Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary Materials for

Precision Control of Flow Rate in Microfluidic Channels Using Photoresponsive Soft Polymer Actuators

Colm Delaney[a], Peter McCluskey[a], Simon Coleman[a], Jeff Whyte[b], Nigel Kent[a,b] and Dermot Diamond*[a]

[a.] *Insight Centre for Data Analytics, National Centre for Sensor research, Dublin City University, Dublin 9, Ireland.*

[b.] *School of Mechanical and Design Engineering, Dublin Institute of Technology, Bolton Street, Dublin, Ireland.*

*To whom correspondence should be addressed. Tel.: + 353 1 700 5404; E-mail: dermot.diamond@dcu.ie

Table of Contents:

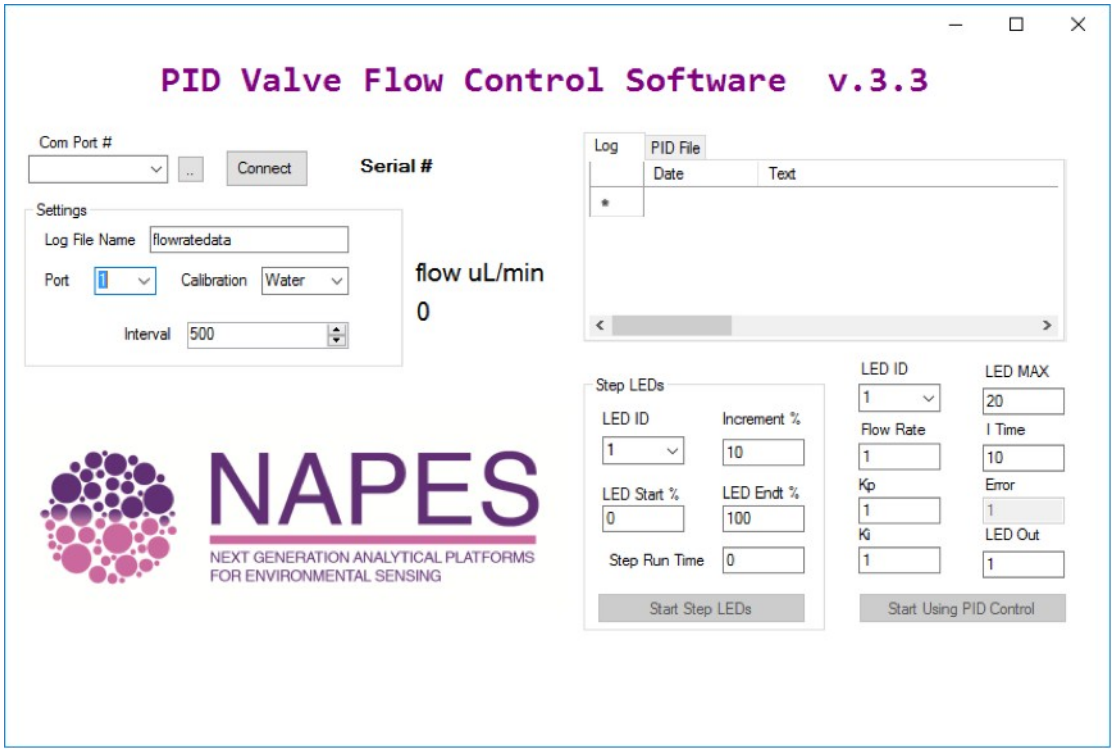
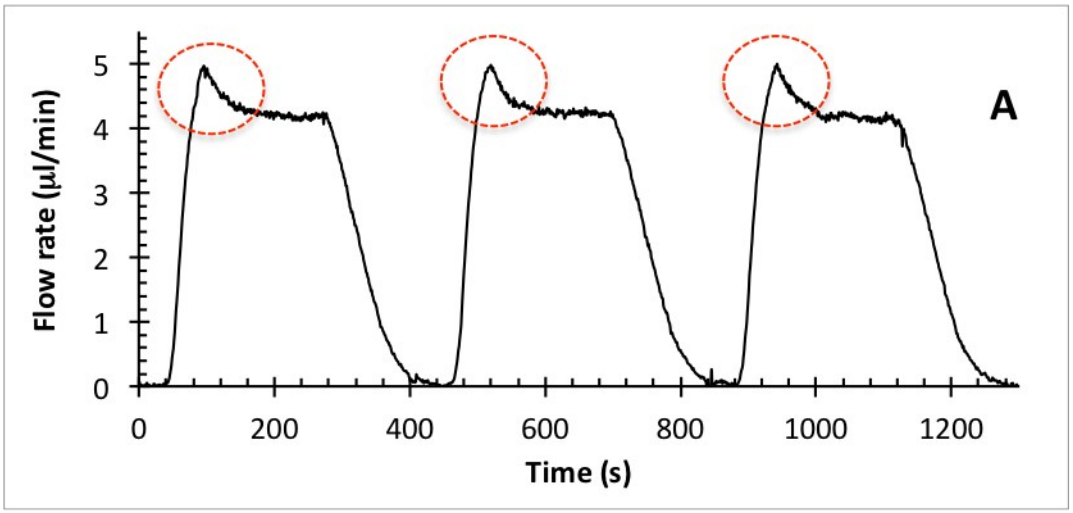


