# **Details of Experimental Setup**

(Refer to Table IV, Table V, and Table VI of the paper)

# Contents

1	In-vitro multiplexed assay	2
2	Dilution of a sample using $REMIA$	4
3	Protein assay	6
4	Linear dilution gradient	9
5	PCR mixing and streaming of PCR mixture droplet 5.1 PCR mixing	11 11 13

<sup>\*</sup>Online: http://www.isical.ac.in/ $\sim$ sukanta\_r/experimental\_setup.pdf

## 1 In-vitro multiplexed assay

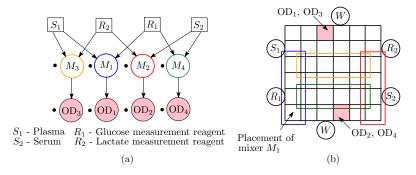


Figure A.1: (a) Sequencing graph of the in-vitro multiplexed assay (s=2,r=2) (b) Old DMF platform of size  $6\times 6$  and the corresponding mixer placements.

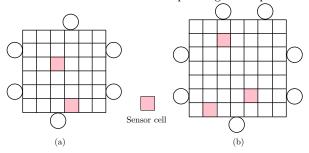


Figure A.2: Enhanced DMFB platform of dimensions (a)  $6 \times 6$ , and (b) chip of size  $7 \times 7$  with sensors.

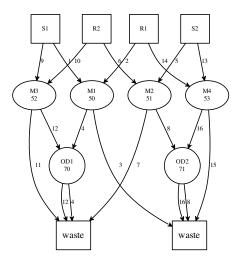


Figure A.3: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to routing paths, mixers, and sensors.

 $\label{eq:A.1:Routing paths} \mbox{ Extracted from the old actuation sequence.}$ 

	Routing paths		
Path ID	Path		
$\mathcal{P}_1$	[(2,1),(3,1)]		
$\mathcal{P}_2$	[(5,1),(6,1)]		
$\mathcal{P}_3$	[(6,1),(6,2),(6,3)]		
$\mathcal{P}_4$	[(3,1),(3,2),(2,2),(1,2),(1,3),(1,4)]		
$P_5$	[(5,6),(6,6)]		
$\mathcal{P}_6$	[(2,6),(3,6)]		
$\mathcal{P}_7$	[(3,6),(3,5),(3,4),(2,4),(1,4)]		
$\mathcal{P}_8$	[(6,6),(6,5),(6,4),(6,3)]		
$\mathcal{P}_9$	[(2,1),(3,1),(3,2)]		
$\mathcal{P}_{10}$	[(2,6),(3,6),(3,5)]		
$P_{11}$	[(3,5),(2,5),(1,5),(1,4)]		
$P_{12}$	[(3,2),(2,2),(1,2),(1,3),(1,4)]		
$\mathcal{P}_{13}$	[(5,6),(5,5)]		
$\mathcal{P}_{14}$	[(5,1),(5,2)]		
$\mathcal{P}_{15}$	[(5,2),(6,2),(6,3)]		
$\mathcal{P}_{16}$	[(5,5),(6,5),(6,4),(6,3)]		

Table A.2: Mixer and detector locations and their types extracted from the old actuation sequence.

Mixers		
Mixer ID	Mixer Type	Mixer location
50	$4 \times 1$	[(3,1),(6,1)]
51	$4 \times 1$	[(3,6),(6,6)]
52	$1 \times 4$	[(3,2),(3,5)]
53	$1 \times 4$	[(5,2),(5,5)]
	Detectors	
Detector ID	Detector Type	Detector location
70	Optical	(1, 3)
71	Optical	(6, 4)

# 2 Dilution of a sample using REMIA

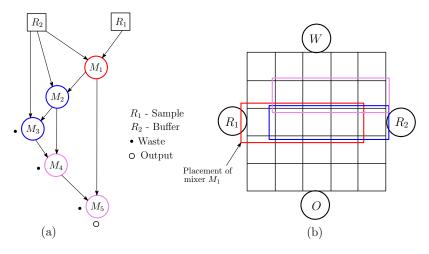


Figure A.4: (a) Sequencing graph of the concentration factor  $(\frac{11}{32})$  using *REMIA* (b) Old DMF platform of size  $5\times 5$  and the corresponding mixer placements.

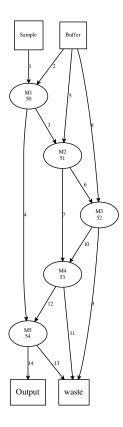


Figure A.5: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to extracted routing paths and mixers.

Table A.3: Routing paths extracted from the old actuation sequence.

	Routing paths		
Path ID	Path		
$\mathcal{P}_1$	[(3,1)]		
$\mathcal{P}_2$	[(3,5),(3,4)]		
$\mathcal{P}_3$	[(3,1),(3,2)]		
$\mathcal{P}_4$	[(3,4),(4,4),(5,4),(5,3),(5,2),(4,2),(3,2),(2,2)]		
$\mathcal{P}_5$	[(3,5)]		
$\mathcal{P}_6$	[(3,2)]		
$\mathcal{P}_7$	[(3,5),(4,5),(5,5),(5,4),(4,4),(3,4),(2,4),(2,5)]		
$\mathcal{P}_8$	[(3,5)]		
$\mathcal{P}_9$	[(3,5),(2,5),(1,5),(1,4),(1,3)]		
$\mathcal{P}_{10}$	[(3,2),(2,2)]		
$\mathcal{P}_{11}$	[(2,2),(1,2),(1,3)]		
$\mathcal{P}_{12}$	[(2,5)]		
$\mathcal{P}_{13}$	[(2,2),(1,2),(1,3)]		
$\mathcal{P}_{14}$	[(2,5),(3,5),(4,5),(5,5),(5,4),(5,3)]		

Table A.4: Mixer locations and types extracted from the old actuation sequence.  $\[$ 

	Mixers	
Mixer ID	Mixer Type	Mixer location
50	$1 \times 4$	[(3,1),(3,4)]
51	$1 \times 4$	[(3,2),(3,5)]
52	$1 \times 4$	[(3,2),(3,5)]
53	$1 \times 4$	[(2,2),(2,5)]
54	$1 \times 4$	[(2,2),(2,5)]

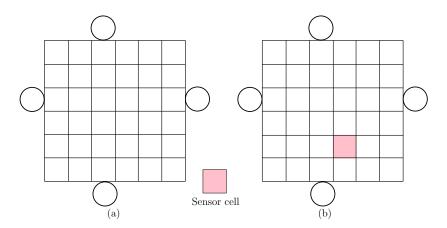


Figure A.6: Enhanced DMFB platform of dimensions (a)  $6\times 6$ , and (b) chip of size  $6\times 6$  with sensor.

