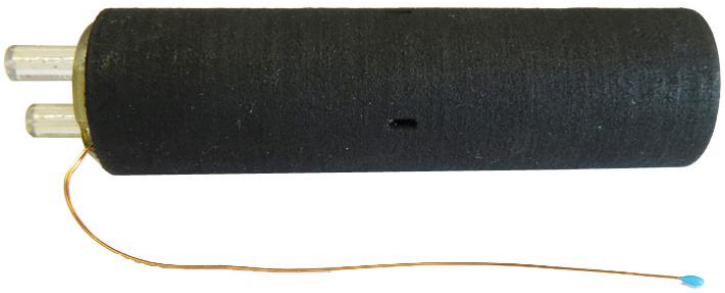
DIGITAL PITOT STATIC PROBE DRIVER SYSTEM

User Manual



WARNING

Read this document before using the product.

This 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	05-2017	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. Addition of appendix containing further comms details.	1.2

1 INTRODUCTION

Principle of operation

This Pitot-static probe driver system includes one high-precision differential pressure sensor for measuring the local stagnation pressure rise, and one vacuum-reference absolute pressure sensor for the static reference. The probe system also contains a six-component inertial measurement unit, a fluid temperature sensor, a case temperature sensor and a humidity sensor. The probe system can communicate either directly to a computer via the on-board USB terminal or be part of an RS-485 network.

System description

Bespoke miniature multi-function two-channel pressure logging system with ancillary sensor arrays.

System components

1x Probe driver assembly	The probe driver assembly consists of a sensor package and an enclosure. This may be supplied with or without a pitot-static probe core with local static sampling sleeve.
1 x Probe sting (optional)	Option of Pitot-static probe sting.
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.

2 DETAILED SPECIFICATION

Standard sensor specifications (custom available on request)	Differential pressure sensor			Static pressure sensor
Product code	ID2HP-160P	ID2HP-1K0	ID2HP-6K9	
Standard pressure ranges	160 Pa FS	1 kPa FS	6.9 kPa FS	1 atm.
Maximum overpressure	33.5 kPa	37.5 kPa	69 kPa	400 kPa
Sensor accuracy[1]	± 0.1 % FS			
Total error band after auto-zero[2]	± 0.5 % FS	± 0.25 % FS	± 0.25 % FS	± 0.25 % FS
Compensated temperature range (extended ranges available)	-40° to +65° C	0° to +50° 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 ambient 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, +/- 0.1kPa			
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)	< 20 g			
Voltage	6-24 VDC or via USB			
Power	min. 290 mW			
Communications interface	USB2.0 or RS485			
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			
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.

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 Tx/Rx lines.

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.

USB stream

Each data packet consists of 52 bytes, beginning with an unsigned-integer frame character ("#") and terminating with a checksum (both inclusive). The data order is shown below.

byte index	Description	Type	Unit
0	Frame character '#'	uint8	-
1	RS-485 address (0…255)	uint8	-
2	Pressure 0	float32	Pa
3			
4			
5			
6	Pressure 1	float32	Pa
7			
8			
9			
10	Atmospheric pressure	float32	Pa
11			
12			
13			
14	External thermistor temperature	float32	°C
15			
16			
17			
18	Internal case temperature (sensor die)	float32	°C
19			
20			
21			
22	Relative humidity	float32	%
23			
24			
25			
26	Accelerometer x component	float32	g
27			
28			
29			
30	Accelerometer y component	float32	g
31			
32			
33			
34	Accelerometer z component	float32	g
35			
36			
37			

38	Gyroscope x component	float32	deg / s
39			
40			
41			
42	Gyroscope y component	float32	deg / s
43			
44			
45			
46	Gyroscope z component	float32	deg / s
47			
48			
49			
50	CRC16-CCITT	uint16	-
51			

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

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

The receiving board must have at least a 50 byte receive buffer to prevent data overrun.

