



FlexTouch: Enabling Large-Scale Interaction Sensing Beyond Touchscreens Using Flexible and Conductive Materials

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GLOBAL INNOVATION EXCHANGE



Computing Era Dominated by Touch



Desktop



Mobile



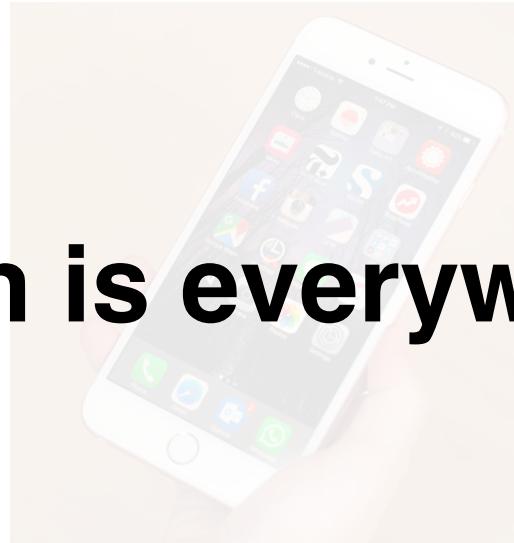
Wearable

Pictures originate from the internet (google picture)

Computing Era Dominated by Touch



Desktop

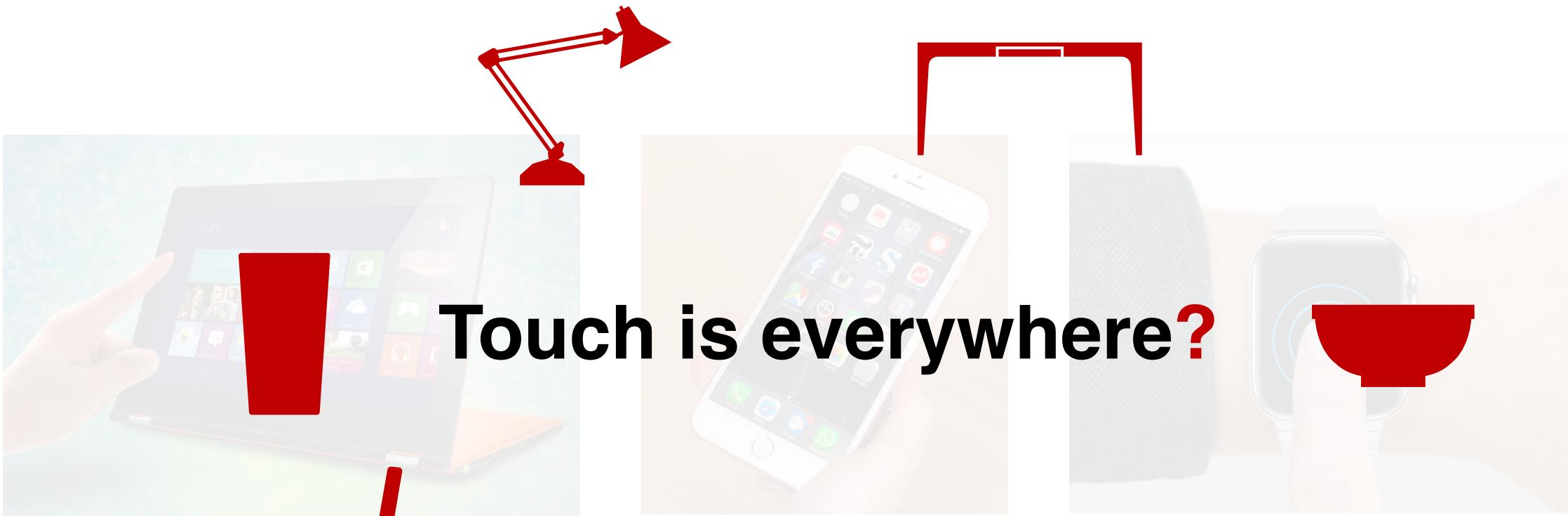


Mobile



Wearable

Computing Era Dominated by Touch



Desktop

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Computing Era Dominated by Touch



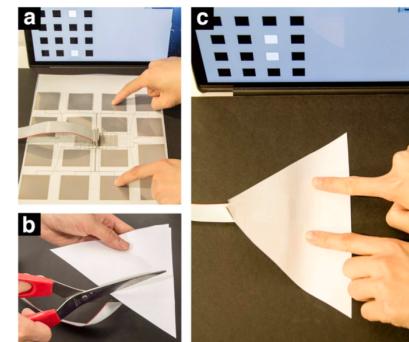
Desktop

Mobile

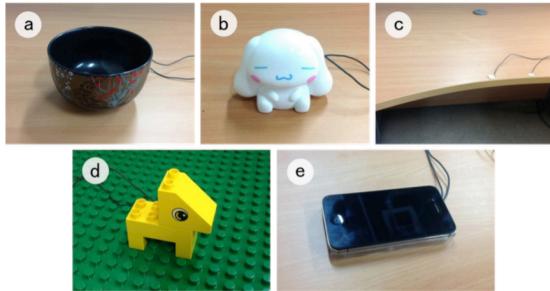
Wearable

Daily Activity

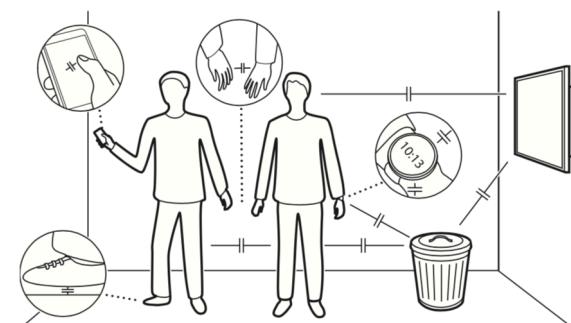
Enabling touch interface on everyday objects



Olberding et.al. UIST13



Touch & Activate
Ono, UIST 13



Grosse-Puppendahl et.al.
CHI17



Touche, Sato et.al. CHI12



WorldKit, Xiao et.al. CHI13

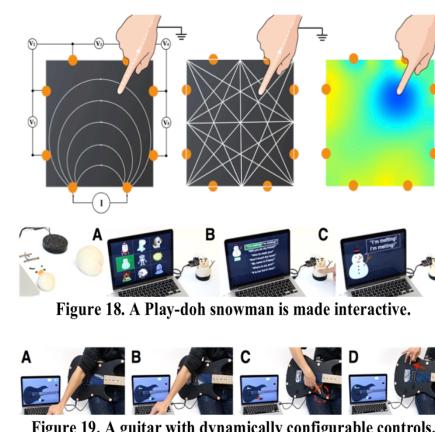


Figure 18. A Play-doh snowman is made interactive.

Figure 19. A guitar with dynamically configurable controls.



Pulp Nonfiction
Zhang et.al. CHI18

Electrick
Zhang et.al. CHI17

Enabling touch interface on everyday objects



Midas
Savage et.al. UIST 12



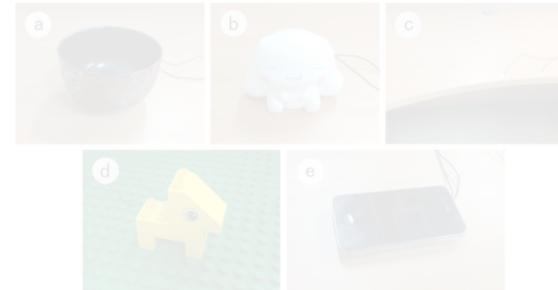
Oberding et.al. UIST 13

Touche, Sato et.al. CHI12



Figure 17. A graph showing signal amplitude versus frequency for different touch gestures.

Require dedicated sensing platforms with embedded systems to provide power supply, external sensors, signal processing, and communication.



Touch and Activate

Grosse-Puppenthal et.al.
CHI17



Figure 18. A Play-doh snowman is made interactive.



Figure 19. A guitar with dynamically configurable controls.



