BIOREC user guide

Biorec, Bioreactor controller 1.3
18.01.2016

Open source disclaimer for Biorec

IMPORTANT READ CAREFULLY

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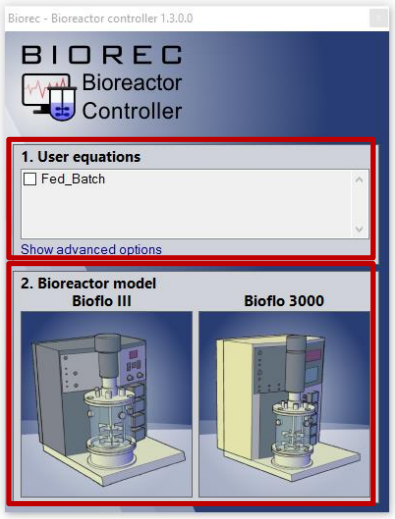
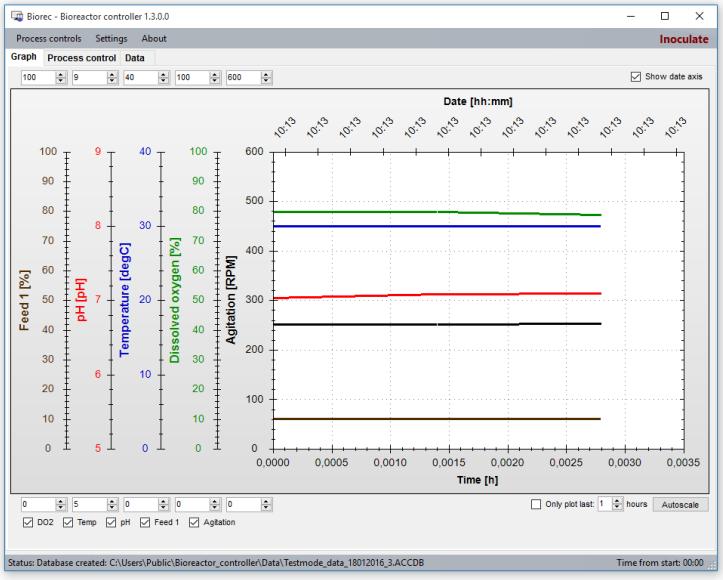
Biorec quick start guide

First, switch on your bioreactor and make sure that it is connected to your computer, and then run **Biorec.exe**



1. Select optional equation groups from the startup **panel 1**

2. Click on the correct bioreactor model on the startup **panel 2**
The main window will then open (Figure below).



3. When you have inoculated your culture, click on the **Inoculate** button in the top right corner of the main window. Then confirm with **Yes**. This action will restart the clock.
All the preparations are now done.

4. You can observe your fermentation process from the **Graph** tab and control it from the **Process control** tab.

Closing Biorec

5. When you are closing Biorec, click on the "**Stop logging and updates**" action from the top left **Process controls** dropdown menu. Confirm this action by clicking **Yes**.

6. Close the program from the **X** at the top right corner of the main window. Confirm this action by clicking **Yes**.

Contents

Introduction

Biorec, bioreactor controller is a control program written for Windows operating systems to provide data logging, process monitoring and control for pilot and laboratory scale BioFlo series (Eppendorf AG, Hamburg/Germany) bioreactors. The supported bioreactor models are BioFlo III and BioFlo 3000 (other BioFlo series models have not been tested in action). Biorec supports process automation through user programming that allows controlling pumps, temperature or agitation by user's mathematical equations.

Installing Biorec

Biorec is a standalone executable that does not require any installation. However, Biorec.exe should be placed outside the 'Program Files' directory because it has administrative protections. A suitable location would be for example "C:\Biorec\".

You may then add a shortcut to the desktop by right-clicking the Biorec.exe and selecting "Create shortcut" and dragging that shortcut to the desktop.

First run setup

First, switch on your bioreactor and make sure that it is connected to your computer (see 'Serial cable' chapter). Then start Biorec and click your bioreactor model on the startup window. If your BioFlo series bioreactor is not represented, select BioFlo 3000.

Go to **Settings**. There are a couple of things to check.

- Multidrop number (General tab) – Check your bioreactor's manual
- Serial port (Serial ports tab) – Use Windows device manager if you are not sure about the bioreactors's COM port number.
- Baud rate (Serial ports tab) – Check your bioreactor's manual (Default: 9600)
- Parity (Serial ports tab) – Check your bioreactor's manual (Default: Even)
- Stop bits (Serial ports tab) – Check your bioreactor's manual (Default: Two)
- Data bits (Serial ports tab) – Check your bioreactor's manual (Default: 8)

After any changes, click **OK** and close Biorec to apply the new settings. Then, open Biorec again and select bioreactor model. Biorec should then start updating sensor values automatically if the serial port and multidrop settings are correct (…and bioreactor is ON and connected).

System requirements

Operating system – Windows Vista, 7, 8 or 10.

Recommended system requirements

CPU – Core 2 Duo or Athlon X2 at 2.4 GHz
Memory – 2 GB RAM
Hard drive – 8 GB of free space

Serial cable

BioFlo bioreactors use a 25-pin serial port that utilizes RS-232 protocol for serial communications. Pins Rx, Tx and GND are required for communications.

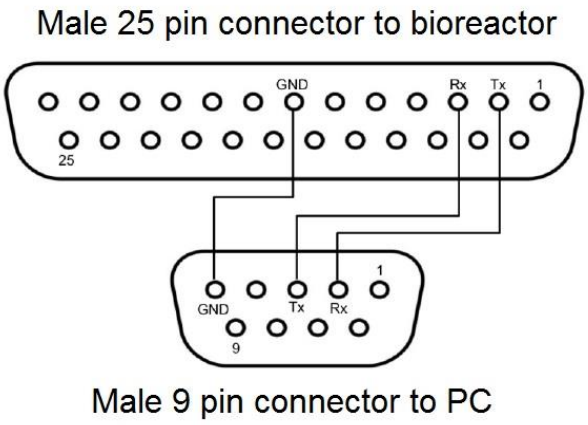


Figure 1. Serial cable's connected pins. Modified from Burdge and Libourel's article: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0092108

If this cable is not available, it can be easily soldered from D-sub connectors:

- Male DE-9 connector - http://www.digikey.com/product-detail/en/DE09P064TXLF/609-1524-ND/1001838
- DE-9 connector hood - http://www.digikey.com/product-detail/en/977-009-010R031/909GPE-ND/858497
- Male DB-25 connector - http://www.digikey.com/product-detail/en/172-E25-103R001/1125MEA-ND/955353
- DB-25 connector hood - http://www.digikey.com/product-detail/en/977-025-010R031/925GPE-ND/858501
- Multiple conductor cable - http://www.digikey.com/product-detail/en/ATUP-P305T/ATUP-P305T-ND/2218210

The provided product links are just examples. Similar components will work as well.

Default directory

The Biorec's default saving directory is: **C:\Users\Public\Bioreactor_controller**

This is the saving directory for process logs, user equations and settings.

Database

Biorec creates a MS Access database to the default directory at the start and updates it constantly. The database contains six data tables: Beforeinoculation, Directives, Sensors, Log, Setpoints and Outputs. The actual sensor, pump and user variable data is logged, first to "Beforeinoculation" data table and after inoculation to "Sensors" data table. "Log" data table contains all the status and error messages. Data tables "Setpoints" and "Output" log the sensor set point and output values.

Running Biorec

Startup window

The startup window (Figure 2) is launched at the beginning when opening the Biorec. It has two numbered panels.

