

# ER832 Software Interface

... 1st edition 27/05/2020

... 2nd edition 02/06/2020 (checked and confirmed with the customer)

## Design Intent

ER832 Bacterial Growth Analyser is an e-corder conductivity sensor integrated with a temperature controller. It can measure the conductivity for up to 64 samples under a certain temperature (  $\pm 0.5$  degrees) set by the user. The standard operation parameters are as follows:

- Sampling Rate: from 1/3600 Hz (1 reading per hour) to 10 Hz
- Duration: from 2 mins to 720 hours

This document is used to describe the software interface for ER832 Bacterial Growth Analyser. The software should be able to take the serial outputs (raw data readings for up to 64 channels plus temperature readings) from the ER832 and provide multi channel signal recording, display and analysis capabilities including:

- Normalization and Calibration
  - Normalization is a rarely done process which is performed to linearize the sensor response.
  - Calibration is a more commonly performed process which assigns a particular value to a particular specific conductivity value.
- Units Conversion
  - Units conversion is used to change a value of conductivity into a value that may represent a user defined value (eg population)
- Baseline Subtraction (first data point)
  - Baseline subtraction is used to set a current value (or user selected value) to be a zero. Every value will be related to this value
- Reference Channel Comparison
  - A user selected channel should be able to be used as a reference channel. This will cause selected channels to be  $\text{value} = \text{value} - \text{reference ch.}$
- Derivative
  - The derivative and second derivative should be calculated using the raw data. The user must be able to set filtering parameters to minimize noise on this calculation.
- Integral
  - The integral of each channel should be calculated. The integral should be calculated on either the complete run or by the user selecting the important area
- Smoothing
  - Smoothing is important to remove low frequency variations in the recorded signal. The user should be able to set some smoothing parameters to be applied

across all incoming data. The system should keep the raw data so that the smoothing operation could be disabled or modified after an experiment is completed.

- Parameter calculation and tabulation
  - The raw data collected during recording is reduced into a set of parameters that can be used to calculate growth curves. The exact equation for the growth curve is researcher specific but uses a number of parameters that can be collected from the raw data of each channel. Parameters include:
    - Start value  $y_0$
    - End value A
    - Delay time  $T_g$
    - Max rate  $R_{max}$
    - Time of max rate  $TR_m$
  - These parameters should be displayed in a table that the user can save to csv or similar format for import into excel or other program
- Curve fitting
  - A calculated curve should be generated and compared with the raw data. The parameters of the fitted curve should be placed into the data table as well as a fit metric. The equation used should be selected from a set of common growth equations or the user could enter a custom trend curve. The user could enter some starting parameters but the system should be able to generate a good fit after the  $T_d$  parameter is measured. The fitted curve should be displayed over the raw data to give the operator a method of monitoring the fitting process. N.B This is important as the final value can often be estimated because the final value is often equal to  $1/0.368$  of the value at the point of inflection.
  - The program should provide a number of methods for displaying the recorded data. The data should be viewable as time vs value graphs, tabulated parameter data or as a grid of growth factor numbers. ( this growth factor number is a simple equation used to characterise each sample into different rates of growth. ( a look up table could be used to show these numbers as black indicating no growth to white indicating high growth.
  - The growth factor numbers should be used to send a command to the er832 unit to change the colour of the sample tube led. This will give a user a quick way to see which tube is growing.

## System operation

The System Requires a number of parameters to be set before operation. Some of these parameters are global and others could be set for a specific channel.

The parameters should be saved to an experiment file so that settings can be reused. The experimental data should also be recorded.

An experiment may have multiple runs. Each run should be viewed or selected by a set of tabs. The user should be able to save settings or settings/data as one file.

The app should look for a device on the serial port chosen by the user. Once detected. The system parameters should be set based on the data stored in the configuration file data. The device parameters should be read from the device and then compared with parameters in an experiment configuration file. The user should be prompted to either use the parameters stored in the device or use the parameters stored in the file.

Some parameters are based on hardware and cannot be changed.

These include

- Device type. ER815 with ET132 head
- Device Serial number. Serial number
- No of channels. 8 to 64, The quantity of channels is detected during power up of the device and could change. The no of channels can be read by using the info command.

