Contents

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1 Quick Start

The purpose of this manual is to explain how to set up, install and use the Alphasense Optical Particle Counter OPC-R1 for measuring PM_1, $PM_{2.5}$ and PM_{10}, as well as measuring particle size distributions in real time. Note it is also possible to set the unit up to measure $PM_{4.25}$.

When using this OPC for the first time we recommend that you use the Alphasense SPI adapter. This will enable you to very quickly use the OPC at your desk by running it off a Windows PC or laptop using the Alphasense software. Apple and Unix compatible software are not available.

Initially a full deployment package will have been provided with the OPC-R1. In the future this will be available via the web site or through contact with Alphasense.

Full instructions for carrying out the installation, (specifically a driver must be installed for the SPI adapter) and for the use of the software are in Appendix B and section 9. Please note the driver and the SPI adapter are the same as that used for the OPC-N2 and N3.

You can view the data options along with the data resolution and range when the OPC-R1 is connected to a PC running the Alphasense-supplied software. Please note that is not the same software that runs the OPC-N2 or the OPC-N3. This also provides a useful reference to those customers who wish to develop their own software.

The OPC-R1, unlike the OPC-N2 and N3, does not have a standalone mode where the data is stored directly on an onboard SD card.

Temperature and humidity sensors are fitted as standard on the OPC-R1. Temperature and humidity compensation is not currently carried out but this will be offered in the future.

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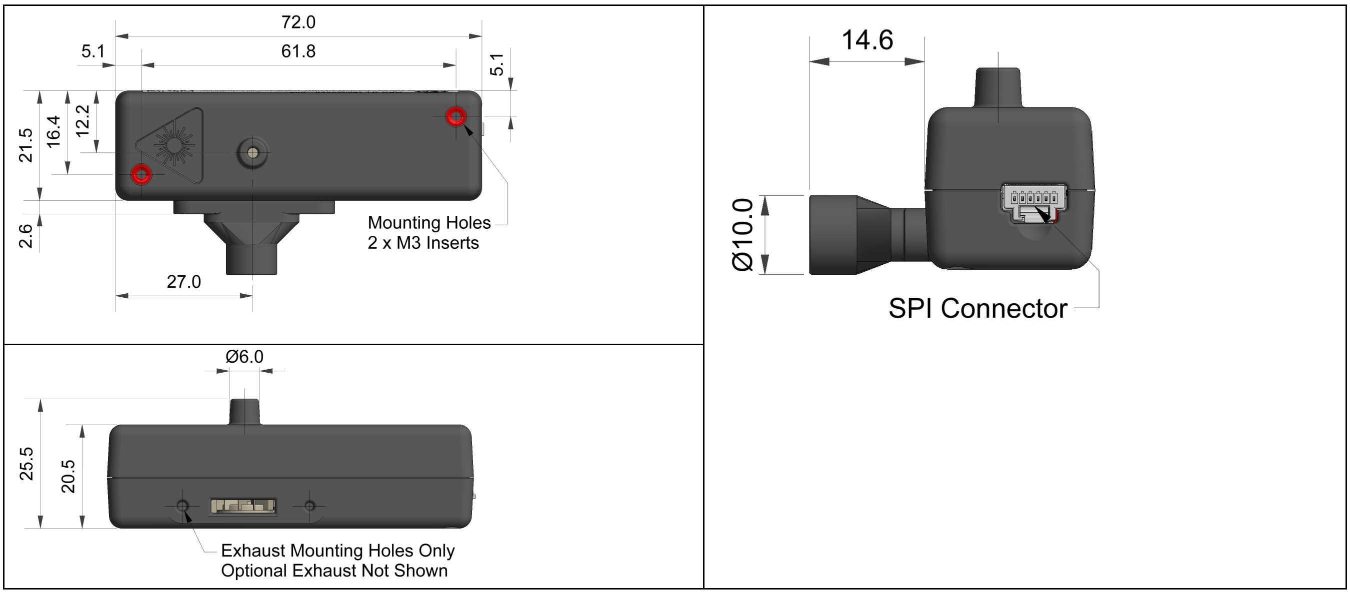
2 OPC-R1 Specification



All dimensions in millimetres (± 0.15 mm)

MEASUREMENT			
Particle range	(µm)	Spherical equivalent size (based on RI of 1.5+i0)	0.35 to 12.4
Size categorisation (standard)		Number of software bins	16
Sampling interval (seconds)		Histogram period (recommended)	1 to 30
Sample flow rate	mL/ min		240
Max particle count rate	Particles/ second		10,000
Detection limits (PM_{10})	Minimum		0.01 µg/m^3
	Maximum (electronic limit)		1 500 mg/m^3
Coincidence probability	%	at 10^6 particles/ L	0.7

POWER			
Measurement mode	mA		95-100
Non-measurement mode	mA	Laser and fan off	5
Transient power on start-up	mW for 1 ms		<5000
Voltage range	V DC		4.8 to 5.2

KEY SPECIFICATIONS		
Digital Interface		SPI (Mode 1)
Laser classification	as enclosed housing	Class 1
Temperature range	°C	-10 to 50
Humidity range	% rh (continuous)	0 to 95 (non-condensing)
Weight	g	< 30

Table 1. Power and environmental performance limits

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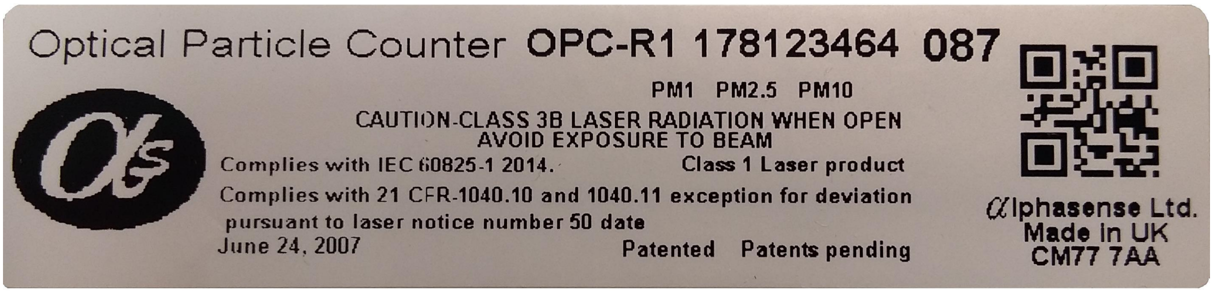
3 Health and Safety



The OPC-R1 uses an embedded diode laser operating at 4-8 mW (max. 11 mW) at a wavelength of 639 nm. The OPC-R1 is a Class 1 laser product, since the user does not have access to the laser source. The OPC-R1 is designed for OEM use, normally mounted in a secondary housing. The user must not open or adjust any parts of the OPC-R1. It is the user's responsibility to ensure that the unit is used safely and complies with any local regulations. **Do not remove any safety stickers or warnings.**

DO NOT remove the external housing: this not only ensures the required airflow but also protects the user from laser light. Removal of the casing may expose the user to Class 3B laser radiation. You must avoid exposure to the laser beam. Do not use if the outer casing is damaged- return to Alphasense. Removal of the external housing exposes the OPC circuitry which contains components that are sensitive to damage by static discharge.

4 How it Works

Like conventional optical particle counters, the OPC-R1 measures the light scattered by individual particles carried in a sample air stream through a laser beam. These measurements are used to determine the particle size (related to the intensity of light scattered via a calibration based on Mie scattering theory) and particle number concentration. Particle mass loadings- PM_1, $PM_{2.5}$ and PM_{10}, are then calculated from the particle size spectra and concentration data, assuming a particle density and refractive index (RI). Default settings, weighting index 2 are: density 1.65 g/ml, RI 1.5+i0. Respiratory profiles are included in the PM calculations. It is also possible to select $PM_{4.25}$ instead of one of the other PM values.

The OPC-R1 contains 10 weighting index sets, each comprising a weighting value for each of the 16 size bins. Index Set 0 can be adjusted by the end user; the other 9 are factory set (See later for more information).

The OPC-R1 classifies each particle size, at rates up to ~10,000 particles per second, recording the particle size to one of 16 "bins" covering the size range from 0.35 to 12.4 μm. Please note the maximum particles per second and the maximum mass detectable are based on the potential performance of the electronics and will be reduced in actual measurements. The resulting particle size histograms can be evaluated with user-defined sampling times from 1 to 30 second duration. Longer times in dirty environments with high particle concentrations can result in the bins "over filling". If longer periods are needed it is recommended to undertake the averaging of shorter measurement periods. This histogram data is transmitted via an SPI interface to a host computer.

The OPC-R1 is designed to minimise particle deposition within the unit and thus allow for prolonged unattended operation in dusty environments. We would recommend the use of the OPC-N3 in very dusty environments.

Consistent with most commercial Optical Particle Counters (OPCs), all particles, regardless of shape are assumed to be spherical and are therefore assigned a 'spherical equivalent size'. This size is related to the measurement of light scattered by the particle as defined by Mie theory, an exact theory to predict scattering by spheres of known size and refractive index (RI). The OPC-R1

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is calibrated using Polystyrene Spherical Latex Particles (PSLs) of a known diameter and known RI. Correction factors can be applied for errors resulting from particles of different density or refractive index.

5 PM measurements

The particle size histogram data recorded by the OPC-R1 sensor can be used to calculate the mass of airborne particles per unit volume of air, expressed as ε g/m^3.
The accepted international standard definitions of particle mass loadings in the air are $PM_{2.5}$ and $PM_{10,}$ PM_1 is not yet an international standard. These definitions relate to the mass and size of particles that would be inhaled by a typical adult.
The OPC-R1 calculates the respective PM values according to the method defined by European Standard EN 481. Conversion from the óptical sizeôof each particle as recorded by the OPC-R1 and the mass of that particle requires knowledge of both particle density and its RI at the wavelength of the illuminating laser beam, 639 nm. The OPC-R1 assumes an average RI value of 1.5 + i0. The OPC-R1 allows a different value to be set for each size bin to correct for particle density variation with particle size. The OPC-R1 has 10 bin weighting indexes, one is adjustable by the end user and 9 are factory set. Please note that not all of these indexes will be defined in early released units.
The default setting for each size bin assumes a Particle Density value of 1.65 g/ml, bin weighting index 2, a figure that equates to a typical value found in many environments. Bin weighting index 0 can be modified by the end user, default setting is currently 1 for all bins.
Where it is known that different size fractions in the ambient aerosol have different densities (for example, the smallest carbon particles will have a higher density than larger aggregates of the same particles); different Particle Density values may be set for different bins to achieve a more accurate determination of PM. The other indexes will be preset with values adjusted for common ambient environments and to ensure that the OPC-R1 matches better to standard reference instruments when used in the field and to correct for some of the missing mass below the OPC detection limit.
Contact Alphasense on how to modify standard settings.

Note

- The EN 481 standard definition for PM_{10} extends to particle sizes beyond the upper measurable size limit of the OPC-R1. In some cases, this can result in the reported PM_{10} value being underestimated.

6 Sampling the environment

The sample air flow rate through the unit is determined by both the fan speed and any obstruction that affects the inlet or outflow of the OPC. Therefore tubing, valves, baffles or obstructions that will restrict air flow into or out of the OPC should be avoided. Particle distributions can also be affected by sharp turns and narrow sample pipes. The maximum pressure drop through the entire flow system must be less than 40 Pa.
However, because fan speed can vary, the sample flow rate through the OPC may vary also. Such variations are monitored and corrected dynamically by the OPC so that the particle concentrations and derived PM values are unaffected by moderate flow variations (patent pending).
The OPC R1 unit will operate adequately on its own on the bench; however it will need to be placed in a secondary housing for use in the field.
Alphasense recommends that the OPC-R1 inlet is exposed directly to the target sample volume and that the fan exhausts into an unconstrained space. An exhaust extension is provided to facilitate this. The OPC-R1 can be positioned in any orientation, but to mitigate the effects of wind direction on sampling it is best for the inlet to be pointing upwards. When mounted pointing upwards care should be taken to avoid very large droplets or soot and grit from entering the unit due to gravity. We recommend an ñumbrellaò or mushroom to protect the inlet but that does not interfere with

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particle flow. Coarse gauze filters can also be used to prevent the ingress of large particles or insects without interfering with the fine particles being measured. All electrical connections must be protected from moisture and temperatures outside of the operational range.
The temperature and humidity sensor is mounted on the OPC-R1 PCB. The values reported may not represent the actual ambient conditions.