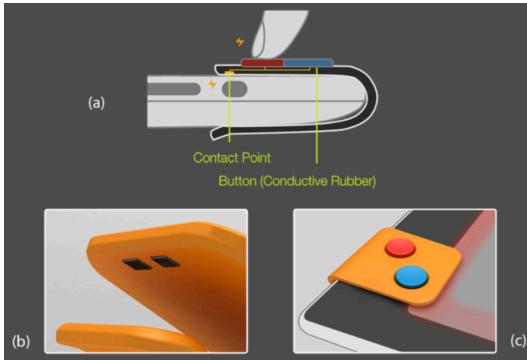
Pulp Nonfiction
Zhang et.al. CHI18

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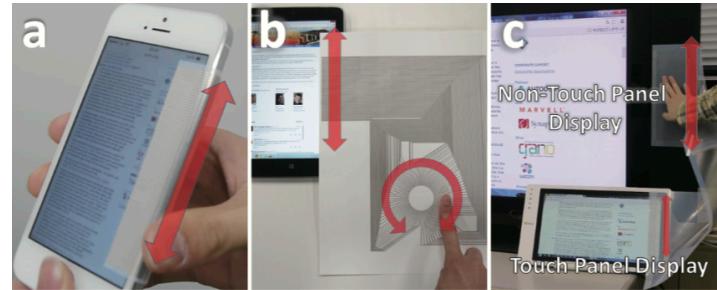
Extending the touch capability from commercial touchscreens to everyday surfaces



Extending touch interface of touchscreens to ambient surfaces



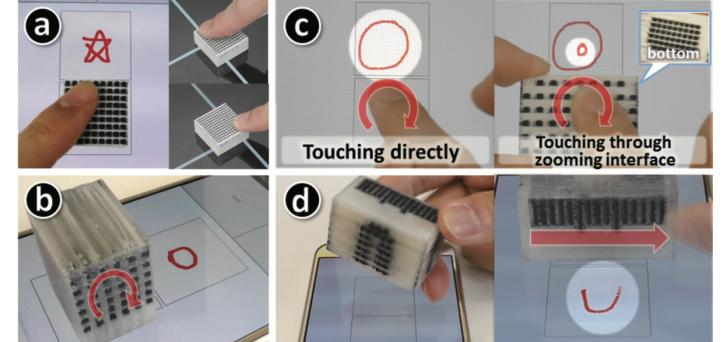
Clip-on Gadgets
Yu et. al. UIST11



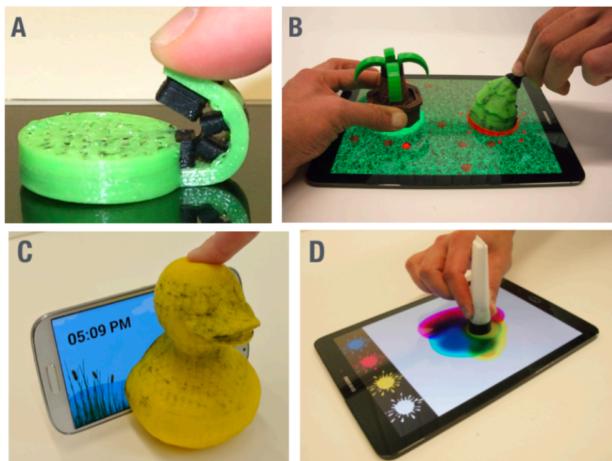
Extension Sticker
Kato et. al. CHI15



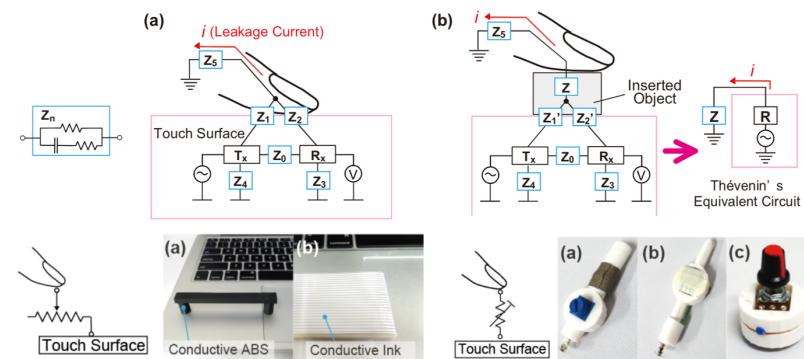
Kato et. al. UIST15



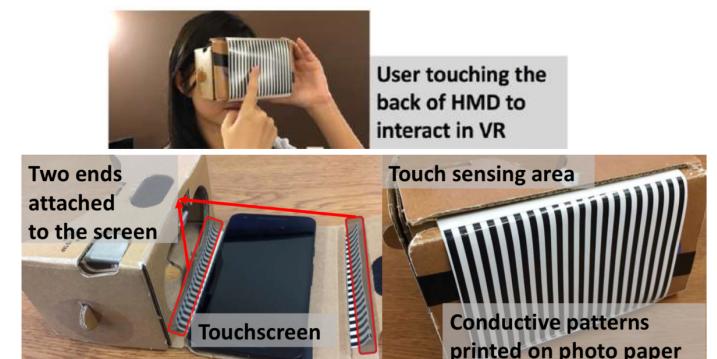
Kato et. al. UIST16



Flexibles
Schmitz et. al. CHI 17

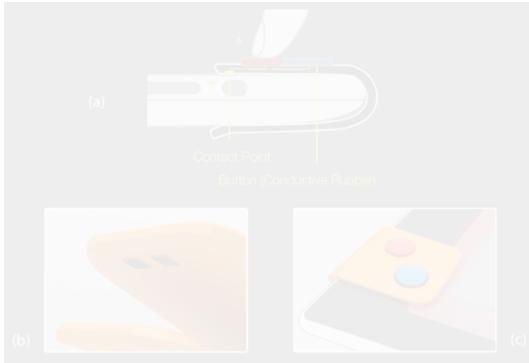


Ohmic-Touch
Ikematsu et. al CHI18



Zhang et. al. MobiCom18

Extending touch interface of touchscreens to ambient surfaces



Clip-on Gadgets
Yu et. al. UIST11

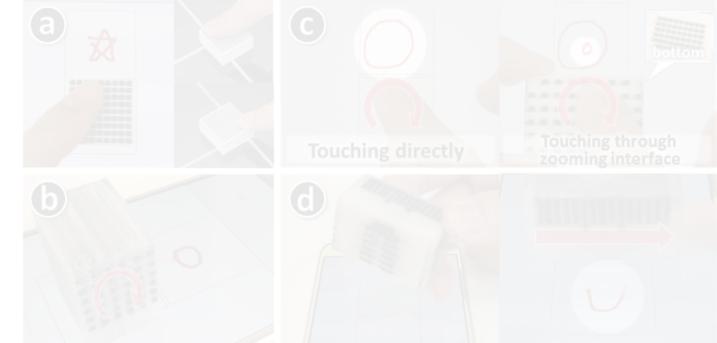


Extension Sticker

Kato et. al. CHI15



Kato et. al. CHI15



Kao et. al. UIST16



Flexibles
Schmitz et. al. CHI 17

Current solutions can only support near range touch interface extended from touchscreens.