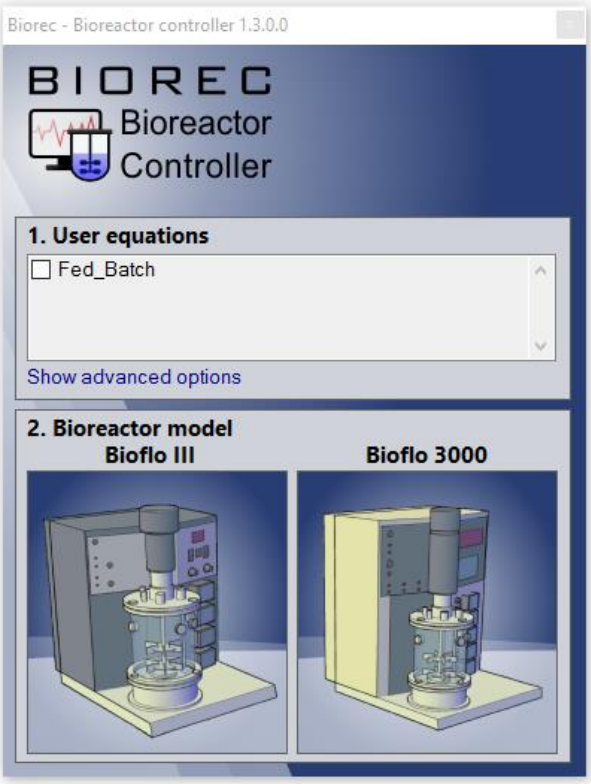


Figure 2. Biorec's startup window.

Panel 1. User equations

User's mathematical equations can be created, edited, deleted and selected from this panel. In the first view, only the quick equation group selections are visible. To see more options, click on the Show advanced options.

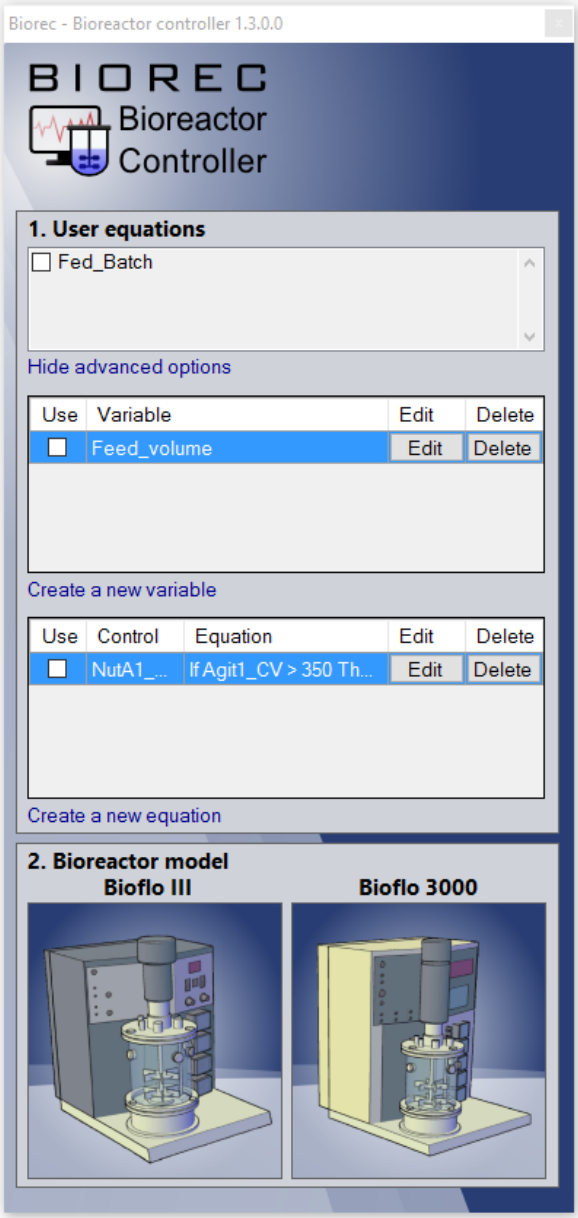


Figure 3, Expanded startup window.

The expanded panel (Figure 3) consists of three lists: Equation group selection, variable selection and equation selection. The group selection is the first list and it is a quick selection that activates all group variables and equations at once. The next lists are for variables and equations. Variables and equations can be created, edited, selected and deleted from here. See more on how to create a variable or an equation from the "User equations" chapter. If a variable or an equation is checked from the Use checkbox, it is included in the process.

Panel 2. Bioreactor model

The third and final panel selects the bioreactor model. This is selected last because the selection starts the process. The selection is done by clicking the correct model. If the used model is not available, try to use the BioFlo 3000.

After the model selection, the main window appears and the process begins.

Main window

The main window is divided into three tabs: graph, process control and data. The graph tab has one dynamic graph. The bioreactor can be controlled from the process control tab that shows all the bioreactor's sensor and pump set point and current values. The data tab contains the raw data and a status log.

Graph tab

The graph tab (Figure 4) has a dynamic graph that can plot all the available variables (sensors, pumps, agitation, gas, foam, sound and user variables) at once. Variables are plotted so that each variable has their own individually scalable y-axis. The x-axis is the elapsed time from the process start and the corresponding real time can be plotted as the second x-axis. All plotted variables are selected from the checkboxes 

below the graph. The graph area can be panned and zoomed with mouse's center wheel.

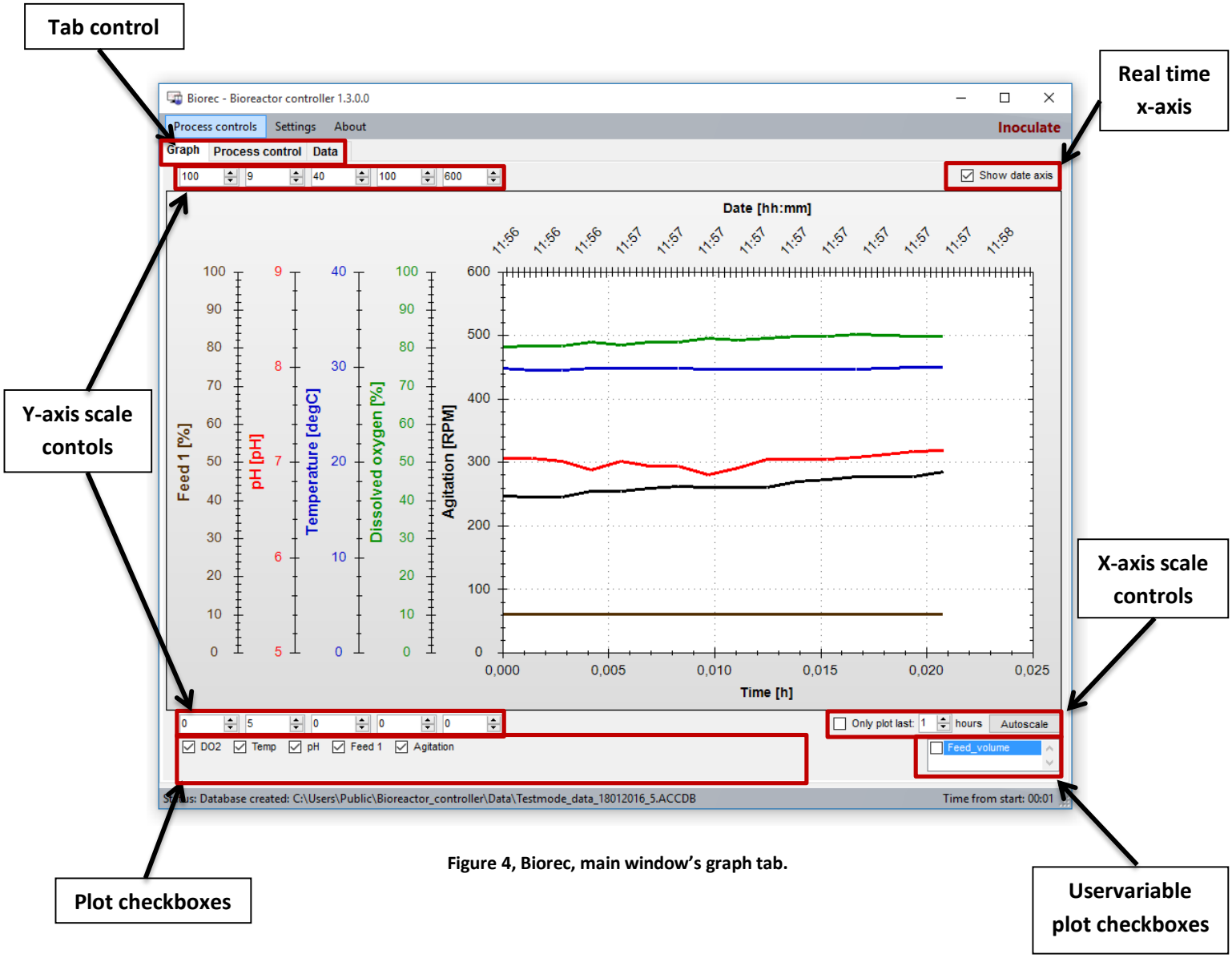


Figure 4, Biorec, main window's graph tab.