Connecting and Operating The OPC R1

7 Connecting power and taking readings

The OPC-R1 is shipped pre-calibrated. There are no user serviceable parts. Power and data communications are provided via the SPI socket. Firmware updates use the SPI connector.

Connection to the OPC-R1 for real-time data transfer can be made via the SPI direct to your own circuitǒs internal bus using your own or the SPI interface provided by Alphasense. The SPI interface supplied by Alphasense requires a USB A-B lead to connect to the USB port of a computer, this must be ordered separately. The green LED shows that power is supplied to the OPC-R1 and the red LED flashes when the PC and OPC-R1 are communicating.

SPI Connection

The SPI socket is a Molex 'Pico Clasp' 6 way Housing, Part Number 501330-0600. Pins are assigned in table 2.

Pin	Function
1	Vcc
2	SCK
3	SDO
4	SDI
5	/SS
6	GND

Table 2. SPI pin assignments

OPC power requirement

The OPC-R1 requires a 4.8 to 5.2 Volt DC supply with minimum electrical noise, (< 30mV pk-pk)
This is stepped down to a 3v3 supply (via the SPI-ISS adapter) for the SPI logic lines. Except for the Slave-Select logic line, the SPI interface lines are 5V tolerant but we recommend to run all at 3v3.
The OPC-R1 requires 95-100 mA with a short one amp transient at switch-on, check that the current limit is not exceeded if multiple units are operated from a shared power supply

It is recommended to allow 2 second for the OPC to respond to the first SPI command after power-up and >0.6 s after a switch peripherals/fan on sequence.

Software interface configuration

The following interface rules will help you to make a reliable connection with the OPC.

1. Set up SPI interface as follows:
   SPI Mode1 (clock idle low, data transmitted on clock leading edge).
   Set SPI frequency to between 300 kHz and 750 kHz.
2. SPI Master system must drive MOSI and SCK and SS communication lines.
3. Delay between a command byte and any subsequent bytes of an SPI communication should be > 10 ms (< 100 ms).

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4. Delay between final byte of one SPI communication and first byte (command byte) of the next SPI communication should be > 10 ms (< 100 ms).
5. Interval between bytes following the command byte of an SPI communication should be > 10 µs (< 100 µs).
6. Under certain circumstances the intervals may need to be longer i.e. the interval between one 'Get Histogram' communication sequence and the next should be greater than 0.5 s and ideally between 30-60 s to give a good average and smoother data. The interval after a 'Switch Peripherals/Fan on' sequence should be > 600 ms (< 2 s) to allow the firmware time to perform multiple attempts to switch the fan on.
   Normally users should allow a much longer time than this anyway e.g. 5-10 s to allow the fan to get up to speed. Following power-up, the OPC should be allowed at least 2 s to initialise before beginning SPI communication.
7. The first histogram data set in a session, or the first histogram obtained after any kind of error condition has passed, will have been recorded over an unknown sampling period and should be discarded.
8. The timings and SPI frequencies specified are guidelines only. Users may experiment with different timings at their own risk.
9. The SS connection to the OPC should be driven LOW during any SPI communication with the OPC.

OPC SPI Commands

A full list of current SPI commands given in 072-0501 Supplemental SPI information for OPC R1, a summary is listed in Appendix D. Further information is available from Alphasense directly.

8 Using the Alphasense Software

The software and necessary drivers to run the OPC from a computer (PC only) will be supplied with the unit initially, in the future it will be available from the Alphasense Website.

Full guided examples for installation using Microsoft Windows XP, 7, 8, 8.1 and 10 are given in Appendix B. We recommend that the Windows PC is running .NET version 3.5 or above.

Connecting the device and running the software

Connect the USB-SPI interface lead and OPC device to the PC. If you are prompted for device drivers refer to the previous section of the user manual. Double click the OPC-R1.exe icon to start the software application. When the application is first started the main form will be in ñstart-up modeòas shown in the next section.

Connect to the OPC-R1 by choosing the virtual COM port it is assigned to. Some text should appear in the softwareôs main text box indicating details of the OPC on successful connection. At this stage the OPC electronics are in default mode and the laser and the fan are switched off. Press Ctrl+R to read the configuration variables stored on the OPC.

There is no uninstall function for the software interface. The interface is stored as a set of files in a single folder (to be kept intact) and will run as a normal Windows application. The entire folder can be deleted or archived when redundant.

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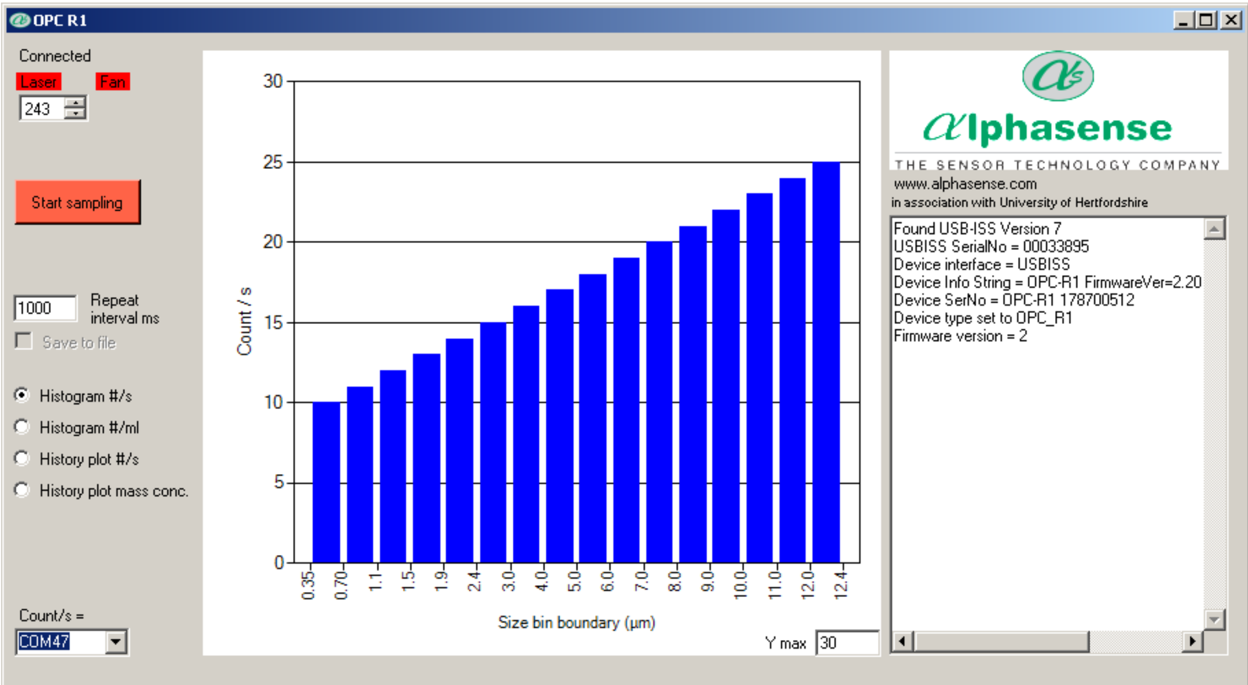
Data Display Screens and taking Measurements

Default start-up screen

Select the allocated COM port: A list of COM ports available on the PC/Laptop is displayed in the drop-down menu at the bottom-left of the screen. Select the correct port number; the software will not respond unless the port with the attached OPC-R1 device is selected.



- **Device information** (Right hand side text window): This shows hardware serial number and firmware versions currently installed on the OPC-R1.
- **Start sampling**: Starts data collection, note on the OPC-R1 this does not start the fan and the laser. The button will then show óStop samplingôto allow termination of the sampling process.
- **Laser and fan icons**: Clicking the laser and fan boxes turns the lasers and fan on. Note that changing the laser power will alter the unitôs response and will put the unit out of calibration. Fan speed cannot be varied on the OPC-R1.
- **Repeat interval ms**: Sets the duration (in milliseconds) over which a particle size histogram is acquired. The default is 1,000 ms. We recommend a maximum of 20,000 to 30,000 ms to avoid the risk of an individual size bin becoming full (65,536 counts). Longer intervals can be set in very clean environments.
- **Y max**: This sets the maximum y-axis value of the histogram screen display
- Histogram y-axis **'Counts/ s':** This displays the recorded counts per second in each size bin, regardless of the setting of the óRepeat interval msô For example, if a 10,000 ms sampling interval is set, the óCounts/ sôfigure will represent the average counts per second over that period. This average figure is also recorded in the CSV file.

Histogram Counts/s vs Particle Size display mode

When the **Start sampling** button is pressed, the OPC-R1 will first ask if the data are to be saved. Once answered, it will begin to display particle size histogram data and if selected it will store data to a specified file.

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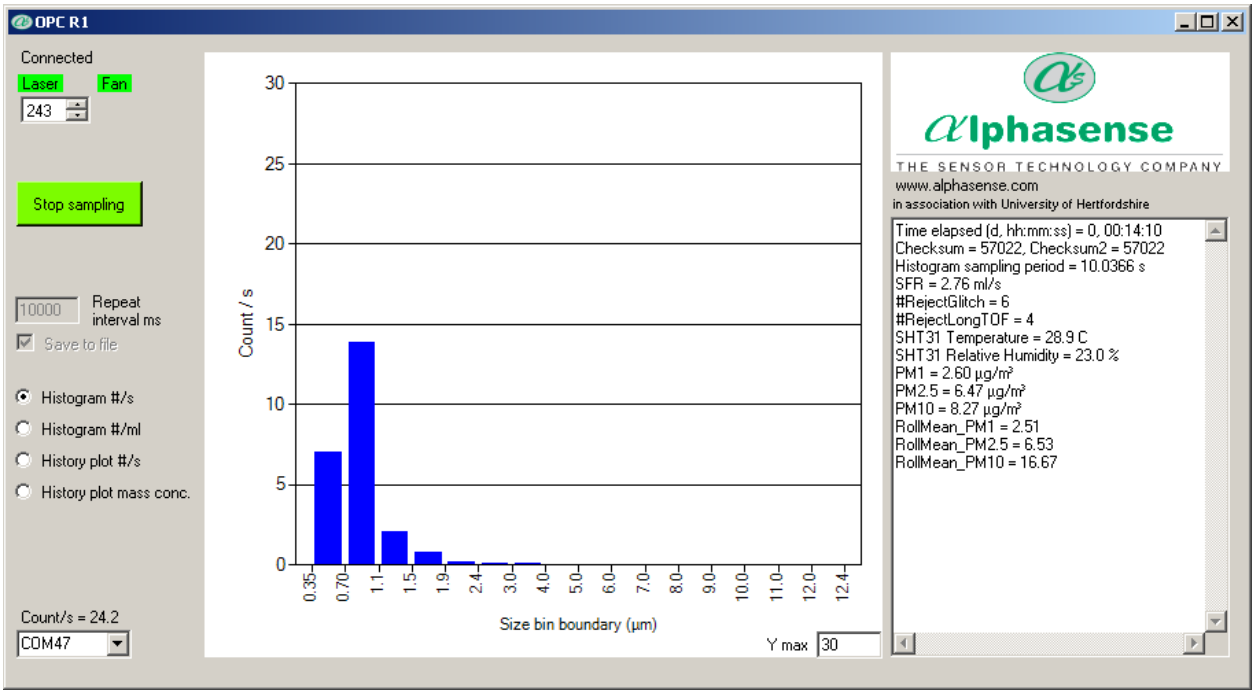

- Data relating to each acquired histogram, including PM values, is given in the right-hand window of the display. The RollMean_PM10, etc., are the current rolling mean values for PM evaluated over the previous 5 minutes or to the beginning of sampling if that is less time. The sample flow SFR, and temperature and humidity are also given.
- Reject Glitch and RejectLong TOF are an indication of the electronic noise and errors in timing, respectively. High values would suggest a problem with the unit or the set up.
- The total particle count rate per second across all size bins (Counts/ s) is displayed in the bottom-left of the screen.
- Clicking on the graph and pressing ďô(lower case L) will display the numerical values for each bin; pressing ďôagain will toggle it back.
- Note: if the laser cuts out, the display will show a pattern of alternate maximum and zero count values in bins across the whole size range of the R1, as shown below. The laser may shut down if unusual power spikes are detected. It can be reset first by trying a stop start cycle or a laser off and on cycle. If this is not successful then a power cycle may be required.

