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-N2 for measuring PM_1, $PM_{2.5}$ and PM_{10}, as well as measuring particle size distributions in real time.

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

A full deployment package will have been provided with the OPC-N2. This is supplied either on a CD or on the SD card on the unit. The SD card can be accessed simply by attaching the OPC to your computer using a micro USB cable.

Full instructions for carrying out the installation, (specifically a driver must be installed for the SPI adapter) and for the use of the software can be found later in this document, Appendix B.

You can view the data options along with the data resolution and range when the OPC-N2 is connected to a PC running the Alphasense-supplied software. This also provides a useful reference to those customers who wish to develop their own software.

The OPC-N2 can work in standalone mode, where the data is stored directly to the onboard SD card. To make full use of these features by changing parameters it is necessary to use the supplied software or be able to send SPI commands through your own interface.

Please note that the on-board temperature and pressure sensor is now an optional extra on the OPC-N2.

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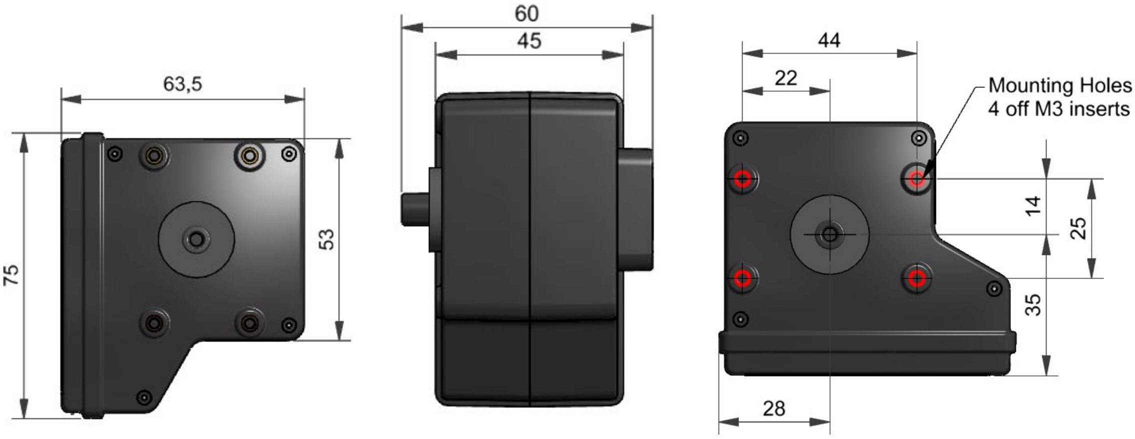
2 OPC-N2 Specification



All dimensions in millimetres (± 0.15 mm)

MEASUREMENT		
Particle range (µm)	Spherical equivalent size (based on RI of 1.5+i0)	0.38 to 17
Size categorisation (standard)	Number of software bins	16
Sampling interval (seconds)	Histogram period (recommended)	1 to 10
Total Flow rate (typical)	L/ min	1.2
Sample flow rate (typical)	mL/ min	220
Max particle count rate	Particles/ second	10,000
Detection limits (PM_{10})	Minimum	0.01 µg/m^3
	Maximum	1 500 mg/m^3
Coincidence probability	% at 10^6 particles/ L	0.84

POWER		
Measurement mode	mA (typical)	175
Non-measurement mode	mA (typical) Laser at minimum power; fan off	95
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), USB 2.0
Data storage	micro SD	16 GB
USB VID		Ox04D8
USB PID		OxF3D5
Laser classification	as enclosed housing	Class 1
Temperature range	°C	-20 to 50
Humidity range	% rh (continuous)	0 to 95 (non-condensing)
Weight	g	< 105

Table 1. Power and environmental performance limits

Ricardo AEA will certify performance and calibration, following ISO 17025 standard, this is ongoing.

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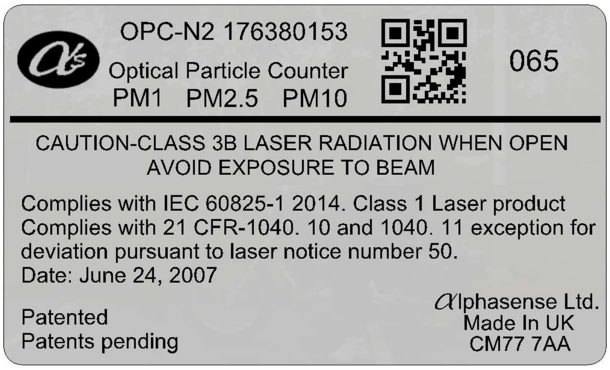
3 Health and Safety



The OPC-N2 uses an embedded diode laser light source that operates at typically 5-8 mW (max. 25 mW) at a wavelength of 658 nm. The OPC-N2 is a Class 1 laser product, since the user does not have access to the laser source. The OPC-N2 is designed for OEM use, normally mounted in a secondary housing. The user must not open or adjust any parts of the OPC-N2. 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-N2 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 are: density 1.65 g/ml, RI 1.5+i0. Respiratory profiles are included in the PM calculations.
An additional weighting is applied on units with Firmware 18 or higher to account for under counting at low particle sizes and the effect of carbon particles in urban air so that the output matches co-located reference detectors. This correction can be retrofitted to units with older firmware, contact Alphasense for additional information.
Most conventional OPCs employ a narrow inlet to physically constrain the airborne particles to pass through a uniform central part of the illuminating laser beam and ensure accurate sizing. Such instruments incorporate both an air-pump sufficiently powerful to draw the sample aerosol through the narrow inlet tube and a particle filter upstream of the pump to avoid pump contamination and ultimate blockage. The result is an OPC with high current consumption and a regular maintenance requirement to replace the pump protection filter (which can be frequent in dirty atmospheres).

The Alphasense OPC-N2 uses a different design: the pump and replaceable particle filter have been removed. Instead, the patented OPC-N2 uses an elliptical mirror and dual-element photodetector to create a 'virtual sensing zone' in free space at the centre of an open scattering chamber. The airflow through the OPC is produced by a low power microfan.

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The OPC-N2 classifies each particle size, at rates up to ~10,000 particle per second, recording the particle size to one of 16 "bins" covering the size range from 0.38 to 17 µm. The resulting particle size histograms can be evaluated over user-defined sampling times from 1 to 10 second duration, when driven using the software or by the customers own system. Longer periods can be used but the OPC will reset if no communication is received for 65s; also, longer times in dirty environments can result in the bins "over filling". If longer periods are needed it is recommended that you carry out averaging of shorter measurement periods. This histogram data is transmitted via an SPI interface to a host computer. The patented OPC-N2 design results in virtually all sampled airborne particles passing straight through the sensor without being deposited, allowing the OPC-N2 to operate for very long periods (>1 year) without the requirement for regular maintenance or cleaning.

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-N2 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.

5 PM measurements

The particle size histogram data recorded by the OPC-N2 sensor can be used to calculate the mass of airborne particles per unit volume of air, normally expressed as µg/m^3.

The accepted international standard definitions of particle mass loadings in the air are $PM_{2.5}$ and PM_{10}, as not all standards groups have defined PM_1 yet. These definitions relate to the mass and size of particles that would be inhaled by a typical adult. So, for example, $PM_{2.5}$ is defined as *'particles which pass through a size-selective inlet with a 50% efficiency cut-off at 2.5 µm aerodynamic diameter'*. The 50% cut-off indicates that a proportion of particles larger than 2.5 µm will be included in $PM_{2.5}$, the proportion decreasing with increasing particle size, in this case out to approximately 10 µm particles.
The OPC-N2 calculates the respective PM values according to the method defined by European Standard EN 481. Conversion from the 'optical size' of each particle as recorded by the OPC-N2 and the mass of that particle requires knowledge of both particle density and its RI at the wavelength of the illuminating laser beam, 658 nm. The latter is required because both the intensity and angular distribution of scattered light from the particle are dependent on RI. The OPC-N2 assumes an average RI value of 1.5 + i0. The OPC-N2 allows a different value to be set for each size bin to correct for particle density variation with particle size. The default setting for each size bin is a Particle Density value of 1.65 g/ml, a figure that equates to a typical value found in many environments. However, 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. Contact Alphasense for further discussion and instructions on how to to modify the particle bin density.
The OPC-N2 also has a Sample Volume Weighting factor for each size bin that is applied to the total mass of particles in that bin. The default values are those defined by European Standard EN 481 for PM_1, $PM_{2.5}$ and PM_{10} with an additional multiplier being used such that the OPC-N2 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 of 0.38 µm.
It is also possible for end users to set their own multipliers to align the OPC-N2 to their own co-located reference instruments.

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Note

- The EN 481 standard definition for PM_{10} extends to particle sizes beyond the upper measurable size limit of the OPC-N2. In some cases, this can result in the reported PM_{10} value being underestimated by up to ~10%.

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. Considering this problem- tubing, valves, baffles or obstructions that will restrict air flow into or out of the OPC should be avoided. Particle distribution can also be affected by sharp turns and narrow sample pipes. Maximum pressure drop through the entire flow system must be less than 75 Pa and ideally less than 40Pa.

However, because fan speed can vary and external factors such as wind direction in the vicinity of the OPC may affect the sample flow rate through the OPC, 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.

The OPC N2 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-N2 inlet is exposed directly to the target sample volume and that the fan exhaust is left free to exhaust into an unconstrained space. The OPC-N2 can be positioned in any orientation. However, 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 in this case to avoid very large droplets or soot and grit from entering the unit due to gravity. Some form of “umbrella” or mushroom should be used which protects the unit but does not interfere with 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. Please note at temperatures between –20 and –10°C the OPC is reliant on its own generated heat to ensure the laser is operating correctly, thermal lagging of the secondary housing or heating may be required.

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Connecting and Operating The OPC N2

7 Connecting power and taking readings

The OPC-N2 is shipped pre-calibrated. There are no user serviceable parts. Power and data communications are provided via the SPI socket. Firmware uploading and SD card downloading are via the micro-USB socket. Use of the SD card will require internal firmware updating if the firmware version is prior to version 0015d.

Connection to the OPC-N2 for real-time data transfer can be made via the SPI direct to your own circuit's 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. The green LED shows that power is supplied to the OPC-N2 and the red LED flashes when the PC and OPC-N2 are communicating. The micro-USB socket can be used for updating the internal firmware and downloading the SD card measured data, it is not possible to download real time data via this socket.

SPI Connection

The SPI socket is a Molex 'Pico Clasp' 6 way Housing, Part Number 501330-0600. Pins are assigned in table 2. Pin 1 on the OPC-N2 is closest to the USB micro connector.

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

Table 2. SPI pin assignments

Please note that it is not possible to put the MISO (SDO) line into a high impedance mode (tri-state). This means that it is not possible to use the OPC on a shared SPI bus.

