Linear Array Evaluation Kits

USEQDAK6000000

USEQDAK7____00

USEQDAK8____00

User Guide

Rev. 3.3

NOV 2020

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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.

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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 4 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, as detailed on the document *KEMET Safety Datasheet ZnSe*. It is important not to inhale or ingest any dust or fragments of ZnSe.

2 GETTING STARTED

This user guide describes the software, hardware, and installation process for the different KEMET IR linear array sensor 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 USEQDAK6000000, the Linear Array Evaluation Board. This is a microprocessor powered board which interfaces to a PC and allows the user to test and evaluate a Linear 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 linear array sensors with the use of Linear Variable Filters (LVF) as solid-state dispersion gratings. Using this technical approach, it is possible to take in a few seconds near, mid, or far IR spectral readings (dependent on the LVF used), and in almost any working environment. The simplified principle of operation is shown below. The USEQDAK7____00 version is with an ATR spectrometer, and the USEQDAK8____00 with a transmission spectrometer. Both are explained in detail below.

This manual covers the following:

- Description, installation and set-up of the kits and safety notes
- Software user guide, including spectrometry
- Description of integrating electronics and sampling theory
- Description of the data produced by the evaluation kit
- Hardware guide

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2.1 Kit Contents

1. Linear Array Evaluation Board USEQDAK6000000

or Linear Array Evaluation Board & ATR Spectrometer Kit USEQDAK7____00

or Linear Array Evaluation Board & Transmission Spectrometer Kit USEQDAK8____00

2. Linear Array Sensor USEQDAAA128L00 (kits USEQDAK7128L00 & USEQDAK8128L00)

or Linear Array Sensor USEQDAAA128500 (kits USEQDAK7128500 & USEQDAK8128500)

(kits USEQDAK6000000, USEQDAK7000000 & USEQDAK8000000 do not include any sensor)

3. 9 V DC power supply
4. USB cable
5. KEMET Linear Array Evaluation Tool Software
6. USB drive with software and documentation

Figure 1 shows one variant, the Line Array Evaluation Board.

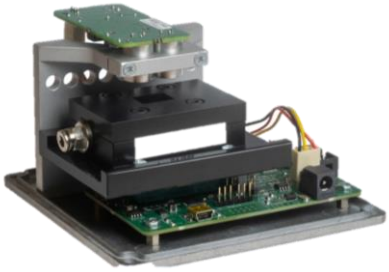

Figure 1 – USEQDAK6000000 *USEQDAK7____00 (0000, 128L or 1285)* *USEQDAK8____00 (0000, 128L or 1285)*

2.2 Minimum System Requirements

1. Microsoft Windows PC with one USB port available for use
2. Local administrative rights to install device drivers
3. Microsoft .NET Framework 4.5 or above (can be installed during setup procedure)
4. 1 free USB port

3 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.

3.1 Installing the KEMET Linear Array Evaluation Tool Software

Run the file named “setup.exe” contained from the software package included with the kit. This will start a windows installer, as shown below, which will guide you through the step-by-step installation procedure.

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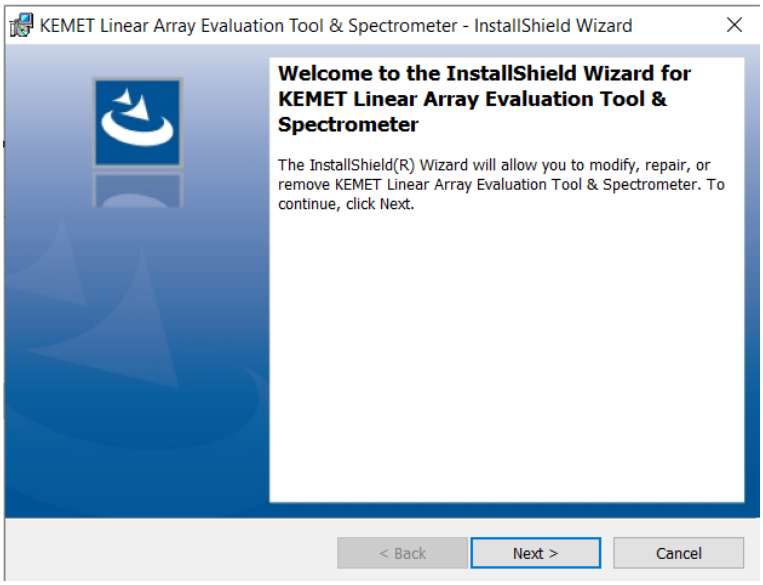

Figure 2 – Installer Screen

Follow the installer instructions until installation is completed. If you encounter problems installing please contact KEMET who will try to help you through the installation process.

3.2 Installing the Device Driver

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 V2 board employs a Silicon Labs CP2102 USB to UART IC, whilst the PYB_201 Rev B 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 V2	CP210x_Universal_Windows_Driver	https://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx
PYB_201 Rev B	STM VCP Driver	https://www.st.com/content/st_com/en/products/development-tools/software-development-tools/stm32-software-development-tools/stm32-utilities/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[1]	System Type[2]	Driver Installation Executable
7 and later	64-bit	CP210xVCPInstaller_x64.exe
7 and later	32-bit	CP210xVCPInstaller_x86.exe

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

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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 and later	64-bit	VCP_V1.5.0_Setup_W8_x64_64bits.exe
8 and 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)**:

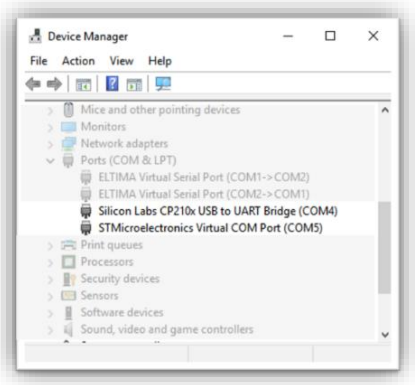
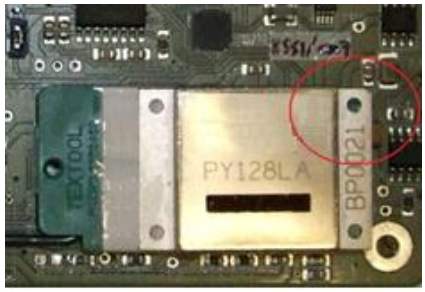


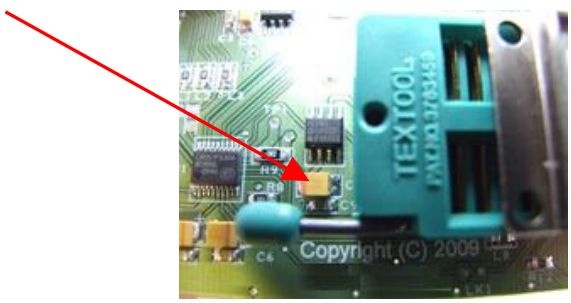
Figure 3 – Device Manager Entries for Evaluation Boards

4 QUICK START GUIDE

1. Install the Linear Array Evaluation Kit software and device driver as detailed above.
2. Ensure power is removed from the Evaluation Board and locate the Linear Array sensor in the socket with pin 1 (highlighted by the cut corner shown below) aligned with slot 1 of the socket (diagonally opposite corner from the lever).



3. Push down to close the lever on the socket to secure the Linear Array sensor.



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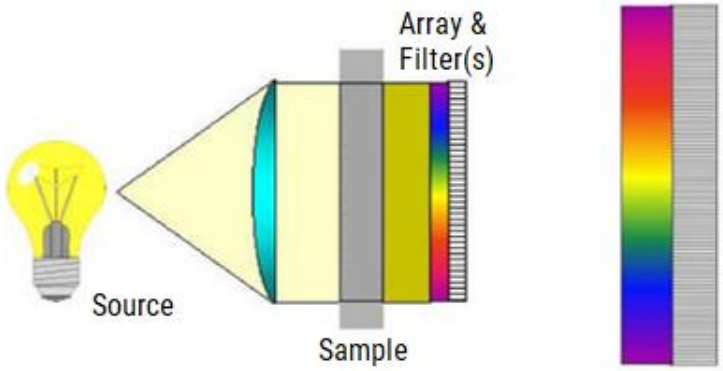
4. Connect the USB cable to your PC.
5. Connect the power to the Evaluation Board.
6. Start the Linear Array Evaluation Kit (section 6, below)

5 SPECTROMETER KITS



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.

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 dispersion grating 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 KEMET sales contact if you would like more information about other approaches to portable spectrometer solutions.

5.1 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.

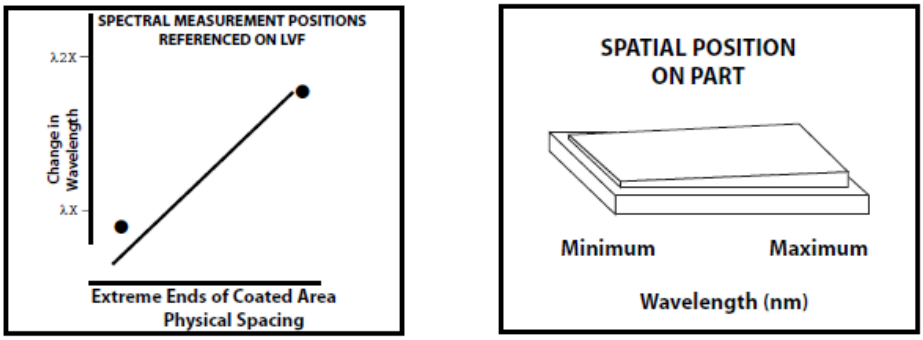


Figure 4 – Linear Variable Filter Information

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

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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.

