PYREOS

Thin Film Pyroelectric

IR Sensor

Demonstrator Kit

For use with Pyreos TO5/TO39 packaged sensors

For development of IR gas sensing, process analytical measurement, and medical applications

User Guide

Version 1.0

Release February 2013

Contents

1 Introduction

This document describes a demonstrator kit that enables simple and efficient data capture from Pyreos TO packaged sensor components. These high performance thin film pyroelectric sensor products are typically used in NDIR gas sensing, process analytical measurement, IR spectroscopy, and medical diagnostic applications.

The purpose of the kit is to enable engineers and technicians to carry out a simple and effective evaluation of Pyreos products, to capture measured data and send it to a PC. The kit is based on the Silicon Labs C8051F350 microcontroller with high precision A-D converter and programmable gain amplifier. It is capable of sample rates up to 333Hz when sampling from a single channel (allows for up to 4 multiplexed signals at ¼ the sample rate).

2 Getting started

2.1 Kit contents

1. Pyreos PCB with C8051f350 microcontroller and ADC
2. Pyreos emitter drive PCB, with Pyreos TO39 emitter
3. Brass gas cell (not gas sealed; please consider safety if used with toxic gases)
4. 9V DC power supply
5. Micro USB cable
6. Software CD

2.2 Minimum system requirements

1. Intel® Pentium® 4 or AMD Athlon® 64 processor
2. Microsoft® Windows® XP with Service Pack 3, Windows Vista® or Windows 7
3. 2 GB of RAM
4. 450 MB of available hard-disk space for installation, additional free space required for storing CSV files
5. 1024x768 display (1280 x 1024 recommended)
6. .NET Framework 4.0 (can be installed during setup procedure)

3 Installation

3.1 Install the Pyreos software

From the software CD included with the kit, select the “setup” file. This will start the installation process.

Figure 1: 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 4.0 is present. If not, it can be installed as part of the setup routine or alternatively the setup routine can be cancelled and the .NET framework 4.0 can be downloaded from Microsoft’s website. The .NET framework can take some time to install but the software requires it.

3.2 Connect the PYDK demo kit

1. Connect the power supply provided to the Pyreos PCB
2. Connect the USB cable to the Pyreos PCB and Windows PC
    a. You may see a message suggesting you are required to install a device driver. You can either:
        i. Follow the on screen instructions and download a driver from Windows Update
        ii. Browse to the “Drivers” directory of the supplied CD.

Your kit is now installed and ready to use.

4 Software user guide

The PYDK-TO Data Capture software runs on Microsoft Windows PCs and communicates with the PYB_040 evaluation PCB, which enables easy testing of Pyreos TO packaged sensors. The software provides an interface to the analogue circuits and A-D (Analogue to Digital) converter, which are provided by a Silicon Labs C8051F350. Additional signal processing algorithms to filter and analyze sensor output for NDIR gas sensing are provided. These include a section to calculate the percentage of required gas present in the system using a modified Beer Lambert formula.

4.1 Starting the software

To start the software select the following from the windows start button in your task bar:

All Programs -> Pyreos Ltd -> PYDK_TO_V3 -> PYDK-TO Data Capture

This will open up the Pyreos sensor data capture main screen as shown below:

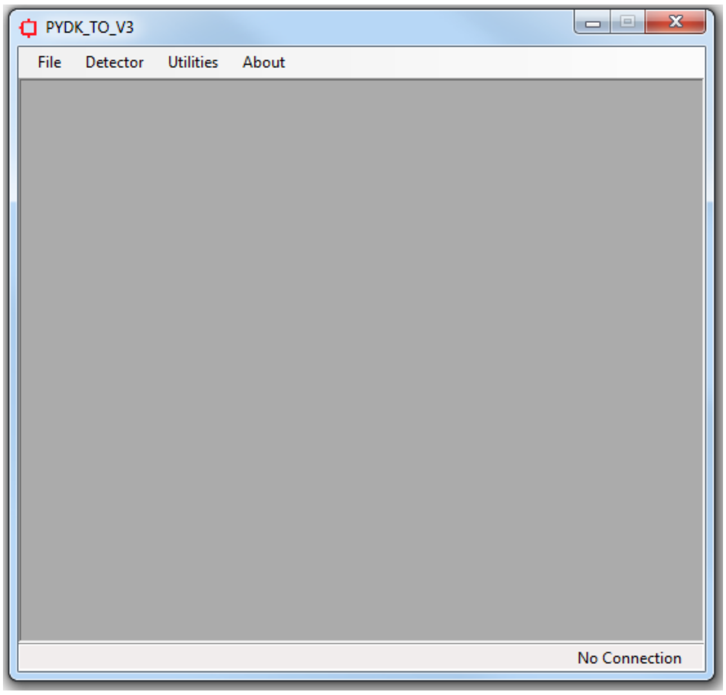


Figure 2: PYDK-TO main application window

4.2 Connecting software to the data capture board

To connect to the PYB_040 data capture board make sure the board is powered and connected to the PC through the USB cable.

From the menu bar select the "Detector" option and then "Connect" as shown overleaf.

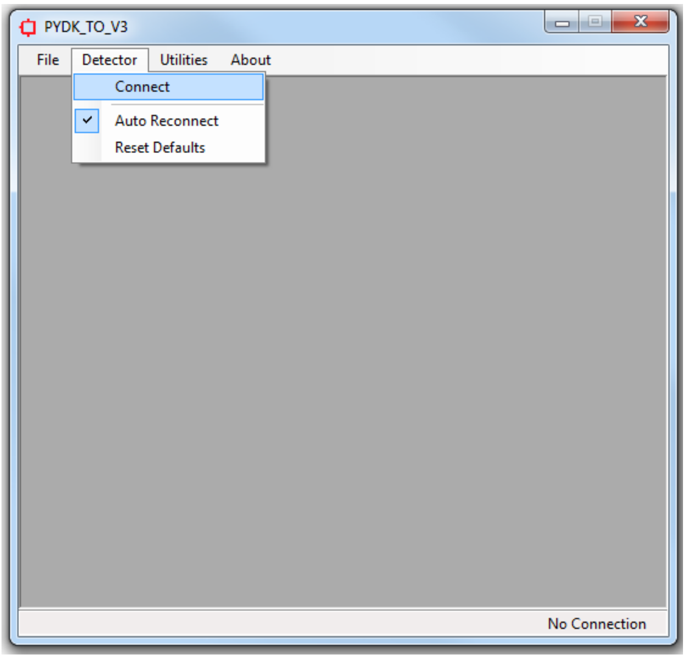


Figure 3: Detector connection

This will open up a further dialog box asking you to select on which COM port the data capture board is using, as shown below.

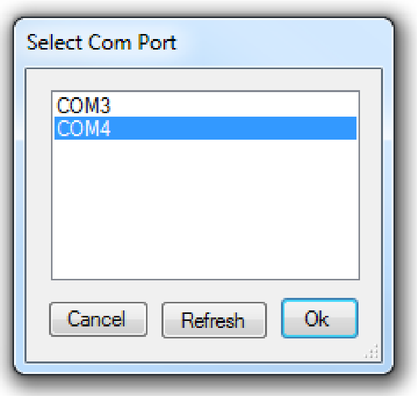


Figure 4: Com port selection

Select the desired COM port. If you are unsure which COM port is assigned to your PCB, you can unplug the USB cable and click "Refresh" which will remove the port assigned to your board from the list. You can then re-connect the USB cable and when you click refresh the correct port will return to the list.

