



TO Pyroelectric Infrared Flame Sensing Evaluation Kit USEQFCK9000000

User Guide Rev. 1.0

MAR 2022

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1 INTRODUCTION

This document describes the KEMET Flame Sensing Evaluation Kit USEQFCK9000000 and its related software.

The purpose of this kit is to enable engineers and technicians to carry out simple and effective evaluation of KEMET flame sensors, experiment with the sample flame detection ratio-based algorithm, and to capture measured data to a PC. The kit is based on the ST microelectronics STM32F303K8 microcontroller.

2 GETTING STARTED



Figure 1 – TO Flame Sensing Evaluation Kit USEQFCK9000000

2.1 Kit Contents

1. USEQFCK9000000 TO prototype flame sensing detector
2. 3 sensors: USEQFCEA500100, USEQFCEA391100 and USEQFCEA448100
3. Micro USB to USB cable
4. KEMET TO Flame Sensing Evaluation Tool (Digital) software
[click here for downloading the software](#)

2.2 Minimum System Requirements

1. Microsoft® Windows PC
2. 2 GB of RAM
3. 450 MB of available hard-disk space for installation, additional free space required for storing CSV files
4. .NET Framework 4.5
5. 1 free USB port

3 INSTALLATION

3.1 Installing the KEMET Flame Sensing Evaluation Tool Software

From the software pack available to download [here](#), select the **setup.exe** file that has this icon. This will start the installation process.

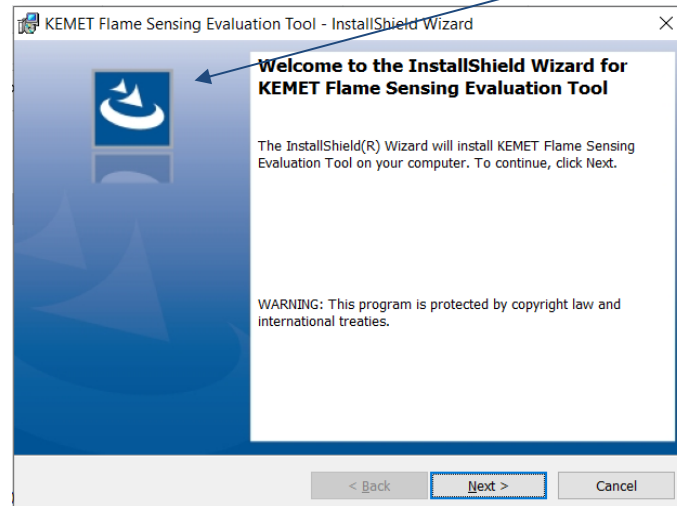


Figure 2 – Installer Screen

Follow the on screen instructions and enter the information required.

As part of the installation process a check will take place to see if .NET Framework 4.5 is present. If not, the setup routine can be cancelled and the .NET framework 4.5 can be downloaded from Microsoft's website.

A driver is needed for the STM32F303K8T6 microcontroller. This is included in the software package.

3.2 Installing the ST Microcontroller USB Driver

The software zip file contains a folder called *en.stsw-link009.zip*. Extract the files and run either the application **dpinst_amd64.exe** if you have a 64 bit system or **dpinst_x86.exe** if you have a 32 bit system. This will install the USB driver for the ST microcontroller that is connected to the PCB.

Once the driver has been installed the USB cable can be connected between the PCB and the computer.

Once connected the green light on the PCB will be on constantly and the red light will flash (the microcontroller is the inverse of this, red is on constantly and green flashes).

3.3 Installing .NET 4.5 Framework

If you do not have the .NET 4.5 framework installed on your computer then use the installer provided (*dotnetfx45_full_x86_x64*) in the software package.

3.4 Connecting the Flame Sensing Evaluation Kit

Connect the USB cable to the kit and Windows PC.

You may see a message suggesting you are required to install a device driver. Follow the on screen instructions and download a driver from Windows Update or install from the software package provided.

4 SOFTWARE USER GUIDE

The KEMET Flame Sensing Evaluation Tool software runs on Microsoft Windows PCs and communicates with the KEMET Evaluation Kit USEQFCK9000000, which enables easy testing of KEMET QFCE flame sensors. Additional signal processing and analysis algorithms for flame sensing are provided. These include a simple flame sensing algorithm using Fast Fourier Transform of sensor signals between a range of frequencies set by the user and ratio-based threshold for flame sensing.

4.1 Starting the Software

Once installed, to start the software find the application **KEMET Flame Sensing Evaluation Tool** in the start menu or on the desktop. This will open up the KEMET sensor data capture main screen as shown below:

