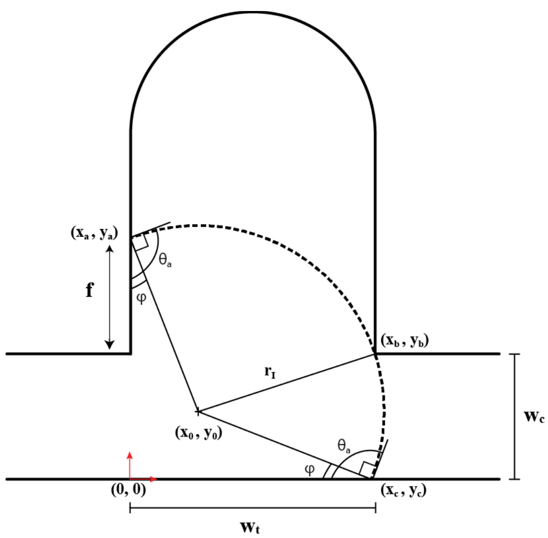
Electronic Supplementary Material (ESI) for Lab on a Chip.

Staggered Trap Arrays for Robust Microfluidic Sample Digitization

Supplementary Information

Figures S1-S3 present the geometric models used to establish the relationships between physical system parameters, including contact angle (θ_a) and channel width ratio (*CR*), and the resulting filling ratio (*F*R) that defines the degree of intrusion of fluid into a given trap. For each model, the non-linear system of equations with associated constraints were solved in Mathematica to determine the fluid intrusion length (*f*) for each design.



Assumptions: Constant interface curvature

Unknowns: x_0, y_0, y_a, r

Knowns: $x_a = 0,\ x_b = w_t,\ x_c = y_a,\ y_b = w_c,\ y_c = 0, \theta, \varphi$

Constraints: $y_a \geq w_c,\ r_I \geq 0$

Equation 1: $x_0^2 + (y_a - y_0)^2 = r_I^2$

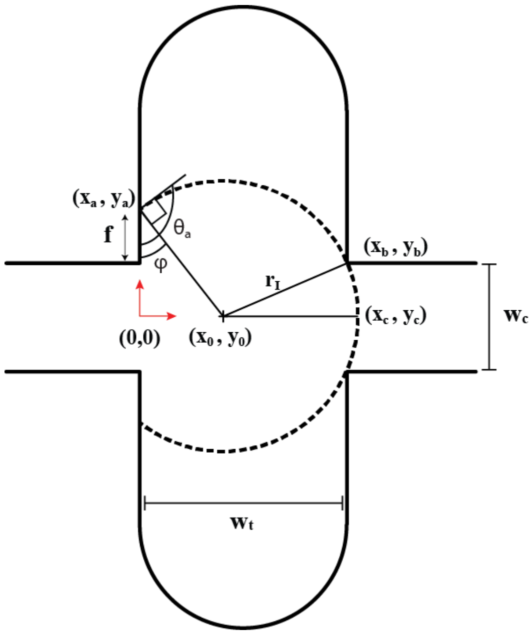
Equation 2: $(w_t - x_0)^2 + (w_c - y_0)^2 = r_I^2$

Equation 3: $(y_a - x_0)^2 + y_0^2 = r_I^2$

Equation 4: $\tan(\varphi) = \frac{x_0}{y_a - y_0}$

Solve: $f = y_a - w_c$

Figure S1. Geometric model for a single-sided trap design.



Assumptions: Constant interface curvature, symmetric advancement of interfaces along both trap walls

Unknowns: x_0, y_a, r

Knowns: $x_a = 0,\ x_b = w_t,\ y_0 = 0\ ,\ y_b = \frac{w_c}{2},\ y_c = 0, \theta, \varphi$