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5.2 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.

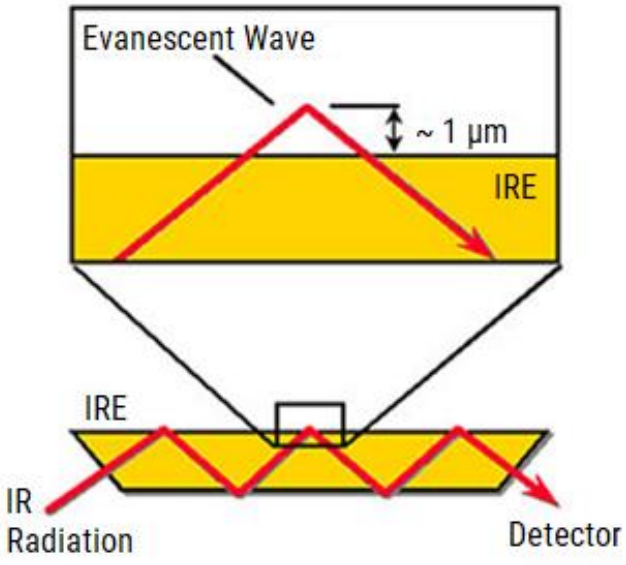
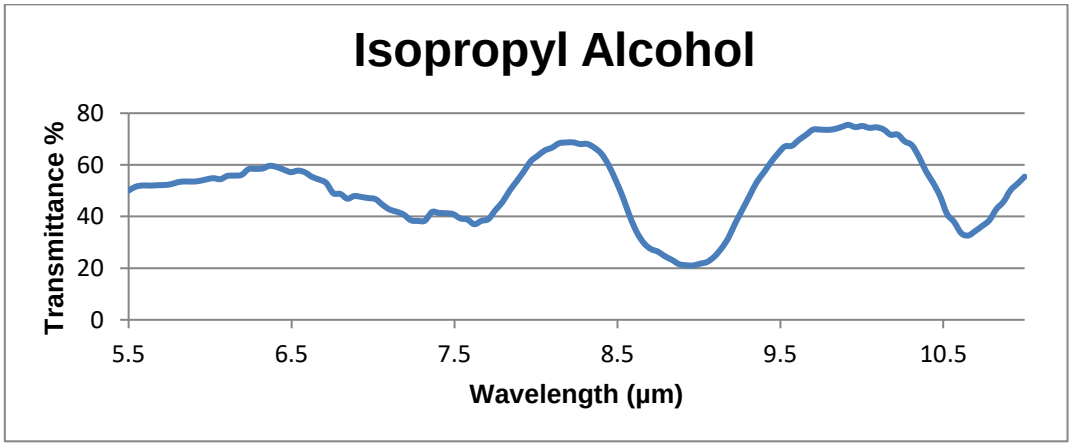


Figure 5 – The Optical Principle of an ATR Spectrometer

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 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.



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5.3 Transmission Spectrometer

The image below shows the transmission spectrometer.

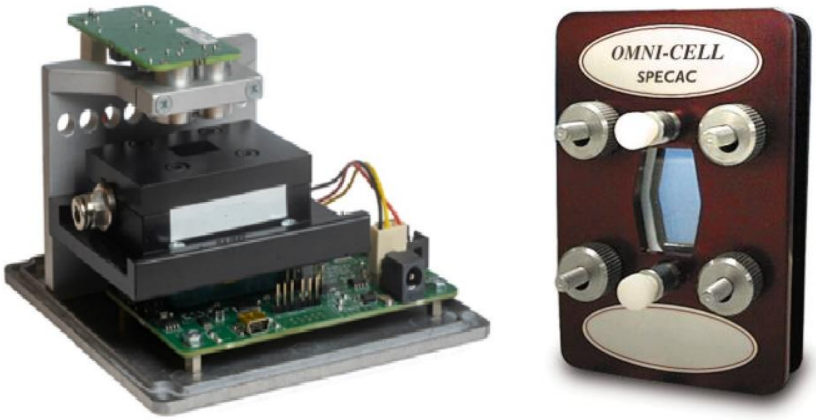
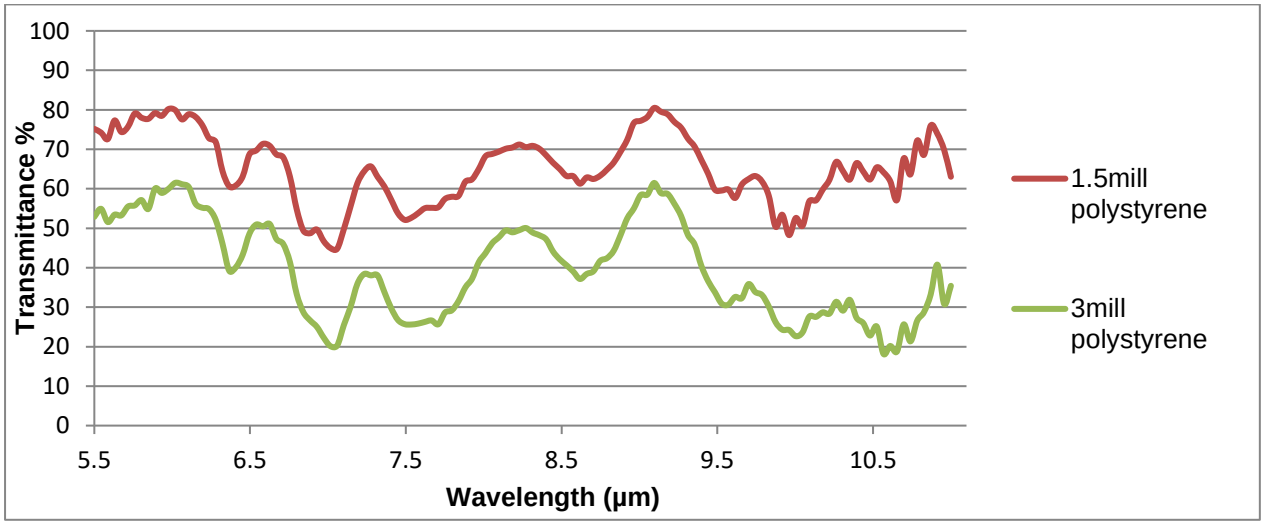


Figure 6 – Transmission Mode Evaluation Kit USEQDAK8____00 and the Specac Transmission Cell

For this system, it is necessary to prepare sample for analysis in a transmission cell, which are available from a variety of suppliers. The transmission spectrometer unit was designed to take the Omni-cell liquid transmission cell system from Specac: Part Number GS01800 “Omni-Cell Body with 3"x2" Slide Mount Assembly”.

5.3.1 Example Measurement

Below are 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.



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, Rosenheim, Germany.

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5.4 Using the Spectrometer

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

5.4.1 Placing Specimens on the ATR Spectrometer

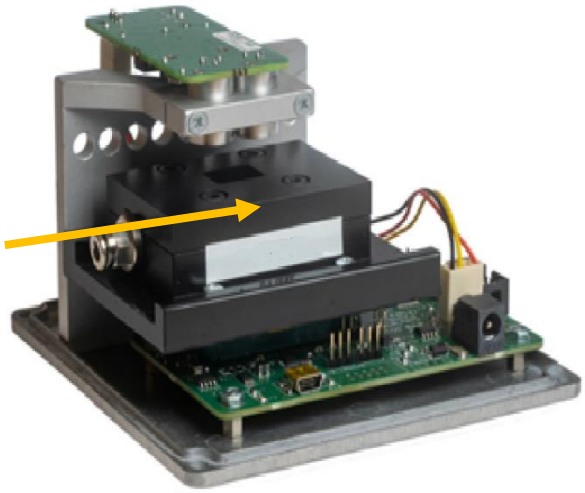
Pipette your specimen onto this window, ensuring that sufficient liquid is used to cover the whole window area.

5.4.2 Cleaning and Care of the ATR Crystal

The ATR crystal window is made from ZnSe, zinc selenide 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.

5.4.3 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.