Process control tab

The process control tab's panel (Figure 5) configuration is customized for each bioreactor model so the outlook will vary based on the model. This tab shows all the current, set point (Op. point:) and output values. New set point and output values can be assigned from here. The set point by definition is the target value set for that variable and the output corresponds to the relative power percentage of the bioreactor's PID controller. A new set point value is assigned by entering a new value into the numerical box 30,0 , and activating it with Set button.

The output % values can be directly controlled if the advanced controls checkbox is checked, but this is not recommended.

The Inoculate button resets the process clock.

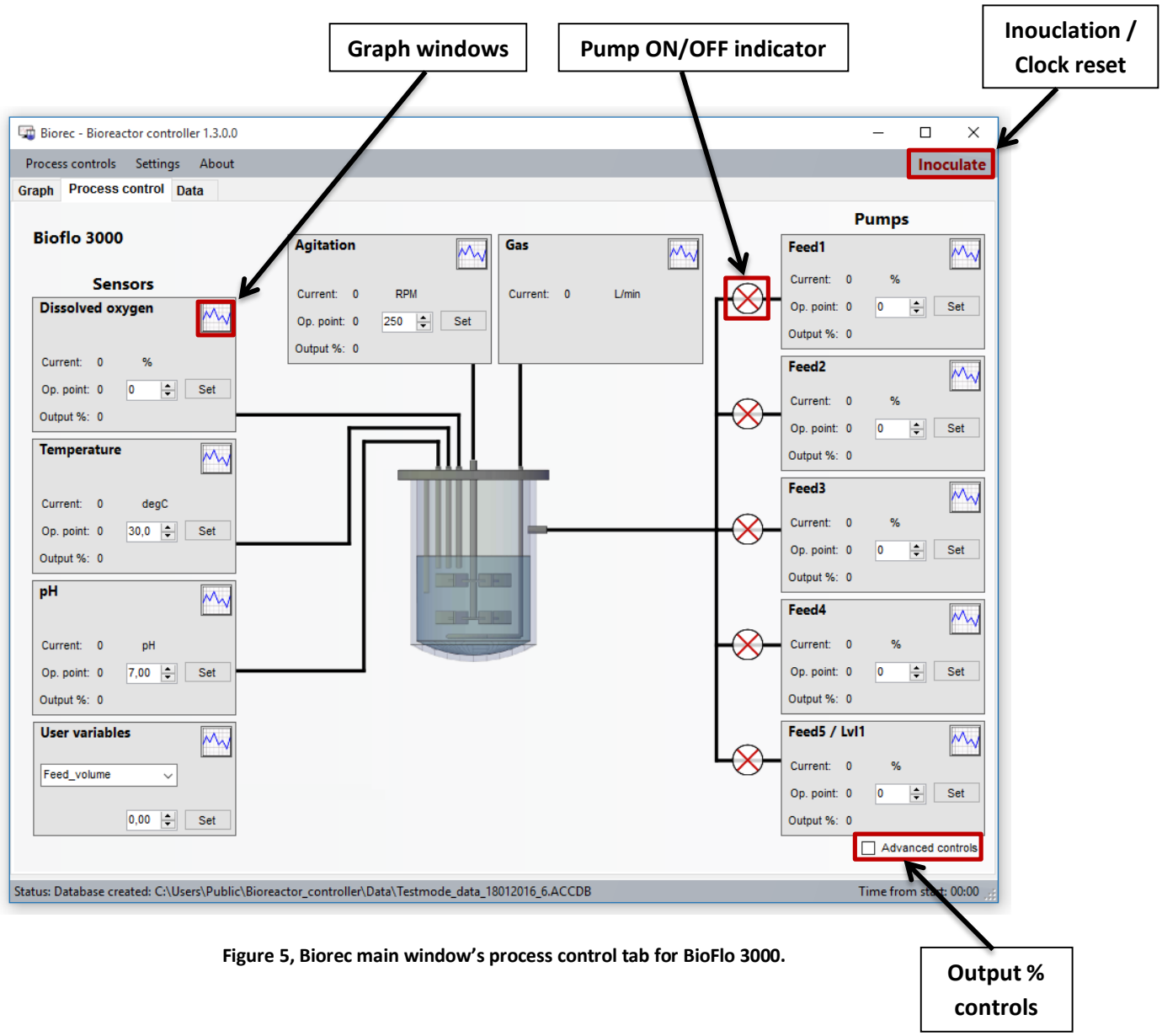


Figure 5, Biorec main window's process control tab for BioFlo 3000.

In addition to the graph tab, each sensor, pump or user variable can be individually plotted in a separate graph window (Figure 6) by clicking the corresponding  icon from the process control tab.

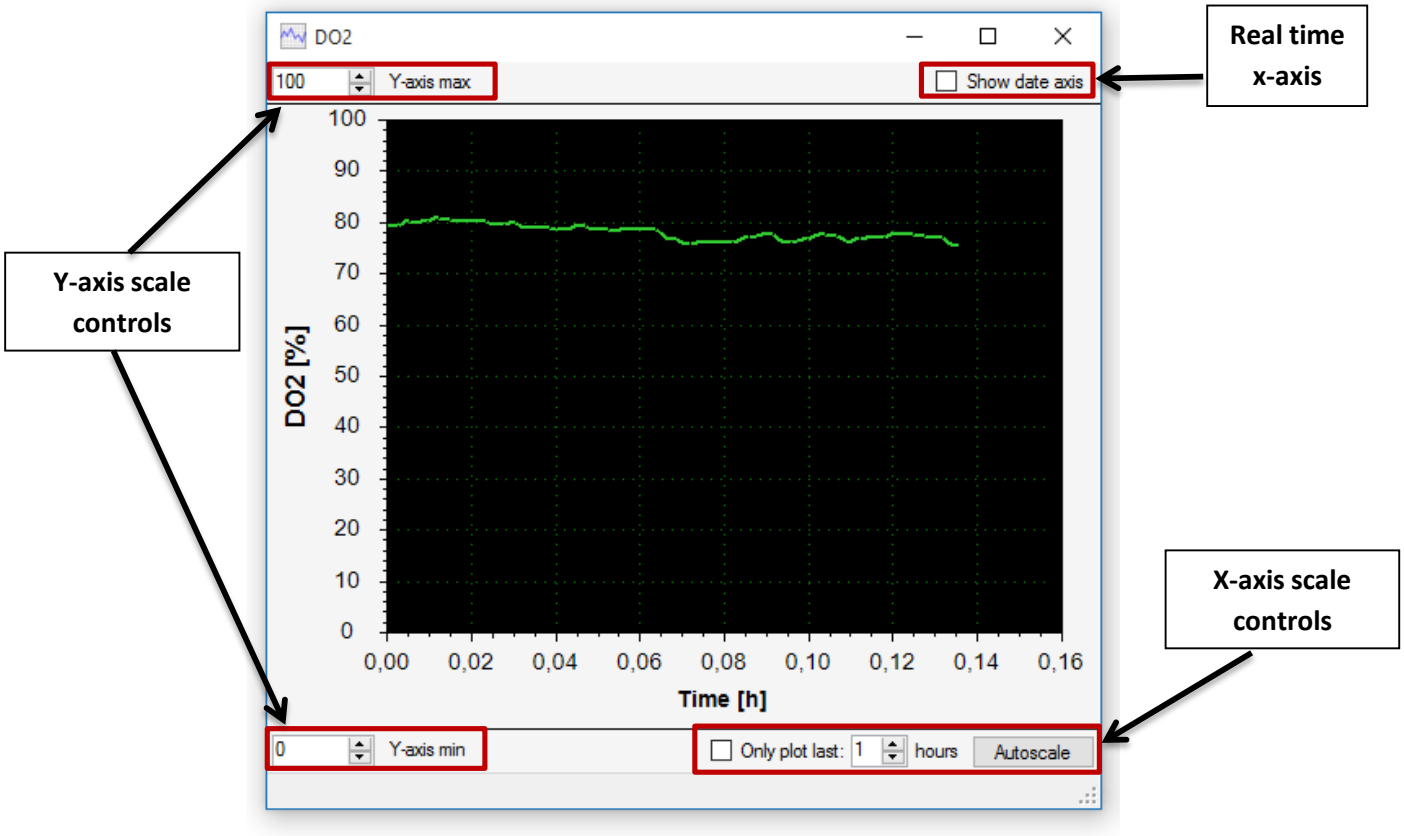


Figure 6, Graph window.