## 3 Protein assay

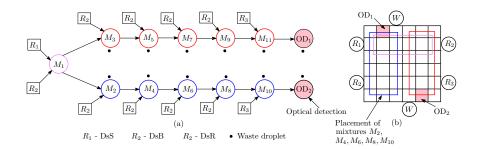


Figure A.7: (a) Sequencing graph of the protein assay (b) Old DMF platform of size  $6\times 6$  and the corresponding mixer and sensor placements.

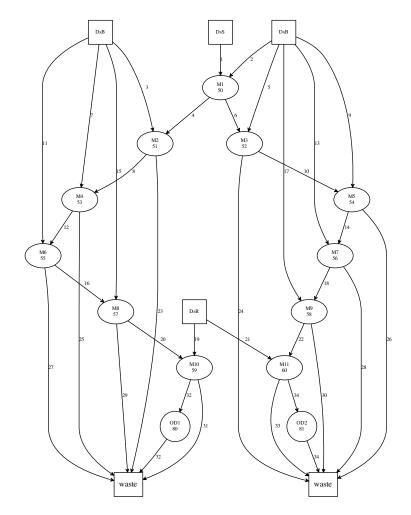


Figure A.8: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to routing paths, sensors, and mixers.

 $\label{eq:A.5:Routing paths extracted from the old actuation sequence.}$ 

$\begin{array}{ c c c c } \hline {\rm Path \ ID} & {\rm Path \ } \\ \hline \hline {\mathcal{P}_1} & [(2,1),(2,2)] \\ {\mathcal{P}_2} & [(2,6),(2,5)] \\ {\mathcal{P}_3} & [(5,1),(5,2)] \\ {\mathcal{P}_4} & [(2,2)] \\ {\mathcal{P}_5} & [(2,6),(2,5)] \\ {\mathcal{P}_6} & [(2,5),(3,5),(4,5),(5,5)] \\ {\mathcal{P}_7} & [(5,1),(5,2)] \\ {\mathcal{P}_7} & [(5,1),(5,2)] \\ {\mathcal{P}_8} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_9} & [(2,6),(2,5)] \\ {\mathcal{P}_{10}} & [(2,5),(3,5),(4,5),(5,5)] \\ {\mathcal{P}_{11}} & [(5,1),(5,2)] \\ {\mathcal{P}_{12}} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_{13}} & [(2,5),(3,5),(4,5),(5,5)] \\ {\mathcal{P}_{14}} & [(2,5),(3,5),(4,5),(5,5)] \\ {\mathcal{P}_{15}} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_{15}} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_{15}} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_{17}} & [(2,5),(3,5),(4,5),(5,5)] \\ {\mathcal{P}_{19}} & [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ {\mathcal{P}_{20}} & [(5,2),(4,2),(3,2),(2,2)] \\ {\mathcal{P}_{23}} & [(2,2),(1,2),(1,3)] \\ {\mathcal{P}_{24}} & [(5,5),(6,5),(6,4)] \\ {\mathcal{P}_{25}} & [(2,2),(1,2),(1,3)] \\ \end{array}$	D (1)				
$ \begin{array}{ c c c c } \hline \mathcal{P}_1 & & & & & & & & & \\ \hline \mathcal{P}_2 & & & & & & & & \\ \hline \mathcal{P}_3 & & & & & & & & \\ \hline \mathcal{P}_4 & & & & & & & & \\ \hline \mathcal{P}_5 & & & & & & & & \\ \hline \mathcal{P}_5 & & & & & & & & \\ \hline \mathcal{P}_6 & & & & & & & & \\ \hline \mathcal{P}_6 & & & & & & & & \\ \hline \mathcal{P}_7 & & & & & & & \\ \hline \mathcal{P}_8 & & & & & & & \\ \hline \mathcal{P}_7 & & & & & & & \\ \hline \mathcal{P}_8 & & & & & & & \\ \hline \mathcal{P}_7 & & & & & & & \\ \hline \mathcal{P}_9 & & & & & & & \\ \hline \mathcal{P}_{10} & & & & & & \\ \hline \mathcal{P}_{10} & & & & & & \\ \hline \mathcal{P}_{11} & & & & & & \\ \hline \mathcal{P}_{12} & & & & & & \\ \hline \mathcal{P}_{13} & & & & & & \\ \hline \mathcal{P}_{14} & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & \\ \hline \mathcal{P}_{16} & & & & & & \\ \hline \mathcal{P}_{17} & & & & & & \\ \hline \mathcal{P}_{18} & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & \\ \hline \mathcal{P}_{20} & & & & & \\ \hline \mathcal{P}_{21} & & & & & \\ \hline \mathcal{P}_{22} & & & & & \\ \hline \mathcal{P}_{23} & & & & & \\ \hline \mathcal{P}_{24} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \end{array}$	Routing paths				
$ \begin{array}{ c c c c c } \hline \mathcal{P}_2 \\ \mathcal{P}_3 \\ \mathcal{P}_4 \\ \mathcal{P}_5 \\ \mathcal{P}_6 \\ \mathcal{P}_6 \\ \mathcal{P}_7 \\ \mathcal{P}_8 \\ \mathcal{P}_9 \\ \mathcal{P}_{10} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{14} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{19} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{14} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{19} \\ \mathcal{P}_{20} \\ \mathcal{P}_{21} \\ \mathcal{P}_{22} \\ \mathcal{P}_{23} \\ \mathcal{P}_{23} \\ \mathcal{P}_{24} \\ \mathcal{P}_{25} \\ \mathcal{P}_{25} \\ \mathcal{P}_{25} \\ \mathcal{P}_{25} \\ \mathcal{P}_{25} \\ \mathcal{P}_{26} \\ \mathcal{P}_{27} \\ \mathcal{P}_{27} \\ \mathcal{P}_{28} \\ \mathcal{P}_{29} \\ \mathcal$					
$ \begin{array}{ c c c c c } \hline \mathcal{P}_3 & & & & & & & & & \\ \mathcal{P}_4 & & & & & & & & & \\ \mathcal{P}_5 & & & & & & & & & \\ \mathcal{P}_6 & & & & & & & & & \\ \mathcal{P}_7 & & & & & & & & & \\ \mathcal{P}_7 & & & & & & & & & \\ \mathcal{P}_7 & & & & & & & & \\ \mathcal{P}_8 & & & & & & & & \\ \mathcal{P}_9 & & & & & & & & \\ \mathcal{P}_9 & & & & & & & & \\ \mathcal{P}_9 & & & & & & & & \\ \mathcal{P}_9 & & & & & & & & \\ \mathcal{P}_{1} & & & & & & & \\ \mathcal{P}_9 & & & & & & & \\ \mathcal{P}_{10} & & & & & & & \\ \mathcal{P}_{11} & & & & & & & \\ \mathcal{P}_{11} & & & & & & & \\ \mathcal{P}_{12} & & & & & & & \\ \mathcal{P}_{13} & & & & & & & \\ \mathcal{P}_{13} & & & & & & & \\ \mathcal{P}_{14} & & & & & & & \\ \mathcal{P}_{15} & & & & & & & \\ \mathcal{P}_{15} & & & & & & & \\ \mathcal{P}_{17} & & & & & & & \\ \mathcal{P}_{18} & & & & & & & \\ \mathcal{P}_{19} & & & & & & & \\ \mathcal{P}_{19} & & & & & & \\ \mathcal{P}_{20} & & & & & & \\ \mathcal{P}_{21} & & & & & & \\ \mathcal{P}_{22} & & & & & \\ \mathcal{P}_{23} & & & & & \\ \mathcal{P}_{24} & & & & & \\ \mathcal{P}_{25} & & & & & \\ \mathcal{P}_{25} & & & & & \\ \end{array} $					
$ \begin{array}{ c c c c } \hline \mathcal{P}_4 \\ \mathcal{P}_5 \\ \mathcal{P}_6 \\ \mathcal{P}_7 \\ \mathcal{P}_8 \\ \mathcal{P}_9 \\ \mathcal{P}_{10} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{19} \\ \mathcal{P}_{10} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{14} \\ \mathcal{P}_{15} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{20} \\ \mathcal{P}_{23} \\ \mathcal{P}_{23} \\ \mathcal{P}_{24} \\ \mathcal{P}_{25} \\ \mathcal{P}_{26} \\ \mathcal{P}_{27} \\ \mathcal{P}_{28} \\ \mathcal{P}_{29} \\ \mathcal{P}_{$					
