



Analog TO
CO₂ Gas Sensing Evaluation Kit
USEQGCK5000000

User Guide
Rev. 4.2

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1 INTRODUCTION

This document describes a demonstrator kit that enables simple and efficient data visualisation and capture from KEMET TO-39 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 the users to carry out a simple and effective demonstration of KEMET two channel CO₂ sensor, as well as to provide a flexible platform to start evaluation and design work with all KEMET TO-39 packaged gas sensors. The software includes facilities to capture measured data and visualise and record it on a Windows PC. The kit is based on the Silicon Labs C8051F350 microcontroller with a high precision A-D converter and programmable gain amplifier. It is capable of sample rates up to 333 Hz when sampling from a single channel (allows for up to 4 multiplexed signals and ¼ the sample rate).



Figure 1 – TO CO₂ Gas Sensing Evaluation Kit USEQGCK5000000

2 GETTING STARTED

2.1 Kit Contents

1. KEMET PCB with C8051F350 microcontroller and ADC
2. USEQGDAC82L00 dual channel CO₂ sensor
3. Emitter driver PCB, with KEMET TO-39 IR emitter, reflector and sapphire window
4. Brass gas cell (**not gas sealed, please consider safety if used with toxic gases**)
5. 9V DC power supply
6. Micro USB cable
7. USB drive with software and documentation

2.2 Minimum System Requirements

1. Microsoft Windows PC (all versions supported currently)
2. 2 GB of RAM
3. 450 MB of available hard-disk space for installation, additional free space required for storing CSV files
4. 1024x768 display (1280x1024 recommended)
5. Local administrative rights to install device drivers
6. Microsoft .NET Framework 4.5 (can be installed during setup procedure)
7. 1 free USB port

3 INSTALLATION

3.1 Installing the KEMET Gas Sensing Evaluation Tool Software

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

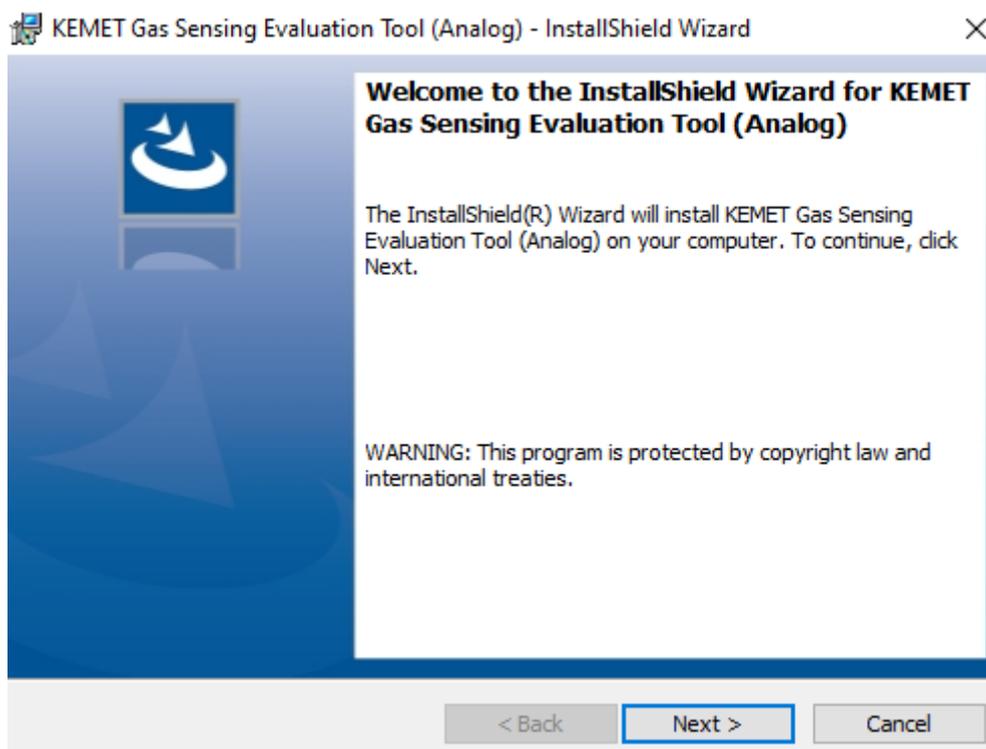


Figure 2 – Installer Screen

Follow the on screen instructions and enter the information required.

As part of the installation process a check will take place to see if .NET Framework 4.5 is present. If not, it can be installed as part of the setup routine or alternatively the setup routine can be cancelled and the .NET framework 4.5 can be downloaded from Microsoft’s website. The framework can take a while to install but the software requires it.

3.2 Connecting the TO Gas Sensing Evaluation Kit

1. Connect the power supply provided to the KEMET PCB
2. Connect the USB cable to the kit and Windows PC
 - a. You may see a message suggesting you are required to install a device driver. Follow the on-screen instructions and download a driver from Windows Update.

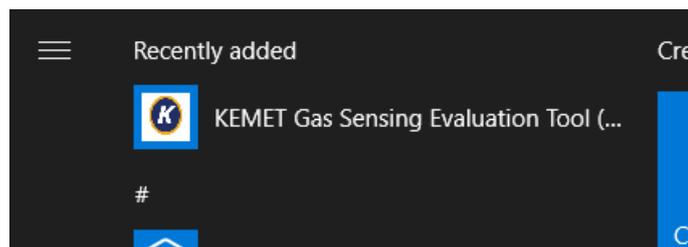
Your kit is now installed and ready to use.

4 SOFTWARE USER GUIDE

The KEMET Gas Sensing Evaluation Tool Data Capture software runs on Microsoft Windows PCs and communicates with the evaluation kit PCB, which enables easy testing of KEMET TO packaged sensors. The software provides an interface to the analog circuits and A-D (Analog to Digital) converter, which are provided by the Silicon Labs C8051F350. Additional signal processing algorithms to filter and analyze sensor output for NDIR gas sensing are provided.

4.1 Starting the Software

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



This will open up the KEMET sensor data capture main screen as shown below.