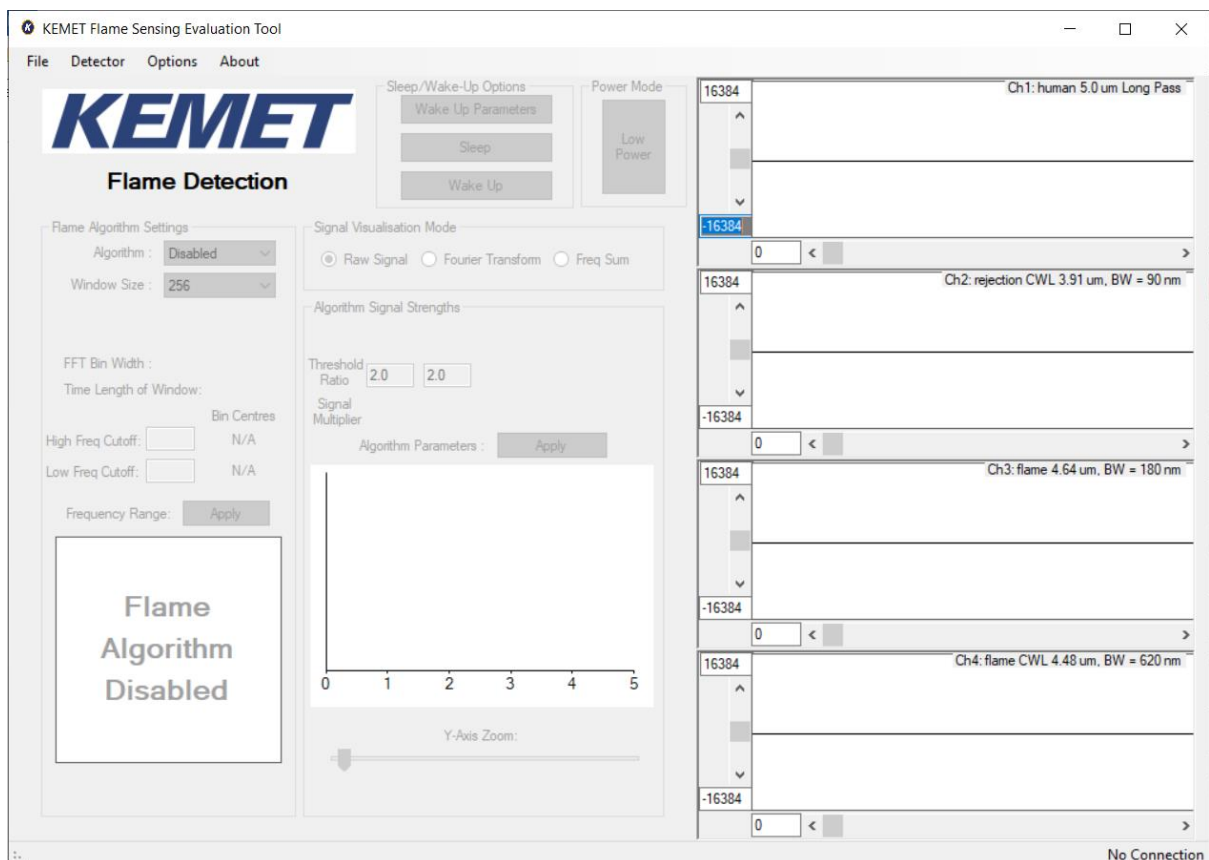


Figure 3 – Flame Sensing Evaluation Tool Main Application Window

4.2 Connecting Software to the Demo Kit

To connect to the TO prototype flame sensing detector make sure the board is connected to the PC through the USB cable.

From the menu bar select the **Detector** option and then **Connect** as shown below.

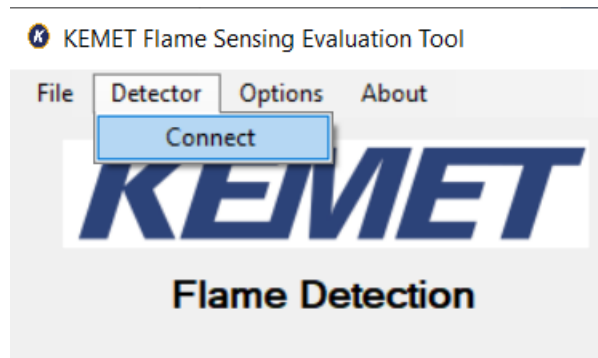


Figure 4 – Detector Connection

This will open a further dialog box asking you to select which com port the data capture board is using, as shown in Figure 5 below.

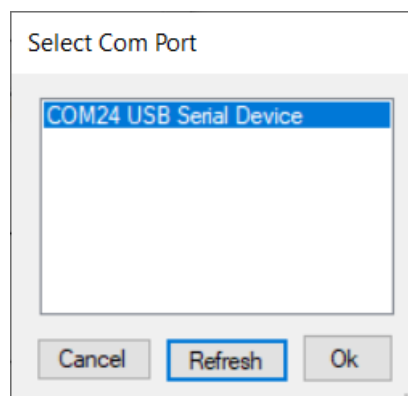


Figure 5 – Com Port Selection

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.