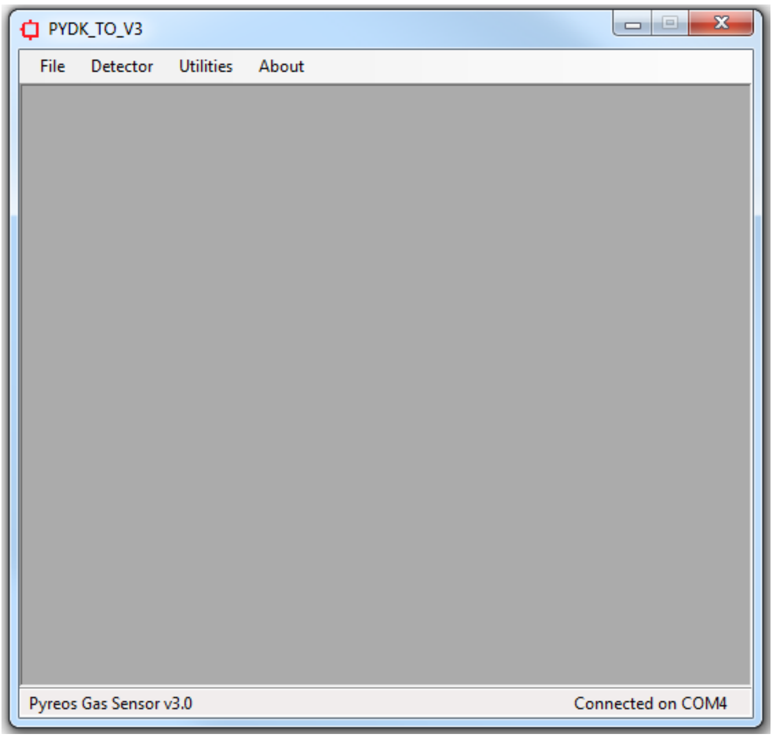


Figure 5: Main application window

If the data capture board is connected to the required com port, the status bar at the bottom of the main display will show the message "Connected on COMXX" on the right side, and the left will show the data capture board firmware version.

If the program fails to make a connection to the data capture board, an error message is displayed and the screen returns to its initial window (Figure 2). Check the USB and power connection and try to connect again.

4.2.1 Auto reconnect facility

If you operate the kit in an environment where there is electrical interference, you may find the PCB loses its data connection. If this happens, the software will display a message stating that it is trying to reconnect to the board and it will attempt to reconnect for up to 30 seconds. This feature is selected by default after initial connection however it can be disabled by unchecking the "Auto Reconnect" option in the "Detector" section of the menu bar.

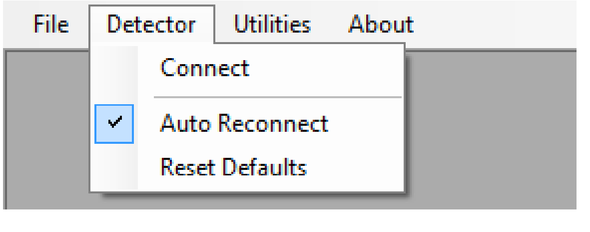


Figure 6: Detector section of menu bar

4.3 Data capture board control

Status and ADC settings in use can be accessed by selecting the “Data Capture Board Control” option in the “Utilities” section of the menu bar, as seen below. This feature is only enabled when the software is successfully connected to the PCB.

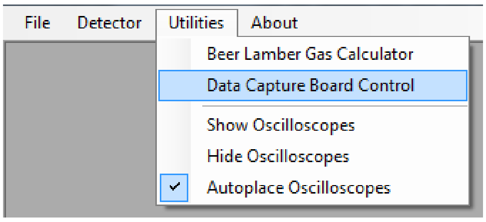


Figure 7: Finding the ADC settings

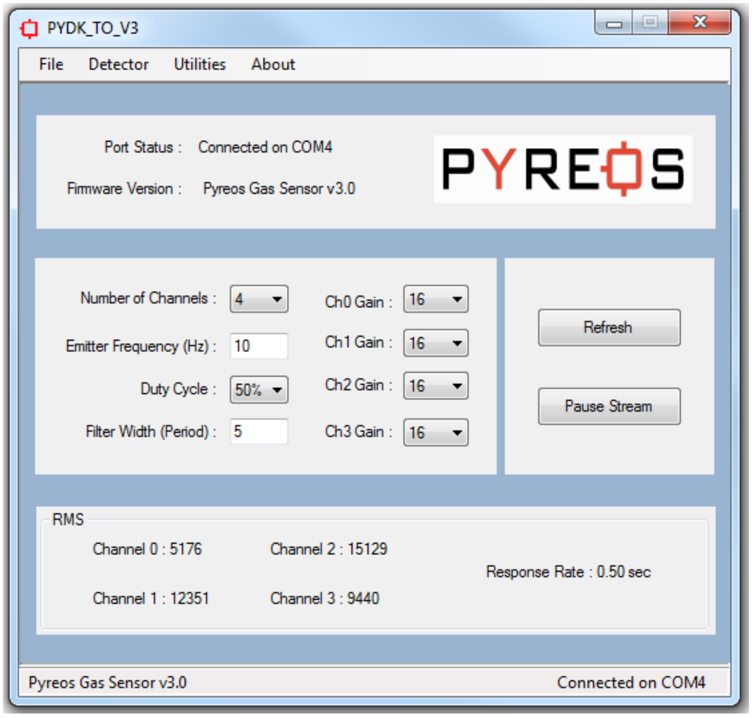


Figure 8: Data capture board control window

The current settings used on the data capture board are displayed and the root mean square (RMS) values update at a rate depending on filter width and emitter frequency.

If there is any doubt about the settings displayed matching the board, there is a refresh button which checks and updates all values in the application window.

There is also the option to pause the stream of data. *Note that this only stops the PC reading the stream and does not stop the actual data capture boards.*

4.3.1 Data capture settings

It is possible to change some of the settings on the data capture board and also the filter calculations through the interface. Settings from the drop down lists are sent to the data capture board immediately. Settings in the frequency and filter width boxes are sent to the data capture board when enter is pressed or moving to a different control in the software (Provided the value is valid). If the value is invalid or out of range, an error message is displayed and the text box is cleared.

The settings the user has access to (shown in Figure 8) are described below:

1. **Number of channels:** The board is capable of sampling inputs from up to 4 different channels. The drop down list allows the user to select the number of channels required. The higher the number of channels selected, the lower the frame rate will be.
2. **Gain:** The C8051F350 chip provides a programmable gain amplifier making it possible to select a gain for each channel independently from 1 to 128 times.
3. **Emitter frequency:** The frequency with which the board pulses the IR emitter can be set between 2Hz and 30Hz.
4. **Duty cycle:** This can be set with two options, either 25% or 50% duty cycle.
5. **Filter width:** The filter width of the RMS can be increased by a number of periods from 1 up to 1000. Anything out of this range will be flagged as out of range. Higher values result in lower noise, but slower response time and vice versa.

4.3.2 RMS values

This section displays the RMS (root mean square) output of each sensor channel calculated to the specified filter widths.

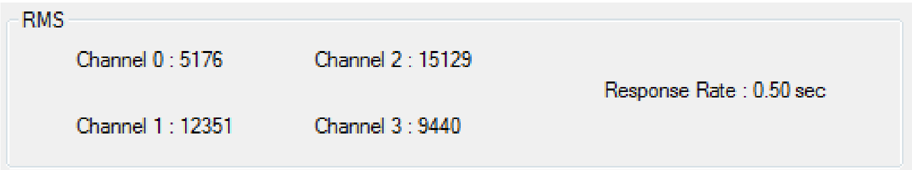


Figure 9: RMS result section

The values are updated when the calculations are complete for each set of data, with a rate that should match the displayed response rate. The response rate is determined by the filter width over the emitter frequency and is displayed in seconds. Inactive channels simply show a value of 0.