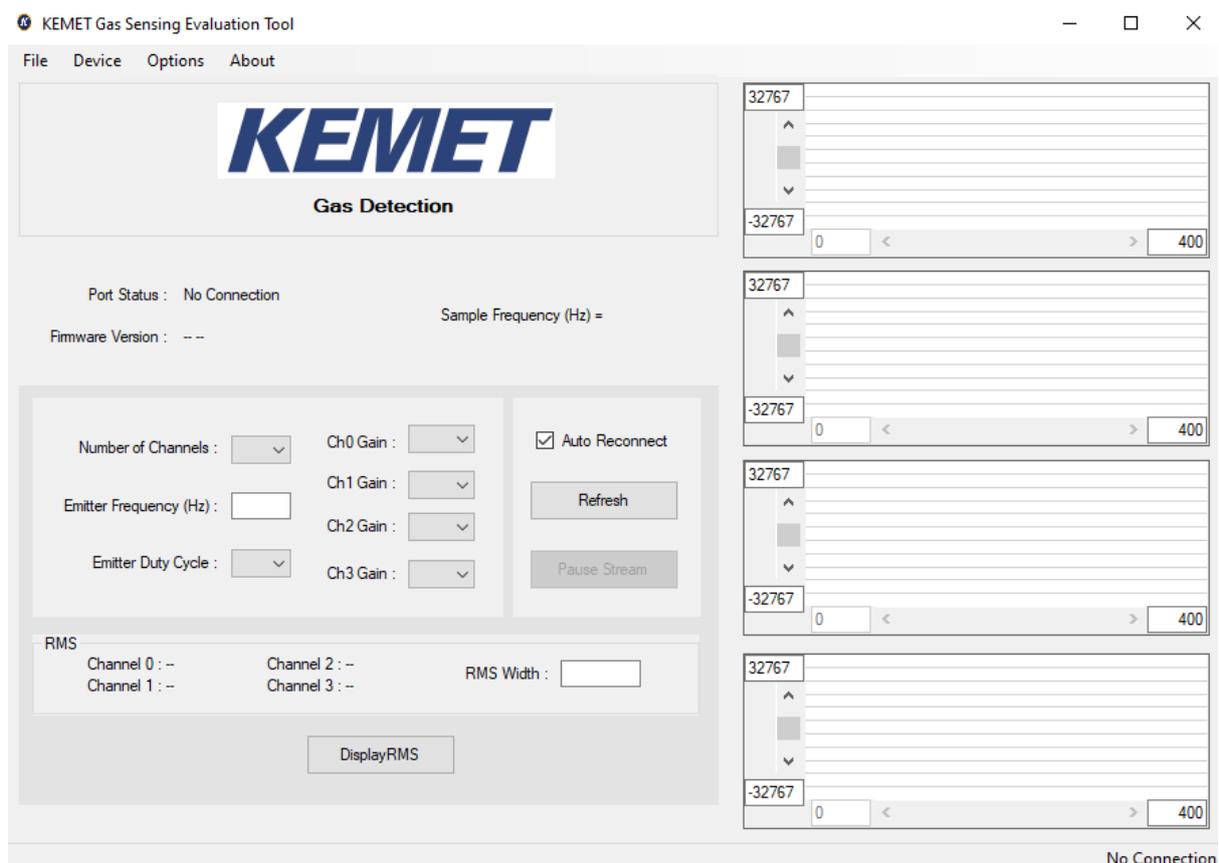


Figure 3 – TO Gas Sensing Evaluation Tool Main Application Window

4.2 Connecting Software to the Data Capture Board

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

From the menu bar select the **Device** option and then **COMXX : Gas Sensor v3.1 VB** as shown below.

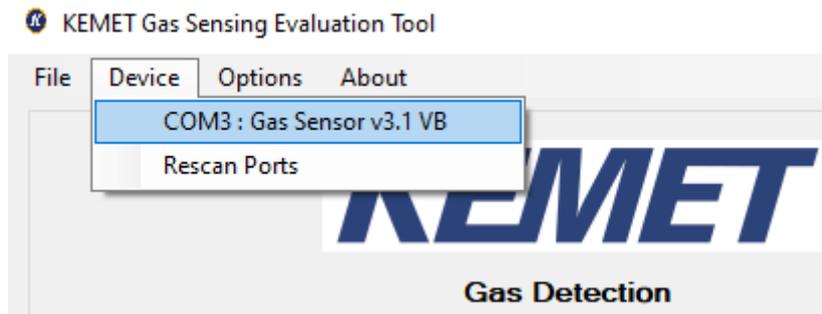


Figure 4 – Detector Connection

If the device does not show up, then click **Rescan Ports**.

Select the device. If the device does not show up, then unplug the USB cable and reconnect then repeat the steps above.