The parameters which can be overwritten by application settings

- Excitation freq. 100k to 1000k
- Excitation value. Low or high. (0-49 is low and 50 to 100 is high)
- Head gain. Each channel can have head gain set low or high
- Normalisation parameters K1 K2
- Calibration on off ( each channel group of 8 ch can independently enable calibration)
- Calibration point e1 value, conductivity value mS
- Calibration point e2 value, conductivity value mS
- Chamber temperature setting
- Detection mode. The er832 will have 3 detection modes.

The values generated by the device will be output at a rate set by the application and will appear as a string of numbers.

The application should capture these values into an experiment file after a trigger event occurs. The trigger would either be “user trigger”: this is caused by a button labeled “start” which would change to “stop”. The other type of trigger would be based on sample tube insertion. The sample tube detection is available on a channel by channel basis and is read as a set of binary numbers after the sample values. When sampling is started a set of values will be printed to the serial port.

Value1 value 2 value3 .....value8 Temperature, 0110101.

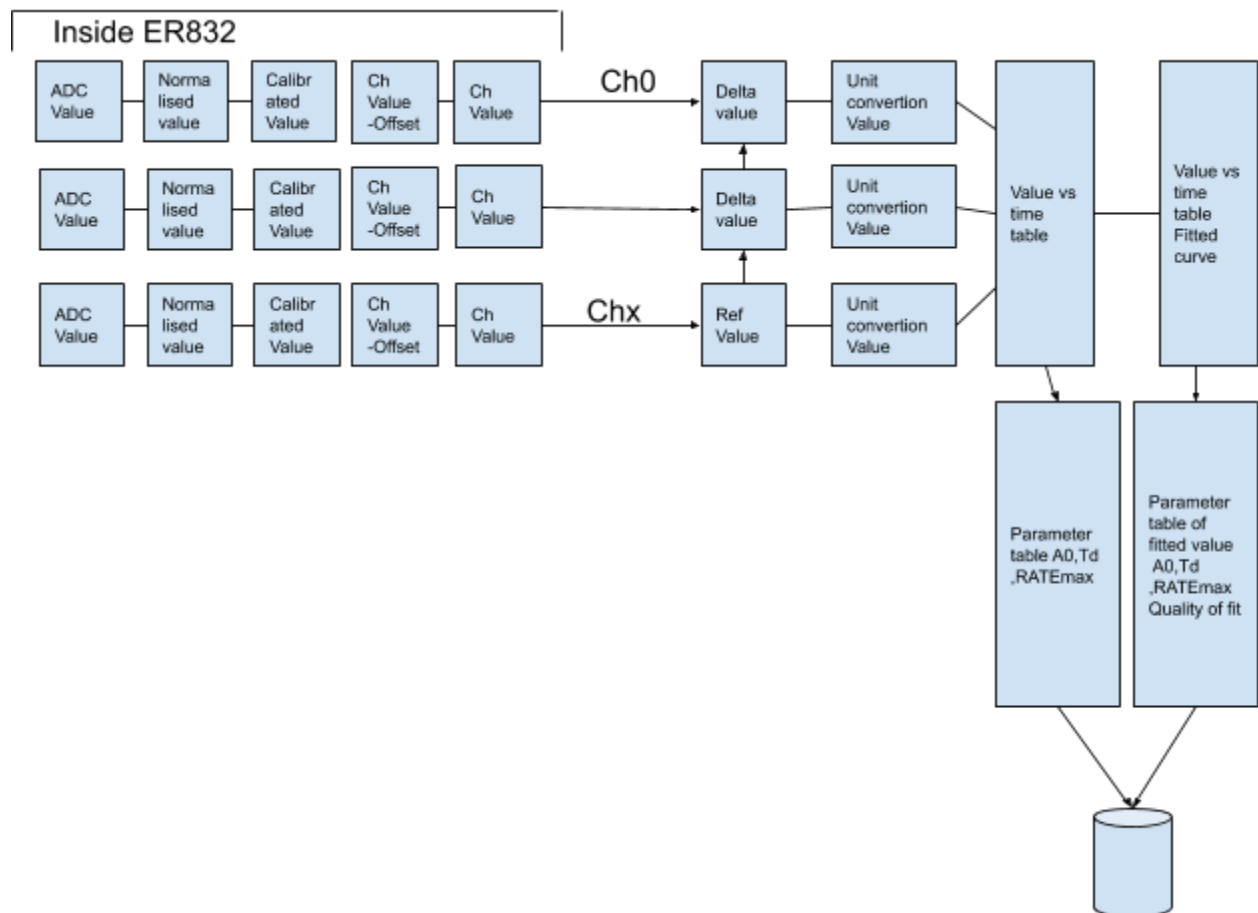
Value9 value 10 value11.. Value16 Temperature, 0110101.