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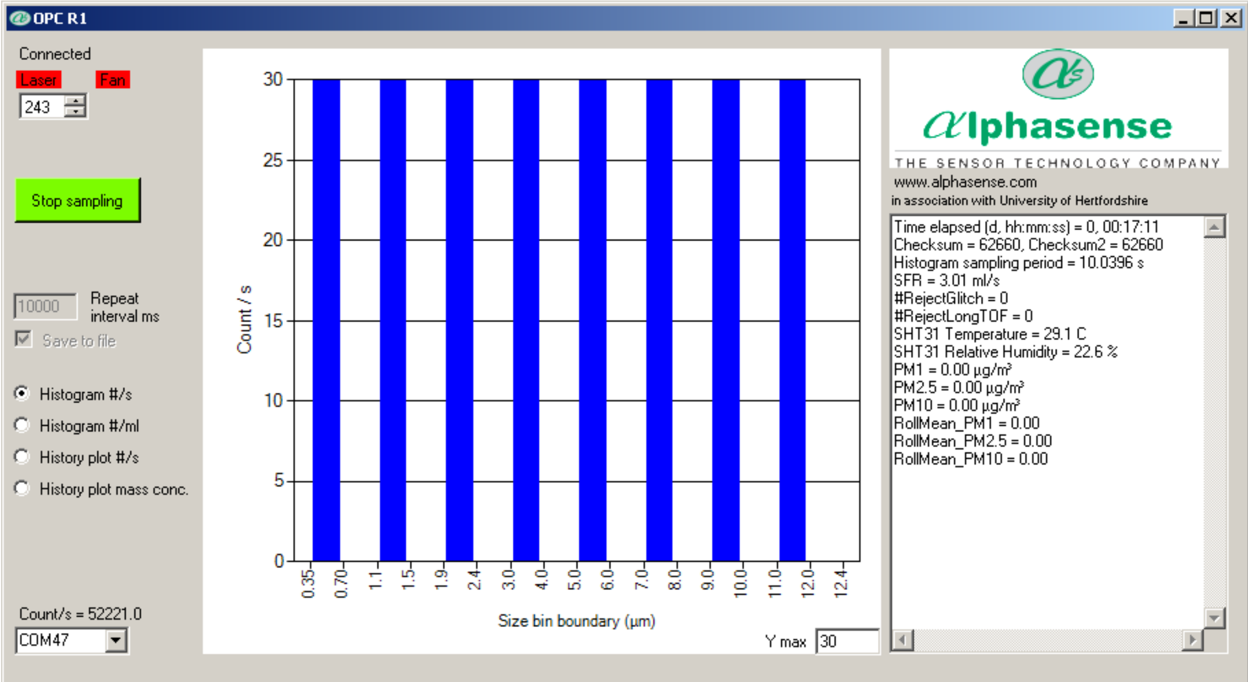
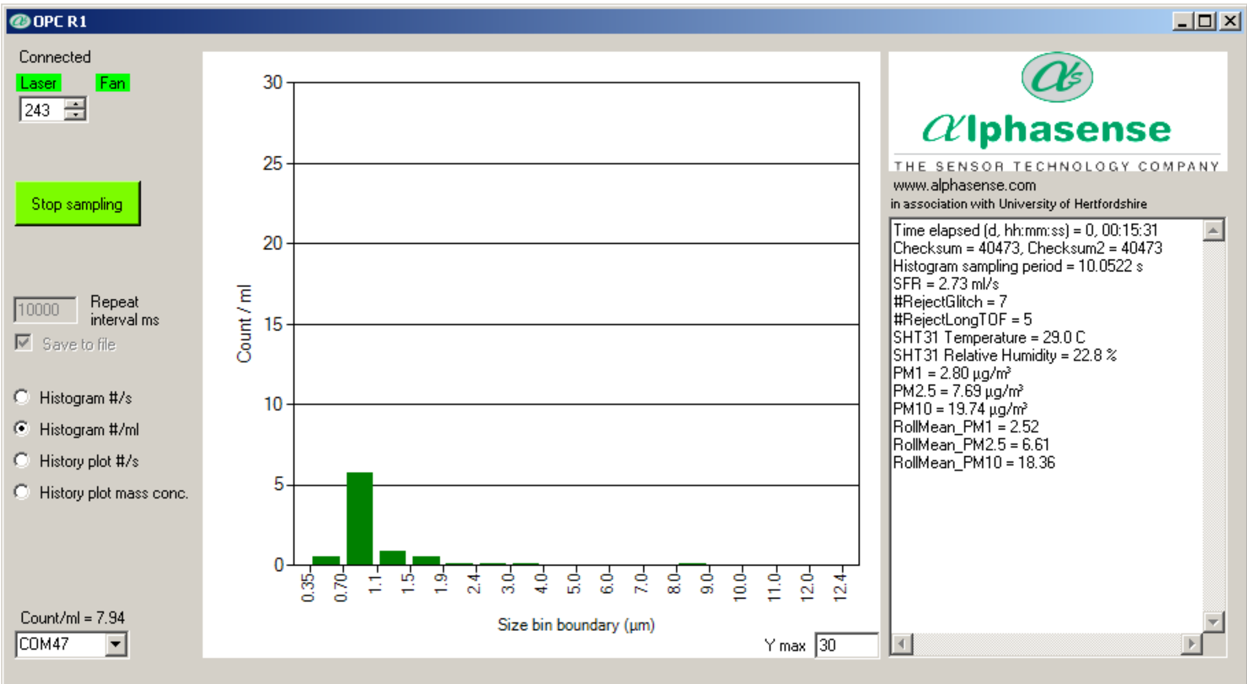


Histogram Number Concentration vs Particle Size display mode

Click the óHistogram #/mlôbutton on the left-hand side of the screen to show the recorded data in particle number concentration (particles per millilitre of sampled air) format, as below:



History Plot of Counts/s display mode

Click the óHistory plot #/sôbutton on the left-hand side of the screen to show a temporal record of the particle count rate since the start of the sampling session. The plot scale will automatically change to show longer recording time periods and/or increasing Counts/ s.

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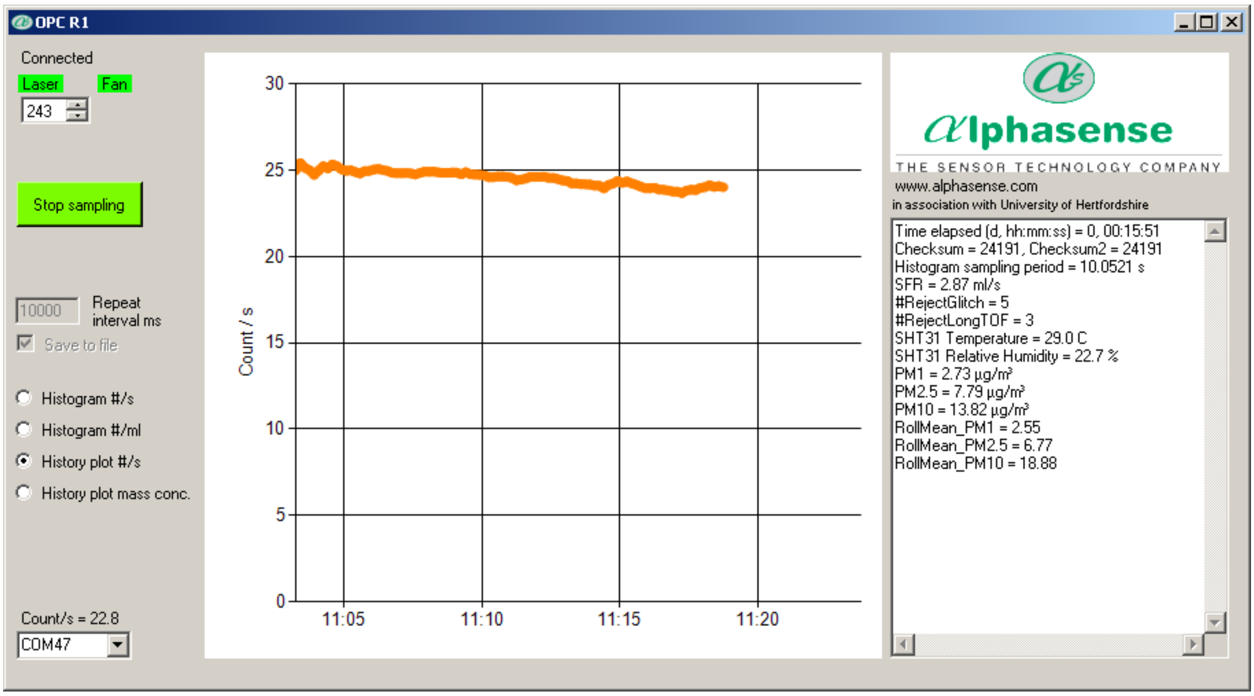
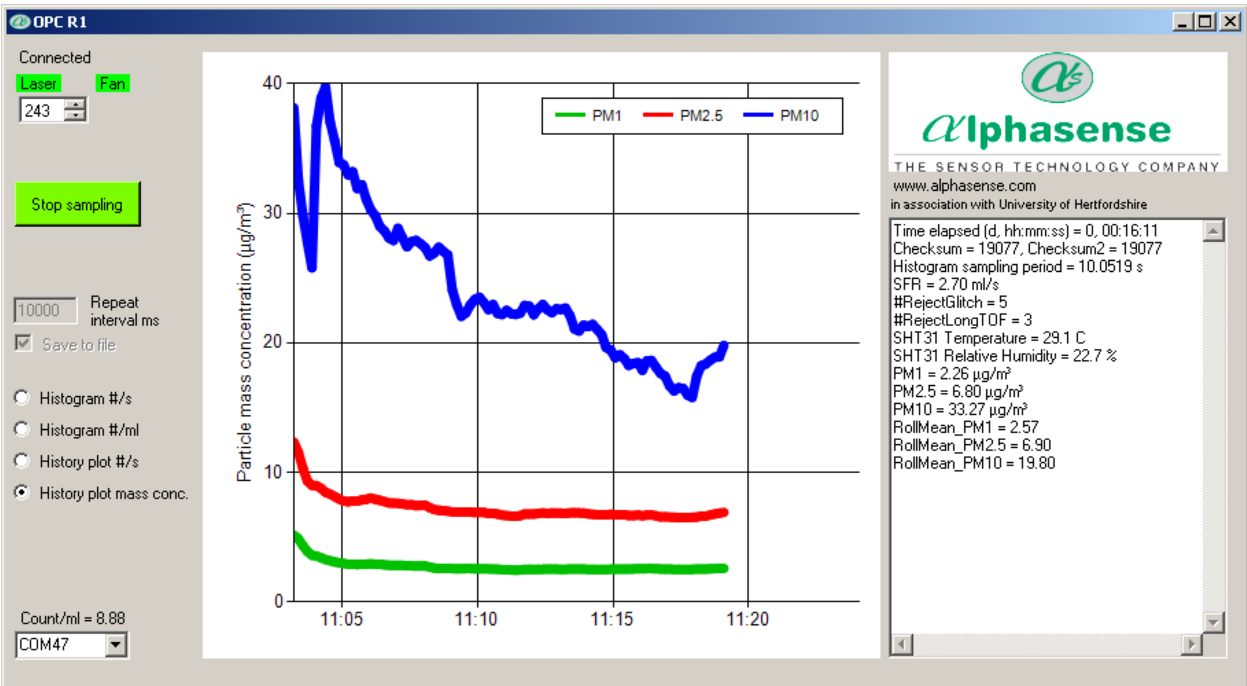


History Plot of Mass Concentration display mode

Click the ôHistogram plot mass conc.ôButton on the left-hand side of the screen to show a temporal record of PM_1, $PM_{2.5}$ and PM_{10} values (in µg/m^3) since the start of the sampling session. The plot scale will automatically change to show longer recording time periods and/or increasing PM values.