Constraints: $y_a \geq \frac{w_c}{2},\ r_I \geq 0, \theta_{lim}(\mathrm{CR})$

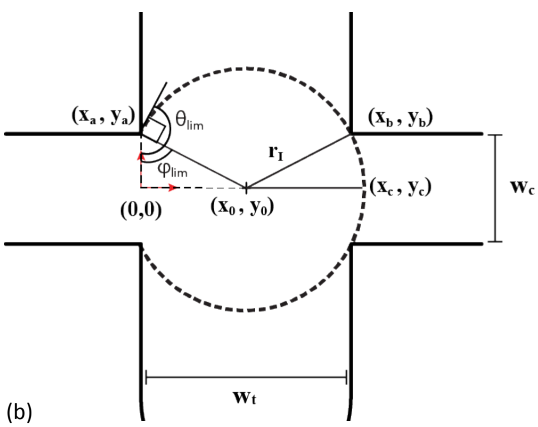
Equation 1: $x_0{}^2 + y_a{}^2 = r_I{}^2$

Equation 2: $(w_t - x_0)^2 + \left(\frac{w_c}{2}\right)^2 = r_I{}^2$

Equation 4: $\tan(\varphi) = \frac{x_0}{y_a}$

Solve: $f = y_a - \frac{w_c}{2}$

(a)



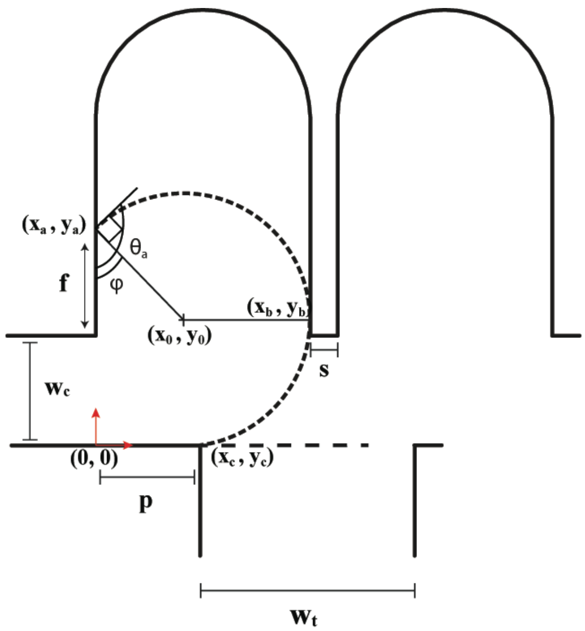
Constant curvature → $x_0 = \frac{w_t}{2}$ and $y_a = \frac{w_c}{2}$

$\tan(\varphi_{lim}) = \frac{w_t}{w_c}$

$\theta_{lim} = \varphi_{lim} + \frac{\pi}{2}$

(b)

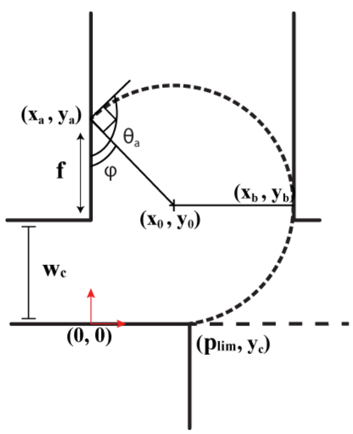
Figure S2. (a) Overall geometric model for a double-sided trap design, and (b) model for determining θ_{lim}, defined as the upper limit of θ_a above which fluid will not advance into the trap. Note that θ_{lim} is a function of the channel width ratio.



Assumptions: Constant interface curvature
Unknowns: x_0, y_0, y_a, r
Knowns: $x_a = 0,\ x_b = w_t,\ x_c = p,\ y_b = y_0,\ y_c = 0, \theta, \phi$
Constraints: $y_a \geq w_c,\ r_I \geq 0, y_0 \geq w_c$
Equation 1: $x_0{}^2 + (y_a{}^2 - y_0{}^2) = r_I{}^2$
Equation 2: $(w_t - x_0)^2 = r_I{}^2$
Equation 3: $(p - x_0)^2 + y_0{}^2 = r_I{}^2$
Equation 4: $\tan(\varphi) = \frac{x_0}{y_a - y_0}$

Solve: $f = y_a - w_c$

(a)