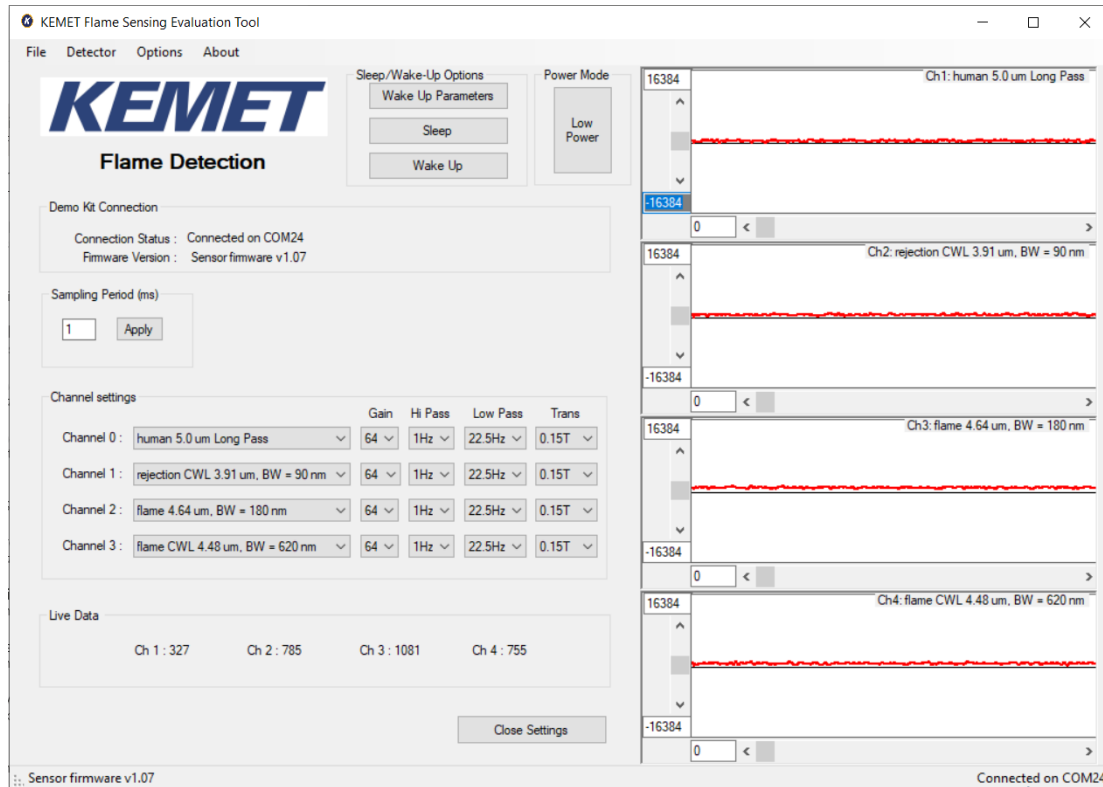


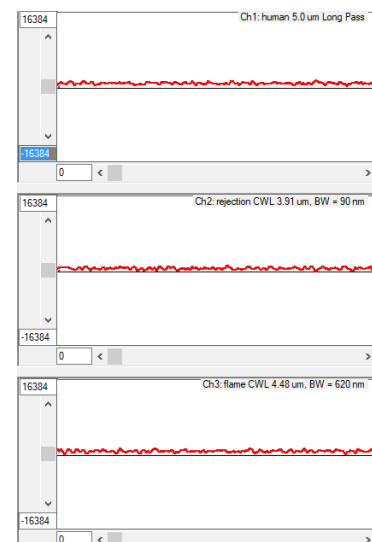
Figure 6 – Software Main Page

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 Evaluation Kit firmware version. Sensor signal will be visible on the signal viewers on the right.

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 screen. Check the USB connection and try to connect again.

Sample Frequency (Hz): This label shows the calculated frequency of incoming data. The calculation is based on the system timer of the computer, so its accuracy and stability are dependent on the computer being used.

The TO version of this evaluation kit consists of 3 sensors rather than 4 (as in the SMD version USEQFSK1000000) so when it is connected only 3 scopes are available.



4.3 KEMET Sensor Settings

The settings of the QFCE sensors within the kit can be accessed by selecting the **Show Settings** item in the **Options** menu, as shown in Figure 7. The settings can only be changed when the software is successfully connected to the Demo Kit.

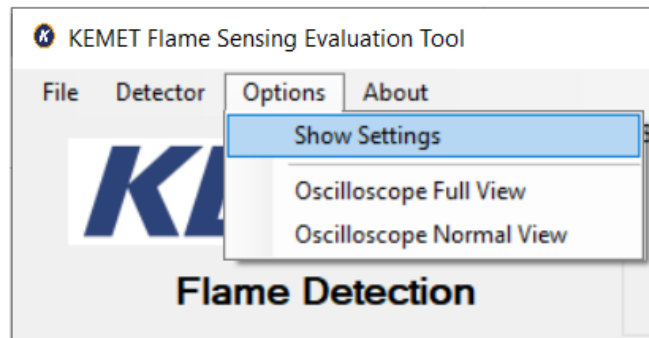


Figure 7 – Finding the Demo Kit Settings

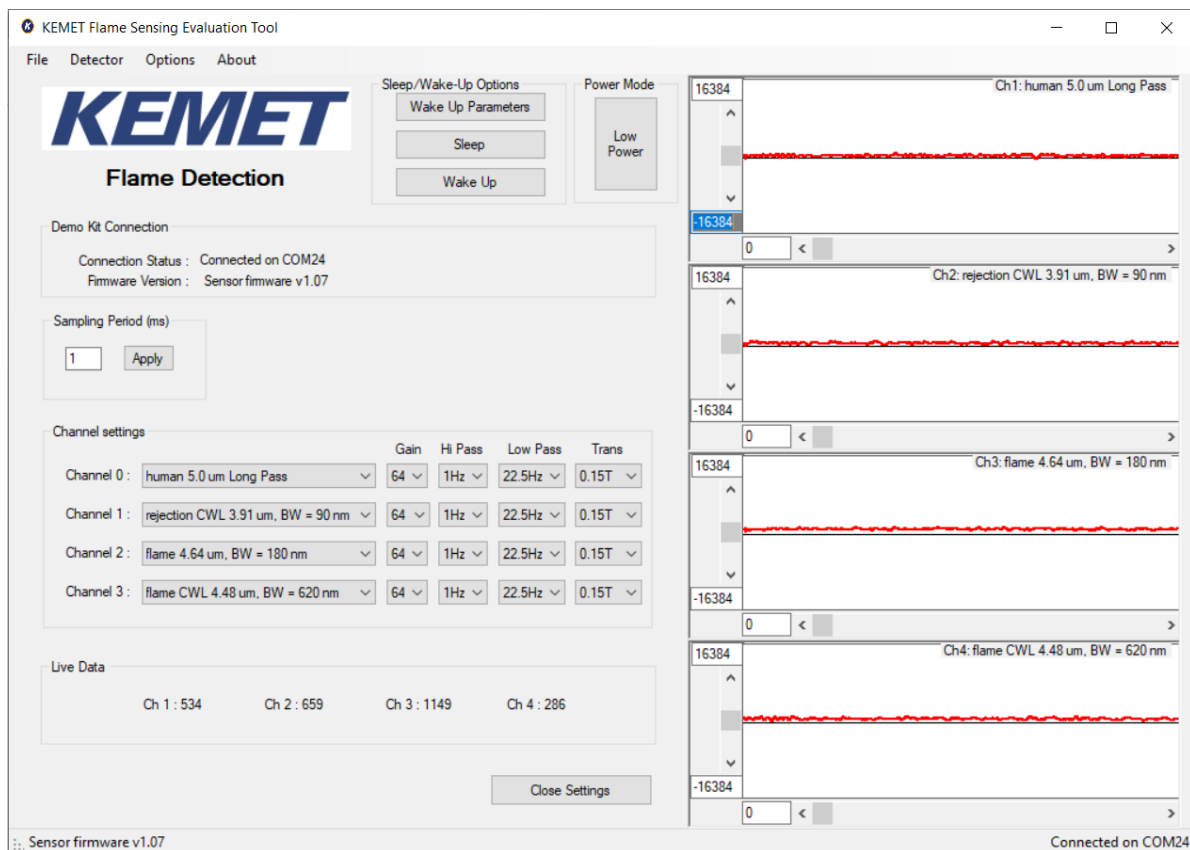


Figure 8 – Demo Kit Settings Page

Sampling Period: Selects how often to retrieve information to be displayed and used in the flame sensing algorithm. Make sure to choose so that the signal frequencies of interest are significantly smaller than the sampling frequency. This is restricted in the flame sensing evaluation software so that the combination of sample rate and power mode do not result in a sample frequency less than 60 Hz as the FFT plots are set up to allow 0 to 30 Hz range. For greater flexibility with the sample rate please use the Sensor Evaluation Tool available to download [here](#). This Sensor Evaluation Tool will provide raw data recording only.