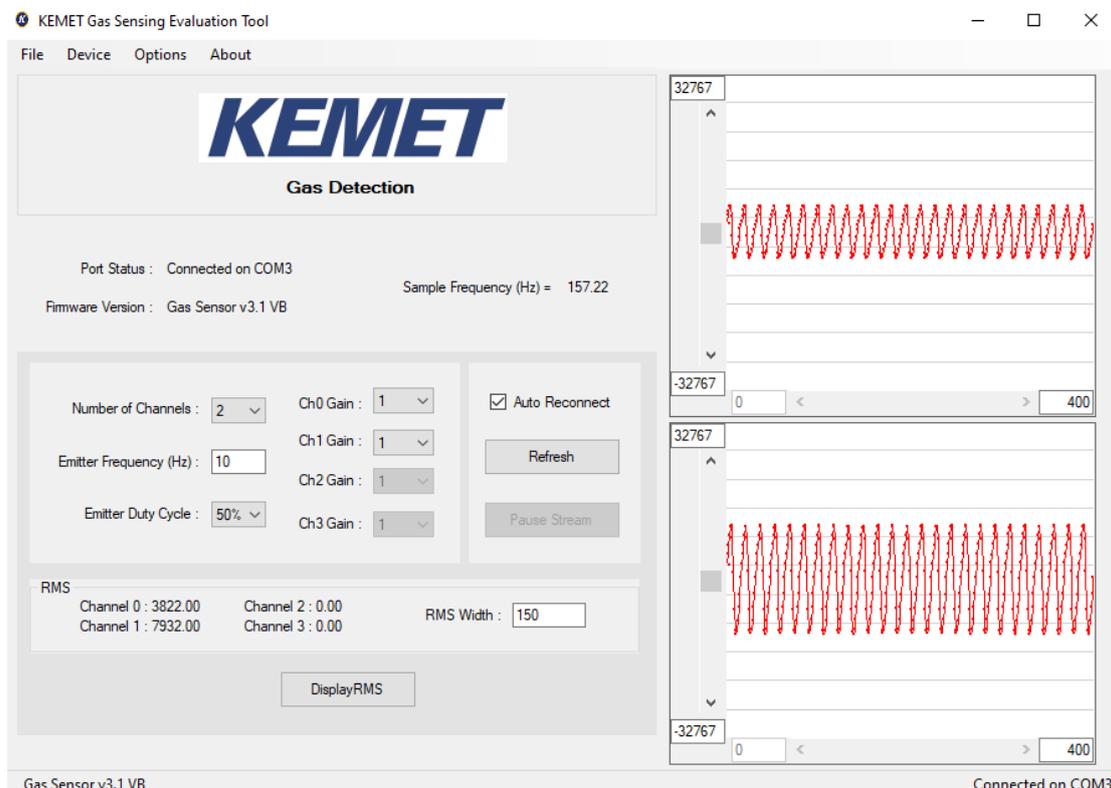
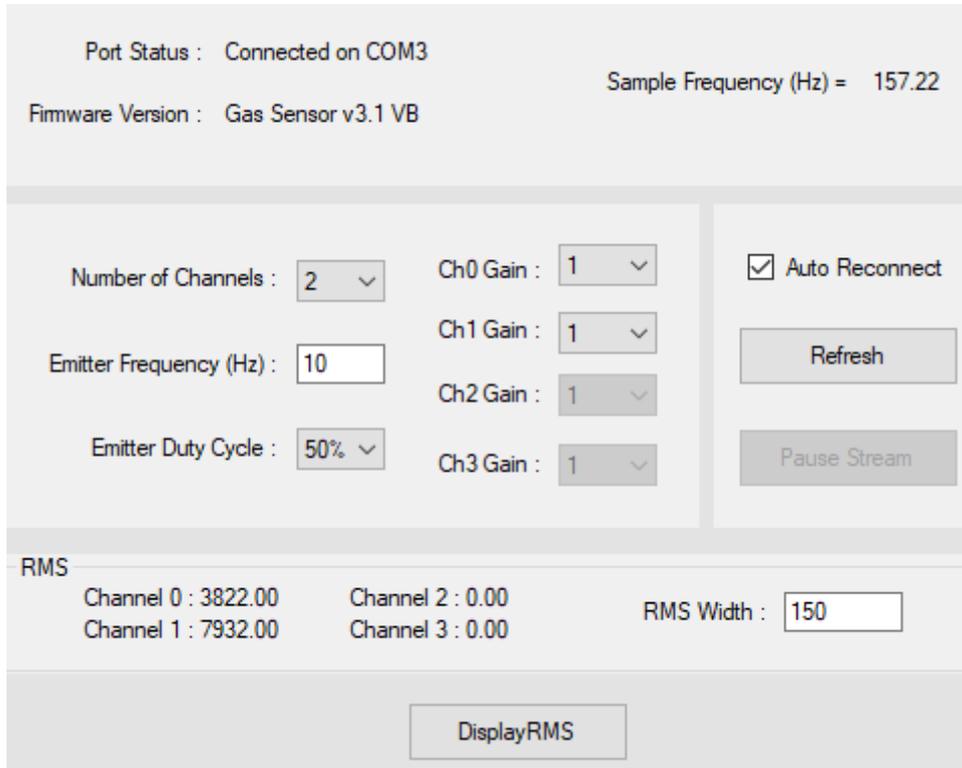


Figure 5 – Main Application Window

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” in the bottom right corner of the window, and the data capture board firmware version will be shown in the bottom left corner, as shown in Figure 5.

4.3 Data Capture Board Control

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.



Port Status : Connected on COM3
 Firmware Version : Gas Sensor v3.1 VB
 Sample Frequency (Hz) = 157.22

Number of Channels : 2
 Emitter Frequency (Hz) : 10
 Emitter Duty Cycle : 50%

Ch0 Gain : 1
 Ch1 Gain : 1
 Ch2 Gain : 1
 Ch3 Gain : 1

Auto Reconnect
 Refresh
 Pause Stream

RMS
 Channel 0 : 3822.00
 Channel 1 : 7932.00
 Channel 2 : 0.00
 Channel 3 : 0.00
 RMS Width : 150

DisplayRMS

Figure 6 – Data Capture Board Control Window

If there is any doubt about the settings displayed matching the board, there is a refresh button which reads back all the settings and updates on 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 data stream.

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. The settings from the drop-down lists update the board immediately once the change takes place and the settings in the boxes update when enter is pressed or leaving to a different control as long as 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 can access are described below:

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.

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.

Emitter Frequency: The frequency with which the board pulses the IR emitter can be set between 2 Hz and 30 Hz.

Emitter Duty Cycle: This can be set with two options, either 25% or 50% duty cycle.

Filter Width: The filter width of the RMS can be increased by a number of periods from 1 up to 1,000. Anything out of this range will be flagged as out of range. The higher values will result in slower response time.

4.3.2 RMS Values

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

RMS		
Channel 0 : 3822.00	Channel 2 : 0.00	RMS Width : <input type="text" value="150"/>
Channel 1 : 7932.00	Channel 3 : 0.00	
<input type="button" value="DisplayRMS"/>		

Figure 7 – 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.

4.3.3 RMS Width Value

In order to choose the best RMS width, the following parameters need to be known about the set-up that you are using.

1. Sample frequency
2. Emitter frequency
3. Number of emitter periods to be used for RMS window

In order to ensure stability of the RMS values, the RMS window should be an integer multiple of the number of samples taken during one emitter period.

