PYREOS

Rev. 1.4

# Linear Array Evaluation Kit
# User Manual

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***Please note:*** *the information contained in this document is subject to change without further notification.*

# 1 Before You Start

There are a few points of safety that need to be taken into consideration before using any of the Linear Array Evaluation Kits.

1. Please be careful when handling a sensor: linear array sensors are susceptible to mechanical vibrations. Be sure to wear an anti-static wrist strap to prevent ESD damage.

2. Care must be taken to ensure the pins are aligned correctly when plugged in to the socket so as not to cause damage during use. See Section 5 for details.

3. The ATR Spectrometer consists of a ZnSe crystal. As with all glass like materials please take safety precautions at all times, and in the unfortunate event that the ATR window is damaged, cracked or broken please refer to safety guidelines for the safe handling of zinc selenide material such as those available at http://msds.chem.ox.ac.uk/ZI/zinc_selenide.html . It is important not to inhale or ingest any dust or fragments of ZnSe.

4. Ensure that the correct drivers are installed for the board type being used. See Section 4.2 for details.

# 2 Introduction

This user guide describes the software, hardware, and installation process for the Pyreos linear array sensor family evaluation kits. It is intended to be used by electronics and software engineers who are familiar with IR sensor components and products.

There are three kits available. The simplest is the Line Array Evaluation Board. This is a microprocessor powered board which interfaces to a PC and allows the user to test and evaluate a Line Array. Two further kits provide spectrometer functionality using the Line Array. The spectrometers are designed to be used as proof of principle demonstrations and as reference designs for customer's design work. The units are based on the pyroelectric line array sensors with the use of Linear Variable filters (LVF) as solid-state dispersion gratings. Using this technical approach, it is possible to take near, mid, or far IR spectral readings (dependent on the LVF used) in a few seconds, and in almost any working environment. The simplified principle of operation is shown below. There are two versions of this, an ATR spectrometer, and a transmission spectrometer. Both are explained in detail below.

This manual covers the following:

- Description, installation, and set-up of the kit.
- Software user guide, including spectrometry.
- Description of integrating electronics and sampling theory.
- Description of the data produced by the demonstration kit.
- Hardware guide.

# 3 Getting started


*Figure 1: Linear Array Evaluation Kit contents (Evaluation board variations PYB_001 V2 and PYB_201 Rev C, and the linear array sensor)*

## 3.1 Kit contents

1. Linear Array Evaluation Board, or ATR Spectrometer kit, or Transmission Spectrometer kit
2. USB Memory stick with the Linear Array Evaluation Kit Windows software.
3. Linear Array Sensor (some versions do not have a sensor fitted).
4. USB cable
5. 9-Volt DC power supply.

## 3.2 Minimum system requirements

1. Microsoft® Windows PC (all versions currently supported)
2. Local administrative rights to install device drivers
3. .NET Framework 4.5
4. 1 free USB port

# 4 Installation

There are two software components required to use the demonstration kit: the device drivers for USB connection and the windows application software supplied with the kit

## 4.1 Install the Pyreos software

From the software pack included with the kit, select the “setup.exe” file that has this icon. This will start the installation process.

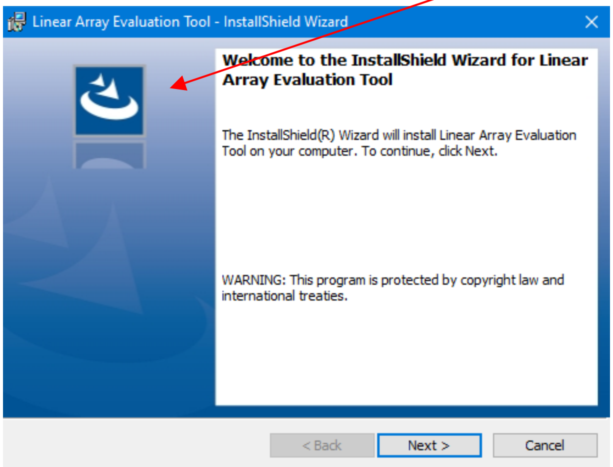



**Figure 2: Installer screen**

Follow the on-screen instructions and enter the information required.

As part of the installation process a check will take place to see if .NET Framework 4.5 is present. If not, the setup routine can be cancelled and the .NET framework 4.5 can be downloaded from Microsoft’s website or use the installer provided (“dotnetfx45_full_x86_x64”) in the software package.

## 4.2 Device Driver Installation

Prior to connecting the Linear Array Evaluation Board for the first time, it is necessary to install the appropriate Virtual COM Port driver. The PYB_001 V1 board employs a Silicon Labs CP2102 USB to UART IC, whilst the PYB_201 Rev C board uses the STM32 USB-FS library incorporated as part of the Linear Array Evaluation Board firmware. The drivers for both boards are provided on the distribution media, under the directory given in Table 1; this table also provides the appropriate download link for each driver.

| Evaluation Board | Directory on media | Device Driver Download Link |
|---|---|---|
| PYB_001 V1 | CP210x_Universal_ Windows_Driver | https://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx |
| PYB_201 Rev C | STM VCP Driver | https://my.st.com/content/my_st_com/en/products/development-tools/software-development-tools/stm32-software-development-tools/stm32-utilities/stsw-stm32102.license=1537977446956.product=STSW-STM32102.html |

***Table 1: Virtual COM Port Driver Selection***

To install The CP2102 driver, run the appropriate file for your operating system as given in Table 2.

| Windows Version | System Type[1] | Driver installation executable |
|---|---|---|
| 7 and later[2] | 64-bit | CP210xVCPInstaller_x64.exe |
| 7 & later | 32-bit | CP210xVCPInstaller_x86.exe |

***Table 2: CP2102 Driver Installer Selection***

To install the STM driver, run the appropriate file for your operating system as given in Table 3.

| Windows Version | System Type | Driver installation executable |
|---|---|---|
| 7 | 64-bit | VCP_V1.5.0_Setup_W7_x64_64bits.exe |
| 7 | 32-bit | VCP_V1.5.0_Setup_W7_x86_32bits.exe |
| 8 & later | 64-bit | VCP_V1.5.0_Setup_W8_x64_64bits.exe |
| 8 & later | 32-bit | VCP_V1.5.0_Setup_W8_x86_32bits.exe |

***Table 3: STM Driver Installer Selection***

Once the drivers are installed, connect a powered Evaluation Board to the PC. Windows will then install the driver. You will then see one of the following entries under “Ports (COM & LPT)” (Figure 3):

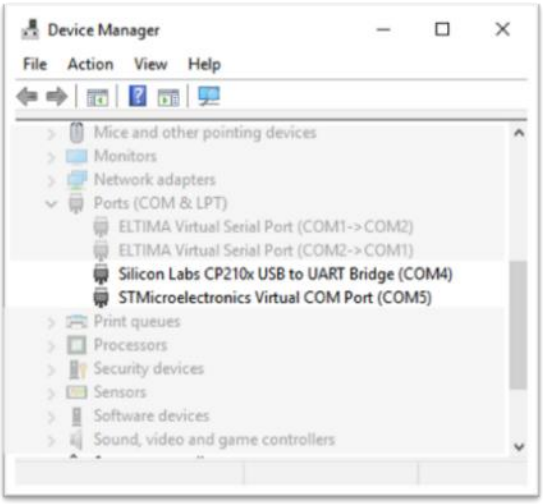



***Figure 3: Device Manager Entries for Evaluation Boards***

[1] This can be found under Control Panel\System and Security\System or using the [Windows key] and [Pause | Break] on certain keyboards.

[2] At time of writing, Windows 10 is the latest operating system, and the STM Windows 8 driver will install without issue on a Windows 10 PC.

# 5 Setup the Pyreos Evaluation kit

Connect the power supply provided to the Demo Kit.
Connect the USB cable to the Demo Kit and Windows PC.
You may see a message suggesting you are required to install a device driver. Follow the on-screen instructions and download a driver from Windows Update.
Your kit is now installed and ready to use.

If a linear array sensor needs to be connected to the board

1. Ensure that all power has been removed from the board by disconnecting the power supply and the USB cable from the Evaluation Board.

2. Locate the Linear Array sensor in the socket with pin 1 (highlighted by the cut corner shown in Figure 4) aligned with slot 1 of the socket (diagonally opposite corner from the lever).

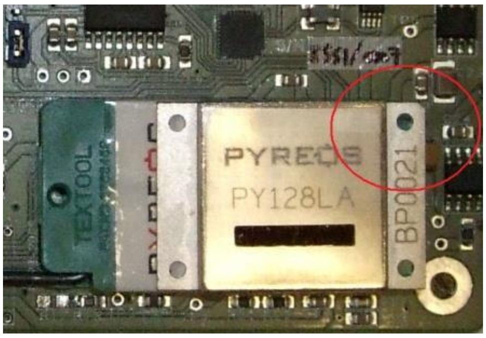



***Figure 4: Locating linear array sensor in the socket***

3. Push down to close the lever on the socket to secure the linear array sensor


***Figure 5: Socket lever***

4. Reconnect the power supply and the USB cable to the board
5. Start the Linear Array Evaluation Tool

# 6 Spectrometer Kits

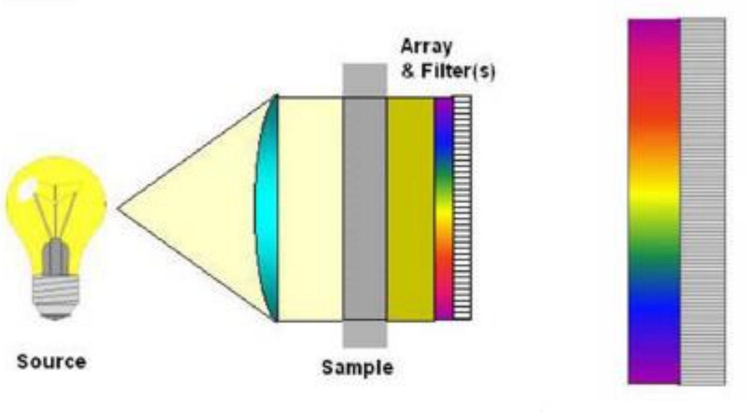



*Figure 6: Optical principle of a linear array spectrometer*

The demonstration units are available in line array sensor resolutions of 1x 128, 1x 255, 1x 510 and come fitted with a linear variable filter (LVF). There is a common board – the LA Evaluation Board which is used to provide the electronics.

The 2.5um to 5um wavelength range LVF will require an additional blocking filter, sapphire for example, to stop much higher wavelengths from passing through at the lower wavelength range.

This format of miniature high-performance solid-state IR spectrometer is just one of several approaches enabled by these unique line array sensor products. The combination of line array sensor and LVF makes for highly robust, compact, lower cost spectral analysis, which can be tailored to an individual customer's wavelength range of interest. Please ask your sales contact if you would like more information about other approaches to portable spectrometer solutions.

## 6.1 Linear Variable Filters (LVF)

There are several different methods for separating light in spectrometers. An LVF is one approach to providing spectrally separated light to the line array sensor elements. An LVF is a band pass filter coating intentionally wedged in one direction. Since the centre wavelength is a function of the coating thickness, the peak centre wavelength will vary in a linear fashion in the direction of the wedge, as shown in the diagrams below.

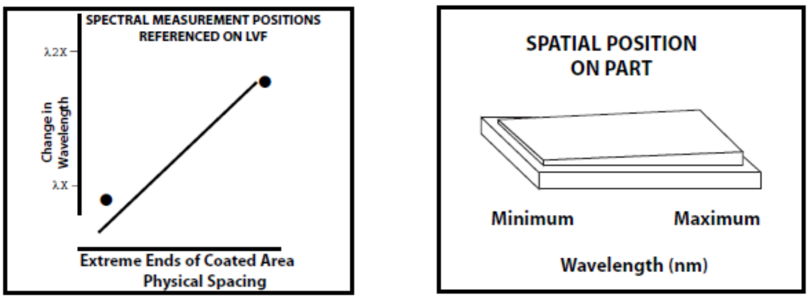



*Figure 7: Linear variable filter information*

The centre transmission wavelength of light transmitted through the LVF varies linearly across the length of the filter. Therefore, different wavelengths will be detected on different sensor elements of the underlying line sensor array.

The overall spectral resolution will be primarily dependent on the wavelength range of the LVF and the optical specification of the LVF, as well as the resolution of the line array sensor used in the spectrometer.

## 6.2 ATR Spectrometer

Attenuated Total Reflection (ATR) spectroscopy is one method for analysing the infra-red spectrum absorbance of liquids. It provides a very simple way to sample liquids onto the sample surface of the ATR spectrometer and quickly take measurements. It also provides a simple way to integrate a spectrometer into an industrial process line enabling continuous process control measurements. The diagram below illustrates the principle of operation of an ATR spectrometer.

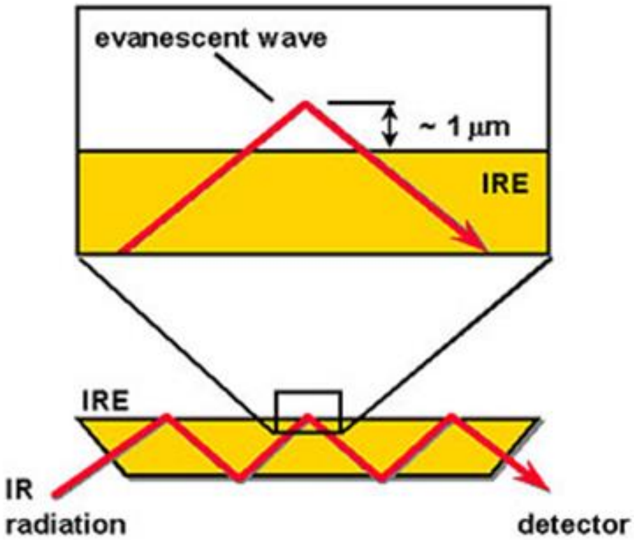



*Figure 8: The optical principle of an ATR spectrometer*

The transmittance plot below was measured using the ATR spectrometer demonstration unit and took 44 seconds to acquire. The alignment of the linear line array to LVF (linear variable filter) is carefully calibrated during manufacture to ensure optimum spectral accuracy and that minimal red or blue wavelength shift occurs in the spectrum.

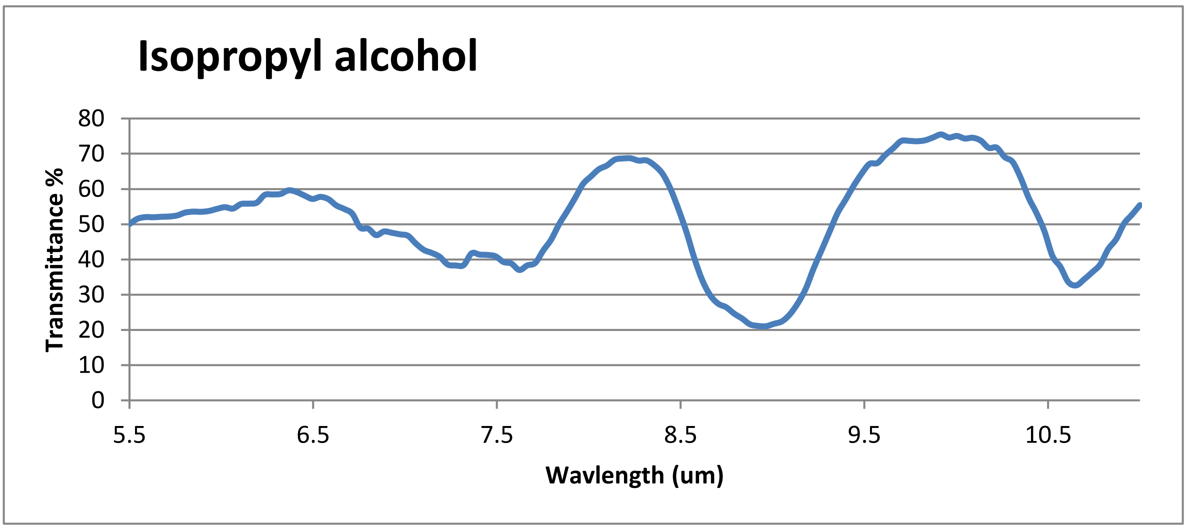



*Figure 9: Transmittance plot of IPA*

## 6.3 Transmission Spectrometer

Figure 10 shows the transmission spectrometer.