Data relating to each acquired histogram, including PM values, is given in the right-hand window of the display.

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Other Software Functions

Closing down the software
It is recommended that the software application is closed before removing the USB to SPI interface to avoid USB communication errors.

Log file
The application will also create a log file from all of the output bins into a single .CSV file. You will be asked if you require a log file after selecting the ñstartò button. If you select ñyesò you will be prompted for a file name and location to store the file. An example of the log file is included in the deployment package and the CSV output is explained later.

Firmware information
The information window on the right of the main form shows the firmware version installed as the software first loads up. For example
Info String = OPC-R1 FirmwareVer=2.21..................................BS

Firmware is upgraded via the SPI port using a Bootloader tool, see Appendix C for more details.

More firmware commands (via software)
There are four commands that can be used to edit factory settings through the OPC software:

1. Ctrl + R: Read and display all configuration variables. This will display the variables available to the user for edit. The data is displayed in the information window to the right of the software window. Changeable values can be over-written in this window.
2. Ctrl + W: Write all values to configuration memory. This command will write the current configuration values to volatile memory, this means that the user can run the OPC with their desired configuration but the changes will be reset once the power is disconnected.
3. Ctrl + S: Save all values to configuration memory. This command will write the current configuration values to non-volatile memory, this means that the user can permanently save their configuration values.
4. Shift Ctrl + W: This allows the Bin weighting Index to be changed.

Changing the PM values reported
The PM values can be changed to report $PM_{4.25}$ instead of one of the other PM values. Please note only 3 values in total can be reported. To carry this out connect the OPC-R1 to the Alphasense software as usual. Then:

1. Type Ctrl + R: Read and display all configuration variables. This will display the variables available to the user for edit. The data is displayed in the information window to the right of the software window.
2. Scroll to the bottom:
   PM values (A, B, C) (um)
   1
   2.5
   10
3. Overwrite one of these values with 4.25
4. Type Ctrl + W, followed by Ctrl + S.
5. The OPC will now report $PM_{4.25}$

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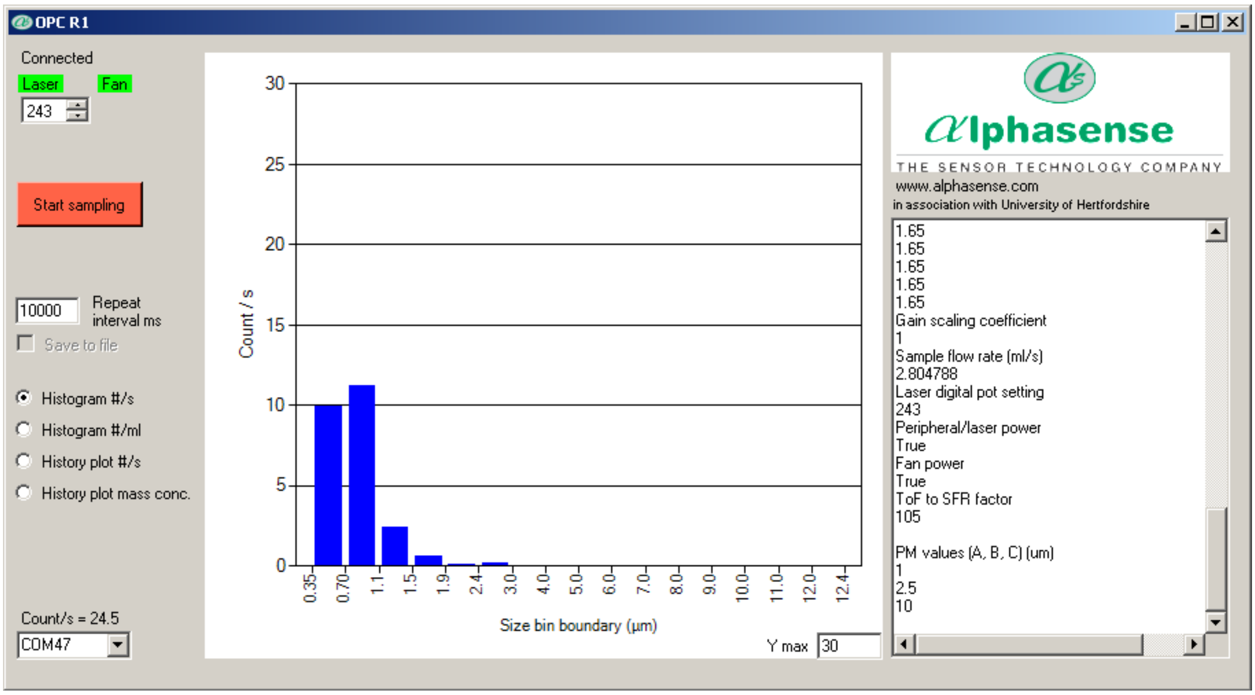

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Explanation of the CSVs

(Please note sheets are truncated to save space)

								Comment
Software ver: OPC-R1 Alphasense 1.0.6473.16786								
Device SerNo	SerNo: 178390116							Unit serial number
InfoString	OPC-R1 FirmwareVer=2.21.................................BS							Firm ware version
Laser digital pot setting	230							Laser setting
Gain scaling coeff	1							Unused Scaling coefficient set at 1
ToF to SFR factor	87							Scaler for dynamic fan speed correction
Bins	Bin00	Bin01	Bin02	Bin03	é ..	Bin15		
Bin low boundary (ADC o/p)	0	9	16	23	é ..	3256	4095	Final figure is top boundary of bin 15
Bin low boundary (particle diameter [um])	0.35	0.7	1.1	1.5	é ..	12	12.4	Final figure is top boundary of bin 15
Bin mean (particle diameter [um])	0.55	0.9	1.3	1.7	é ..	12.2		
Vol of a particle in bin (um3)	0.087	0.382	1.150	2.572	é ..	950.8		
Weighting for bin	1.65	1.65	1.65	1.65	é ..	1.65		Individual bin weighting

Data:																			
OADate Time	Bin00	é	Bin15	Mean ToF Bin1 (us)	é	Mean ToF Bin7 (us)	Count/s	Samp é Period (s)	SFR (ml/s)	#Reject Glitch	#Reject Long TOF	Temp (C)	Rel. Hum. %	PM1 (ug/m3)	é	PM10 (ug/m3)	Roll Mean_ PM1	é	Roll Mean_ PM10
42341.6282	8.001	é	0	6	é	0	20.00	1	0.79	0	0	29.3	39.2	1.38	é	6.85	1.38	é	6.85
42341.6282	5.946	é	1.982	9.33	é	0	18.83	1.009	0.79	1	0	29.4	39.5	1.09	é	198.75	1.24	é	102.8
42341.6282	8.003	é	0	7	é	0	32.01	1	0.79	0	0	29.4	39.8	2.36	é	108	1.61	é	104.53
42341.6282	7.925	é	0.991	5.67	é	0	28.72	1.01	0.78	0	0	29.4	39.9	1.88	é	149.15	1.68	é	115.69
42341.6282	8.008	é	0	6	é	0	23.02	0.999	0.79	1	0	29.5	39.9	1.46	é	87.34	1.63	é	110.02
42341.6282	11.997	é	0	6.67	é	0	25.99	1	0.79	0	0	29.5	39.7	1.74	é	3.56	1.65	é	92.27
42341.6282	4.954	é	0	7.67	é	23	20.80	1.009	0.8	0	1	29.5	39.5	1.52	é	12.79	1.63	é	80.92
	Counts per s in each bin			Used for dynamic fan compensation			Total counts per s across all bins		Sample flow through the OPC	Noise and invalid particle error indicator				Instantaneous PM1, 2.5, 10			5 minute averaged PM1, 2.5, 10		

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9 Running the OPC R1 using direct SPI control

Full details of the SPI commands and connections are available for the OPC-R1. This is should be sufficient for the user to be able to design their own SPI system to control the device and gather data.
A flow chart outlining simple operation of the OPC R1 is given in 072-0501 Supplemental SPI information for OPC-R1.

The R1 has a very low power off state unlike the OPC-N2, if the unit is placed into the low power mode we recommend that the fan and laser are powered up for a minimum of 10 s before taking a measurement.

10 Revision Control

Version	Comment	Release Date	Released by
A	First Draft	October 2017	Mark Giles
B	Second Draft	October 2017	Mark Giles
C	Third Draft	November 2017	Mark Giles
D	Fourth Draft	February 2018	Mark Giles
E	Fifth Draft	August 2018	Mark Giles
F	Sixth Draft	February 2019	Mark Giles
1	Issue 1	February 2019	Mark Giles

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Appendix A: FAQs

- **Can the OPC be connected to a gas flow at 500 SCCM (or similar)?**
  - The OPC is designed to sample ambient air using its own fan. Connecting to a pressurised system will alter the calibration and may also lead to deposition of particles on the inside of the unit. The OPC is also designed to have air pulled through it rather than blown into it.

- **What is the effect of low pressure (altitude)?**
  - Fans are constant volume devices and so, at altitude where the air density is lower, the mass transported through the fan will be reduced but the volume is constant (assuming the fan speed remains the same). The unit should operate normally at altitude with particle size and number concentrations being accurate. However, when ambient temperatures are expected to fall to below -10°C the system should be heated or well insulated to ensure correct operation of the OPC.

- **How are the units calibrated?**
  - The units are calibrated for sizing using controlled aerosols of monodisperse polystyrene latex microspheres of specific sizes. Aerosol number concentration is assessed by comparison to an OPC ógold standardô, previously calibrated against a certified TSI 3330 OPS instrument.

- **What maintenance can be carried out on the OPC-R1?**
  - The OPC-R1 does not have any user-serviceable parts. The fan and laser are both chosen to give good lifetimes. The flow path is designed to minimise particle deposition on any internal surfaces of the OPC. The unit must not be opened for cleaning as this may expose the worker to class 3B-laser radiation and could affect the calibration. Careful cleaning with compressed air may be successful but this should be discussed with Alphasense

- **Raspberry Pi and Arduino**
  - The OPC-R1 is ideally suited to be operated by devices such as Raspberry Pi or Arduino via its SPI interface. While Alphasense does not distribute OPC-R1 control programs to be used on these devices, many of its customers have successfully implemented such control programs following the OPC-R1 SPI commands list.

