Electronic Supplementary Material (ESI) for Analytical Methods.

Supplementary Information

Balance-in-a-box: An integrated paper-based weighing balance for infant birth weight determination

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Readout system with graphite separators of 500 ohms each

A readout system with a total resistance of 1000 ohms was fabricated in which the graphite separators were 500 ohms each in resistance. The critical weights in which the segments changed color were 1.35 kg and 2.5 kg.

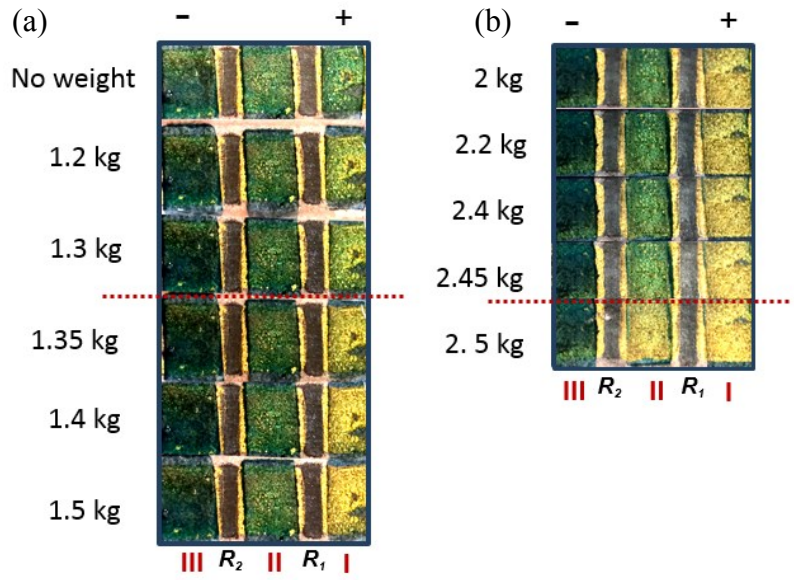
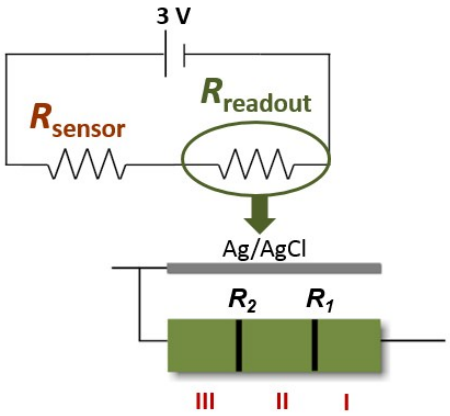


Fig. S1. Images of paper-based readout systems comprising three gold nanoparticle films segments and two graphite resistive separators. The graphite separators were 500 Ω each in resistance. The color change for (a) segment I and (b) segment II was observed upon application of various weights to the pressure sensor. The horizontal red dashed lines indicate the weight at which the segment changed color (segment I at 1.35 kg and segment II at 2.5 kg).

Tuning the readout system to obtain critical weight values of 1.5 kg and 2.5 kg

To obtain a critical weight value of 1.5 kg for segment I and 2.5 kg for segment II, both the total resistance of the readout system and the values of the individual graphite separators are adjusted.



First the total resistance of the readout system ($R_{readout}$) is calculated using equation 1,

$$R_{readout} = \frac{R_{sensor}\ V_{readout}}{V_{total} - V_{readout}} \qquad (1)$$

When a weight of 1.5 kg is placed to the sensor, the sensor yields a resistance of $R_{sensor} = 3200\ \Omega$. Since $V_{total} =$ 3 V (coin cell battery) and the voltage across the readout system for segment I to change color is $V_{readout}$ = -0.6 V then substituting the values into equation 1 gives,

$$R_{readout} = \frac{3200 \times 0.6}{(3 - 0.6)}$$

$$R_{readout} = 800\ \Omega$$

Thus, $R_{readout}$ of 800 Ω allows 1.5 kg weight to be distinguished by the color change at segment I.