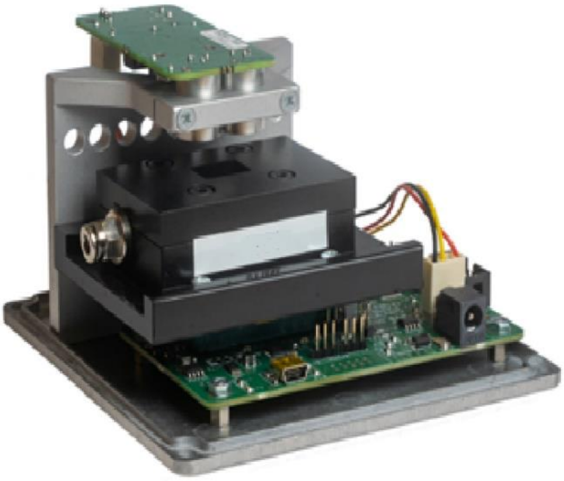



*Figure 10: Transmission mode evaluation kit (left) and Specac transmission cell (right)*

For this system, it is necessary to prepare a sample for analysis in a transmission cell, a range of which are available from a variety of suppliers. The Pyreos transmission spectrometer unit was designed to take the Omni-cell liquid transmission cell system from Specac – part number: GS01800 – "Omni-Cell Body with 3" x 2" Slide Mount assembly".

### 6.3.1 Example measurement

Figure 11 shows two measurements of Polystyrene spectrometer calibration cards from Thermo Scientific. These measurements were collected in under 30 seconds. The results are consistent with the standard films and provide evidence that the miniature spectrometer units can be used to provide out of the laboratory spectral analysis.

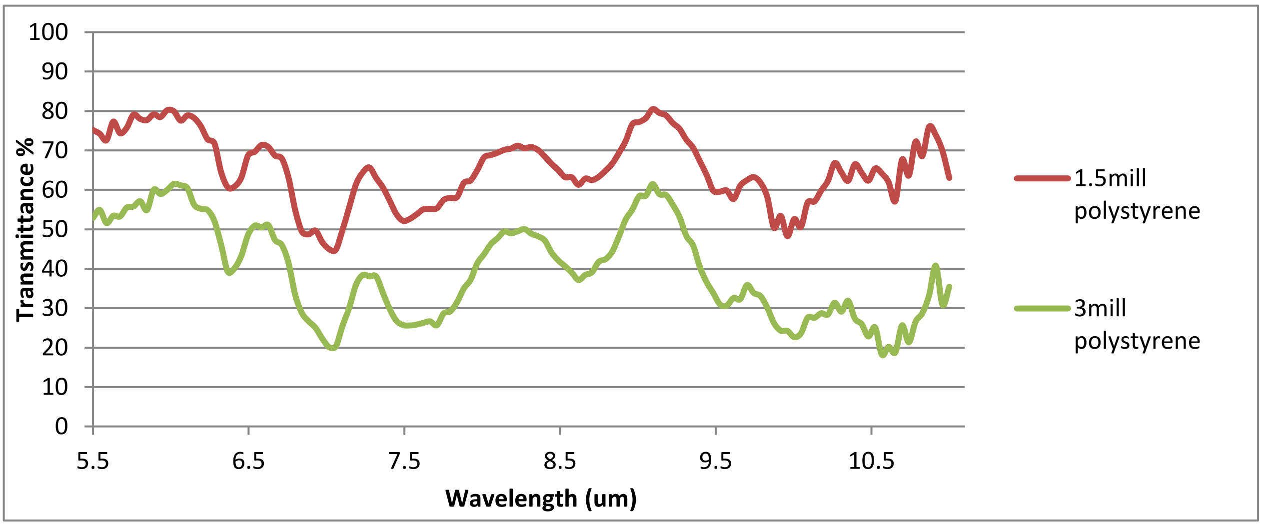



*Figure 11: Transmittance plot of 2 thicknesses of Polystyrene*

A variety of leading Universities and industry leaders have already developed ground-breaking inline and continuous process monitoring and quality control solutions using the ATR and transmission spectrometer units as the starting point for their designs. Publicly available results include the following publication which achieved accuracy similar to that of an FT-IR spectrometer in a real application setting.

[1] Wiesent, B.R.; Dorigo, D.G.; Schardt, M.; Koch, A.W.  Gear oil condition monitoring for offshore wind turbines using band limited resolution spectra. In: *Proc. of OilDoc Conference and Exhibition 2011*, 01.-03.02.2011, Bavaria, Germany.

# 7 Using your spectrometer

This section outlines key handling and operating procedures for the spectrometer variants.

## 7.1 Placing specimens on your ATR spectrometer

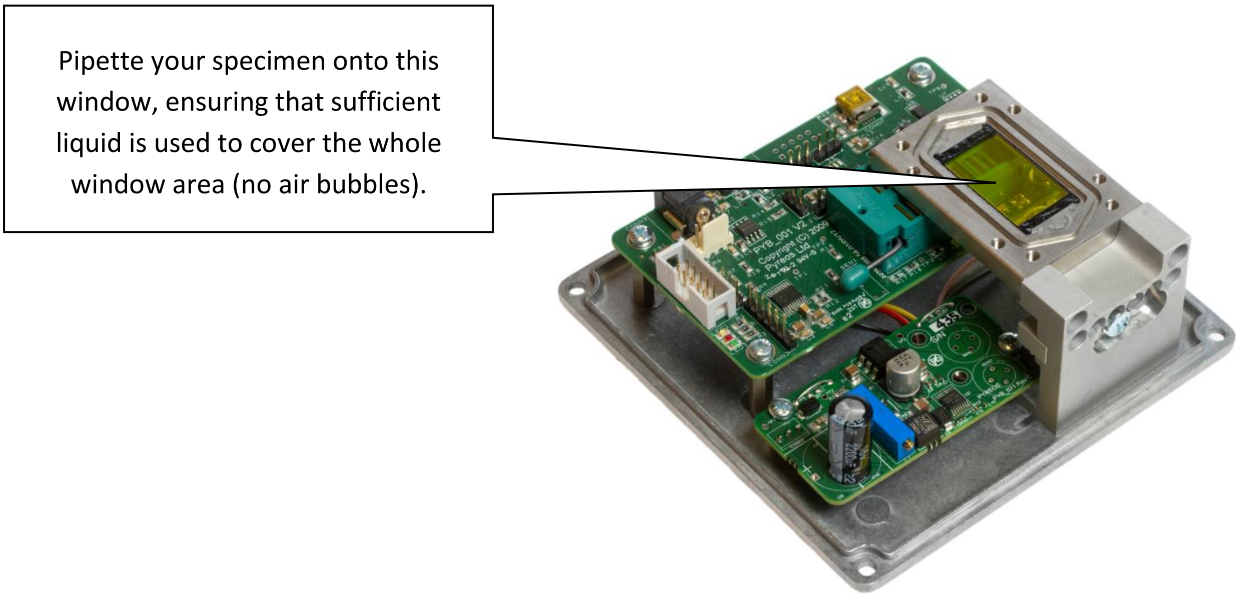



***Figure 12:  ATR spectrometer***

## 7.2 Cleaning and care of the ATR crystal

The ATR crystal window is made from zinc selenide (ZnSe) coated to provide a toughened scratch resistant surface and has the appearance of yellow coloured glass. Zinc selenide is chosen for its high IR optical transmission and its mechanical robustness. It is important to keep the ATR scratch free, as scratches create optical aberrations on the surface of the ATR which prevent the spectrometer from working to maximum potential.  Please ensure the ATR window is clean before starting your measurements. If using tissues for cleaning processes use lint free lens tissues or other non-scratch materials.

## 7.3 Placing the transmission cell into the transmission mode spectrometer

The transmission sample cell can be placed in the spectrometer unit by sliding it into the black draw in the transmission kit, as shown in the images below. The cell can be used to record a background reading and then filled with sample material to record a spectrum.

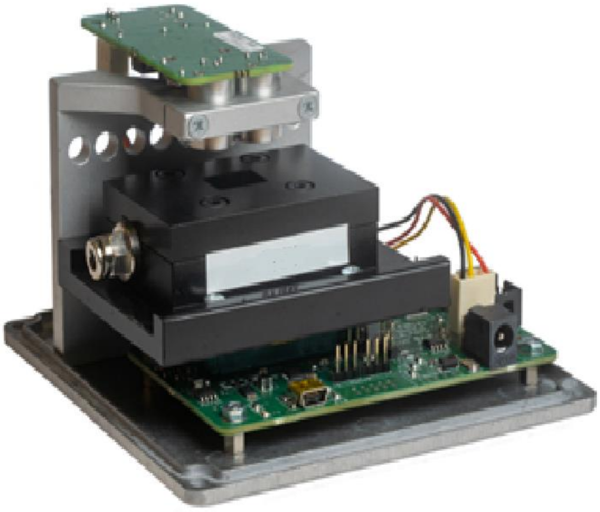


*Figure 13: Transmission Cell spectrometer*

# 8 Software user guide

This section describes how to use the Linear Array Evaluation Kit software with your Linear Array sensor and Evaluation Board.

## 8.1 Starting the software

You will find a link in your Windows Start menu to “Line Array Sensor Evaluation Tool”. Clicking this link will load the software. The main form is shown in Figure 14.

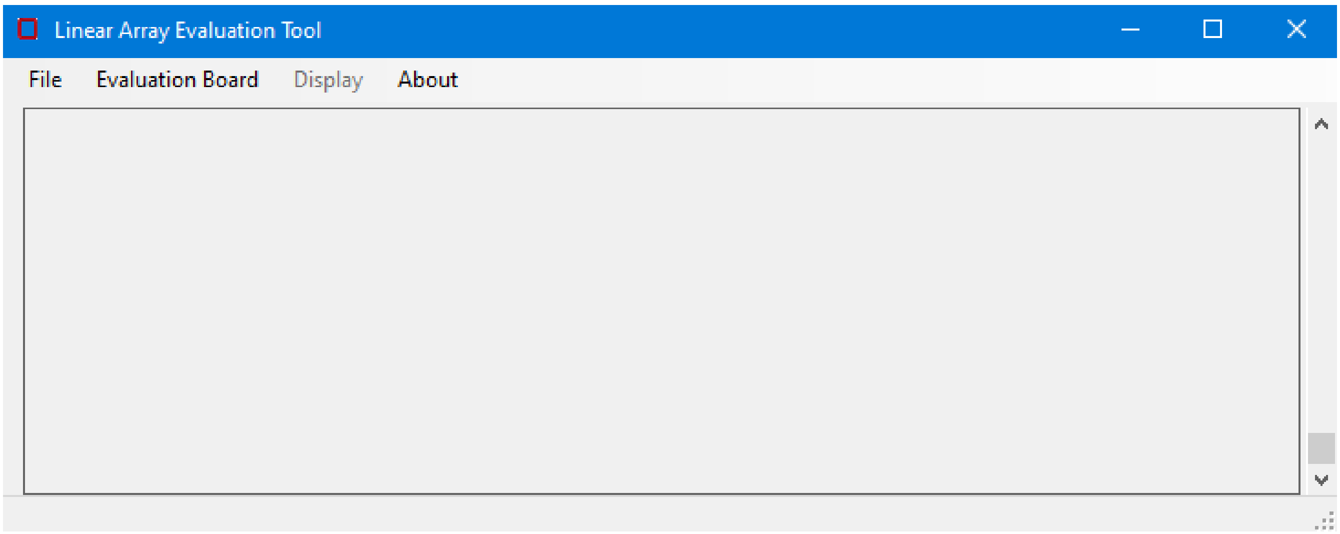



*Figure 14: Linear Array Sensor Evaluation Kit Main Form*

### 8.1.1 Connecting the Software to the Evaluation Board

Connect the Evaluation Board to your computer and select **Connect** from the **Evaluation Board** menu. The software will display a dialog box (Figure 15) asking you to "Select Evaluation Board" from the available list. If no items are displayed, check your USB connection, and click **Refresh**[3].

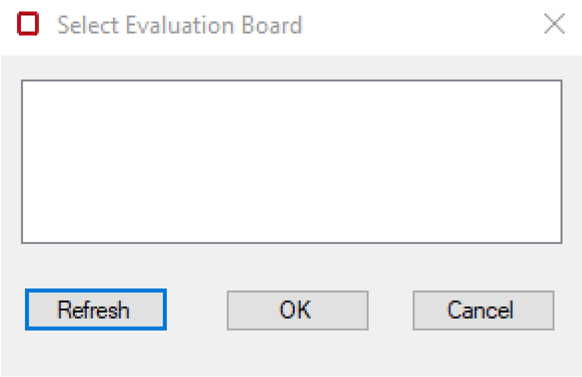



*Figure 15: Evaluation Board Selection Form*

Select the appropriate Evaluation Board and click **OK**, and the Evaluation Kit will attempt to connect to the Evaluation Board and begin streaming data from the Linear Array sensor.

The software should now be connected and will start reading data from the Linear Array sensor and display the captured data as a continuously updated histogram plot (Figure 16) from all sensor elements (pixels) in the Linear Array sensor under evaluation.

The connected board type will be displayed in the status bar alongside the connected status and the temperature of the line array (in Celsius). The temperature can be updated from the option in the 'Display' menu.

