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White Paper

UniGo™ Pump — Increasing Pump Control Performance

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Introduction and UniGo Pump Operating Principle

UniGo pump is comprised of an internal manifold which contains two proportional valves: one regulates the injection of air in the reservoir and the second regulates the ejection. Nevertheless, due to physical constraints within the valves (orifice size, etc), the maximum air flow rate through these valves is limited. Therefore, the capacity of the UniGo pump to build up or release the pressure within the reservoirs containing the media is also limited.

UniGo Pump Control Basic Principle: PID Algorithm

Standard PID settings

- Proportional (P): the proportional gain defines how quickly the system will change its output to reduce the existing error (flow rate set point minus current flow rate). Therefore, the proportional parameter will increase the speed of the control system response. However, if the proportional value is too large, the system will begin to oscillate. Using P parameter on its own may lead to a steady-state error (offset) between desired flow rate and current flow rate.

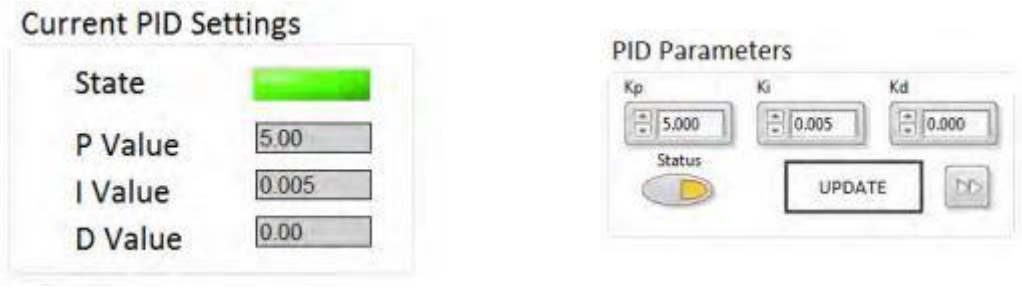

Figure 1

- Integral (I): the integral term sums the instantaneous flow rate error over time and gives the accumulated offset that should have been corrected. Thus, its main purpose is to drive the flow rate steady-state error to zero. A large value of the Integral parameter may cause the system to overshoot the set point value and even oscillate.
- Derivative (D): the derivative term is proportional to the rate of change of the system output (pump flow rate). Therefore, it "predicts" the system behaviour decreasing the system output if the flow rate is changing rapidly. This parameter helps to reduce overshoot and settling time, but an incorrect value may cause the system to become unstable

Advanced options

- Lift-off current (LOC): the lift-off current is the minimum current required for the valves to open. This value is dependent on the input pressure as well as the operating pressure. Represents the minimum current applied to the valves in the steady state. Changing this parameter may increase the responsiveness of the control but a value too high will impede the valve to close completely in the steady state which may lead to a leaky system. The maximum value allowed is the maximum current value

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- Maximum current: this represents the maximum current applied to the valves in order to open fully. Reducing this value might reduce the instability of the system. However, the maximum air flow that the system is able to inject, or release is reduced accordingly. The minimum value allowed is the current LOC value.

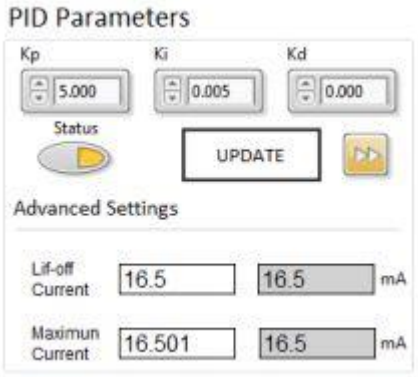

Figure 2

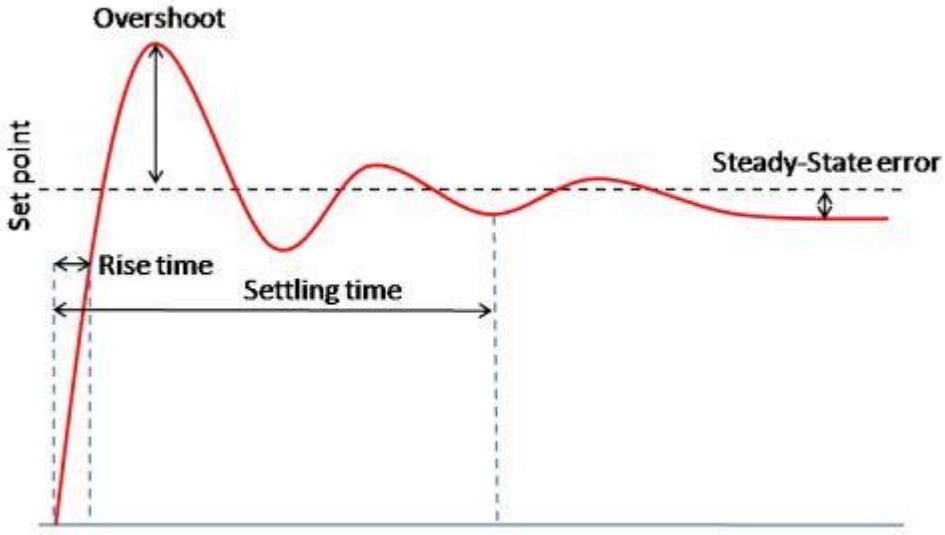

Figure 3

How to tune PID

- Set all parameters to 0.
- Increase P and change the set point until the dynamic response of the pump is fast enough without oscillating.
- Increase gradually the I value in order to minimize the steady-state error. Integral parameter can be any value between 0 and 1 but it is very sensitive and may cause the system to oscillate. Therefore, it is recommended to start using a value of 0.001. A value over 0.1 will probably lead the system to become unstable.
- In case of a large overshoot when changing the set point, increase the D value gradually until the optimal ratio overshoot/response time is achieved. However, a large value of D may slow down the dynamic response of the system.