First take the sample frequency and emitter frequency and determine the periods of each.

$$\text{Sample period} = \frac{1}{\text{Sample frequency}}$$

$$\text{Emitter period} = \frac{1}{\text{Emitter frequency}}$$

From this the number of samples that should be used for the RMS window is

$$\text{RMS width} = \frac{\text{Emitter period}}{\text{Sample period}} * n$$

for some integer 'n'. This ensures that the RMS is taking one period or a multiple of periods effectively. Taking values of n that are not integers will produce a varying output in terms of RMS due to sampling more or less than one complete waveform, as shown below.

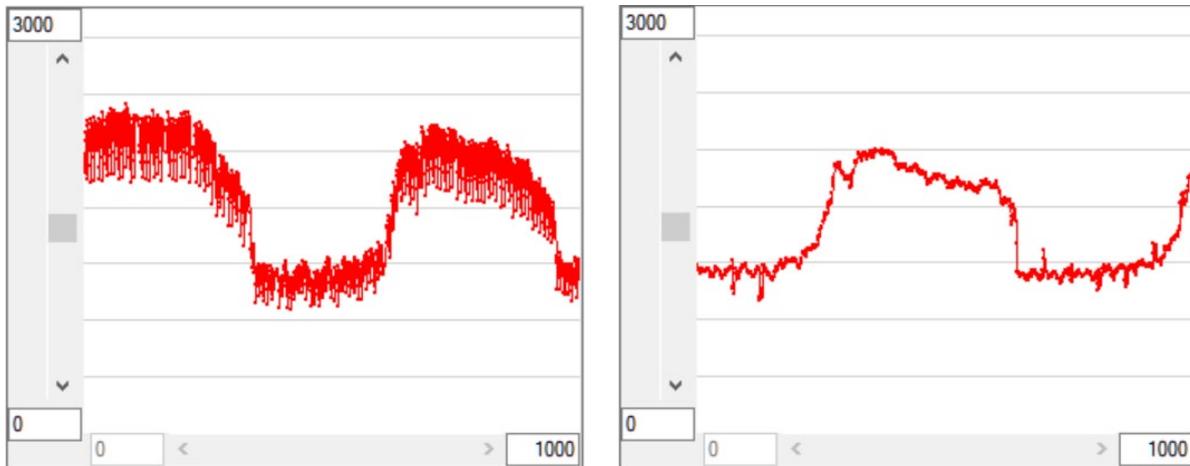


Figure 8 – Standard Deviation of Raw Signal – 10 Hz Emitter Pulsing and 80 Hz Sample Frequency

The above plots show an example of the KEMET Gas Sensing Evaluation Kit when running at a sample frequency of approximately 80 Hz. The right hand side shows the effect of taking the window width to be 8 samples - 10 Hz emitter frequency gives 8 samples per emitter period. If we change this to 7 instead then we are looking at a different part of the waveform each time and it introduces the noise seen on the left plot which is simply an artefact of the data processing.

4.4 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 **Oscilloscope Full View** or **Oscilloscopes Normal View** respectively from **Options** on the menu bar.

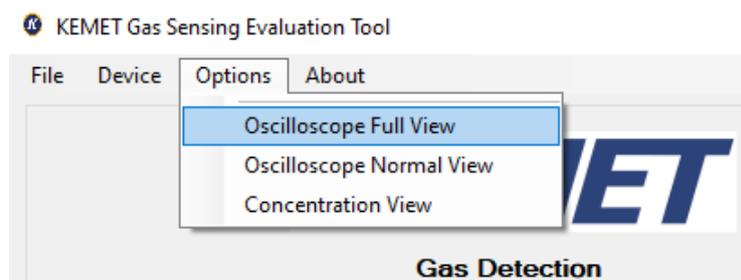


Figure 9 – View Options

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.

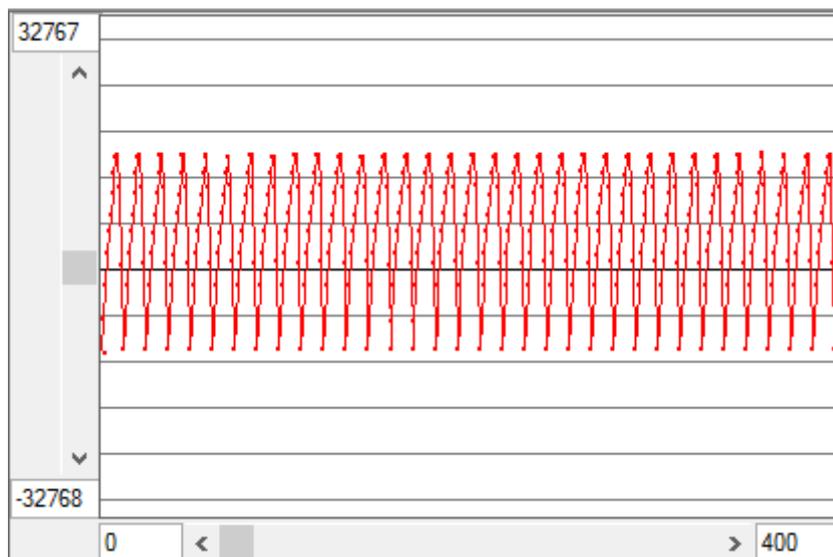


Figure 10 – Oscilloscope Window - Normal View

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

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

When entering the values, the color 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.

2. By using the mouse.
 - The scroll bars along both axes can be used to move the display position and to zoom in or out.
 - Moving the position is achieved by moving the scrollbar position.
 - Scaling is changed by entering a new set of values for the upper and lower limits of the graphing area. Click on the axis value and type the new value, pressing enter causes the change to take effect.
 - 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**, which is accessed by right clicking on the scopes graphing area, allows the user to enable or disable the horizontal grid lines and also set the spacing in A-D counts.

4.5 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 Data to CSV File** will appear requesting information about how long the software should save data for.

