BME280_ident, BMI160_ident, BMI160_acc_pass, BMI160_gyr_pass, T0_val_ok, T1_val_ok, EEPROM_chk_pass	
S	Perform self-test and retrieve status bytes	4x uint8	P_chk_ok, P_tmp_ok, P_val_ok, BME280_ident, BMI160_ident, BMI160_acc_pass, BMI160_gyr_pass, T0_val_ok, T1_val_ok, EEPROM_chk_pass	
z	Perform temporary auto-zero	7x float32	P_raw_offset(1 to 7)[28]	Excludes abs. pressure sensor
Z	Perform permanent auto-zero (write values to EEPROM)	7x float32	P_raw_offset(1 to 7)[28]	Excludes abs. pressure sensor
R	Read all EEPROM values	78x uint8	P_raw_offset(0 to 7)[32], P_atm_offset[4], T0_offset[4], T1_offset[4], 0[4], 0[4], acc_xyz_factor[4], 0[4], 0[4], gyr_x_offset[4], gyr_y_offset[4], gyr_z_offset[4], 0, Checksum[1]	
W	Write all EEPROM values (including new checksum)	-		
D	Enable USB/UART streaming	78x uint8	'#'[1], P0[4], P1[4], P2[4], P3[4], P4[4], P5[4], P6[4], P7[4], T0_ext[4], T1_ext[4], P_atm[4], Tint[4], RH[4], ax[4], ay[4], az[4], wx[4], wy[4], wz[4], chk[1]	Returns at [Datarate] until stream is disabled. USB or UART enabled according to physical layer on which the command was sent
d	Disable USB/UART streaming	-		USB or UART disabled according to physical layer on which the command was sent
A	Enable USB streaming on power-up	-		
a	Disable USB streaming on power-up	-		
Y	Enable UART streaming on power-up	-		
y	Disable UART streaming on power-up	-		
P	Set UART stream full data packet mode (power-up default)	-	Send 1x uint8. 1 = full data, 0 = partial data	
p	Get UART stream full data packet mode	1x uint8	1 = full data, 0 = partial data	

F	Set data rate	-	Send 1x uint16, DataRate[2] containing one of the allowable integer data rates.	
f	Get data rate	1x uint16	Data rate (Hz)	
J	Set data rate (power-up default)	-	Send 1x uint16, DataRate[2] containing one of the allowable integer data rates.	
X	Set inertial sensor modes (power-up defaults)	-	Send 3x bytes, {acc_Range_Mode, gyr_Range_Mode, IMU_Rate_Mode}	
x	Get inertial sensor modes	3x uint8	{acc_Range_Mode, gyr_Range_Mode, IMU_Rate_Mode}	Refer to "IMU modes table.xls" for description of mode bytes
N	Get serial number	1x float32	Serial_num[4] (EEPROM index 44…47)	
G	Get current data packet (full)	78x uint8	'#'[1], P0[4], P1[4], P2[4], P3[4], P4[4], P5[4], P6[4], P7[4], T0_ext[4], T1_ext[4], P_atm[4], Tint[4], RH[4], ax[4], ay[4], az[4], wx[4], wy[4], wz[4], chk[1]	
g	Get current data packet (partial)	42x uint8	'#'[1], P0[4], P1[4], P2[4], P3[4], P4[4], P5[4], P6[4], P7[4], T0_ext[4], T1_ext[4], chk[1]	
B	Set UART baud rate (bps) (power-up default)	-	Send 1 float32 (as 4 bytes), Baud[4]	
b	Get UART baud rate (bps)	1x float32	Baud[4]	

IMU Mode bytes

Accelerometer range		
Mode (byte)	Eng. Value	Unit
0	±2	g
1	±4	g
2	±8	g
3	±16	g

Gyroscope range		
Mode (byte)	Eng. Value	Unit
0	±125	°/s
1	±250	°/s
2	±500	°/s
3	±1000	°/s
4	±2000	°/s

IMU refresh rate		
Mode (byte)	Eng. Value	Unit
0	6.25	Hz
1	12.5	Hz
2	25	Hz
3	50	Hz
4	100	Hz
5	200	Hz
6	400	Hz
7	800	Hz
8	1600	Hz