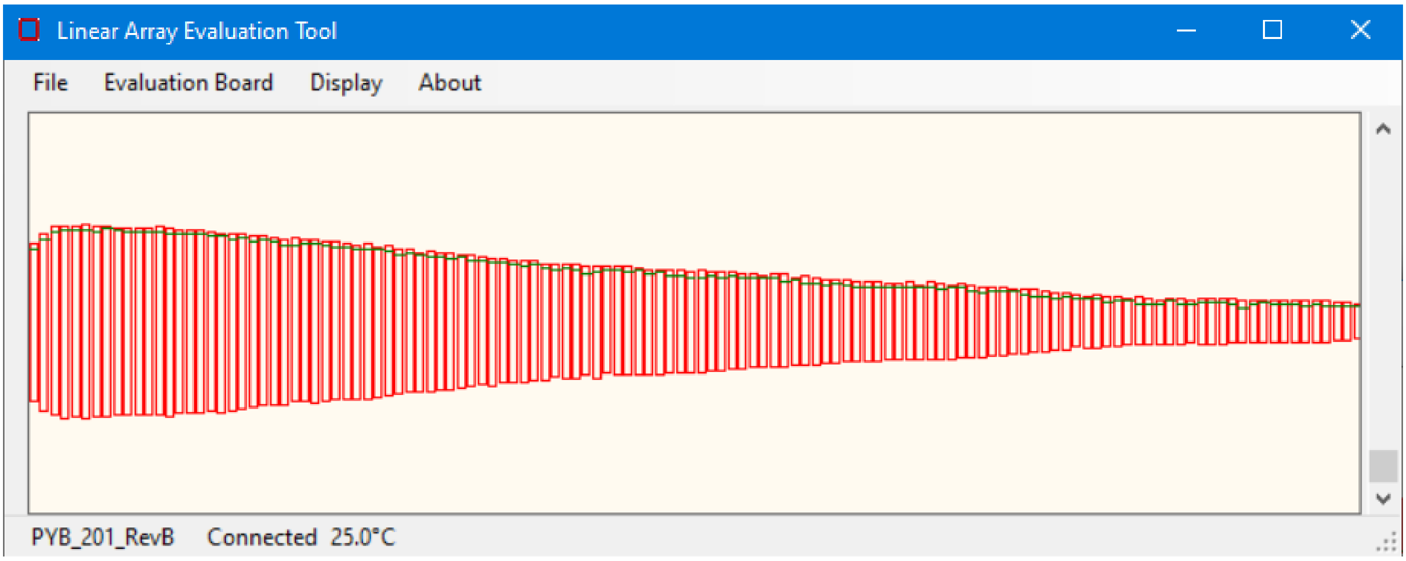



*Figure 16: Histogram Display for Connected Sensor*

[3] All COM ports are scanned and queried for the version text from the evaluation board firmware; therefore, the loading and refresh of the Sensor Selection dialog box may take a few minutes, depending on COM port devices attached.

Once connected to an Evaluation Board and streaming data, more choices will appear on the menu bar. These are described in the following sections. When finished with an Evaluation Board connection it can be disconnected via the **Evaluation Board** menu or by exiting the application. In the latter case, a dialog box (Figure 17) will be displayed if the sensor is connected giving you the option to disconnect and exit or to cancel the exit operation, with the sensor still connected.

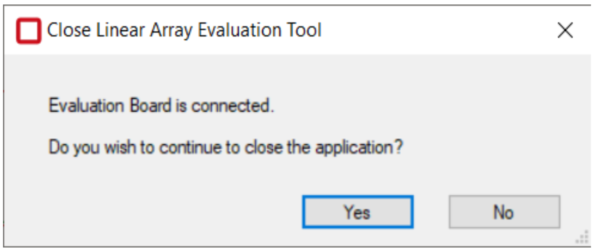



***Figure 17: Exit Dialog Box***

## 8.2 Using and understanding the main display

The main display of the software shows live data from the Linear Array sensor when connected correctly. When the default configuration is used, each sensor element (pixel) that is being read out from the Linear Array sensor under test, is shown as an individual red rectangle with a green line within, as shown below.

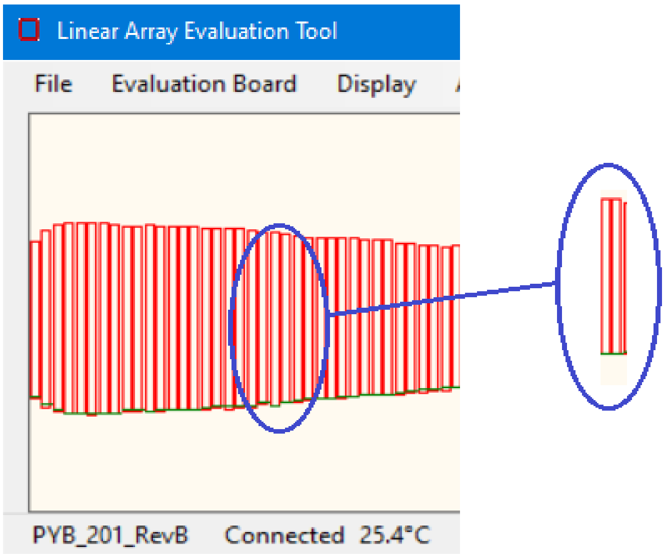



***Figure 18: Histogram Detail***

The lower and upper sides of the red rectangle represent the minimum and maximum values read from that pixel over a set number of recent samples, and the green line displays the present value. The position of these values on the screen indicates the voltage read from the corresponding pixel, with 2.5V in the middle of the screen, 0V[4] at the bottom and 5V[4] at the top. Pixel 0 is located on the left-hand side.

The status bar provides information about the current connection and the Line Array temperature (See Section 11.2.3 for more details).

[4] This range is only valid when the scroll bar handle is at the bottom (default).

The vertical scroll bar provides a zoom function: when the scroll bar handle is at the bottom of the screen the display shows the full 0 to 5V range, and as it is moved up the range is reduced by 10mV each increment. Alternatively, use your mouse wheel or track pad to zoom in and out as per your settings.

To examine the data from a single pixel, a virtual oscilloscope window can be opened by double clicking on any specific pixel, or by selecting **Oscilloscope view** from the **Display** menu and then entering the desired pixel number in the dialog box. A further explanation of "Oscilloscope view" is provided in Section 8.5.

Data from the Linear Array sensor under test can be displayed in several different ways using the evaluation software. The following sections describe how to select and use these options.

To view the raw signal from the line array as a spectra there is a feature named '**Spectrometer'** under the 'Display' menu which will open a new window with numerous spectroscopy features as detailed in Section 9.

## 8.3 Sensor properties

The evaluation software supports several Pyreos Linear Array Sensor products. A properties dialog box (Figure 19) is available from the **Properties** option under **Evaluation Board** menu. This dialog allows for the configuration of how the Evaluation Board firmware captures pixel data from the Linear Array sensor.

This section details the different options available and what affect they have on the data available from the Linear Array. Except for the Sample rate, any changes selected from this dialog box will not take effect until the **Apply** or **OK** button is pressed.

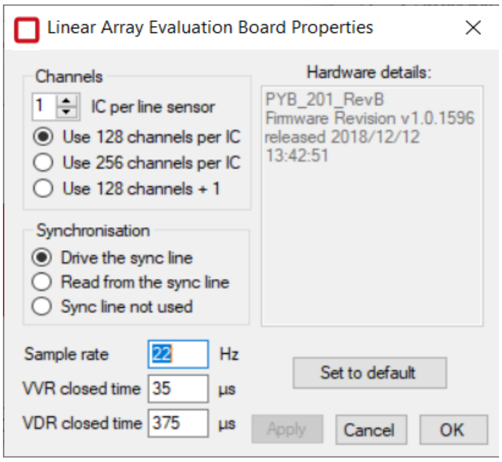



**Figure 19: Evaluation Board Properties**

### 8.3.1 Selecting the Pixel Configuration to be captured from the Linear Array sensor

Pyreos Linear Array Sensor products are available for 128, 128+1, 255 or 510 pixels. Each Linear Array sensor has either one or two application specific integrated circuits (ASICs) within the product package. The ICs provide all the necessary front-end amplification circuits for each pixel in the Linear Array sensor. Figure 19 gives the optimal settings for the range of Linear Array sensors. Please note, the first channel of each IC is not connected. The Linear Array Sensor Evaluation Kit display will, therefore, show a zero value for the first pixel in the 1 x 256 configuration, and a zero value for the first and last pixels in the 2 x 256 configuration.

In addition to these configurations the 510 Linear Array sensor can be configured as 2 x 128 to provide 256 valid pixels.

| Number of Sensor Elements | Pyreos product code | Optimal Configuration | Properties Dialog Settings | |
|---|---|---|---|---|
| | | | IC per Linear Array sensor | Use channels per IC |
| 128 | PY-LAS-128 | 128 x 1 | 1 | Use 128 channels per IC |
| 129 | PY-LAS-128+1 | 128 + 1 | N/A | Use 128 channels + 1 |
| 255 | PY-LAS-255 | 256 x 1 | 1 | Use 256 channels per IC |
| 510 | PY-LAS-510 | 256 x 2 | 2 | Use 256 channels per IC |

***Table 4: Linear Array sensor Configurations***

If *Use 128 channels + 1* is selected, the main form Display menu will display the *Oscilloscope + 1* option.

### 8.3.2 Synchronising the Linear Array Sensor to an IR Light Source

There are three options available for synchronisation between an IR illumination source and the sampling of data from the Linear Array sensor under test. The radio buttons in the **Properties** dialog box detail which option is being used by the demonstration kit and can be selected by the user. These options are detailed in Table 5.

| Radio Button | Description |
|---|---|
| Drive the Sync line | When this option is selected the Evaluation Board will drive a 5V square wave signal with a 50% duty cycle to the synchronisation header[5].<br><br>The frequency of the generated signal is specified in the Sample rate box on the **Properties** dialog. See Section 8.3.3 for details.<br><br>This option is typically used in a spectrometer application, where the Evaluation Board firmware controls the IR beam illuminating the sensor. |
| Read from the sync line | When this option is selected the Evaluation Board will read a 5V signal applied to the synchronisation header[5].<br><br>In these circumstances, it is common that this signal is generated by a device employing a rotating disk or shutter to mechanically chop the IR beam illuminating the sensor. |
| Sync line not used | This option would typically be used if the Linear Array sensor is intended for use in an application where there is no means of synchronisation between the firmware and the IR illumination source: for example, a thermal difference imager.<br><br>Selecting this option will result in the capture of data at the frequency entered in the sample rate box on the dialog (Section 8.3.3). |

***Table 5: Synchronisation Options***

[5] Please refer to the appropriate Appendix for the evaluation board you are connecting to.

With the selection of any of these options, the Evaluation Board firmware will capture a sample of the Linear Array sensor pixel data on both the rising and falling edges of the signal.

If synchronisation with an IR source is not required, leave the synchronisation header unpopulated and select the **Drive the Sync line** option.

Section 0 of this user guide further details why IR source and sample synchronisation are useful.

### 8.3.3 Specifying the Sample rate

The **Sample rate** box of the **Properties** dialog allows configuration of the required capture frequency. The value to be specified is twice that of the frequency of the square wave signal. The maximum value that can be set is 250 Hz. However, depending on the Pixel Configuration (Section 8.3.1) and the baud rate setting negotiated on connection, it may not be possible to achieve the value set. In this case, you will be alerted and the value set to the maximum possible.

Figure 20 provides an example of the alert dialog box informing you that the Evaluation Board firmware has a limit of 256 Hz, which is the maximum that the firmware can sustain.

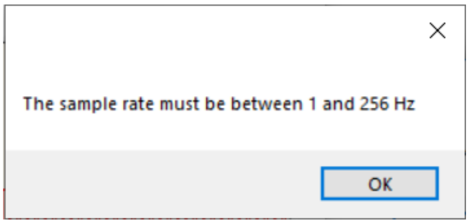



***Figure 20: Invalid Frequency Alert Message***

The maximum sampling frequency setting of 256 Hz is achievable for all pixel/IC configurations. However, if the VVR/VDR timings (Section 8.3.4) are increased from the default values, the VDR value will be assessed against the sample rate and other timings and the following dialog box will be displayed (Figure 21); you will need to reduce the VDR value accordingly before proceeding.

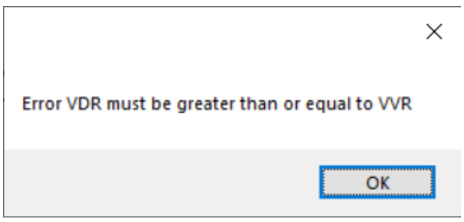



***Figure 21: Invalid VDR Alert Message***

### 8.3.4 Selecting the correct timings for operating the Linear Array sensor

There are three different options available to select the timing of the Linear Array sensor electronics, VVR, VDR and sample rate. The VVR and VDR high timings are used to start a sample, further information on these can be found in your product datasheet. It is rare for these timings to be changed from the default values. The sample rate value dictates the sample rate measured in Hz, changing this value will alter the integration time used by the Evaluation Board to collect data (This is only used when the kit is configured to either “Drive the sync line” or “sync line not used”).

Remember to click “**Apply**” or “**Ok**” for changes selected from the Properties dialog box to take effect.

## 8.4 Display show rendering options dialog box

The Linear Array Evaluation Kit has several options for processing and displaying the data generated by the Linear Array sensor. Between capture and display the software performs the following processes (Figure 22) to render the data according to the user's requirements.

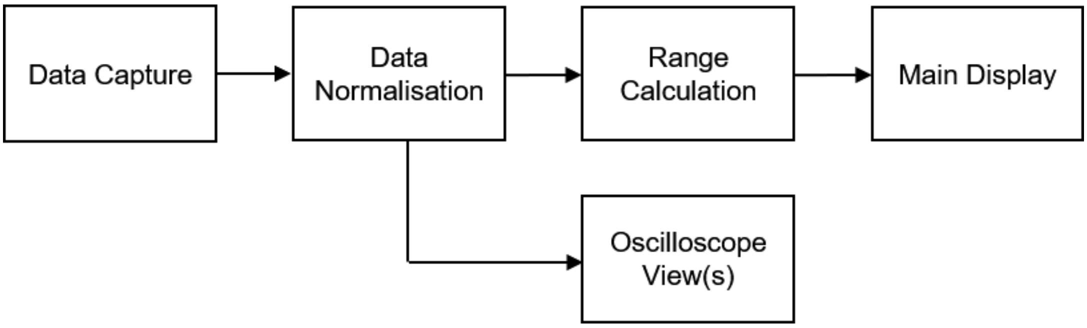



*Figure 22: Data Manipulation Processes*

The configuration of these processes is governed by the details entered into the rendering properties dialog box (Figure 23). There are five options available in this dialog box each of which alters how the software processes and displays data from the Linear Array sensor. These are explained in the following sections.

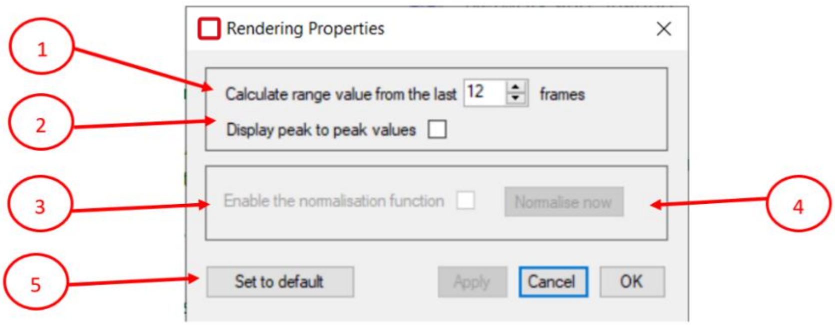



*Figure 23: Rendering Properties Dialog*

### 8.4.1 Data Capture

The software reads frames of data from the Linear Array sensor Evaluation Board via a virtual COM port. Each frame contains the 16-bit pixel values and a frame marker which specifies whether the associated data is synchronised with a high or low illumination pulse. Full details of the data format are detailed in Section 9.5.

Checking the *Display peak to peak values* (2) in the rendering properties dialog box, the software will calculate and display the peak to peak values from two consecutive data frames by subtracting the low illumination pulse values from the high illumination pulse values. Peak to peak values are useful for spectroscopic analysis, either internally (see Section 8.4.2), or externally via CSV output (Section 8.6).