4.4 Modified Beer Lambert gas calculator

The gas calculator can be accessed under the “Utilities” section in the menu bar, as shown below:

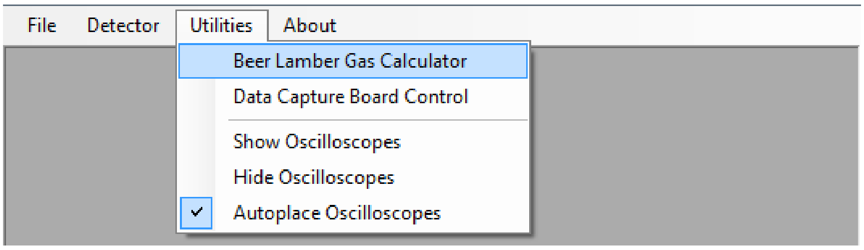


Figure 10: Utilities menu option – beer lambert gas calculator

The main gas calculator window displays the live data, settings and a window to store measurements, which can be stored in a CSV file.

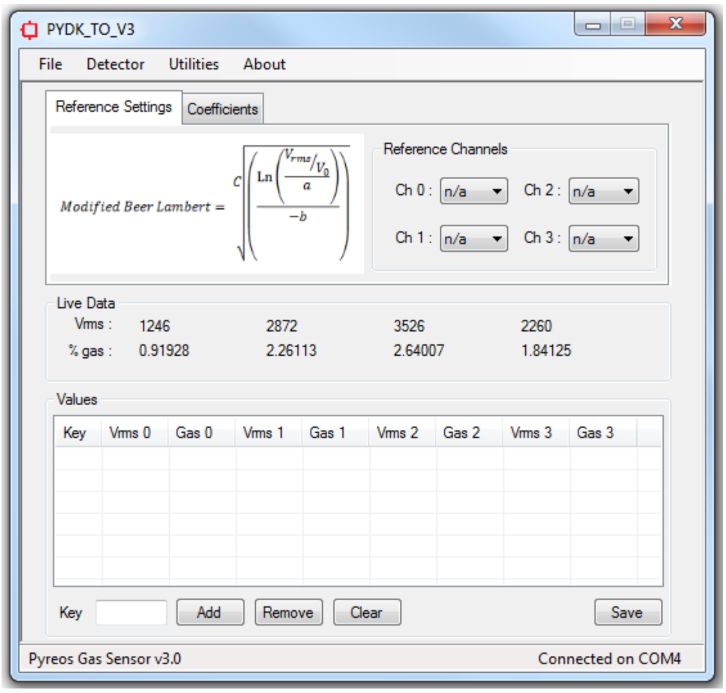


Figure 11: Modified Beer Lambert main window

The live data shows the Vrms and percentage of gas present for each channel. The gas percentage is calculated using a modified version of the Beer Lambert equation shown below:

$$Gas\ concentration = \sqrt[c]{\left(\frac{\mathrm{Ln}\left(\frac{V_{rms}/V_0}{a}\right)}{-b}\right)}$$

Where a, b and c are constants for this system and Vo the measurement with no gas present.

These values are stored on the data capture board during the calibration of the system and are loaded when the software connects to the data capture board.

Vrms can be calculated either from a single channel or from both a gas and reference channel. Each channel can use any other channel as a reference, but care must be taken that the same options are used as when the system was calibrated, otherwise the constants won't be applicable.

When using a reference channel the Vrms is the Vgas over the Vref:

$$Vrms = \frac{Vgas}{Vref}$$

By default no reference channel is used, but this can be changed in the "Reference Settings" tab:

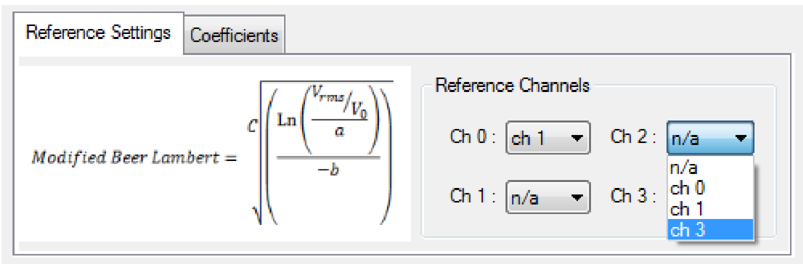


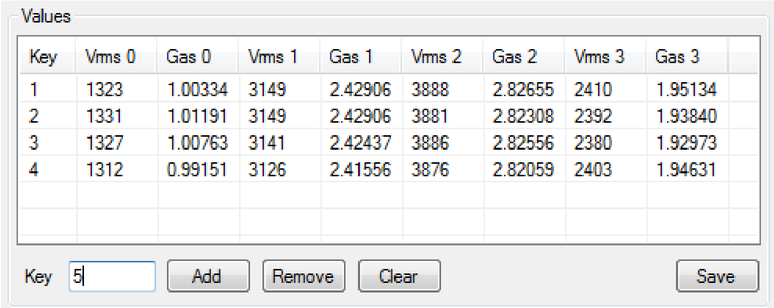
Figure 12: Channel reference settings

When the reference of a channel changes this is applied immediately, so the next update of the percentage of gas present will be with this taken into account.

Please note that if the response time of the system is large, then there might be a delay until the live data updates and shows the correct gas percentage. If the response time is over 5 seconds a warning will be displayed reminding the user of this delay.

4.4.1 Saving data

It is possible to store a number of measurements by adding them to the table in the Values section. These measurements can be added with a key (usually gas concentration in %). The user may remove any entries that are not required, by highlighting the desired row and pressing the delete key.



Values

Key	Vrms 0	Gas 0	Vrms 1	Gas 1	Vrms 2	Gas 2	Vrms 3	Gas 3
1	1323	1.00334	3149	2.42906	3888	2.82655	2410	1.95134
2	1331	1.01191	3149	2.42906	3881	2.82308	2392	1.93840
3	1327	1.00763	3141	2.42437	3886	2.82556	2380	1.92973
4	1312	0.99151	3126	2.41556	3876	2.82059	2403	1.94631

Figure 13: Measurement storage

Once all measurements required are gathered, they can be stored into a CSV file for analysis in Matlab, Excel, etc. by clicking on the "Save" button and selecting the desired file path and name.

4.4.2 Calibration

The constants can be entered by the user under the "Coefficients" section and are specified per channel. Alternatively they can be calculated by calibrating the sensor using predetermined gas mixtures.

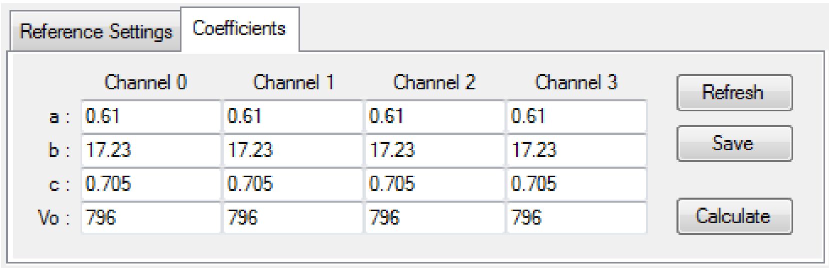


Figure 14: Coefficients section

When the new values are entered, they won't take effect until the save button is clicked. This also writes the values to the data capture boards' memory.