Gain Settings: The gain for the amplifier is set by selecting a capacitor to be used in the charge amplifier inside the sensor package. The gain is proportional to $1/\text{capacitance}$ but has been normalized with respect to minimum gain value on the settings screen.

Hi Pass: The high-pass filter allows signal filtering within the package before transmitting data to the MCU.

Low pass: The low-pass filter allows signal filtering within the package before transmitting data to the MCU.

Trans: The transimpedance setting is used to set the resistance of the feedback resistor in the gain amplifier. It works together with the capacitance value chosen to set the time constant of the gain amplifier through the RC response of the two parameters.

4.4 Signal Viewing

After connection, raw signals from the sensors will be shown in the signal viewers on the right side of the software window, as shown in Figure 9.

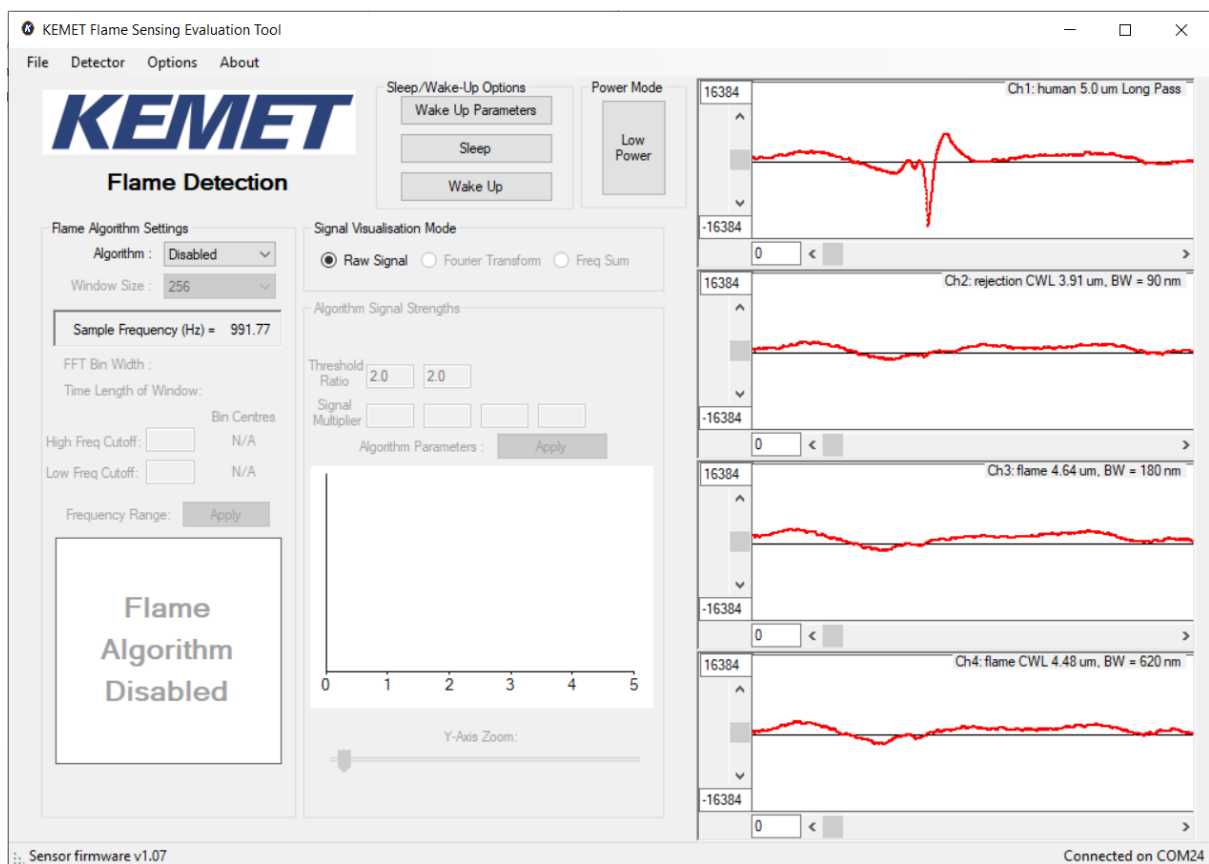


Figure 9 – Signal Viewers

4.5 Flame Sensing Algorithm

For any operation beyond raw signal viewing, the flame sensing algorithm needs to be enabled by selecting **Algorithm: Enabled** under **Flame Algorithm Settings** on the main screen.

4.5.1 Additional Signal Viewing Features

The additional features which will be enabled with the algorithm are:

- **Fourier Transform:** Frequency domain representation of the signal – useful for looking at dominant frequencies in signals (relative magnitude), for example comparison of flame flicker frequency and human motion frequency.

A bar plot is used to represent the frequency bins.¹ These are shown by selecting the Fourier transform shown below.

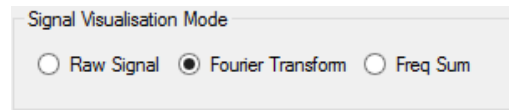


Figure 10 – Selecting Fourier Transform View

Selecting the above option will provide the user with the following signal views of each channel.