Assumptions: Constant interface curvature
Unknowns: x_0, y_0, y_a, r
Knowns: $x_a = 0,\ x_b = w_t,\ y_a = p_{lim},\ y_c = 0, \theta, \varphi$
Constraints: $y_a \geq w_c,\ r_I \geq 0$
Equation 1: $x_0{}^2 + (p_{lim} - y_0)^2 = r_I{}^2$
Equation 2: $(w_t - x_0)^2 + (w_c - y_0)^2 = r_I{}^2$
Equation 3: $(p_{lim} - x_0)^2 + y_0{}^2 = r_I{}^2$
Equation 4: $\tan(\varphi) = \frac{x_0}{p_{lim} - y_0}$

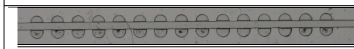
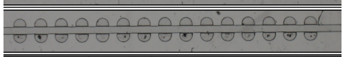
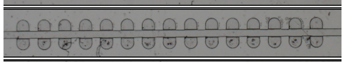
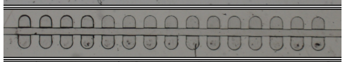
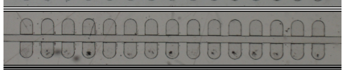
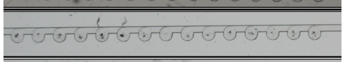
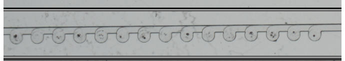
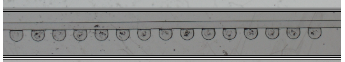
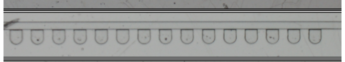
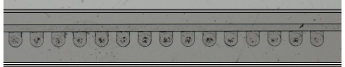
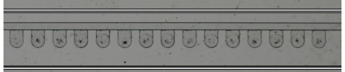
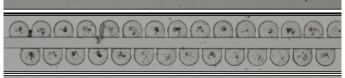
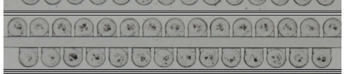
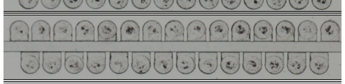
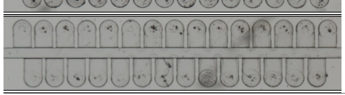
Solve for p_{lim} (FR, θ_a) using the single sided model. If $p > p_{lim}$ then pinning does not occur for that configuration.

(b)

Figure S3. (a) Geometric model for a staggered trap design. (b) Derivation for the p_{lim} which determines at what p the staggered configuration will act as a single sided configuration because the pinning point is not reached before the interface contacts the opposite wall. Note that p_{lim} is a function of the filling ratio and advancing contact angle.

Table S1. Loading efficiency data for staggered, double-sided, and single-sided trap configurations at different channel width ratios and maximum filling ratios (see Figure 6). Data is presented for the case where (a) the main channel is identical to the trap depth, and (b) the main channel depth is greater than the trap depth.

(a)

Design	FR (f/w_t)	CR (w_c/w_t)	Config	Filling % for each experiment					Mean	σ
				1	2	3	4	5		
	0.49	0.55	Double	100%	100%	100%	100%	100%	100%	0%
	0.64	0.55	Double	97%	100%	100%	100%	97%	99%	2%
	0.73	0.55	Double	93%	100%	90%	90%	97%	94%	4%
	0.88	0.55	Double	97%	100%	97%	100%	90%	97%	4%
	1.06	0.55	Double	50%	47%	57%	77%	67%	59%	11%
	1.17	0.55	Double	47%	63%	60%	57%	63%	58%	6%
	1.31	0.55	Double	33%	41%	40%	53%	27%	39%	9%
	0.65	0.55	Single	100%	100%	100%	100%	100%	100%	0%
	0.76	0.55	Single	100%	100%	100%	100%	100%	100%	0%
	0.88	0.55	Single	93%	93%	100%	80%	73%	88%	10%
	1.06	0.55	Single	27%	0%	0%	7%	0%	7%	10%
	1.17	0.55	Single	0%	47%	47%	33%	33%	32%	17%
	1.31	0.55	Single	0%	0%	0%	0%	0%	0%	0%
	1.59	0.55	Single	0%	0%	0%	0%	0%	0%	0%
	0.88	0.59	Staggered	100%	100%	100%	100%	100%	100%	0%
	1.06	0.59	Staggered	100%	100%	100%	100%	100%	100%	0%
	1.17	0.59	Staggered	97%	100%	97%	97%	100%	98%	2%
	1.31	0.59	Staggered	97%	97%	97%	100%	97%	97%	1%
	1.59	0.59	Staggered	55%	48%	28%	31%	31%	39%	11%