Selecting the "Calculate" button opens the Calibration window:

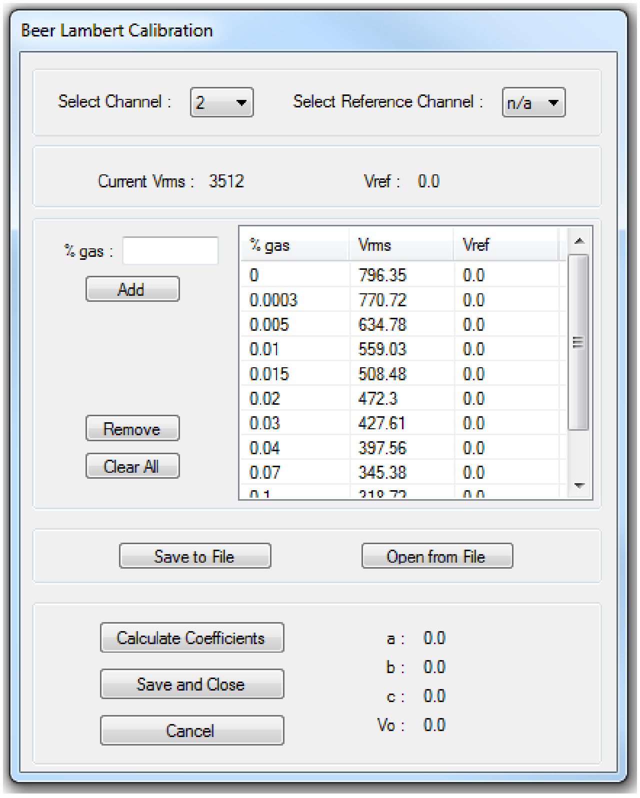


Figure 15: Calibration window

To calibrate the sensor and find the required coefficients the following steps should be followed:

i) Select the correct channel and, if required, select a reference channel.

ii) Take a number of measurements with premixed known gas mixes, entering the known gas percentage in the "% gas" field.
Measurements **must** be taken using a 0% and 100% gas mix for the calibration to work and at least 10 measurements must be taken

iii) Once all measurements have been completed click on the "Calculate Coefficients" button. This can take a few seconds to complete.

iv) The resulting values are displayed and can be saved to the main Beer Lambert window and data capture board by clicking on "Save and Close".

v) There is also the option to save the measurements taken and the calculated coefficients to a CSV file or to open and load up a previously saved CSV file.

Please note that is if the response time is slow, then care must be taken to ensure the measurement is valid for the gas present.

If there is no 0% or 100% gas measurement, an error message will be displayed and the coefficient calculation will be aborted.

4.5 Viewing live data – Oscilloscope window

While the software is connected to a data capture board, it is possible to view the data sampled in real time. Virtual oscilloscopes are provided for each channel and can be shown or hidden by selecting “Show Oscilloscopes” or “Hide Oscilloscopes” respectively from the “Utilities” option in the menu bar.

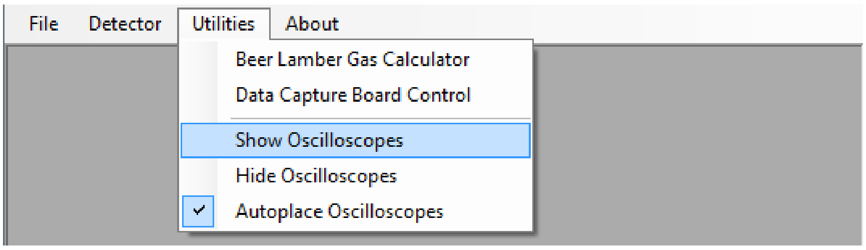


Figure 16: Utilities options

The oscilloscope window has several features which emulate a basic oscilloscope for viewing live sampled data. It can be adjusted to display the desired range on both the y-axis (amplitude) and the x-axis (time domain).

The number of oscilloscope windows displayed is equivalent to the number of channels selected and will change every time the number of active channels changes.

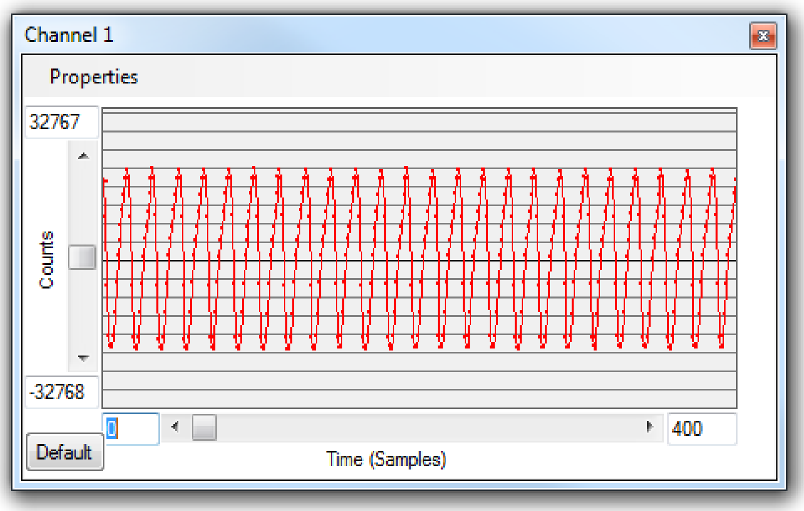


Figure 17: Oscilloscope window

The oscilloscope value display range can be adjusted by two different methods:

a. By entering the maximum and minimum values in the text box at the end of each axis.

   When entering the values the colour of the box will change to signify that the value in the box is not currently being used for the display. After setting the text value to the desired number, press enter 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.

b. By using the mouse

   - The scroll bars along both axes can be used to move the display position and to zoom in or out.
     - Zooming in or out is achieved by positioning the mouse over the scroll bar (horizontal or vertical) and scrolling the mouse wheel.
     - Moving the position is achieved by moving the scrollbar position.
   - The viewing offset can also be adjusted in both x and y directions by holding down the right mouse button when over the viewing area and dragging the mouse (up, down, left or right).

The properties option allows the user to enable or disable the horizontal grid lines and also set the spacing in A-D counts.

By default the oscilloscope windows are positioned around the main window, and keep their relative position when the main window moves. This can be disabled by deselecting the “Autoplace Oscilloscopes” option in the Utilities section of the menu bar, allowing the user to place the windows where they prefer.

4.6 Saving data to CSV (comma separated value) file

From the file menu on the main screen it is possible to save the captured data to Comma Separated Value files, for analysis in Matlab, Excel, etc. After selecting “Save to CSV” a pop up window “capture settings dialogue” will appear requesting information about how long the software should save data for.

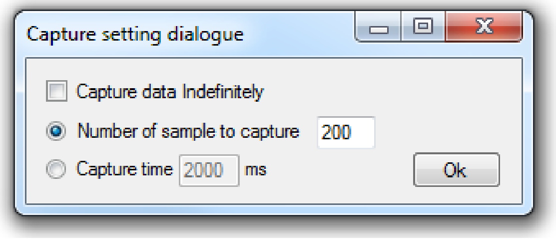


Figure 15: Save to CSV capture settings

It is possible to choose:

- To capture data indefinitely; which will capture data until the software is instructed to stop, or the PC runs out of disk space.
- To specify the number of samples which the PC should capture data for.
- To specify the time period over which the software will capture samples.

After selecting this click "OK" and a "save as" dialogue window will appear requesting a file name be chosen.