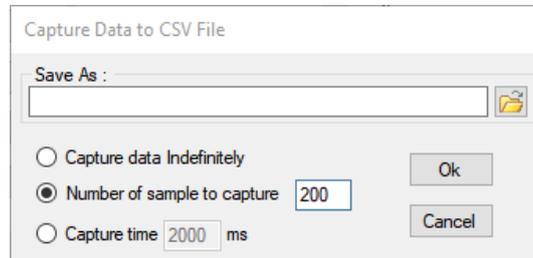


Figure 11 – CSV File Writing Settings

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 the duration of data capture and entering the desired file name to **Save As**.

After choosing a file name and selecting **Ok** 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 KEMET software.

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

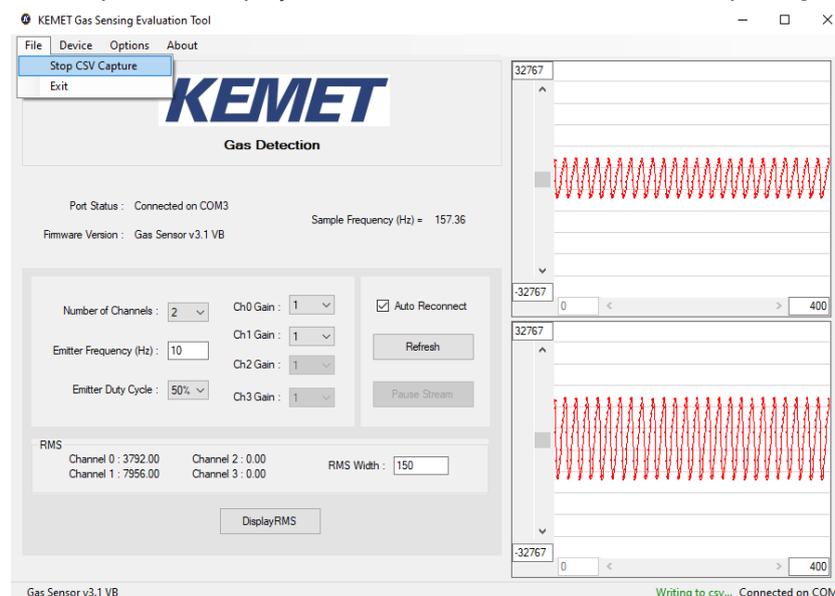


Figure 12 – Saving Data to CSV File in Process

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

5 CONCENTRATION VIEW

The ability to turn the sensor signals into a known concentration of gas is of course the requirement of most gas detection systems. The gas concentration view of the KEMET Gas Sensing Evaluation Tool is available by selecting it from the drop down **Options** menu.

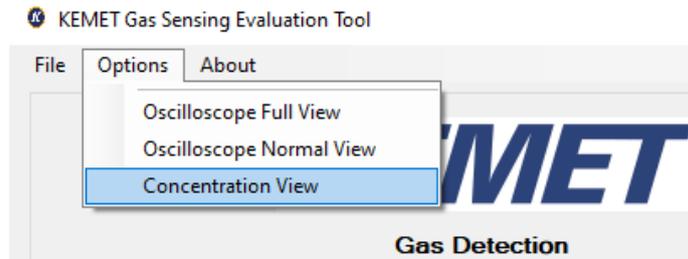


Figure 13 – Options Menu

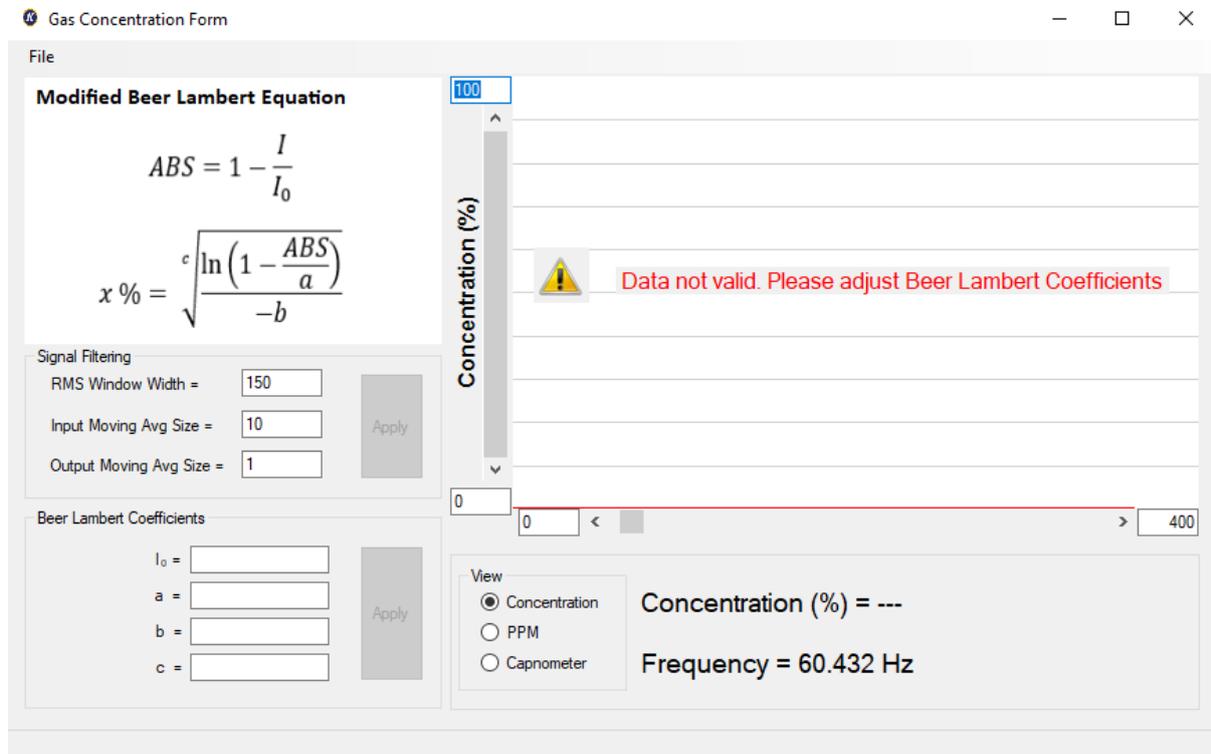


Figure 14 – Gas Concentration View

Once opened the initial output of the concentration form will be nonsensical information as the system has not been calibrated. In order to calibrate the system please determine the coefficients according to the Beer Lambert law.