OPC power requirement

The OPC-N2 requires a 4.8 to 5.2 Volt DC supply with minimum electrical noise, this is then stepped down to a 3v3 supply (via the SPI-ISS adapter) for the SPI logic lines. The logic lines are NOT 5 volt tolerant.
The OPC N2 requires 175 mA continuous (95 mA continuous with fan off and laser at low power) with a short one amp current surge at switch-on. Care must be taken that the current limit is not exceeded if multiple units are operated from of a single computer

It is recommended to allow 1 second for the OPC to respond to the first SPI command after power-on and >0.5s after any control system code. (Note this is longer than on previous versions)

Software interface configuration

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

1. The SPI mode is a Mode 1 device, where the idle state for the clock is low and data is transmitted on the leading edge (transition from idle to active clock) and is received on the trailing edge of the signal.
2. SPI clock acceptable frequency range: 300-750kHz. (Other frequencies may also be acceptable, but are untested).

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3. SPI word length is 8 bits
4. The OPC is an SPI slave device.
5. No CRCs or checksums are used on the data stream.
6. Generally, an 8 bit command is sent to the OPC, which then responds after a short period with a sequence of one or more 8 bit values, depending on the command.
7. SPI sequence timing is given in 072-0325 Supplemental SPI information for OPC N2

OPC SPI Commands
A full list of current SPI commands given in 072-0325 Supplemental SPI information for OPC N2, a summary is listed in Appendix D. This can also be found on the supplied software CD, on the OPC N2 unit's SD card for recent releases or is available from Alphasense directly, as are command lists for earlier versions of the firmware.
The file name is of the form: OPC N2-Firmware command list for "Firmware Version"

8 Using the Alphasense Software

The software and necessary drivers to run the OPC from a computer (PC only, a version for Apple Computers is not available) is supplied either on the CD supplied with the OPC or can be downloaded from the SD card on board the instrument (firmware 18 and above)

Full guided examples for installation using Microsoft Windows XP, Microsoft Windows 7, 8, 8.1 and 10 are given in Appendices C. It is recommended 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-N2.exe icon to start the software application. When the application is first started the main form will be in "start-up mode" as shown in the next section.

Run the software as with previous versions and connect to the OPC-N2 by choosing the virtual COM port it is assigned to. Some text should appear in the software's main text box indicating some details of the OPC on successful connection. At this stage the OPC electronics are on but the laser is running at reduced power and the fan is switched off. Press Ctrl+R to read out all the configuration variables stored 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.

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. Be sure to select the correct port number; the software will not respond unless the port with the attached OPC-N2 device is selected.

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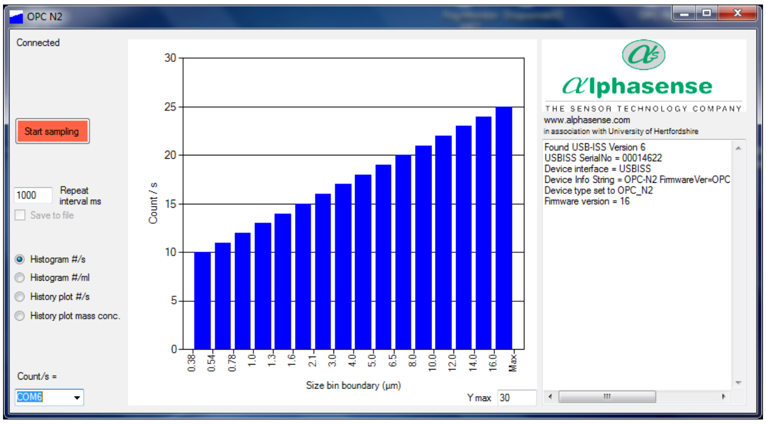


- **Device information** (Right hand side text window): This shows hardware serial number and firmware versions currently installed on the OPC-N2.

- **Start sampling**: Starts data collection with the fan and laser running continuously. The button will then show 'Stop sampling' to allow termination of the sampling process.

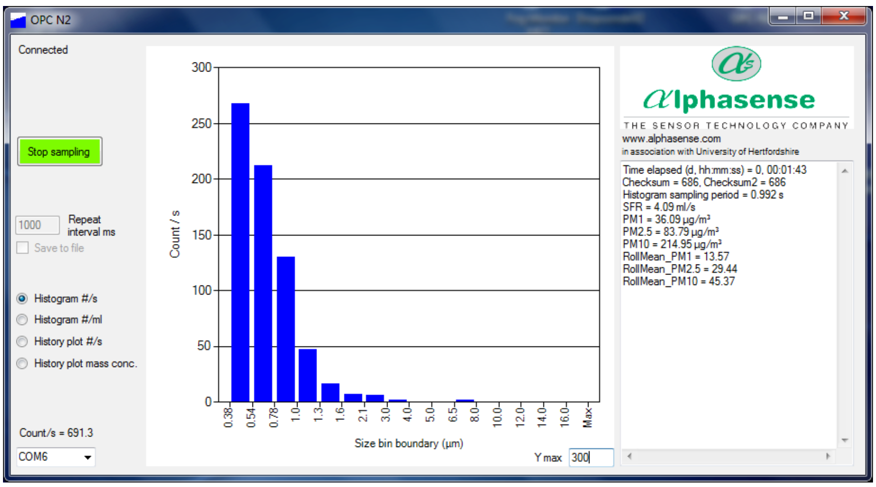
- **Repeat interval ms**: Sets the duration (in milliseconds) over which a particle size histogram is acquired. The default is 1,000 ms. We recommend a maximum of 10,000 ms to avoid the risk of an individual size bin becoming full (65,536 counts). Longer intervals can be set in very clean environments, but the unit will reset if no communication is received for 65s.

- **Y max**: This sets the maximum y-axis value of the histogram screen display. **Note**: If the displayed data reaches the top of the display, enter a larger Y max value.

- Histogram y-axis **'Counts/ s':** This displays the recorded counts per second in each size bin, regardless of the setting of the 'Repeat interval ms'. For example, if a 10,000 ms sampling interval is set, the 'Counts/ s' figure 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-N2 will first ask if the data are to be saved. Once answered, it will begin to display particle size histogram data and if selected, store data to a file.



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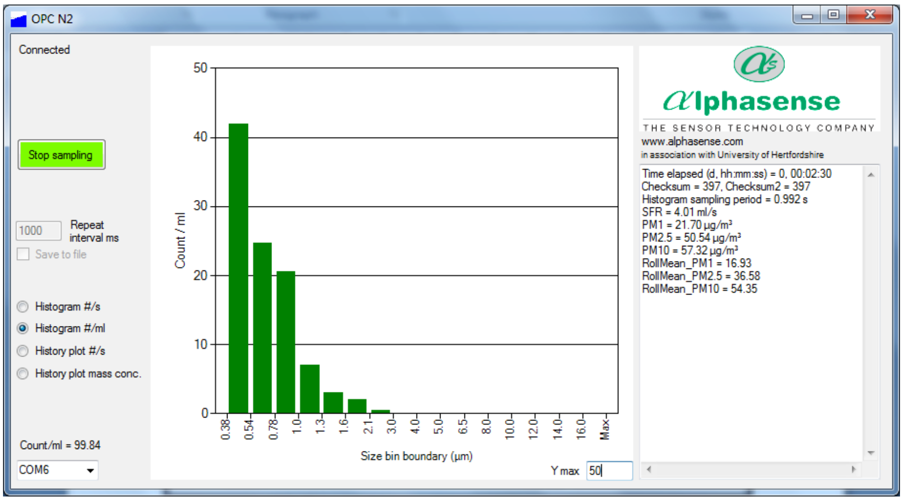
- Data relating to each acquired histogram, including PM values, is given in the right-hand window of the display. The RollMean_PM10, etc., are the current rolling mean values for PM evaluated over the previous 5 minutes or to the beginning of sampling if that is less time.

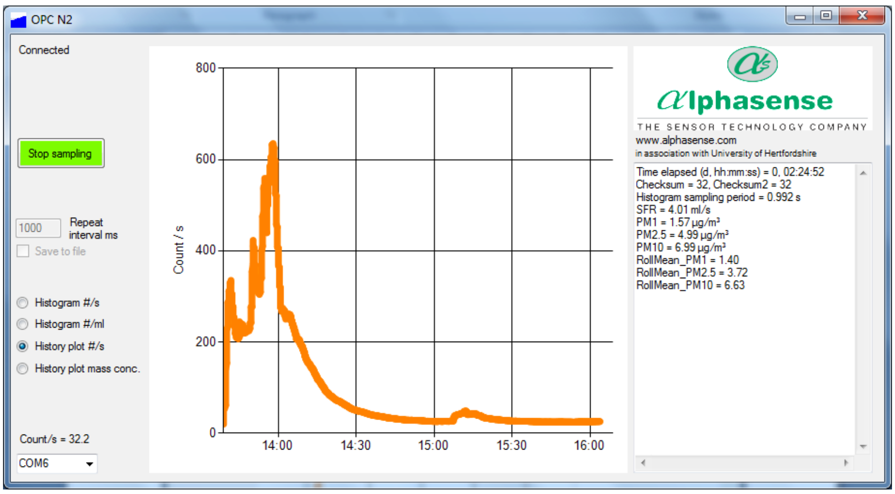
- The total particle count rate per second across all size bins (Counts/ s) is given in the bottom-left of the screen.

- Clicking on the graph and pressing I will display the values for each bin, pressing I again will toggle it back.

Histogram Number Concentration vs Particle Size display mode
Click the 'Histogram #/ml' button 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 'Histogram plot #/s' button 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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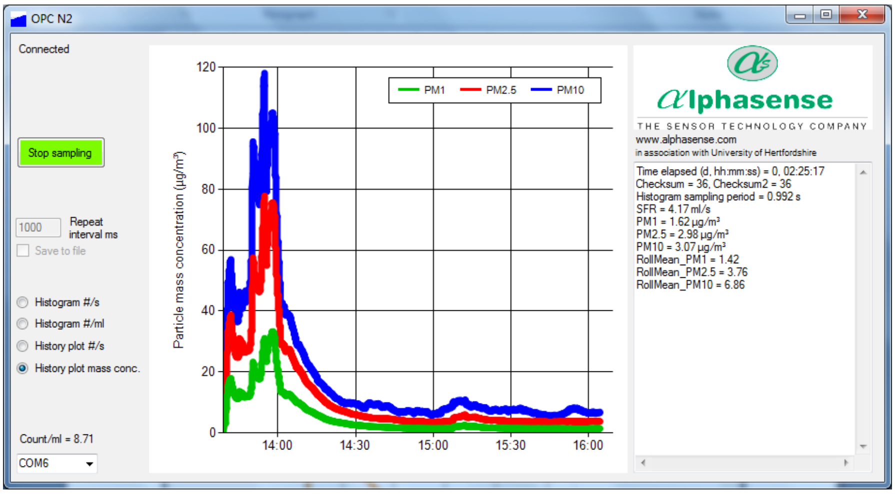
History Plot of Mass Concentration display mode
Click the 'Histogram plot mass conc.' Button on the left-hand side of the screen to show a temporal record of PM_1, $PM_{2.5}$ and PM_{10} values (in µg/m^3) since the start of the sampling session. The plot scale will automatically change to show longer 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.