### 8.4.2 Histogram Range Calculation

In order for the histogram plot to display a box showing the extent of the variation of each pixel to the pulsating illumination source, it is necessary to establish over what time period this peak to peak magnitude should be calculated. The default is to display the maximum and minimum values from the last 12 frames of data. This is especially useful if the capture is not synchronised with a pulsating IR illumination source (Section 8.3.2).

The number of frames to be scanned to obtain the maximum and minimum values can be adjusted by entering a value in the *Calculate range value from the last [ ] frames* box (1) in the rendering properties dialog box and clicking either the Apply or OK button.

### 8.4.3 Normalisation

The Linear Array Evaluation Kit provides a normalisation process to facilitate the demonstration of the use of a Linear Array sensor for spectroscopic analysis.

To illustrate, consider the case of a Linear Array sensor fitted with a linearly varying filter (LVF) crystal to 'tune' each pixel to IR radiation of a particular wave number. Figure 16 (Section 8.1.1) shows the regular histogram plot for the sensor in air. Clearly, lower wave numbers are more prominent.

Checking the peak to peak option (2) results in the display shown in Figure 24.

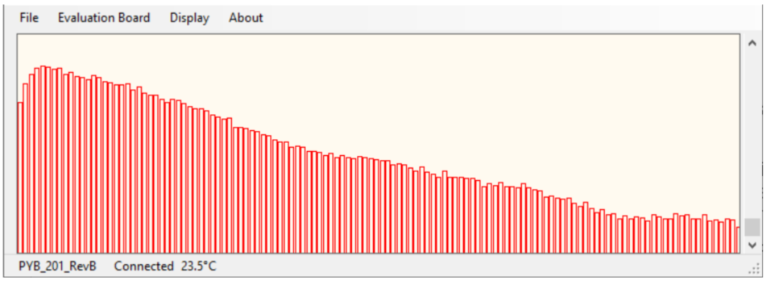



***Figure 24: Peak to Peak values (Air)***

Covering the sensor window with a 1.5 mil polythene sheet affects the transmittance of radiation of all wave numbers but more so for certain wave numbers that are characteristic of the composition of the polythene.

Figure 25 shows how the peak to peak values are affected by the polythene, and the wave numbers most affected.

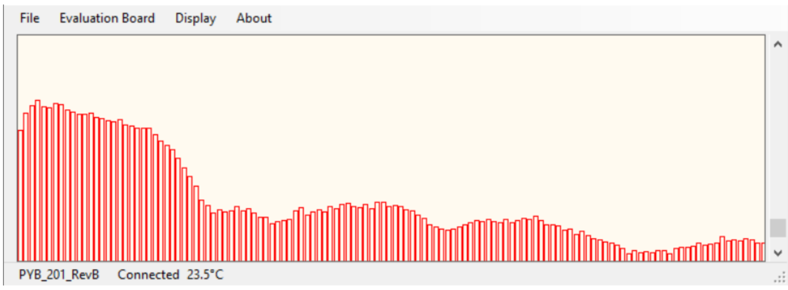



***Figure 25: Polythene (1.5mil) transmittance effects***

Normalisation of the peak to peak values for air enables the transmittance effects of the polystyrene to be more clearly discernible, as illustrated by Figure 26.

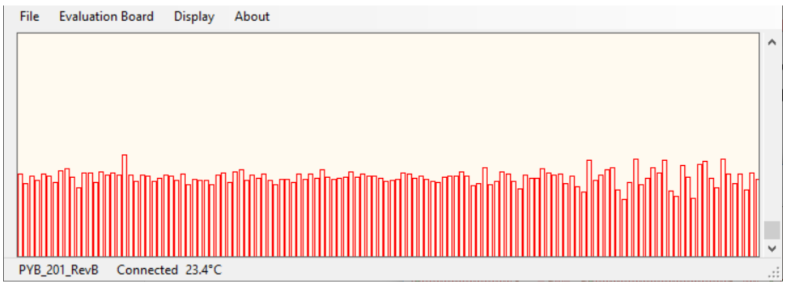



***Figure 26: Polythene (1.5mil) - Normalised plot***

The normalisation process involves weighting each peak to peak pixel value to provide a similar value for each pixel. The weighting of each pixel ($\propto_i$), is calculated from each pixel peak-to-peak value ($p_i$) of a single frame on demand (at time$t_{norm}$) by Equation 1.

$$\propto_i (t_{norm}) = \frac{1000}{p_i(t_{norm})}$$

***Equation 1: Normalisation Weight Calculation***

For subsequent frames the weighting is applied using Equation 2 so that $p_i'(t)$ is roughly 1000.

$$\boldsymbol{p_i'(t) = \propto_i (t_{norm}) \times p_i(t)}$$

***Equation 2: Adjustment of pixel values***

Checking the *Enable normalisation function* option (3) in the Rendering Properties dialog box and clicking the Normalise now button (4) will calculate the weightings for the current frame (Equation 1) and the plot will display the normalised subsequent frames according to Equation 2.

## 8.5 Oscilloscope view

The Oscilloscope view has several different features which aim to emulate a basic oscilloscope for viewing live sampled data from an individual channel of the Linear Array sensor. It is possible to open several individual oscilloscope views at a time.

Figure 27 shows the saw-tooth pixel value of a synchronised capture.

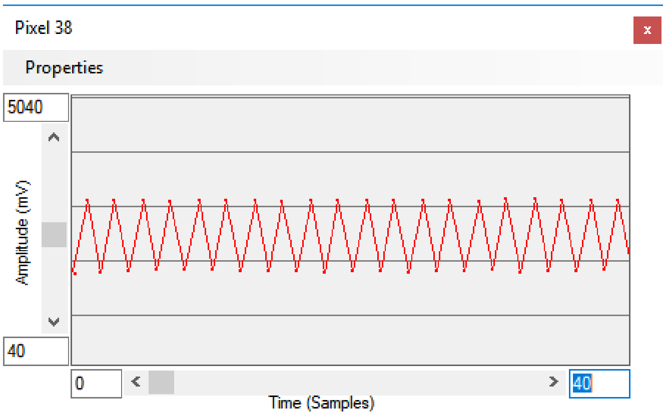



***Figure 27: Oscilloscope view – synchronised pixel***

To create a new Oscilloscope view, either double-click on the required pixel on the histogram plot or select **Oscilloscope view** from the **Display** Menu and entering the pixel number (Figure 28).

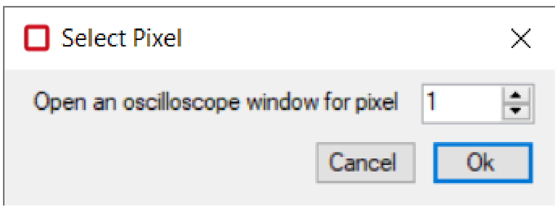



***Figure 28: Select Pixel Dialog Box***

The oscilloscope view component can be adjusted to enable the desired operation, on both the y-axis (amplitude) and the x-axis (time domain) maximum and minimum values can be entered in the appropriate boxes.

### 8.5.1 Oscilloscope display range

The amplitude and range of the signal being viewed (Figure 27, Figure 30) can be changed in two different ways. First the max and min values can be entered in the boxes on the control (for both the x and y axis) or these can be set using the PC mouse control:

1) Entering the values in the text boxes
   a. When entering the values, the colour of the box will change to signify that the value in the box is not currently being displayed. When you have set the text value to the desired number press **Enter** on the keyboard and the display will update (the text box changes back to white to signify that the value in the box is being used). If the new value is not accepted (for example if the minimum value is greater than the maximum value or text has been entered instead of a number) then the previous value will automatically re-load.
2) Using the mouse
   a. When the Oscilloscope window has control focus (it can be selected by clicking on the title bar) the scroll bars at the side can be used to move the display position and zoom in or out. Zooming in or out is achieved by positioning the mouse over the scroll bar (horizontal or vertical) and using the mouse wheel. Moving the position is achieved by dragging the bar position.
   b. The position viewed can also be adjusted in both x and y directions by holding down the right mouse button when over the viewing area and moving the mouse pointer (up, down, left, or right).

### 8.5.2 Oscilloscope menu

- Properties
  - This displays the Oscilloscope view Properties dialog box (Figure 29) which controls display and spacing (in mV) of the horizontal grid lines.

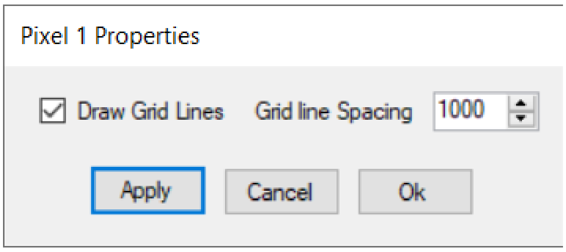



***Figure 29: Oscilloscope view Properties Dialog Box***

### 8.5.3 Oscilloscope +1 menu

When using a 128 + 1 Linear Array sensor (e.g. PY-LAS-128+1) and enabling 128 + 1 capture on the Sensor Properties dialog box (Section 8.3.1), the Display menu will show the Oscilloscope view +1 option. Selecting this option will display the “+1” pixel value (Figure 30).

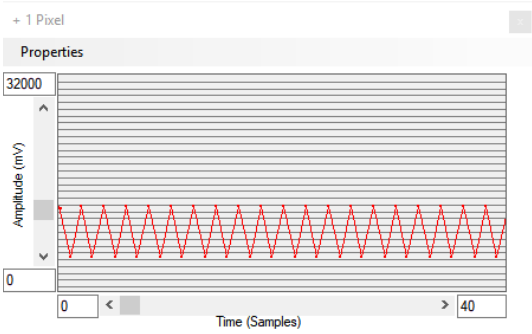



***Figure 30: Oscilloscope view - + 1 pixel***

## 8.6 Saving data to a CSV file

In the **File** menu there are two options to save data from the demonstration kit to a Comma Separated Value (CSV) file which can be opened by Microsoft Excel or similar software package. Selecting the menu option ***Save to CSV*** will show three further options: **Capture 200 samples**, **Capture until stopped**, and **Specify samples to capture**. Selecting the last option will display a dialog box (Figure 31) to specify the number of samples to capture.

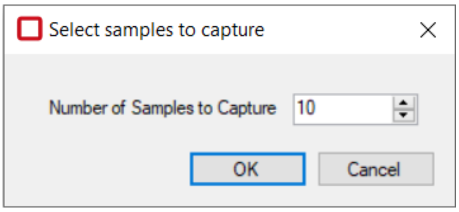



***Figure 31: Save to CSV Samples Selection Dialog Box***

On closing the **Select samples to capture** dialog box, or by selection of either of the other two options, the Open File dialog box will be displayed. After the file name is specified the Linear Array Evaluation Kit will automatically write data to the specified file until either the required samples are saved or the operation is stopped by selection of the **Stop Capture** option from the **File** Menu. Progress of the capture is shown to the right of the status bar (Figure 32).

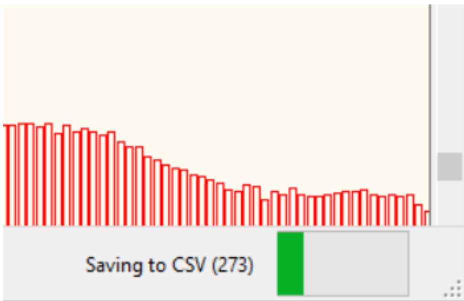



***Figure 32: Save to CSV Status Progress Indicator***

The contents of the file is dictated by the selections made in the Rendering Properties dialog box (see Section 8.4) including the "+1" pixel if selected (as Pixel 129).

If normalisation (Section 8.4.3) is being applied, the CSV output will be the result of the normalisation. Averaging each pixel column and creating a plot of the average normalised values versus the pixel number, then shows more clearly where the peaks are. For example, the averaged 1.5 mil Polystyrene capture (Figure 26) CSV output is seen in Figure 33 below.


*Figure 33: Averaged normalised CSV data for 1.5 mil Polystyrene*

If Spectrometer view is selected from the Display drop down menu then the data that is saved is slightly different, see Sections 9.2 and 9.3.

### 8.6.1 Using the Linear Array Evaluation Kit for accurate Spectral Analysis

Using a combination of peak to peak, saving to CSV and post-processing with Excel or a comparable computing environment, the absorption and transmittance spectra can be obtained as follows:

1) Capture the background spectra (no sample in spectrometer) using the peak to peak pixel values by checking the Peak to Peak option in the **Rendering Properties** dialog box and capturing 200 samples to CSV.
2) Add the substance under test, e.g. a 1.5 mil polystyrene sheet, and capture another 200 samples to CSV.
3) In Excel, separately average the pixel data columns for the baseline ($\bar{B}_i$) and the substance under test ($\bar{S}_i$ ), and either of the following formulae for each pixel:

- Absorption, $A_i = -log_{10}(\frac{\bar{S}_i}{\bar{B}_i})$
- % Transmittance, $T_i = 100\ (\frac{\bar{S}_i}{\bar{B}_i})$

Figure 34 shows the % Transmittance spectra for 1.5mil polystyrene. Comparing with Figure 33, the peaks are better defined.

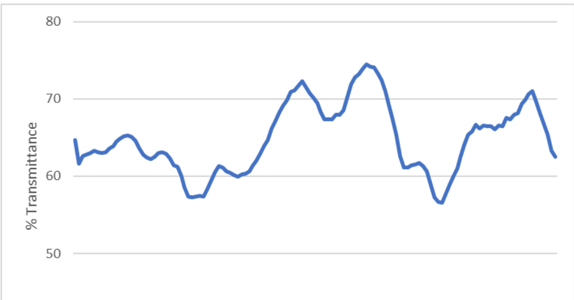



*Figure 34: Transmittance plot for 1.5 mil Polystyrene*

The Pyreos Linear Array sensor comprises an array of pyroelectric crystals (pixels) which react to changes in IR radiation (i.e. temperature) rather than the actual temperature. In Linear Array applications the aim is to measure the changes in the IR signal. To do this we must synchronize the IR illumination source (emitter) and the sensor.

Figure 35 is a signal/time plot of the signal produced by *one single sensor element* (pixel) in the Linear Array sensor in response to a synchronised IR illumination source. The figure shows the IR illumination source pulse (square wave signal at the top) and the response of the sensor element (red signal plot).

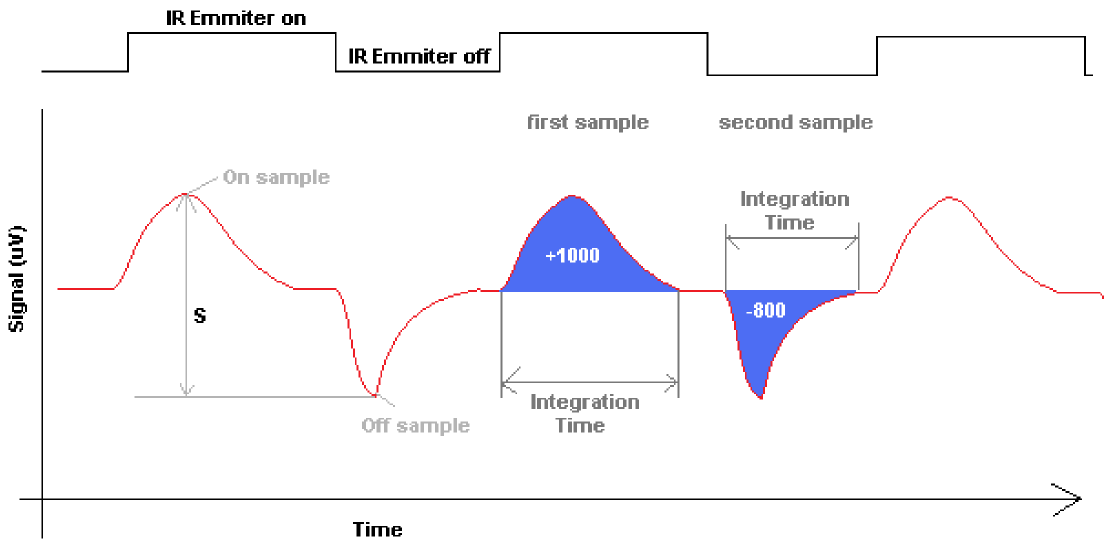



***Figure 35: Signal versus Time for one pixel***

To calculate the maximum change in the IR signal it is necessary to measure the peak to peak signal size (depicted as S in the diagram). To achieve this, the signal is measured when the IR illumination source is on, and when the IR illumination source is off. The sensor response is the difference between the first sample (IR illumination source on), and the second sample (IR illumination source off).