Once the system has been calibrated then it is possible to save the coefficients of the modified Beer Lambert law by selecting file then **Save Coefficients**.

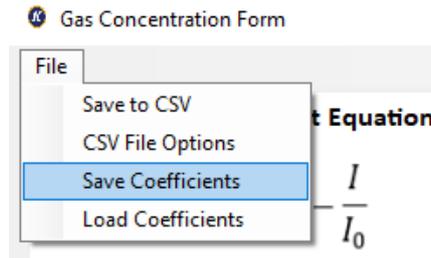


Figure 15 – Save Coefficients

The next time this system is connected to the software the coefficients can be loaded from the file using the **Load Coefficients** option. It is worth mentioning that the same set of coefficients cannot be used for different systems. Each system must be calibrated individually as there are system differences such as sensor responsivity and emitter characteristics that vary from evaluation kit to evaluation kit.

The input to the modified Beer Lambert law equation is the RMS per emitter period. This is chosen for its stability. In order to provide greater stability a larger number of emitter periods can be averaged using the text box and apply button in the signal filtering section.

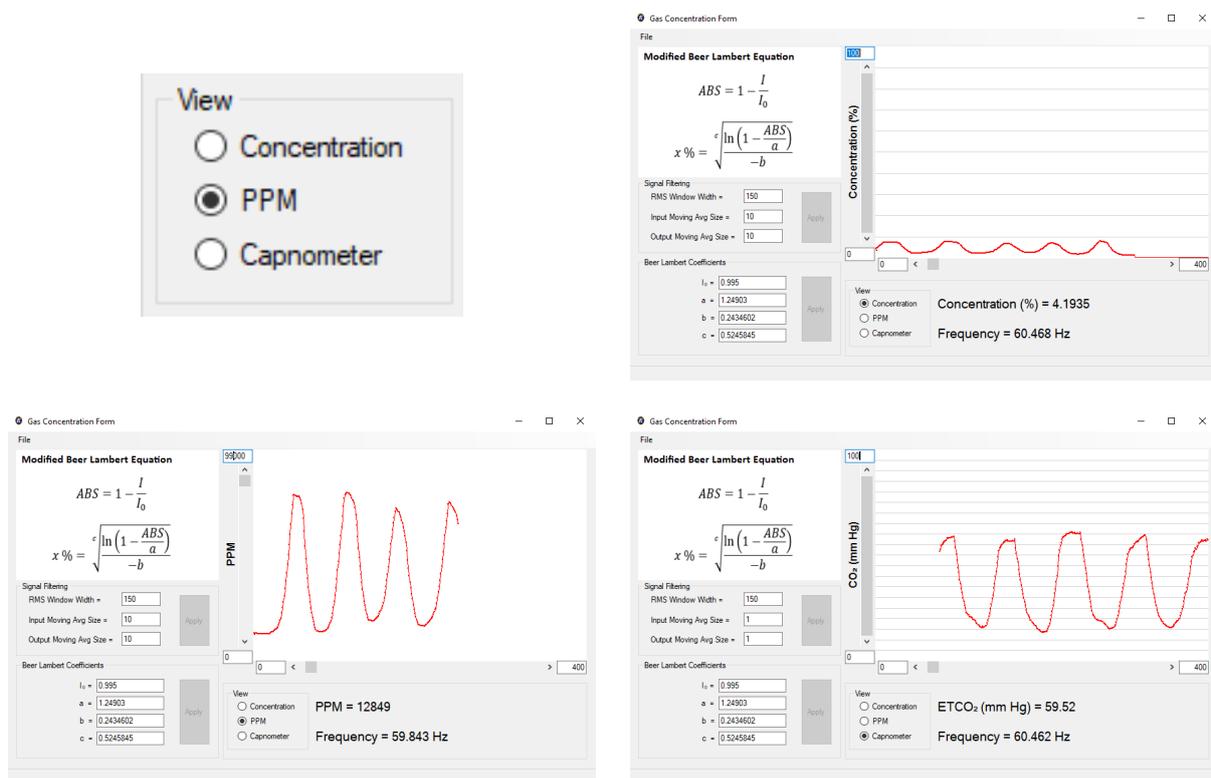


Figure 16 – Gas Concentration Options

There are 3 options for viewing gas concentration, which can be selected in the View panel under the scope.

If the **CSV options** is selected from this view, there is an additional option of saving the concentration values calculated. This must be opened and selected to save concentration data.

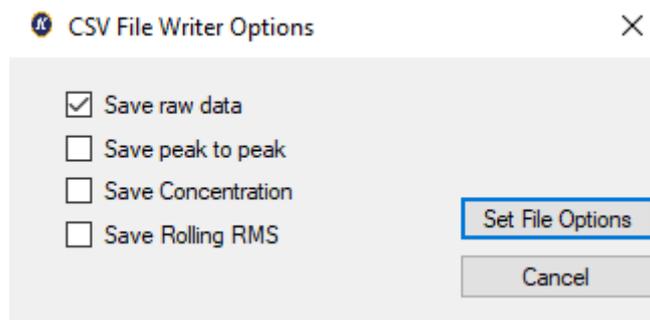


Figure 17 – CSV Options from Concentration View

5.1 Signal Processing

RMS Rolling – Sampling Frequency: This calculates the RMS for a window of data every time a new data point arrives. This is the fastest updating but most unstable processing method.

Input Moving Average: This is simply the number of rolling average windows being averaged to provide the RMS data point that is passed to the concentration calculations.

Output Moving Average Size: This changes the moving average window size on the calculated concentration value.

6 PC TO PCB COMMUNICATIONS

- Communications with the PCB are via a CP2102 USB to UART adapter, fitted to the KEMET 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 1 second, then the command has not reached the PCB and should be resent.
- If the board requests a value, the value must be sent as a binary value (for example Channel 4 must be sent as 0x04).