Other Software Functions

Shutting down the software
It is recommended that the software application be 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 "start" button. If you select "yes" 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 out put explained in more detail later in the document.

Firmware information
The information window on the right of the main form shows the firmware version installed as the software first loads up. The OPC-N2 also has the ability to install firmware upgrades via the USB port. This is achieved using a Bootloader tool see Appendix C for more details. To check to see if your device can upgrade firmware via the USB port, check the information string printed as the device is first connected. To upgrade firmware via USB you need to have firmware version 0015d or above.

Example: "OPC-N2 FirmwareVer=OPC-015d…………………………..BD"

As the firmware first loads it follows the procedure below:
Check for SD memory card. All versions of the OPC-N2 will come with a 16GB micro SD card fitted. This card is internal and is not accessible from outside the case, please note it may not be fitted on early release OPC-N2 units.

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1. If a SD card is found, the OPC will check for a USB connection. The OPC-N2 comes equipped with a micro USB port.
2. If a USB connection is found the device will switch to “USB mode”. This makes the OPC-N2 behave like an external storage device (pen-drive) until the USB is disconnected.
3. If a USB connection is not found then it will check for the SPI master connection (SCLK). The OPC will wait up to 60 seconds for an SPI connection to be established.
4. If an SPI connection is not found the OPC-N2 will switch to standalone “SD card mode”. When in SD card mode the SPI is still active, if SPI command “SPIShutDownDAC” (0x03) is sent, the OPC will close the current SD card log file and exit SD card mode.

Please note that if the unit has entered standalone mode before you have connected the software the following error will be returned:

Found USB-ISS Version 6
USBISS SerialNo = XXXXXXXX
Device interface = USBISS
InfoStr not Found
SPI Busy

This can be cleared by connecting a second time or if this fails unplugging and replugging in the unit

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.
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. Ctrl + B: Enter Bootloader mode. This allows the OPC to interact with the Bootloader application so that new firmware can be installed via USB port.
5. These commands are also needed to make full use of the stand alone mode

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Explanation of the CSVs

Please note sheets have been truncated to save space

							Comment
Software ver: OPC-N2 Alphasense 1.0.5779.33206							
Size LUT file	OPC-N2_06-02-2015.LUT						
Device SerNo	SerNo: 176390116						Unit serial number
InfoString	OPC-N2 FirmwareVer=OPC-018.2.............................BD						
Gain scaling coeff	1						Scaling coefficient that can be applied to all bins
Laser digital pot setting	200						Laser setting
Fan digital pot setting	255						Fan setting
ToF to SFR factor	74						Needed for dynamic fan speed correction
Bins	Bin00	Bin01	Bin02	Bin03	…..	Bin15	
Bin low boundary (ADC o/p)	12	17	27	41	…..	3685	
Bin high boundary (ADC o/p)	17	27	41	60	…..	4095	
Bin low boundary (particle diameter [um])	0.38	0.54	0.78	1.05	…..	16	
Bin high boundary (particle diameter [um])	0.54	0.78	1.05	1.34	…..	17.5	
Bin centre (particle diameter [um])	0.46	0.66	0.915	1.195	…..	16.75	Diameter at the centre is used for PM cals
Vol of a particle in bin (um3) (calculated by software)	0.051	0.1505	0.4011	0.8935	…..	2460.612	
Vol of a particle in bin (um3) (values stored on OPC)	0.051	0.1505	0.4011	0.8935	…..	2460.612	
Density of a particle in bin (g/ml)	1.65	1.65	1.65	1.65	…..	1.65	Default 1.65
Sample volume weighting for bin	1	1	1	1	…..	1	Individual additional bin weighting

Annotated CSV produced by an OPC-N2 run by the Alphasense Software top section

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Data:																
OADate Time	Bin00	…	Bin15	MeanToF Bin1(us)	…	MeanToF Bin7(us)	Count/s	Sampling Period(s)	SFR (ml/s)	Temperature (C) or Pressure(Pa)	PM1 (ug/m3)	…	PM10 (ug/m3)	RollMean _PM1	…	RollMean _PM10
42341.6282	8.001	…	0	6	…	0	20.003	1	3.2	x	1.38	…	6.85	1.38	…	6.85
42341.6282	5.946	…	1.982	9.33	…	0	18.83	1.009	3.1	x	1.09	…	198.75	1.24	…	102.8
42341.6282	8.003	…	0	7	…	0	32.014	1	3.21	x	2.36	…	108	1.61	…	104.53
42341.6282	7.925	…	0.991	5.67	…	0	28.727	1.01	3.44	x	1.88	…	149.15	1.68	…	115.69
42341.6282	8.008	…	0	6	…	0	23.023	0.999	3.55	x	1.46	…	87.34	1.63	…	110.02
42341.6282	11.997	…	0	6.67	…	0	25.993	1	3.56	x	1.74	…	3.56	1.65	…	92.27
42341.6282	4.954	…	0	7.67	…	23	20.806	1.009	3.52	x	1.52	…	12.79	1.63	…	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	x if no sensor fitted	Instantaneous PM1, 2.5, 10			5 minute averaged PM1, 2.5, 10		

Annotated CSV produced by an OPC-N2 run by the Alphasense Software bottom section

For CSVs generated in standalone mode the main difference is that the bin count is the total count in the sampling period and is not a count/s

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9 Standalone mode (Recording to onboard SD card)

If the OPC-N2 unit is powered but receives no SPI communication for 60s it starts running and logs data to the on board SD card. The default settings are such that it will run with the fan and laser on continuously and record a histogram every ~1.4s. Every 24 hours a new data file is recorded and the files are numbered sequentially.
Please note the histogram records total counts in the 1.4s time period and does not quote an average figure in counts/s. The unit does not have a real time clock so any break and resumption in power will result in the next numbered file being created. Only the default option was offered on previous versions of firmware (16b and 17b), the latest version firmware 18 now offers other variables.

Autonomous Mode Variables
The easiest way to access these is to use the supplied Alphasense Software. The variables can be changed by SPI commands using your own system if preferred (See the commands list summary in Appendix D for details).
Connect the OPC-N2 to the software in the standard manner. Type control R and scroll to the bottom of the text list. Listed here are the Autonomous Mode variables. The variables listed in table 3.

Command	Description	Default
AMSamplingInterval count	The number of 1.4s samples taken for each measurement	1
AMIdleInterval count	The number of 1.4s periods between each measurement	0
AMMaxDataArraysInFile	The number of saved histograms per CSV (default is 24 hours of continuous 1.4s measurements)	61798
AMFanOnInIdle	Selects if the fan is on or off during the idle phase	0
AMLaserOnInIdle	Selects if the fan is on or off during the idle phase	0
AMOnlySavePMDataToSD	Selects full data or PM data only to be saved	0

Table 3. Autonomous Mode Variables

When running with an Idle Interval the unit automatically runs the fan and laser for a period of 7 ~1.4s cycles before starting the measurement. This allows the laser and fan to come up to full power. As a result in the CSV file the Data RequestInterval(s) is the total time of the cycle, so includes the Idle Interval, the warm up time and the measurement time, the SamplingPeriod(s) is the time taken for the active measurement.

To alter these variables type the new value in the window, then press control W, and confirm that you want to change the current OPC configuration then type Ctrl + S: Save all values to configuration memory, and again confirm it. The OPC should then be disconnected from the software and unplugged and will start logging when powered up again.

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10 Running the OPC N2 using direct SPI control

Full details of the SPI commands and connections are given for the OPC-N2. 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 coding example is given in given in 072-0325 Supplemental SPI information for OPC N2

If, to save power the OPC is to be run periodically with the fan off and laser at low power, it is recommended that the fan and laser are powered up for a minimum of 10 s before taking a measurement.

Alphasense can offer only limited support for programming/coding and customers may need to seek third part assistance if they are unfamiliar with SPI protocols.

11 Revision Control

Version	Comment	Release Date	Released by
5	Update to version 18 firmware, and combine documents into one manual	December 2015	Mark Giles

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Appendix A: FAQs

- **What are the differences between the different firmware versions**

Firmware 16 and 17 including 16B and 17B

- Firmware 18 builds on the previous firmware release 16 and 17. Please note Firmware 16 and 17 are basically equivalent, different versions were needed to support the use of two different PCBs, issue 2 with Firmware 16 and issue 3 with 17. Similarly for version 18, 18.1 is for issue 2 and 18.2 for issue 3. In operation the only significant difference is that units with Issue 2 boards use more power in the standby mode as the standby laser power is not as low as in issue 3. Units with issue 2 boards must only be updated with the correct firmware as irreversible damage to the laser may occur otherwise.
- General running and features of 16 and 17 are the same in issue 18. All have dynamic correction for sample flow-rate caused by changes to the of the fan speed and also apply the respiratory profiles to the PM values
- Issue 18 has more advanced standalone recording to the onboard SD card and some additional commands to make it easier for end users to write their own software. The serial number of the OPC is stored on the unit and is recorded on any CSV files.
- Issue 18 units have, in addition a scaling factor applied to each bin to align the unit more closely to reference detectors following co-location studies. This scaling factor can be retrofitted to units in the field; details can be obtained by request from Alphasense.
- It is recommended that you continue to use the initial software release in deployment versions 9.7 and 9.8 for units with firmware 16 and 17.
- If you are running 16, 17, 16B or 17B using your own software developed for an earlier version such as 15D please allow more time at start up before issuing the first command, ~1 s. The main commands are the same across most releases. Data positions in the call histograms and read functions may have changed; see the full list of commands for details.

Firmware 15D

- There are differences in firmware commands and responses between units with 15D and later firmware.
- In terms of performance these units to not offer the dynamic correction of sample flow-rate for variations in fan speed and have a simplified method of calculating the PM values
- If you continue to use these units is recommended that you use the initial software released in deployment 9.5.
- It is possible to update the majority of these units in the field to firmware 18.1.

Older Units, other Firmware 15 variants and 14
Substantial improvements have been made since these units have been issued. It is not possible to update these units in the field. Please Contact Alphasense to discuss potential upgrade options.

- 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)
    - Fundamentally, fans are constant volume devices and so, at altitude where the density of air is lower, the mass transported through the fan will be reduced but the volume stays the same (assuming the fan speed remains the same).

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- The unit should therefore operate normally at altitude with particle size and number concentrations being accurate. However, in situations at altitude where ambient temperatures are expected to fall to -20°C, care should be taken to ensure the OPC itself has some thermal insulation to allow the heating effect of the laser and electronics to maintain the internal temperature to approximately -10°C or above. If the ambient temperature falls to lower than -20°C, additional heating should be provided to the OPC to ensure correct operation..