Figure SI 1: GUI Developed to implement the PID control algorithm

Through the GUI, the user can;

- Set the desired flow rate profile (constant or switched between values at specific times);
- Set system limits (e.g. maximum LED power allowed);
- Set values for proportional and integral control constants, K_P and K_I.
- Set the time over which the error between the set and the measured flow rate is integrated.



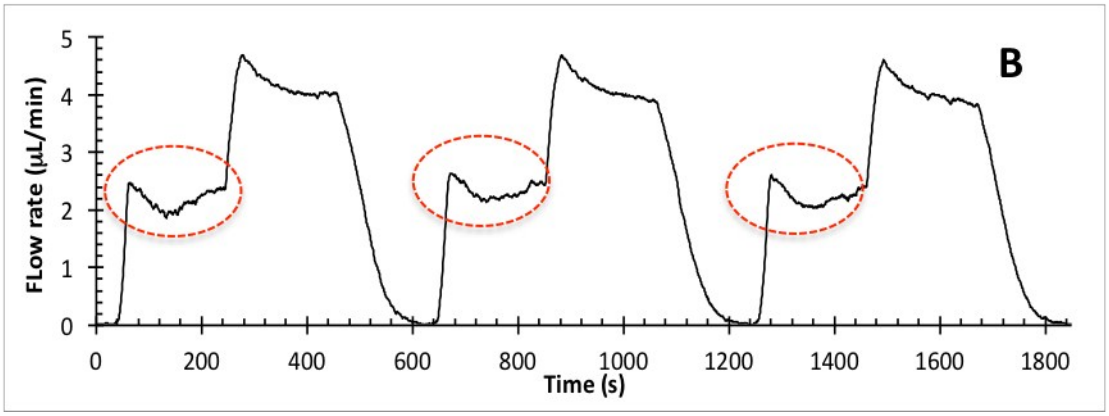


Figure SI 2: A) Flow behaviour presented by Coleman et al.[1] , reproduced with the permission of the authors, achieved by three repeats of: (i) 60s LED on, (ii) 180s pulsed LED (1s on, 2s off), and (iii)180s LED off. Classic overshoot behaviour of the flow rate (highlighted) is evident followed by establishment of a steady-state flow at ca. 4.0 µL/min; B) Flow behaviour produced by three repeats of (i) 30s LED on, 180s pulsed LED (1s on, 2s off), (iii) 30s LED on, (iv) 180s pulsed LED (1s on, 2s off), 180s LED off. Once again overshoot occurs for every case of change in flow rate. The shorted LED initial 'on' time causes the flow to begin to settle at a lower flow rate (ca. 2.0 µL/min). However, the pulsed LED causes the flow rate subsequently to increase slowly as the steady state under these conditions is closer to 4.0 µL/min. The second part of the flow pattern is very similar to (A).