The blue coloured area illustrates how the integrating amplifier works in the Linear Array sensor package. The signal is summed during the integration amplification time. The voltage output is directly proportional to the area highlighted in blue. In order to achieve the maximum signal, the integration time must coincide with the IR illumination source on and off pulses.

When the IR illumination source and detector sample measurement are synchronised, the maximum signal is always measured, and Nyquist noise removed. The integrating amplifier electronics in the Linear Array sensor enable any small signals to be measured successfully. This is why the light source and detector must have their timing controlled accurately (synchronized) as described in the clocking diagram, Figure 36.

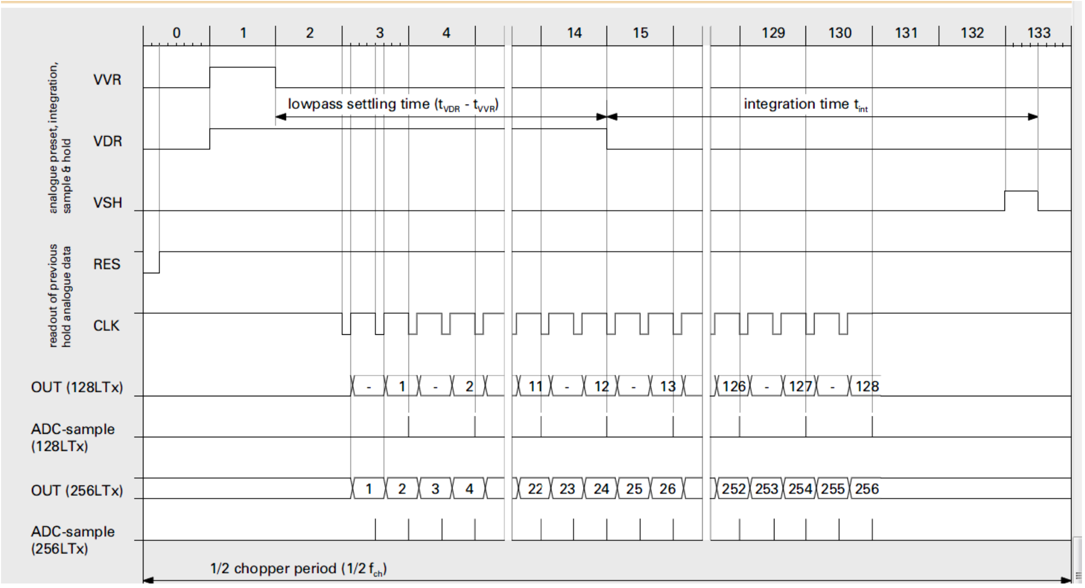



*Figure 36: Linear Array Sensor Signal Timings*

Figure 37 illustrates what would happen if the timings were not synchronized (bad arrangement). The integrated amplified response signal would not be correct, as half of the signal is +Ve and half –Ve and the sum of blue areas will be close to 0 (therefore no signal would be measured):

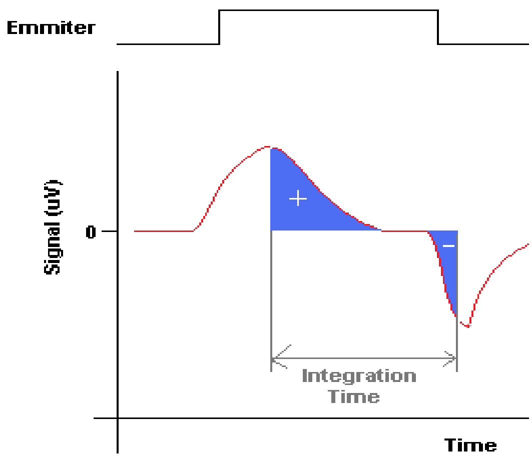



*Figure 37: Integration Time Overlap – No Synchronisation*

The Linear Array Evaluation Boards provide a header which is configured by the firmware to either transmit or receive an IR illumination source synchronisation signal. The location and details of this header can be found in the appropriate Evaluation Board section below (Section 10 for PYB_001_V2 and 10.2 for PYB_201_Rev C).

To maintain a useful sampling system, it is recommended that the sensor integration time stays within the range of 1ms to 100ms at all times. If saturation of the sensor occurs, the integration time should be reduced until no saturation occurs. By optimising the integration time and the sampling regime it is often possible to further improve the overall signal to noise ratio. See Section 8.3.4 for details concerning the setting of the integration time by adjustment of the VDR pulse length.

# 9 Spectrometer Software

This feature can be found under the 'Display' menu which will open a new window keeping the 'Linear Array Evaluation Kit' window open in the background. The first thing that will be noticed is that the live view of the signal from the line array stops which is normal as the signal capture is now being controlled by the 'Spectrometer' window.

The Spectrometer feature has been added to aid the conversion of raw signal from the line array sensor into a simple spectra for some elementary analysis on the samples being measured.

## 9.1 Main Features

Some of the main features are as follows:

- Capture (Section 9.2)
    - Capture spectrum against a background scan
    - Auto save spectra in 'Session' csv files
- Compare (Section 9.3)
    - Spectra comparison overlaid on one plot
    - Add previously collected spectrum to the plot
    - Change plot display between Absorbance and Transmittance

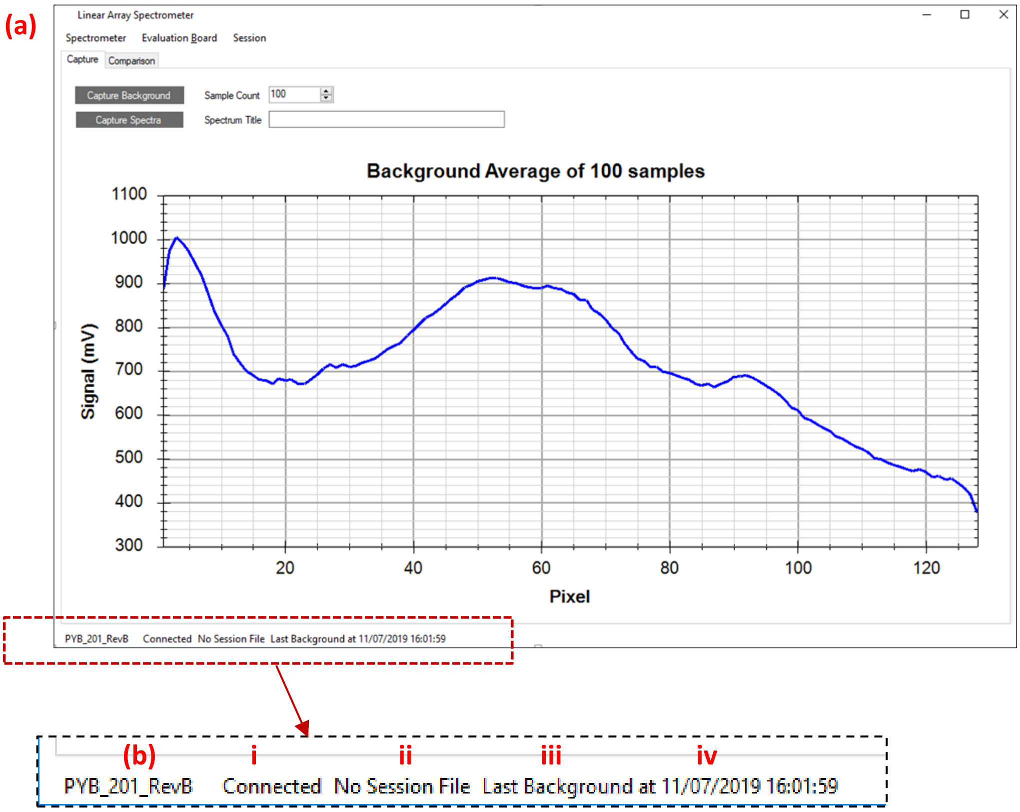



*Figure 38: (a) View of the Spectrometer window (b) Magnified status bar showing (i) PCB firmware version of the spectrometer board (ii) connection status (iii) Session file added (iv) Time the last background was collected*

## 9.2 Capturing a Spectrum

It is important to understand the operation of 'Session' when using this feature.

### 9.2.1 Session

Session as its name suggests is a file (.csv format), when created, automatically stores the spectra as well as the backgrounds captured until that session file is closed again or the program is restarted.

A session file will contain the following information:

- Date and time of capture
- Number of samples averaged
- Sample name (entered on the Spectrum Title window)
- Pixel data in Transmission (%) if a background was collected, for all the pixels (depending on the Pyreos Line Array sensor this could be: 128, 129 (for 128+1), 256 or 512)
    - In case of a background file the data saved for each pixel will be in millivolts (mV).

#### 9.2.1.1 Raw File

When the program is first opened, a line array evaluation kit connected, and a background or spectra collected (using an older background) raw spectra files are auto created for each spectra in the following folder:

Documents\Pyreos\Spectrometer

The files will have a prefix 'scratch' and will contain raw pixel information. To convert this info to millivolt and to learn more about peak-peak conversion please refer to Section 8.6.

Please note that these are always generated irrespective of any active session files.

### 9.2.2 Capture Background/Spectrum

#### 9.2.2.1 Sample Count

As with most spectrometers every reading contains a mix of signal and noise.  As noise typically has a normal distribution, taking the average of a large number of readings improves the accuracy of the measurement. However, it also takes longer to take the measurement as more samples must be collected, so selection of the appropriate number of samples is a trade-off between quality of measurement and time taken to collect the readings. Generally, increasing the number of samples by a factor of four will double the detection accuracy.

$$\text{Capture times (s)} = \frac{Sample\ Count\ \times 2}{Sample\ Rate}$$

Note: If you change the number of samples or any other settings, it is necessary to re-capture the background.

#### 9.2.2.2 Spectrum title

By clicking the "Capture spectrum" button, all readings taken will be named with the text entered in this box. The name will appear in both the CSV Session file (if it is being used) and in the title of the Capture window (more on this in the following sections).

### 9.2.2.3 Capture buttons

There are two different capture buttons on the main display shown below: “Capture background” and “Capture spectrum”. The latter is only available after a background reading has been measured. PC to Linear Array Evaluation Board Communications.

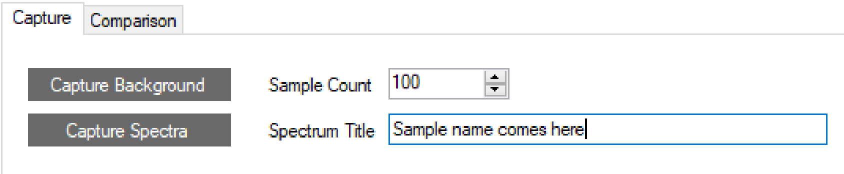



***Figure 39: Capturing options in the Spectrometer application***

It is possible to write software to communicate with the Evaluation Board directly without using the Pyreos Linear Array Evaluation Kit. This section describes the communications system and command protocol implemented by the Evaluation Board firmware.

Before placing your sample for analysis on/in the spectrometer it is necessary to take a reading of the background signal, which is done by clicking “Capture Background”. The background signal is ‘subtracted’ from the sample signal so that any change or difference can be detected. The background signal can therefore be chosen by the user. Typically, a background scan may be of the empty sample transmission cell, or of the initial liquid or gas material for continuous monitoring applications. A progress bar will be displayed on the bottom right of the window while it is collecting the specified number of background samples. The number shown will count down to zero during this time. When this is complete the spectrometer will be ready for use.

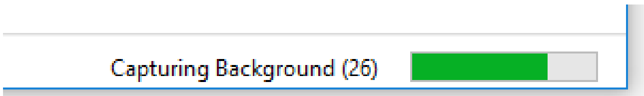



***Figure 40: Progress bar of Capturing spectra***

The “Capture spectrum” button will now be available, and the captured background will be displayed on the window main screen. It should be noticed that the background signal is always measured in millivolts (mV) over the entire pixels stretch.

It is now time to place your sample for analysis on/in the spectrometer. Next enter the title you wish to give this in the “Spectrum title” box and click “Capture spectrum”.

The window should now be updated with the spectrum of the new sample and the y-axis will be changed to ‘Absorbance’. It shold also be noted that this plot will be ‘replaced’ with the next sample being measured (i.e. its only shows the snapshot of the current sample). To view the ‘overlays’ of the spectra there is a ‘Comparison’ submenu which will be expalined in details in the following sections.

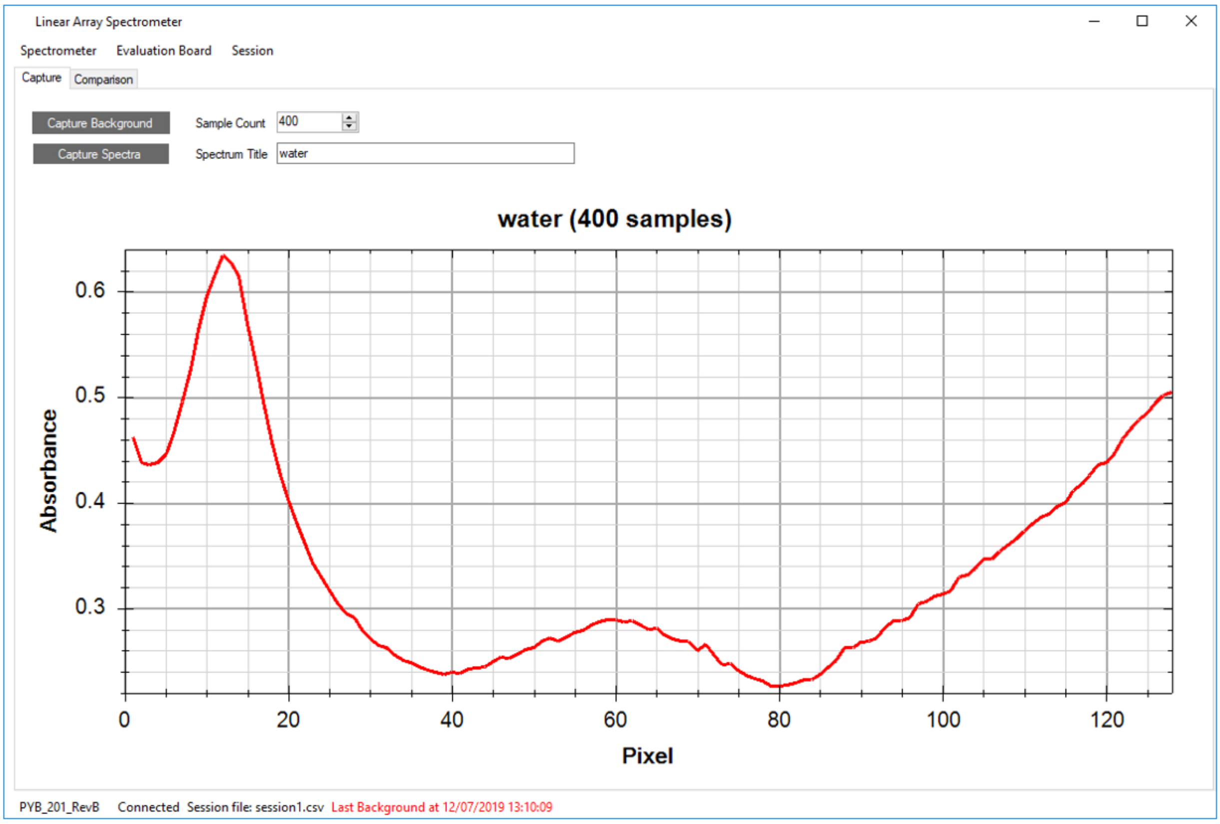



*Figure 41: Spectrometer window displaying the spectrum of water captured*

### 9.2.2.4 Current Background Details

The status bar will display the 'Last Background' time and date. When a fresh background is collected it will be displayed in black font, however, after 20 mins this will change to 'red' to signify its age.