- **How are the units calibrated**
  - The units are calibrated for sizing using controlled aerosols of polystyrene latex microspheres, taking into account the small response difference caused by the higher refractive index (1.58) of these particles) compared to the refractive index (1.5) used in the OPC-N2 calibration curve. Aerosol number concentration is assessed by comparison to an OPC N2 ‘gold standard’, previously calibrated against a certified TSI 3330 OPC instrument.

- **What maintenance can be carried out on the OPC N2**
  - The OPC-N2 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 effect the calibration.

- **Raspberry Pi and Arduino**
  - The OPC-N2 is ideally suited to be operated by devices such as Raspberry Pi or Arduino via its SPI interface. While Alphasense does not yet distribute example OPC-N2 control programs to be used on these devices, many of its customers have successfully implemented such control programs following the OPC-N2 SPI commands list. Further information may be released in a separate annex in 2016

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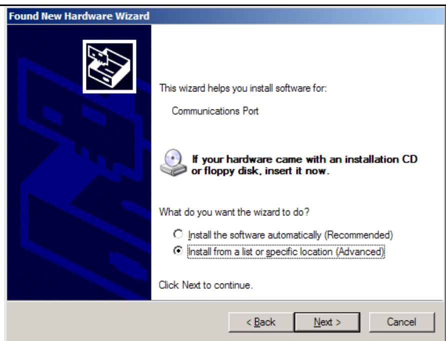
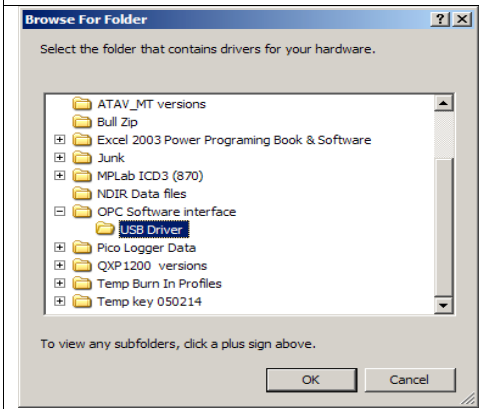
Appendix B: Installing the device driver

Windows XP

Copy the folder "OPC Interface Software" 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 "Found New Hardware" wizard. Select the "Yes, this time only" 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 "Install from a list or a specific location (Advanced)". Navigate to the OPC folder containing the folder named "USB Driver", this contains the driver file *devtech2.inf* which Windows needs to drive the OPC device.

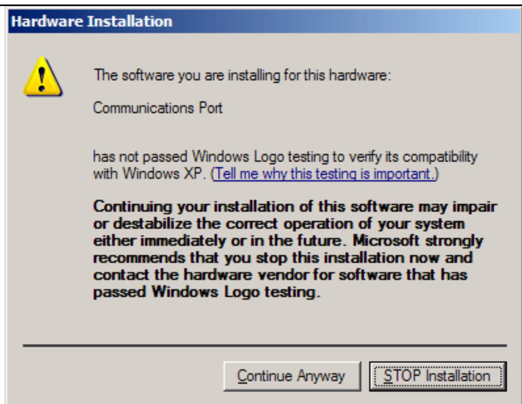




Click OK to allow Windows to locate and install the device driver. This process is automatic but you will be prompted by the form below to confirm the installation.

Click "Continue Anyway" to finish the installation. Once the device driver is installed correctly, the OPC device should appear in the Device Manager window as a "Communication Port" 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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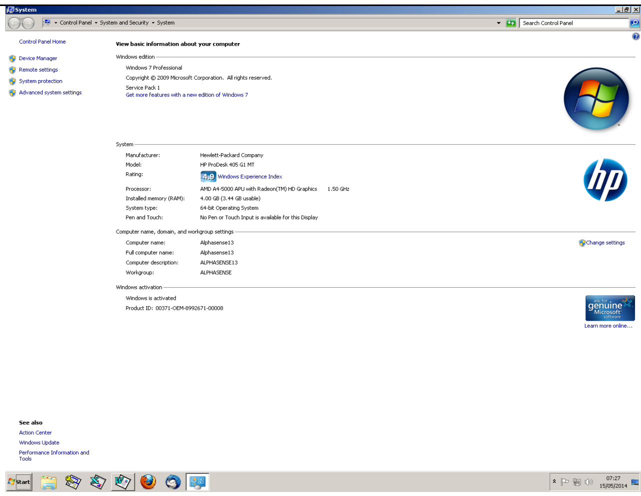
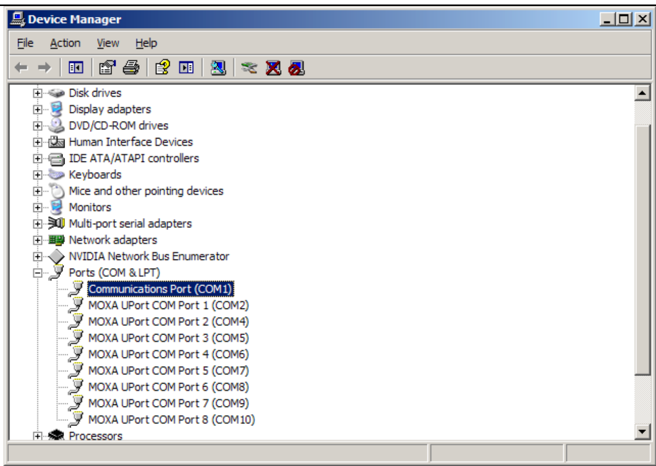
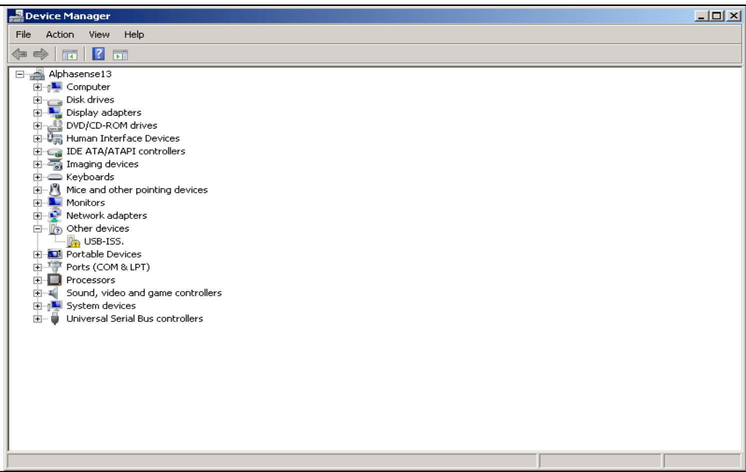
<table>
<tr><th colspan="2">Windows 7</th></tr>
<tr><td>Copy the folder “OPC Interface Software” to the PC desktop. Connect the USB interface lead to the PC. If the USB interface lead (USB to SPI converter) is connected to the PC for the first time, Windows will need a device driver.</td><td></td></tr>
<tr><td>Open the system properties and locate the device manager.</td><td>
</td></tr>
<tr><td>Windows 7 will show the new device as “USB-ISS” with a yellow exclamation mark indicating a driver problem.</td><td>
</td></tr>
</table>

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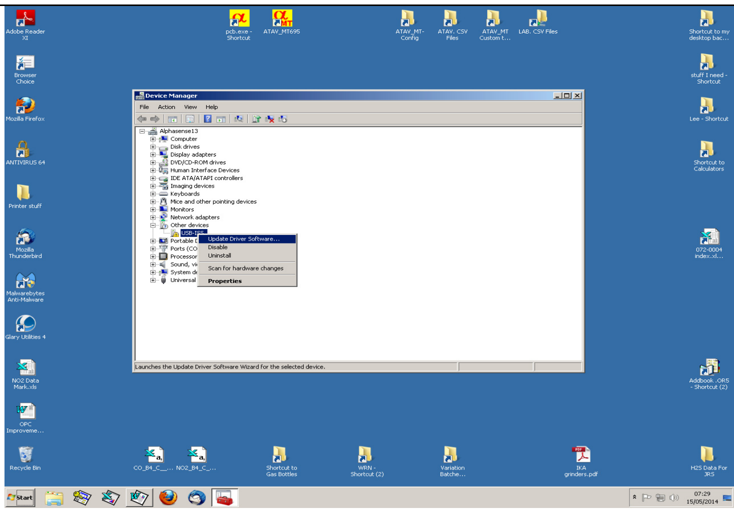
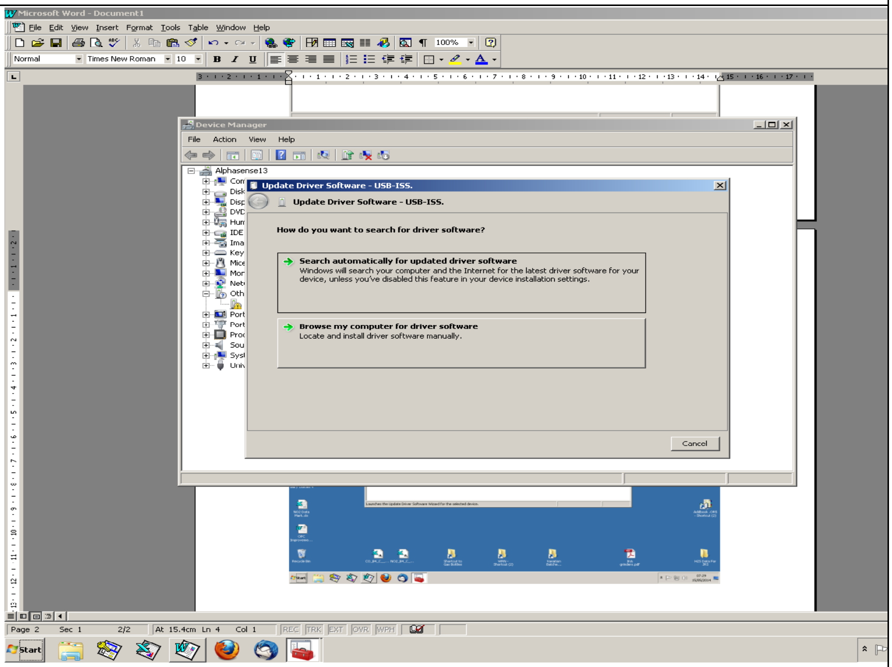
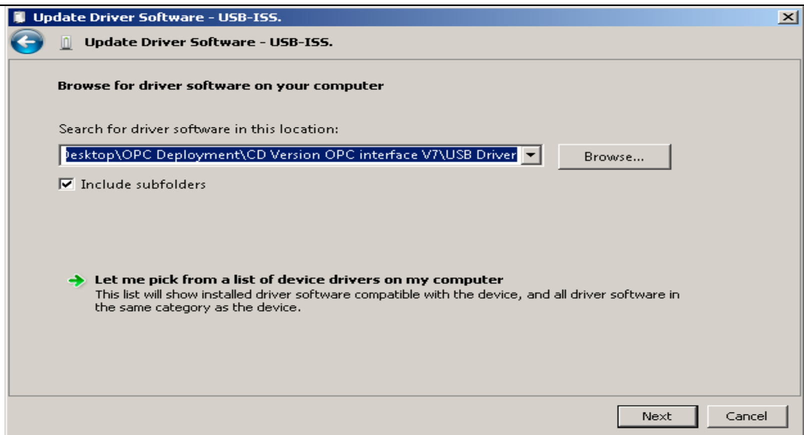
Right click the icon and select "Update Driver Software".	
Select the "Browse my computer for driver software" option.	
Navigate to the folder "OPC Interface Software" copied to your desktop and locate the folder named "USB Driver", Click Next.	