Data tab

The data tab (Figure 7) has all raw sensor, pump and user variable data in a chart and a status log. The status log shows all process events, alerts and error messages. The last status message is always shown in the status bar at the bottom which is visible in all tabs. The process clock is located in the same bar on the right side.

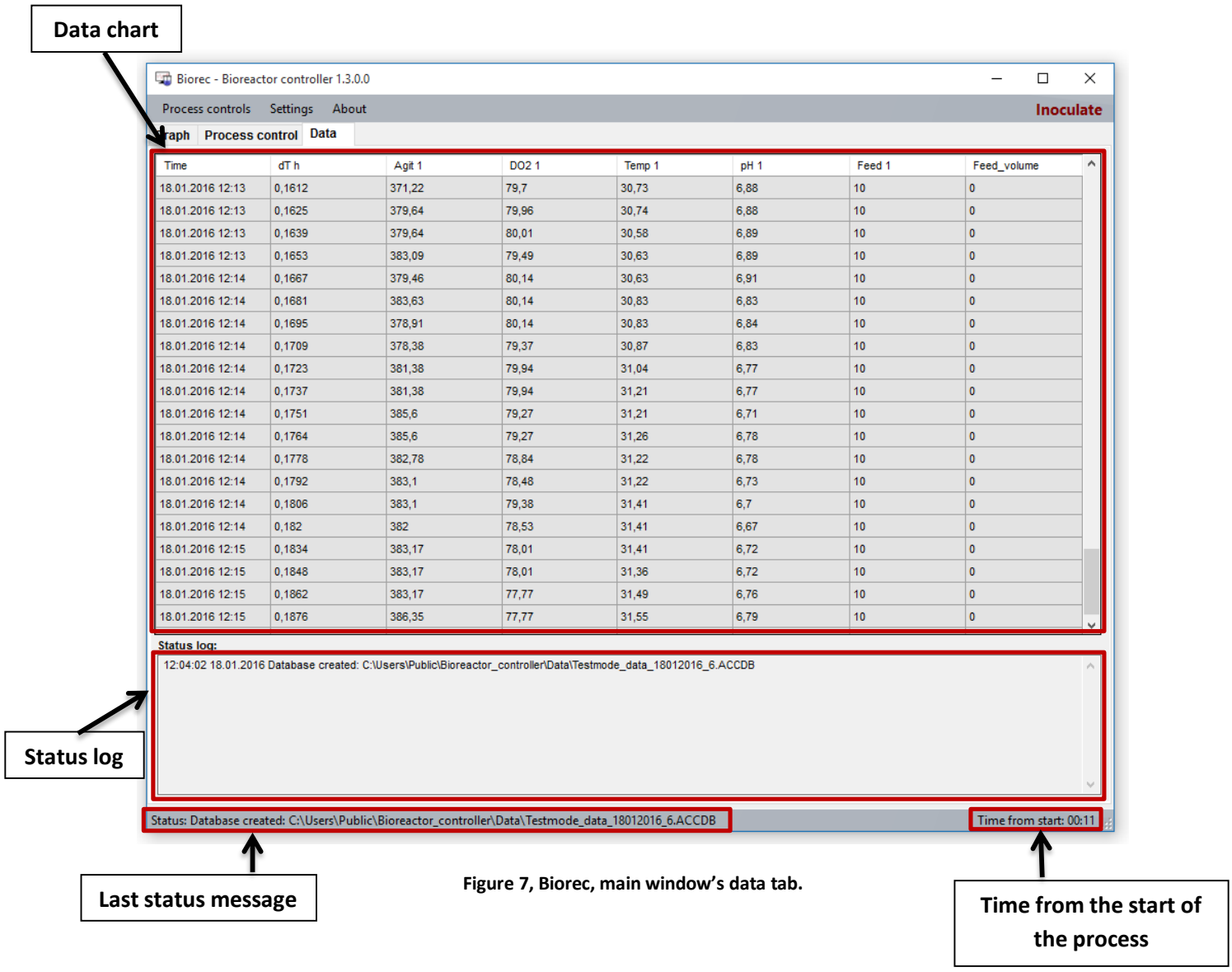


Figure 7, Biorec, main window's data tab.

Settings

The settings can be accessed from the Settings button that is located in the tool strip at the top of the main window. The settings window is divided into five tabs: General, Serial ports, Email, Alerts, and Equations.

General

The general tab includes options for the main graph colors and for the bioreactor's multidrop number.

Each default variable's color can be changed by clicking the label in the settings general tab (Figure 8).

For the multidrop number, see your bioreactors manual.

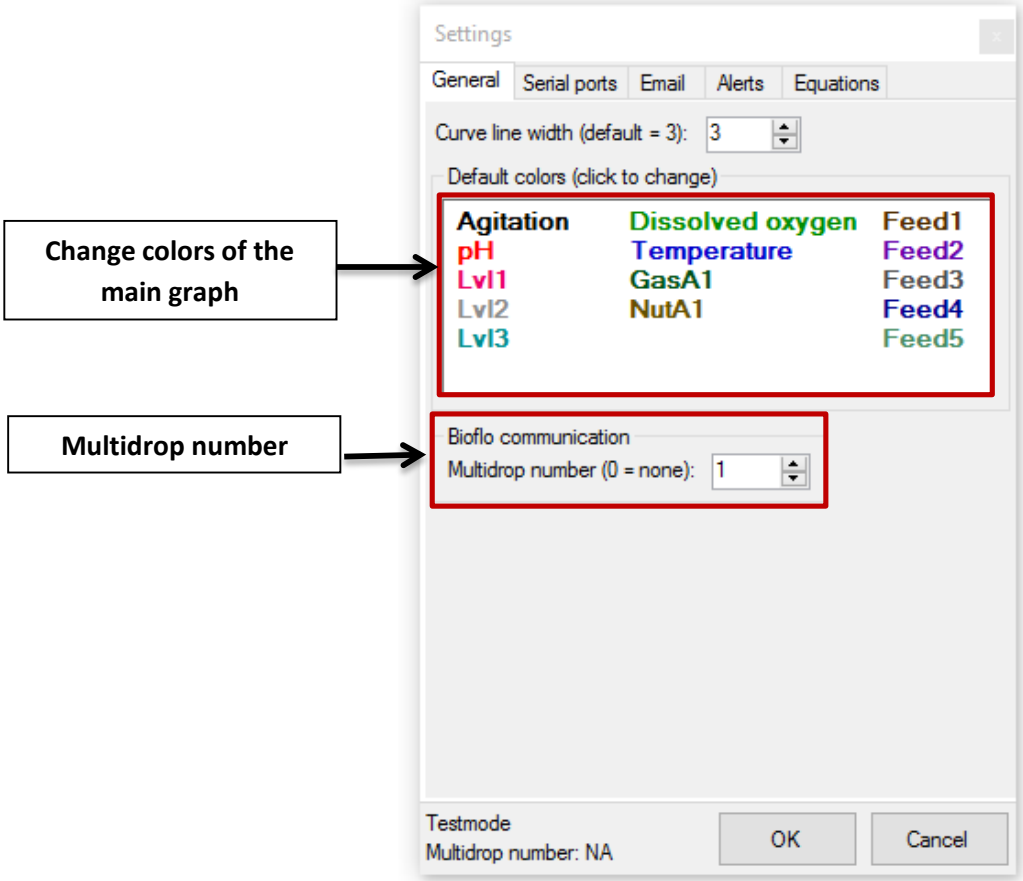


Figure 8, Settings, general tab.