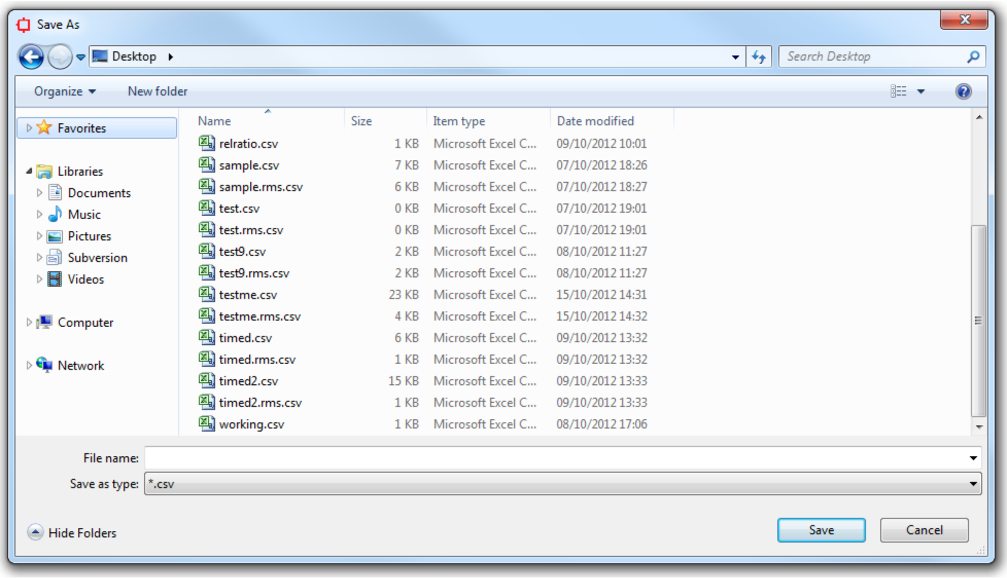


Figure 19: Save to CSV window

After choosing a file name and selecting "Save" the software will automatically create two files in the location with the name you specified. The first will contain the raw sampled data and the second (which will have ".rms" added to the end of the file name) will contain the RMS data as calculated by the Pyreos software.

The software will also update its display on the status bar to show that it is capturing data to a file.

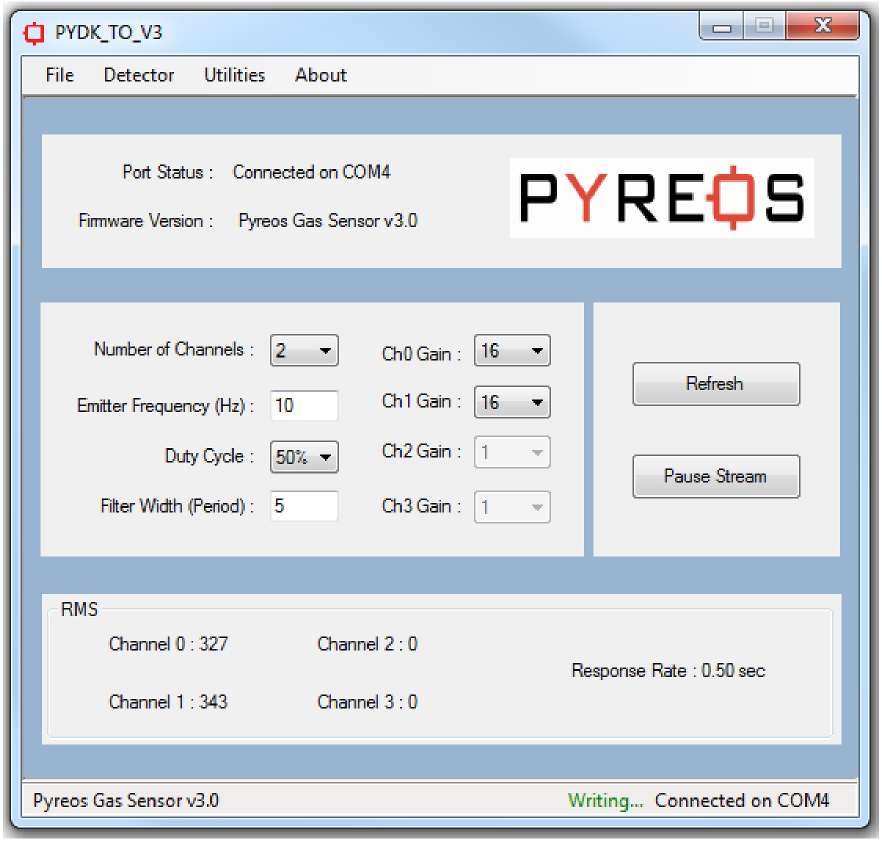


Figure 20: Saving data to CSV file in process

At any time while the software is capturing data to a file it is possible to stop the data capture by selecting "Stop Capture" from the file menu.

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5 PC to PCB communications

- Communications with the PCB are via a CP2102 USB to UART adapter, fitted to the Pyreos PCB.
- UART settings: Baud 115200, 8 data bits, no parity, 1 stop bit, no handshaking
- All responses from the PCB are terminated with "\n"
- All commands sent to the PCB are single bytes
- It's important to wait for the PCB response after sending each command as writing another byte too soon may overwrite the previous command resulting in an error. If no response is received within 1s, then the command has not reached the PCB and should be resent
- If the board requests a value it is the binary value required (e.g. setting number of channels use ASCII (4)= "♦").

5.1 Commands description

Command Character Code	Description	Response
0	Null command	"ok"
1	Get product details	"Pyreos PYDK-TO data capture V2.0"
2	Set number of channels	"Send number of channels (1,2 or 4 accepted)" "ok" or "Error setting not accepted"
3	Set Gain	"Send channel number (1,2,3 or 4 accepted)" "Send gain setting (1,2,4,8,16,32,64,128 accepted)" or "Error setting not accepted" "ok" or "Error setting not accepted"
4	Set emitter frequency	"Send Frequency (2 to 30 accepted)" "ok" or "Error setting not accepted"
5	Get MS[1] CH1	"12345"
6	Get MS[1] CH2	"12345" or "Channel not active"
7	Get MS[1] CH3	"12345" or "Channel not active"
8	Get MS[1] CH4	"12345" or "Channel not active"
9	Start streaming raw data	"ok" then the kit will stream binary data values
10	Set RMS filter width	"Send filter width (1-254 accepted)" "ok" or "Error setting not accepted"
11	Set duty cycle	"Send duty cycle, 2=50%, 4=25%" "ok" or "Error setting not accepted"
12	Get settings	"No channels = x, Gain 1 = x, Gain 2 =x, Gain 3 = x, Gain 4 =x, RMS filter width = x, Duty cycle = x%"
13	Reset defaults	"System reset to default"
255	Stop streaming data	"ok"