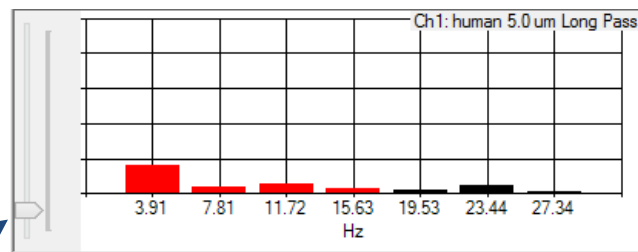


Figure 11 – Fourier Transform Bar Plot

The y-axis slider allows for changing the scale of the bar plot to allow different signal levels to be visualised proportionally next to each other.

- **Freq Sum** – This is the value acquired by summing the frequency bins set by the user, shown with red columns in Figure 11. These are the values produced prior to the signal multipliers² so the effect of the signal multipliers will not appear on this view.

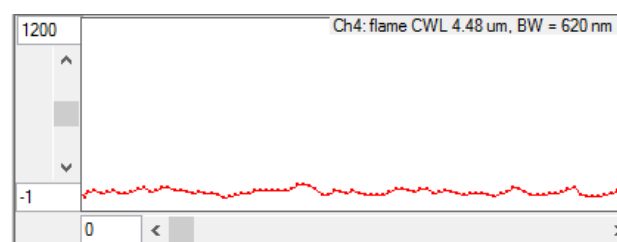


Figure 12 – Frequency Summation View

¹ The term bins is used to indicate the grouping of a range of signals into a single value stored in an element known as a bin, the range grouped together is determined by the resolution of the FFT (see Section 7) produced by the Fourier transform.

² For more info on the signal multipliers, please refer to the Application Notes *Sample Flame Detection Ratio Based Algorithm.pdf*, Section 3.5.

- Algorithm Signal Strengths** – This view is the bar plot that is always visible when the algorithm is enabled. This contains the signal levels being compared by the algorithm.

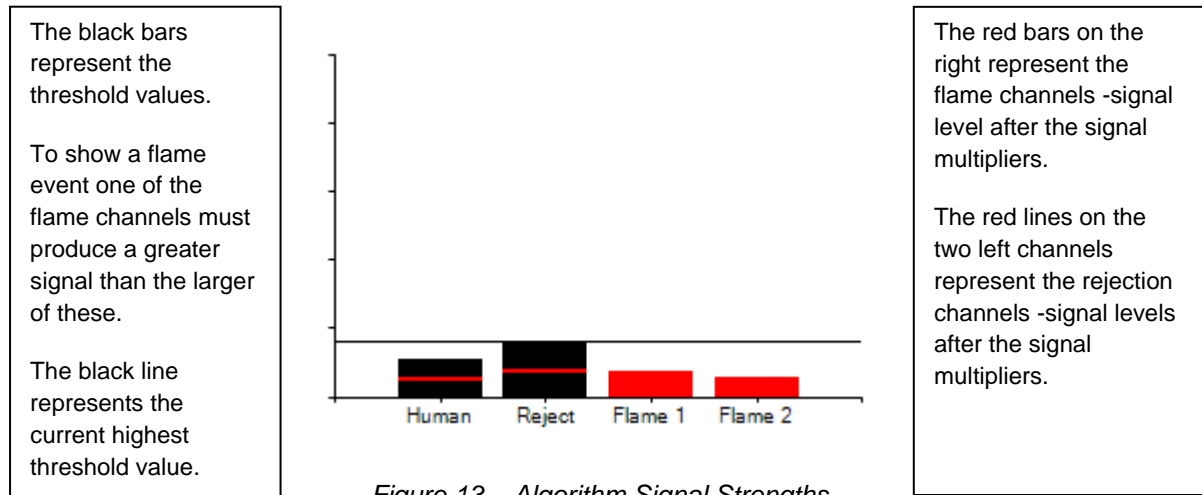


Figure 13 – Algorithm Signal Strengths

If the threshold ratio of a channel is set to less than 1 then the red line will be higher than the black bar resulting in the red line floating above it as shown in Figure 19.

4.5.2 Flame Algorithm Settings

The flame algorithm of this software uses Fast Fourier Transform (FFT) of the signal to provide a view of the frequencies that the signal is composed of. These frequencies are viewed by following the steps listed in the previous section on signal viewing.