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6 SOFTWARE USER GUIDE

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

6.1 Getting Started

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

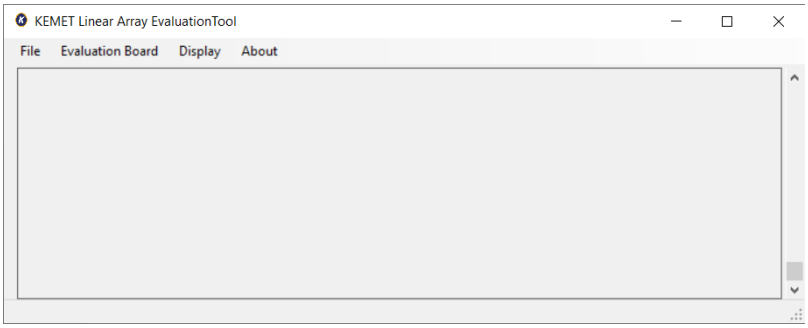

Figure 7 – Linear Array Evaluation Tool Main Form

6.2 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) asking you to "Select Evaluation Board" from the available list. If no items are displayed, check your USB connection, and click **Refresh**[3].

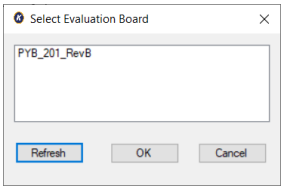

Figure 8 – Evaluation Board Selection Form

Select the appropriate Evaluation Board and click **OK**, and the software 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) 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.

[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.

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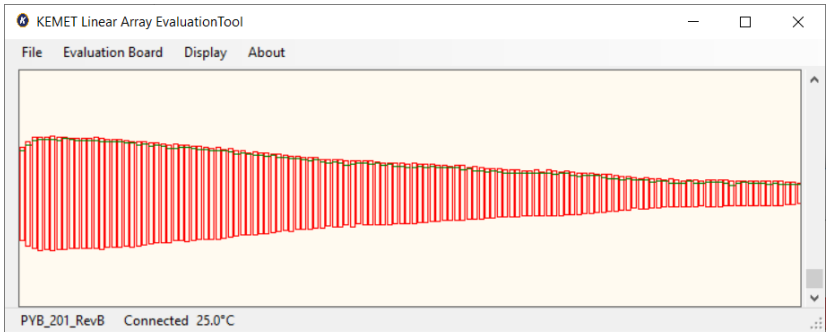

Figure 9 – Histogram Display for Connected Sensor

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 10) 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.

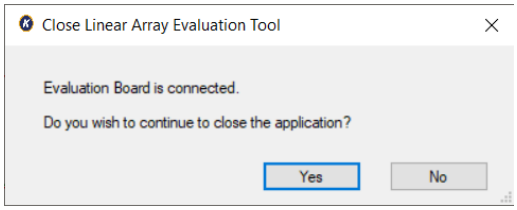

Figure 10 – Exit Dialog Box

6.3 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.

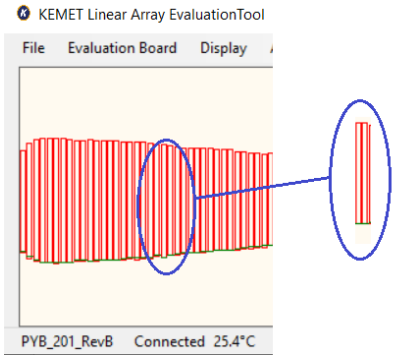

Figure 11 – Histogram Detail

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

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corresponding pixel, with 2.5 V in the middle of the screen, 0 V[4] at the bottom and 5 V[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 0 for more details).

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 5 V range, and as it is moved up the range is reduced by 10 mV 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 the oscilloscope view is provided in section 6.6.

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 Linear 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 8.

6.4 Sensor Properties

The evaluation software supports several KEMET Linear Array Sensor products. A properties dialog box (Figure) 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. With the exception of the Sample rate, any changes selected from this dialog box will not take effect until the **Apply** or **OK** button is pressed.

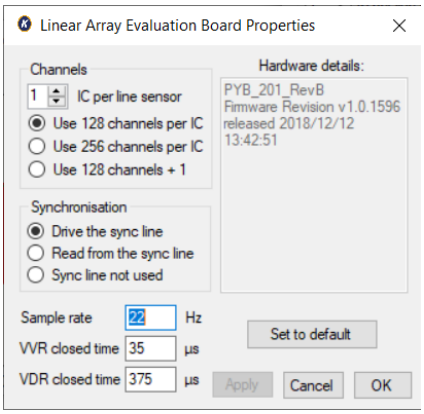

Figure 12 – Evaluation Board Properties (PYB_201_RevB)

6.4.1 Selecting the Pixel Configuration to be Captured from the Linear Array Sensor

KEMET 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

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

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the product package. The ICs provide all the necessary front-end amplification circuits for each pixel in the Linear Array sensor.

Table 4 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	KEMET Part Number	Optimal Configuration	Properties Dialog Settings	
			IC per Linear Array Sensor	Use Channels per IC
128	USEQDAAA128500 USEQDAAA128L00 USEQDAAA128S00	128 x 1	1	Use 128 channels per IC
129	USEQDAAA128A00 USEQDAAA128W00	128 +1	N/A	Use 128 channels +1
255	USEQDAAA255S00	256 x 1	1	Use 256 channels per IC
510	USEQDAAA510100	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.

6.4.2 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: either the Evaluation Board can generate a synchronisation signal which can be directed to an external emitter arrangement; be driven by an external signal (for example from a rotary chopper); or not be synchronised with any IR illumination source.

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 5 V square wave signal with a 50% duty cycle to the synchronisation header[5]. The frequency of the generated signal is specified in the Sample rate box on the **Properties** dialog. See section 0 for details. This option is typically used in a spectrometer application, where the Evaluation Board firmware controls the IR beam illuminating the sensor.

[5] Please refer to section 9.1 or 9.2, depending on the Evaluation Board you are connecting to.

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Radio Button	Description
Read from the Sync line	When this option is selected the Evaluation Board will read a 5 V signal applied to the synchronisation header[5]. 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. Selecting this option will result in the capture of data at the frequency entered in the sample rate box on the dialog (section 0).

Table 5 – Synchronisation Options

With the selection of either option, 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 7 of this user guide further details why IR source and sample synchronisation are useful.

6.4.3 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 0) 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 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.

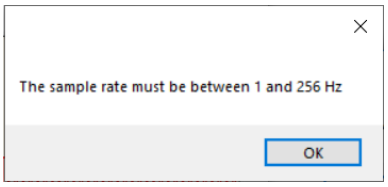

Figure 13 – Invalid Frequency Alert Message

The maximum sampling frequency setting of 256 Hz is achievable for all pixel/IC configurations. However, if the VVR/VDR timings (section 0) 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 2); you will need to reduce the VDR value accordingly before proceeding.

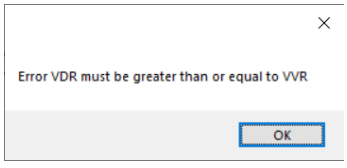

Figure 2 – Invalid VDR Alert Message

6.4.4 Selecting the Correct Timings for Operating the Linear Array Sensor

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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.

6.5 Display Show Rendering Options Dialog Box

The Linear Array evaluation kits have 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 3) to render the data according to the user’s requirements.

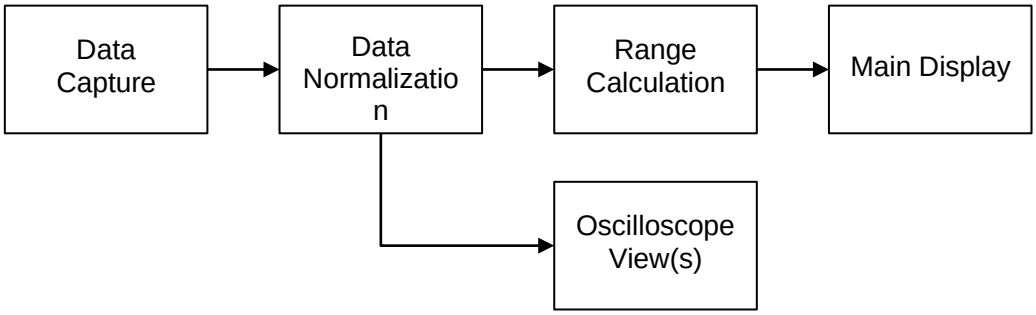

Figure 3 – Data Manipulation Processes

The configuration of these processes is governed by the details entered into the rendering properties dialog box (Figure 4). 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.

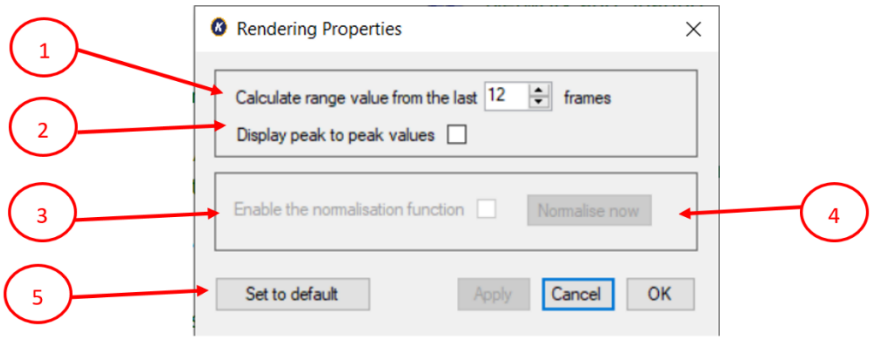

Figure 4 – Rendering Properties Dialog

6.5.1 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 8.5.