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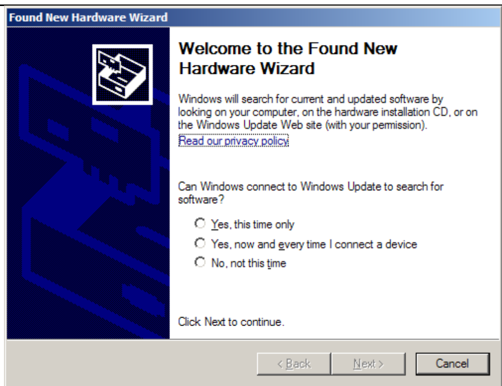
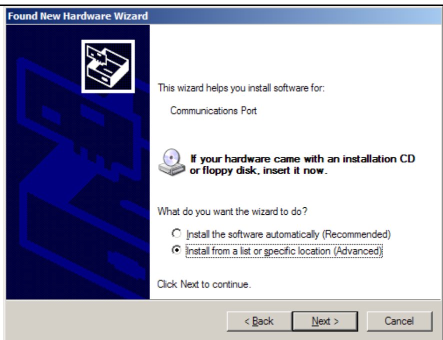
Appendix B: Installing the device driver (drivers unchanged from OPC-N2)

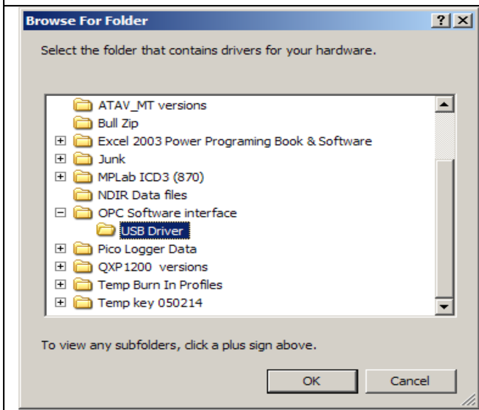
Windows XP

Copy the folder ñOPC Interface Softwareò to the PC desktop. Connect the USB interface lead to the PC. If the USB interface lead (USB to SPI converter) is connected to the PC for the first time, Windows will need a device driver and this will start the ñFound New Hardwareò wizard.
Select the ñYes, this time onlyò option and click next.



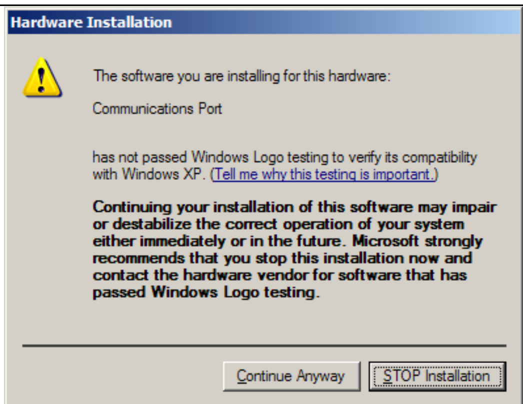
The following window will give you an option as to whether to use a CD to install the device driver or to use another location. Select ñInstall from a list or a specific location (Advanced)ò
Navigate to the OPC folder containing the folder named ñUSB Driverò this contains the file *devtech2.inf* needed to drive the OPC device.





Click OK to allow Windows to locate and install the device driver. This process is automatic but you will be prompted by the form below to confirm the installation.
Click ñContinue Anywayò to finish the installation.
Once the device driver is installed correctly, the OPC device should appear in the Device Manager window as a ñCommunication Portò with an assigned COM port number. Make a note of this assigned port number, as you will need it when starting the software.

The Driver installation is now complete.



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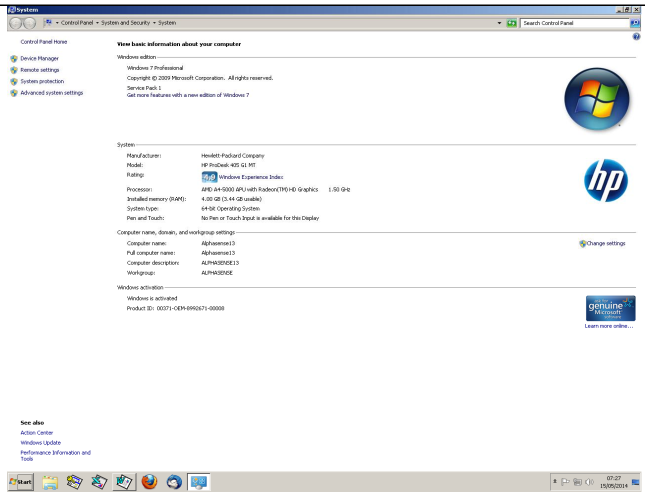
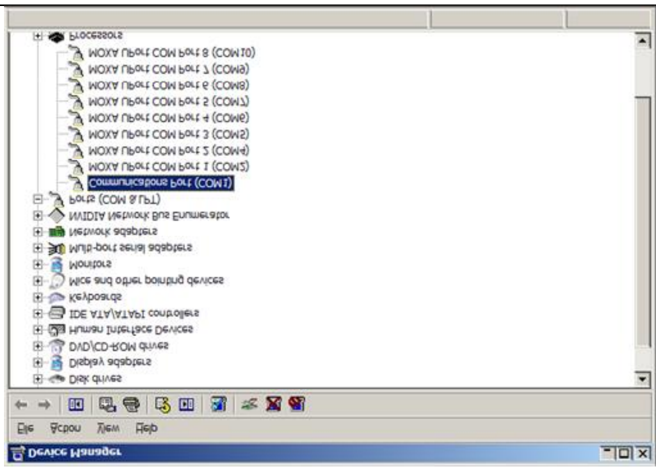
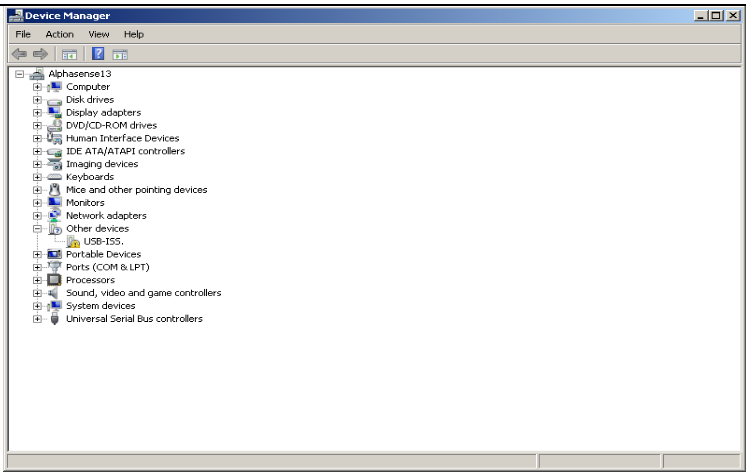
Windows 7	
Copy the folder ñOPC Interface Softwareòto the PC desktop. Connect the USB interface lead to the PC. If the USB interface lead (USB to SPI converter) is connected to the PC for the first time, Windows will need a device driver.	
Open the system properties and locate the device manager.	
Windows 7 will show the new device as ñUSB-ISSòwith a yellow exclamation mark indicating a driver problem.	

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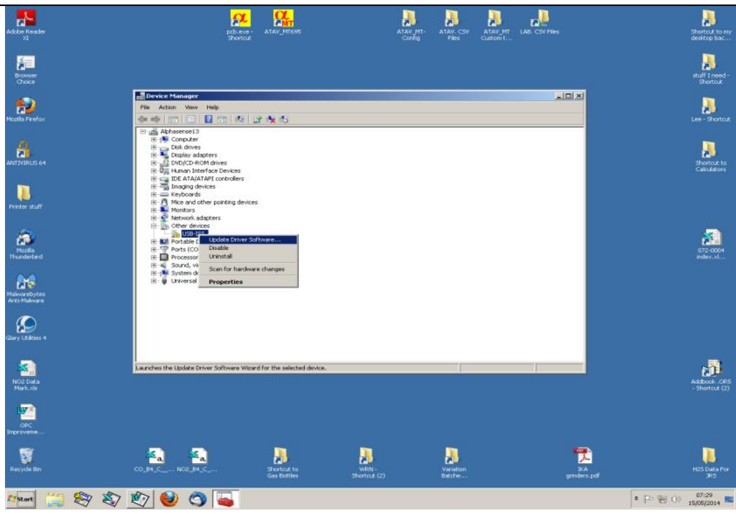
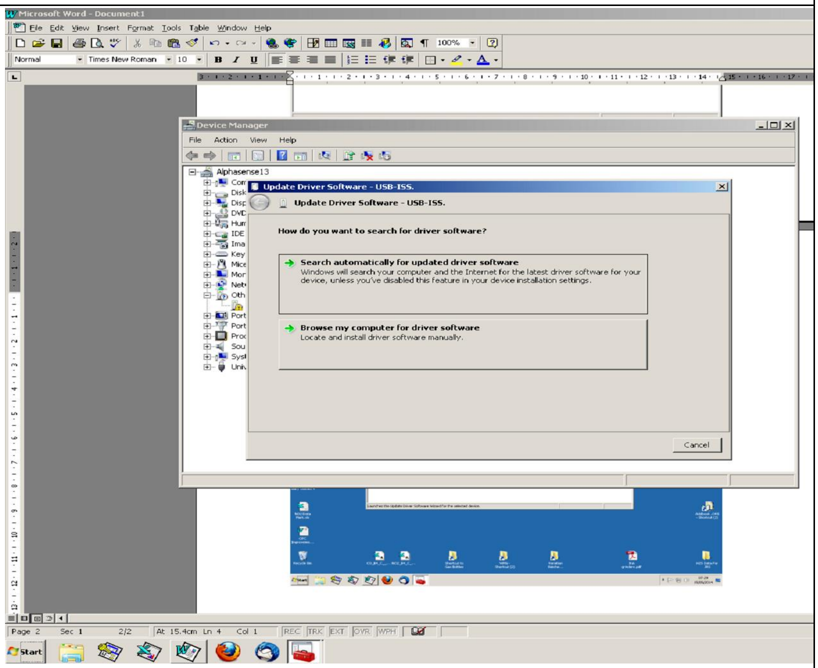
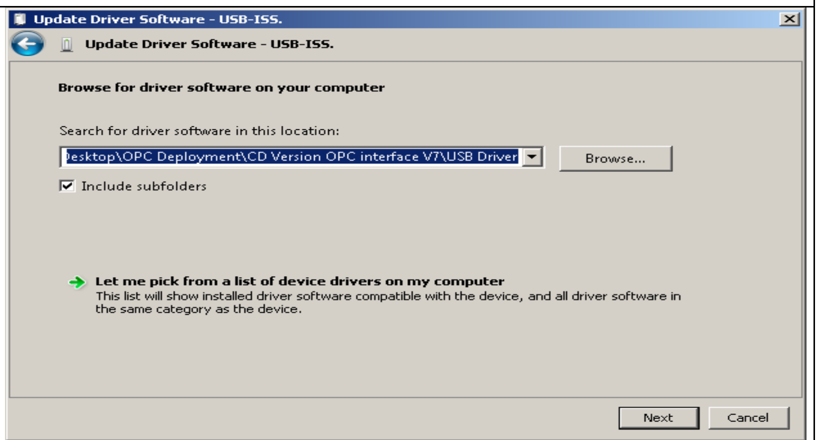
Right click the icon and select ñUpdate Driver Softwareò	
Select the ñBrowse my computer for driver softwareòoption.	
Navigate to the folder ñOPC Interface Softwareòcopied to your desktop and locate the folder named ñUSB Driverò. Click Next.	