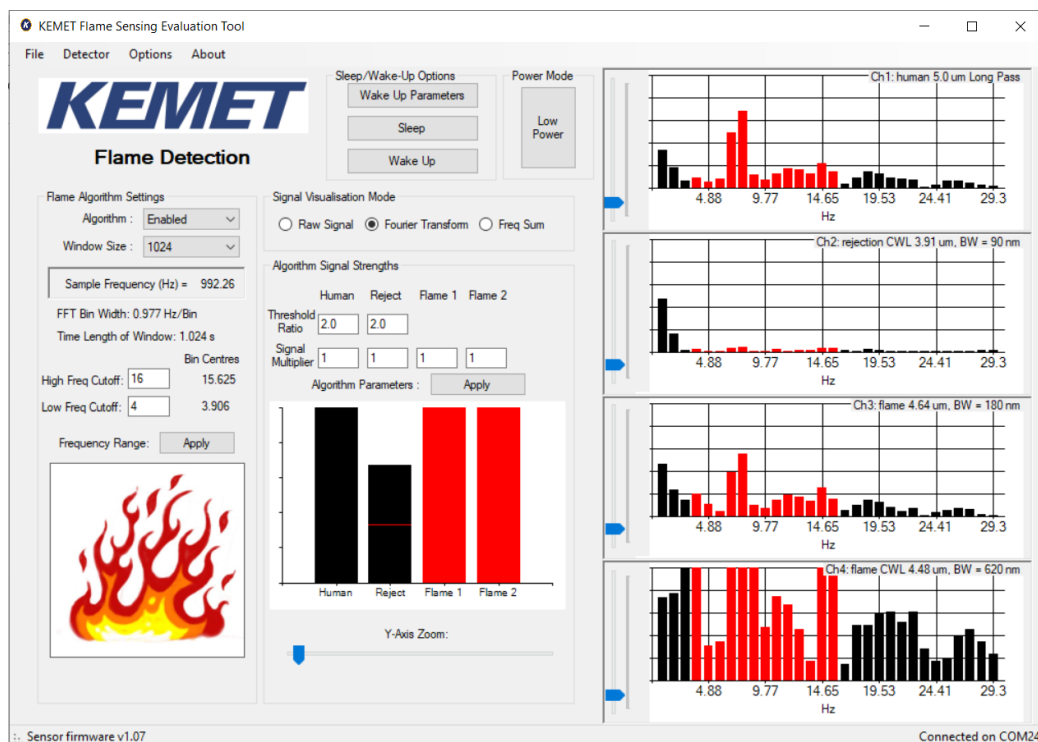


Figure 14 – Flame Sensing

Window Size: This controls the speed of the algorithm versus the stability to momentary fluctuations. A value of 256 is the lowest value available, please see Section 7 for a justification of this lowest value. A lower value of window size gives faster response, but also less immunity to noise, both from the sensor and electronics and from the scene seen by the sensors. A higher value increases stability and glitch rejection.

FFT Bin Width: This informs the user of the current frequency groupings imposed by the algorithm parameters. For example, a 0.977 Hz/Bin means that if a frequency bin was centered at 10 Hz it would contain frequencies in the range $10 \pm 0.977/2$ Hz. So, this bin would contain signals of both 9.8 Hz and 10.2 Hz.

Time Length of Window: This value is indicative of the response time of the algorithm. It is simply the sample rate (Figure 14 shows 1 ms) multiplied by the FFT Window Size (1,024).

Bin Centers: This informs the user of the first and last FFT bin centers being used by the algorithm. Since the value input by the user is an integer, it will never be a perfect match for the bin centers. Therefore, the algorithm uses the first bin that includes the frequency input by the user.

High Freq Cutoff: This field is set to the value for the upper limit of frequency to be used by the algorithm.

Low Freq Cutoff: This field is set to the lower limit of frequency to be used by the algorithm.

Threshold Ratio: This allows the user to set the threshold ratio. The example value of 2.0 requires that a flame channel's post processing signal strength must be twice that of the rejection channel for a flame event to register.

Signal Multiplier: This allows each channel's signal strength to be modified. This should be used for calibration purposes to account for differences between the sensors on each kit.

4.5.3 FFT Related Parameters Quick Guide

The input parameters that the user can change that affect the performance of the FFT are

Sample Rate/Low Power Mode and FFT Window Size: These affect both the maximum frequency detectable and the time duration of a window of certain size. Please refer to Section 7 for the effect of these parameters.

High Freq Cutoff/Low Freq Cutoff: These parameters allow the user to select which frequencies are included in the algorithm. This is easily visualized by showing the response of the software to a change of these parameters.

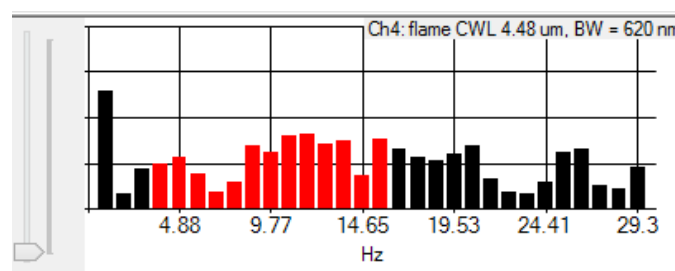


Figure 15 – 1 kHz Sample Freq – 1,024 FFT Window - 4 to 16 Hz Summation Range

The above figure shows the bins being used by the algorithm colored in red with the bins being ignored colored black. To see the above graphs of the FFT of each sensor follow the instructions of Section 4.5.1 for the Fourier transform view.

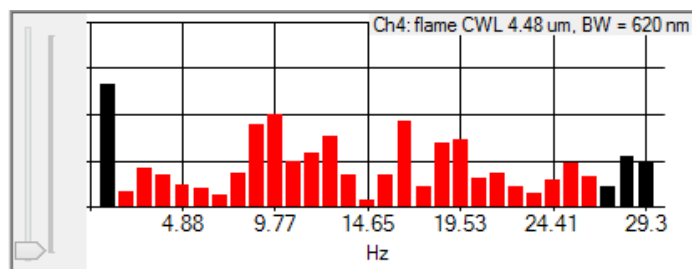


Figure 16 – 1 kHz Sample Freq – 1,024 FFT Window - 2 to 26 Hz Summation Range

In this example the range of frequencies has been increased to contain 2 to 26 Hz as instructed by the user input to the text fields followed by clicking **Frequency Range: Apply**.

4.5.4 Threshold Ratio and Signal Multiplier Quick Guide

This section gives a descriptive and visual guide to the effect of the threshold ratios and signal multipliers.³

By using the section of the software called **Algorithm Signal Strengths** shown in Figure 17, the effects of the thresholds and multipliers can be observed. It is recommended to put the flame sensing detector into a box so that only noise levels are affecting the signal. This will give steadier signal levels to observe purely the effects of the parameters being discussed in this section.

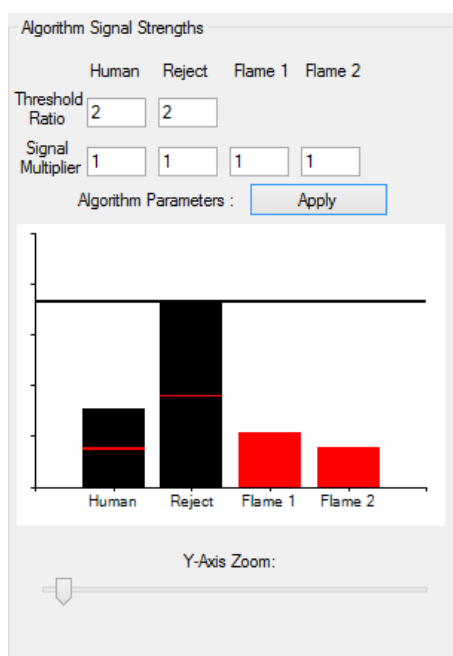


Figure 17 – Algorithm Signal Strengths

³ For a more detailed description, please refer to the Application Notes *Sample Flame Detection Ratio Based Algorithm.pdf*.