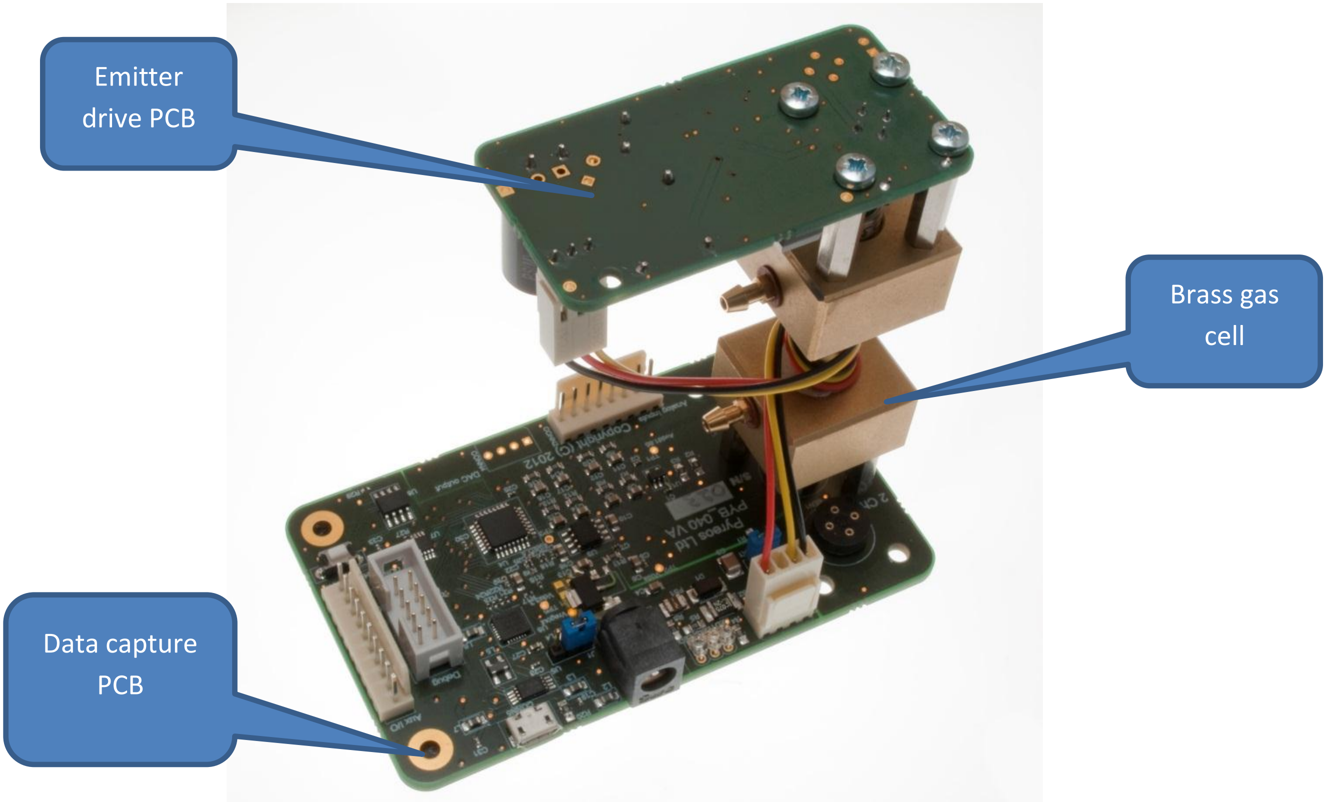
[1]MS = (Mean Squares) The square of the measured AC RMS sensor output, the unit is ADC counts and is linearly proportional to the output in V.

If the MS is to be used for Beer-Lambert calculations it is necessary to first take the square root of the MS.

e.g. Result = √ (Get_MS_CHx)

6 Hardware

Pyreos demo kit consists of three different components; data acquisition PCB, an emitter drive PCB and an unsealed gas cell.



6.1 Gas cell

The gas cell is made from a Brass tube with gas inlet/ outlet nozzles and fixing holes added. This is a simple gas cell construction and is suitable for sensor evaluation. Pyreos does **not** seal the cells. Customers wishing to test toxic or flammable gasses must take suitable precautions to ensure safe operation.

6.2 Data capture PCB

6.2.1 PCB drawing

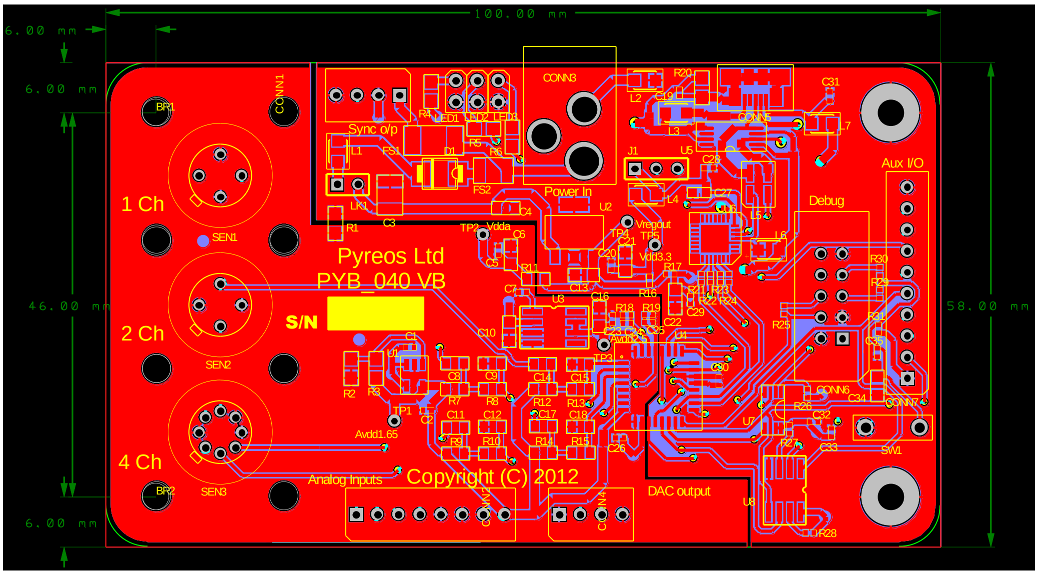


Figure 16: Sensor readout PCB

6.2.2 Connector & Jumper descriptions

Connector number	Name	Description
CONN1	Sync o/p	4 pin header providing, Supply voltage, 3.3V regulated power, ground and a square wave pulsed output for emitter synchronisation.
CONN2	Analogue inputs	8 pin header with all connections to power and sample from Pyreos sensors up to 4 channels
CONN3	Power input	2.1mm power connector: requires, 9V-26V, DC, centre positive
CONN4	DAC output	Connector not used
CONN5	Micro USB	Connection for micro USB cable to PC (same cable as many mobile phones, e.g. blackberry)
CONN6	Debug connector	C8051F350 programming and debug connector. *Reprogramming void's warrantee*
CONN7	Aux I/O	Connector Not used
J1	Microcontroller power source	Default connect pin's 1-2 (powered from power supply) Non-standard pins 2-3 (microcontroller powered from usb)