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

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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 0), or externally via CSV output (section 6.7).

6.5.2 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 0).

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.

6.5.3 Normalisation

The Linear Array evaluation kits provide 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 (section 6.2) 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 5.

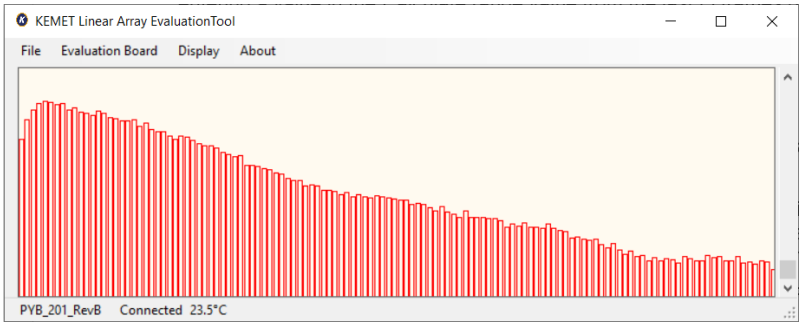

Figure 5 – Peak to Peak Values (Air)

Covering the sensor window with a 1.5 mil polythene sheet affects the transmittance of radiation of all wave number but more so for certain wave numbers that are characteristic of the composition of the polythene. Figure 68 shows how the peak to peak values are affected by the polythene, and the wave numbers most affected.

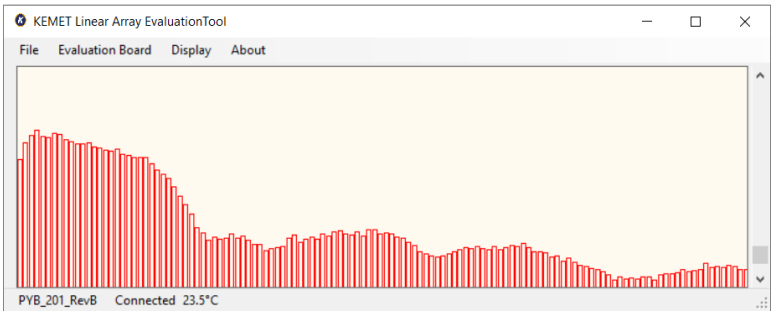

Figure 68 – Polythene (1.5 mil) Transmittance Effects

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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 7.

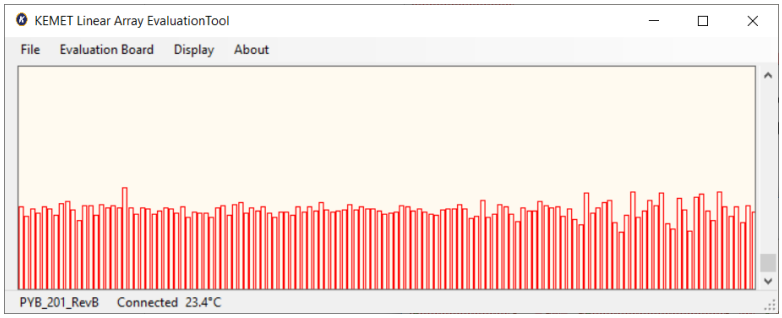

Figure 7 – Polythene (1.5 mil) – Normalised Plot

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.

$$\propto_i (t_{norm}) = \frac{1{,}000}{p_i(t_{norm})}$$

Equation 1 – Normalisation Weight Calculation

For subsequent frames the weighting is applied using Equation 2 so that $p_i'(t)$ is roughly 1,000.

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

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.

6.6 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 8 shows the saw-tooth pixel value of a synchronised capture.

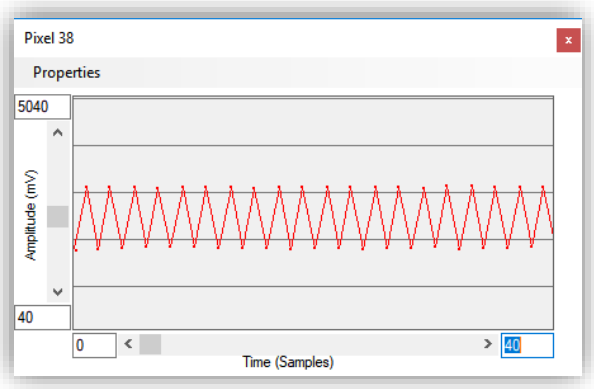

Figure 8 – Oscilloscope View – Synchronised Pixel

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 ().

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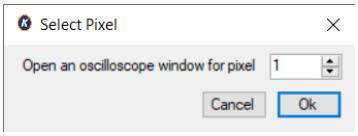

Figure 9 – Select Pixel Dialog Box

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.

6.6.1 Oscilloscope Display Range

The amplitude and range of the signal being viewed (Figure 8, Figure 11) can be changed in two different ways. First the maximum and minimum 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).

6.6.2 Oscilloscope Menu

- Properties
  - This displays the **Oscilloscope View Properties** dialog box (Figure 10) which controls display and spacing (in mV) of the horizontal grid lines.

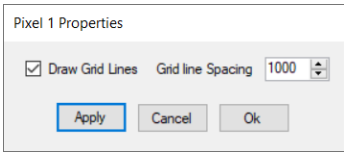

Figure 10 – Oscilloscope View Properties Dialog Box

6.6.3 Oscilloscope +1 Menu

When using a 128 +1 Linear Array sensor (for example USEQDAAA128W00 or USEQDAAA128A00) and enabling 128 +1 capture on the **Sensor Properties** dialog box

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(section 0), the **Display** menu will show the **Oscilloscope view +1** option. Selecting this option will display the “+1” pixel value (Figure 11).

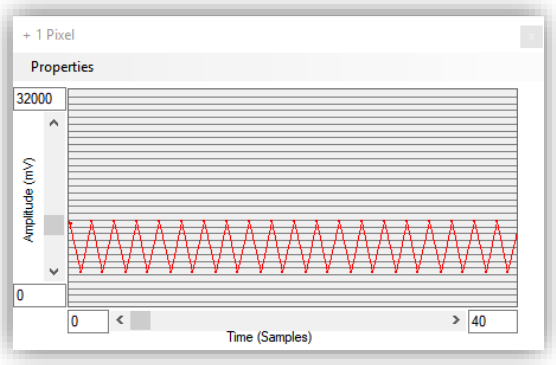

Figure 11 – Oscilloscope View – +1 Pixel

6.7 Saving Data to CSV (Comma Separated Value) File

In the **File** menu there are two options to save data from the evaluation kits 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 12) to specify the number of samples to capture.

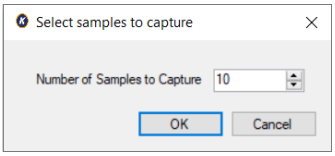

Figure 12 – Save to CSV Samples Selection Dialog Box

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 13).

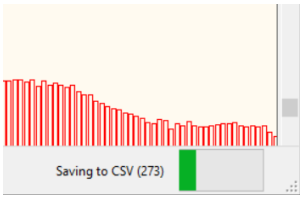

Figure 13 – Save to CSV Status Progress Indicator

The contents of the file is dictated by the selections made in the **Rendering Properties** dialog box (see section 6.5) including the “+1” pixel if selected (as Pixel 129).

If normalisation (section 0) is being applied, the CSV output will be the result of the normalisation. Averaging each pixel column and creating a plot of the average normalized values versus the pixel number, shows then more clearly where the peaks are. For example, the averaged 1.5 mil polystyrene capture (Figure 7) CSV output is seen in

Figure *14* below.

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Figure 14 – 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 8.2 and 8.3.

6.7.1 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 something similar, the absorption and transmittance spectra can be obtained as follows:

1) Capture the baseline (air) 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, for example 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 15 shows the % Transmittance spectra for 1.5 mil polystyrene. Comparing with Figure 14, the peaks are better defined.

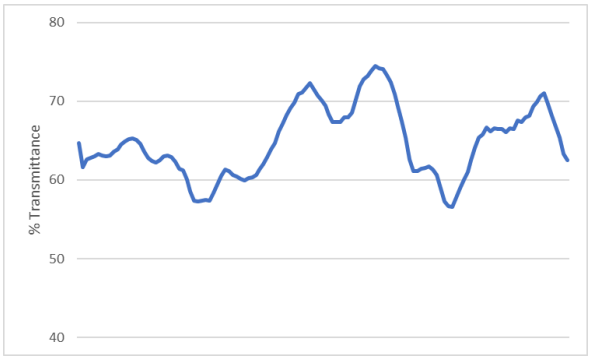

Figure 15 – Transmittance Plot for 1.5 mil Polystyrene

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7 SYNCHRONISATION OF LINEAR ARRAY SENSOR AND IR ILLUMINATION SOURCE

The KEMET 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 16 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 below).