RS-485 Communications

The system may also operate independently of a computer, returning data over a half-duplex RS-485 line. Valid commands are as follows:

Cmd	Description	Return size (bytes)	Comments
G	Retrieve all sensor data (RS-485 one-shot)	52	'#'[1], Addr[1], P0[4], P1[4], T_ext[4], P_atm[4], Tint[4], RH[4], ax[4], ay[4], az[4], wx[4], wy[4], wz[4], CRC16[2]
g	Retrieve P & T data only (RS-485 one-shot)	16	'#'[1], Addr[1], P0[4], P1[4], T_ext[4], CRC16[2]
s	Retrieve status bytes	4	See"Status bytes map.xls" for details
S	Perform self-test and retrieve status bytes	4	See"Status bytes map.xls" for details
z	Perform temporary auto-zero	8	2x float32 (P0 and P1 auto-zero values respectively)
Z	Perform permanent auto-zero (write values to EEPROM)	8	2x float32 (P0 and P1 auto-zero values respectively)
R	Read all EEPROM values	51	See "EEPROM map.xls" for details
W	Write all EEPROM values (including new checksum)	-	See "EEPROM map.xls" for details
D	Enable USB streaming	52	Data returned at desired rate until disabled
d	Disable USB streaming	-	
F	Set data rate (Hz)	-	See "Data rate command strings.xls" for details
N	Get serial number	4	Returned as float32
A	Set RS-485 address	-	Address sent as uint8 at comand byte index 3
a	Get RS-485 address	1	Returned as uint8
B	Set RS-485 baud rate	-	Baud rate sent as float32 starting at command byte index 3
b	Get RS-485 baud rate	4	Returned as float32

Table of valid command bytes to go at byte index 2 of Cmd packet
Format: ASCII char

Commands are issued to the system using the following packet structure:

Byte index	Description	Type	Unit
0	Start character '@'	uint8	-
1	RS-485 address (0…255)	uint8	-
2	Command (ASCII char)	uint8	-
3	Data	float32	-
4			
5			
6			
7	CRC16-CCITT	uint16	-
8			

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

Interface details	
Voltage	3.3 V
Duplex	Half
Baud	921600
Endian	Little

"All sensor" data (command G) are returned by the system using the following packet structure:

Byte index	Description	Type	Unit
0	Start character '#'	uint8	-
1	RS-485 address (0…255)	uint8	-
2	Pressure 0	float32	Pa
3			
4			
5			
6	Pressure 1	float32	Pa
7			
8			
9			
10	External thermistor temperature	float32	°C
11			
12			
13			
14	Atmospheric pressure	float32	Pa
15			
16			
17			
18	Internal case temperature (sensor die)	float32	°C
19			
20			
21			
22	Relative Humidity	float32	%
23			
24			
25			

26	Accelerometer_x	float32	g
27			
28			
29			
30	Accelerometer_y	float32	g
31			
32			
33			
34	Accelerometer_z	float32	g
35			
36			
37			
38	Gyroscope_x	float32	deg / s
39			
40			
41			
42	Gyroscope_y	float32	deg / s
43			
44			
45			
46	Gyroscope_z	float32	deg / s
47			
48			
49			
50	CRC16-CCITT	uint16	-
51			

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

"Pressures only" data (command g) are returned by the system using the following packet structure:

Byte index	Description	Type	Unit
0	Start character '#'	uint8	-
1	RS-485 address (0…255)	uint8	-
2	Pressure 0	float32	Pa
3			
4			
5			
6	Pressure 1	float32	Pa
7			
8			
9			
10	External thermistor temperature	float32	deg C
11			
12			
13			
14	CRC16-CCITT	uint16	-
15			

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

IMPORTANT NOTE: The RS-485 packet format shown here is indicative only. Firmware is updated regularly depending on customer requirement, and may vary from unit to unit. Please refer to documentation supplied with the system.