It is necessary in some applications to collect a fresh background for each sample, which ensures any changes such as crystal cleanliness/contamination or effect of ambience conditions on the IR emitter are not affecting the sample spectrum. This is also done where the application requires high accuracies and quantitative study of their samples.

### 9.2.2.5 Saving Files Separately

As discussed earlier the software auto-saves the measurements in 'Session' csv files. In the Spectrometer menu one can access other options to save measurements separately files. See Figure 42.

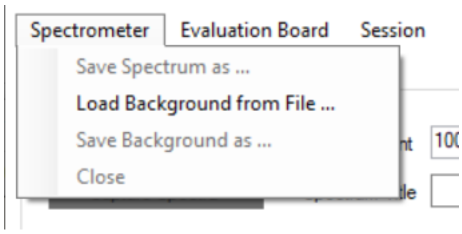



*Figure 42: Menu for saving measurements separately*

This option is rather important for backgrounds, as previously collected backgrounds which were saved using this menu can now be imported into the software and any subsequent spectra collected will use this background to calculate the 'Absorbance' values.

## 9.3 Spectral Comparison

### 9.3.1 Overview

This section details the use of the 'Comparison' option on the Spectrometer application for simple spectral comparison and some of the main features are as follows:

- Plot currently measured spectra
- Add / Remove spectrum to plot
- Save / Load session files
- Display spectra in Absorption or Transmission
- Can be accessed even if the spectrometer is not connected to visualise previously collected spectra

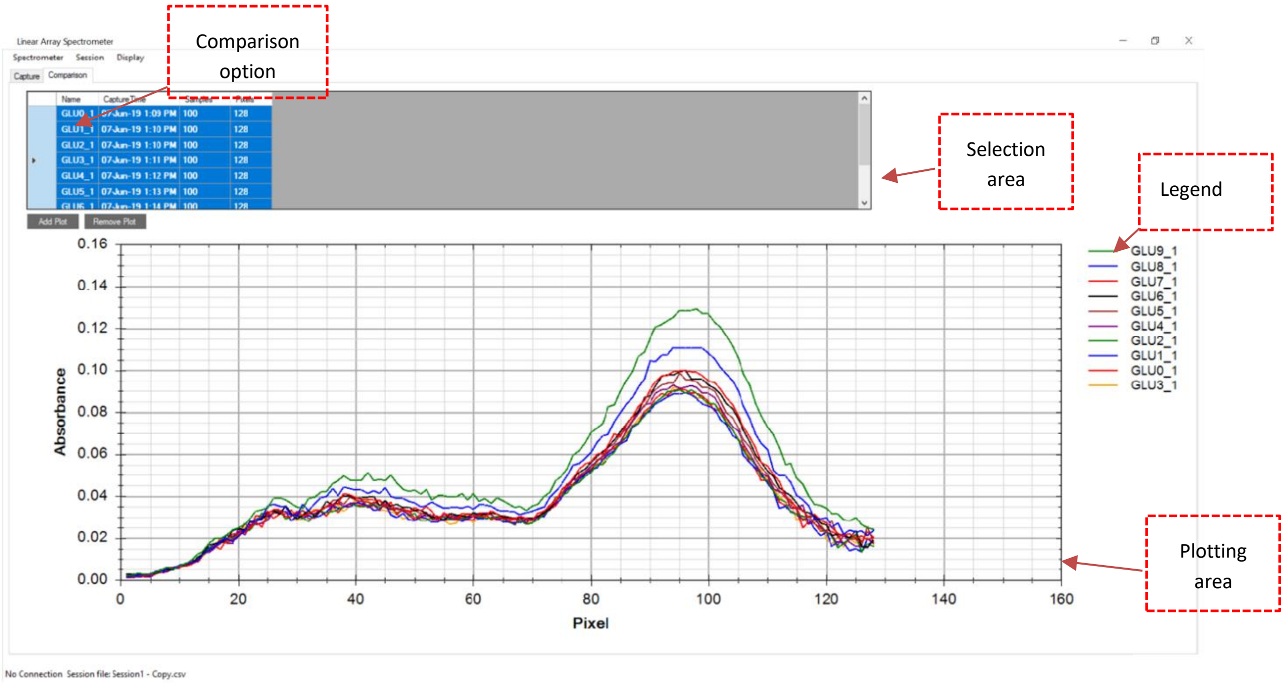



*Figure 43: Overview of the Spectra Comparison environment of the software*

### 9.3.2 Add/Remove Plots

Adding individually saved spectrum from '.csv' under

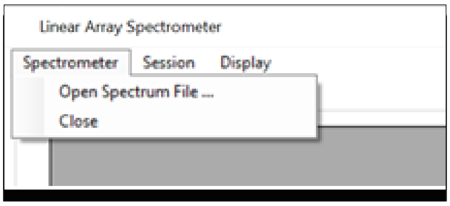



*Figure 44: Spectrometer menu*

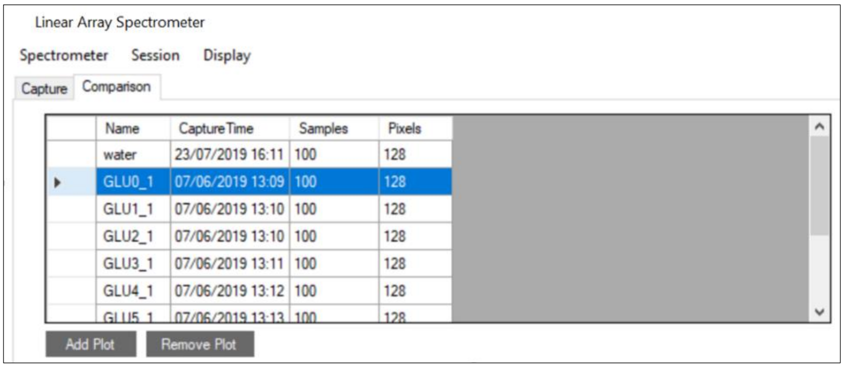



*Figure 45: Selecting a spectra from the table to plot*

To add a plot, it's necessary to select the relevant spectra from the Table. This can be achieved by selecting from the far-left column and the row is highlighted in blue as shown in Figure 45. Multiple plots can be added by holding the Ctrl or Shift button and clicking. Select all by clicking on the left column on any row and then using the 'Ctrl + A' option. Then click on the 'Add Plot' option. It should be noted that the software has the feature for adding the same spectra multiple times and auto assigning a colour to the plot for distinguishing one from another.

Removing plots is done in the same way but clicking on 'Remove Plot' after the relevant plots have been selected from the table.

### 9.3.3 Display options

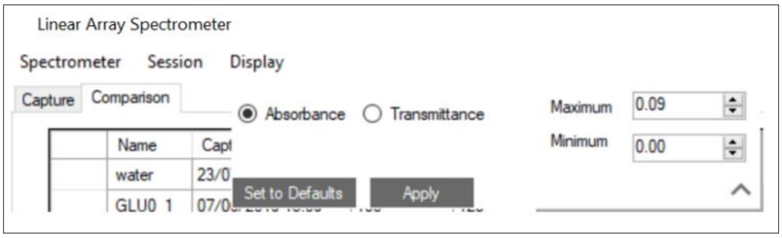



*Figure 46: Plot display options*

The plot's display options can be accessed from the Display -> Vertical Axis Properties and the options to convert from Absorption (default) to Transmission % can be accessed. The plot's y-axis minimum or maximum properties can also be modified here.

Additional display properties can be accessed directly from the plot through right clicking as shown in Figure 47.

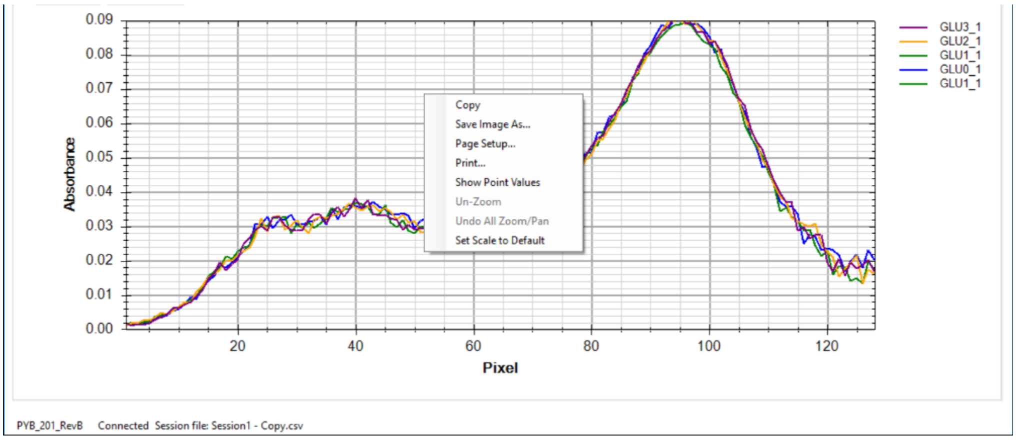



***Figure 47: Option to save image of the plot and scaling options (through right-click)***

The following options can be accessed from the plot itself:

- Right click: Copy screenshot of the plot to Clipboard (can also Save Image As to file)
- Right click: Print image through a printer
- Right click: Show point values (x and y points after hoovering on the plot line)
- Right click: Zooming options (default zoom – fit all)
- Scroll: Zoom up or down
- Click and drag: Zooms in to the area

### 9.3.4 Session Files

The Session menu in the Capture varies slightly differently to the Comparison environment, but the underlying concept and format of creating and storing '.csv' files with the spectrum information for each session stays the same. This just provides the opportunity for the user to create a separate session environment for themselves because there could be various session files of the spectra captured (i.e. different days or experimental conditions) but one would want to compare the spectra these various session file on this one platform.

One way is to Create a new session (Session -> New Session) once the application is opened and then adding the relevant spectra or capture session .csv files to plot on the window. After comparing and finishing the process, the use can close the session through the menu. It should be noted that the session information may be lost if the software is closed without prior to Closing the session through the menu (Session -> Close Session).

Another way to achieve this is to add all the relevant spectra on the Comparison window, make the relevant removals and then save all these in the order they were added to a session file. This can be done through: Session -> Save Session As and then saving a relevant '.csv' file.

These session files can be loaded anytime in the future for further analytics.

## 9.4 Communications used

Both Evaluation Boards connect to a PC via USB to a Virtual COM Port (VCP). The PYB_001_V2 board utilises a silicon labs CP2102 UART to USB bridge. The PYB_201_Rev C board uses a direct USB connection from the microprocessor and appears to Windows as a STM VCP. See Section 4.2 for driver installation.

The default settings for the firmware on both boards are 115200 baud, 8 data bits, 1 stop bit, no parity, no handshaking. If the PYB_001_V2 firmware receives a command other than those detailed in this section it will return to the default baud rate settings; the PYB_201_Rev C firmware will reset the processor. All commands and data sent to the Evaluation Boards are single ascii character commands; where a setting requires more than one byte of data the kit will request the data one byte at a time. It is necessary to wait for the firmware to respond before sending the next byte of data or command.

## 9.5 Data format

The Evaluation Board firmware will transmit a frame of data per synchronisation event.

| Offset | Data size | Description |
|---|---|---|
| 0 | 2 | Frame Code: 0xFFFF[6] or 0xFFFE. Which code is sent details the state of the sync input/output pin on the kit at the time of the sample, 0xFFFF = 0V and 0xFFFE = 5V. |
| 4 | $N_p$ x 2 | Pixel data. $N_p$ is either 128, 129, 256 or 512 depending on the settings. Each data point is a 2-byte word; however, it represents the raw data from the 12-bit analogue to digital converter; as such, each value is the range 0 to 4095 (0x0FFF). In this way, the data values can never be confused with the framing codes as it is impossible for a data value to have the same value. |

***Table 6: Data Frame***

Table 6 details the contents of each frame. The frame is transmitted as big-endian (most significant byte first).

When the firmware is configured to read from one IC (128 x 1, 256 x 1) the pixel values transmitted are in ascending pixel order. However, when reading from a sensor with two IC's (256 x 2) the values in the frame will be interleaved as detailed in Table 7. The reason for this is that the second IC is rotated so that channel 256 on IC 2 is the 2nd pixel in the array.

| Configuration | Pixel Order |
|---|---|
| 128 x 2 | 1, 256, 3, 254, 5, 252, …, 251, 6, 253, 4, 255, 2[7] |
| 256 x 2 | 1, 512, 3, 510, 5, 508, …, 507, 6, 509, 4, 511, 2 |

***Table 7: Pixel Ordering with 2 ICs***

[6] All values preceded by "0x" are represented in hexadecimal notation
[7] The pixel index used here is the index into the transmitted data values, and not the physical pixel number.

The data values are all in the range 0 to ($2^{12}$ -1) = 4095 and are generated directly from the A-D converter in the microprocessor. Each count from the A-D converter represents ≈ 1.2mV and is calculated by the equation below:

$$voltage = \frac{value * 5}{4095}$$

## 9.6 Firmware commands

This section details the command protocol required for the Evaluation Board firmware. All commands stated in single quotes (e.g. 'g') are case sensitive, encoded using ASCII and sent to the demonstration kit as 8-bit values. Responses, which request information from the firmware, comprise ASCII strings, and are enclosed in double quotes (e.g. "ok") in the following descriptions. Numerical responses are sent in bytes, most-significant byte first.