Serial ports

Bioreactors serial port settings (Figure 9). Every time these settings are changed, the Biorec must be restarted.

The default settings for BioFlo communications are: COM1, Baud 9600, Parity Even, Stop bits 2, Data bits 8.

Check the bioreactor's manual for your serial communications settings.

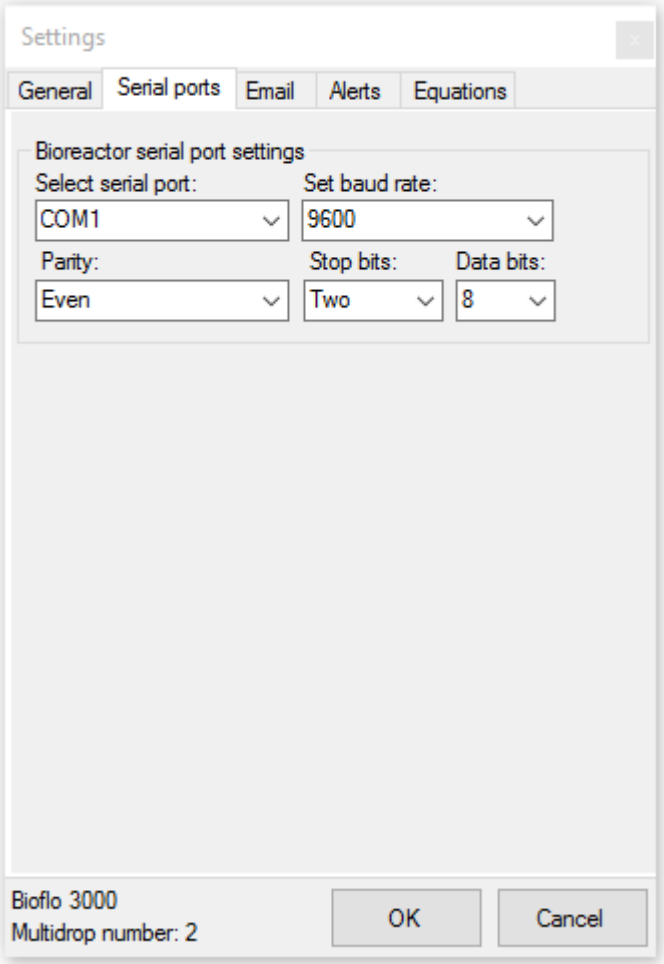


Figure 9, Settings, serial ports tab.

Email

Biorec can send email process updates or alerts to user's email address. The user's email address is typed into the specified field in settings, email tab (Figure 10), and after clicking OK, Biorec has to be restarted for the changes to take effect.

Biorec uses gmail servers for sending emails and it needs a gmail account to do so. Create a gmail account for Biorec and type the account name and password for the provided fields. Then click OK and restart Biorec.

The process updates can include all the current values in text form and a picture of the current main graph area (Graph tab).

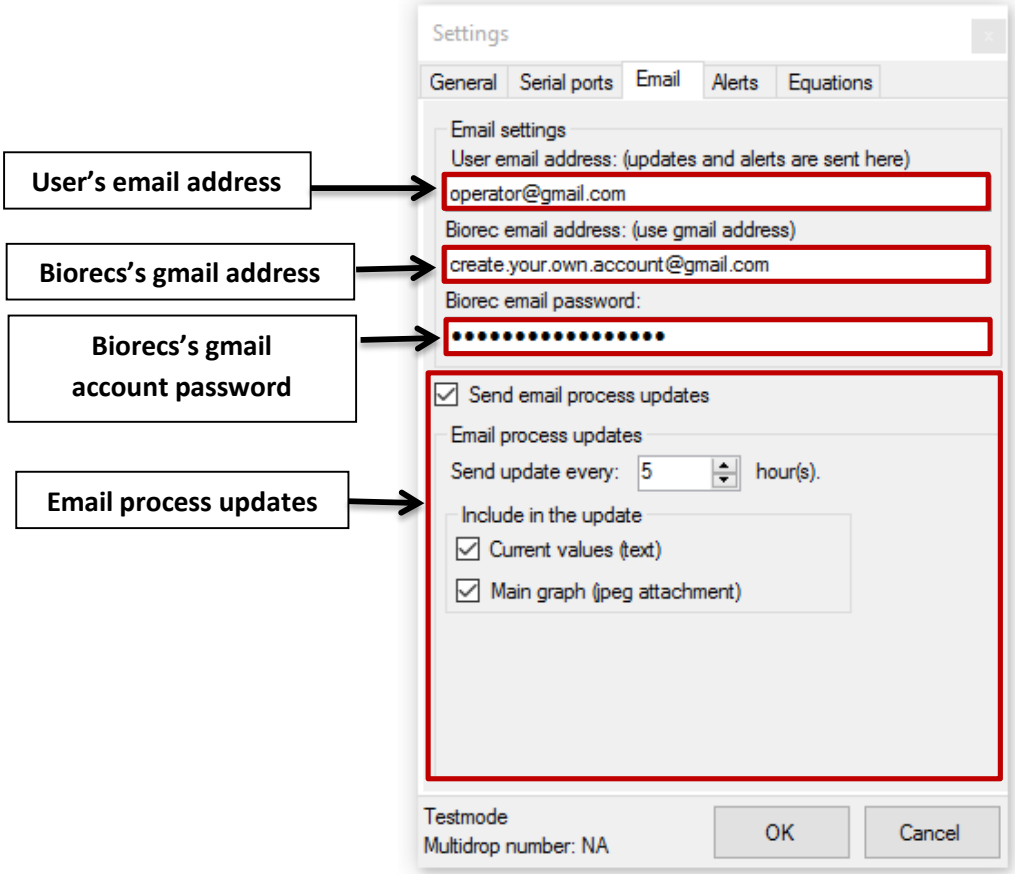


Figure 10, Settings, Email tab

Alerts

Low and high alert levels can be assigned for each variable and those levels can be configured in the alert tab (Figure 11). When alerts are enabled and an alert level is passed, an exclamation mark  icon is shown next to the corresponding sensor or pump in the main window's process control tab. Additionally, an alert message will show up in the status log.

Biorec can also send email alerts. These can be configured so that they are not sent immediately and that there is a minimum gap between email alerts for the same variable if the alert persist.