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 loss or corruption in transmission. Example C++ code and DLL files to compute the CRC-16 checksum are available upon request. 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 may be supplied as a single integrated unit. If so, 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.

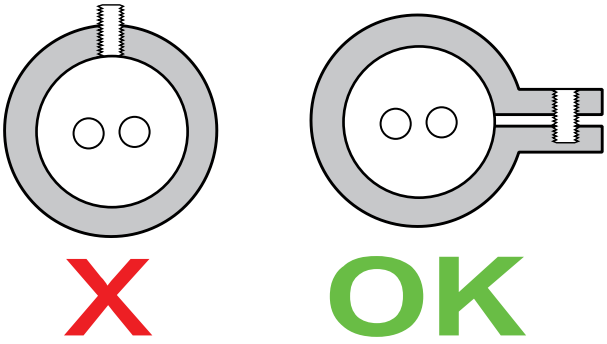


Figure 1: Correct probe mounting

Probe assembly

If supplied with a probe sting, the sting assembly will consist of a stagnation pressure probe core surrounded by a static pressure sleeve, and has been machined with a hemispherical tip to minimise sensitivity to nonzero flow angles.

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

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), D+ (3) and D- (4), where pin 1 is on the left when the probe is oriented such that the serial port is above the micro-USB port.

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

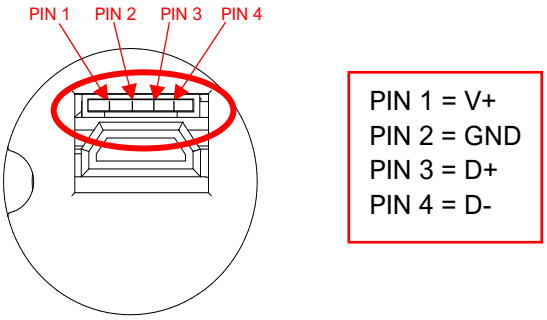


Figure 2: Serial comms pin assignment

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 sting when not in use (if supplied), 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. Sensible ESD precautions should be taken before handling.
- Ensure that no dust, dirt or liquid enters the probe enclosure. 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.
- Connect cables to the system 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 system.

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. Ensure that the 64-bit version of the 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 Figure 3 and 4 below.