$ \begin{array}{c c} \mathcal{P}_{5}^{5} & [(2,0),(2,5)] \\ \mathcal{P}_{6} & \mathcal{P}_{7} \\ \mathcal{P}_{8} & [(2,5),(3,5),(4,5),(5,5)] \\ \mathcal{P}_{9} & [(5,1),(5,2)] \\ \mathcal{P}_{10} & [(5,2),(4,2),(3,2),(2,2)] \\ \mathcal{P}_{11} & [(5,2),(4,2),(3,2),(2,2)] \\ \mathcal{P}_{12} & [(5,2),(4,2),(3,2),(2,2)] \\ \mathcal{P}_{13} & [(5,2),(4,2),(3,2),(2,2)] \\ \mathcal{P}_{15} & [(2,5),(3,5),(4,5),(5,5)] \\ \mathcal{P}_{16} & [(2,5),(3,5),(4,5),(5,5)] \\ \mathcal{P}_{17} & [(5,2),(4,2),(3,2),(2,2)] \\ \mathcal{P}_{18} & [(2,5),(3,5),(4,5),(5,5)] \\ \mathcal{P}_{19} & [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ \mathcal{P}_{20} & [(5,5),(5,4),(5,3),(5,2)] \\ \mathcal{P}_{21} & \mathcal{P}_{22} & [(5,6),(5,5)] \\ \mathcal{P}_{23} & [(2,2),(1,2),(1,3)] \\ \mathcal{P}_{24} & [(5,5),(6,5),(6,4)] \\ \mathcal{P}_{25} & [(2,2),(1,2),(1,3)] \end{array} $	$\mathcal{P}_3$	[(5,1),(5,2)]			
$ \begin{array}{c c} \mathcal{P}_6 \\ \mathcal{P}_7 \\ \mathcal{P}_8 \\ \mathcal{P}_9 \\ \mathcal{P}_{10} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{16} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{21} \\ \mathcal{P}_{21} \\ \mathcal{P}_{22} \\ \mathcal{P}_{21} \\ \mathcal{P}_{22} \\ \mathcal{P}_{22} \\ \mathcal{P}_{23} \\ \mathcal{P}_{23} \\ \mathcal{P}_{25} \\ \mathcal{P}_{26} \\ \mathcal{P}_{27} \\ \mathcal{P}_{27} \\ \mathcal{P}_{28} \\ \mathcal{P}_{29} \\ \mathcal{P}_{29$	$\mathcal{P}_4$	[(2,2)]			
$ \begin{array}{c c} \mathcal{P}_7 \\ \mathcal{P}_8 \\ \mathcal{P}_9 \\ \mathcal{P}_{10} \\ \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{16} \\ \mathcal{P}_{16} \\ \mathcal{P}_{16} \\ \mathcal{P}_{27} \\ \mathcal{P}_{28} \\ \mathcal{P}_{29} \\ \mathcal{P}_{21} \\ \mathcal{P}_{21} \\ \mathcal{P}_{21} \\ \mathcal{P}_{22} \\ \mathcal{P}_{22} \\ \mathcal{P}_{23} \\ \mathcal{P}_{23} \\ \mathcal{P}_{24} \\ \mathcal{P}_{25} \\ \mathcal{P}_{27} \\ \mathcal{P}_{28} \\ \mathcal{P}_{29} \\ \mathcal{P}_$	$\mathcal{P}_5$	[(2,6),(2,5)]			
$ \begin{array}{ c c c c c } \hline \mathcal{P}_8 & & & & & & & & & & & \\ \hline \mathcal{P}_9 & & & & & & & & & \\ \hline \mathcal{P}_9 & & & & & & & & & \\ \hline \mathcal{P}_{10} & & & & & & & \\ \hline \mathcal{P}_{11} & & & & & & & \\ \hline \mathcal{P}_{12} & & & & & & \\ \hline \mathcal{P}_{13} & & & & & & \\ \hline \mathcal{P}_{14} & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & \\ \hline \mathcal{P}_{16} & & & & & & \\ \hline \mathcal{P}_{17} & & & & & \\ \hline \mathcal{P}_{18} & & & & & \\ \hline \mathcal{P}_{19} & & & & & \\ \hline \mathcal{P}_{20} & & & & & \\ \hline \mathcal{P}_{22} & & & & & \\ \hline \mathcal{P}_{24} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \mathcal{P}_{26} & & & & & \\ \hline \mathcal{P}_{27} & & & & & \\ \hline \mathcal{P}_{28} & & & & & \\ \hline \mathcal{P}_{29} & & & & & \\ \hline \mathcal{P}_{29} & & & \\ \hline \mathcal{P}_{29} & & & & \\ \hline \mathcal{P}_{29} & & & & \\ \hline \mathcal{P}_{29} & & & \\ \hline \mathcal{P}_{29} & & & & \\ \hline \mathcal{P}_{29} & & & & \\ \hline \mathcal{P}_{29} & & & \\ \hline \mathcal{P}_{29} & & & & \\ \hline \mathcal{P}_{29} & & \\$	$\mathcal{P}_6$	[(2,5),(3,5),(4,5),(5,5)]			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\mathcal{P}_7$	[(5,1),(5,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{10} & & & & & & & & & & \\ \hline \mathcal{P}_{11} & & & & & & & & & \\ \hline \mathcal{P}_{12} & & & & & & & & \\ \hline \mathcal{P}_{13} & & & & & & & \\ \hline \mathcal{P}_{13} & & & & & & & \\ \hline \mathcal{P}_{14} & & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & \\ \hline \mathcal{P}_{16} & & & & & & \\ \hline \mathcal{P}_{17} & & & & & & \\ \hline \mathcal{P}_{18} & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & \\ \hline \mathcal{P}_{20} & & & & & & \\ \hline \mathcal{P}_{21} & & & & & & \\ \hline \mathcal{P}_{22} & & & & & \\ \hline \mathcal{P}_{23} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \end{array} $	$\mathcal{P}_8$	[(5,2),(4,2),(3,2),(2,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{11} \\ \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \hline \mathcal{P}_{14} \\ \mathcal{P}_{15} \\ \hline \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \hline \mathcal{P}_{18} \\ \hline \mathcal{P}_{21} \\ \hline \mathcal{P}_{21} \\ \hline \mathcal{P}_{22} \\ \hline \mathcal{P}_{22} \\ \hline \mathcal{P}_{23} \\ \hline \mathcal{P}_{25} \\ \hline \mathcal{P}_{26} \\ \hline \mathcal{P}_{27} \\ \hline \mathcal{P}_{27} \\ \hline \mathcal{P}_{28} \\ \hline \mathcal{P}_{29} \\ \hline \mathcal{P}_{$	$\mathcal{P}_9$	[(2,6),(2,5)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{12} \\ \mathcal{P}_{13} \\ \mathcal{P}_{14} \\ \mathcal{P}_{15} \\ \mathcal{P}_{15} \\ \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{20} \\ \mathcal{P}_{23} \\ \mathcal{P}_{24} \\ \mathcal{P}_{25} \\ \end{array} } \begin{array}{ c c c c } [(5,2),(4,2),(3,2),(2,2)] \\ [(5,5),(3,5),(4,5),(5,5)] \\ [(5,1),(5,2)] \\ [(5,1),(5,2)] \\ [(5,1),(5,2)] \\ [(2,5),(3,5),(4,5),(5,5)] \\ [(2,6),(2,5)] \\ [(2,6),(2,5)] \\ [(2,6),(2,5)] \\ [(2,6),(5,5),(5,5)] \\ [(5,5),(4,5),(5,5)] \\ [(5,5),(4,2),(3,2),(2,2)] \\ [(5,5),(5,5)] \\ [(2,2),(1,2),(1,3)] \\ [(5,5),(6,5),(6,4)] \\ [(5,5),(6,5),(6,4)] \\ [(2,2),(1,2),(1,3)] \\ [(2$	$\mathcal{P}_{10}$	[(2,5),(3,5),(4,5),(5,5)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{13} & \mathcal{P}_{14} & [(2,6),(2,5)] \\ \hline \mathcal{P}_{15} & [(2,5),(3,5),(4,5),(5,5)] \\ \hline \mathcal{P}_{16} & [(5,2),(4,2),(3,2),(2,2)] \\ \hline \mathcal{P}_{17} & [(2,6),(2,5)] \\ \hline \mathcal{P}_{18} & [(2,5),(3,5),(4,5),(5,5)] \\ \hline \mathcal{P}_{20} & [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ \hline \mathcal{P}_{21} & [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ \hline \mathcal{P}_{22} & [(5,6),(5,5)] \\ \hline \mathcal{P}_{23} & [(2,2),(4,2),(3,2),(2,2)] \\ \hline \mathcal{P}_{24} & [(5,5),(6,5),(6,4)] \\ \hline \mathcal{P}_{25} & [(2,2),(1,2),(1,3)] \\ \hline \end{array} $	$\mathcal{P}_{11}$	[(5,1),(5,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{14} & & & & & & & & & & \\ \hline \mathcal{P}_{15} & & & & & & & & & \\ \hline \mathcal{P}_{16} & & & & & & & & \\ \hline \mathcal{P}_{17} & & & & & & & \\ \hline \mathcal{P}_{18} & & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & \\ \hline \mathcal{P}_{20} & & & & & & \\ \hline \mathcal{P}_{21} & & & & & & \\ \hline \mathcal{P}_{22} & & & & & \\ \hline \mathcal{P}_{23} & & & & & \\ \hline \mathcal{P}_{24} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \end{array} $	$\mathcal{P}_{12}$	[(5,2),(4,2),(3,2),(2,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{15} & & & & & & & & & & \\ \hline \mathcal{P}_{16} & & & & & & & & & \\ \hline \mathcal{P}_{17} & & & & & & & & \\ \hline \mathcal{P}_{18} & & & & & & & \\ \hline \mathcal{P}_{19} & & & & & & & \\ \hline \mathcal{P}_{20} & & & & & & \\ \hline \mathcal{P}_{20} & & & & & & \\ \hline \mathcal{P}_{21} & & & & & & \\ \hline \mathcal{P}_{22} & & & & & & \\ \hline \mathcal{P}_{23} & & & & & & \\ \hline \mathcal{P}_{24} & & & & & \\ \hline \mathcal{P}_{25} & & & & & \\ \hline \end{array} $	$\mathcal{P}_{13}$	[(2,6),(2,5)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{16} \\ \mathcal{P}_{17} \\ \mathcal{P}_{18} \\ \mathcal{P}_{19} \\ \mathcal{P}_{20} \\ \mathcal{P}_{21} \\ \mathcal{P}_{22} \\ \mathcal{P}_{23} \\ \mathcal{P}_{25} \\ \mathcal{P}_{25} \\ \end{array} \begin{array}{ c c c c } \hline [(5,2),(4,2),(3,2),(2,2)] \\ \hline [(2,5),(3,5),(4,5),(5,5)] \\ \hline [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ \hline [(5,2),(4,2),(3,2),(2,2)] \\ \hline [(5,5),(5,5)] \\ \hline [(2,5)] \\ \hline [(2,5)] \\ \hline [(2,2),(1,2),(1,3)] \\ \hline [(5,5),(6,5),(6,4)] \\ \hline [(2,2),(1,2),(1,3)] \\ \hline \end{array} $	$\mathcal{P}_{14}$	[(2,5),(3,5),(4,5),(5,5)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{17} & & & & & & & & & & \\ \mathcal{P}_{18} & & & & & & & & \\ \mathcal{P}_{19} & & & & & & & & \\ \mathcal{P}_{20} & & & & & & & \\ \mathcal{P}_{21} & & & & & & & \\ \mathcal{P}_{22} & & & & & & \\ \mathcal{P}_{23} & & & & & & \\ \mathcal{P}_{24} & & & & & & \\ \mathcal{P}_{25} & & & & & & \\ \hline \end{array} $	$\mathcal{P}_{15}$	[(5,1),(5,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{18} & [(2,5),(3,5),(4,5),(5,5)] \\ \hline \mathcal{P}_{19} & [(5,6),(5,5),(5,4),(5,3),(5,2)] \\ \hline \mathcal{P}_{20} & [(5,2),(4,2),(3,2),(2,2)] \\ \hline \mathcal{P}_{21} & [(5,6),(5,5)] \\ \hline \mathcal{P}_{22} & [(2,5)] \\ \hline \mathcal{P}_{23} & [(2,2),(1,2),(1,3)] \\ \hline \mathcal{P}_{24} & [(5,5),(6,5),(6,4)] \\ \hline \mathcal{P}_{25} & [(2,2),(1,2),(1,3)] \\ \hline \end{array} $	$\mathcal{P}_{16}$	[(5,2),(4,2),(3,2),(2,2)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{19} & [(5, \hat{6}), (5, \hat{5}), (5, \hat{4}), (5, \hat{3}), (5, 2)] \\ \hline \mathcal{P}_{20} & [(5, 2), (4, 2), (3, 2), (2, 2)] \\ \hline \mathcal{P}_{21} & [(5, 6), (5, 5)] \\ \hline \mathcal{P}_{22} & [(2, 5)] \\ \hline \mathcal{P}_{23} & [(2, 2), (1, 2), (1, 3)] \\ \hline \mathcal{P}_{24} & [(5, 5), (6, 5), (6, 4)] \\ \hline \mathcal{P}_{25} & [(2, 2), (1, 2), (1, 3)] \\ \hline \end{array} $	$\mathcal{P}_{17}$	[(2,6),(2,5)]			
$ \begin{array}{ c c c c } \hline \mathcal{P}_{20} & & & & & & & & \\ \hline \mathcal{P}_{21} & & & & & & & \\ \hline \mathcal{P}_{22} & & & & & & & \\ \hline \mathcal{P}_{22} & & & & & & & \\ \hline \mathcal{P}_{23} & & & & & & & \\ \hline \mathcal{P}_{24} & & & & & & \\ \hline \mathcal{P}_{24} & & & & & & \\ \hline \mathcal{P}_{25} & & & & & & \\ \hline \end{array} $		[(2,5),(3,5),(4,5),(5,5)]			
$ \begin{array}{ c c c c }\hline \mathcal{P}_{21} & & & & & & & \\ \mathcal{P}_{22} & & & & & & & \\ \mathcal{P}_{22} & & & & & & & \\ \mathcal{P}_{23} & & & & & & & \\ \mathcal{P}_{24} & & & & & & & \\ \mathcal{P}_{25} & & & & & & & \\ \end{array} $					
$ \begin{array}{ c c c c c }\hline \mathcal{P}_{22} & & & & & & \\ \hline \mathcal{P}_{23} & & & & & & \\ \hline \mathcal{P}_{24} & & & & & & & \\ \hline \mathcal{P}_{25} & & & & & & & \\ \hline \end{array} $					
$ \begin{array}{ c c c c c }\hline \mathcal{P}_{23} & & & & & & & & \\ \mathcal{P}_{24} & & & & & & & \\ \mathcal{P}_{25} & & & & & & & \\ \hline \end{array} $	$\mathcal{P}_{21}$	[(5,6),(5,5)]			
$ \begin{array}{ c c c c c c } \hline \mathcal{P}_{24} & & [(5,5),(6,5),(6,4)] \\ \hline \mathcal{P}_{25} & & [(2,2),(1,2),(1,3)] \\ \hline \end{array} $	$\mathcal{P}_{22}$	[(2,5)]			
$\mathcal{P}_{25}$ [(2,2),(1,2),(1,3)]	$\mathcal{P}_{23}$	[(2,2),(1,2),(1,3)]			
		[(5,5),(6,5),(6,4)]			
$\mathcal{P}_{26}$ [(5,5), (6,5), (6,4)]		[(2,2),(1,2),(1,3)]			
	$\mathcal{P}_{26}$	[(5,5),(6,5),(6,4)]			
$\mathcal{P}_{27}$ [(2,2), (1,2), (1,3)]					
$\mathcal{P}_{28}$ [(5,5), (6,5), (6,4)]		[(5,5),(6,5),(6,4)]			
$\mathcal{P}_{29}$ [(2,2),(1,2),(1,3)]					
$\mathcal{P}_{30}$ [(5,5), (6,5), (6,4)]					
		[(5,2),(4,2),(3,2),(2,2),(1,2),(1,3)]			
$\mathcal{P}_{32}$ [(2,2),(1,2),(1,3)]	$P_{32}$				
		[(2,5),(3,5),(4,5),(5,5),(6,5),(6,4)]			
$\mathcal{P}_{34}$ [(5,5), (6,5), (6,4)]	$\mathcal{P}_{34}$	[(5,5),(6,5),(6,4)]			