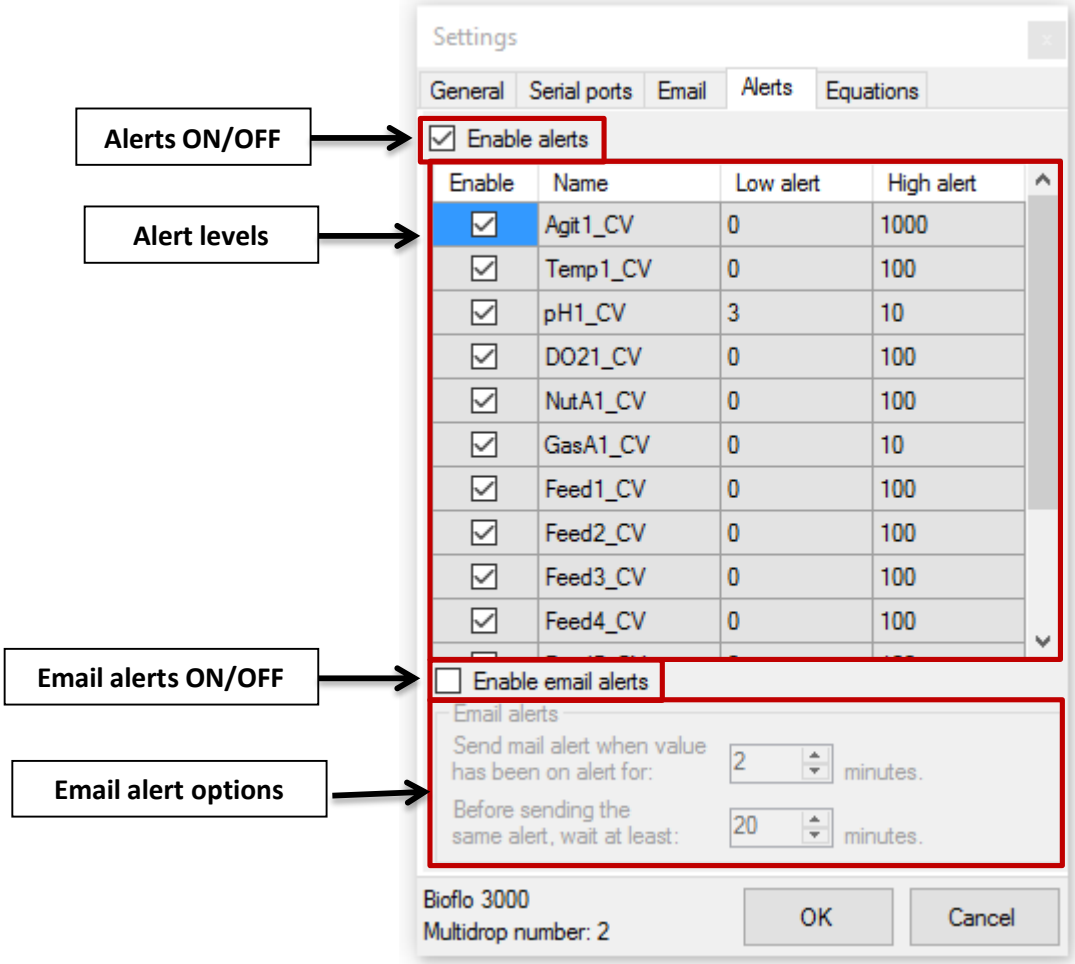


Figure 7, Settings, alerts tab.

Equations

All the current (those that were selected from startup window) user equations and variables can be edited or enabled/disabled from the equations tab (Figure 12). More about editing and creating these equations and variables can be found in the user equations chapter.

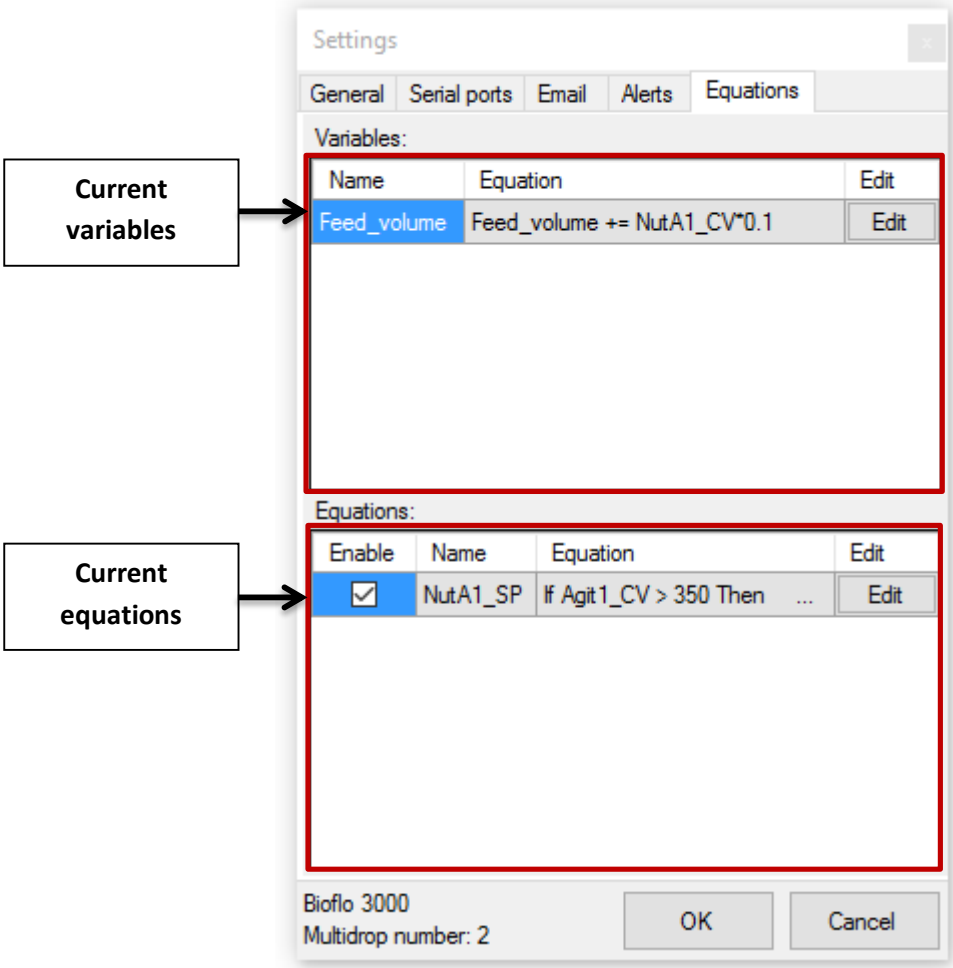


Figure 12, Settings, equations tab.

Pump control panel

All of the active pumps can be controlled from the pump control panel (Figure 13) that is accessed from the "**Pump control panel**" of the Process controls dropdown menu. Exact volume amounts can be added from this panel based on the tube's internal diameter. The pumps are set to 10% duty cycle when ON. The calculations assume that the tubes are already filled with liquid.

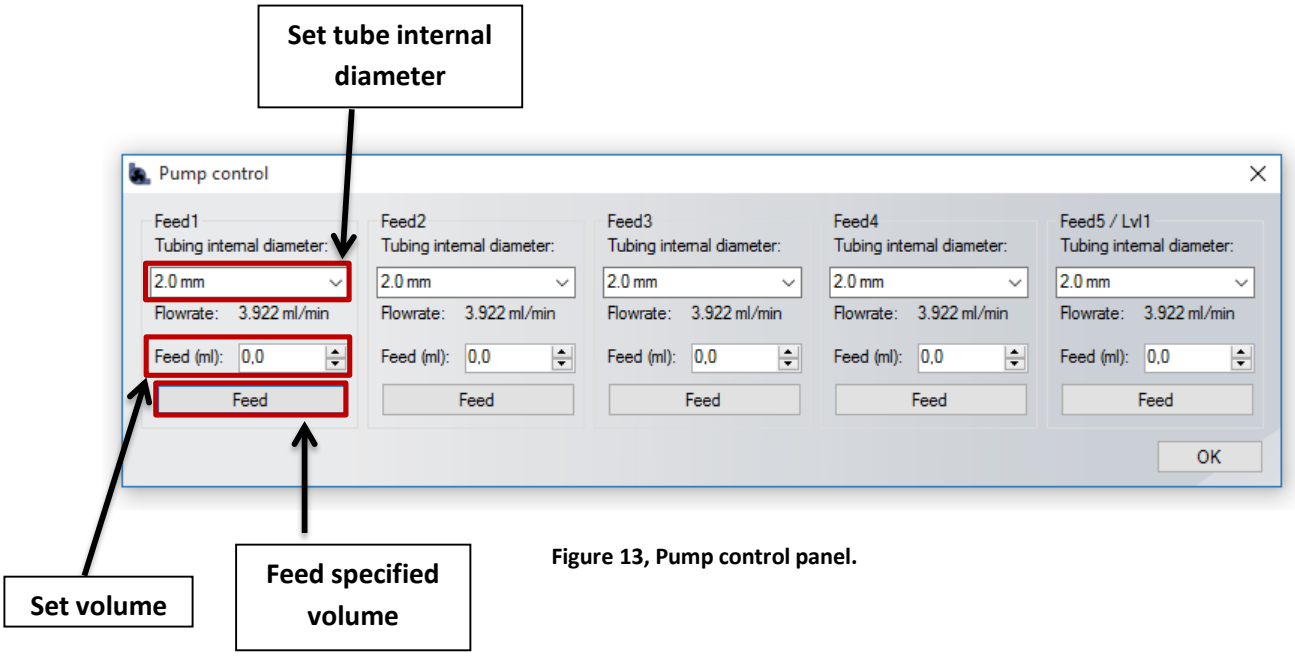


Figure 13, Pump control panel.