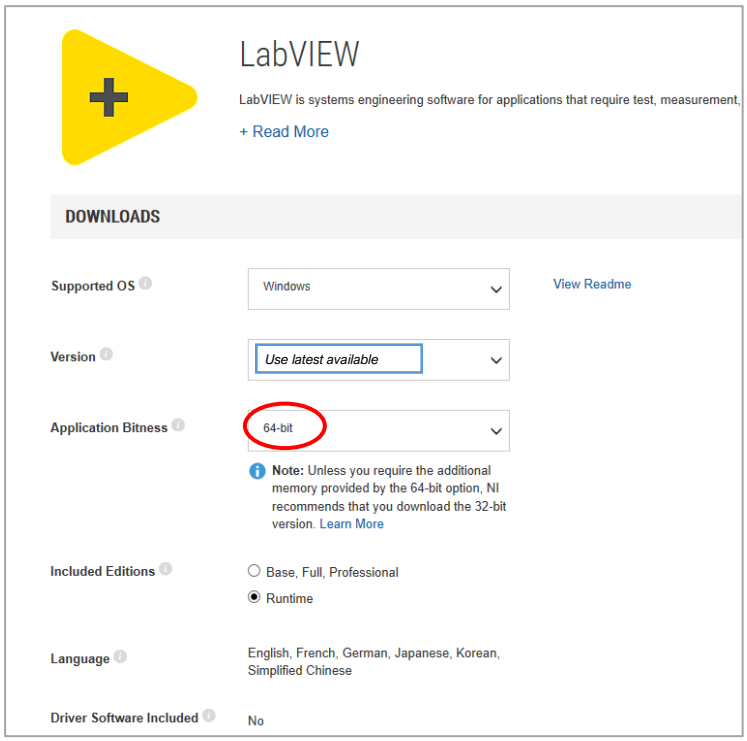


Figure 3: Download settings for NI Labview Runtime Engine

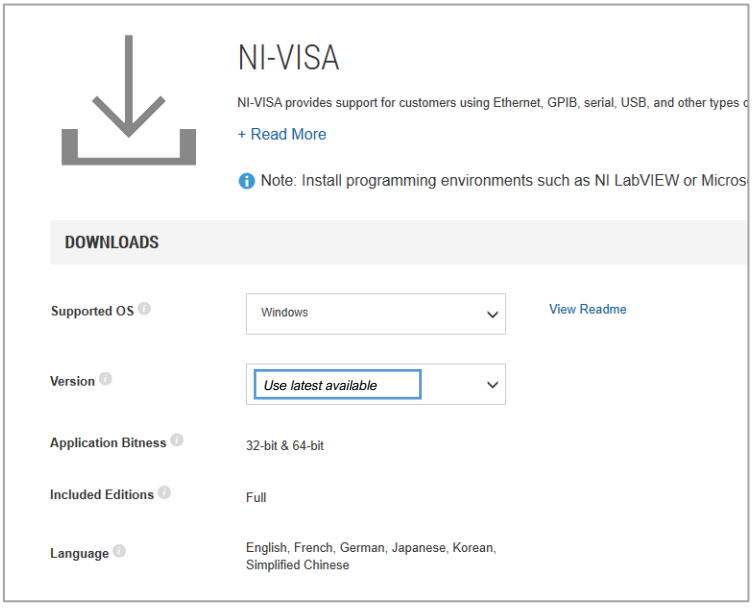


Figure 4: Download settings for NI VISA Runtime Engine

Additionally, a further comms system 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 5).

Starting procedure

1) Load the program. It will start in the [ACTION] tab.
2) Using the [COM PORT] drop down menu, note any existing COM ports.
3) Connect the computer to the system's USB socket using the included cable.
4) The system will perform a power-on self-test, lasting a couple of seconds. If all tests pass, the on-board green LED will light up.
5) Using the [COM PORT] drop down menu, select [REFRESH] at the bottom of the menu ring. The new addition to the list is the probe board, select this entry.
6) Press the white arrow near the top left corner of the window to run the application.
7) 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.

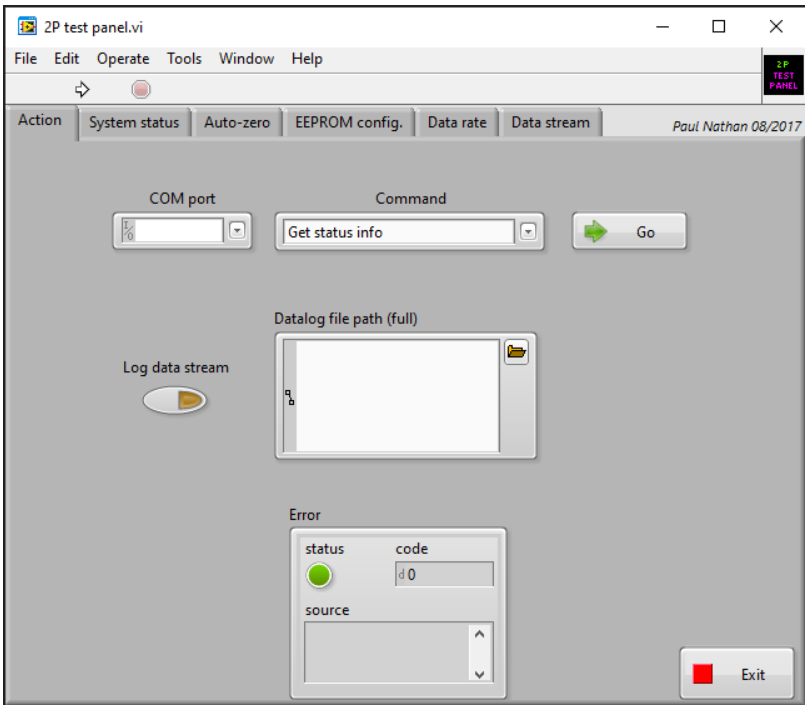


Figure 5: Probe system companion software screen-shot

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 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 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 [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.