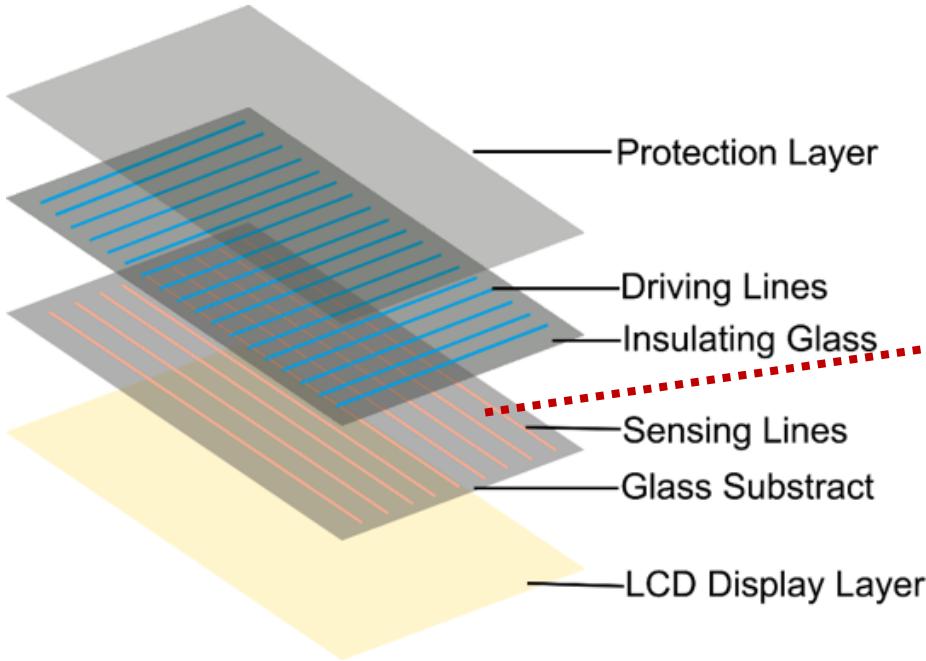
Ohmic-Touch
Ikematsu et. al CHI18



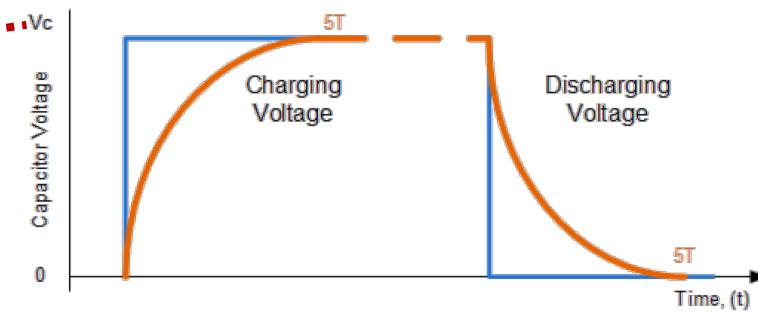
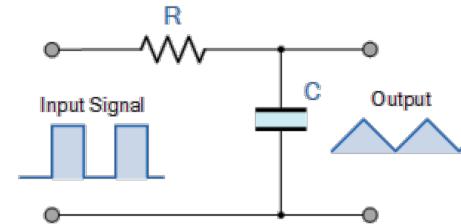
Zhang et. al. MobiCom18



How touchscreen works – Capacitance Measurement



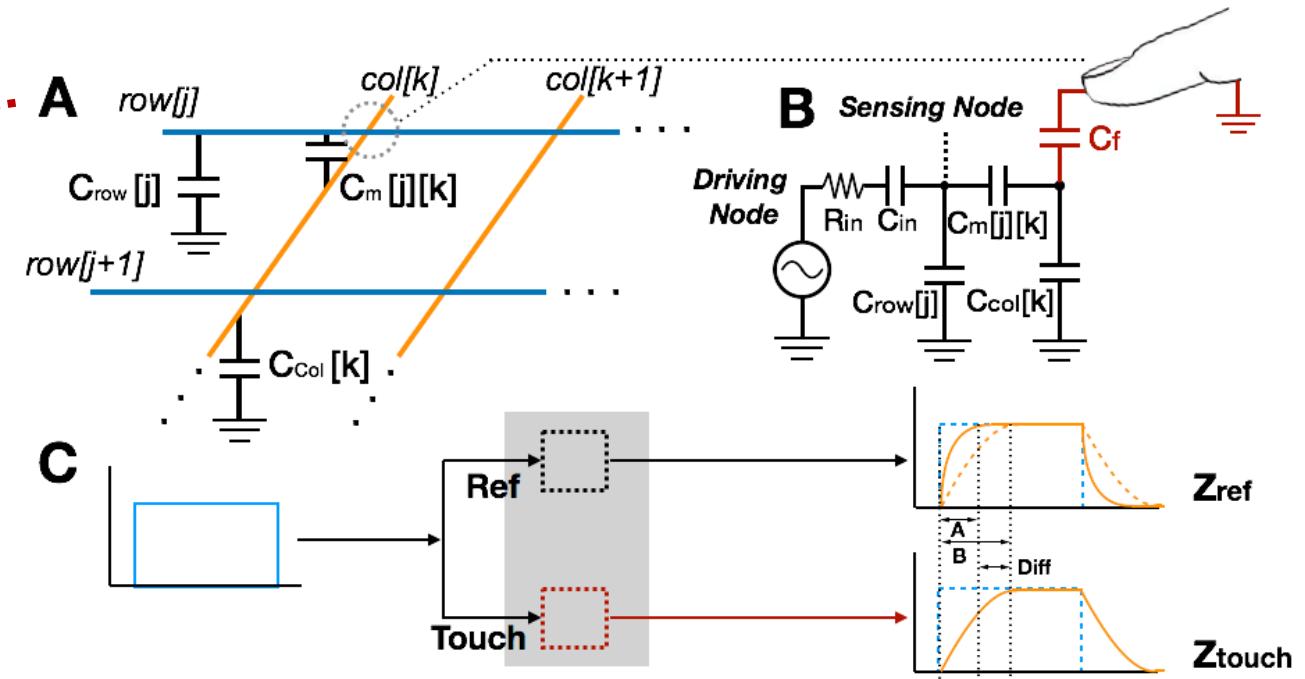
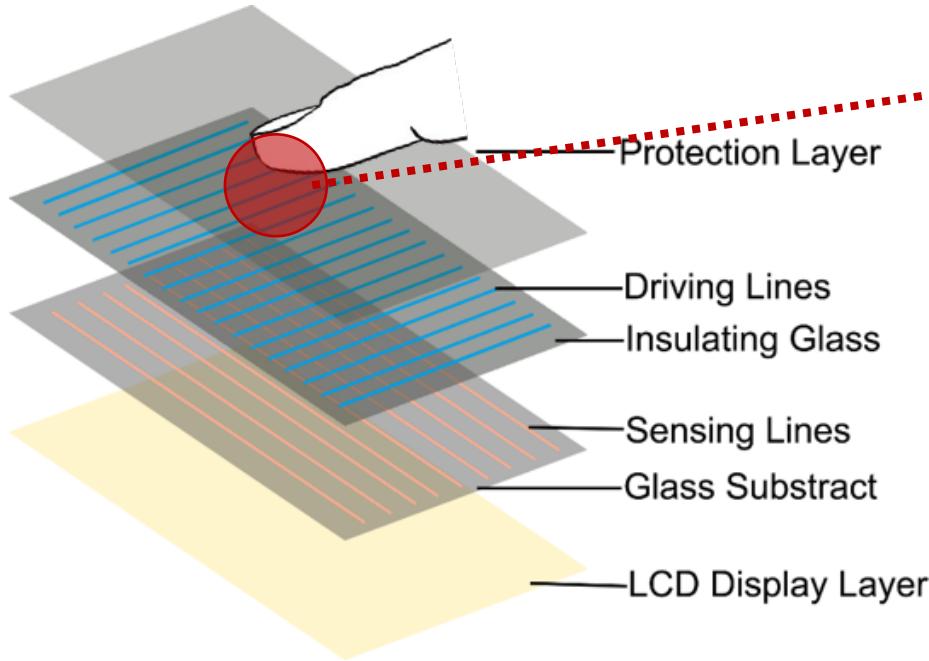
Simple RC Circuit