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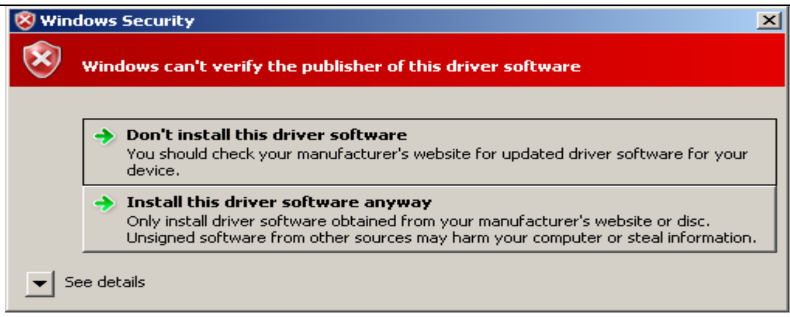
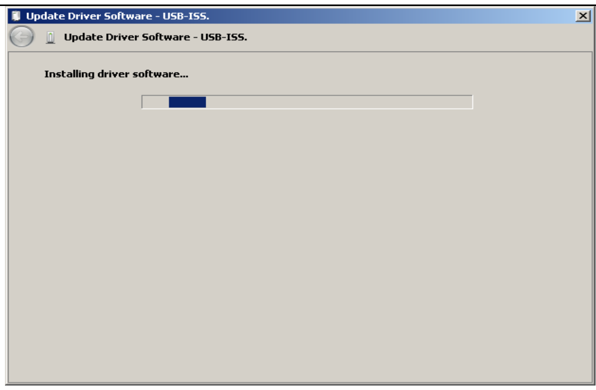
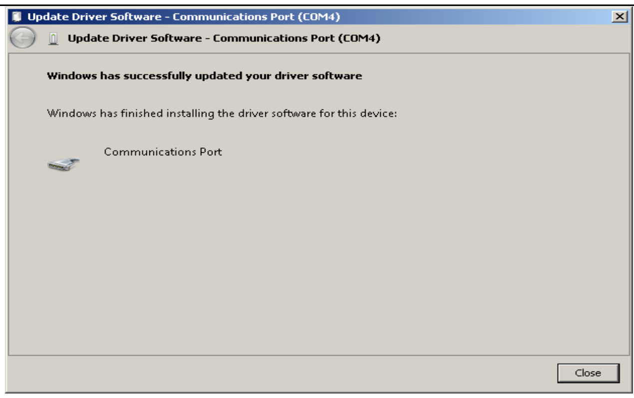
Windows 7 will then issue a security warning. This is due to a licence issue and not a concern to the operating system. Select the "Install this driver software anyway" option.



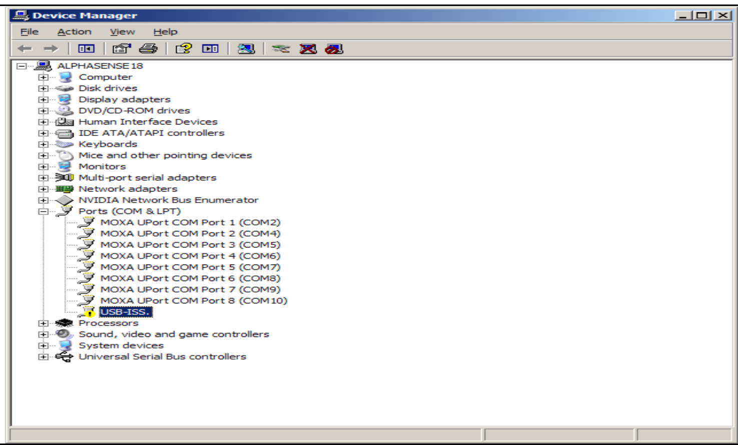
Windows will then install the driver files for the device.



Once the device driver software has been installed the form below will be displayed. Make a note of the allocated COM port number (COM4 in the example below).



If the device driver is installed incorrectly the Device Manager will indicate this with a yellow exclamation mark symbol shown below.
If this should happen, remove the USB lead and uninstall the device by right clicking the symbol and selecting "Uninstall". Return to the beginning of the "Installing the device driver" (Windows XP or Windows 7) section.



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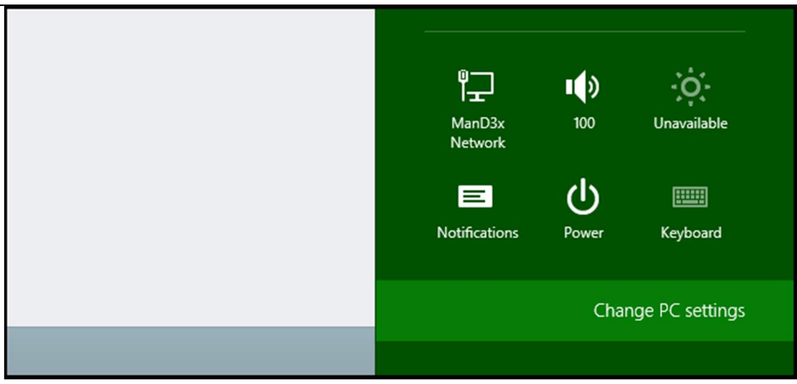
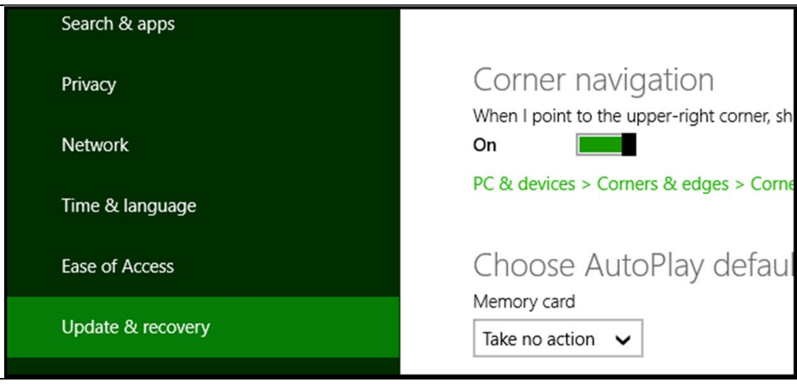
Windows 8, 8.1 and 10

This procedure will guide you through the process of disabling the digital device driver verification in Windows 8, 8.1 and 10. The method for 8.0 is different than for 8.1 and 10.

Background
64-Bit editions of Windows require digitally signed drivers. Digitally signed drivers include an electronic fingerprint that indicates which company produced the driver as well as an indication as to whether the driver has been modified since the company released it. This increases security, as a signed driver that has been modified will no longer have an intact signature. Drivers are signed using code signing certificates. The driver for the SPI converter does not have a Microsoft endorsed signature so this protection must be circumvented.

How to Disable Driver Signature Verification on Windows 8.0

<table>
<tr>
<td>Press the Win + C keyboard combination to bring up the Charms Bar, then click on the Settings Charm.</td>
<td>
</td>
</tr>
<tr>
<td>We need to head into the Modern Control Panel, so go ahead and click on the Change PC settings link.</td>
<td>
</td>
</tr>
<tr>
<td>When the Control Panel opens, switch over to the ñUpdate & recoveryòsection.</td>
<td>
</td>
</tr>
</table>

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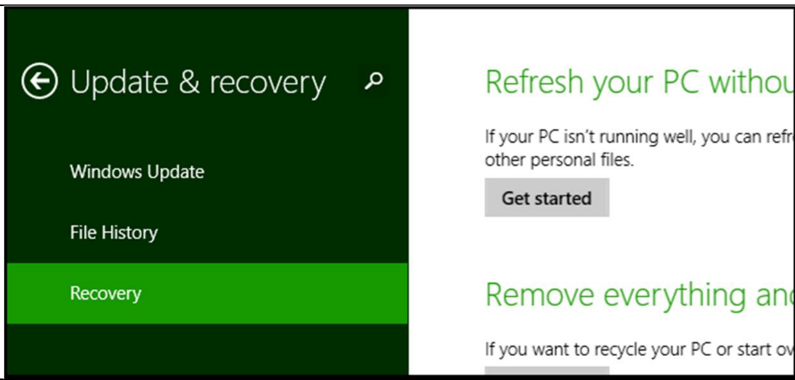
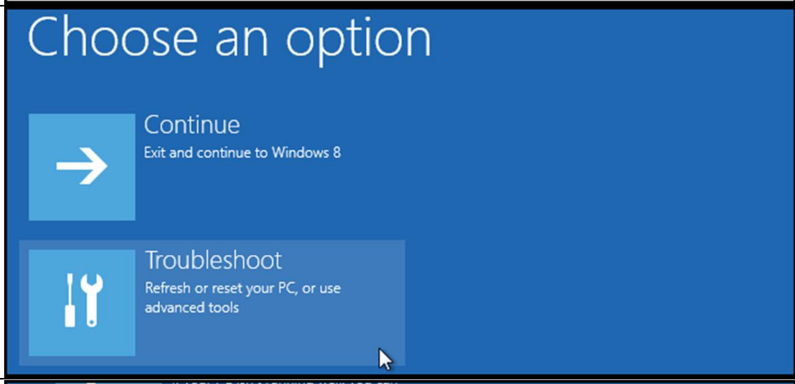
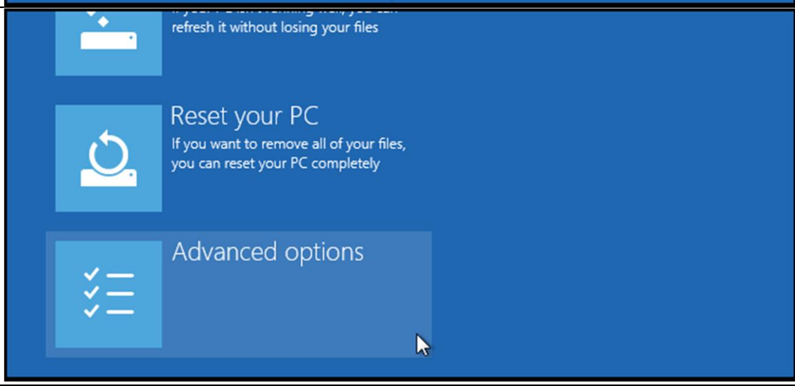
Then click on the Recovery option on the left hand side.	
Once selected, you will see an advanced startup section appear on the right hand side. You will need to click on the ñRestart nowòbutton.	
Once your Computer has rebooted you will need to choose the Troubleshoot option.	
Then head into Advanced options.	

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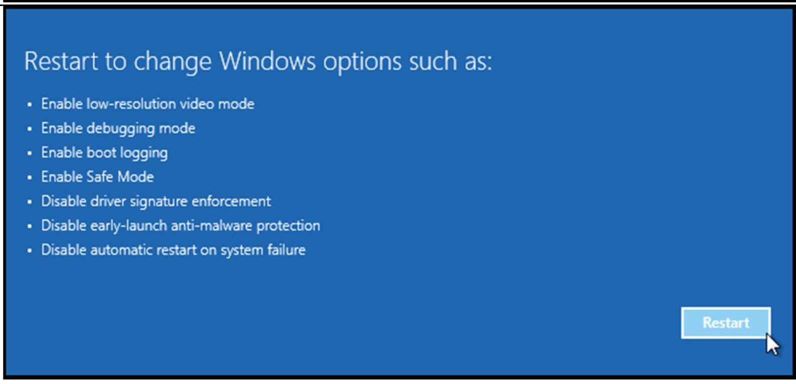
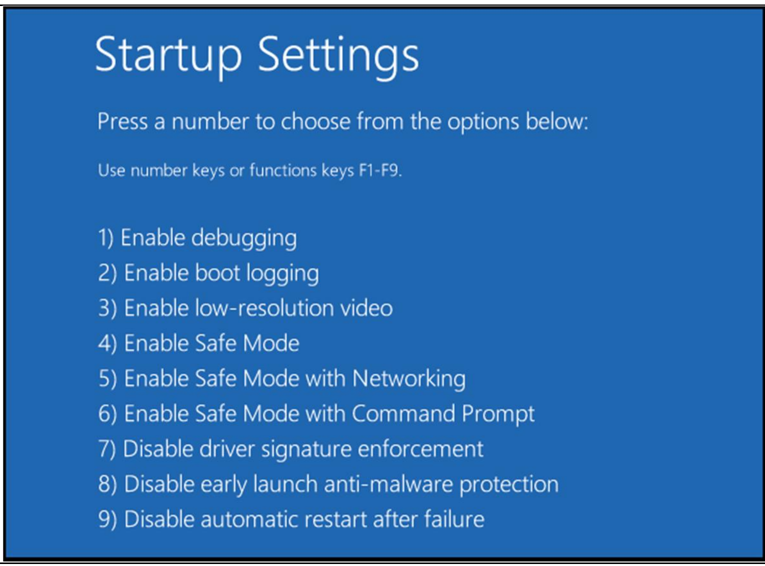
Then Startup Settings.

Since we are modifying boot time configuration settings, you will need to restart your Computer one last time.



Finally, you will be given a list of startup settings that you can change. The one we are looking for is ñDisable driver signature enforcementò To choose the setting, you will need to press the **F7** key.
Your PC will then reboot and you will be able to install unsigned drivers without any error message. You should then be able to install the driver for the SPI connector in the standard manner.