(b)

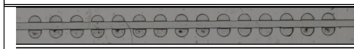
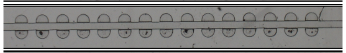
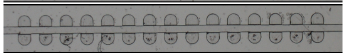
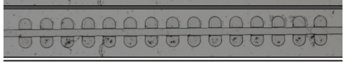
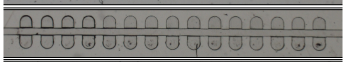
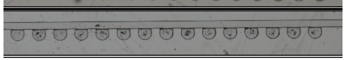
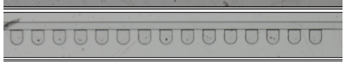
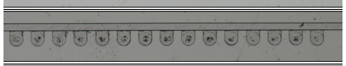
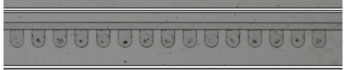
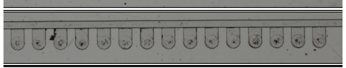
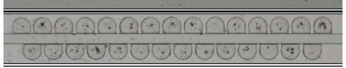
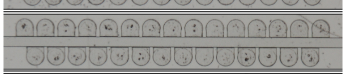
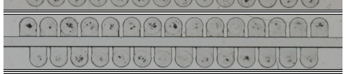
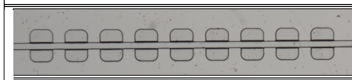
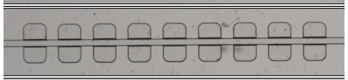
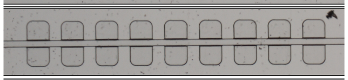
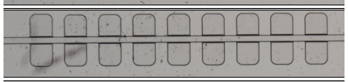
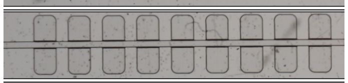
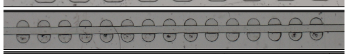
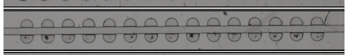
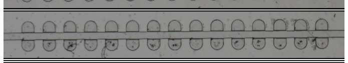
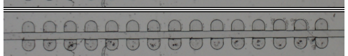
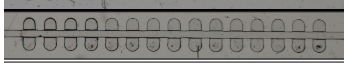
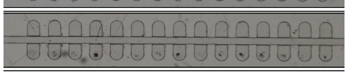
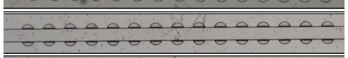
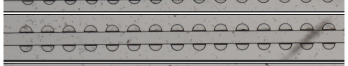
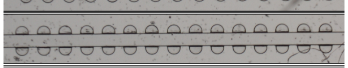
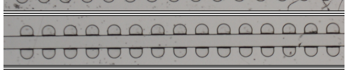
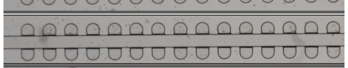
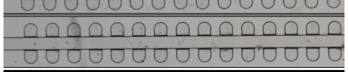
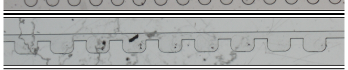
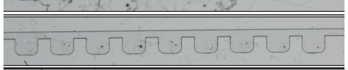
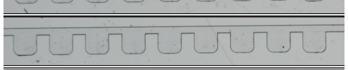