The trigger value could be used to record the incoming data for each channel. If trigger is enabled for a channel the system would start collecting values but only store the data when the trigger was true.

Before recording, the user needs to do normalization and calibration for all channels. The normalisation parameters apply to a particular set of parameters and typically are done rarely. Calibration is done after this and may occur on a daily schedule or as required. The user should

not be able to change excitation value or frequency once normalisation is active. Normalisation should be deactivated prior to changing these parameters.

Calibration will only apply to a set of user parameters normalisation parameters. So if the user want to override the user parameters calibration and normalisation must be redone.



This diagram shows 3 channels and how data is moved from the ADC to the parameter table. The user can select a channel to be a reference channel of a group and the group of channels will output a delta value.

The current hardware has a number of built in functions but it may be advantageous to perform these functions in the GUI. The functions built into the ER832 include

Offset Value.

The user can set the offset value for each channel by either entering a value to offset the signal or by allowing the system to remove offset from the data.

Normalisation and parameter storage.

(K1,K2 values are required to linearize the sensor response for each channel)

The K1,K2 values are dependent primarily on the sensor geometry and the user

should be able to perform linearisation on individual channels or apply one set to all channels.

#### Channel Calibration and parameter storage.

The user can apply a calibration to sensor readings. This is done by recording the response for one value (eg 1ms= 1V, 10ms=2=2V). After calibration, the system supplies these values instead of the sensor voltages. This applies a correction factor and offset value to the recorded values.

Once the channel hardware is set and the above functions have been chosen, the user can choose to use a channel as a “reference channel” This will then be able to be used when a user sets “DeltaMode” for a channel. The deltamode will subtract the reference channel values from the channel value. The ER832 can only have one reference channel per system but also multiplies the difference values by 10. The reference channel cannot be used as a deltamode channel as this would always output zero. (value= value-value) The advantage of performing this function in the GUI is the system could have a separate reference channel for a user define group of channels.

The values can be scaled after recording, or before recording by clicking on an axis and typing in a value. A user selects a block of data and then selects a region which is used to select either a pair of values or a change(delta values) and then the user can enter a unit and value, This way the values can be scaled to any arbitrary unit desired. By default the unit conversion is 1 to 1 but these values are then used to calculate the parameters in the data table.

Phase 1 Setup	Phase 2 Calbration	Phase 3 Operation
<ol style="list-style-type: none"><li>1. Set default Freq</li><li>2. Channel Gain</li><li>3. Offset</li><li>4. Normalisation</li><li>5. Calibration</li><li>6. Save defaults</li></ol>	<ol style="list-style-type: none"><li>1. Calibration</li><li>2. Save defaults</li></ol>	<ol style="list-style-type: none"><li>1. Set trigger mode</li><li>2. Set filter mode</li><li>3. Select Reference Ch</li><li>4. Zero ch</li></ol>

The picture below shows approximate layout of the main page.

The program has a “start button” and a set of thumbnails that should provide a way to check on a sample recording. If a ch is recording ie a trigger event has occurred, the thumbnail could change color.

The user could select a channel by clicking on a chanel box or use shift click to select multiple channels. A selected channel or channel group could display a menu that the user could display options such as configuration or other function.

This program must provide a mechanism such as this to allow the user to use and operate a large group of channels. A series of time vs value graphs become difficult when more than 16 channels are available so this or some other method should provide a easy method to operate the large number of channels available

This screen would have a menu bar across the top that would allow for saving or loading experiments, setting configuration of global and channel parameters.