How to Disable Driver Signature Verification on Windows 8.1 and 10

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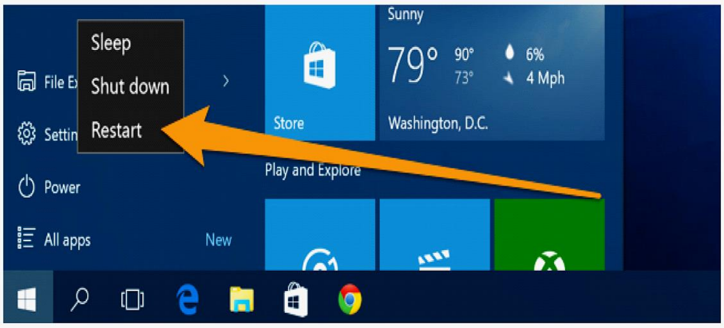
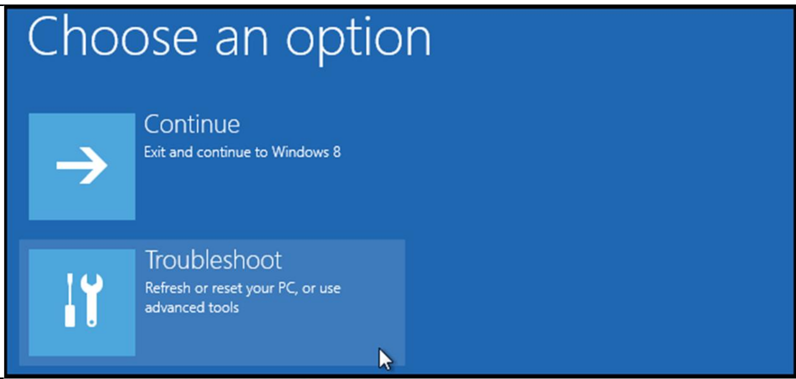
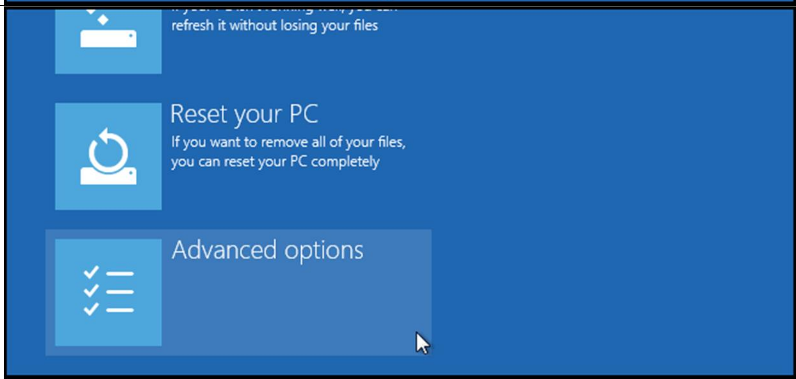
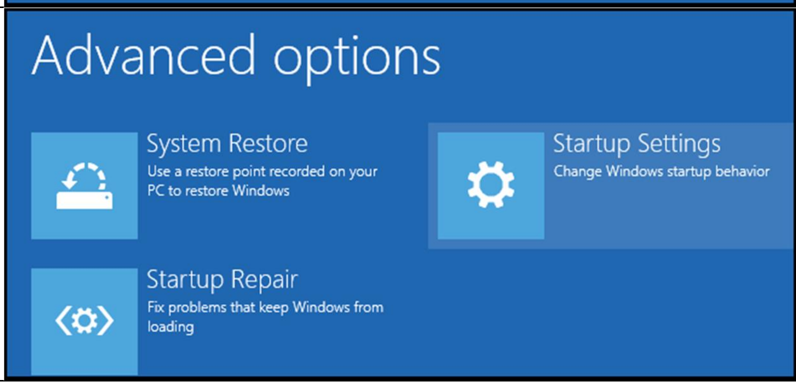
<table>
<tr><td>To disable the signature verification it is necessary to get into Troubleshooting options from the boot manager. Select Restart from the power options menu (for Windows 8 this is under Charms on the login screen and on Windows 10 this is on the start Menu. Hold down the shift key whilst clicking restart.</td><td>
</td></tr>
<tr><td>Once your Computer has rebooted you will need to choose the Troubleshoot option.</td><td>
</td></tr>
<tr><td>Then head into Advanced options.</td><td>
</td></tr>
<tr><td>Then Startup Settings.</td><td>
</td></tr>
</table>

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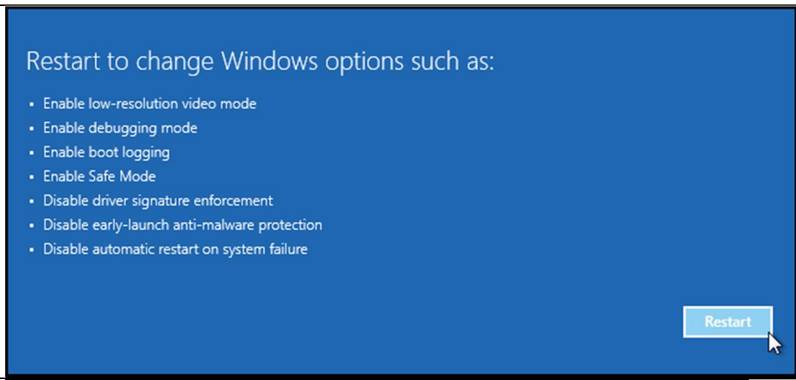
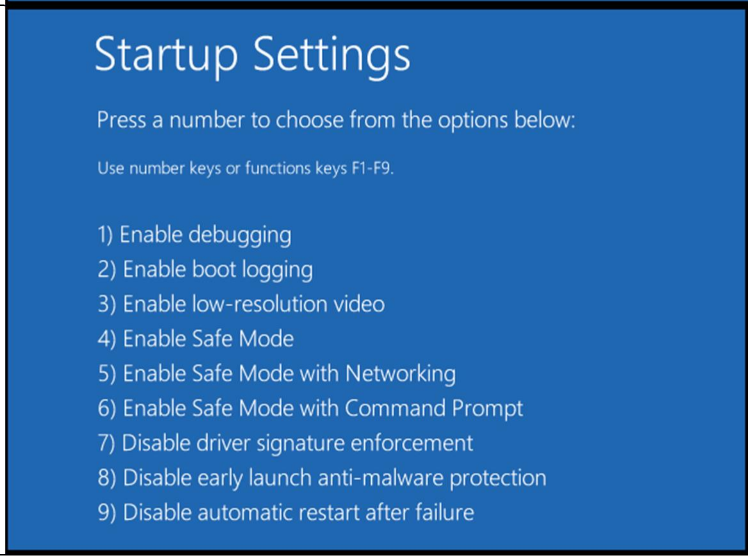
Since we are modifying boot time configuration settings, you will need to restart your Computer one last time.	
Finally, you will be given a list of startup settings that you can change. The one we are looking for is ŕDisable driver signature enforcementà To choose the setting, you will need to press the **F7** key. Your PC will then reboot and you will be able to install unsigned drivers without any error message. You should then be able to install the driver for the SPI connector in the standard manner.	

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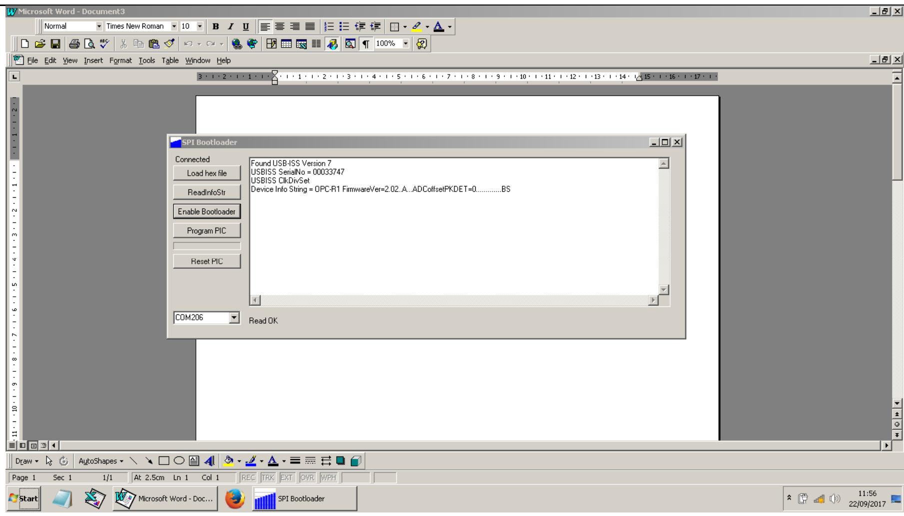
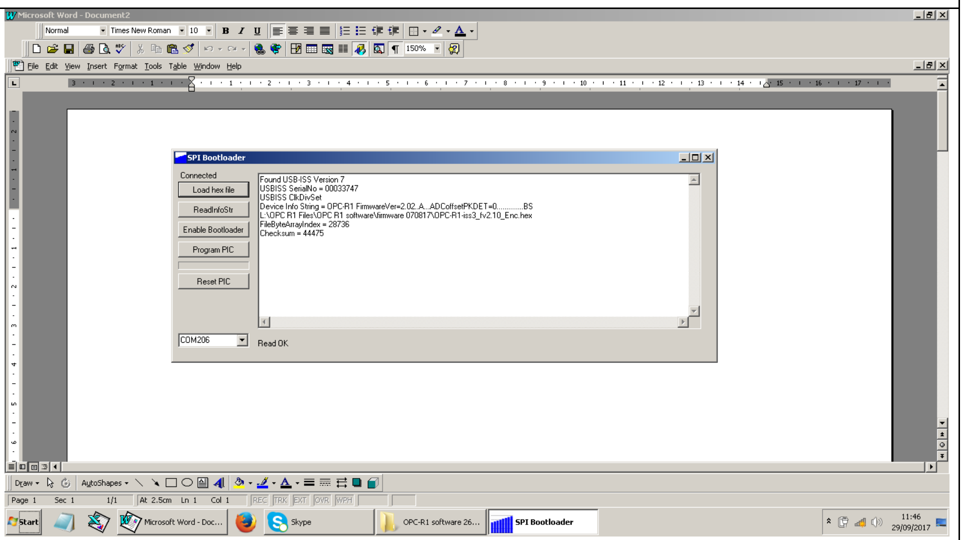
Appendix C: Updating the Firmware

Firmware is updated on the OPC-R1 device using the supplied Bootloader tool. This will be supplied with the appropriate hex files, when needed. Please note the method is different than with the OPC-N2. Please record the laser setting and ToF to SFR factor before updating the firmware as this may be reset to default, once updated. To upgrade the firmware on your OPC-R1 device requires:

- Bootloader tool
- Alphasense USB to SPI converter
- New firmware upgrade package including the firmware file (.HEX).