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: 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	252
	1	Pressure sensor 1 checksum okay	1 yes, 0 no	0	
	2	1	-	4	
	3	1	-	8	
	4	1	-	16	
	5	1	-	32	
	6	1	-	64	
	7	1	-	128	
1	0	Pressure sensor 0 temperature in range	1 yes, 0 no	0	252
	1	Pressure sensor 1 temperature in range	1 yes, 0 no	0	
	2	1	-	4	
	3	1	-	8	
	4	1	-	16	
	5	1	-	32	
	6	1	-	64	
	7	1	-	128	
2	0	Pressure sensor 0 value in range	1 yes, 0 no	0	252
	1	Pressure sensor 1 value in range	1 yes, 0 no	0	
	2	1	-	4	
	3	1	-	8	
	4	1	-	16	
	5	1	-	32	
	6	1	-	64	
	7	1	-	128	
3	0	BME280 ident pass	1 yes, 0 no	0	192
	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 value in range	1 yes, 0 no	0	
	5	EEPROM checksum okay	1 yes, 0 no	0	
	6	1	-	64	
	7	1	-	128	

USB Command list

After @

Cmd. Byte	Description	Return	Additional information
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, EEPROM_CRC16_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, EEPROM_CRC16_pass
z	Perform temporary auto-zero	2x float32	P_raw_offset(0 to 1)[8]
Z	Perform permanent auto-zero (write values to EEPROM)	2x float32	P_raw_offset(0 to 1)[8]
R	Read all EEPROM values	51x uint8	P_raw_offset(0 to 1)[8], P_atm_offset[4], T0_offset[4], Serial_num[4], RS-485_baud[4], acc_xyz_factor[4], 0[4], 0[4], gyr_x_offset[4], gyr_y_offset[4], gyr_z_offset[4], RS-485_address[1], CRC16[2]
W	Write all EEPROM values (including new checksum)	-	
D	Enable USB streaming	52x uint8	'#'[1], Addr[1], P0[4], P1[4], P_atm[4], T_ext[4], Tint[4], RH[4], ax[4], ay[4], az[4], wx[4], wy[4], wz[4], CRC16[2] Returns at [Datarate] until stream is disabled
d	Disable USB streaming	-	
F	Set data rate (Hz)	-	Append uint16 DataRate[2], e.g. {'@', 'F', Datarate[2]}.
N	Get serial number	1x float32	Serial_num[4] (EEPROM index 16…19)
A	Set RS-485 address	-	
a	Get RS-485 address	1x uint8	Returns address
B	Set RS-485 baud rate	-	
b	Get RS-485 baud rate	1x float32	Returns baud rate

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	Atmospheric pressure offset	float32	Pa
9			
10			
11			
12	External thermistor temperature offset	float32	deg C
13			
14			
15			
16	Serial number	float32	-
17			
18			
19			
20	RS-485 baud rate	float32	bps
21			
22			
23			
24	Accelerometer xyz scale factor	float32	-
25			
26			
27			
28	0	-	-
29			
30			
31			
32	0	-	-
33			
34			
35			
36	Gyroscope x component offset	float32	deg / s
37			
38			
39			
40	Gyroscope y component offset	float32	deg / s
41			
42			
43			
44	Gyroscope z component offset	float32	deg / s
45			
46			
47			
48	RS-485 address	uint8	-
49	CRC16-CCITT	uint16	-
50			

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

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`	