The second step is then to determine the voltage across the readout system that is necessary so that segment II will change color when 2.5 kg is applied to the pressure sensor. As $R_{readout} = 800\ \Omega$, $R_{sensor} = 1500\ \Omega$ (for 2.5 kg weight), the voltage across the readout system becomes,

$$V_{readout} = \frac{R_{readout}\ V_{total}}{R_{readout} + R_{sensor}}$$

$$V_{readout} = \frac{800 \times 3}{800 + 1500}$$

Solving for $V_{readout}$ gives

$$V_{readout} = 1.05\ \text{V}$$ when 2.5 kg is placed to the pressure sensor.

The final step is adjusting the resistances of each graphite resistive separators (R_1 and R_2).

If segment II is used to measure a critical weight value of 2.5 kg, then the voltage drop at segment II (V_2) needs to be -0.6 V for the segment to change color when -1.05 V drops across the readout system. Thus, the resistance of these two graphite separators can be calculated using,

$$V_2 = \frac{V_{readout}}{R_{readout}} \times R_2$$

$$0.6 = \frac{1.05}{800} \times R_2$$

$$R_2 = 457\ \Omega$$

Since $R_{readout} = R_1 + R_2$, substituting $R_2 = 457\ \Omega$ into this equation gives,

$$800 = R_1 + 457$$

$$R_1 = 343\ \Omega$$

Thus for the fabrication of the readout system, R_1 and R_2 were rounded and set to 450 Ω and 350 Ω, respectively with a total resistance of 800 Ω.

Readout system with graphite separators of 350 and 450 ohms

A readout system with a total resistance of 800 ohms was fabricated in which the graphite separators were R_1 = 350 ohms and R_2 = 450 ohms in resistance. The critical weights in which the segments changed color were 1.5 kg and 2.5 kg.

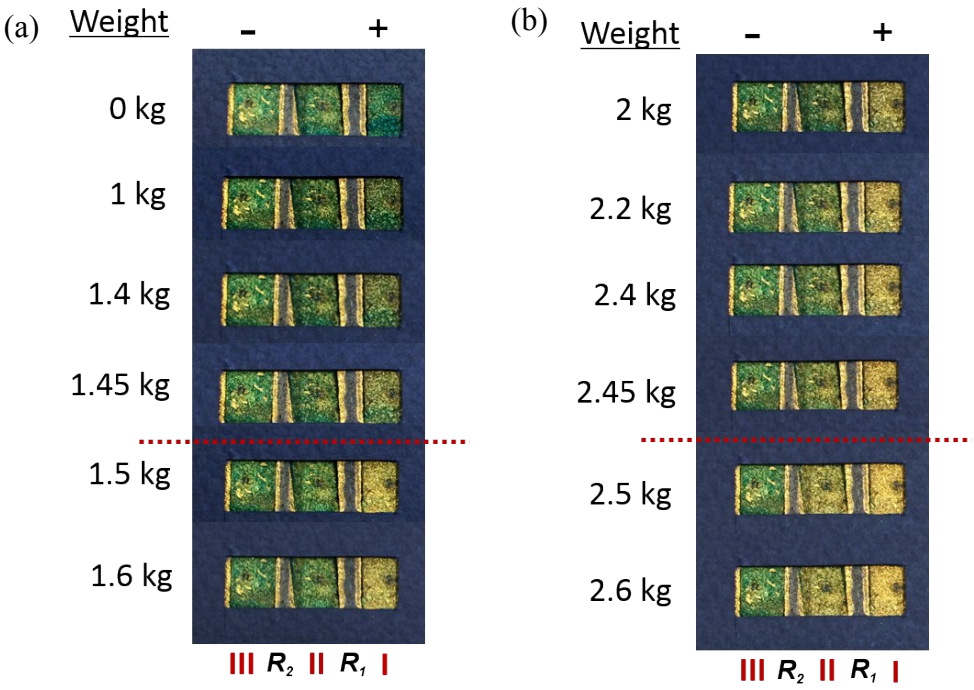


Fig. S2. Images of paper-based readout systems comprising three gold nanoparticle film segments and two graphite resistive separators. The graphite separators R_1 and R_2 350 Ω and 450 Ω, respectively. The color change for (a) segment I and (b) segment II was observed upon application of various weights to the pressure sensor. The horizontal red dashed lines indicate the weight at which the segments change color (segment I at 1.5 kg and segment II at 2.5 kg).