To upgrade the firmware file follow the instruction below:

1. Open SPI bootloader software. Connect the OPC-R1 to the computer using the SPI convertor Connect to the correct comms port using the drop down at bottom left 2. Press Enable bootloader	
3. Press Load hex file and navigate to the new firmware file that needs to be installed. 4. Press Program pic 5. Press Rest pic 6. Select none in the COM port selection box to disconnect the OPC from the bootloader tool	

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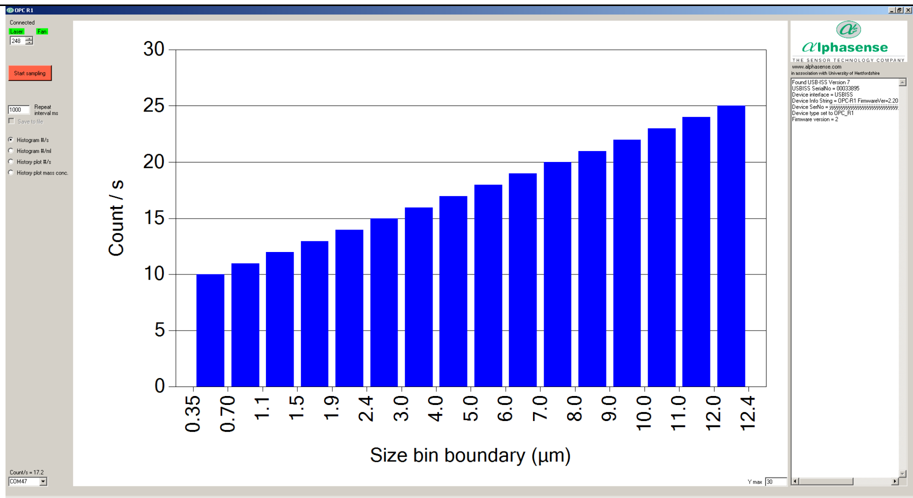
7. Re-establish communications with the OPC using the OPC software, this will confirm that the new firmware file has been installed correctly and is ready for use.
8. Press Ctrl+R to check that the displayed config data is upto date and also that the laser DAC settings are returned to the original setting. See the main section of the manual for information on setting EEPROM configuration.



Appendix D: Summary of firmware commands

OPC-R1 SPI functions (from point of view of SPI Master system) for firmware versions 2.01-2.21.

Function	**Command byte**	**Byte(s) out**	**Byte(s) in (0xF3 is set as standard initial return byte value from OPC-R1)**	**Notes**
Peripheral/fan power ON/OFF	**0x03**	0x03	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x03	0xF3	
		Option byte	0x03	Bit 0 of this byte corresponds to peripheral (laser) power. Bit 1 corresponds to fan power. Bit value = 1 for ON, 0 for OFF.
Digital pot Set Laser Power	**0x04**	0x04	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x04	0xF3	
		LaserDAC	0x04	LaserDAC is an unsigned 8bit integer.
Set Bin Weighting Index	**0x05**	0x05	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x05	0xF3	
		BinWeightingIndex	0x05	BinWeightingIndex (0-10) is an unsigned 8bit integer that represents the index of the preset bin weightings to use.

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Read information string	**0x3F**	0x3F	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x3F	0xF3	
		0x3F	InfoStr ascii char00: "O" (=0x4F)	SerialStr is a string of 60 characters. Note an example is given exact outpurt is dependant on FW
		0x3F	InfoStr ascii char01: "P" (=0x50)	Value of shaded bytes doesn't matter.
		0x3F	InfoStr ascii char02: "C" (=0x43)	
		0x3F	InfoStr ascii char03: "-" (=0x2D)	
		0x3F	InfoStr ascii char04: "R" (=0x52)	
		0x3F	InfoStr ascii char05: "1" (=0x31)	
		0x3F	InfoStr ascii char06: " " (=0x20)	
		0x3F	InfoStr ascii char07: "F" (=0x46)	
		0x3F	InfoStr ascii char08: "i" (=0x69)	
		0x3F	InfoStr ascii char09: "r" (=0x72)	
		0x3F	InfoStr ascii char10: "m" (=0x6D)	
		0x3F	InfoStr ascii char11: "w" (=0x77)	
		0x3F	InfoStr ascii char12: "a" (=0x61)	
		0x3F	InfoStr ascii char13: "r" (=0x72)	
		0x3F	InfoStr ascii char14: "e" (=0x65)	
		0x3F	InfoStr ascii char15: "V" (=0x56)	
		0x3F	InfoStr ascii char16: "e" (=0x65)	
		0x3F	InfoStr ascii char17: "r" (=0x72)	
		0x3F	InfoStr ascii char18: "=" (=0x3D)	
		0x3F	InfoStr ascii char19: "0" (=0x30)	
		0x3F	InfoStr ascii char20: "2" (=0x32)	
		0x3F	InfoStr ascii char21: "." (=0x2E)	
		0x3F	InfoStr ascii char22: "1" (=0x32)	
		0x3F	InfoStr ascii char23: "0" (=0x2E)	
		0x3F	InfoStr ascii char24: "." (=0x2E)	
		0x3F	é é é .	See 072-0501 for full details
		0x3F	InfoStr ascii char59: "S" (=0x53)	
Read serial number string	**0x10**	0x10	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x10	0xF3	
		0x10	SerialStr ascii char00	SerialStr is a string of 60 characters.
		0x10	SerialStr ascii char01	Value of shaded bytes doesn't matter.
		0x10	é é é é é é é é é ..	See 072-0501 for full details
		0x10	SerialStr ascii char59	

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Write serial number string	**0x11**	0x11	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x11	0xF3	
		SerialStr ascii char00	0x11	SerialStr is a string of 60 characters. This string can only be written once.
		SerialStr ascii char01	SerialStr ascii char00	
		SerialStr ascii char58	é é é é é é é é é .	See 072-0501 for full details
		SerialStr ascii char59	SerialStr ascii char58	
Read Firmware Version	0x12	0x12	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x12	0xF3	
		0x12	FirmwareVerMajor	FirmwareVerMajor is unsigned 8bit integer variable.
		0x12	FirmwareVerMinor	FirmwareVerMinor is unsigned 8bit integer variable.
Read Configuration Variables				See 072-0501 for full details
Write Configuration Variables				See 072-0501 for full details
Read histogram data (and reset histogram)	**0x30**	0x30	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x30	0xF3	
		0x30	Bin0 LSB	Bin Counts (Bin0 - Bin15) are unsigned 16bit integer variables.
		0x30	Bin0 MSB	Value of shaded bytes doesn't matter.
		0x30	é é é é .	
		0x30	Bin15 LSB	
		0x30	Bin15 MSB	
		0x30	Bin1 MToF	'MToF' is an unsigned 8bit integer that represents the average
		0x30	Bin3 MToF	amount of time that particles sized in the stated bin took to
		0x30	Bin5 MToF	cross the OPC's laser beam. Each value is in 1/3 us. i.e. a value
		0x30	Bin7 MToF	of 10 would represent 3.33us.

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		0x30	Sample Flow Rate Byte0	'Sample Flow Rate' is a float variable occupying 4 bytes that represents the sample flow rate in ml/s.
		0x30	Sample Flow Rate Byte1	
		0x30	Sample Flow Rate Byte2	
		0x30	Sample Flow Rate Byte3	
		0x30	Temperature Byte0	Temperature is unsigned 16bit integer.
		0x30	Temperature Byte1	
		0x30	Relative humidity Byte0	Relative humidity is unsigned 16bit integer.
		0x30	Relative humidity Byte1	
		0x30	Sampling Period Byte0	Sampling Period' is a float variable occupying 4 bytes and is a
		0x30	Sampling Period Byte1	measure of the histogram's actual sampling period in seconds.
		0x30	Sampling Period Byte2	
		0x30	Sampling Period Byte3	
		0x30	Reject count Glitch	'Reject count Glitch' is unsigned 8bit integer.
		0x30	Reject count Long	'Reject count Long' is unsigned 8bit integer.
		0x30	PM_A Byte0	PM_A is a float variable occupying 4 bytes. Units are ug/m3.
		0x30	PM_A Byte1	
		0x30	PM_A Byte2	
		0x30	PM_A Byte3	
		0x30	PM_B Byte0	PM_B is a float variable occupying 4 bytes. Units are ug/m3.
		0x30	PM_B Byte1	
		0x30	PM_B Byte2	
		0x30	PM_B Byte3	
		0x30	PM_C Byte0	PM_C is a float variable occupying 4 bytes. Units are ug/m3.
		0x30	PM_C Byte1	
		0x30	PM_C Byte2	
		0x30	PM_C Byte3	
		0x30	Checksum Byte0	Checksum is unsigned 16bit integer.
		0x30	Checksum Byte1	
Read PM data (and reset histogram)	**0x32**	0x32	0x31	Suggest that 10 ms be used as delay between command byte and following byte.

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		0x32	0xF3	
		0x32	PM_A Byte0	PM_A is a float variable occupying 4 bytes. Units are ug/m3.
		0x32	PM_A Byte1	
		0x32	PM_A Byte2	
		0x32	PM_A Byte3	
		0x32	PM_B Byte0	PM_B is a float variable occupying 4 bytes. Units are ug/m3.
		0x32	PM_B Byte1	
		0x32	PM_B Byte2	
		0x32	PM_B Byte3	
		0x32	PM_C Byte0	PM_C is a float variable occupying 4 bytes. Units are ug/m3.
		0x32	PM_C Byte1	
		0x32	PM_C Byte2	
		0x32	PM_C Byte3	
		0x32	Checksum Byte0	Checksum is unsigned 16bit integer.
		0x32	Checksum Byte1	
Save Configuration Variables in non-volatile memory	**0x43**	0x43	0x31	Suggest that 10 ms be used as delay between command byte and following byte.
		0x43	0xF3	
		0x3F	0x43	Initial command byte must be followed by sequence of bytes (shown in red).
		0x3C	0x3F	
		0x3F	0x3C	
		0x3C	0x3F	
		0x43	0x3C	
Check Status	**0xCF**	0xCF	0x31	
		0xCF	0xF3	
Reset	**0x06**	0x06	0x31	
		0x06	0xF3	
Enter bootloader mode	**0x41**	0x41	0x31	
		0x41	0xF3	

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In response to any initial command byte, the OPC-R1 should return a byte of value 0x31, indicating it is busy.
Upon receiving a command byte OPC-R1 will stop its activities and prepare data for a response if required.
During this period, until the response data is ready, if further bytes are sent to the OPC-R1, the returned byte will continue to be 0x31 (busy). When the OPC-R1 has prepared its response data it will load the SPI buffer with a byte value 0xF3 to indicate it is ready to transfer data.
The command byte value must remain consistent with the original command byte value sent for the command to be validated by the OPC-R1. If it is not, the OPC-R1 will load the SPI buffer with 0x31 (busy) value and return to its normal mode of operation. THE SAMPLING TRIGGER WILL NOT BE ARMED IF THIS OCCURS. Rearming of the trigger can be achieved by a successful histogram or PM data request.

To communicate with the OPC-R1, the SPI master should poll the OPC-R1 with the command byte value, checking the returned byte for the value 0x31 (busy) or 0xF3 (ready). The first returned byte should always be 0x31 (busy). Subsequent returned bytes will either be 0x31 (busy) or 0xF3 (ready) depending on the status of the OPC-R1. If another byte value is received by the SPI master at this stage, an error has occurred and communication should cease for > 2s to allow the OPC-R1 to realise the error and clear its buffered data. The SPI master should also clear any buffered data.

We recommend that the command byte polling interval is 10 ms and the delay between byte transfers following a receipt of byte value 0xF3 (ready) is 10 µs.

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Appendix E Checksum

A 16-bit CRC checksum is transmitted after each histogram data set, which can be used, if desired, to verify the data sent. If the OPC is configured to only transmit PM data, a checksum will still accompany this data.
The CRC calculation is a 16-bit method similar to that used in MODBUS communication. It uses the generator polynomial value 0xA001 and is initialised to 0xFFFF. Example 'C' programming code showing how the checksum can be recalculated is shown.

```
unsigned int CalcCRC(unsigned char data[], unsigned char nbrOfBytes)
{
  #define POLYNOMIAL 0xA001 //Generator polynomial for CRC
  #define InitCRCval 0xFFFF //Initial CRC value

  unsigned char _bit; // bit mask
  unsigned int crc = InitCRCval; // initialise calculated checksum
  unsigned char byteCtr; // byte counter

  // calculates 16-Bit checksum with given polynomial
  for(byteCtr = 0; byteCtr < nbrOfBytes; byteCtr++)
  {
    crc ^= (unsigned int)data[byteCtr];
    for(_bit = 0; _bit < 8; _bit++)
    {
      if (crc & 1) //if bit0 of crc is 1
      {
        crc >>= 1;
        crc ^= POLYNOMIAL;
      }
      else
        crc >>= 1;
    }
  }
  return crc;
}
```

End of Manual

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