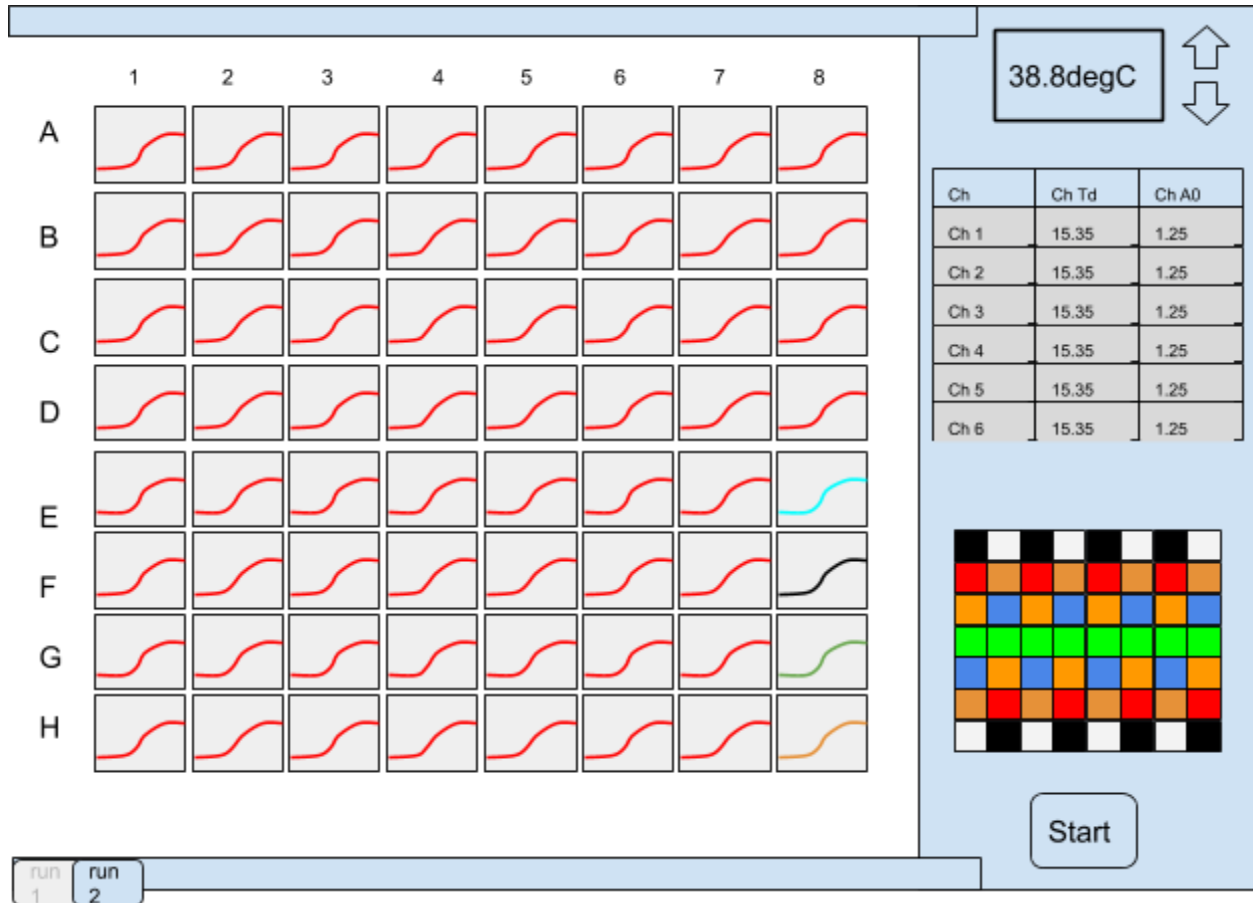
The chamber temperature should display current temp but also allow a set temperature to be set. The arrows would allow temperature to be raised or lowered.

The set of postage stamps should show a representation of the channel. This should be updated as the experiment proceeds. This allows the user to see if any channel is not performing correctly or is overloaded.

The user could zoom any channel or group of channels so that operations could be set or monitored in detail.

The Table of parameters, that the user wants to see should be shown on the right hand side, This would be a set of values shown in a scrollable table. These parameters could be saved as a csv file for use in another program.

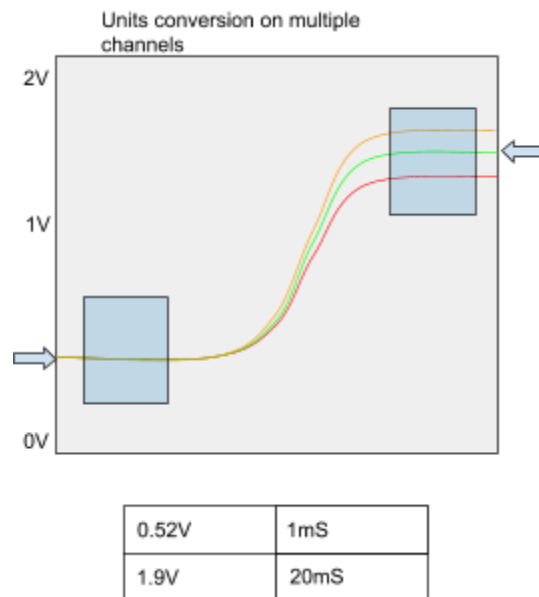
The array of colored boxes are the result of the Growth Factor calculation. This can be generated when the experiment data reaches the time of maximum rate this is 0.368 of the total height. .