- The two red lines in the black bar plots represent the signal levels of the rejection sensors.
- The black bars themselves represent the threshold level that the flame signal must be greater than for that rejection channel to be dominated by the flame signal.
- The black line represents the highest value of the two rejection thresholds. This is the current value required by a flame sensor for flame event to be registered. It should be noted that this line will always be at the level of the highest threshold rejection value.

The above example shows that all signal multipliers are set to unity leaving them unchanged. The threshold ratios are set to a value of 2. This means that the threshold value is double that of the algorithm signals for the rejection channels.

Reducing the threshold values to be less than 1 will result in the black bar being under the red lines that represent the signal level of that channel as shown below.

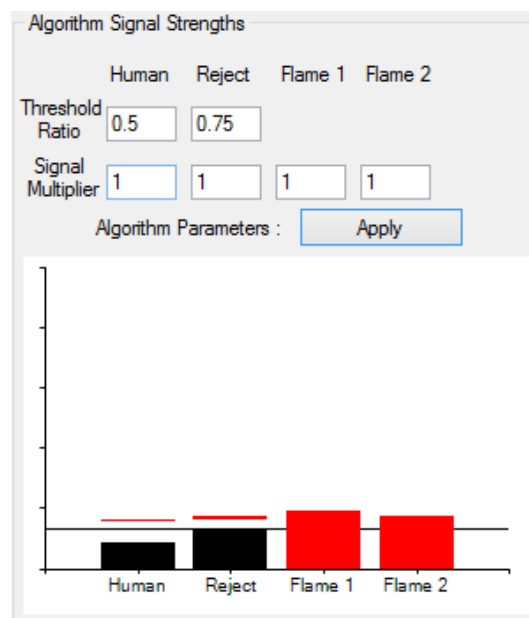


Figure 18 – Reduced Threshold Ratios

As can be seen the required threshold for a flame event has been lowered to less than the signal level for both channels. Human motion threshold is half the actual signal and Reject is 75% of the actual signal value. This is an unlikely situation for setting the ratios when the signal multipliers are set to 1 as there is constantly a false alarm occurring.

You could leave the threshold as above and increase the signal level using the signal multipliers.

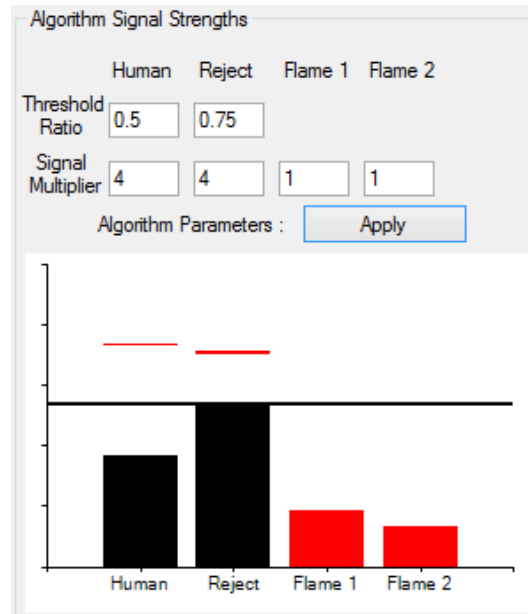


Figure 19 – Reduced Threshold Ratios and Increased Rejection Channel Multipliers

Although the threshold is still below the actual signal multiplier, the signal level has been increased. This should be done to compensate for differences in system performance. These features allow calibration of a system.

4.6 Key Adjustments

- If the algorithm is constantly triggering and the flame icon is showing in the left side of the application, the user should either increase the threshold ratio of the rejections channels or apply a signal multiplier of greater than one to the rejections. A third option is to apply a signal multiplier of less than one to the flame channels to reduce the algorithm signal strengths on those.
- If the algorithm is not triggering when a flame is present, then do the opposite of the above. Reduce the threshold ratios and/or increase the rejection channels signal multiplier or increase the flame channel multipliers.
- To reduce noise on the signals, lower the low pass filter value. Or alternatively change the frequency summation range. If the environment has a high noise level at 12 Hz that is causing the algorithm to produce a flame event, then set 11 Hz as the highest value to be used.

4.7 MCU Based Algorithm

Due to the computational expense of the FFT, especially on larger window sizes, no manufacturers use the FFT calculation on a microcontroller.

It is extremely useful to view the data in such a way as it shows you the actual frequencies that you should be interested in. For initial testing with our evaluation kit this is very desirable.

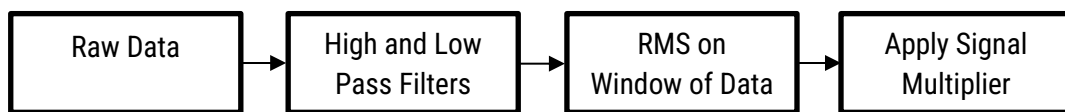
Most system designers use a computationally less expensive form of the same type of processing explained in this document.

1. High and low pass filter implemented in op-amps when using an analog sensor. When using a digital product such as this sensor, the same effect can be accomplished with digital signal processing.

At this stage the signal still contains the frequencies you are interested in as set by the filters being used. However if the evaluation kit used this method you might not see other frequencies that could use in your algorithm.

2. Perform RMS on a window of data to determine the signal strength of the combination of the frequencies in the bandpass of the filters used.

This is equivalent to being at the beginning of stage 5 of the data processing described in this document prior to applying the signal multipliers.



The window of data in the third box has the same effect as increasing the FFT window width in terms of the time response to an input signal. Longer windows are more stable but slower to respond. This can be set to any value desired as it does not have the restriction of being value of the form 2^x like the FFT.