RC Time Constant

$$\tau = RC$$

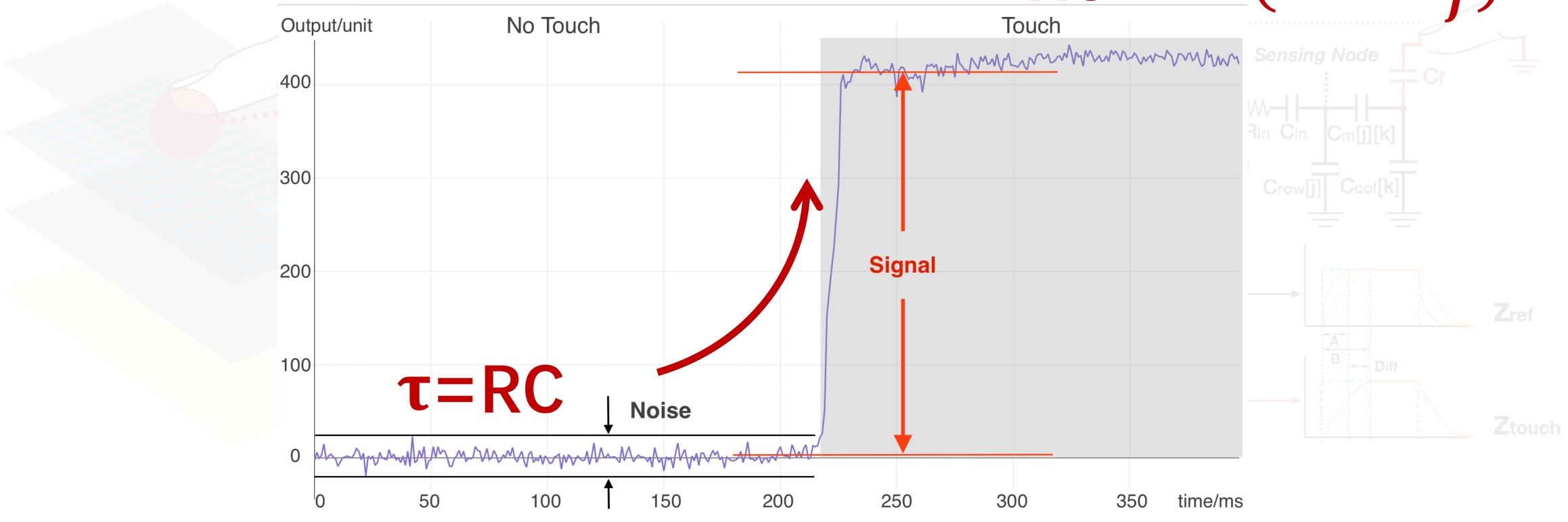
How touchscreen works – Capacitance Measurement



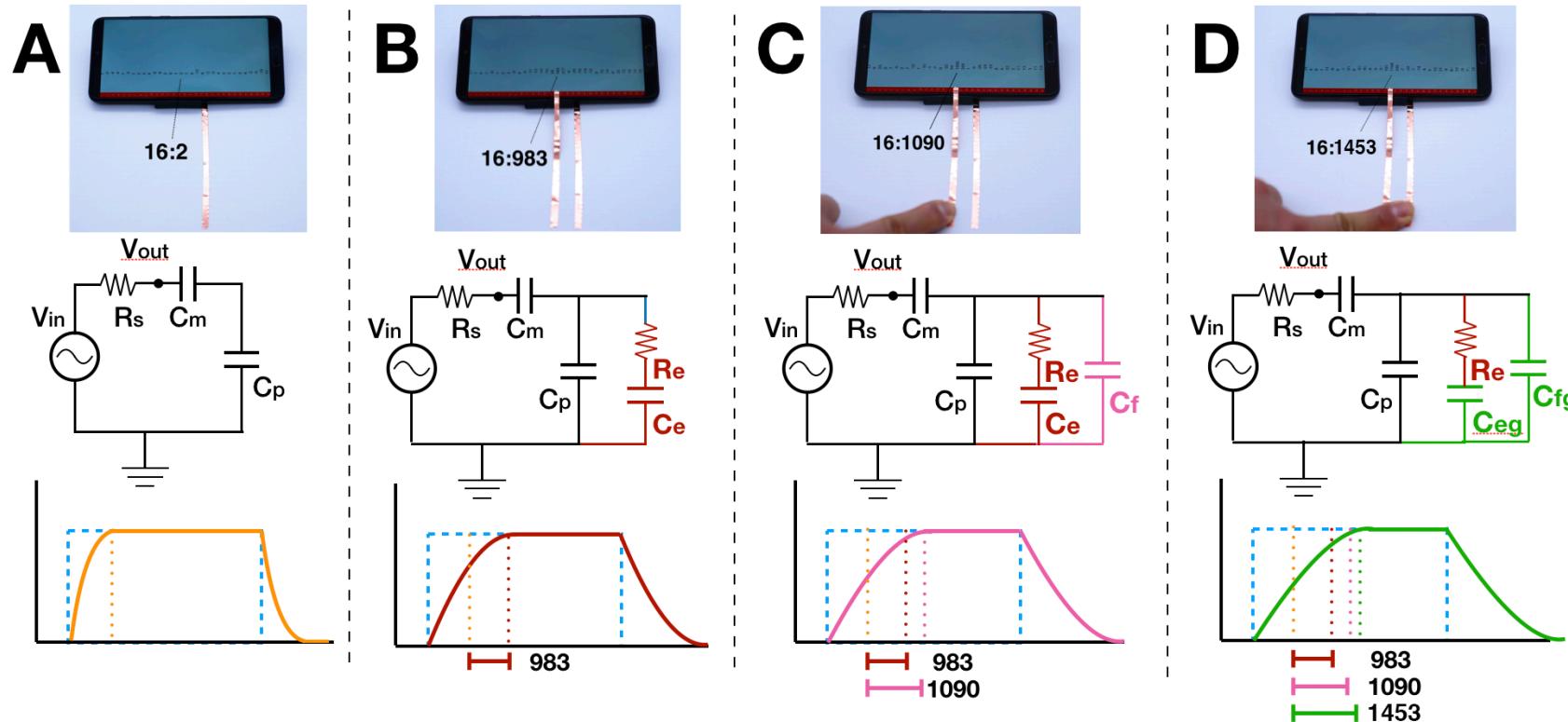
$$\tau = RC \longrightarrow \tau' = RC' = R(C + C_f)$$

How touchscreen works – Capacitance Measurement

$$\tau' = RC' = R(C + C_f)$$



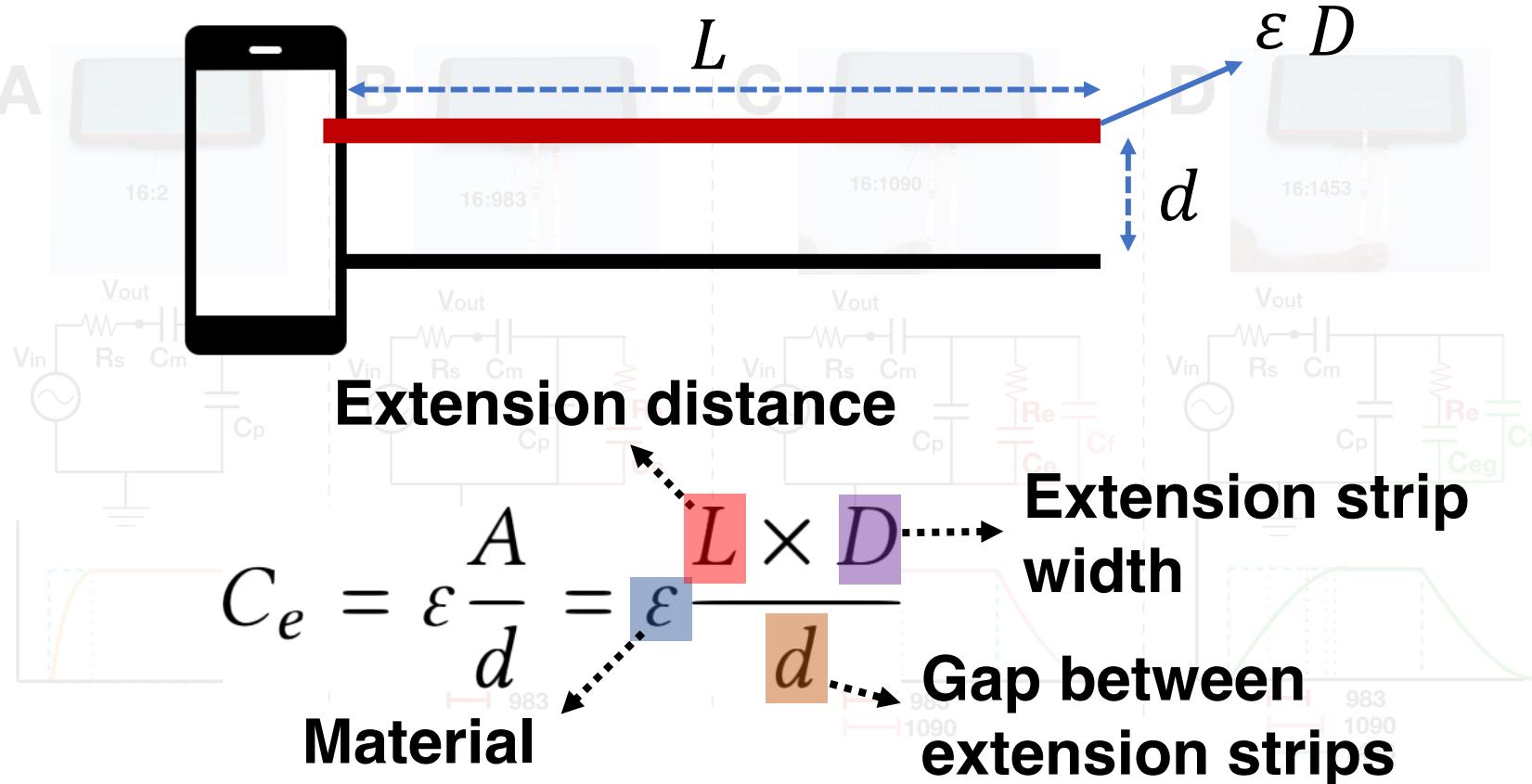
FlexTouch enables long-range touch sensing by **introducing local ground** into the extension circuit design.



