Supplementary information

Derivation of equation 3

The complete derivation involves the theory of conformal mapping and tedious integral calculation. Consequently, we describe only the main steps hereafter. More details can be found in [1]. Applying the general conformal mapping theory to planar metal electrode within a long access channel, it can be shown that the two-dimensional cell constant is given by

$$\kappa_{2D} = \frac{2K(k^2)}{K(1-k_2^2)}$$

where $K(x)$ is the complete elliptic integral of the first kind

$$K(x) = \int_0^1 \frac{dt}{\sqrt{(1-t^2)(1-x^2t^2)}}$$

and the parameter k is given by

$$k \approx 1 - 2\sqrt{\frac{2}{\cosh(\pi \frac{r_d}{h})}}$$

where h is the channel height and r_d is the channel length. Since $r_d \gg h$, we have $k_2 \rightarrow 1$ and we obtain the following approximations

$$k_2^2 \approx 1 - 4\sqrt{\frac{2}{\cosh(\pi \frac{r_d}{h})}} \tag{1}$$

and

$$\kappa_{2D} \approx \frac{4}{\pi}[2\ln(2) - \ln(\sqrt{1-k_2^2})] \tag{2}$$

By inserting Eq.1 in equation Eq. 2 and some simplifications we obtain

$$\kappa_{2D} \approx \frac{2\ln(2)}{\pi} + \frac{r_d}{h}$$

The corresponding three-dimensional cell constant κ is given by

$$\kappa = \frac{1}{w_{ch}}(\frac{2\ln(2)}{\pi} + \frac{r_d}{h})$$

where w_{ch} is the width of the channel. The first term accounts for the curving of the field lines down towards the metal electrode and the second term corresponds to the resistance due to a channel length equal to r_d.

For two electrodes that are spaced by a distance s_{el} from each other, we consequently obtain

$$\kappa = \frac{1}{w_{ch}}\left(\frac{4\ln(2)}{\pi} + \frac{s_{el}}{h}\right)$$

Resistance range extension with interdigitated electrode

The measured resistance of sub-sensor 3 is decreased by using interdigitated electrodes. This leads to an increased total resistance range D (R_1 is constant). Simultaneously, P decreases because of a decreased $f_{c,5}$. This means that the resistance range can be increased by the expense of a decreased resistance plateau length P. This might be acceptable to the extent where the PRFs and their corresponding R may still be identified. Both, D and P are a function of the number of interdigitated electrode fingers n [2].

It is now possible to calculate the plateau length for a desired resistance range and thus a given n. For this P calculates as follows:

$$P = log\left(\frac{f_3}{f_2}\right) \times log\left(\frac{f_5}{f_4}\right) = P_1 \times P_2$$

where $P_1 = P_2$ and thus $\frac{f_3}{f_2} = \frac{f_5}{f_4}$ for a maximized M. We summarize the ratio of the frequencies as m:

$$m = \frac{f_3}{f_2} = \frac{f_5}{f_4}$$

Consequently, for a given n, m can be calculated as follows

$$m = 10^{\sqrt{P(n)}}$$

We have plotted both the resistance range and the frequency ratio m in Fig. S1. In conclusion, we are able to extend the total resistance range and thus the resistance ranges of each sub-sensor by increasing n. This is accompanied by a decreased resistance plateau ratio m which makes the identification of the PRFs more difficult.

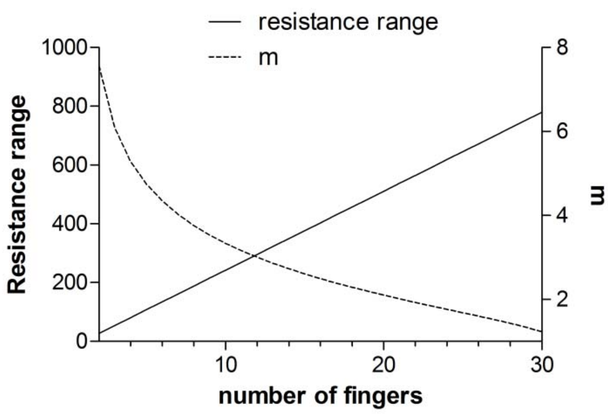

Fig. S1 The resistance range and the P-specific ratio m are plotted as a function of the number of interdigitated electrode fingers.

Capacitive bridge

a)　　**b)**

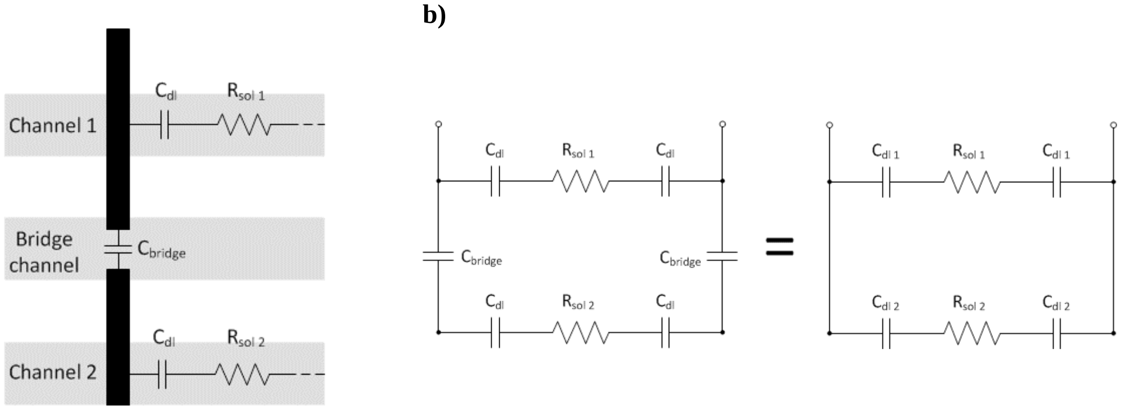

Fig. S2 Capacitive bridge. a) Scheme of a potential chip design with a capacitive bridge. b) Equivalent electrical circuit of a). It is shown that the value of C_{dl} can be modified by implementing a “bridge capacitor”.

An additional microfluidic channel is used to create a series electrode-electrolyte capacitor. This one adds up to the double layer capacitor of channel 2 and consequently changes the total capacitor value of sub-sensor 2. The resistance in the bridge channel may be neglected if this one contains a highly concentrated ionic solution. Thus, an identical electrode width for sensor 1 and 2 can be used.

1 T. Braschler, PhD thesis, p.200, Ecole Polytechnique Fédérale de Lausanne, 2009.

2 W. Olthuis, W. Streekstra, and P. Bergveld, *Sensors and Actuators B: Chemical*, 1995, 24, 252-256.