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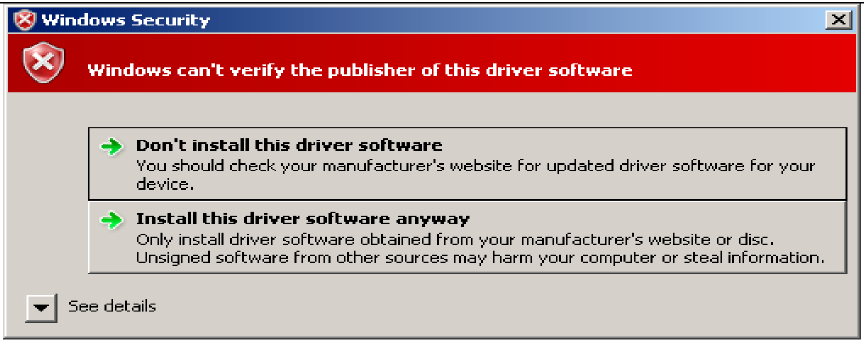
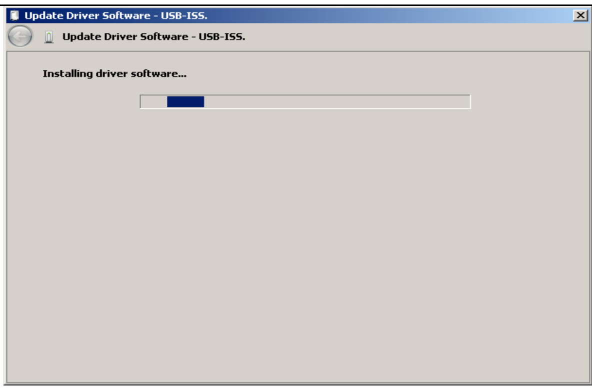
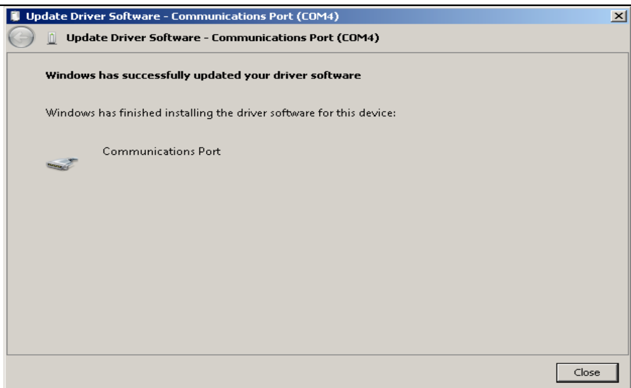
Windows 7 will then issue a security warning. This is due to a licence issue and not a concern to the operating system. Select the "Install this driver software anyway" option.



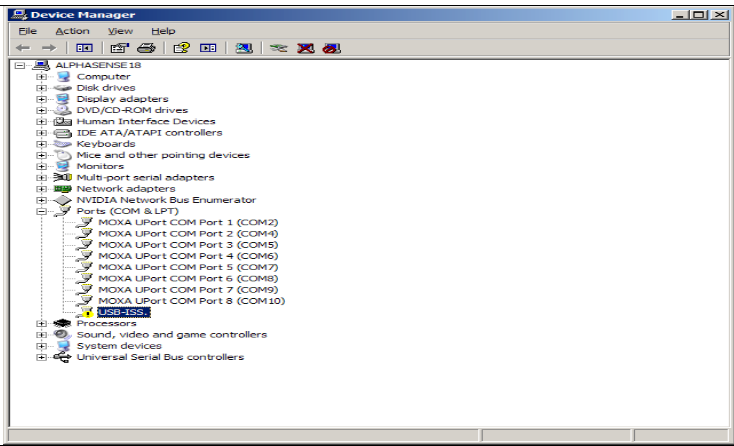
Windows will then install the driver files for the device.



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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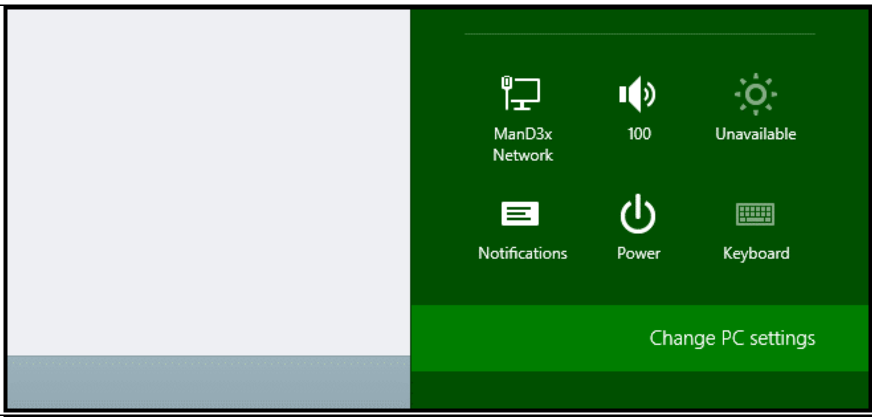
Windows 8, 8.1 and 10

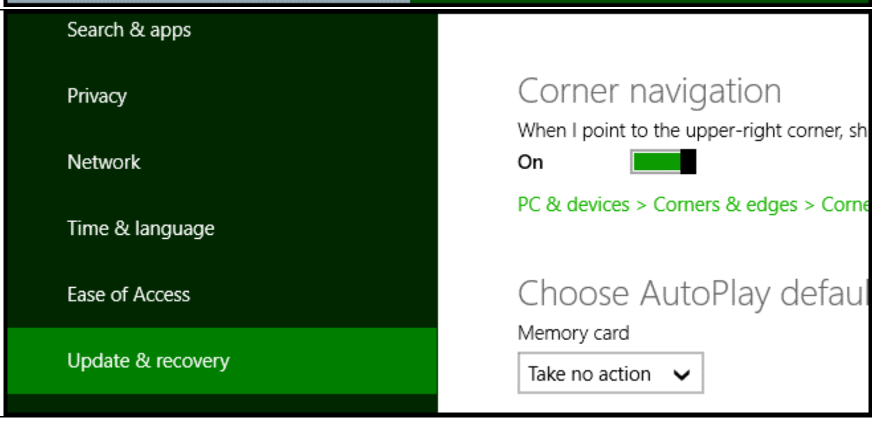
This procedure will guide you through the process of disabling the digital device driver verification in Windows 8, 8.1 and 10. The method for 8.0 is different than for 8.1 and 10

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 “Update & recovery” section.</td><td>


</td></tr>
</table>

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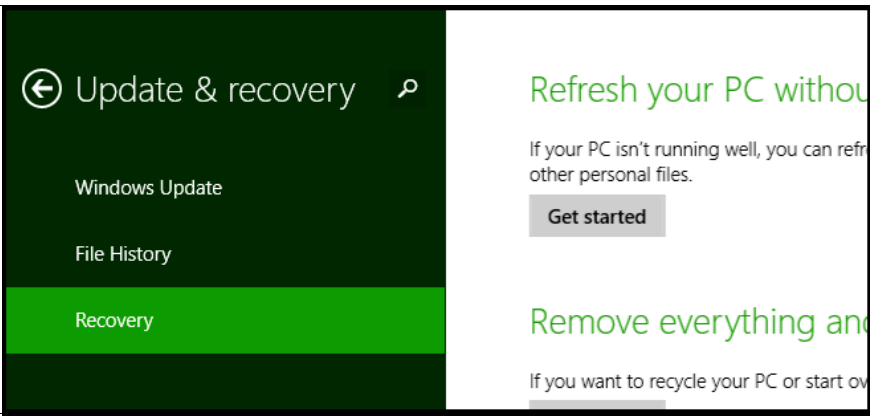
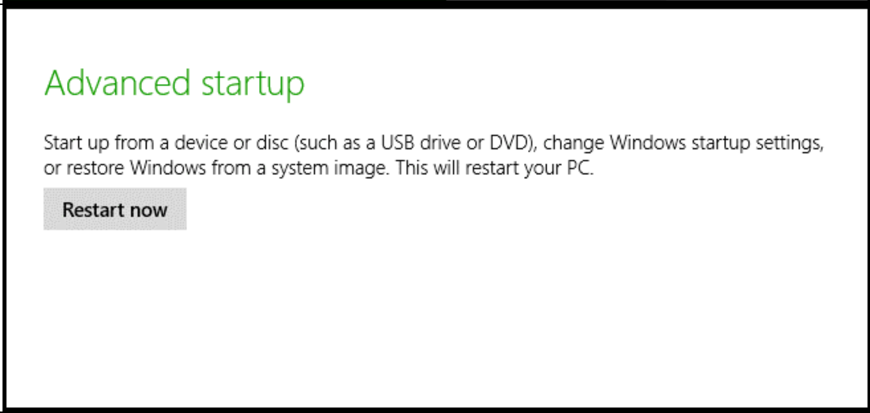
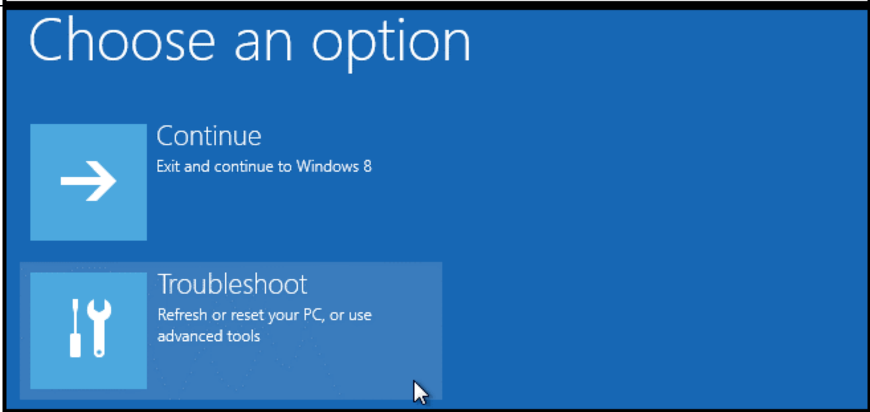
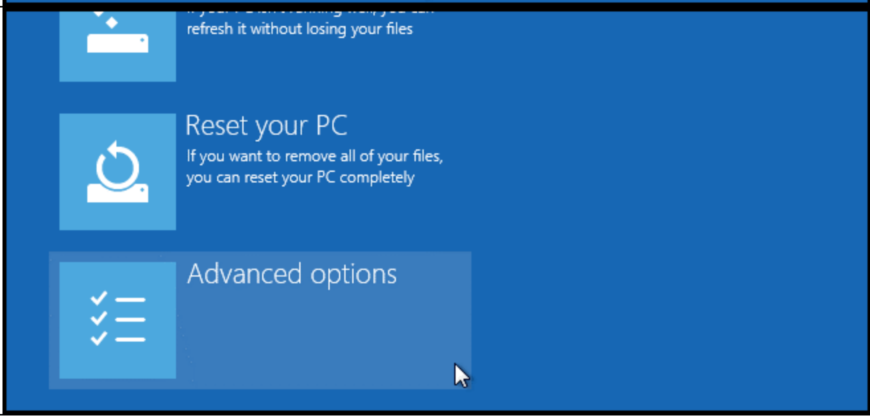
<table>
<tr><td>Then click on the Recovery option on the left hand side.</td><td>
</td></tr>
<tr><td>Once selected, you will see an advanced startup section appear on the right hand side. You will need to click on the “Restart now” button.</td><td>
</td></tr>
<tr><td>Once your Computer has rebooted you will need to choose the Troubleshoot option.</td><td>
</td></tr>
<tr><td>Then head into Advanced options.</td><td>
</td></tr>
</table>

