# MKS 647c Software User Guide

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# 1 Purpose of Software

The purpose of this software is to enable users to create and run dynamic experiments using an MKS 647c Gas Flow/Pressure controller. This software allows users to design experiments that use pressure or flow rate as independent variables and modulate the values dynamically with respect to time. The capabilities of this modulation include: static (constant), linear, exponential, and periodic behavior.

The dynamic nature of the software allows users to choose any length of experiment composed of up to 100 cycles of identical behaviors. These cycles each have have the same time span and are composed of the same manipulation of the variable in question (i.e pressure or flow rate).

For example, this software could produce an experiment of 15 30-minute cycles in which the pressure in the system increases at a rate of 10 Pa/minute from 10 Pa to 160 Pa during the first 15 minutes of a cycle and then decreases from 160 Pa to 10 Pa over the second half of the cycle at the same rate. As the experiment is characterized by having 15 cycles, this process would repeat 15 times until the experiment is finally complete.

# 2 General Usage Overview

This section will provide a brief explanation of how to create and conduct experiments using this software.

## 2.1 Experiment Setup

1. Select whether you want to create your own custom experimental setup or implement a saved experimental setup.

2. Saved Experiment File Selection or Independent Variable Choice

(Saved) If you chose to implement a previously designed experiment, then select the ".data" file containing the setup details from where it is stored on your computer and hit "Start Experiment" to begin data collection. (End of experiment setup)

(Custom) If you chose to create your own experimental setup, the next step is to decide whether you want to use pressure or flow rate as your independent variable.

3. Select the number of cycles and the length of each cycle. If you want either 1 cycle or the length of a cycle to be 1 minute, you will have to click through a yes/no info box. This measure is in place so that the program knows that you are making this decision consciously.

4. Pressure Behavior Selection or Flow Rate Port Selection

(Pressure) If you chose pressure as your independent variable, you will now be given the chance to select the type of behavior (static, linear, exponential, periodic) and any relevant parameters for the selected behavior. Once you have finished entering in the required information, select the "Okay" button. If you omit any necessary information during this process, an error box will appear stating what remains to be entered.

> You cannot change information or behavior types of previously entered data after selecting "Okay". The only way to alter this information is by clicking the

"Back Arrow" in the top left-hand corner of the screen and reentering in all of the information.

Once you have supplied the program with information on what the pressure behavior should be over the entire course of each cycle (from 0 minutes through the end of the cycle,) you will proceed to the next screen.

(Flow Rate) If you chose flow rate as your independent variable, you must select the check box next to each port to which an MFC is connected. These check boxes correspond to the ports on the back side of the MKS 647c.

Ensure that the port you have selected is indeed occupied, otherwise, the program will not function properly.

Once you have selected a port, you must choose which gas is being controlled by the MFC connected to it. There will also be a check box labeled "Slave"[1], a drop-down menu labeled "Master"[2], and an entry field labeled "Ratio"[3] If you want to classify a port as a "slave" to another port, ensure that you have entered in all of the values necessary (master, ratio, gas.)

If you misclick or change your mind about using a specific port or designating a port as "slave" simply click on the check box again to deselect it before continuing onto the next page.

Once you have entered in all of the required information, click the "Submit" button at the bottom of the screen to continue on to the next screen.

[1] If a port is classified as a "slave," its behavior at any given moment will be determined by its "master" port flow rate multiplied by the provided ratio. This functionality is useful when specific gas compositions are needed.

[2] The "master" port is the port that is connected to the MFC whose behavior dictates the behavior of the slave. The flow rate of the "master" multiplied by the "ratio" will determine the corresponding "slave" port's flow at any given moment.

[3] See above.

If you have failed to enter a required data field or have selected an invalid "master" port, the program will generate an error message informing you what details to adjust.

## 5. Active MFC/Port Selector or Flow Rate Behavior Selection

(Pressure) If you chose pressure as your independent variable, you must now select the check mark next to each port that has an MFC connected to it. The port numbers are visible on the rear of the MKS 647c machine. Once you select a port, choose which gas is flowing through the attached MFC from the dropdown.

If you misclick or change your mind about using a specific port simply click on the check box again to deselect it before continuing onto the next page.

Once you have made all of your decisions, click on the start experiment button. If you have failed to enter any required fields, the program will generate an error message instructing you to fill them in.

If the data is entered correctly, you will be given the option to save your experimental setup or not. If you choose "No," the experiment will begin, otherwise you will need to choose a file name and location. The experimental setup you have created will be saved in that location under that name as a ".data" file.

(Flow Rate) If you selected flow rate as your independent variable, you will now be given the chance to select the type of behavior (static, linear, exponential, periodic) and any relevant parameters for the selected behavior for each gas over the course of a cycle. The gas and port whose behavior you are assigning is displayed on the left-hand side of the selection screen. You will choose the behavior of one gas at a time, all the way through the duration of a cycle. The gas behavior selection process will direct you to select the behavior of gasses by order of port number ($1 \rightarrow 8$). Note: You will not have the option to assign behavior to ports designated as "slave" as their behavior is dependent upon their respective "master" port.

Once you have finished entering in the required information for each

behavior instance, select the “Okay” button. If you omit any necessary information during this process, an error box will appear stating what remains to be entered.

> You cannot change information or behavior types of previously entered data after selecting “Okay”. The only way to alter this information is by clicking the “Back Arrow” in the top left-hand corner of the screen and reentering in all of the information.

Once you have supplied the program with information on what the flow behavior should be over the entire course of each cycle (from 0 minutes through the end of the cycle) for every gas, click the “Start Experiment” button. You will then be given the option of whether you want to save your experimental setup, or not. If you choose “No,” the experiment will begin, otherwise you will need to choose a file name and location. The experimental setup you have created will be saved in that location under that name as a “.data” file.

## 2.2 End of Experiment

Select a location and name for the data. It will be stored in the selected location under this name as a “.csv” file type. It can be accessed using Microsoft Excel.

# 3 Behavior Equations

The pressure and flow rate behavior is modeled based on the standard form of the representative equations (1-4). The practical equations, used to calculate the set points of the independent variable(s) are given in equations 5-8.

$$M(t) = m \qquad Static \tag{1}$$
$$M(t) = mt + b \qquad Linear \tag{2}$$
$$M(t) = ae^{rt} \qquad Exponential \tag{3}$$
$$M(t) = \alpha \sin(\omega t) + \beta \qquad Periodic \tag{4}$$

The following equations were used to assign pressure and flow rate set points on the machine.

Let us define the constants provided by the user: $M_i :=$ initial magnitude, $M_f :=$ final magnitude, $t_i :=$ start time, $t_f :=$ end time, $s :=$ number of oscillations. Also, let $t :=$ time at any given point.

$$M(t) = M_{i,f} \qquad Static \tag{5}$$
$$M(t) = \frac{M_f - M_i}{t_f - t_i}(t - t_f) + M_f \qquad Linear \tag{6}$$
$$M(t) = \frac{M_i}{2} \exp\left((t - t_i)\frac{\ln M_f - \ln M_i}{t_f - t_i}\right) \qquad Exponential \tag{7}$$
$$M(t) = \frac{M_f - M_i}{2} \sin\left(\frac{2\pi s}{t_f - t_i}t\right) + \frac{M_i + M_f}{2} \qquad Periodic \tag{8}$$