By selecting a sample ch a user can view a selection of channels and perform operations on the data displayed. The user could select a ch and using a right click could choose a channel to be

a “reference ch” By selecting a group of chs the user could zoom into the channel to perform functions like unit conversion calibrate or normalise or selection reference mode..

A zoomed view of a selected group of channels



This type of dialog would allow a user to select a region of a graph and this would be used to set the calibration or other similar settings. The dialog would show the selected channels the user would select a region and the system would place the arrow on a curve position. The arrow could then be used to copy the value into the text box or the user could enter it directly.. When showing multiple channels the system may choose one to be the example and this could be bolder. The equivalent position could be applied to all channels in a group or the user could table through each chanel using some control and then approve the seting for all channels in the displayed group.

Configuration

Display selected channels (channel 1 - channel n)

	On	Channel Title	Range	Input Settings	Units	Computed Input	Color	Style	Calculation
1		Channel 1					Red	----	No Calculation
2		Channel 2					Blue	----	No Calculation
3		Channel 3					Green	----	No Calculation
4		Channel 4					Magenta	----	No Calculation
5		Channel 5					Dark Blue	----	No Calculation
6		Channel 6					Brown	----	No Calculation
7		Channel 7					Olive	----	No Calculation
8		Channel 8					Purple	----	No Calculation
9									
10									
11									
12									
13									
14									
15									
16									

Number of channels: 8

OK Cancel

The user can use a configuration window to set number of channels, channel name, channel parameter, display colour, unit name, line style, channel calculation could allow deltamode function as  $val=val-refch$ . Channel functions could include a operator and a input source channel, Operators such as differential, integral, +,-.

This could be broken into a set of global setting, and a set of channel parameters. This could be accessed via the user selecting a channel box and selecting configuration.

## 2 Set the operational parameters for all channels

- Temperature
- Sampling rate
- Excitation
- Detection mode
- Filter mode
- Start Time (e.g. 2 mins, start recording 2 mins after clicking "START")
- End Time , on stop, or triggered stop

## 3 Set the scale and units for x and y axis

This would be after the calibration done inside the er832. This would allow the user to set the zero point and scale units of the graphs.

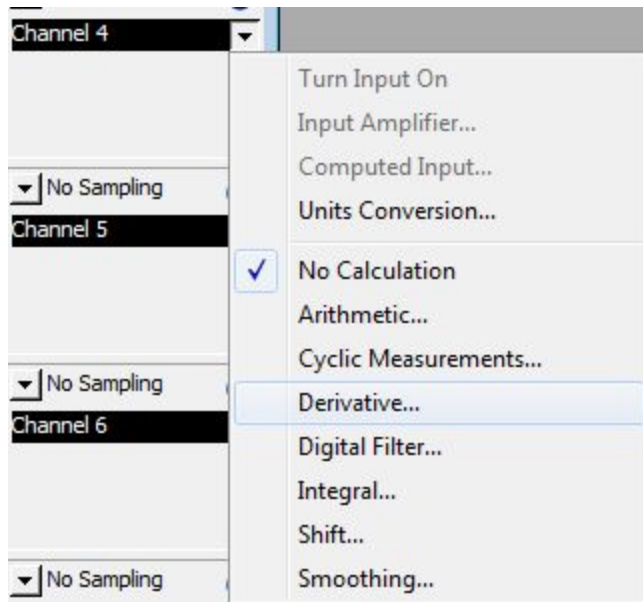
## 4 Start, pause and terminate the recording

The system will have standby, where calibration,setup can be done. Start recording, the unit will begin collecting data depending on the trigger state and options or start time values, pause will temporarily stop recording, and stop.