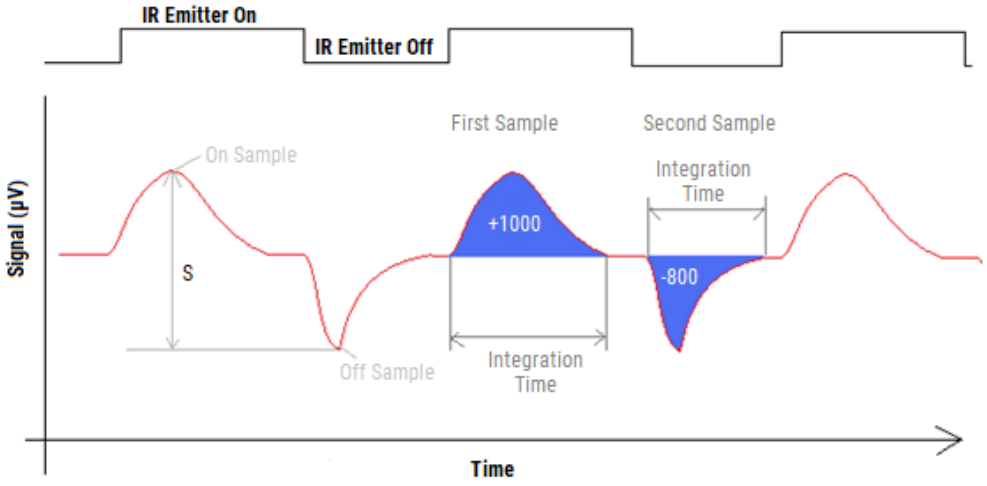

Figure 16 – Signal versus Time for One Pixel

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 17.

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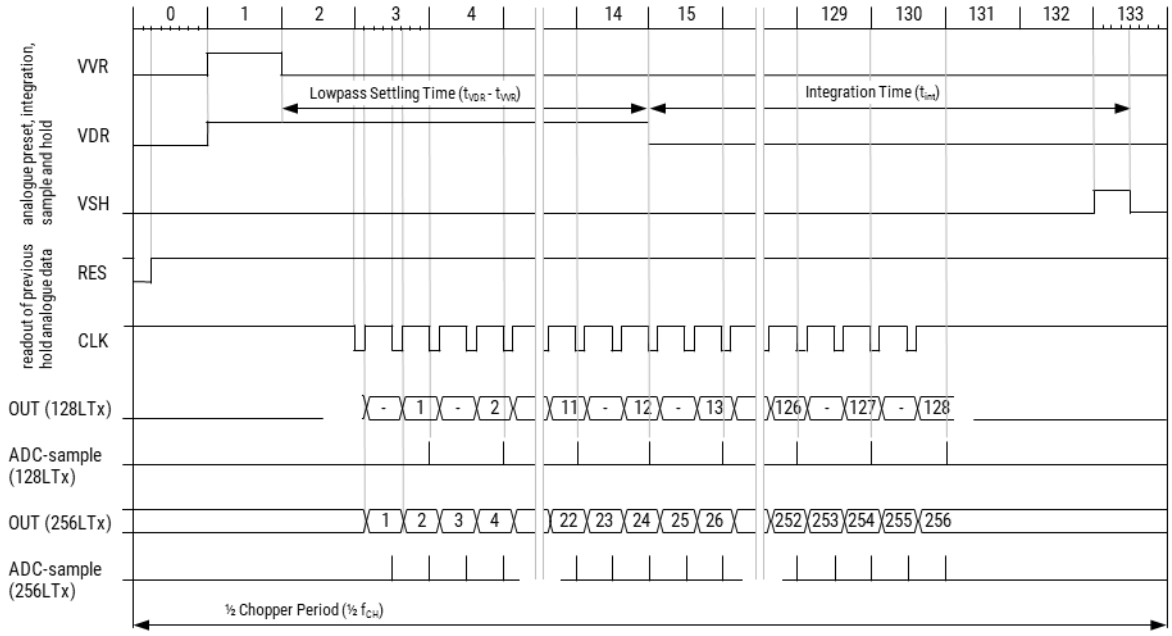

Figure 17 – Linear Array Sensor Signal Timings

Figure 18 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):

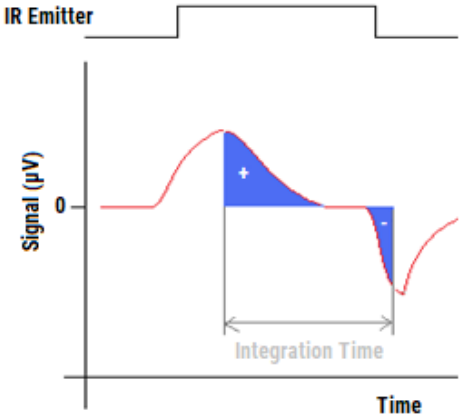

Figure 18 – Integration Time Overlap – No Synchronisation

The Linear Array Evaluation kits 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, respectively 9.1 or 9.2.

To maintain a useful sampling system, it is recommended that the sensor integration time stays within the range of 1 ms to 100 ms 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 0 for details concerning the setting of the integration time by adjustment of the VDR pulse length.

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8 SPECTROMETER SOFTWARE

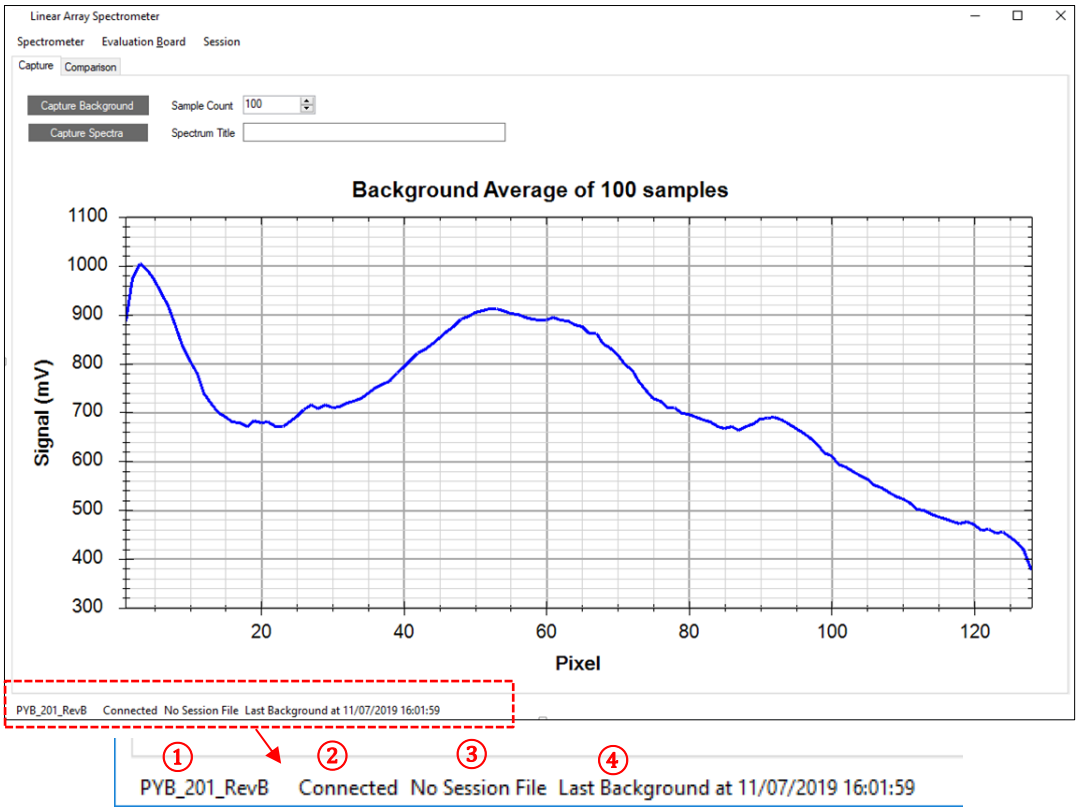
This feature can be found under the **Display** menu which will open a new window keeping the **KEMET Linear Array Evaluation Tool** window open in the background. The first thing that will be noticed is that the live view of the signal from the Linear Array stops which is normal as the signal capture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

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

8.1 Main Features

Some of the main features are as follows:

- Capture (section 8.2)
    - capture spectrum against a background scan
    - auto save spectra in **Session** csv files
- Compare (Section 8.3)
    - spectra comparison overlaid on one plot
    - add previously collected spectrum to the plot
    - change plot display between **Absorbance** and **Transmittance**



① PCB Firmware Version of the Spectrometer Board

② Connection Status

③ Session File Added

④ Time the Last Background Was Collected

Figure 19 –View of the Spectrometer Window and Magnified Status Bar

8.2 Capturing a Spectrum

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

8.2.1 Session

Session as its name suggests is a file (.csv format) that, 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 KEMET Linear 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)

Raw File

When the program is first opened, a Linear 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\KEMET\Spectrometer*.

The files will have a prefix ‘scratch’ and will contain raw pixel information. To convert this info millivolt and to learn more about peak-peak conversion please refer to section 6.7.

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

8.2.2 Capture Background/Spectrum

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.[6]

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

8.2.3 Spectrum Title

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

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By clicking the **Capture Spectra** 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).

8.2.4 Capture Buttons

There are two different capture buttons on the main display shown below: **Capture Background** and **Capture Spectra**. The latter is only available after a background reading has been measured.