EEPROM Map

Byte index	*Description*	*Type*	*Unit*
0	Pressure 0 raw offset	float32	-
1			
2			
3			
4	Pressure 1 raw offset	float32	-
5			
6			
7			
8	Pressure 2 raw offset	float32	-
9			
10			
11			
12	Pressure 3 raw offset	float32	-
13			
14			
15			
16	Pressure 4 raw offset	float32	-
17			
18			
19			
20	Pressure 5 raw offset	float32	-
21			
22			
23			
24	Pressure 6 raw offset	float32	-
25			
26			
27			
28	Pressure 7 raw offset	float32	-
29			
30			
31			
32	Atmospheric pressure offset	float32	Pa
33			
34			
35			
36	External thermistor 0 temperature offset	float32	°C
37			
38			
39			
40	External thermistor 1 temperature offset	float32	°C
41			
42			
43			

44	Serial number	float32	-
45			
46			
47			
48	UART baud rate (Set to zero to use the UART Rx as hardware trigger)	float32	bps
49			
50			
51			
52	Accelerometer xyz scale factor	float32	-
53			
54			
55			
56	Gyroscope x component offset	float32	deg/s
57			
58			
59			
60	Gyroscope y component offset	float32	deg/s
61			
62			
63			
64	Gyroscope z component offset	float32	deg/s
65			
66			
67			
68	Default data rate on power-up	uint16	(Hz)
69			
70	UART streaming enabled on power-up (Set to zero to use the UART Rx as hardware trigger)	unit8	-
71	USB streaming enabled on power-up	unit8	-
72	UART streaming full data packet	unit8	-
73	Accelerometer range mode	unit8	-
74	Gyroscope range mode	unit8	-
75	IMU update rate mode	unit8	-
76	HW trigger edge polarity (0 for falling, 1 for rising)	unit8	0, 1
77	EEPROM CRC16-CCITT	uint16	-
78			

Summary of CRC-16-CCITT Implementation in C++

Global Variables and Constants

```
uint16_t CRC16_LUT[256];
const uint16_t poly = 0x1021;
const uint16_t crc_init = 0xFFFF;
```

CRC-16 Lookup Table (LUT) Generation

The following function is called once at the start. The 1D array of length 256 “CRC16_LUT” is then stored in memory for all time and used whenever a CRC is computed.

```
void Generate_CRC16_LUT()
{
	for (uint16_t i = 0; i < 256; i++)
	{
		uint16_t Byte = i << 8;

		for (uint8_t Bit = 0; Bit < 8; Bit++)
		{
			if ((Byte & 0x8000) != 0)
			{
				Byte <<= 1;
				Byte ^= poly;
			}
			else
			{
				Byte <<= 1;
			}
		}

		CRC16_LUT[i] = Byte;
	}
}
```