Table A.6: Mixer and detector locations and types extracted from the old actuation sequence.  $\,$ 

Mixers		
Mixer ID	Mixer Type	Mixer location
50	$1 \times 4$	[(2,2),(2,5)]
51	$4 \times 1$	[(2,2),(5,2)]
52	$4 \times 1$	[(2,5),(5,5)]
53	$4 \times 1$	[(2,2),(5,2)]
54	$4 \times 1$	[(2,5),(5,5)]
55	$4 \times 1$	[(2,2),(5,2)]
56	$4 \times 1$	[(2,5),(5,5)]
57	$4 \times 1$	[(2,2),(5,2)]
58	$4 \times 1$	[(2,5),(5,5)]
59	$4 \times 1$	[(2,2),(5,2)]
60	$4 \times 1$	[(2,5),(5,5)]
Detectors		
Detector ID	Detector Type	Detector location
80	Optical	(1, 2)
81	Optical	(6,5)

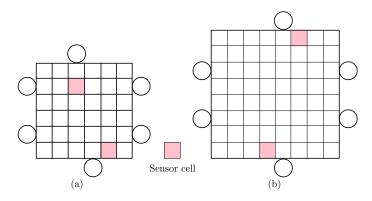


Figure A.9: Enhanced DMFB platform of dimensions (a)  $6\times 6,$  and (b) chip of size  $8\times 8$  with sensors.