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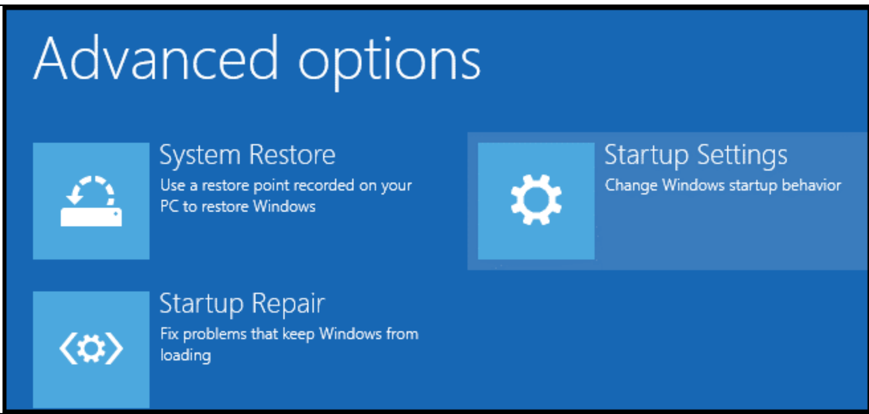
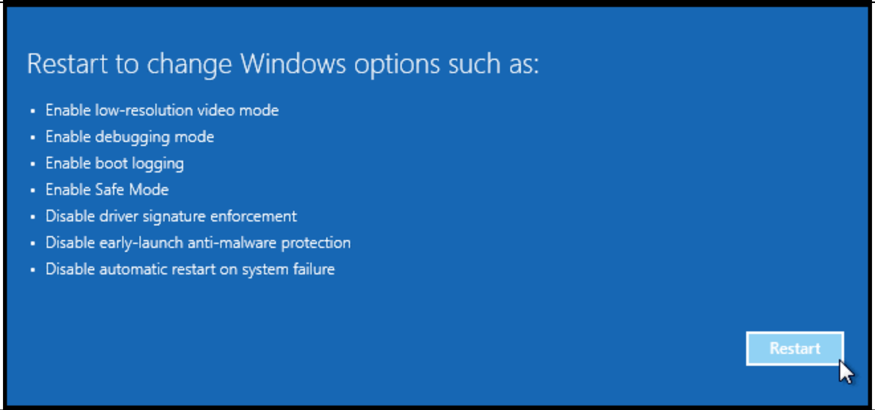
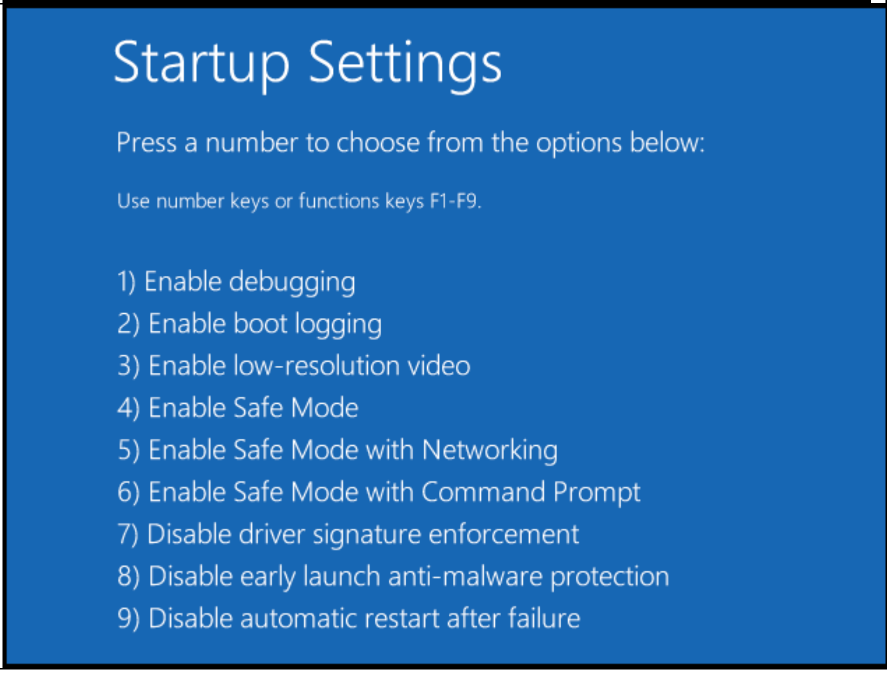
Then Startup Settings.	
Since we are modifying boot time configuration settings, you will need to restart your Computer one last time.	
Finally, you will be given a list of startup settings that you can change. The one we are looking for is “Disable driver signature enforcement”. To choose the setting, 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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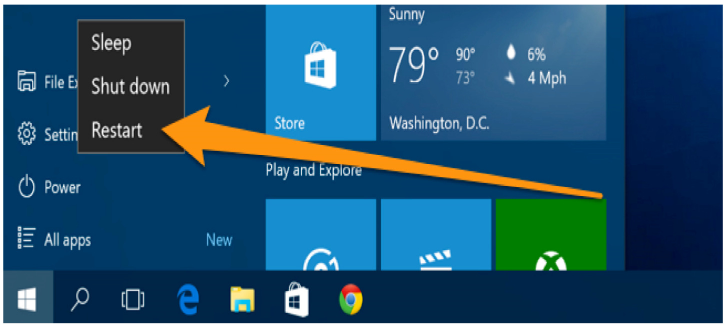
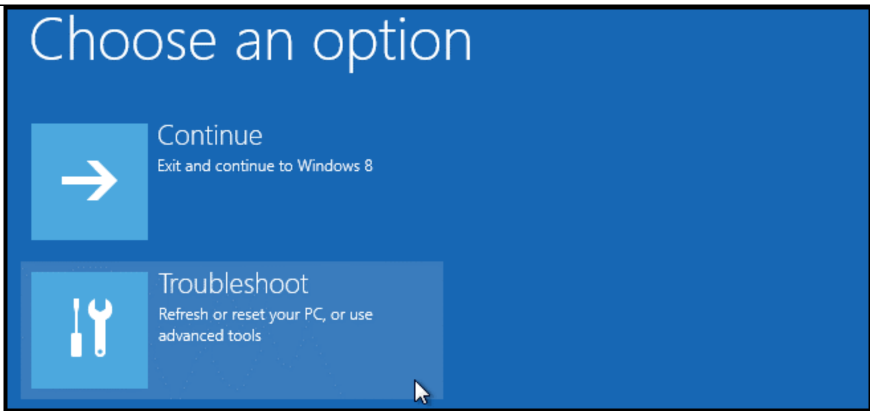
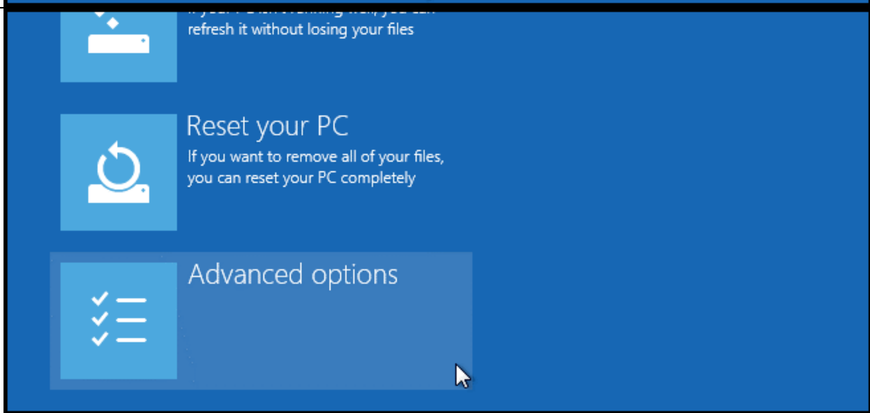
To disable the signature verification it is necessary to get into Troubleshooting options from the boot manager. Select Restart from the power options menu (for Windows 8 this is under Charms on the login screen and on Windows 10 this is on the start Menu. Hold down the shift key whilst clicking restart.



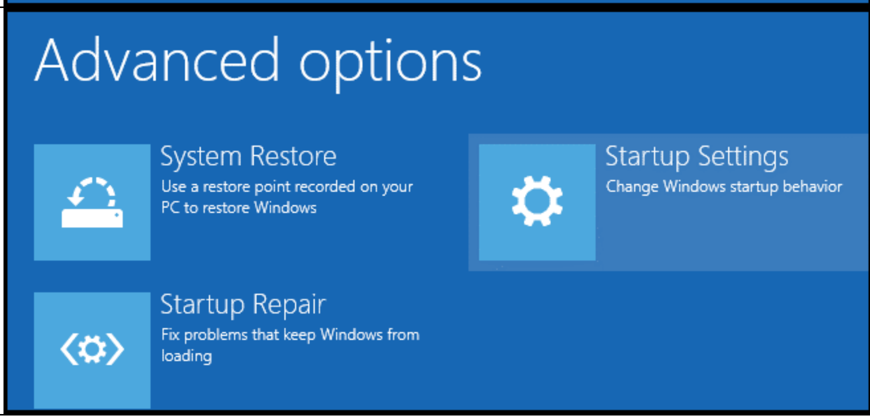
Once your Computer has rebooted you will need to choose the Troubleshoot option.