6.2.3 Schematic

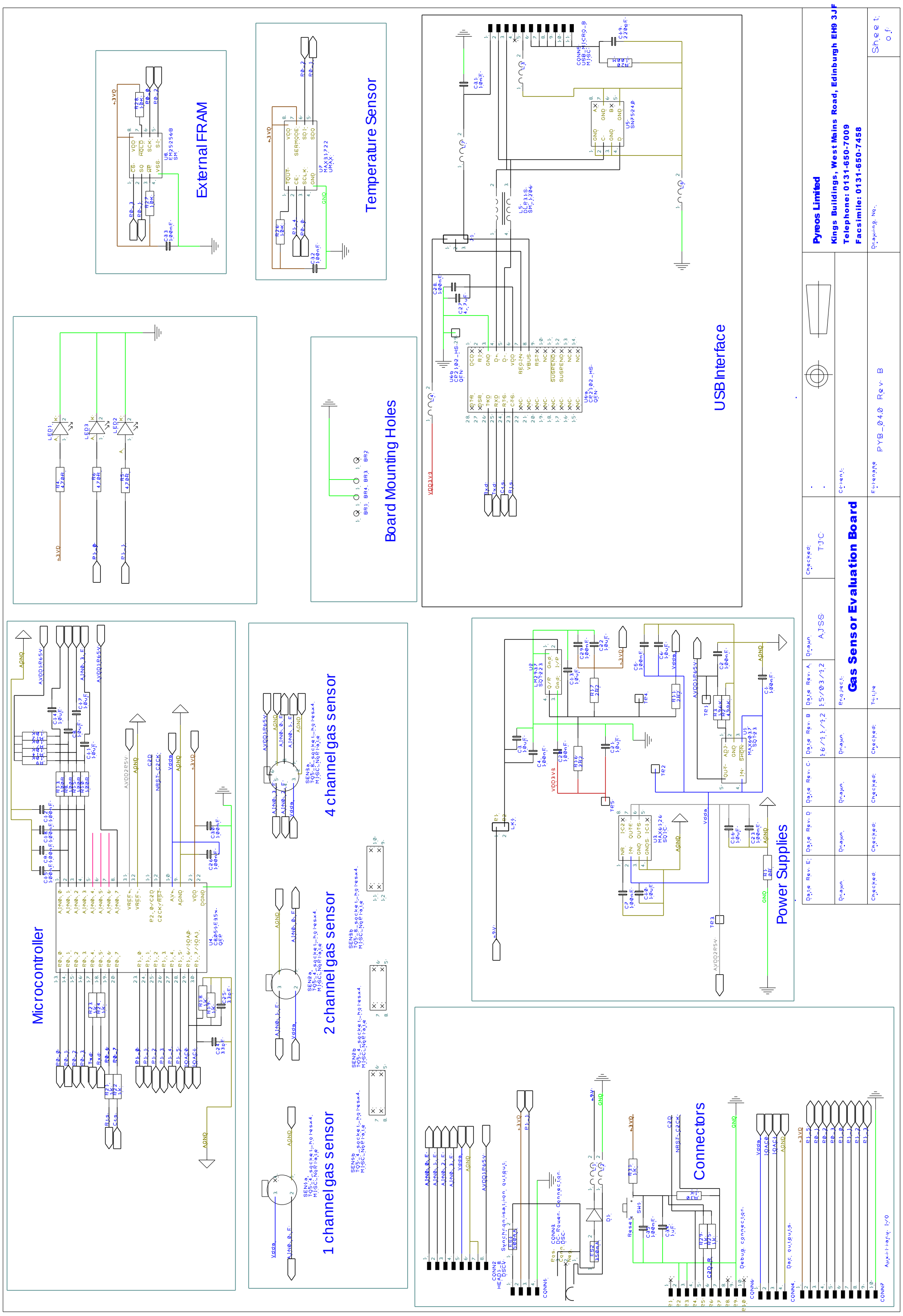
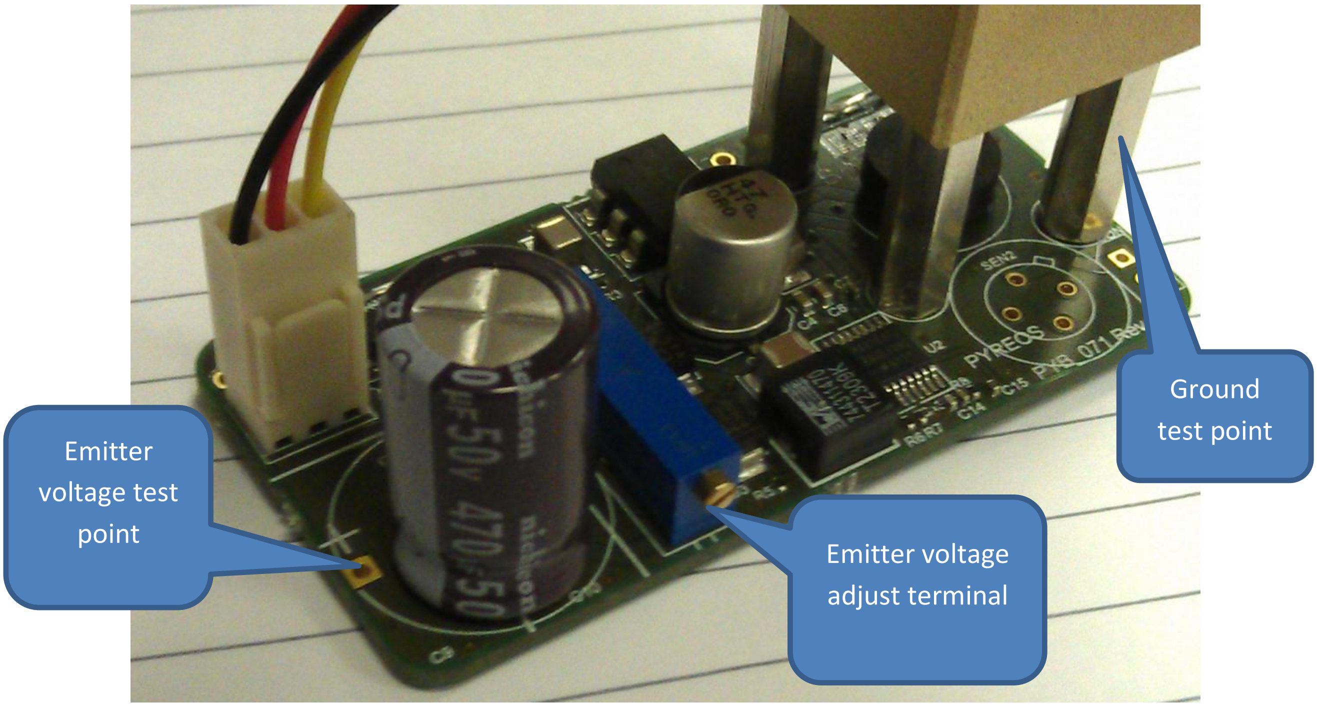