6.1 Commands Description

Command Character Code	Description	Response
0	Null command	"ok"
1	Get product details	Product string
2	Set number of channels	"Set 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 to 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"

6.2 Sampling and Signal Processing for KEMET TO Sensors

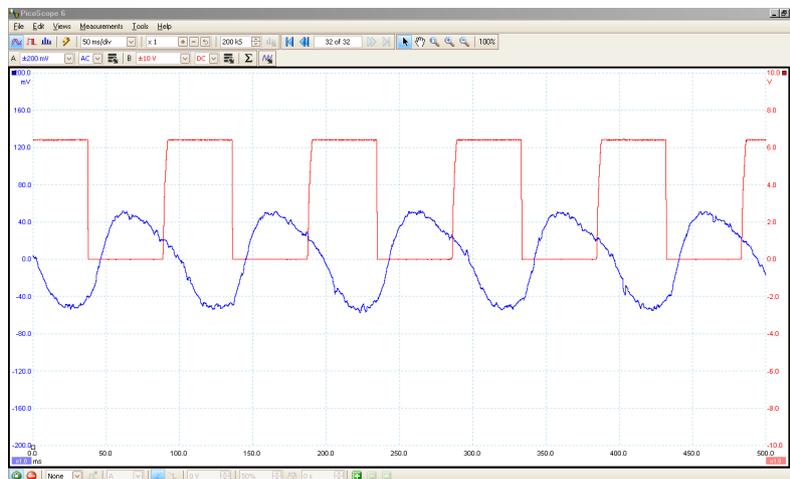
KEMET's unique thin film pyroelectric sensors have excellent response at higher modulation frequencies than many existing competitor sensors. This higher frequency performance has the benefit of reducing the impact of pink (1/F) noise that can plague both sensors and electronics at the low frequencies often used in infrared applications. Good system engineers will be aware that pink noise may be the dominant noise source when operating at below ~4 Hz. 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 KEMET sensors at higher modulation frequencies the pink noise can be further suppressed, improving the signal to noise ratio. KEMET sensors will still outperform competitors' sensors in the 1-4 Hz operational range in a circuit optimized for KEMET.

KEMET 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 KEMET's advanced MEMs based thin film device structure with a low noise transimpedance amplifier, which includes a 31 Hz first order low pass filter.

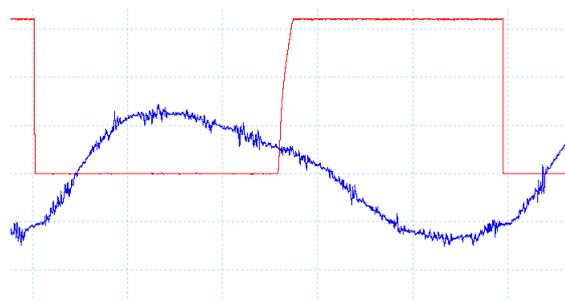
¹ If the MS is to be used for Beer-Lambert calculations it is necessary to take the square root of the MS value returned, as the C8051F350 doesn't calculate the square root, as for example, Result = sqrt (Get MS CHx)

To maximize the competitive advantage offered by this 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 KEMET TO sensors when illuminated with a 10 Hz emitter pulsed with a square wave.



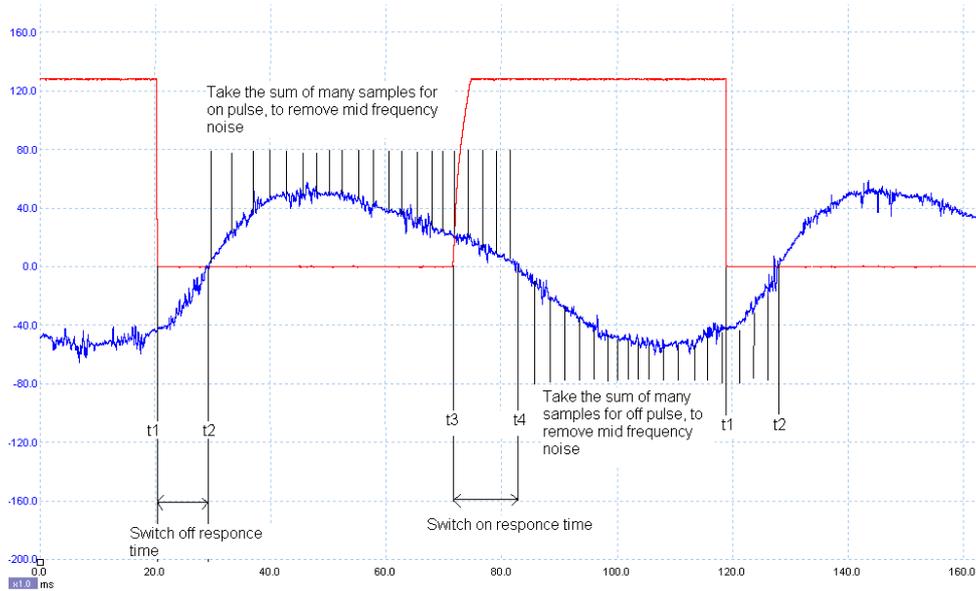
There are two points to note about the signal shown above, as highlighted by the figure below in more detail.



1. There is mid frequency noise present in the signal.²
2. Even at 10 Hz the waveform is not completely sinusoidal, demonstrating the higher speed performance of KEMET sensors.

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

² This noise can easily be removed by oversampling



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 KEMET sensors.
The signal size = Sum (on samples) – Sum (off samples)

7 EMITTER VOLTAGE SETTING

As with all electronics, there are tolerances for each of the components. The gas demo is no different and hence a calibration methodology is required to ensure optimal settings for maximum sensor output whilst not saturating the sensor. The method is best described by looking at the waveform on both the KEMET Software as well as using an external oscilloscope.

7.1 Saturation of Signal

When the sensor's output is fully saturated, the KEMET software will have a waveform similar to the following picture.