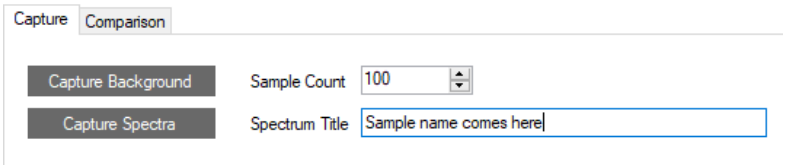

Figure 20 – Capturing Options in the Spectrometer Application

It is possible to write software to communicate with the Evaluation Board directly without using the KEMET 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.

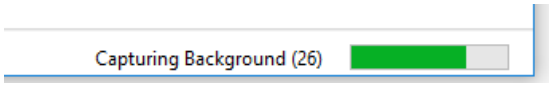

Figure 21 – Progress Bar of Capturing Spectra

The **Capture Spectra** 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 Spectra**.

The window should now be updated with the spectrum of the new sample and the y-axis will be changed to **Absorbance**. It should also be noted that this plot will be 'replaced' with the next sample being measured (i.e. it 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.

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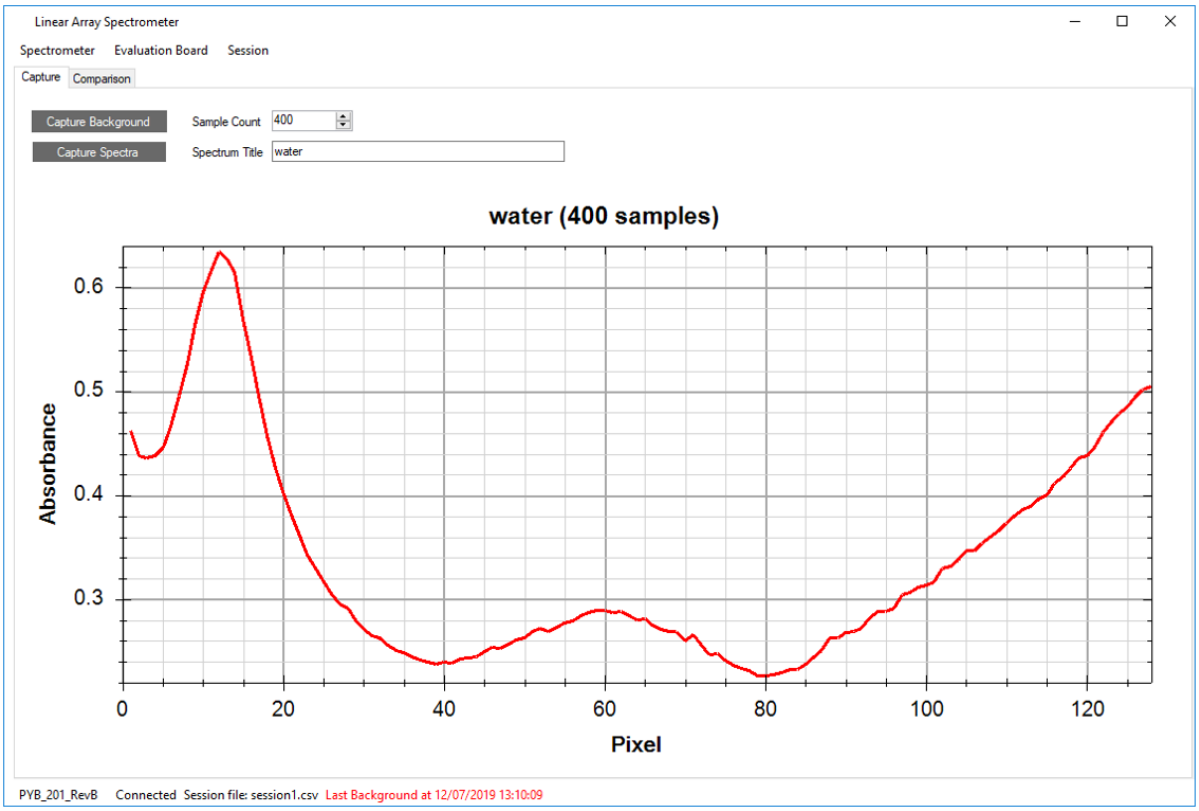

Figure 22 – Spectrometer Window Displaying the Spectrum of Water Captured

Current Background Details

The status bar will display the **Last Background** time and date. When fresh background is collected it will be displayed in black font, however, after 20 minutes 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.

Saving Files Separately

As discussed earlier, the software autosaves the measurements in **Session** CSV files. In the **Spectrometer** menu one can access other options to save measurements separately files, as shown in Figure 35.

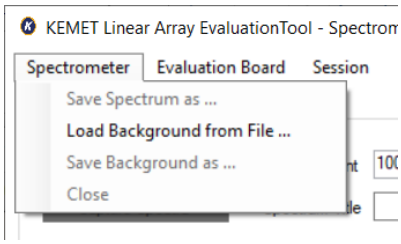

Figure 23 – Menu for Saving Measurements Separately

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.

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8.3 Spectral Comparison

8.2.1 Overview

This section details the use of the **Comparison** option on the Spectrometer application for simple spectral comparison. 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

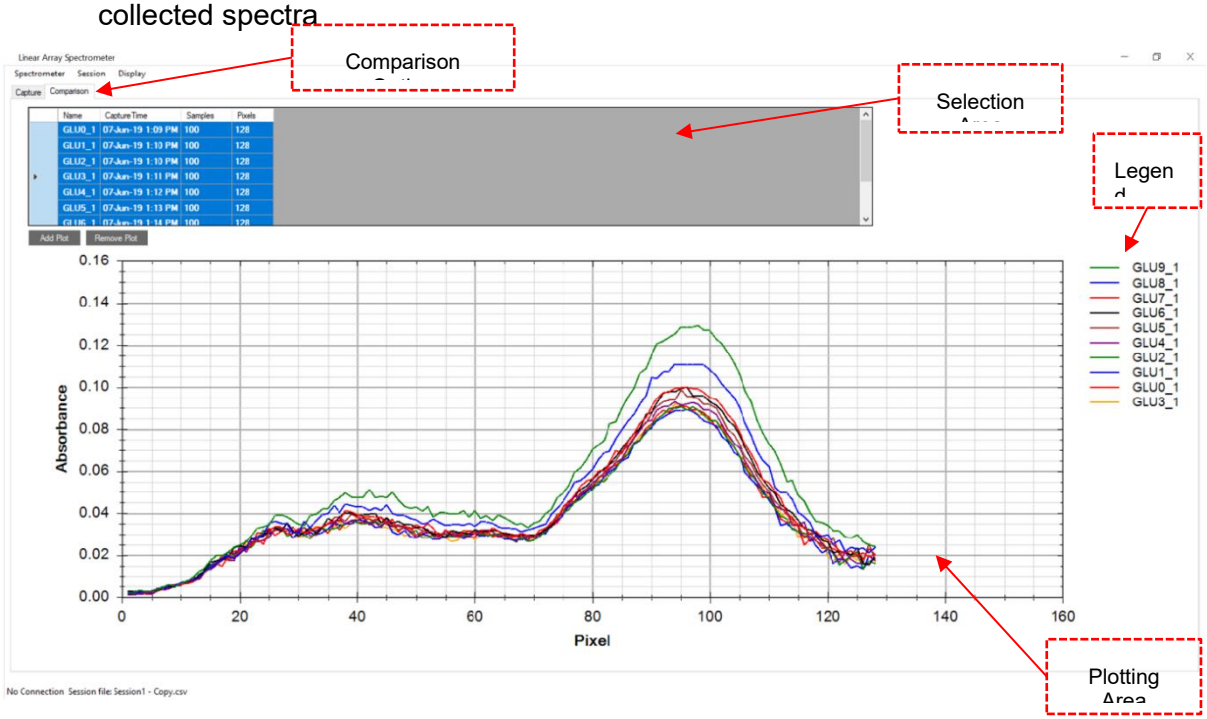
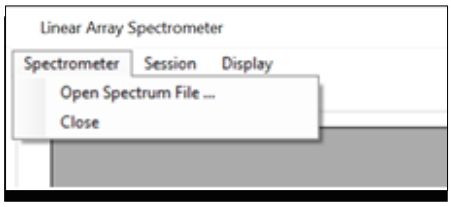


Figure 24 – Overview of the Spectra Comparison Environment of the Software

8.2.2 Add/Remove Plots

Adding individually saved spectrum from .csv under



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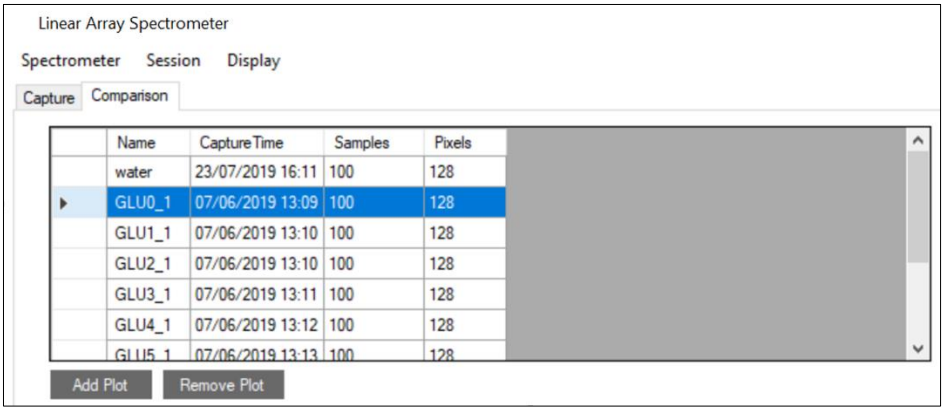

Figure 25 – Selecting a Spectra from the Table to Plot

To add a plot, its 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 25. 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 **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 color 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.