Saving

The Biorec saves automatically everything to a MS Access database that is created to the default directory. The user can also save data in CSV (tab separated) text format that can be imported to MS excel. Data can be saved as CSV from Process controls and selecting the "**Save data as *CSV**" and then selecting the data table of interest. The "**Process data**" contains all the sensor, pump and user variable logs.

"**More options**" opens a "**Save as CSV**" panel (Figure 14). It offers an option to choose a saving interval that removes data points from the data so that the saved points correspond to the selected time interval.

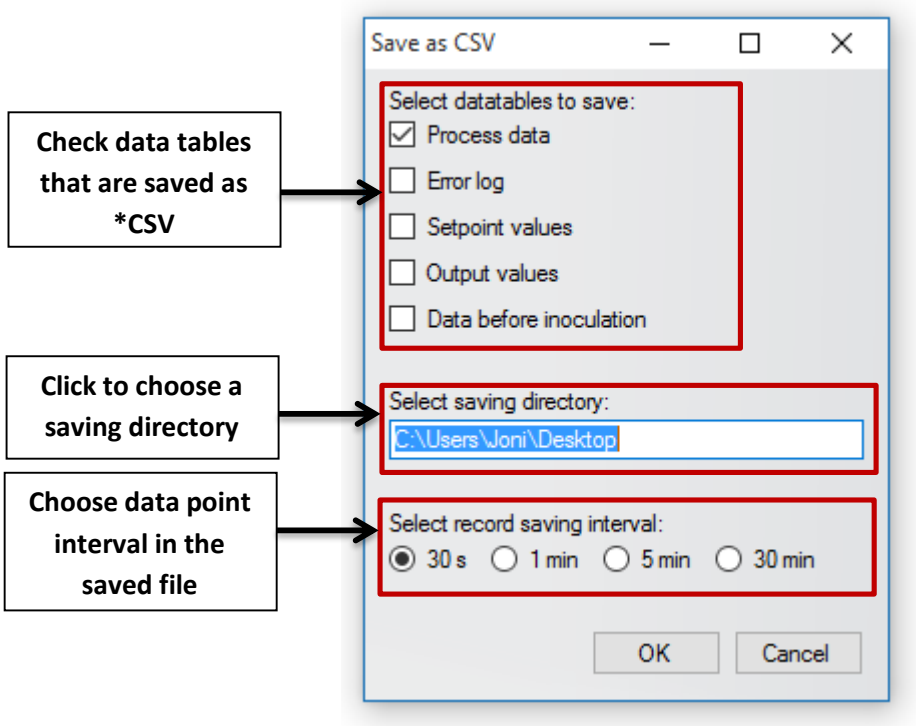


Figure 14, Save as CSV panel from Biorec.

Test mode

Biorec can be run in test mode without a bioreactor. It is useful for testing the controls of Biorec. To enter the test mode, press **F12** while on the startup window and click the appearing test mode icon.

User equations

The Biorec has a “User equations” feature that allows the user to create mathematical equations to control the bioreactor. This can be used for example to automate a pump.

Biorec allows the user to create variables and equations. Variables are shown in the main graph and they are logged to database just as any sensor. Equations however, control the bioreactor. They set new set points to a pump, agitation or temperature every 30 second (update cycle).

Create a variable

A new variable can be created from the startup window by expanding the window from Show advanced options and clicking the Create a new variable label. This opens a “**Create a new variable**” window (Figure 15).

There are three required fields: variable name, group name and variable code. The name can contain only alphanumeric characters and no special characters (no spaces, commas, dots etc.). If variables and equations have the same group name, they can be selected in group from the quick selection at the startup window.

The programming language is Visual Basic .NET and it can refer to sensors, pumps and existing variable names that are listed in the “**Reference variables**”. The sensors and pumps of the bioreactor contain “***_CV**”, “***_SP**” or “***_OU**” suffixes that are short for “**Current Value**”, “**Set Point**” and “**OutPut**”. Before creating a variable, the code can be checked for errors with Debug code button.

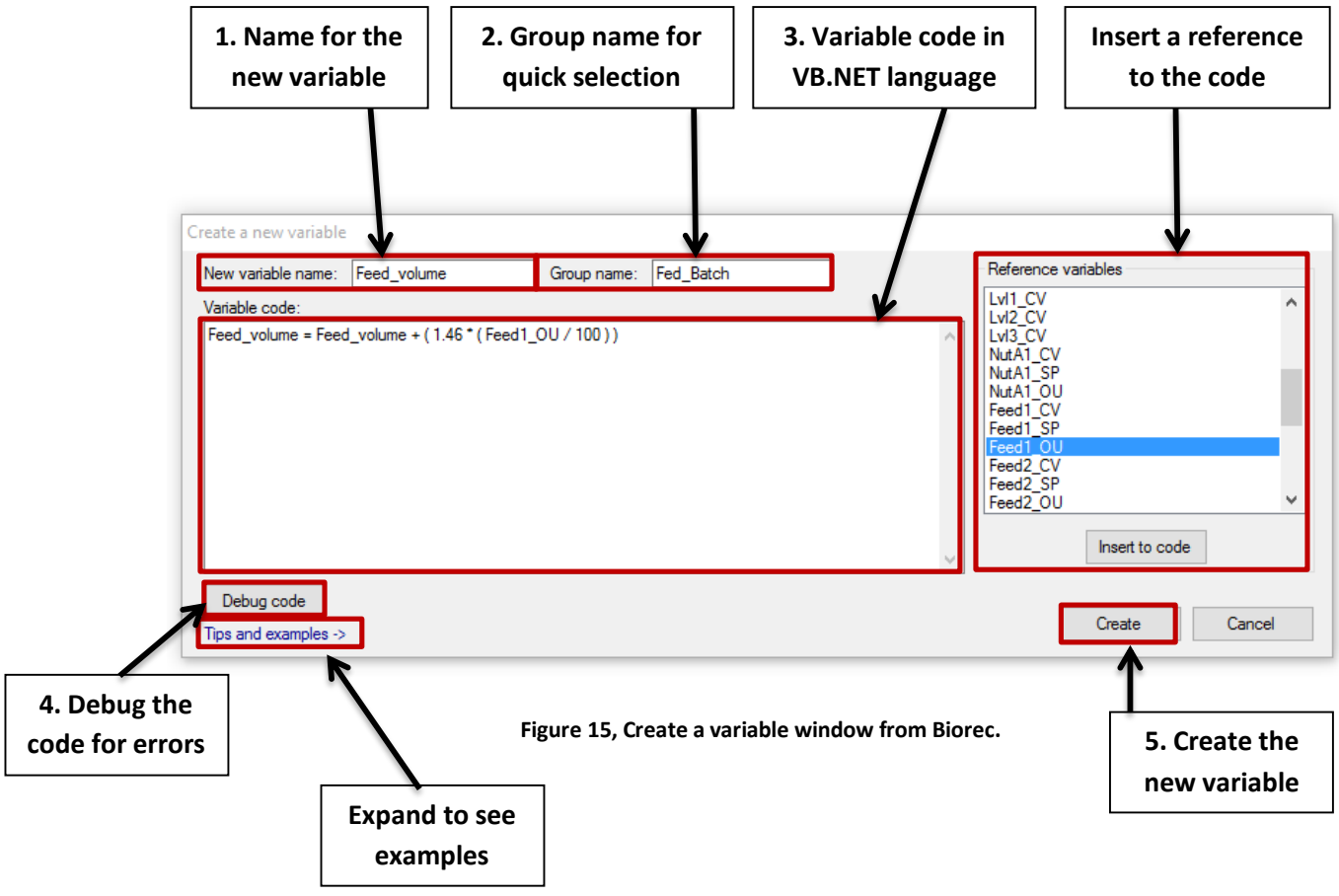


Figure 15, Create a variable window from Biorec.