$$\tau = R_s \frac{C_m(C_p + C_{e(g)} + C_{f(g)})}{C_m + C_p + C_{e(g)} + C_{f(g)}}$$

- Constant parameters
- Extension circuit introduced capacitance
- Touch introduced capacitance

FlexTouch enables long-range touch sensing by **introducing local ground** into the extension circuit design.



$$\tau = R_s \frac{C_m(C_p + C_{e(g)} + C_{f(g)})}{C_m + C_p + C_{e(g)} + C_{f(g)}}$$

Constant parameters

Extension circuit introduced capacitance

Touch introduced capacitance

Maximum extension distance

$$C_e = \varepsilon \frac{A}{d} = \varepsilon \frac{L \times D}{d}$$

FlexTouch can support large-scale capacitive sensing with **a coverage range up to 4 meters** across hardware.

Huawei P10, P20

$D = 6mm, d = 2cm$

Length[m]	0.10	0.25	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00
P20, CFT	6.8	3.5	1.6	1.1	0.6	-	-	-	-	-
P20, IPF	6.6	3.4	1.4	0.9	0.5	-	-	-	-	-
P20, CP	6.5	3.1	1.9	0.8	-	-	-	-	-	-
P20, SNI	6.4	2.9	1.3	0.9	-	-	-	-	-	-
P20, CFT w/ GND	15.8	9.8	5.8	4.7	3.3	2.6	2.0	1.5	1.3	0.7
P20, IPF w/ GND	16.5	10.8	5.5	4.0	3.1	2.0	1.6	1.1	0.8	0.5
P20, CP w/ GND	15.4	10.1	6.0	3.7	2.2	1.7	1.0	0.8	-	-
P20, SNI w/ GND	15.3	9.8	5.4	3.1	2.2	1.7	1.4	1.2	0.9	0.5
P10, CFT	15.7	7.6	4.3	2.7	1.7	1.1	0.7	-	-	-
P10, IPF	14.2	7.5	3.9	2.9	1.4	1.0	0.5	-	-	-
P10, CP	14.4	6.8	3.2	1.6	0.8	0.5	-	-	-	-
P10, SNI	14.9	6.9	3.1	2.8	1.4	1.0	0.6	-	-	-
P10, CFT w/ GND	20.4	10.2	7.0	4.3	3.1	2.3	1.9	1.5	1.1	0.8
P10, IPF w/ GND	21.4	11.5	7.9	5.3	3.2	2.7	1.7	1.2	0.8	0.5
P10, CP w/ GND	20.1	12.4	8.1	4.3	2.8	2.1	1.2	0.7	-	-
P10, SNI w/ GND	19.4	11.2	8.6	4.1	2.8	2.0	1.6	1.2	0.8	0.5

Copper foil tape (CFT), ITO PET film (IPF), carbon paint (CP), and silver nanoparticle ink (SNI)



Without GND



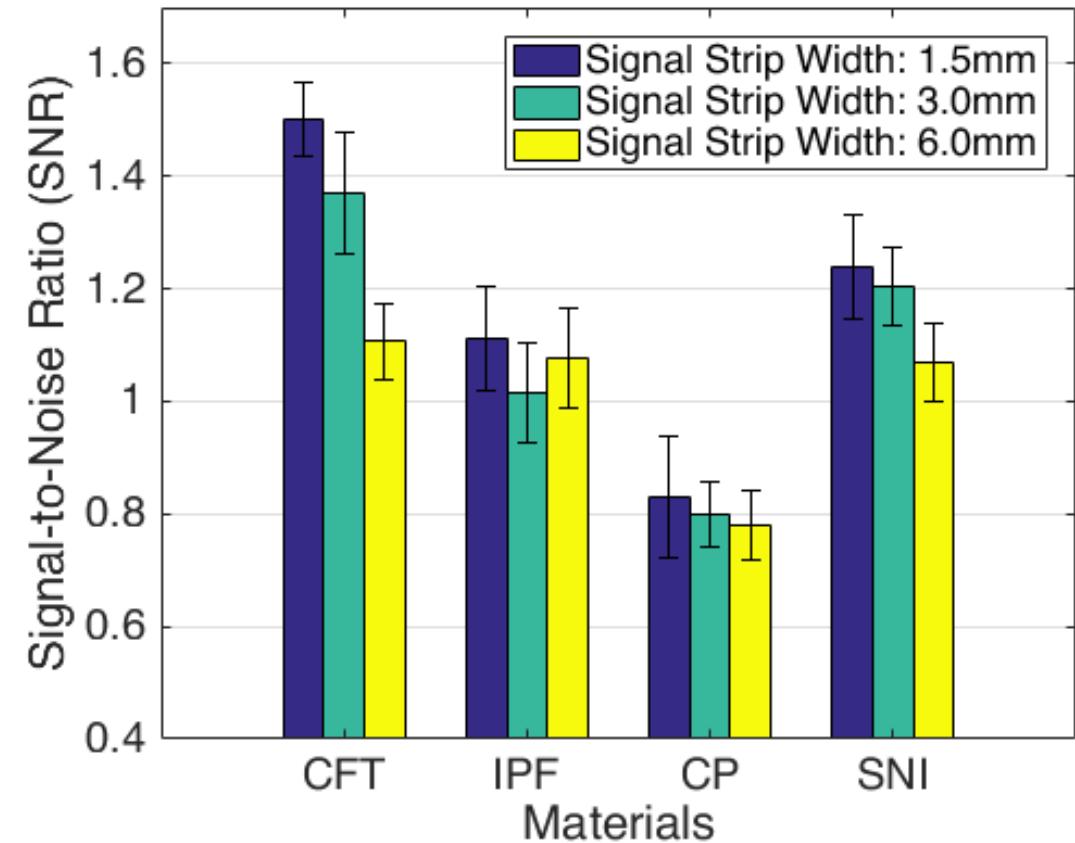
With GND

SNR: signal-to-noise ratio

Effect of the material and width

$$C_e = \epsilon \frac{A}{d} = \boxed{\epsilon} \frac{L \times D}{d}$$

1. Sensing range is **positively correlated with material conductivity**.
2. The extension distance **increases as the width of the signal strip decreases**.