8.2.3 Display Options

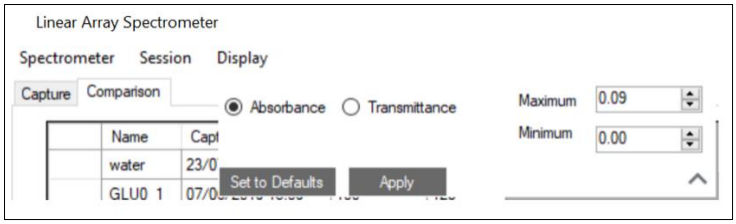

Figure 26 – Plot Display Options

The plot's display options can be accessed from the **Display** menu by selecting **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 the following image.

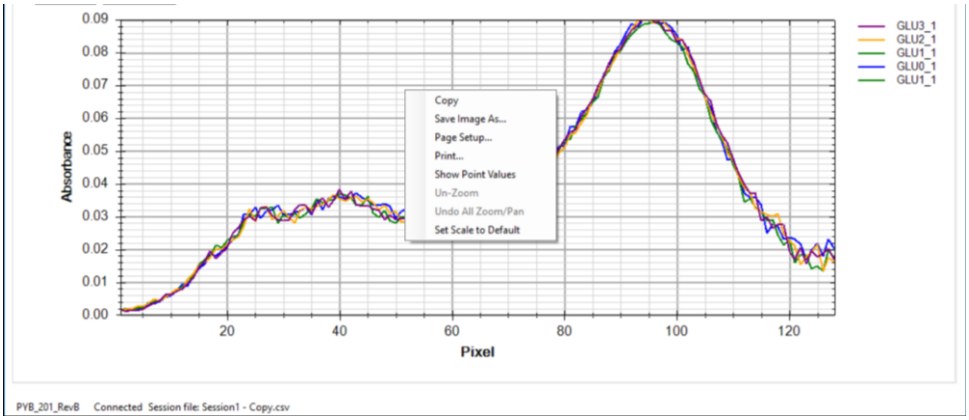

Figure 27 – Option to Save Image of the Plot and Scaling Options (through Right-Click)

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The following options can be accessed from the plot itself:

- Right-click: **Copy** screenshot of the plot to the 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

8.2.4 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 of these various session files on this one platform.

One way is to create a new session by selecting **New Session** in the **Session** menu 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 selecting **Close Session** through the menu **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 **Save Session As** in the **Session** menu and then saving a relevant .csv file.

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

8.4 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 B board uses a direct USB connection from the microprocessor and appears to Windows as a STM VCP. See section 3.2 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 B 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.

8.5 Data Format

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

Offset	Data Size	Description

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0	2	Frame Code: 0xFFFF[7] 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 = 0 V and 0xFFFE = 5 V.
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 4,095 (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[8]
256 x 2	1, 512, 3, 510, 5, 508, …, 507, 6, 509, 4, 511, 2

Table 7 – Pixel Ordering with 2 ICs

The data values are all in the range 0 to (2^{12} -1) = 4,095 and are generated directly from the A-D converter in the microprocessor. Each count from the A-D converter represents ~1.2 mV and is calculated by the equation below:

$$voltage = \frac{value * 5}{4{,}095}$$

8.6 Firmware Commands

This section details the command protocol required for the Evaluation Board firmware. All commands stated in single quotes (as for example '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 (for example "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 B firmware. The functionality of these commands is now managed through the **Operating Settings** detailed below.

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

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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, Linear 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

8.6.1 Start Sending Data

Command	Byte Value	Action	Response
‘g’	103	Start streaming sensor data in accordance with its settings.	None

8.6.2 Stop Sending Data

Command	Byte Value	Action	Response
‘s’	115	Stop streaming sensor data.	“ok”

8.6.3 Get the Firmware Version

Command	Byte Value	Action	Response
‘v’	118	Send the firmware description string.	Example: “PYB_001_V2, Firmware Revision 1.0.1, released 18/11/2009”

8.6.4 Read the Temperature from the Evaluation Kit

Command	Byte Value	Action	Response
‘t’	116	Sample the Linear Array thermistor voltage and microprocessor internal temperature.	See below

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Response Details

Offset	Size	Description
0	2	Evaluation Board microcontroller temperature: ○ **PYB_001 V2**: raw A-D conversion value for thermistor on the Silicon labs C8051f530 microcontroller. ○ **PYB_201 Rev B**: temperature of STM32F303 microcontroller in tenths of a degree Celsius (for example 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[9] into temperature.

8.6.5 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.

Value to Send	Baud Rate
1	115,200
2	230,400
4	460,800
8	921,600

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.[10]

8.6.6 Set the Operating Frequency

[9] And C8051f530 microcontroller temperature value.
[10] For PYB_201_RevB, the baud rate setting is not required, as the serial communications is handled by firmware USB CDC driver routines.

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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"

8.6.7 Get the Operating Frequency

Command	Byte Value	Action	Response
'F'	70	Get the operating frequency.	One byte representing the sample rate – 1[11]

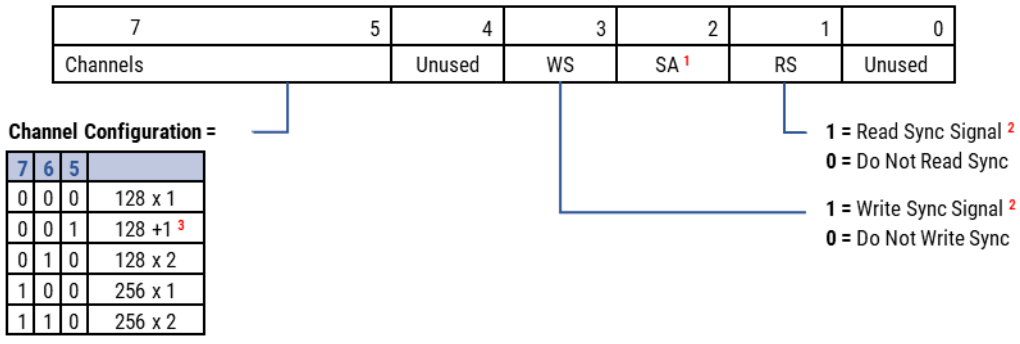
8.6.8 Set the Operating Settings

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 28 shows the bit values and positions.



[1] 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.

[11] 0 indicates a sample rate of 1Hz.

[2] 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 6.4.3.
[3] The 128 +1 channel configuration is not available for the PYB_001 V2 firmware.

Figure 28 – Definition of Operating State

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

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

8.6.9 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 28

8.6.10 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 B 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 16,382 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

8.6.11 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

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"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 8.5), with the PYB_201 Rev B 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 3.2 for driver installation.

The default settings for the firmware on both boards are 115,200 baud, 8 data bits, 1 stop bit, no parity, no handshaking. The PYB_201 Rev B 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 LINEAR ARRAY SENSOR EVALUATION BOARDS

9.1 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.

The image below shows the location of the relevant connectors and jumpers. Table 10 to Table 17 describe the pin assignments and options associated with each one.

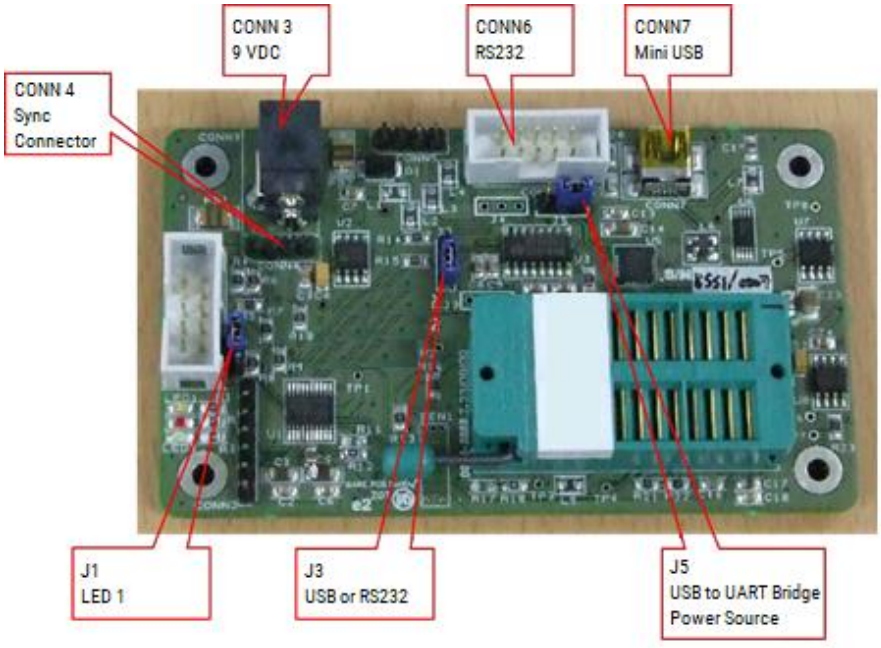

Figure 29 – PYB_001 V2 Connector and Jumper Locations

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9.1.1 CONN3 – 9 VDC Power Connector

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

Pin N°	Signal	Direction
1	0V	In
2	No connection	
3	+9 VDC	In

Table 10 – CONN3 Power Connector

9.1.2 CONN4 – Synchronisation Connection

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

Pin N°	Signal	Direction
1	9 VDC	In/Out
2	VDD 5 V	Out
3	SYNC	In/Out
4	GND	In/Out

Table 11 – Synchronisation Connections

9.1.3 CONN6 – RS232 Serial Communications

The RS232 driver included on the kit has a maximum rated speed of 230,400 baud. KEMET recommends not using it for communications with the included software.