# 4 Linear dilution gradient

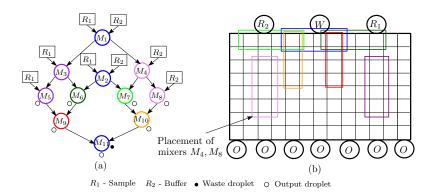


Figure A.10: (a) Sequencing graph of the linear dilution gradients (b) Old DMF platform of size  $8\times13$  and the corresponding mixer placements.

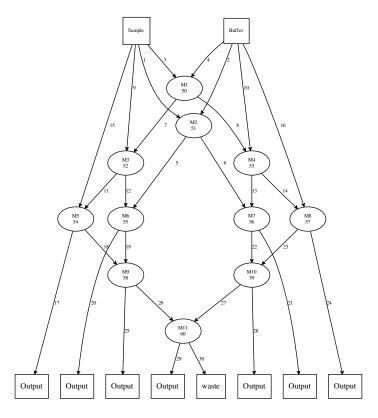


Figure A.11: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to extracted routing paths and mixers.

Table A.7: Routing paths extracted from the old actuation sequence.

	Routing paths		
Path ID	Path		
$\mathcal{P}_1$	[(1,11),(1,10),(1,9),(1,8)]		
$\mathcal{P}_2$	[(1,3),(1,4),(1,5)]		
$\mathcal{P}_3$	[(1,11),(1,10),(1,9),(1,8)]		
$\mathcal{P}_4$	[(1,3),(1,4),(1,5)]		
$\mathcal{P}_5$	[(1,8)]		
$\mathcal{P}_6$	[(1,5)]		
$\mathcal{P}_7$	[(1,8),(1,9),(1,10),(1,11),(2,11),(3,11)]		
$\mathcal{P}_8$	[(1,5),(1,4),(1,3),(2,3),(3,3)]		
$\mathcal{P}_9$	[(1,11),(2,11),(3,11),(4,11),(5,11),(6,11)]		
$\mathcal{P}_{10}$	[(1,3),(2,3),(3,3),(4,3),(5,3),(6,3)]		
$\mathcal{P}_{11}$	[(6,11)]		
$\mathcal{P}_{12}$	[(3,11),(3,12),(3,13),(2,13),(1,13),(1,12),(1,11)]		
$\mathcal{P}_{13}$	[(3,3),(3,2),(3,1),(2,1),(1,1),(1,2)]		
$\mathcal{P}_{14}$	[(6,3)]		
$P_{15}$	[(1,11),(2,11),(3,11)]		
$\mathcal{P}_{16}$	[(1,3),(2,3),(3,3)]		
$P_{17}$	[(6,11),(7,11),(8,11)]		
$P_{18}$	[(3,11),(3,10),(3,9),(4,9),(4,8)]		
$\mathcal{P}_{19}$	[(1,8)]		
$P_{20}$	$\big[ (1,11), (2,11), (3,11), (4,11), (5,11), (6,11), (7,11), (8,11), (8,10), (8,9) \big] \big $		
$P_{21}$	[(1,2),(2,2),(3,2),(4,2),(5,2),(6,2),(6,3),(7,3),(7,4),(7,5),(8,5)]		
$P_{22}$	[(1,5)]		
$\mathcal{P}_{23}$	[(3,3),(3,4),(3,5),(4,5)]		
$P_{24}$	[(6,3),(7,3),(8,3),(8,2),(8,1)]		
$\mathcal{P}_{25}$	[(4,8),(5,8),(5,9),(5,10),(5,11),(6,11),(7,11),(8,11)]		
$\mathcal{P}_{26}$	[(1,8)]		
$\mathcal{P}_{27}$	[(1,5)]		
$\mathcal{P}_{28}$	[(4,5), (5,5), (5,4), (5,3), (6,3), (7,3), (8,3)]		
$\mathcal{P}_{29}$	[(1,8),(1,7),(2,7),(3,7),(4,7),(5,7),(6,7),(7,7),(8,7)]		
$\mathcal{P}_{30}$	[(1,5),(1,6),(1,7)]		

Table A.8: Mixer locations and types extracted from the old actuation sequence.

1		
Mixers		
Mixer ID	Mixer Type	Mixer location
50	1 × 4	[(1,5),(1,8)]
51	$4 \times 1$	[(1,5),(1,8)]
52	$4 \times 1$	[(3,11),(6,11)]
53	$4 \times 1$	[(3,3),(6,3)]
54	$4 \times 1$	[(3,11),(6,11)]
55	$1 \times 4$	[(1,8),(1,11)]
56	$1 \times 4$	[(1,2),(1,5)]
57	$4 \times 1$	[(3,3),(6,3)]
58	$4 \times 1$	[(1,8),(4,8)]
59	$4 \times 1$	[(1,5),(4,5)]
60	$1 \times 4$	[(1,5),(1,8)]

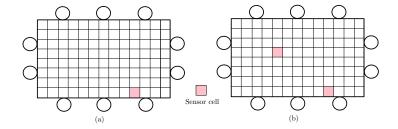
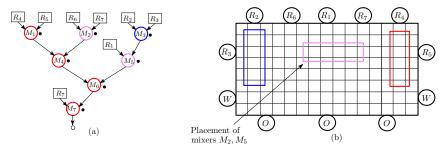


Figure A.12: Enhanced DMFB platform of dimensions (a)  $8\times13,$  and (b) chip of size  $8\times13$  with sensors.