After the signal multipliers the same comparisons can be performed as written in Sections 4.4 and 4.5.

5 SLEEP AND WAKE-UP

5.1 Sleep Mode

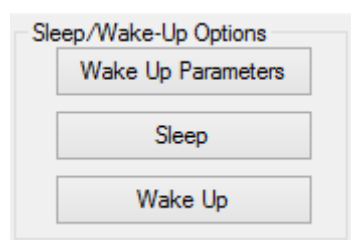


Figure 20 – Sleep and Wake Up Controls

Using the KEMET [Flame Sensing Evaluation Tool software](#), it is possible to put a device into Sleep Mode. This can be done by simply clicking the **Sleep** button. Unless the WUP is configured to allow a signal-based wake-up event you will have to click the **Wake Up** button.

If the flame algorithm was enabled when the device was asleep then it will be re-enabled once a wake-up event occurs through the press of the **Wake Up** button or due to the signal level meeting the requirements of the WUP packet.

5.2 Wake Up Parameters – The WUP Register

As mentioned in the previous sub section the device can be woken up from the sleep state through either an I²C command from the MCU which is sent by pressing the **Wake Up** button or through an internal event raised due to the signal being within certain criteria set within the WUP register.

It is worth reading this section alongside the *SMD Sensor Reference Manual* section on the WUP register.

For valid wake up settings, the UHT and ULT cannot be set to the same value, the LHT and LLT cannot be set to the same value, the thresholds cannot be set to the maximum and minimum values. The WT threshold must be set to at least the minimum number of samples.

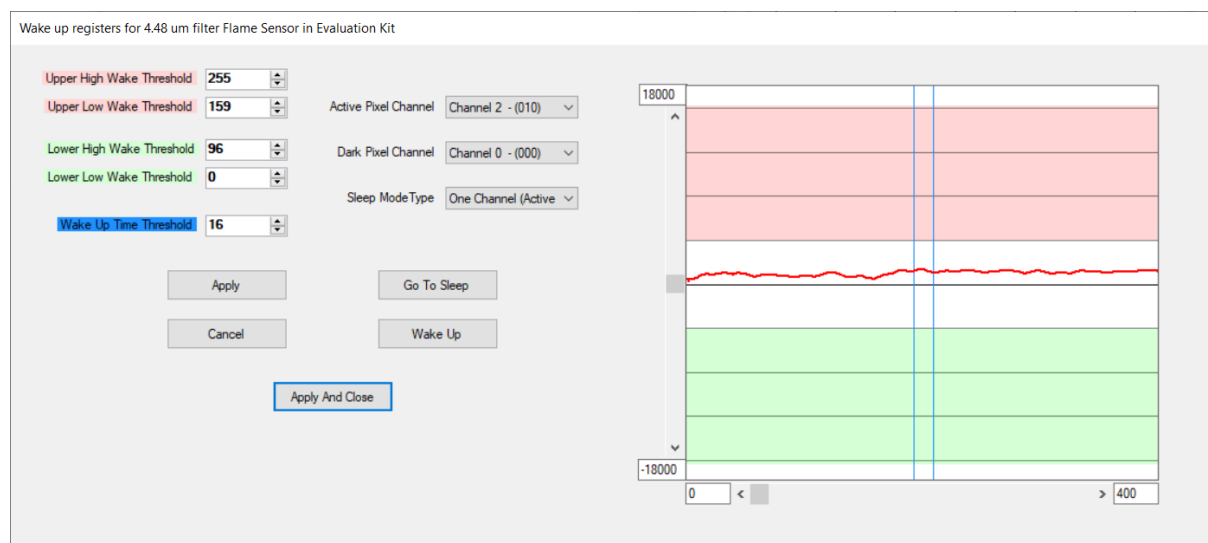


Figure 21 – Valid LHT, LLT, UHT and ULT Settings

If these conditions are not met, the following warning message is displayed.

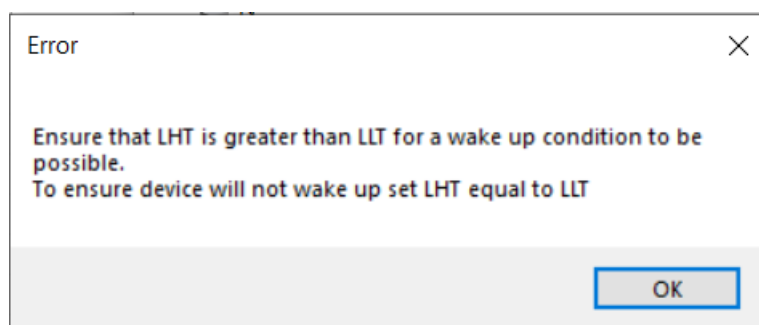


Figure 22 – Wake Up Settings Warning Message

Using this view with the TO Flame Sensing Evaluation Kit (Digital) always displays the main flame sensor (4.48 μ m).

6 LOW POWER MODE

This can be used in conjunction with the Sleep Mode to provide a very low power mode for the device. This means that when a wake-up event occurs the communications and data processing can be performed until either the flame is registered as real and an alarm is set, or no flame is detected and the device can be put back to sleep. The frequency of wake-up conditions then sets the limitation on the lowest power capabilities of the system.

If setting the WUP registers for use in low power mode, the calibration of the WUP should also be performed in low power mode as there are performance differences between the two modes resulting in different signal levels for the same input.

For further information on the digital sensors low power mode please consult the *SMD Sensor Reference Manual*.

7 FFT RESOLUTION

The table below shows the resolution of the FFT based upon the FFT window width when using a sample rate of 1ms and normal power mode.

FFT Window Width	Resolution (Hz/Bin)	Time Duration of Window (ms)
256	3.906	256
512	1.953	512
1,024	0.977	1,024
2,048	0.488	2,048
4,096	0.244	4,096

Table 23 – FFT Window Width and Frequency Resolution

What the above table shows is that if you require a finer control of the frequency range being considered by the algorithm you will need to increase the FFT window width. However, increasing the window width also increase the response time to an input.