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

Pin N°	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 – RS232 Serial Communications

9.1.4 CONN7 – USB PC Connector

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

Pin N°	Signal	Direction
1	Vbus	In
2	D-	In/Out
3	D+	In/Out

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4	No connection	
5	GND	
6	100 MΩ to GND	
7	100 MΩ to GND	
8	100 MΩ to GND	
9	100 MΩ to GND	

Table 13 – USB Connector

9.1.5 Jumpers

Table 14 to Table 17 detail the jumper settings. Yellow background indicates the default jumper setting.

Position	Function
1-2	LED 1 indicates 5 V 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 5 VDC supply

Table 15 – J3 RTS Input

Position	Function
1-2	CP2102 powered from VCC 5 V 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 RS232

Table 17 – J2 Micro Controller RX Source

9.2 PYB_201 Rev B Evaluation Board

This section describes the PYB_201 Rev B hardware; it details the use of the jumper and connectors on the PCB. Figure shows the locations of relevant connectors and headers and the following sections give further details. It is important not to supply power to any pin detailed as “Direction Out” in the tables below.

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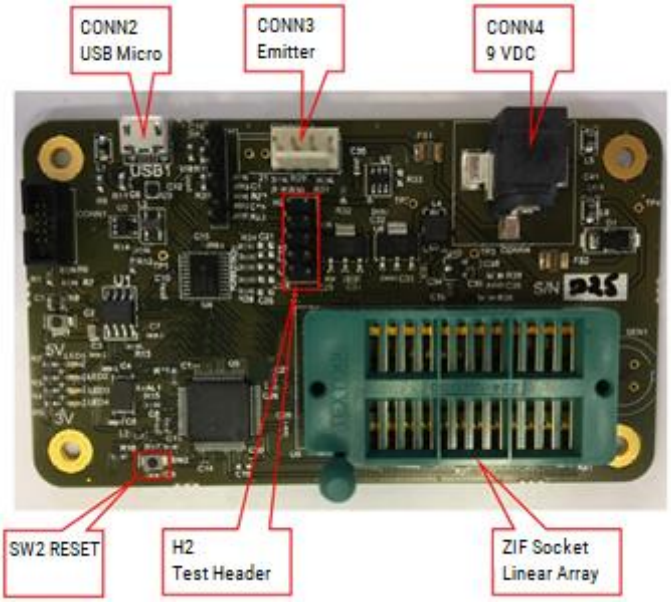

Figure 42 – PYB_201 Rev B Connectors

9.2.1 CONN2 – USB Micro-USB Connector

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

9.2.2 CONN3 – Synchronisation Header

CONN3 provides 4-way Molex, 2.54mm pitch male header to connect to an external emitter or synchronisation source. Table 18 details the pin assignments.

Pin N°	Signal	Direction
1	9 VDC	Out
2	5 VDC	Out
3	Synchronisation signal (5 V)	In/Out
4	GND	Out
5	Not used	
6	Not used	

Table 18 – Synchronization Header

9.2.3 CONN4 – 9 VDC Power Connector

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

Pin N°	Signal	Direction
1	0 V	In
2	No connection	
3	+9 VDC	In

Table 19 – 9 VDC Connector

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9.2.4 H2 – Test Header

This header enables the Linear Array and emitter signals to be connected to an oscilloscope or logic analyser. Specification: DIL-10. Table 20 details the connected signals and the pin assignments.

Pin N°	Signal	Direction
1	LED_1A	Out
2	3V3	Out
3	Linear Array CLK (5 V)	Out
4	Linear Array VVR (5 V)	Out
5	Linear Array RES (5 V)	Out
6	Linear Array VDR (5 V)	Out
7	Linear Array VSH (5 V)	Out
8	Synchronization signal (3 V)	In/Out
9	GND	Out
10	GND	Out

Table 20 – H2 Test Header

9.2.5 ZIF Socket

The Linear Array sensor is attached using this connector. Please refer to section 3 for insertion details.

9.2.6 SW2 – Reset

The firmware should reset itself if a lock-up occurs. In the eventuality that it fails to reset, press **SW2** to reset the firmware.

10 APPENDIX A DATA CONVERSION EQUATIONS

10.1 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.

$$Volts = \frac{value * 5}{4{,}095}$$

10.2 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 evaluation 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 10.6.4.

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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.

10.2.1 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.

10.2.2 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 evaluation kit.

$$Temperature\ (centigrade) = \left(\left(\frac{count * 5{,}000}{4{,}095}\right) - 0.89\right) * 0.0284$$

10.2.3 Linear Array Sensor Thermistor Measurements

The temperature sensor in the KEMET Linear Array sensor is connected to the A-D in the microcontroller using the circuits in the following figures:

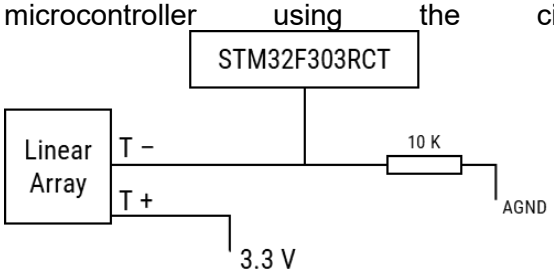

Figure 30 for PYB_001 V2 and Figure 31 for PYB_201 Rev B.

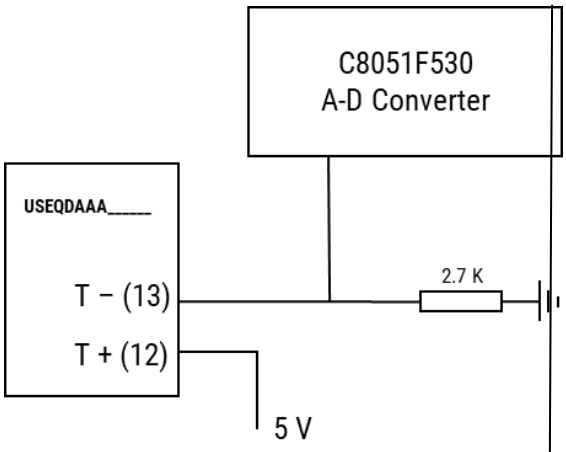

Figure 30 – Thermistor Connection PYB_001 V2

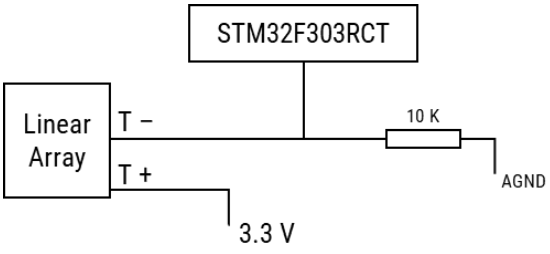

Figure 31 – Thermistor Connection PYB_201 Rev B

To date, the KEMET 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 32 gives the circuit diagram for the Thermistor connection.

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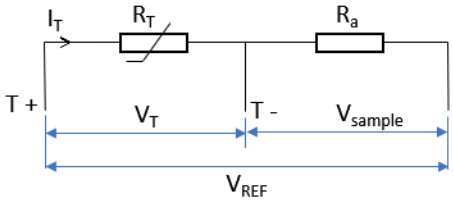

Figure 325 – Linear Array Thermistor Circuitry

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

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

Equation 4 – Thermistor Temperature Calculation

From Figure 325, the voltage sampled is given by

$$V_{sample} = \frac{V_{REF} \times sample}{4{,}095} \qquad (1)$$

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:

$$R_T = \frac{1 - \frac{sample}{4{,}095}}{R_0 + R_a}$$

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	3,435
R_a	10 K (PYB_201 Rev B) 2.7 K (PYB_001 V2)
R_0	10 K
T_0	298.15 K
V_{REF}	3.3 V (PYB_201 Rev B) 5 V (PYB_001 V2)

Table 21 – Thermistor Calculation Constants

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