The PYB_001_V2 firmware will also accept the commands, 'r' and 'w', which are included for conformance with earlier revisions of the firmware. These are deprecated in the PYB_201_Rev C firmware. The functionality of these commands is now managed through the **operating settings** detailed below.

| *Command* | *Byte value* | *Description* |
|---|---|---|
| ***'g'*** | ***103*** | ***Start streaming sensor data in accordance with its settings.*** |
| ***'s'*** | ***115*** | ***Stop streaming sensor data.*** |
| ***'v'*** | ***118*** | Send the firmware description string. |
| ***'t'*** | ***116*** | ***Sample the Linear Array thermistor voltage, and microprocessor internal temperature.*** |
| ***'b'*** | ***98*** | ***Set the baud rate.*** |
| ***'f'*** | ***102*** | ***Set a new operating frequency.*** |
| ***'F'*** | ***70*** | ***Get the operating frequency.*** |
| ***'S'*** | ***83*** | ***Set the operating settings: synchronisation method, line array configuration.*** |
| ***'T'*** | ***84*** | ***Get the operating settings.*** |
| ***'V'*** | ***86*** | ***Set the VVR delay time.*** |
| ***'D'*** | ***68*** | ***Set the VDR delay time. Affects when integration is to start.*** |

***Table 8: Firmware Command Summary***

#### 9.6.1.1 Start sending data

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'g' | 103 | Start streaming sensor data in accordance with its settings. | None |

#### 9.6.1.2 Stop sending data

| Command | Byte value | Action | Response |
|---|---|---|---|
| 's' | 115 | Stop streaming sensor data. | "ok" |

#### 9.6.1.3 Get the firmware version

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'v' | 118 | Send the firmware description string | e.g. "PYB_001_V2, Firmware Revision 1.0.1, released 18/11/2009" |

#### 9.6.1.4 Read the temperature from the demonstration kit

| Command | Byte value | Action | Response |
|---|---|---|---|
| 't' | 116 | Sample the Linear Array thermistor voltage, and microprocessor internal temperature. | See Section 12.2 |

#### 9.6.1.5 Response Details

| Offset | Size | Description |
|---|---|---|
| 0 | 2 | Temperature of Evaluation Board microcontroller.<br>• **PYB_001_V2**: raw A-D conversion value for thermistor on the Silicon labs C8051f530 microcontroller<br>• **PYB_201_RevC**: Temperature of STM32F303 microcontroller in tenths of a degree Celsius (e.g. a value of 245 equals 24.5°C) |
| 2 | 2 | Linear Array Sensor temperature: raw A-D conversion value for thermistor internal to the sensor. Appendix A details the formulae required to convert this value[8] into temperature. |

#### 9.6.1.6 Set the baud rate

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'b' | 98 | Set the baud rate. | See below. |

The firmware will respond with

"Send baud multiplier i.e. baud rate = 115200 * x"

The PC should send a single byte from Table 9 to indicate which baud rate the firmware should change to.

[8] And C8051f530 microcontroller temperature value.

| Value to send | baud rate |
|---|---|
| 1 | 115200 |
| 2 | 230400 |
| 4 | 460800 |
| 8 | 921600 |

***Table 9: Baud Multiplier values***

The firmware responds with "ok" and then calculates if a reduction in sample frequency is required to stay within allowable operating parameters. If so, the kit will then reduce the frame rate to the maximum allowable and send

"* however, the sample frequency has been reset max allowable rate".

After sending this response the kit will reconfigure the UART to the new baud rate, and the same must be done by the PC. If any value not supported is sent, then the kit will reply with "Unsupported baud rate" and its baud rate will remain unchanged.

**NOTE:** For PYB_201_Rev C, the baud rate setting is not required, as the serial communications is handled by firmware USB CDC driver routines.

#### 9.6.1.7 Set the operating frequency

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'f' | 102 | Set the operating frequency | See below. |

The firmware will respond with

"Send desired sample frequency in range 0-255 (0=1Hz, 255=256Hz)"

The PC should then send a single byte representing the desired sample frequency, the value sent will have 1 added to it by the kit, so sending the value 0 will set a sample rate of 1Hz and sending the value 255 will set a sample rate of 256 Hz.

Depending on the settings in place, the firmware will either respond with "ok" if successful, or

"Insufficient UART bandwidth, the sample frequency has been reset to the max allowable rate"

#### 9.6.1.8 Get the operating frequency

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'F' | 70 | Get the operating frequency | One byte representing the sample rate – 1* |

* 0 indicates a sample rate of 1Hz.

#### 9.6.1.9 Set the operating settings

| Command | Byte value | Action | Response |
|---|---|---|---|
| ‘S’ | 83 | Set the operating settings | See below |

The firmware will respond with

“Send state byte”

***The PC should then send a single byte representing the required operating state as described below.***

Figure 48 shows the bit values and positions.

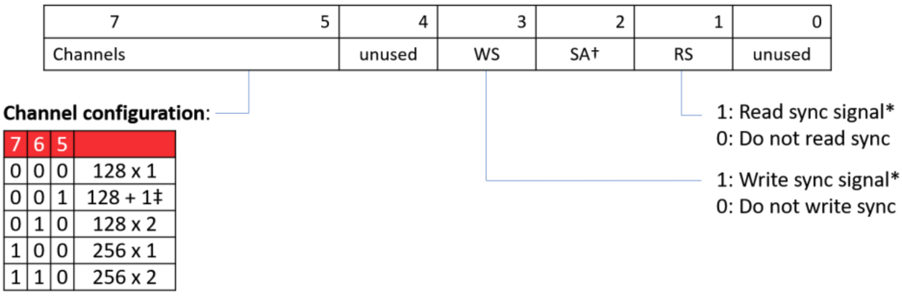



***Figure 48: Definition of Operating State***

† The SA bit is used in the firmware to indicate whether streaming is active. However, there is no need for the PC to assign this bit in the state byte to be sent to the firmware.
* If both sync bits are set to 0, the firmware will not be synchronised with an IR illumination source; however, the firmware will continue to sample data from the Linear Array based on the sample rate set as described in Section 8.3.3
‡ Note: the 128 + 1 channel configuration is not available for the PYB_001_V2 firmware

Depending on the settings in place, the firmware with then respond with “ok” if successful or,

“state set ok; however, the sample frequency has been reset max allowable rate”.

#### 9.6.1.10 Read the operating settings

| Command | Byte value | Action | Response |
|---|---|---|---|
| ‘T’ | 84 | Get the operating settings | ***Single byte representing the operating state as defined in*** Figure 48. |

#### 9.6.1.11 Set the VVR pulse width

| Command | Byte value | Action | Response |
|---|---|---|---|
| ‘V’ | 86 | Set the VVR pulse width | See below |

The firmware will respond with the string,

“Send VVR delay most significant byte”

The PC should send the most significant byte of an unsigned 16-bit integer detailing the VVR high pulse width value as described below. The firmware will respond with the string, "Send VVR delay least significant byte"

The PC should send the least significant byte of an unsigned 16-bit integer detailing the pulse width value.

For the PYB_201_Rev C Evaluation Board, the value to be sent is the pulse width in microseconds. For the PYB_001_V2 board, the value to be sent is a delay counter which is implemented directly by the firmware according to the following formula,

$$Delay_{\mu s} = 1.2 + 0.86 * value$$

The $value$ to be set must be between 0 and 16382 inclusive and is calculated from the required microsecond delay time by,

$$value = \frac{Delay_{\mu s} - 1.2}{0.86}$$

***Equation 3: Formula to calculate delay value***

#### 9.6.1.12 Set the VDR delay time

| Command | Byte value | Action | Response |
|---|---|---|---|
| 'D' | 68 | Set the VDR pulse width | See below |

The firmware will respond with the string,

"Send VDR delay most significant byte"

The PC should send the most significant byte of an unsigned 16-bit integer detailing the VDR high pulse width value as described below. The firmware will respond with the string,

"Send VDR delay least significant byte"

The PC should send the least significant byte of an unsigned 16-bit integer detailing the pulse width value.

The value to be sent follows the same rules as for setting the VVR pulse width (Section 9.5), with the PYB_201_Rev C Evaluation Board requiring a microsecond value and PYB_001_V2 board requiring a delay count as determined by Equation 3.

The Evaluation Board connects to a PC via USB to a Virtual COM Port (VCP). The board uses a direct USB connection from the microprocessor and appears to Windows as a STM VCP. See Section 4.2 for driver installation.

The default settings for the firmware on both boards are 115200 baud, 8 data bits, 1 stop bit, no parity, and no handshaking. The PYB_201_Rev C firmware will reset the processor. All commands and data sent to the Evaluation Boards are single ascii character commands; where a setting requires more than one byte of data the kit will request the data one byte at a time. It is necessary to wait for the firmware to respond before sending the next byte of data or command.

# 10 Linear Array Sensor Evaluation Boards

## 10.1 PYB_001_V2 Evaluation Board

This section details the connectors and jumper on the PYB_001_V2 Evaluation Board. It is important not to supply power to any pin detailed as **Direction** "**Out**" in the tables below.

Figure 49 shows the location of the relevant connectors and jumpers. Table 11 to Table 18 describe the pin assignments and options associated with each one.

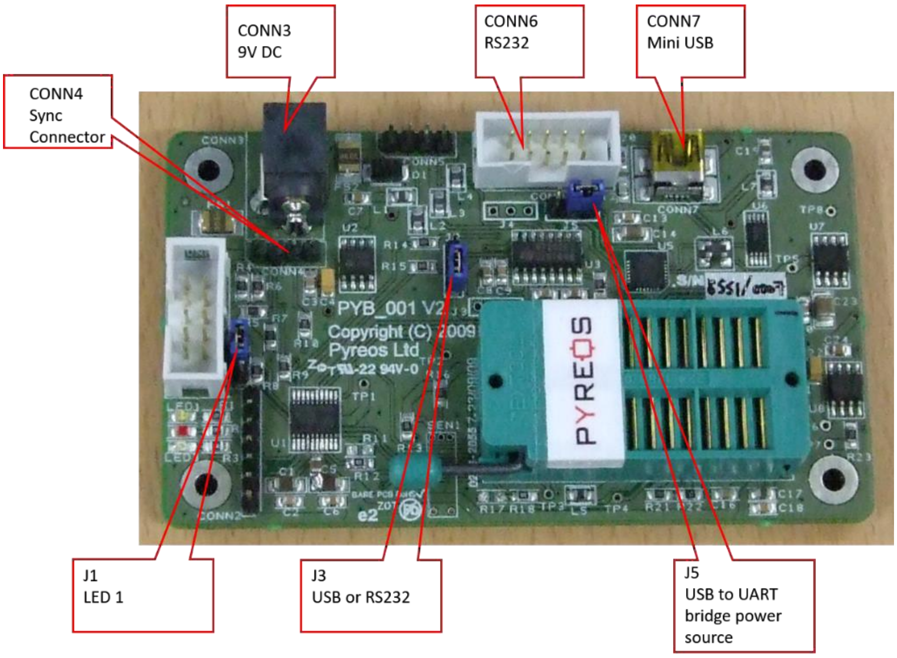



***Figure 49: PYB_001_V2 connector and jumper locations***

### 10.1.1 CONN3: 9V DC Power Connector

Specification: 2.1mmØ centre pin positive. Table 10 details the pin assignments.

| Pin no | Signal | Direction |
|---|---|---|
| 1 | 0V | In |
| 2 | No connection | |
| 3 | +9V DC | In |

***Table 10: CONN3 Power connector***

### 10.1.2 CONN4 – Synchronisation connection

Specification: 4-pin SIL header. Table 11 details the pin assignments.

| Pin no | Signal | Direction |
|---|---|---|
| 1 | 9v DC | In/Out |
| 2 | VDD5V | Out |
| 3 | SYNC | In/Out |
| 4 | GND | In/Out |

***Table 11: Synchronisation connections***

### 10.1.3 CONN6 – RS-232 serial communications

The RS-232 driver included on the kit has a maximum rated speed of 230400 baud. Pyreos recommends not using it for communications with the included software and offer it as an optional extra

Specification: 10-pin DIL header. Table 12 details the pin assignments.

| Pin no | Signal | Direction |
|---|---|---|
| 1 | No connection | |
| 2 | No connection | |
| 3 | Txd | Out |
| 4 | No connection | |
| 5 | Rxd | In |
| 6 | No connection | |
| 7 | No connection | |
| 8 | No connection | |
| 9 | GND | Out |
| 10 | No connection | |

***Table 12: RS-232 serial communications***

### 10.1.4 CONN7 – USB PC Connector

Specification: Mini USB. Table 13 details the pin assignments.

| Pin no | Signal | Direction |
|---|---|---|
| 1 | Vbus | In |
| 2 | D- | In/Out |
| 3 | D+ | In/Out |
| 4 | No connection | |
| 5 | Ground | |
| 6 | 100MΩ to Gnd | |
| 7 | 100MΩ to Gnd | |
| 8 | 100MΩ to Gnd | |
| 9 | 100MΩ to Gnd | |

***Table 13: USB connector***

### 10.1.5 Jumpers

Table 14 -Table 17 detail the jumper settings. Yellow indicates the default jumper settings.

| Position | Function |
|---|---|
| 1-2 | LED 1 indicates 5v power supply on |
| 2-3 | Port pin P0.6 (C2D) controls LED 1 |

***Table 14: J1 LED1 function***

| Position | Function |
|---|---|
| 1-2 | RTS input connected to ground |
| 2-3 | RTS input connected to 5v DC supply |

***Table 15: J3 RTS input***

| Position | Function |
|---|---|
| 1-2 | CP2102 powered from VCC 5v board supply |
| 2-3 | CP2102 powered from external USB |

***Table 16: J5 USB power supply***

| Position | Function |
|---|---|
| 1-2 | Received data on SCI sourced from USB (CP2102) |
| 2-3 | Received data on SCI sourced from RS-232 |

***Table 17: J2 Microcontroller RX source***

## 10.2 PYB_201_Rev C

This section describes the PYB_201_Rev C hardware; it details the use of the jumper and connectors on the PCB.

Figure 50 shows the locations of relevant connectors and headers and the following sections give further details.

**IMPORTANT:** It is important not to supply power to any pin detailed as **Direction "Out"** in the tables below.

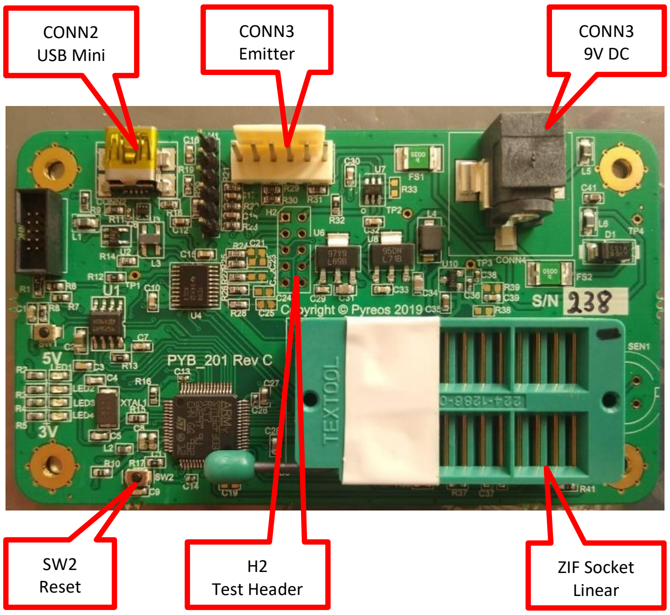



*Figure 50: PYB_201_Rev C Connectors*

### 10.2.1 CONN2 – USB Mini-USB Connector

The Evaluation Board connects to the PC via CONN2 for configuration and streaming.