# 5 PCR mixing and streaming of PCR mixture droplet

#### 5.1 PCR mixing



 $R_1 - \text{Reactant buffer} \quad R_2 - \text{dNTP} \quad R_3 - \text{Forward primer} \quad R_4 - \text{Reverse primer} \quad R_5 - \text{DNA template} \quad R_6 - \text{Optimase} \quad R_7 - \text{Water} \\ R_1 : R_2 : R_3 : R_4 : R_5 : R_6 : R_7 = 2 : 1 : 1 : 1 : 1 : 1 : 1 : 1 : 9 \\ \bullet \quad \text{Wate droplet} \quad \bigcirc \quad \text{Output droplet}$ 

Figure A.13: (a) Sequencing graph of the PCR mixture (b) Old DMF platform of size  $8\times15$  and the corresponding mixer placements.

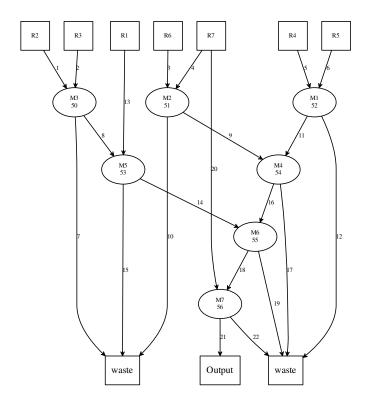


Figure A.14: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to extracted routing paths and mixers.

Table A.9: Routing paths extracted from the old actuation sequence.

Routing paths			
Path ID	Path ID Path		
$\mathcal{P}_1$	[(1,2),(2,2)]		
$\mathcal{P}_2$	[(3,1),(4,1),(5,1),(5,2)]		
$\mathcal{P}_3$	[(1,5),(2,5),(3,5),(3,6),(3,7)]		
$\mathcal{P}_4$	[(1,11),(2,11),(3,11),(3,10)]		
$\mathcal{P}_5$	[(1,14),(2,14)]		
$\mathcal{P}_6$	[(3, 15), (4, 15), (5, 15), (5, 14)]		
$\mathcal{P}_7$	[(5,2),(6,2),(7,2),(7,1)]		
$\mathcal{P}_8$	[(2,2),(2,3),(2,4),(3,4),(3,5),(3,6),(3,7)]		
$\mathcal{P}_9$	[(3,10), (4,10), (5,10), (5,11), (5,12), (5,13), (5,14)]		
$\mathcal{P}_{10}$	[(3,7),(4,7),(5,7),(6,7),(7,7),(7,6),(7,5),(7,4),(7,3),(7,2),(7,1)]		
$\mathcal{P}_{11}$	[(2,14)]		
$\mathcal{P}_{12}$	[(5,14),(6,14),(7,14),(7,15)]		
$\mathcal{P}_{13}$	[(1,8), (1,9), (1,10), (2,10), (3,10)] $[(3,10), (4,10), (5,10), (5,11), (5,12), (5,13), (5,14)]$		
$\mathcal{P}_{14}$ $\mathcal{P}_{15}$			
$\mathcal{P}_{16}^{15}$	[(3,7),(4,7),(5,7),(6,7),(7,7),(7,6),(7,5),(7,4),(7,3),(7,2),(7,1)]		
$\mathcal{P}_{17}^{16}$	[(5,14),(6,14),(7,14),(7,15)]		
$\mathcal{P}_{18}^{17}$	[(0,14),(0,14),(1,14)]		
$\mathcal{P}_{19}^{18}$	[(5,14),(6,14),(7,14),(7,15)]		
$\mathcal{P}_{20}^{19}$	[(1,11),(1,12),(2,12),(3,12),(4,12),(5,12),(5,13),(5,14)]		
$\mathcal{P}_{21}^{^{20}}$	[(5, 14), (6, 14), (7, 14), (8, 14), (8, 13)]		
$\mathcal{P}_{22}$	[(2,14),(3,14),(4,14),(5,14),(6,14),(6,15),(7,15)]		

Table A.10: Mixer locations and types extracted from the old actuation sequence.  $\,$ 

	Mixers	
Mixer ID	Mixer Type	Mixer location
50	$4 \times 1$	[(2,2),(5,2)]
51	$1 \times 4$	[(3,7),(3,10)]
52	$4 \times 1$	[(2,14),(5,14)]
53	$1 \times 4$	[(3,7),(3,10)]
54	$4 \times 1$	[(2,14),(5,14)]
55	$4 \times 1$	[(2,14),(5,14)]
56	$4 \times 1$	[(2,14),(5,14)]

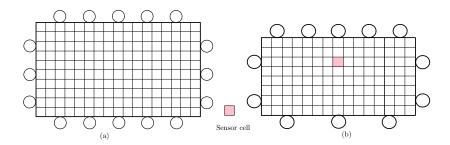


Figure A.15: Enhanced DMFB platform of dimensions (a)  $10\times17,$  and (b) chip of size  $8\times15$  with sensor.

#### 5.2 Streaming of PCR mixture droplets

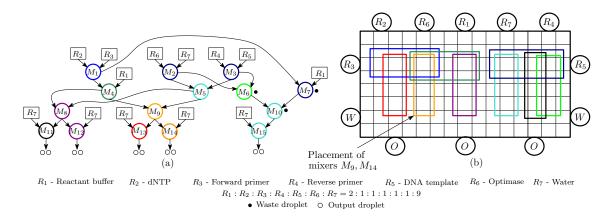


Figure A.16: (a) Sequencing graph of droplet streaming for the PCR mixture with waste droplet sharing (b) Old DMF platform of size  $8\times15$  and the corresponding mixer placements.

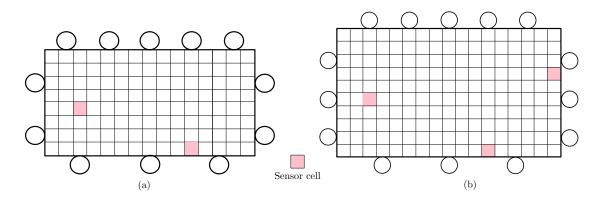


Figure A.17: Enhanced DMFB platform of dimensions (a)  $8\times15$  with sensors, and (b) chip of size  $10\times17$  with changes in reservoir and sensor geometry.

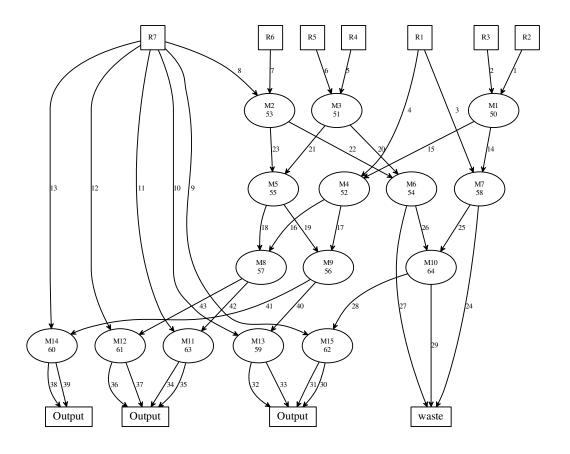


Figure A.18: Sequencing graph extracted from old actuation sequence using SimBioSys and assignment of  $\mathcal{ID}s$  to extracted routing paths and mixers.