Figure 17: Sensor readout PCB schematic

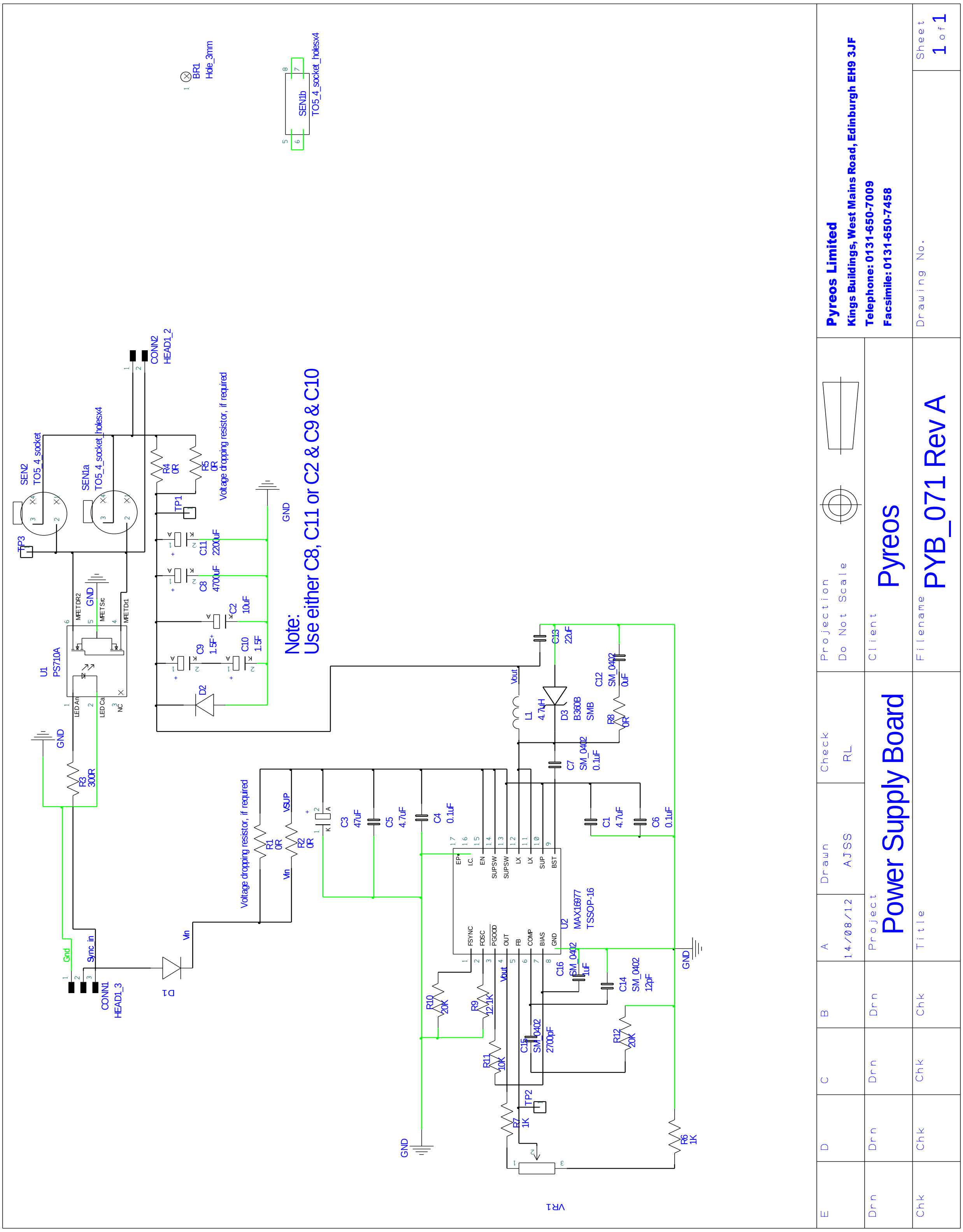
6.3 Emitter drive PCB

Your kit includes a variable voltage emitter drive PCB. It is important to set the correct emitter drive voltage for your chosen emitter and this varies between emitter types. Details of the correct voltage can be found in the emitter datasheet.

6.3.1 PCB image



6.3.2 Schematic



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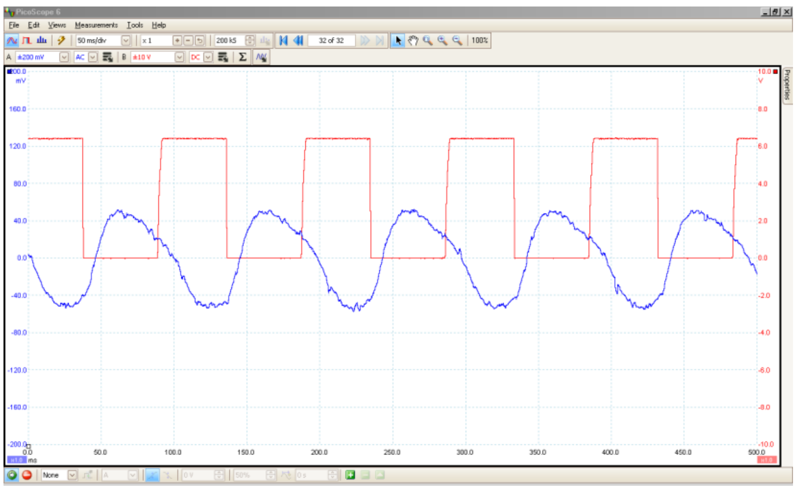
7 Sampling and signal processing for Pyreos TO sensors

Pyreos unique thin film pyroelectric sensors have better response at higher modulation frequencies than many existing competitor sensors. This higher frequency performance has the benefit of reducing the impact of pink (1/F) noise that can plague both sensors and electronics at the low frequencies often used in infrared applications. Good system engineers will be aware that pink noise may be the dominant noise source when operating at below ~4Hz. This is in stark contrast to most electronics applications where signals in excess of 1 KHz are examined, and pink noise is less significant. For many applications, including NDIR gas sensing and IR spectroscopy, by operating Pyreos sensors at higher modulation frequencies the pink noise can be further suppressed, improving the signal to noise ratio. Pyreos sensors can outperform competitors sensors in the 1-4 Hz operational range in a circuit optimized for Pyreos.

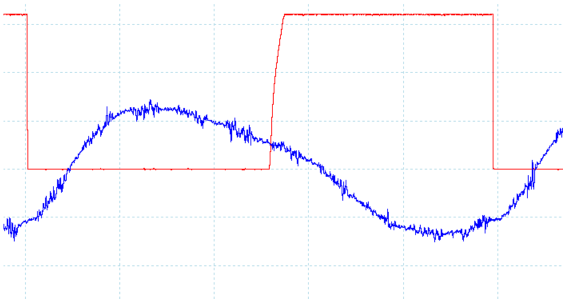
Pyreos ITV sensor products provide customers with a combination of class leading S/N and unparalleled temperature stability, as well as excellent part to part uniformity. These advantages are brought about by the combination of Pyreos' advanced MEMs based thin film device structure with a low noise transimpedance amplifier, which includes a 31Hz first order low pass filter.

To maximize the competitive advantage offered by our product it is recommended that sampling and filtering regimes are modified in accordance with the following diagrams.

The figure below shows a typical waveform from Pyreos TO sensors when illuminated with a 10Hz emitter pulsed with a square wave.

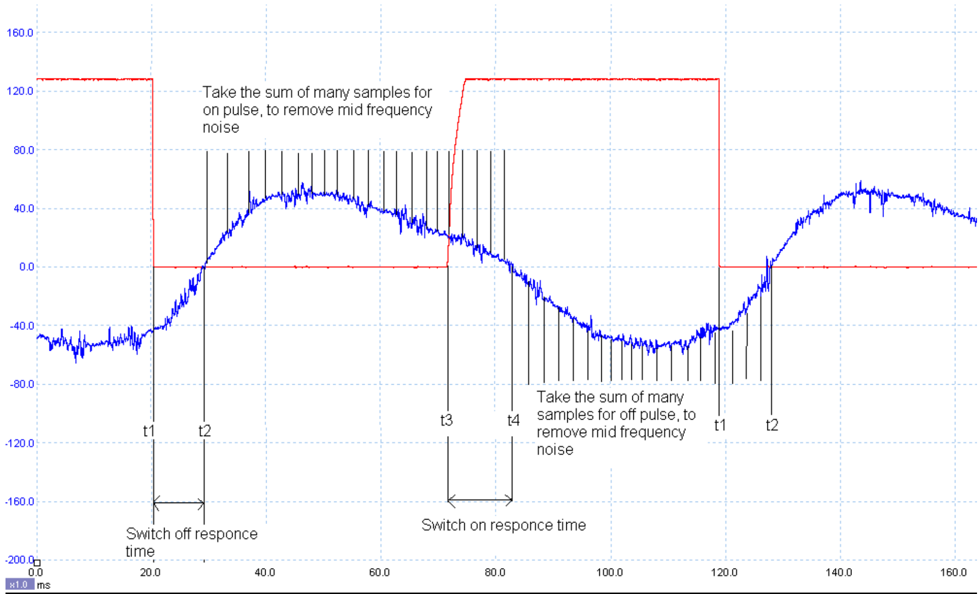


There are two points to note about the signal shown above, as highlighted by the figure overleaf in more detail:



1. There is mid frequency noise present in the signal
   (This noise can easily be removed by oversampling)
2. Even at 10Hz the waveform is not completely sinusoidal, demonstrating the higher speed performance of Pyreos sensors

The diagram below illustrates how to sample the above waveform so as to minimize noise present in the signal:



1. For each different NDIR design the timings for switch on (t2-t1) and switch off (t4-t3) time will have to be measured, as they are more correlated to emitter design than Pyreos sensors.

The signal size = Sum

(on samples) –S