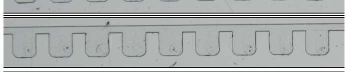
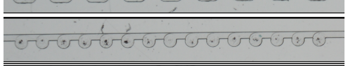
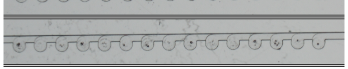
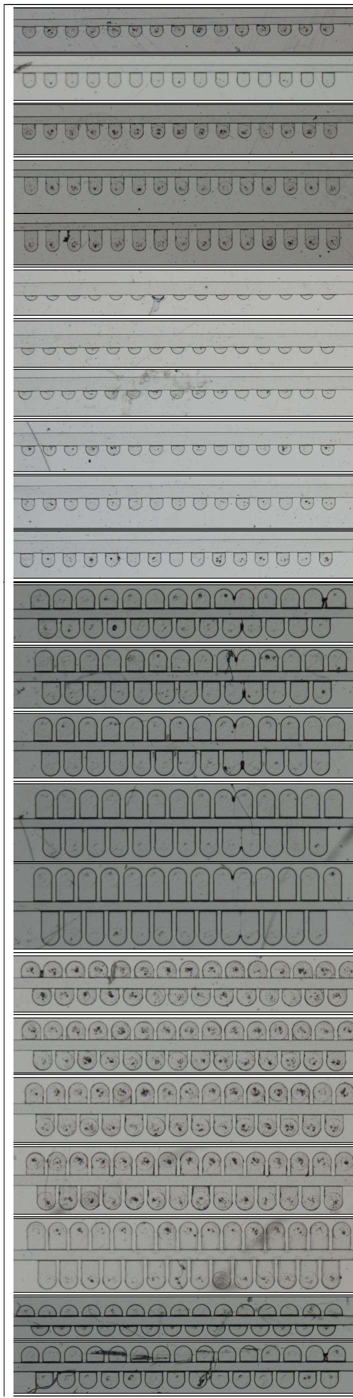
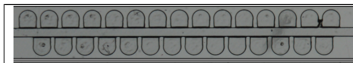
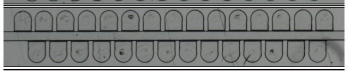
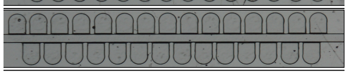
Design	FR (f/w_t)	CR (w_c/w_t)	Config	Filling % for each experiment					Mean	σ
				1	2	3	4	5		
	0.49	0.55	Double	100%	93%	100%	100%	100%	99%	3%
	0.64	0.55	Double	100%	100%	100%	100%	100%	100%	0%
	0.73	0.55	Double	100%	100%	100%	90%	100%	98%	4%
	0.88	0.55	Double	97%	100%	97%	100%	90%	97%	4%
	1.06	0.55	Double	53%	57%	53%	87%	83%	67%	15%
	1.17	0.55	Double	53%	40%	53%	57%	53%	51%	6%
	1.31	0.55	Double	53%	33%	37%	53%	40%	43%	8%
	0.88	0.55	Single	100%	93%	93%	87%	100%	95%	5%
	1.06	0.55	Single	40%	33%	53%	53%	33%	43%	9%
	1.17	0.55	Single	20%	60%	53%	13%	20%	33%	19%
	1.31	0.55	Single	7%	13%	20%	20%	20%	16%	5%
	1.59	0.55	Single	40%	0%	0%	27%	7%	15%	16%
	0.88	0.55	Staggered	100%	100%	100%	100%	100%	100%	0%
	1.06	0.55	Staggered	100%	100%	90%	100%	100%	98%	4%
	1.17	0.55	Staggered	90%	86%	100%	100%	100%	95%	6%
	1.31	0.55	Staggered	100%	100%	100%	100%	100%	100%	0%
	1.59	0.55	Staggered	90%	100%	66%	100%	93%	90%	13%

Table S2. Experimental data used to evaluate the impact of L/w_t and CR on trap loading efficiency (see Figure 7).