6 Have an option to display either original, derivative or integral data

\*similar to Chart as picture shown below

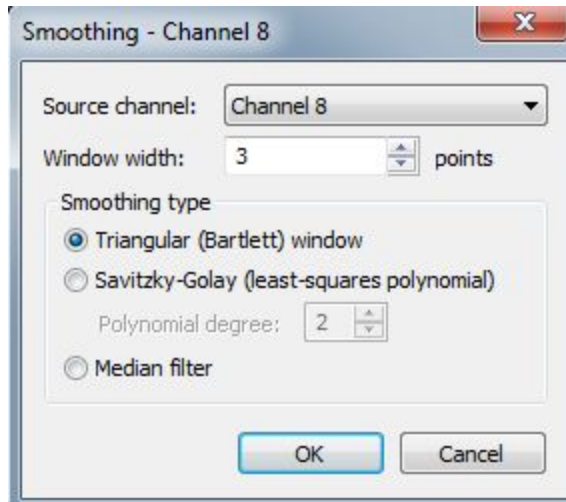


8 Reference channel for subtraction,  $ChN = ChN - Ch_{ref}$ , Original, derivative or integral options are also available after the subtraction. Recommend to use a tick box to activate the function and a scroll-down bar for reference channel selection.

7 New function,  $ReadingN = ReadingN - Reading_1$ . This function will take the value at the start of recording and then subtract this value on the subsequent values. The channel calculations mentioned in other areas would be calculated based on this value original, derivative or integral options are also available after the subtraction. Recommend to use a tick box, by ticking it to activate the function.

9 Smooth the curve

Some filter function can be built into the ER832 hardware so the gui must set filter state for each channel. Any additional filtering or smoothing will be done on data after it is received from the ER832 hardware.



10 Show the corresponding time for essential points

For example, derivative curve, show all points when  $dv/dt=0$  and  $d^2v/dt^2=0$  on the original curve (click once to display, click again to hide)

The system must extract parameters to a table.

The start and end amplitude

The point of infection time ( $t_D$ )

The max rate

The Delay time

This could be shown in a table

In addition to the Measured parameters, It would be very useful to fit a user defined equation to the measured data. The equations used could be chosen from a list of standard growth equations, The parameter of accuracy of fit should be shown as well as fit parameters, The calculated curve should be overlaid over the measured data to provide feedback of the quality of fit. The system could use the fit quality to indicate the experiment can stop. This would allow for the system to calculate the growth factor before waiting until the end of the experiment. This is very useful as the shape of the growth curve is quite predictable and normally would take 10 hours to complete. By using a curve fit factor the system could calculate a curve that would accurately show the end result much fast that waiting till the end. The system could calculate the growth factor and display a flashing colour on the ER832 top panel. This would not stop recording but would allow for the user to decide if they wanted to stop early as the system would be able to give an answer much earlier.

11 The curve parameters, or fitted parameters can, in addition to saving to a file as above, can be used to calculate Growth factor or other metric. This provides a single number indicating biological activity. This parameter should be displayed in a array of colored squares so that the user can see at a glance which samples are active. The colour scale should be adjustable in the setup dialog so that a range of values will have different spectrum of colours.

The ER832 has a set of RGB LEDs on the top panel that will display this value to a user.

12 Display multiple channel curves on the same graph (click the box to choose which channel to be displayed)

13 Customize the curves (colours, Style, thickness and so on)

\*similar to channel settings “Color”, “Style”

14 Save the graph to PDF or JPG, rename the graph

15 Export data (including raw data and modified data)

16 Open the saved data, be able to edit and continue

17 Help and manual should be available

## Appendix

1)

This is a set of sample data.

The spreadsheet shows the recording of two samples one is a negative and one is a positive

The initial value of each recording is used to set a “zero” and after a small amount of samples have been removed, the values are calculated by  $valx = valx - valzero$ . This shows the changes in the samples.

The third set is the difference between the sample vs the reference value. In this case the negative value is the reference and the response is now made clear.

This spread sheet shows typical experiment data

[https://docs.google.com/spreadsheets/d/1CYMXfXEv7Gr1uglNMXNCsA06aKROw-zba0Wy0Ov5\\_wl/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1CYMXfXEv7Gr1uglNMXNCsA06aKROw-zba0Wy0Ov5_wl/edit?usp=sharing)

2)

This is a folder with papers that explain the curves that are use to analyze the data

<https://drive.google.com/drive/folders/1qNBL60ufy0T7L1hUkf7KeaM2qFtw2LAp?usp=sharing>