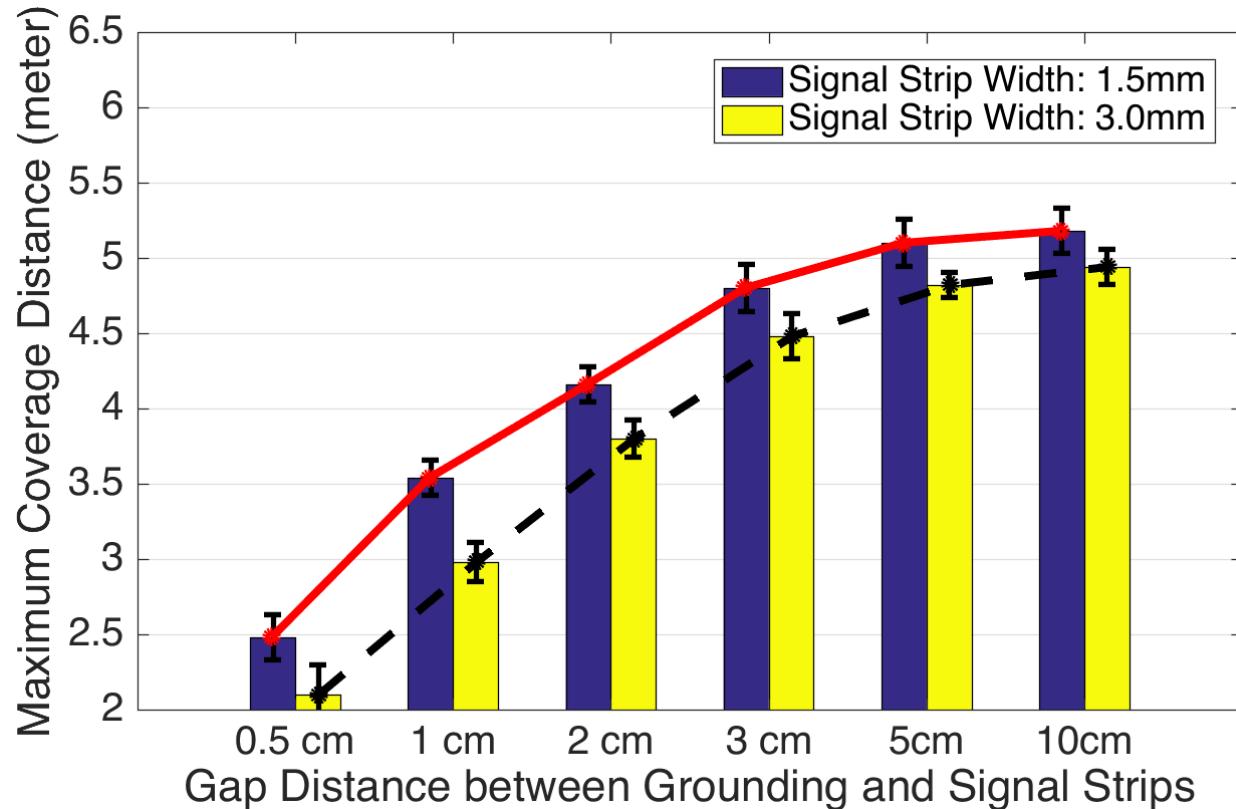


Copper foil tape (CFT), ITO PET film (IPF), carbon paint (CP), and silver nanoparticle ink (SNI)

Effect of the gap between extension strips

$$C_e = \varepsilon \frac{A}{d} = \varepsilon \frac{L \times D}{d}$$

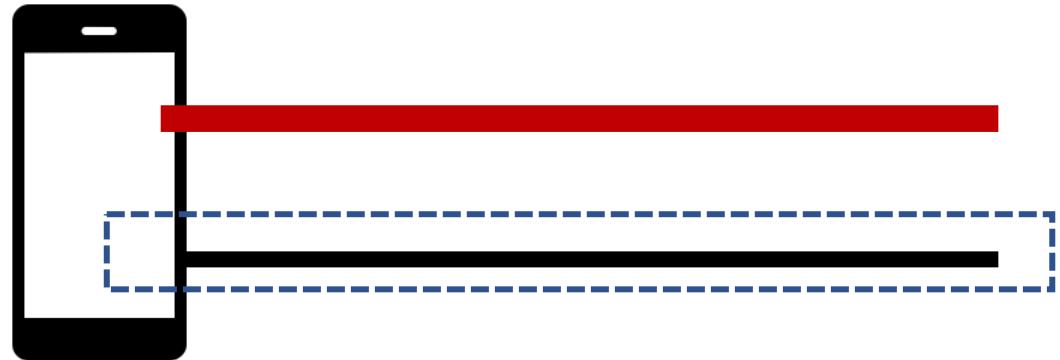
The maximum touch sensing distance **increases as the gap distance increases.**



P20, Copper foil tape (CFT)

Effect of Grounding Strip

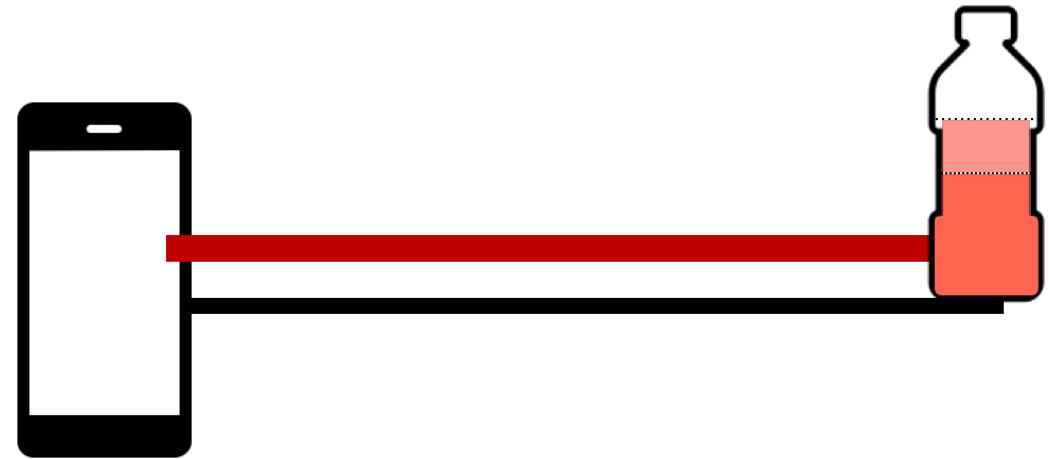
$$C_e = \epsilon \frac{A}{d} = \boxed{\epsilon} \frac{L \times D}{d}$$



1. The touch sensing coverage distance is **negatively correlated with the grounding strip's width**.
2. FlexTouch sensing range is **positively correlated with material conductivity of the grounding strip in general**.

Tracking everyday objects

FlexTouch can detect everyday object's presence with an extension distance up to 2m.



Length[m]	0.10	0.25	0.50	1.00	1.50	2.00	3.00
Finger Touch (reference)	15.8/6.8	9.8/3.5	5.8/1.6	4.7/1.1	3.3/0.6	2.6/-	1.5/-
5cm × 5cm Copper Foil Tape	15.3/3.2	9.5/1.9	5.5/0.8	4.6/-	3.0/-	2.3/-	1.3/-
Stainless Steel Water Cup	12.6/3.4	10.0/2.0	4.3/1.1	2.0/-	1.6/-	1.5/-	0.7/-
MacBook Pro 13'	5.4/2.4	3.7/1.7	1.2/0.6	0.6/-	-/-	-/-	-/-
Carving Knife	5.6/1.5	2.7/0.6	1.3/-	-/-	-/-	-/-	-/-
iPhone XR	4.6/2.5	2.5/2.0	1.2/0.5	0.7/-	-/-	-/-	-/-
550 ml Bottled Water	4.3/2.8	2.8/1.2	0.6/-	-/-	-/-	-/-	-/-
50 ml Bottled Water	3.1/1.3	2.0/0.7	-/-	-/-	-/-	-/-	-/-
Glass Cup	2.7/0.6	1.0/-	-/-	-/-	-/-	-/-	-/-
Notebook	0.9/0.8	-/-	-/-	-/-	-/-	-/-	-/-
Cardboard Box	0.5/0.6	-/-	-/-	-/-	-/-	-/-	-/-
Mouse	0.5/0.5	-/-	-/-	-/-	-/-	-/-	-/-