Then head into Advanced options.



Then Startup Settings.



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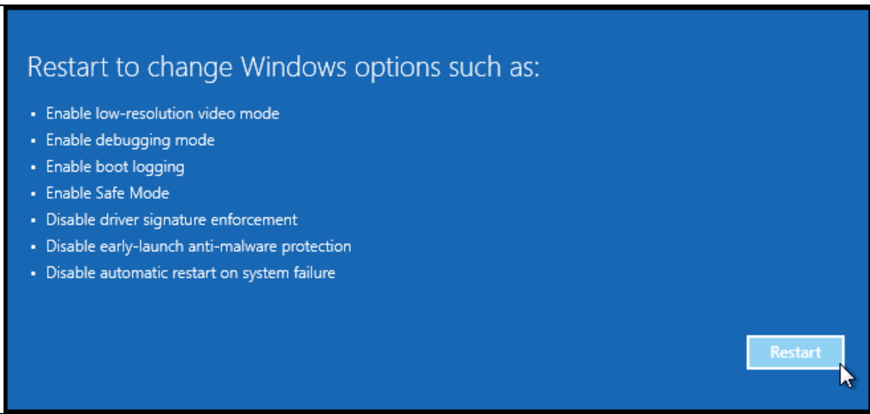
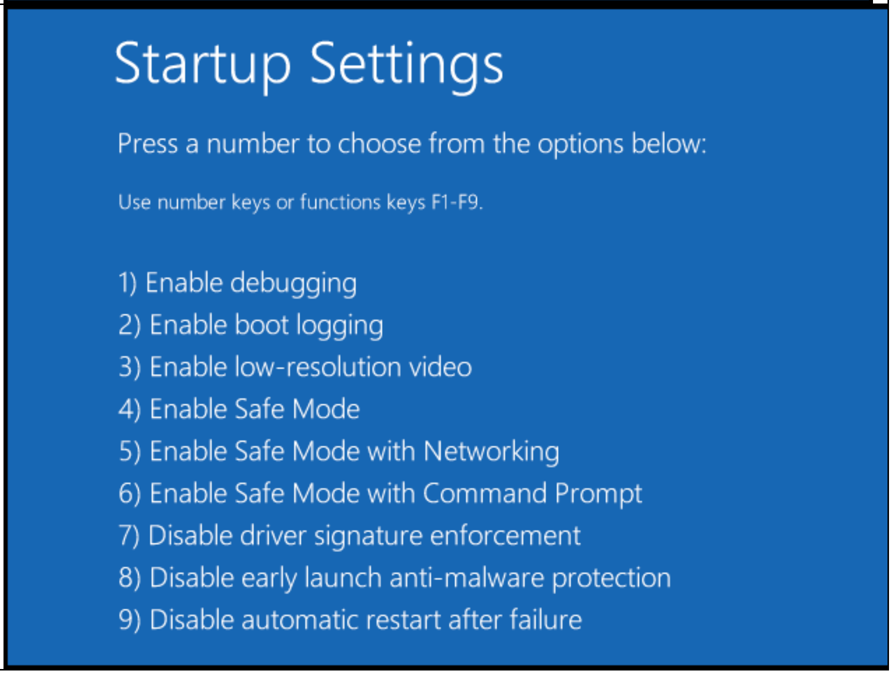
Since we are modifying boot time configuration settings, you will need to restart your Computer one last time.	
Finally, you will be given a list of startup settings that you can change. The one we are looking for is “Disable driver signature enforcement”. To choose the setting, you will need to press 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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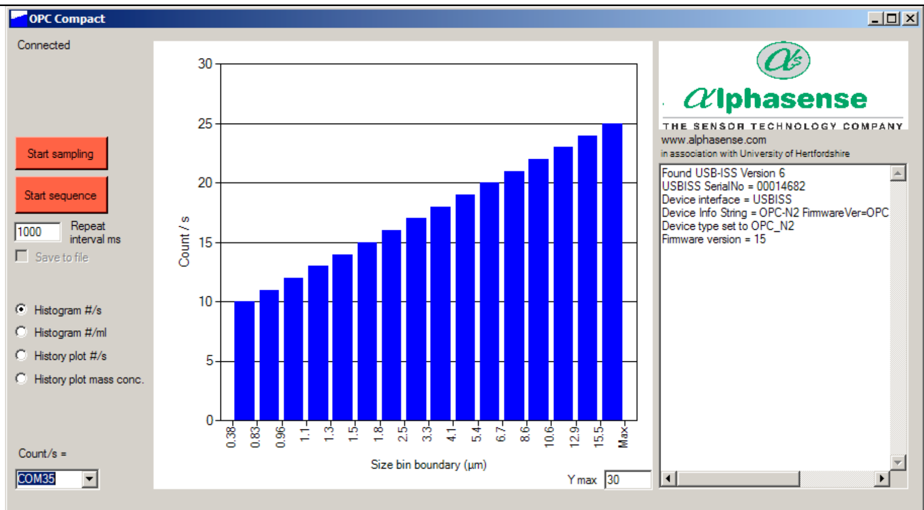
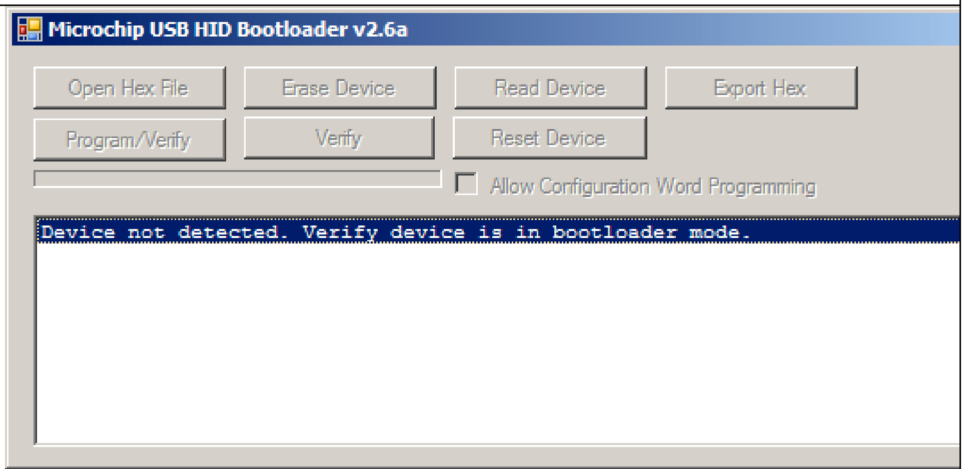
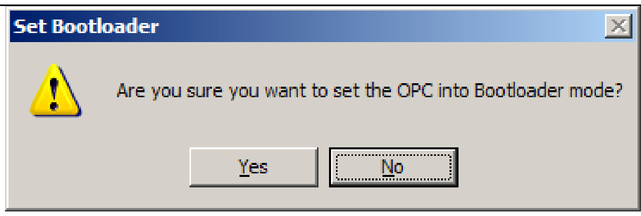
Appendix C: Updating the Firmware

It is possible to update the firmware on the OPC-N2 device using the supplied Bootloader tool when running firmware version 0015d (and above). To upgrade the firmware on your OPC-N2 device requires:

- An OPC-N2 with firmware 0015d and above (please check with Alphasense if uncertain).
- The PC software that is supplied with the unit (on CD or on SD card).
- USB to SPI converter.
- USB (Micro) lead.
- A new firmware upgrade package including the firmware file (.HEX), this will be supplied on request to Alphasense.

To upgrade the firmware file follow the instruction below:

<table>
<tr><td>1. Connect the OPC-N2 device to your PC and initiate communications (see earlier in the manual) and make a note of the current value set to the laser (you can see this by pressing Ctrl+L or by typing Ctrl +R and scrolling to the bottom of the window).</td><td>
</td></tr>
<tr><td>2. Connect the OPC-N2 device to the PC using the USB (micro) lead. Leave the SPI connection in place and open the Bootloader tool</td><td>
</td></tr>
<tr><td>3. Click the header on the OPC interface software (to make it active) and press Ctrl+B, this will put the OPC software into “bootloader mode”.Click “Yes” to the following prompt.</td><td>
</td></tr>
</table>