Table A.11: Routing paths extracted from the old actuation sequence.

	Routing paths			
Path ID	~ .			
$\mathcal{P}_1$	[(1,2),(2,2),(3,2)]			
$\mathcal{P}_2$	[(3,1),(3,2),(3,3),(3,4),(3,5)]			
$\mathcal{P}_3$	[(1,8),(1,9),(1,10),(1,11),(2,11),(3,11),(3,12),(3,13),(3,14)]			
$\mathcal{P}_4$	[(1,8),(2,8),(3,8)]			
$\mathcal{P}_5$	[(1,14),(2,14),(3,14)]			
$\mathcal{P}_6$	[(3,15),(3,14),(3,13),(3,12),(3,11)]			
$\mathcal{P}_7$	[(1,5),(2,5),(3,5),(3,6),(3,7),(3,8),(3,9),(3,10),(3,11)]			
$\mathcal{P}_8$	[(1,11),(2,11),(3,11),(3,12),(3,13),(3,14)]			
$\mathcal{P}_9$	[(1,11),(2,11),(3,11)]			
$\mathcal{P}_{10}$	[(1,11),(2,11),(3,11),(3,10),(3,9),(3,8),(3,7),(3,6),(3,5),(3,4),(3,3)]			
$\mathcal{P}_{11}$	[(1,11),(2,11),(3,11),(3,12),(3,13)]			
$\mathcal{P}_{12}$	[(1,11),(2,11),(3,11),(3,10),(3,9),(3,8)]			
$\mathcal{P}_{13}$	[(1,11),(2,11),(3,11),(3,10),(3,9),(3,8),(3,7),(3,6),(3,5)]			
$\mathcal{P}_{14}$	[(3,2),(3,3),(2,3),(1,3),(1,4),(1,5),(1,6),(1,7),(1,8),(1,9),(1,10),(1,11),(2,11),(3,11)]			
$\mathcal{P}_{15}$	[(3,5)]			
$\mathcal{P}_{16}$	[(3,8),(4,8),(5,8),(6,8)]			
$\mathcal{P}_{17}$	[(3,5),(4,5),(5,5),(6,5)]			
$\mathcal{P}_{18}$	[(6,11),(5,11),(4,11),(3,11),(3,10),(3,9),(3,8)]			
$\mathcal{P}_{19}$	[(3,11),(3,10),(3,9),(3,8),(3,7),(3,6),(3,5)]			
$\mathcal{P}_{20}$	[(3,14),(4,14),(5,14),(6,14)]			
$\mathcal{P}_{21}$	[(3,11),(4,11),(5,11),(6,11)]			
$\mathcal{P}_{22}$	[(3,14)]			
$\mathcal{P}_{23}$	[(3,11)]			
$\mathcal{P}_{24}$	[(3,14),(4,14),(5,14),(6,14),(7,14),(7,15)]			
$\mathcal{P}_{25}$	[(3,11)]			
$\mathcal{P}_{26}$	[(3,14),(4,14),(5,14),(6,14),(6,13),(6,12),(6,11)]			
$\mathcal{P}_{27}$	[(6,14),(7,14),(7,15)]			
$\mathcal{P}_{28}$	[(3,11),(4,11),(5,11),(6,11)]			
$\mathcal{P}_{29}$	[(6,11),(6,12),(6,13),(6,14),(6,15),(7,15)]			
$\mathcal{P}_{30}$	[(6,11),(6,12),(6,13),(7,13),(8,13)]			
$\mathcal{P}_{31}$ $\mathcal{P}_{32}$	[(3,11), (3,12), (3,13), (4,13), (5,13), (6,13), (7,13), (8,13)] $[(6,3), (7,3), (8,3)]$			
$\mathcal{P}_{32}$ $\mathcal{P}_{33}$	[(3,3),(4,3),(5,3),(6,3),(7,3),(8,3)]			
$\mathcal{P}_{34}$	[(3,3),(4,3),(5,3),(6,3),(7,3),(8,3)] $[(3,13),(4,13),(5,13),(6,13),(7,13),(8,13)]$			
$\mathcal{P}_{35}$	[(6,13),(7,13),(8,13)] $[(6,13),(7,13),(8,13)]$			
$\mathcal{P}_{36}$	[(6,8),(7,8),(8,8)]			
$\mathcal{P}_{37}$	[(3,8),(4,8),(5,8),(6,8),(7,8),(8,8)]			
$\mathcal{P}_{38}$	[(6,5),(6,4),(6,3),(7,3),(8,3)]			
$\mathcal{P}_{39}$	[(3,5),(3,4),(3,3),(4,3),(5,3),(6,3),(7,3),(8,3)]			
$\mathcal{P}_{40}$	[(6,5),(6,4),(6,3)]			
$\mathcal{P}_{41}$	[(3,5),(4,5),(5,5),(6,5)]			
$\mathcal{P}_{42}$	[(6,8),(6,9),(6,10),(6,11),(6,12),(6,13)]			
$\mathcal{P}_{43}$	[(3,8),(4,8),(5,8),(6,8)]			

Table A.12: Mixer locations and types extracted from the old actuation sequence.  $\[$ 

Mixers		
Mixer ID	Mixer Type	Mixer location
50	$1 \times 4$	[(3,2),(3,5)]
51	$1 \times 4$	[(3,11),(3,14)]
52	$1 \times 4$	[(3,5),(3,8)]
53	$1 \times 4$	[(3,11),(3,14)]
54	$4 \times 1$	[(3,14),(6,14)]
55	$4 \times 1$	[(3,11),(6,11)]
56	$4 \times 1$	[(3,5),(6,5)]
57	$4 \times 1$	[(3,8),(6,8)]
58	$1 \times 4$	[(3,11),(3,14)]
59	$4 \times 1$	[(3,3),(6,3)]
60	$4 \times 1$	[(3,5),(6,5)]
61	$4 \times 1$	[(3,8),(6,8)]
62	$4 \times 1$	[(3,11),(6,11)]
63	$4 \times 1$	[(3,13),(6,13)]
64	$4 \times 1$	[(3,11),(6,11)]