### 10.2.2 CONN3 – Synchronisation header

CONN3 provides 6-way Molex, 2.54mm pitch male header to connect to an external emitter or synchronisation source. Table 18 details the pin assignments.

| Pin | Signal | Direction |
|---|---|---|
| 1 | 9V DC | Out |
| 2 | 5V DC | Out |
| 3 | Synchronisation signal (5V) | In/Out |
| 4 | Ground | Out |
| 5 | Power supply voltage monitor | In |
| 6 | DAC output | Out |

*Table 18: Synchronisation Header*

### 10.2.3 CONN4 – 9V DC Power Connector

Specification: 2.1mmØ centre pin positive. Table 19 details the pin assignments.

| Pin | Signal | Direction |
|---|---|---|
| 1 | 0V | In |
| 2 | No connection | |
| 3 | +9V DC | In |

***Table 19: 9V DC Connector***

### 10.2.4 H2 – Test Header

This header enables the Linear Array and Emitter signals to be connected to an oscilloscope or Logic Analyser. Table 20 gives details of the connected signals. Specification DIL-10. Table 20 details the pin assignments.

| Pin | Signal | Direction |
|---|---|---|
| 1 | LED_1A | Out |
| 2 | 3V3 | Out |
| 3 | Linear Array CLK (5V) | Out |
| 4 | Linear Array VVR(5V) | Out |
| 5 | Linear Array RES(5V) | Out |
| 6 | Linear Array VDR(5V) | Out |
| 7 | Linear Array VSH(5V) | Out |
| 8 | Synchronisation signal (3V) | In/Out |
| 9 | Ground | Out |
| 10 | Ground | Out |

***Table 20: H2 Test Header***

Note that this header is not populated on the board as it interferes with the mechanics of the transmission spectrometer. However the connections are all still active and the board can easily be wired by hand so these signals can be monitored.

### 10.2.5 ZIF Socket

The linear array sensor is attached using this connector. Please refer to Section 5 for insertion details.

### 10.2.6 SW2 – Reset

The firmware should reset itself if a lock-up occurs. If this fails to happen, press SW2 to reset the firmware.

# 11 Appendix A - Data Conversion Equations

## 11.1 A-D voltage measurements

Each time the Evaluation Board firmware takes a reading it uses a 12-bit analogue to digital converter. The values are sent as a 16-bit unsigned integer (two bytes) with the most significant byte first. The following equation details the conversion of A-D counts to the corresponding voltage at the A-D input.

$$Volts = \frac{value * 5}{4095}$$

## 11.2 Temperature measurements

The Evaluation Board firmware provides a facility to measure the voltage at its input from the Linear Array sensor thermistor. This section details the interpretation of the data set by the demonstration kit. When the temperature values are requested, two 16-bit integers are sent by the Evaluation Board firmware to the PC as detailed in section 9.6.1.4.

The first value represents the temperature as measured on the microprocessor. The second value sent, details the voltage measured at the output from the Linear Array sensor thermistor.

### 11.2.1 STM32F303RCT temperature measurement

The measurement sent back to the PC is the actual temperature in tenths of a Celsius. For example, a value of 234 would represent a value of 23.4°C.

### 11.2.2 C8051F530 temperature measurements

The temperature sensor in the C8051F530 (PYB_001_V2) provides a voltage which is linearly proportional to the actual temperature of the microcontroller as detailed by the formula below, count is the unsigned integer received from the demonstration kit.

$$Temperature\ (centigrade) = \left(\left(\frac{count * 5000}{4095}\right) - 0.89\right) * 0.0284$$

### 11.2.3 Linear Array sensor thermistor measurements

The temperature sensor in the PYREOS Linear Array sensor is connected to the A-D in the microcontroller using the circuits in the following figures: Figure 51 for PYB_001_V2 and Figure 52 for PYB_201_Rev C.

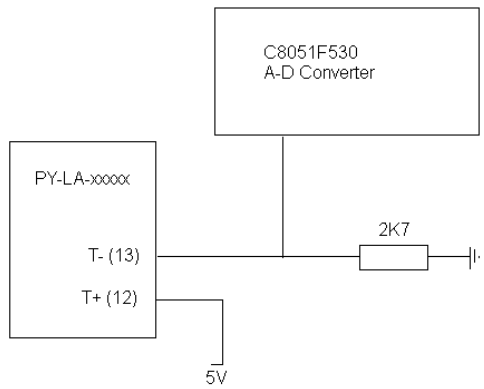



*Figure 51: Thermistor Connection PYB_001_V2*

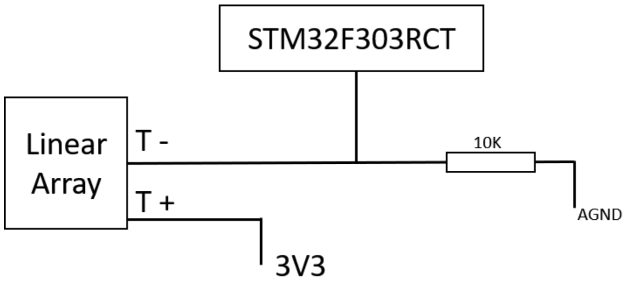



*Figure 52: Thermistor Connection PYB_201_Rev C*

To date, the Pyreos Linear Array sensors contain the Panasonic ERTJZEG103FA Thermistor. The following calculation applies to this thermistor. Please check the datasheet for your Linear Array sensor for compatibility.

Figure 53 gives the circuit diagram for the Thermistor connection.

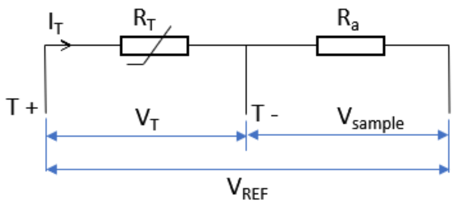



*Figure 53: Linear Array Thermistor Circuitry*

In the following equations, let $R_T$ be the thermistor resistance at any given instant; $R_0$ is the nominal resistance at $T_0$ (= 298.15K), then the temperature,$T_{TH}$ is given by Equation 4:

$$T_{TH} = \frac{B}{\frac{B}{T_0} + \ln(\frac{R_T}{R_0})}$$

*Equation 4: Thermistor Temperature Calculation*

From Figure 53, the voltage sampled is given by

$$V_{sample} = \frac{V_{REF} \times sample}{4095} \qquad (1)$$

Hence the voltage across the Thermistor is

$$V_T = V_{REF} - V_{sample} \qquad (2)$$

And the Current,$I_T$ is given by

$$I_T = \frac{V_{REF}}{R_0 + R_a} \qquad (3)$$

Finally, the thermistor resistance,$R_T$ is thus

$$R_T = \frac{V_T}{I_T} \qquad (4)$$

Substitution of the equations (1) – (3) in (4) gives:

$$R_T = \frac{1 - \frac{sample}{4095}}{R_0 + R_a}$$

***Equation 5: Thermistor Resistance Calculation***

The temperature can then be calculated by entering the result of Equation 5 in to Equation 4 with the constants given by Table 21. This is implemented in the Linear Array Evaluation Kit.

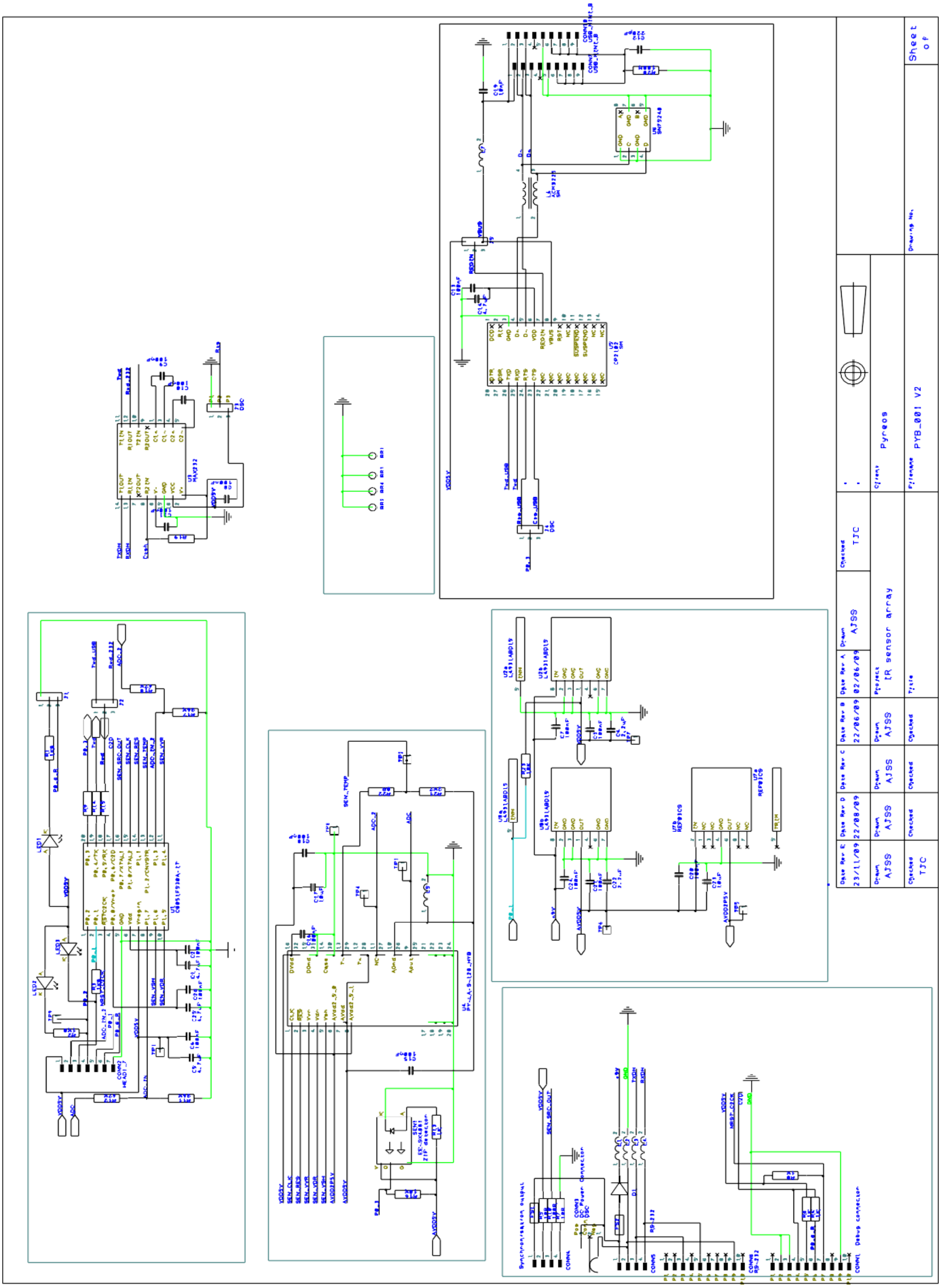
| Constant | Value |
|---|---|
| B | 3435 |
| $R_a$ | 10K (PYB_201_Rev C)<br>2K7 (PYB_001_V2) |
| $R_0$ | 10K |
| $T_0$ | 298.15 K |
| $V_{REF}$ | 3V3 (PYB_201_Rev C)<br>5V (PYB_001_V2) |

***Table 21: Thermistor Calculation Constants***

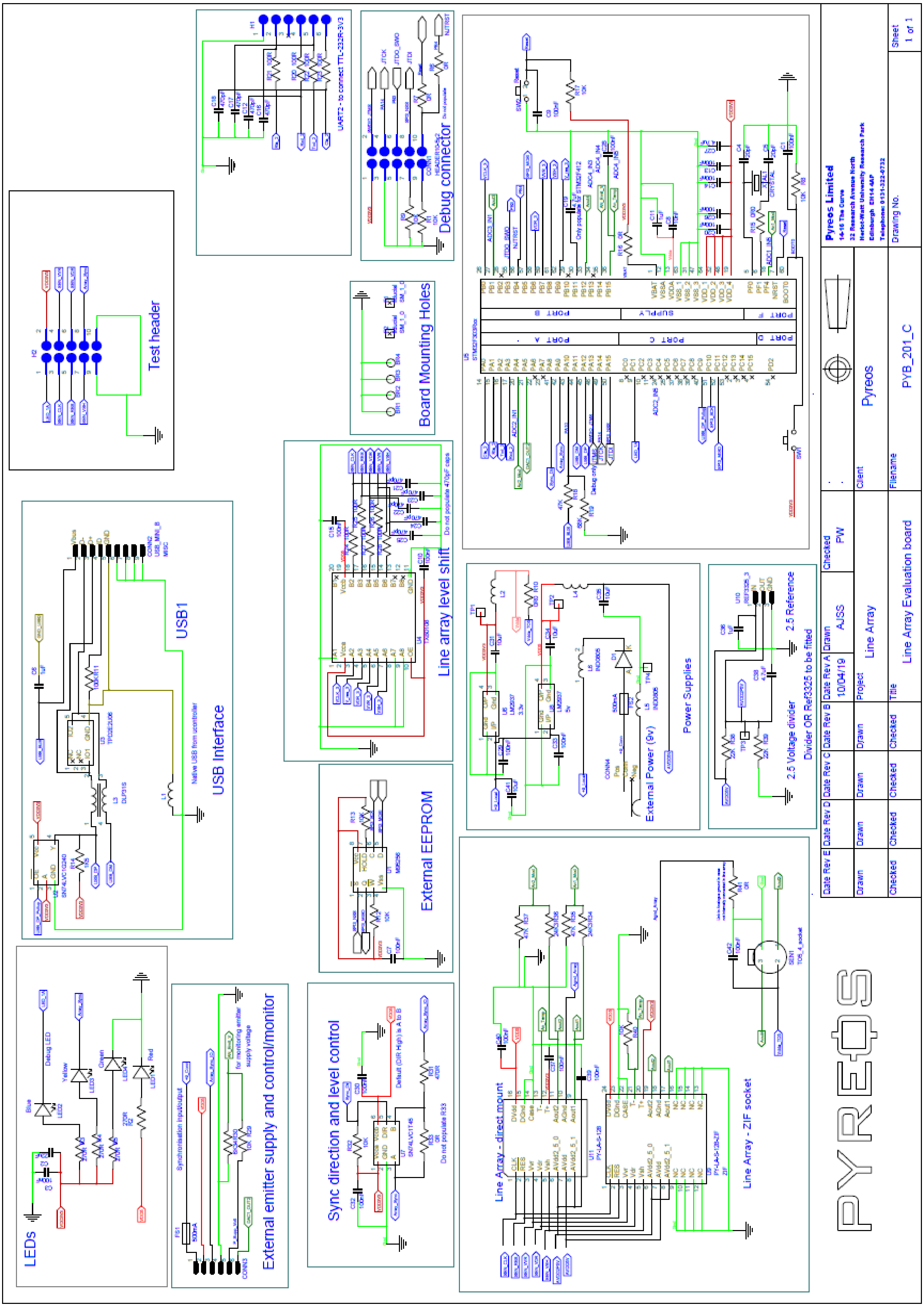
  

# 12 Appendix B – Evaluation Board Schematics

The following pages show the electrical schematics for each of the Evaluation Boards, PYB_001_V2 and PYB_210_Rev C.




Test header
Debug connector
Board Mounting Holes
Line array level shift
USB1
USB Interface
External EEPROM
Power Supplies
2.5 Reference
LEDs
External emitter supply and control/monitor
Sync direction and level control
Line Array - direct mount
Line Array - ZIF socket
Pyreos Limited
Pyreos
Line Array
Line Array Evaluation board
PYB_201_C

# 13 Further Information and Support

The Pyreos website has a list resources available to help our customers

https://pyreos.com/resource-centre

If you encounter any difficulties with the kit, please contact Pyreos Support

E-mail: support@pyreos.com