Alternatively, the LUT can be hard-coded as a constant:

```
// CRC-16 lookup table for CCITT polynomial 0x1021

static const uint16_t CRC16_LUT[256] =
{
  0x0000, 0x1021, 0x2042, 0x3063, 0x4084, 0x50A5, 0x60C6, 0x70E7,
  0x8108, 0x9129, 0xA14A, 0xB16B, 0xC18C, 0xD1AD, 0xE1CE, 0xF1EF,
  0x1231, 0x0210, 0x3273, 0x2252, 0x52B5, 0x4294, 0x72F7, 0x62D6,
  0x9339, 0x8318, 0xB37B, 0xA35A, 0xD3BD, 0xC39C, 0xF3FF, 0xE3DE,
  0x2462, 0x3443, 0x0420, 0x1401, 0x64E6, 0x74C7, 0x44A4, 0x5485,
  0xA56A, 0xB54B, 0x8528, 0x9509, 0xE5EE, 0xF5CF, 0xC5AC, 0xD58D,
  0x3653, 0x2672, 0x1611, 0x0630, 0x76D7, 0x66F6, 0x5695, 0x46B4,
  0xB75B, 0xA77A, 0x9719, 0x8738, 0xF7DF, 0xE7FE, 0xD79D, 0xC7BC,
  0x48C4, 0x58E5, 0x6886, 0x78A7, 0x0840, 0x1861, 0x2802, 0x3823,
  0xC9CC, 0xD9ED, 0xE98E, 0xF9AF, 0x8948, 0x9969, 0xA90A, 0xB92B,
  0x5AF5, 0x4AD4, 0x7AB7, 0x6A96, 0x1A71, 0x0A50, 0x3A33, 0x2A12,
  0xDBFD, 0xCBDC, 0xFBBF, 0xEB9E, 0x9B79, 0x8B58, 0xBB3B, 0xAB1A,
  0x6CA6, 0x7C87, 0x4CE4, 0x5CC5, 0x2C22, 0x3C03, 0x0C60, 0x1C41,
  0xEDAE, 0xFD8F, 0xCDEC, 0xDDCD, 0xAD2A, 0xBD0B, 0x8D68, 0x9D49,
  0x7E97, 0x6EB6, 0x5ED5, 0x4EF4, 0x3E13, 0x2E32, 0x1E51, 0x0E70,
  0xFF9F, 0xEFBE, 0xDFDD, 0xCFFC, 0xBF1B, 0xAF3A, 0x9F59, 0x8F78,
  0x9188, 0x81A9, 0xB1CA, 0xA1EB, 0xD10C, 0xC12D, 0xF14E, 0xE16F,
  0x1080, 0x00A1, 0x30C2, 0x20E3, 0x5004, 0x4025, 0x7046, 0x6067,
  0x83B9, 0x9398, 0xA3FB, 0xB3DA, 0xC33D, 0xD31C, 0xE37F, 0xF35E,
  0x02B1, 0x1290, 0x22F3, 0x32D2, 0x4235, 0x5214, 0x6277, 0x7256,
  0xB5EA, 0xA5CB, 0x95A8, 0x8589, 0xF56E, 0xE54F, 0xD52C, 0xC50D,
  0x34E2, 0x24C3, 0x14A0, 0x0481, 0x7466, 0x6447, 0x5424, 0x4405,
  0xA7DB, 0xB7FA, 0x8799, 0x97B8, 0xE75F, 0xF77E, 0xC71D, 0xD73C,
  0x26D3, 0x36F2, 0x0691, 0x16B0, 0x6657, 0x7676, 0x4615, 0x5634,
  0xD94C, 0xC96D, 0xF90E, 0xE92F, 0x99C8, 0x89E9, 0xB98A, 0xA9AB,
  0x5844, 0x4865, 0x7806, 0x6827, 0x18C0, 0x08E1, 0x3882, 0x28A3,
  0xCB7D, 0xDB5C, 0xEB3F, 0xFB1E, 0x8BF9, 0x9BD8, 0xABBB, 0xBB9A,
  0x4A75, 0x5A54, 0x6A37, 0x7A16, 0x0AF1, 0x1AD0, 0x2AB3, 0x3A92,
  0xFD2E, 0xED0F, 0xDD6C, 0xCD4D, 0xBDAA, 0xAD8B, 0x9DE8, 0x8DC9,
  0x7C26, 0x6C07, 0x5C64, 0x4C45, 0x3CA2, 0x2C83, 0x1CE0, 0x0CC1,
  0xEF1F, 0xFF3E, 0xCF5D, 0xDF7C, 0xAF9B, 0xBFBA, 0x8FD9, 0x9FF8,
  0x6E17, 0x7E36, 0x4E55, 0x5E74, 0x2E93, 0x3EB2, 0x0ED1, 0x1EF0
};
```

CRC-16 Computation

The following function is called whenever a CRC-16 is required from an array of data.

```
uint16_t Calc_CRC16(uint8_t *Data, uint16_t DataLen, uint16_t crc)
{
       for (uint16_t i = 0; i < DataLen; i++)
       {
              uint8_t index = Data[i] ^ (crc >> 8);

              crc = CRC16_LUT[index] ^ (crc << 8);
       }

       return crc;
}
```

CRC-16 Function Call Example

The data for which the CRC is to be computed is first of all typecast into an array of unsigned char (uint8_t) "DataBytes". This can be done using the `memcpy` function. When generating a CRC value for an array of data the length value "Len" passed to the function is that of the number of bytes in the entire array. However, when checking a CRC value appended to an array of data, the length value passed to the function is two less than that of the entire array so as to exclude the appended CRC word. The CRC value passed to the function is that of the initialiser constant "crc_init", which, for the CCITT specification, is hexadecimal `0xFFFF`.

```
uint16_t CRC_computed = Calc_CRC16(&DataBytes, Len, crc_init);
```