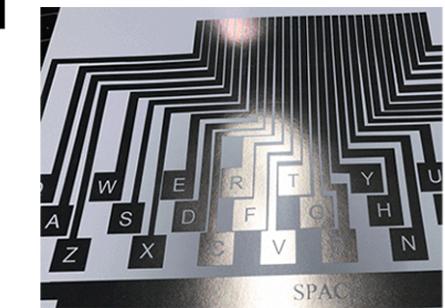
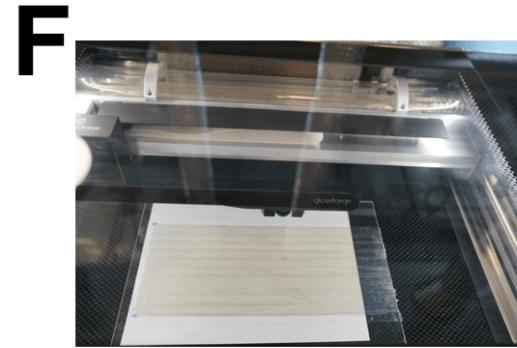
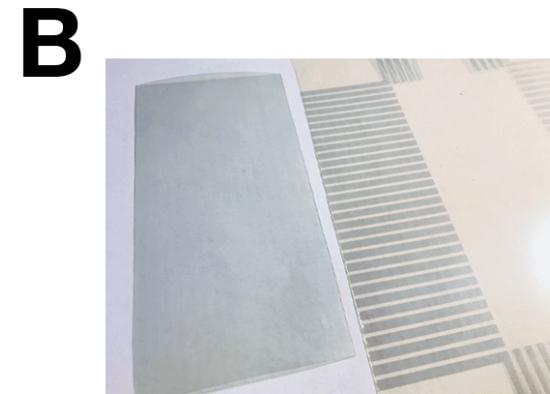
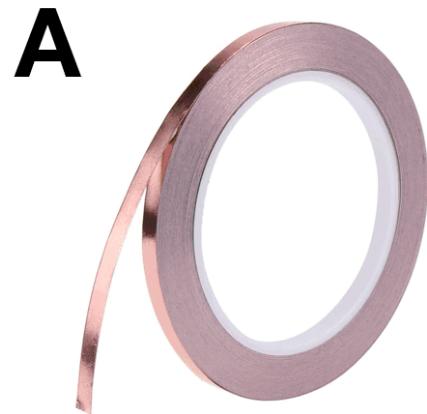
Summary

To enhance the effect introduced by touch, less capacitance between the signal strip and the grounding strip is preferred (C_e). The sensing distance can be represented as:

$$L = \frac{C_e \times d}{\epsilon \times D}$$

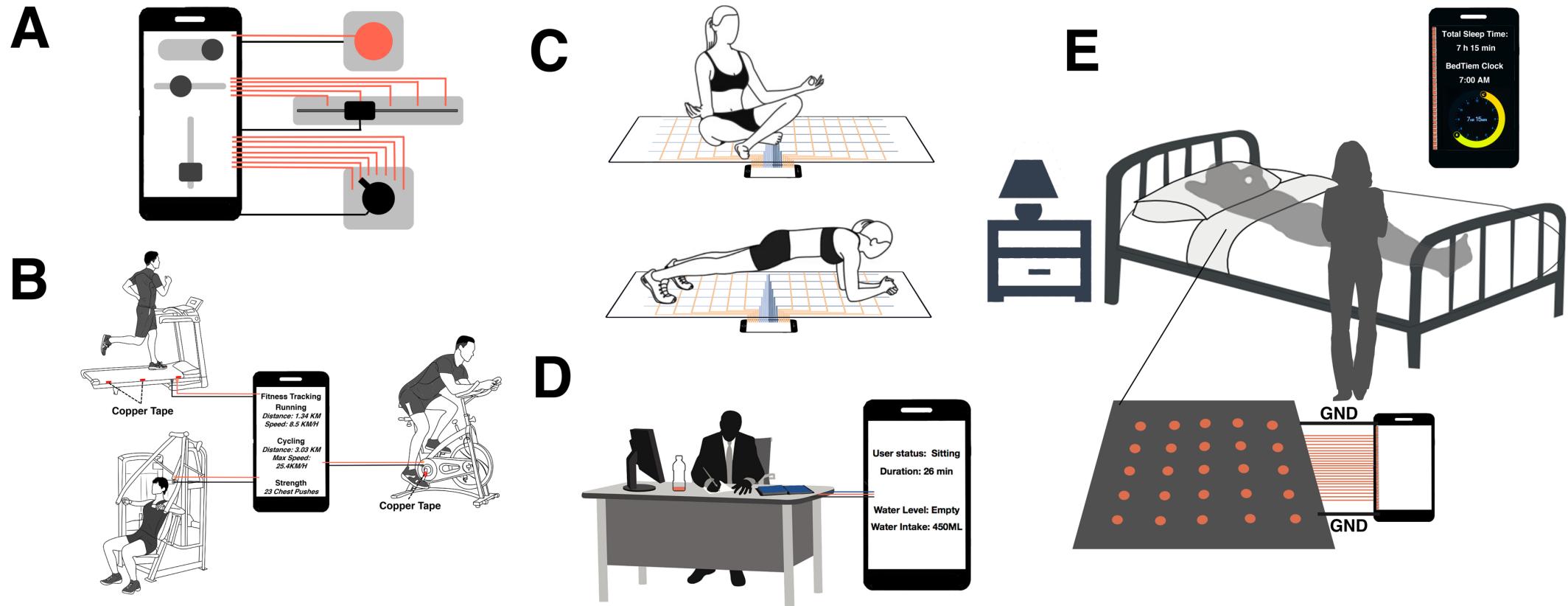
Smaller extension strip width (D), larger gap distance (d), more conductive material and more insulating material between strips (smaller ϵ) will help extending the sensing range.

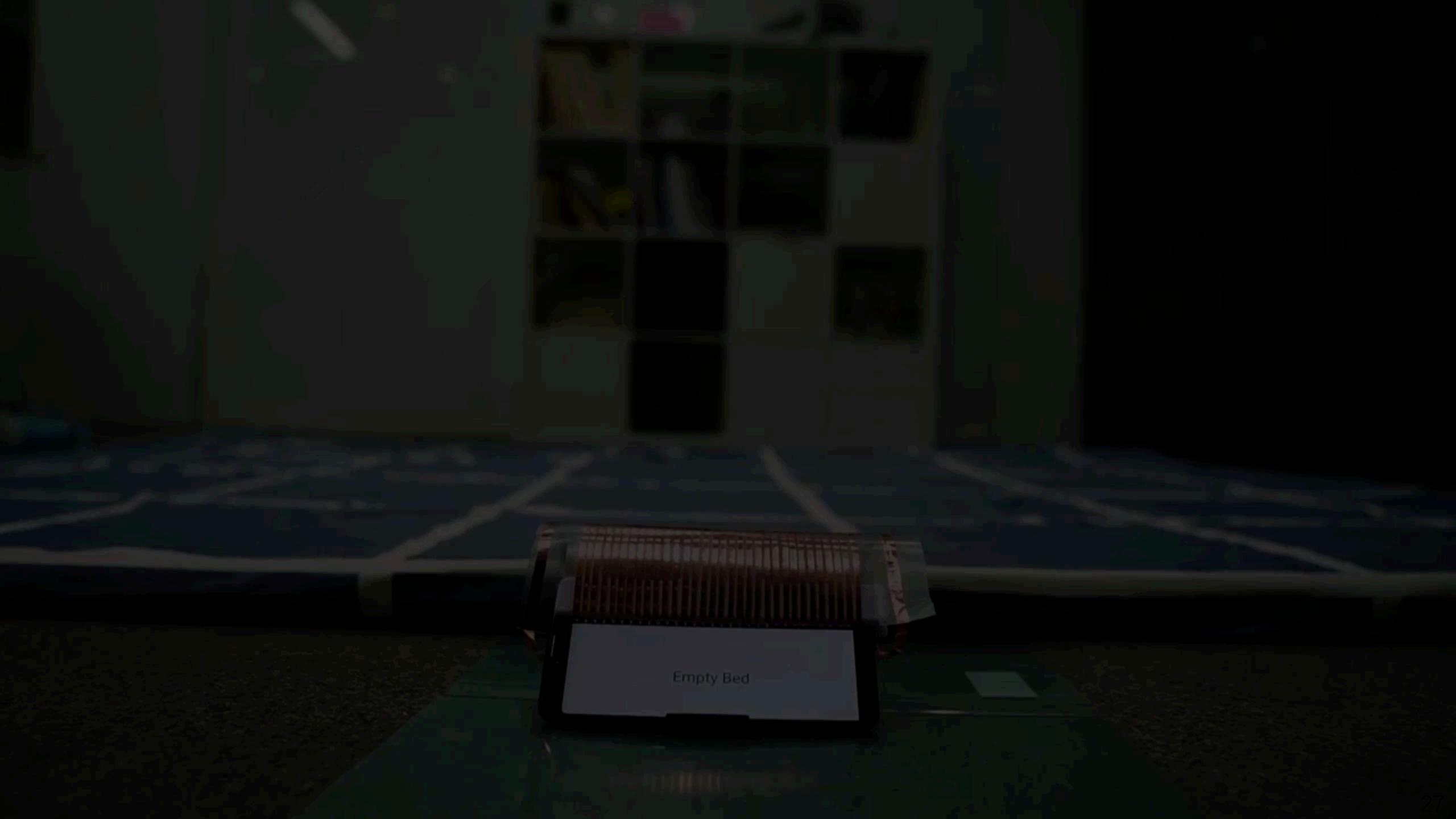
FlexTouch is easy to fabricate



Copper foil tape (CFT), ITO PET film (IPF), carbon paint (CP), and silver nanoparticle ink (SNI)