Create an equation

A new equation can be created from the startup window from Show advanced options and clicking the Create a new equation label. This opens a "**Create a new equation**" window (Figure16).

There are three required fields: The controlled variable (pump, temperature, or agitation set point or output), group name and the equation code. If variables and equations have the same group name, they can be selected in group from the quick selection at the startup window.

The equation code has to be in Visual Basic .NET language and it can refer to sensors, pumps and existing variable names that are listed in the "**Reference variables**". The sensors and pumps of the bioreactor contain "***_CV**", "***_SP**" or "***_OU**" suffixes that are short for "**Current Value**", "**Set Point**" and "**OutPut**".

Before creating an equation, the code can be checked for errors with Debug code button. The equations are saved with running indexes so if there are two equations for Agit1_SP, the first one will show in the startup window as Agit1_SP_1 and the second one Agit1_SP_2. **The equation calculations are rounded to two decimals** so if the code uses old variable value to calculate a new one, this rounding must be taken into account. If the change in new value is rounded away then the equation is not progressing. The rounding limitation can be bypassed by calculating values only every X:th cycle using "**Mod**" operator (see examples).

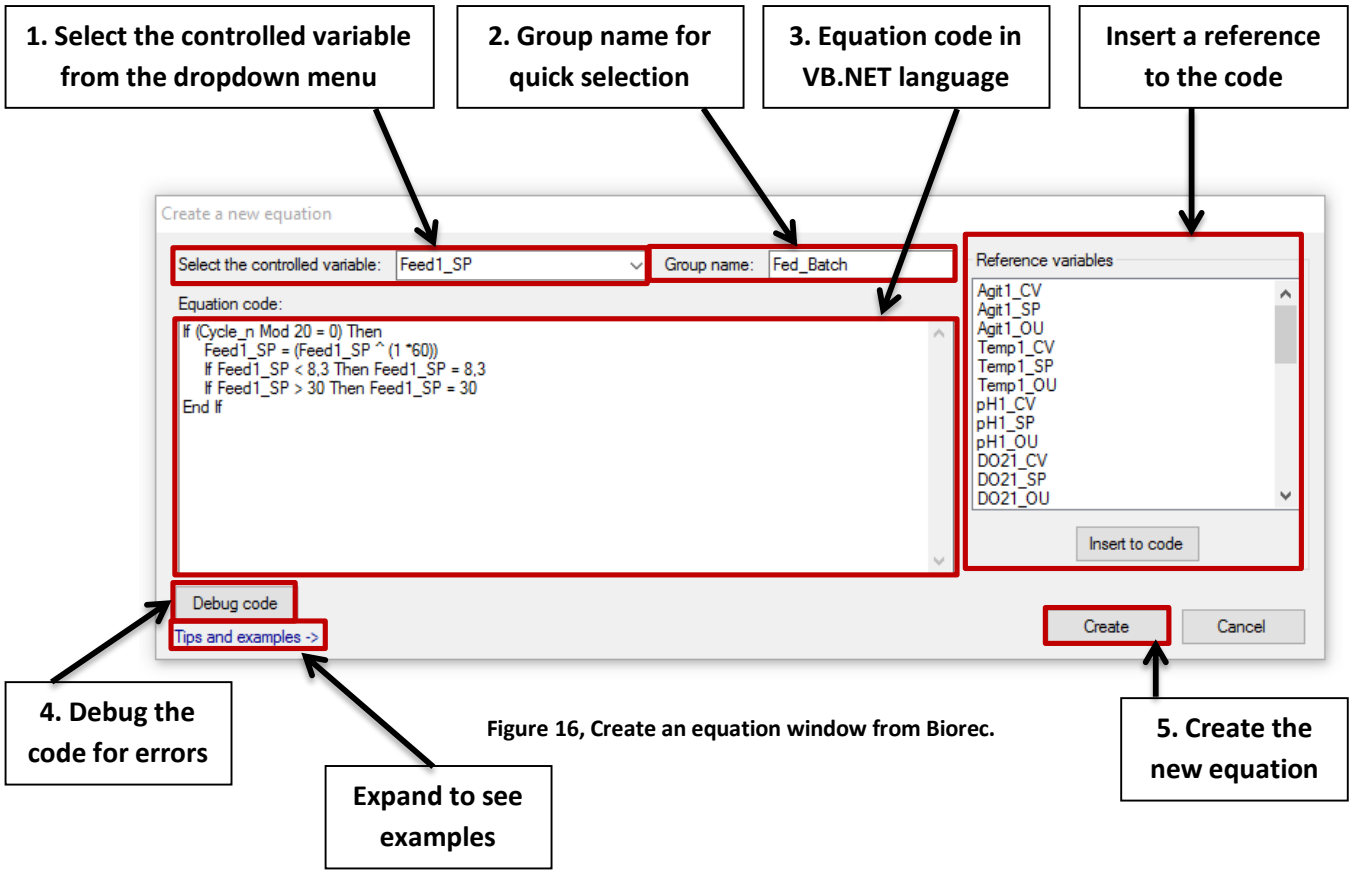
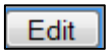


Figure 16, Create an equation window from Biorec.

Edit variables and equations

The variables and equations can be edited from the expanded startup window by pressing the 

button next to the variable or equation. This will open a similar editor as in the creation process. Variables and equations can also be edited while the program is running from the settings equation tab.

Delete variables and equations

The variables and equations can be deleted from the expanded startup window by pressing the 

button next to the variable or equation.

User equation programming language (VB .NET)

This language reference is not meant to be comprehensive and other information sources are recommended to learn Visual Basic .NET programming language.

Arithmetic operators

7 **+** 2 = 9	Addition
7 **-** 2 = 7	Subtraction
7 **/** 2 = 3.5	Division
7 **** 2 = 3	Integer division
7 ***** 2 = 14	Multiplication
7 **^** 2 = 49	Exponentiation
7 **Mod** 2 = 1	Remainder division (leaves only the division remainder)
sqrt(4**)** = 2	Square root
Log(9**)** = 2.19...	Natural logarithm
Log(100 **,** 10**)** = 2	Logarithm of specified number
Round(3.5**)** = 4	Round to the nearest integer
Floor(3.5**)** = 3	Round to inferior
Ceiling(3.2**)** = 4	Round to superior
Max(3 **,** 4**)** = 4	Returns the larger of two numbers
Min(3**,** 4**)** = 3	Returns the smaller of two numbers
Sin(pi**)** = 0	Sine of an angle in radians
Cos(pi**)** = -1	Cosine of an angle in radians
Tan(pi**)** = 0	Tangent of an angle in radians
Asin(0**)** = 0	Returns the angle whose sine is the specified number
Acos(-1**)** = 3.1...	Returns the angle whose cosine is the specified number
Atan(0**)** = 0	Returns the angle whose tangent is the specified number

Logical operators

=, **<**, **>**, **>=**, **<=**, **<>**
And, **Or**, **Xor**, **Not**

Examples

New variable: NewUnder

```
If DO21_CV < 40 then                    If dissolved oxygen's current value is under 40 then
   NewUnder = NewUnder + 1                 Add one to the variable if the if rule is true
End If                                  End of the first if rule

If NewUnder < 0 then                    If NewUnder is below 0 then
   NewUnder = 0                            make it 0
ElseIf NewUnder > 1 then                If the NewUnder is not under 0 but it is over 1
   NewUnder = 1                            make it 1
End If                                  End the second if rule
```

New equation: Feed1_SP

```
If (Cycle_n Mod 20) = 0 Then            If the update cycle number divisible by 20 (run every
                                        10 minutes)
   Feed1_SP = (Feed1_SP ^ (1 / 60))     Grow feed exponentially
   If Feed1_SP < 8.3 Then Feed1_SP = 8.3   Set lower limit for feed
   If Feed1_SP > 30 Then Feed1_SP = 30     Set upper limit for feed
End If                                  end of the outer if statement
```

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Version 3, 29 June 2007

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The precise terms and conditions for copying, distribution and modification follow.

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1. Source Code.
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