Checksum Test

A checksum test is passed if the computed and transmitted checksum values are equal. With the CRC appended at the end of the transmitted data array the test is carried out as follows

```
uint16_t CRC_appended;

memcpy(&CRC_appended, &DataBytes[Len – 2], 2);

bool CRC_pass = (CRC_appended == CRC_computed);
```

Code implementation can be validated by cross-checking results with a reputable online CRC calculator such as https://crccalc.com/

CRC-16-CCITT Algorithm Parameters:

Polynomial divisor:	`0x1021`	$(x^{16} + x^{12} + x^5 + 1)$
CRC initialiser:	`0xFFFF`	
Input reflection:	`False`	
Output reflection:	`False`	
Output XOR:	`0x0000`	

Appendix 2: Hardware triggering

The probe includes an internal clock for data acquisition and timing. Occasionally, it may be necessary to begin acquisition on receipt of an external trigger pulse. If so, the probe's UART Rx pin can be reconfigured as a trigger input, and the Tx port as a trigger output. Consequently the probe can only be operated via USB if the external trigger function is used.

If external triggering was specified as a requirement at the time of order, then the probe would have shipped with the required settings. If not, the settings can be modified by the user.

Instructions

Step 1: Launch the user interface application, select the appropriate COM port and run the application by clicking the white arrow in the menu bar.

Step 2: Under the [ACTION] tab, select [GET EEPROM VALUES] from the [COMMAND] drop-down menu and click [GO]. This will populate the [EEPROM CONFIG] tab.

Step 3: It is strongly recommended that a a copy of the factory-set EEPROM values are saved in case of accidental corruption.

Step 4: Make the following changes to the EEPROM configuration (if required), following instructions in the manual:

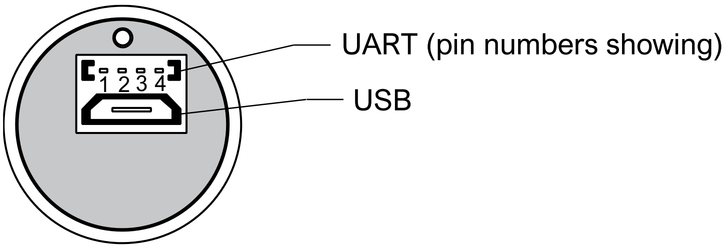
- Set [UART BAUD RATE] to [0] (zero)
- Set [UART STREAMING] to [0] (zero)
- Set [HW TRIGGER POLARITY] to either [0] (zero) or [1] (one). A value of zero will trigger USB data streaming on a falling edge, while a value of one will trigger on a rising edge.

Note that the serial digital lines may be labelled as either TTL or UART in the user interface, depending on the version used.

Step 5: Connect the input trigger signal to the Rx pin (pin 3) on the probe's UART connector (see Figure 10) and the trigger system ground to the GND pin (pin 2).

IMPORTANT: Be sure to use the correct cable assembly for the UART connection, and that this is inserted in the correct orientation.

WARNING: The probe logic operates at 3.3V levels but is 5V tolerant. Any voltage values applied outside of this range to the Tx/Rx pins may damage the probe and will void the warranty.



UART
Pin 1 = V+
Pin 2 = GND
Pin 3 = Rx
Pin 4 = Tx

Figure 10: connector interface and pin assignment

Note that the pin numbering shown here is for the hardware end. Cable assemblies are not cross-linked: if a mating cable assembly is used, the pin order will be reversed on the cable end.

Step 6: Enter the desired parameters for acquisition in the user interface software, under the [ACTION] tab.

Step 7: From the [COMMAND] drop-down menu, select [SET HW TRIG] and click [GO].

The probe trigger input is now armed, and acquisition will begin on receipt of the trigger signal. Note that the latency in response is significantly smaller than the smallest sampling time, and can be considered as negligible.

When configured for hardware triggering, the probe's UART Tx line will automatically act as an output trigger. Whenever the probe is streaming data, the polarity of the UART Tx line will switch (following the same convention as the [HW TRIGGER POLARITY] selection). The polarity will switch when the probe is triggered (either by a hardware trigger or software command), and will return to its original state when acquisition stops. The use of the Tx line is optional (it can be left open or unconnected), but care must be taken to ensure that the line is used only to provide trigger pulses when in this mode.