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The default control parameters will satisfy most of the users demands, offering a fast, stable and accurate control of the desired fluidic's flow rate. The accuracy of the flow rate in the case of the UniGo pump is mostly related to the accuracy of the Flow sensor and not to the control strategy itself. Thus, the guidelines described below will focus on the other two main parameters which define the UniGo's performance: speed and stability.

Increasing the Stability of the UniGo Pump

When running an experiment with fixed flow rate set point over a long period of time, the UniGo control system will try to reduce the accumulated flow rate error to zero. However, when in absence of an external source of disturbances, the system presents significant variations from the set point or continuous disruptions on the flow; the user must try to identify the source of the instability and apply one of the correctives actions in order to improve the flow control.

Low operating pressure

Definition

Normally the UniGo pump requires a minimum operating pressure between 10 and 30 mbar[1] in order to have a satisfactory control of the flow. This parameter is intrinsically related to the fluidic resistance of the microfluidic channel to which the UniGo pump is connected.

Corrective actions

- The user must artificially increase the fluidic resistance of the channel by adding a fluidic restrictor in series or by modifying the geometry of the channel.

High pressure gradient

Definition

This occurs when the input pressure is orders of magnitude above the required operating pressure of the system. If the pressure gradient is too high, the minimum injection of air possible causes a big distortion on the fluidic flow rate which may lead to the instability of the system.

Corrective actions

- Decrease the input pressure: as a general rule, it is recommended to use an input pressure between 20 and 50% above the maximum operating pressure required.
- Decrease the maximum current parameter of the valves: reducing the maximum current will reduce the opening range of the valves and therefore reduce the minimum air injection rate.

[1] This value has been experimentally determined by Cellix Ltd. and may vary according to the customer's final setup.

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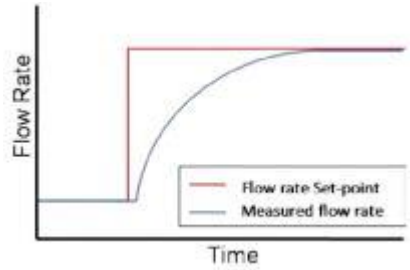
Increasing UniGo Pump Dynamic Response

In applications that require rapid changes of the flow rate set point or in which the flow rate must follow a complicated flow rate profile, the default control parameters of the UniGo pump may be not satisfactory enough for the end user.

UniGo does not respond fast enough to the set point changes (undershoot)

Definition



When changing the set point, the measured flow rate takes a long time to reach the desired value.

Corrective actions

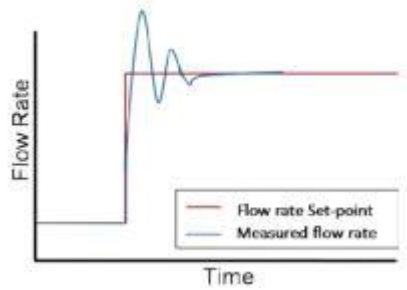
- Gradually increase the P parameter of the PID until the response is acceptable.[2]
- Gradually increase the input pressure: increasing the input pressure will allow more air to flow into the reservoir increasing the pressure more rapidly and therefore increasing the flow rate accordingly.[3]
- Reduce the volume of the reservoir: reducing the size of the reservoir will allow the UniGo to build up or decrease the pressure more rapidly.

[2] Increasing the P value too much may improve the dynamic response of the pump but may lead to oscillations

[3] Increasing the input pressure may improve the dynamic response of the pump but may increase the instability of the pump for stationary flow rates. Please refer to section 3 for more information.

UniGo responds too fast to the set point changes (overshoot)

Definition



When changing the set point, the measured flow rate changes fast but it goes significantly over (or under) the desired value.

Corrective actions

- Decrease the P value of the PID.
- Reduce the input pressure.
- Gradually increase the D value of the PID.
- Increase the volume of the reservoir.

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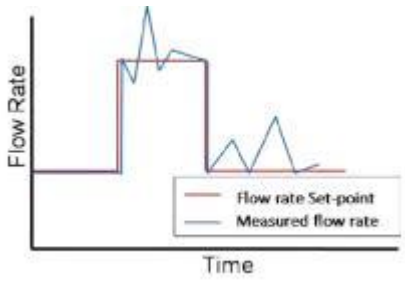
UniGo shows good dynamics but instability

Definition



When changing the set point, the measured flow rate changes fast and accurately but then the flow becomes instable.

Corrective actions

- Decrease the I value of the PID.
- Reduce the period of the set point changes: sometimes the frequency of changes in the set point is too fast (specially below 2 seconds for sine wave and step functions[4]).
- Gradually increase the lift off current of the valves: when the lift off current is low, this results in some values of the control of the system being unresponsive. Increasing the lift off current value will adjust the operation range of the control to be more responsive.

[4] Refer to the UniGo sser manual for more information.

For more information on the UniGo pump or any other Cellix product or service, please call: Republic of Ireland: +353-1-4500-155.