Table SI 1: Summary statistics for data from *Figure 4*; units for columns (*) µL/min

Peak	mean (n=30)*	SD*	Mean Error*	ABS Error*
1	9.997	0.044	-0.0031	0.0031
2	10.002	0.045	0.0015	0.0015
3	9.993	0.020	-0.0066	0.0066
4	9.999	0.022	-0.0009	0.0009
5	10.009	0.030	0.0090	0.0090
6	10.012	0.049	0.0117	0.0117
7	9.998	0.014	-0.0017	0.0017
8	9.994	0.022	-0.0056	0.0056
9	10.018	0.049	0.0180	0.0180
10	10.006	0.028	0.0055	0.0055
average	10.003	0.032	0.0028	0.0064

Mean = Average of 30 points on the steady state just behind the initial small overshoot.
SD = Standard Deviation of the same 30 points.
Mean Error = Mean flow rate – set flow rate (10 µL/min)

$ABS\ Error = \left|(FR_{mean} - FR_{SP})\right|$ (modulus of the error)

Table SI 2: Summary statistical data from *Figure 5.* Averages and standard deviations are calculated from 100 consecutive points randomly selected on the steady-state regions for each flow rate.

Set Flow rate (µL/min)	5.0	10.0	15.0	10.0	5.0	mean
Average Flow rate (µL/min)	5.034	10.141	15.123	10.124	5.036	N/A
Standard Deviation (µL/min)	0.016	0.053	0.051	0.049	0.018	0.037
%RSD	0.327	0.525	0.334	0.481	0.356	0.405
Mean Error (set µL/min)	0.034	0.140	0.123	0.123	0.036	0.091
Mean Error (average µL/min)	0.013	0.042	0.040	0.038	0.014	0.029
%RE (vs. set flow rate)	0.679	1.407	0.820	1.235	0.721	0.972
%RE (vs. average flow rate)	0.257	0.412	0.266	0.372	0.276	0.316
Average Power (mW)	20.58	82.32	185.11	82.35	20.60	N/A

Table SI 3: Summary statistics for data presented in *Figure 7*.

Set Flow Rate	Average Flow Rate	SD	%RSD	%RE	MOD error	Power
5.0	5.039	0.018	0.351	0.772	0.039	20.598
10.0	10.050	0.048	0.476	0.502	0.050	82.280
15.0	15.048	0.047	0.315	0.317	0.048	185.260
10.0	10.064	0.039	0.391	0.638	0.064	82.197
5.0	5.032	0.018	0.366	0.636	0.032	20.650
10.0	10.045	0.029	0.290	0.449	0.045	82.316
15.0	15.030	0.037	0.246	0.200	0.030	185.506
10.0	10.043	0.034	0.343	0.428	0.043	82.474
5.0	5.021	0.020	0.390	0.425	0.021	20.598
10.0	10.023	0.029	0.287	0.226	0.023	82.602
15.0	14.996	0.034	0.226	-0.027	0.004	184.974
10.0	10.033	0.026	0.259	0.327	0.033	82.226
5.0	5.019	0.016	0.321	0.388	0.019	20.573
10.0	10.019	0.026	0.260	0.187	0.019	82.189
15.0	14.974	0.026	0.173	-0.176	0.026	185.053
10.0	10.011	0.021	0.213	0.105	0.011	82.384
	Average =	0.0292	0.3068		0.0316	

Flow rate units are μL/min; Power Units are mW. Averages and standard deviations are for n=100 consecutive points selected randomly from each steady-state flow-rate region.

References

1. Coleman, S. *et al.* Tuning Microfluidic Flow by Pulsed Light Oscillating Spiropyran-based Polymer Hydrogel Valves. *Sensors and Actuators B: Chemical* doi:http://dx.doi.org/10.1016/j.snb.2017.01.112