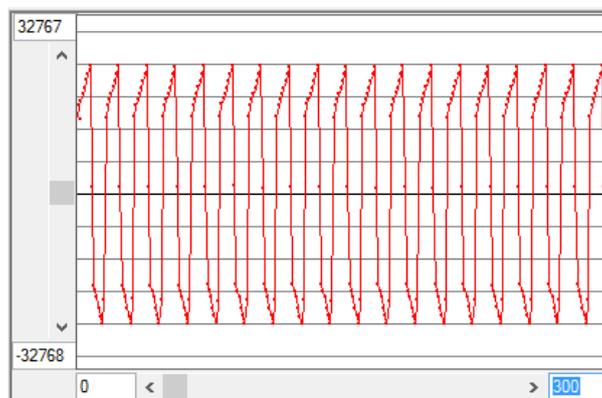


Figure 18 – Saturated Signal

The graph can be explained by following the output of the sensor through the hardware signal conditioning components. Using an oscilloscope to capture the output on the pin of the TO packaged sensor shows the following the graph when the output is saturated.

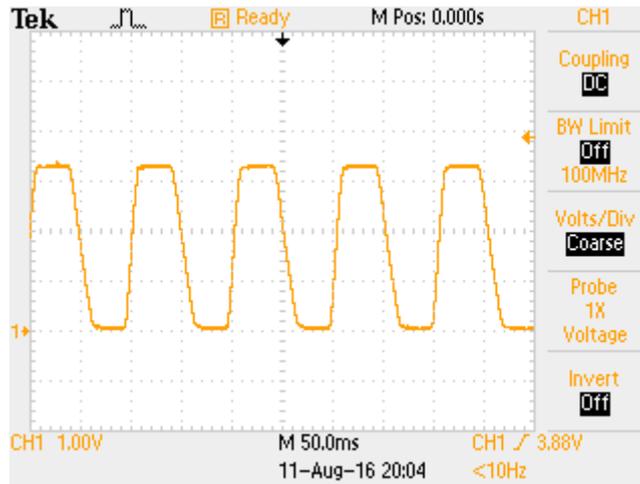


Figure 19 – Output Pin

The signal saturation is shown by the flat peaks and troughs of the waveform. After the signal has gone through a low pass and a high pass filter the signal changes to the same as shown in the KEMET software.

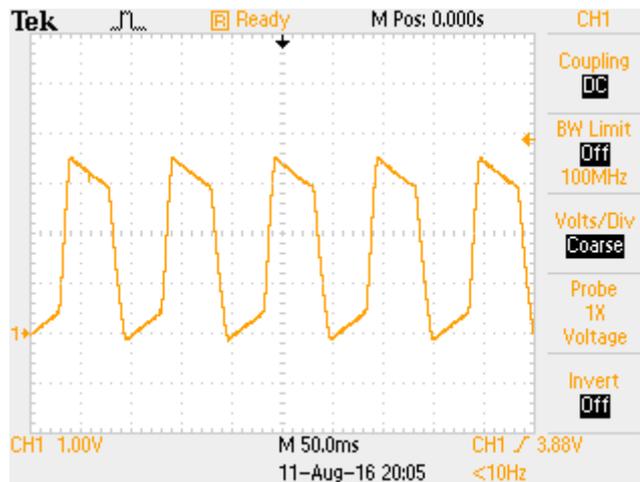


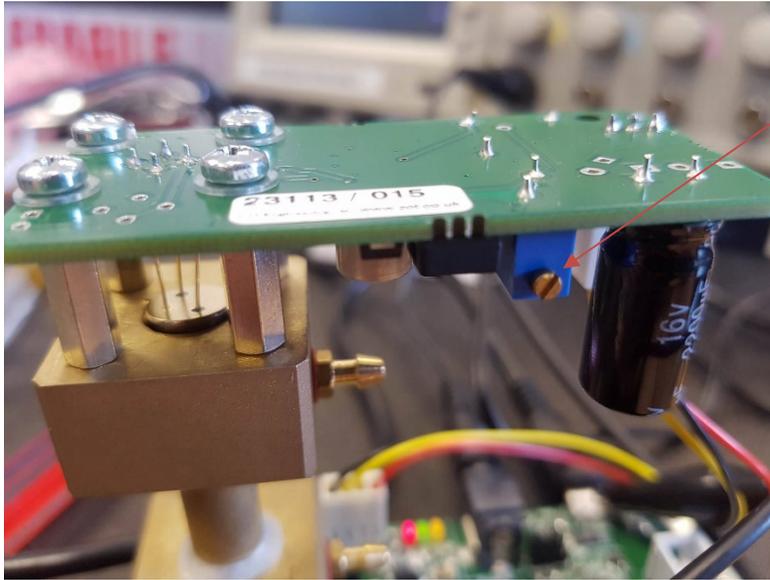
Figure 2 – Input to ADC

The signal is the same as is shown in the KEMET software. The reason that the gradients at the top and bottoms are reversed is simply that the produced waveforms are moving in opposite directions; the oscilloscope has new data added to the right-hand side and the KEMET software has new data added to the left-hand side.

7.2 Method

For setting up the gas demo kit, it is best to use an oscilloscope if one is available, because the waveform will be cleaner than that produced by the KEMET software. Starting with the emitter voltage set to the point of causing saturation of signal, slowly reduce the voltage until no saturation is occurring. For most applications this will be fine. For using the system in environments that have less CO₂ than average environmental CO₂ levels, it will be necessary to reduce the voltage slightly further again to ensure that when the level of absorbing gas drops, the additional signal strength will not cause the output to saturate.

The emitter board has a potentiometer for altering the voltage across the emitter.



Turn clockwise to increase voltage and anti-clockwise to decrease the voltage.

1. Turn the voltage up until one of the signals has saturated, looking out for the waveforms listed above for saturation.
2. Slowly reduce the voltage until no evidence of saturation is detected.
3. Reduce slightly further if the application requires it.

Following these three steps will ensure maximum signal strength for your application.

Please note that the maximum emitter voltage is higher than is generally required, this is due to the different lengths of brass pipe for each gas detection application differing dramatically, and it should never need to be set to maximum for CO₂. Running at higher voltages causes the emitter to deteriorate faster so should be avoided unless necessary due to a longer path length.