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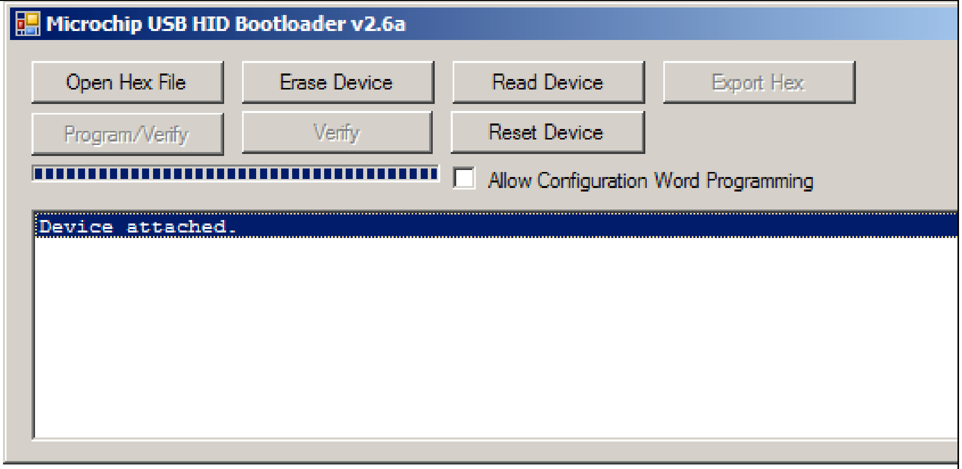
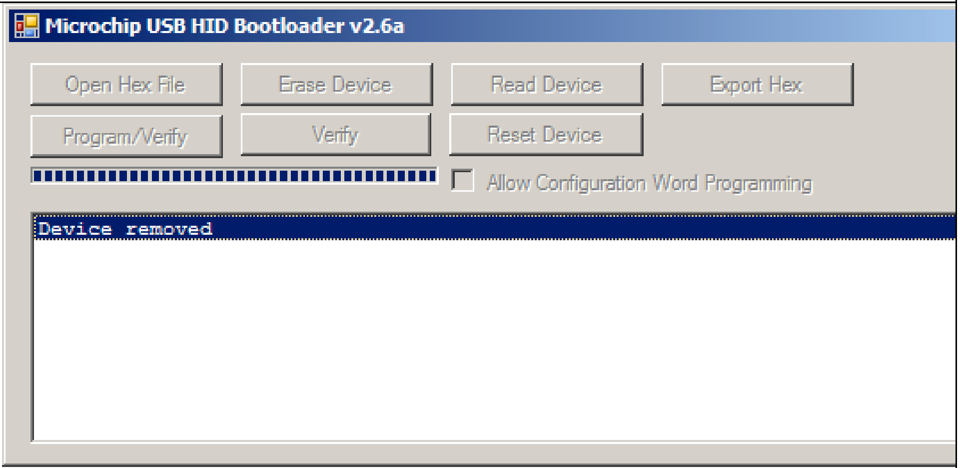
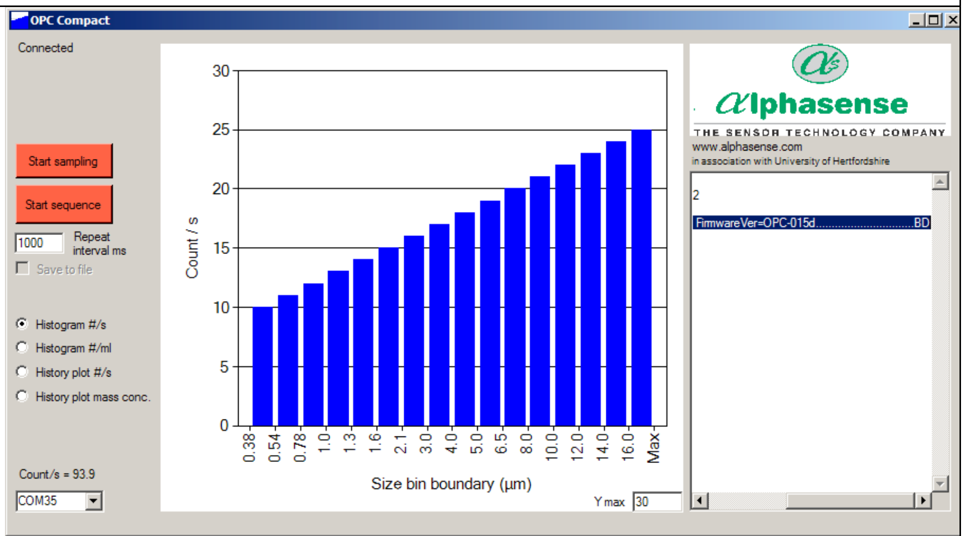
<table>
<tr><td></td><td></td></tr>
<tr><td>4. The Bootloader tool will automatically initialise if connected via USB and if the software is in Bootloader mode. The text on the Bootloader form will change to confirm that communication is established (see image below).
5. Click “Open Hex File” and navigate to the new firmware file that needs to be installed. This will enable the “Program/Verify” command button, click this to install the new firmware.</td><td>
</td></tr>
<tr><td>6. The bootloader will then proceed to install the new firmware file. The bootloader will show a verify error after the file is installed. This is caused by the bootloader not being able to verify the encrypted file and is not a problem, the new firmware file is now installed.
7. Use the “Reset Device” command to cycle the power and disconnect the bootloader software.</td><td>
</td></tr>
<tr><td>8. You can now disconnect the your USB lead and 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.
9. Check that your laser DAC settings are returned to the original setting. See the main section of the manual for information on setting EEPROM configuration.</td><td>
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Appendix D: Summary of firmware commands

OPC-N2 SPI functions (from point of view of SPI Master system) for firmware version 18.

Function	Firmware Versions	Command byte	Byte(s) out	Byte(s) in (0xF3 is set as standard initial return byte value from OPC-N2)	Measured time between end of current and start of next byte	Notes
Digital pot (fan and laser power) ON	**14/15 16/17 18**	**0x03**	0x03	0xF3	3ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x00	0x03	NA	
Digital pot (fan and laser power) OFF	**14/15 16/17 18**	**0x03**	0x03	0xF3	1.5ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x01	0x03	NA	
Digital pot (fan power only) ON	**16/17 18**	**0x03**	0x03	0xF3	5ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x04	0x03	NA	
Digital pot (fan power only) OFF	**16/17 18**	**0x03**	0x03	0xF3	3ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x05	0x03	NA	
Digital pot (laser power only) ON	**16/17 18**	**0x03**	0x03	0xF3	6ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x02	0x03	NA	
Digital pot (laser power only) OFF	**16/17 18**	**0x03**	0x03	0xF3	3ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x03	0x03	NA	
Digital pot Set Laser Power	**14/15 16/17 18**	**0x42**	0x42	0xF3	3.5ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x01	0x42	6us	LaserDAC is a unsigned 8bit integer variable.
			LaserDAC	0x01	NA	
Digital pot Set Fan Power	**14/15 16/17 18**	**0x42**	0x42	0xF3	7ms	Suggest that 10ms be used as delay between command

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						byte and following byte.
			0x00	0x42	6us	FanDAC is a unsigned 8bit integer variable.
			FanDAC	0x00	NA	
Digital pot Read Status	**18**	**0x13**	0x13	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			0x13	FanON		FanON is unsigned 8bit integer variable (1 or 0).
			0x13	LaserON		LaserON is unsigned 8bit integer variable (1 or 0).
			0x13	FanDACVal		FanDACVal is unsigned 8bit integer variable.
			0x13	LaserDACVal		LaserDACVal is unsigned 8bit integer variable.
Read information string	**14/15 16/17 18**	**0x3F**	0x3F	0xF3	1.5ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x3F	InfoStr ascii char00: “O” (=0x4F)	6us	SerialStr is a string of 60 characters. Value of shaded bytes doesn’t matter.
			0x3F	InfoStr ascii char01: “P” (=0x50)	“	
			0x3F	InfoStr ascii char02: “C” (=0x43)	“	
			0x3F	InfoStr ascii char03: “-“ (=0x2D)	“	
			0x3F	InfoStr ascii char04: “N” (=0x4E)	“	
			0x3F	InfoStr ascii char05: “2” (=0x32)	“	
			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: “O” (=0x4F)	“	
			0x3F	InfoStr ascii char20: “P” (=0x50)	“	
			0x3F	InfoStr ascii char21: “C” (=0x43)	“	
			0x3F	InfoStr ascii char22: “-“ (=0x2D)	“	
			0x3F	InfoStr ascii char23: “0” (=0x30)	“	

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			0x3F	InfoStr ascii char24: "1" (=0x31)	"	
			0x3F	InfoStr ascii char25: "6" (=0x36)	"	
			0x3F	……..	"	See separate Doc for details
			0x3F	InfoStr ascii char59: "." (=0x2E)	NA	
Read serial number string	**18**	**0x10**	0x10	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			0x10	SerialStr ascii char00		SerialStr is a string of 60 characters.
			0x10	SerialStr ascii char01		Value of shaded bytes doesn't matter.
			0x10	……..		See separate Doc for details
			0x10	SerialStr ascii char59		
Read Firmware Version	18	0x12	0x12	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			0x12	FirmwareVerMajor		FirmwareVerMajor is unsigned 8bit integer variable.
			0x12	FirmwareVerMinor		FirmwareVerMinor is unsigned 8bit integer variable.
Read Configuration Variables	**14/15 16/17 18**					See separate Document for details
Write Configuration Variables	**14/15 16/17 18**	**0x3A**	0x3A	0xF3	3ms	Suggest that 10ms be used as delay between command byte and following byte.
Read Configuration Variables 2	**18**	**0x3D**	0x3D	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			0x3D	AMSamplingIntervalCount LSB		AMSamplingIntervalCount is unsigned 16bit integer variable.
			0x3D	AMSamplingIntervalCount MSB		
			0x3D	AMIdleIntervalCount LSB		AMIdleIntervalCount is unsigned 16bit integer variable.
			0x3D	AMIdleIntervalCount MSB		
			0x3D	AMFanOnInIdle		AMFanOnInIdle is unsigned 8bit integer variable (1 or 0).
			0x3D	AMLaserOnInIdle		AMLaserOnInIdle is unsigned 8bit integer variable (1 or 0).
			0x3D	AMMaxDataArraysInFile LSB		AMMaxDataArraysInFile is unsigned 16bit integer variable.
			0x3D	AMMaxDataArraysInFile MSB		
			0x3D	AMOnlySavePMData		AMOnlySavePMData

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						is unsigned 8bit integer variable (1 or 0).
Write Configuration Variables 2	**18**	**0x3B**	0x3B	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			AMSamplingIntervalCount LSB	0x3B		AMSamplingIntervalCount is unsigned 16bit integer variable.
			AMSamplingIntervalCount MSB	AMSamplingIntervalCount LSB		
			AMIdleIntervalCount LSB	AMSamplingIntervalCount MSB		AMIdleIntervalCount is unsigned 16bit integer variable.
			AMIdleIntervalCount MSB	AMIdleIntervalCount LSB		
			AMFanOnInIdle	AMIdleIntervalCount MSB		AMFanOnInIdle is unsigned 8bit integer variable (1 or 0).
			AMLaserOnInIdle	AMFanOnInIdle		AMLaserOnInIdle is unsigned 8bit integer variable (1 or 0).
			AMMaxDataArraysInFile LSB	AMLaserOnInIdle		AMMaxDataArraysInFile is unsigned 16bit integer variable.
			AMMaxDataArraysInFile MSB	AMMaxDataArraysInFile LSB		
			AMOnlySavePMData	AMMaxDataArraysInFile MSB		AMOnlySavePMData is unsigned 8bit integer variable (1 or 0).
Read histogram data (and reset histogram)	See note	**0x30**	0x30	0xF3	9ms	**Output depends on Firmware version**
			0x30	Bin0 LSB	6us	**See separate doc**
Read PM data (and reset histogram)	**18**	**0x32**	0x32	0xF3		Suggest that 10ms be used as delay between command byte and following byte.
			0x32	PM1 Byte0		PM1 is a float variable occupying 4 bytes. Units are ug/m^3.
			0x32	PM1 Byte1		
			0x32	PM1 Byte2		
			0x32	PM1 Byte3		
			0x32	PM2.5 Byte0		PM2.5 is a float variable occupying 4 bytes. Units are ug/m^3.
			0x32	PM2.5 Byte1		
			0x32	PM2.5 Byte2		
			0x32	PM2.5 Byte3		
			0x32	PM10 Byte0		PM10 is a float variable occupying 4 bytes. Units are ug/m^3.
			0x32	PM10 Byte1		

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			0x32	PM10 Byte2		
			0x32	PM10 Byte3		
Save Configuration Variables in non-volatile memory	**14/15 16/17 18**	**0x43**	0x43	0xF3	5ms	Suggest that 10ms be used as delay between command byte and following byte.
			0x3F	0x43	6us	Initial command byte must be followed by sequence of bytes (shown in red).
			0x3C	0x3F	"	
			0x3F	0x3C	"	
			0x3C	0x3F	"	
			0x43	0x3C	NA	
Check Status	**14/15 16/17 18**	**0xCF**	0xCF	0xF3	NA	
Enter bootloader mode	**14/15 16/17 18**	**0x41**	0x41	0xF3	NA	

In general, suggest that the delay following first byte of any command sequence is 10ms and the delay between subsequent byte transfers is 10us.

End of Manual

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