Design	FR (f/w_t)	CR (w_c/w_t)	Config	Filling % for each experiment					Mean	σ
				1	2	3	4	5		
	0.60	0.31	Double	100%	100%	100%	100%	100%	100%	0%
	0.73	0.31	Double	94%	100%	100%	94%	100%	98%	3%
	0.88	0.31	Double	78%	56%	83%	83%	83%	77%	11%
	1.02	0.31	Double	50%	50%	50%	61%	50%	52%	4%
	1.18	0.31	Double	50%	50%	33%	22%	56%	42%	12%
	0.49	0.55	Double	100%	100%	100%	100%	100%	100%	0%
	0.64	0.55	Double	97%	100%	100%	100%	97%	99%	2%
	0.73	0.55	Double	93%	100%	90%	90%	97%	94%	4%
	0.88	0.55	Double	97%	100%	97%	100%	90%	97%	4%
	1.06	0.55	Double	50%	47%	57%	77%	67%	59%	11%
	1.17	0.55	Double	47%	63%	60%	57%	63%	58%	6%
	1.31	0.55	Double	33%	41%	40%	53%	27%	39%	9%
	0.40	1.00	Double	100%	100%	100%	100%	100%	100%	0%
	0.57	1.00	Double	97%	100%	97%	100%	100%	99%	2%
	0.67	1.00	Double	87%	93%	90%	80%	93%	89%	5%
	0.83	1.00	Double	75%	77%	90%	53%	83%	76%	12%
	0.95	1.00	Double	64%	80%	60%	50%	77%	66%	11%
	1.08	1.00	Double	33%	40%	37%	30%	30%	34%	4%
	0.56	0.31	Single	100%	100%	100%	100%	100%	100%	0%
	0.70	0.31	Single	100%	100%	100%	100%	100%	100%	0%
	0.85	0.31	Single	100%	89%	78%	89%	100%	91%	8%
	1.01	0.31	Single	44%	56%	67%	22%	44%	47%	15%
	0.65	0.55	Single	100%	100%	100%	100%	100%	100%	0%
	0.76	0.55	Single	100%	100%	100%	100%	100%	100%	0%



0.88	0.55	Single	93%	93%	100%	80%	73%	88%	10%
1.06	0.55	Single	27%	0%	0%	7%	0%	7%	10%
1.17	0.55	Single	0%	47%	47%	33%	33%	32%	17%
1.31	0.55	Single	0%	0%	0%	0%	0%	0%	0%
1.59	0.55	Single	0%	0%	0%	0%	0%	0%	0%
0.38	1.00	Single	100%	100%	100%	100%	100%	100%	0%
0.51	1.00	Single	100%	100%	100%	100%	100%	100%	0%
0.65	1.00	Single	100%	100%	100%	100%	100%	100%	0%
0.78	1.00	Single	60%	20%	27%	20%	27%	31%	15%
0.94	1.00	Single	20%	47%	27%	7%	13%	23%	14%
1.10	1.00	Single	0%	0%	0%	0%	0%	0%	0%
1.02	0.41	Staggered	100%	100%	100%	100%	100%	100%	0%
1.18	0.41	Staggered	100%	100%	100%	100%	100%	100%	0%
1.34	0.41	Staggered	100%	100%	100%	100%	100%	100%	0%
1.64	0.41	Staggered	73%	73%	82%	73%	73%	75%	4%
1.92	0.41	Staggered	9%	0%	0%	27%	0%	7%	11%
0.88	0.59	Staggered	100%	100%	100%	100%	100%	100%	0%
1.06	0.59	Staggered	100%	100%	100%	100%	100%	100%	0%
1.17	0.59	Staggered	97%	100%	97%	97%	100%	98%	2%
1.31	0.59	Staggered	97%	97%	97%	100%	97%	97%	1%
1.59	0.59	Staggered	55%	48%	28%	31%	31%	39%	11%
0.59	0.81	Staggered	100%	100%	100%	100%	100%	100%	0%
0.88	0.81	Staggered	92%	100%	100%	100%	100%	98%	3%

		1.04	0.81	Staggered	92%	92%	100%	100%	100%	97%	4%
		1.15	0.81	Staggered	93%	93%	71%	86%	93%	87%	8%
		1.28	0.81	Staggered	21%	14%	7%	14%	14%	14%	5%