Example Applications





FlexTouch

Yuntao Wang

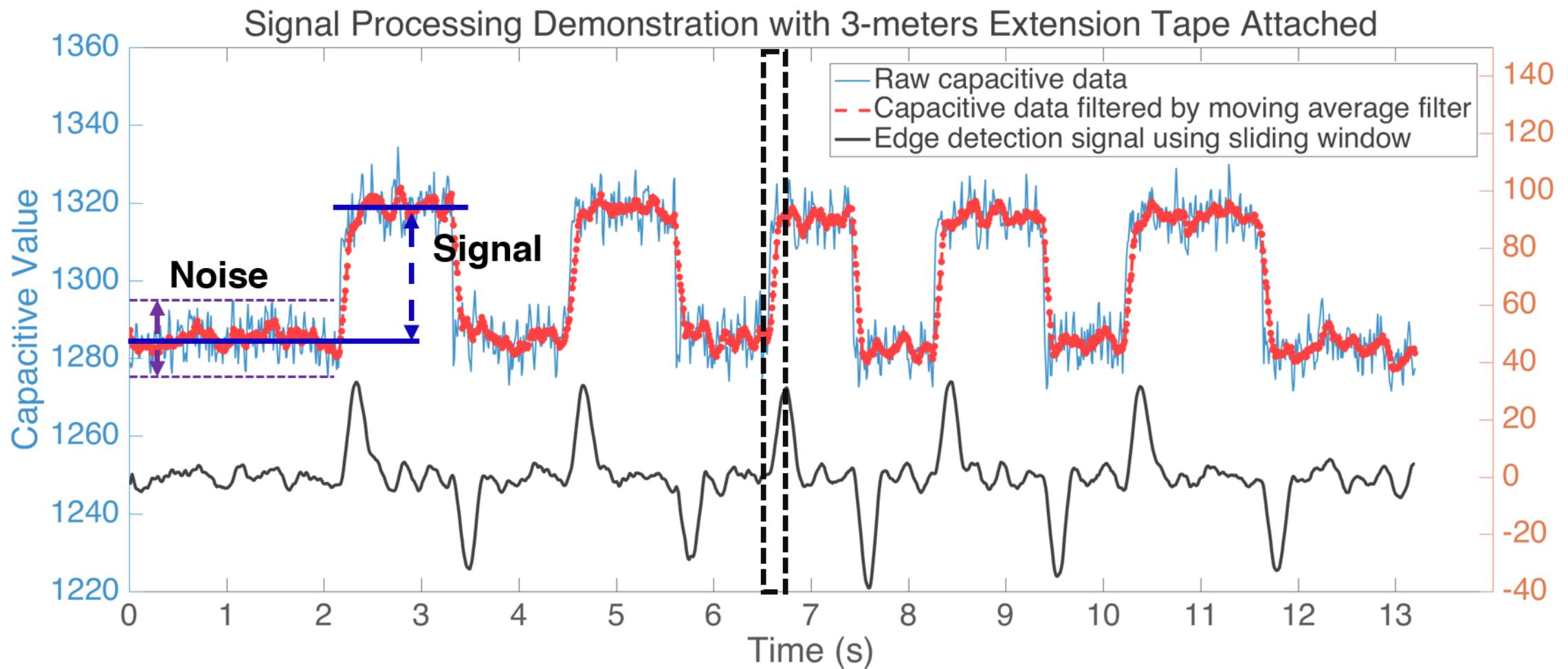
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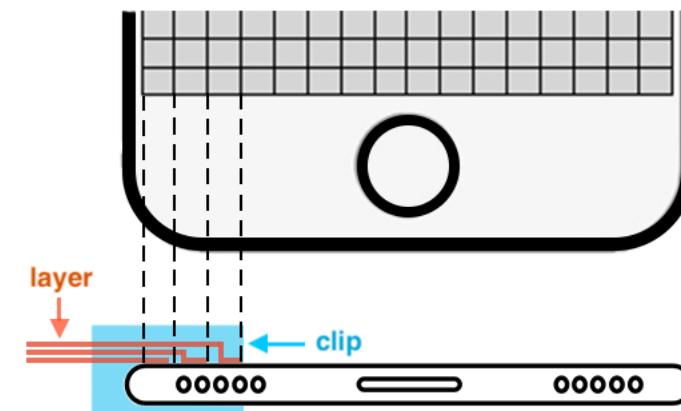
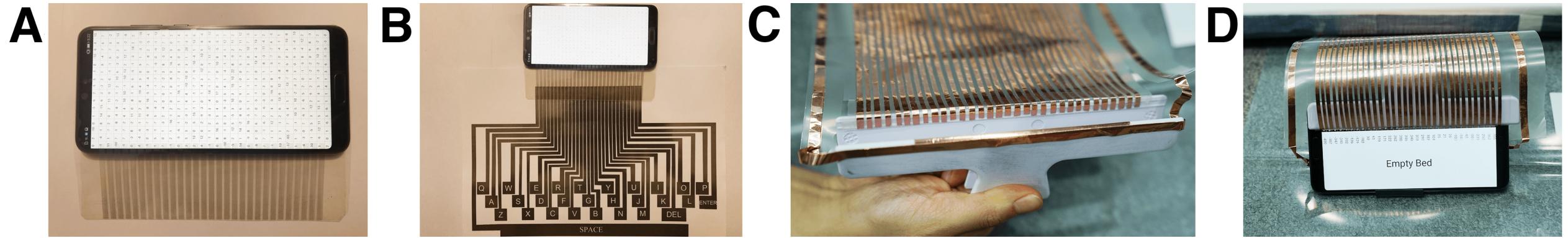
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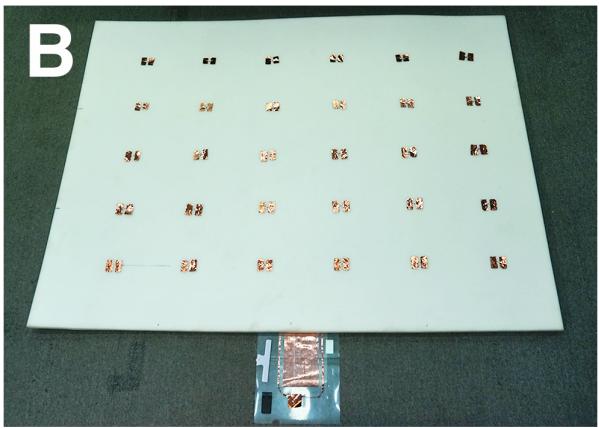


<https://gixnetwork.org/>



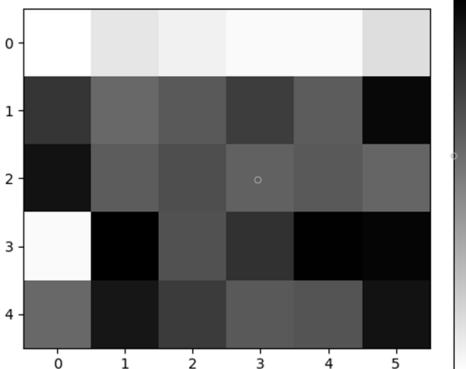
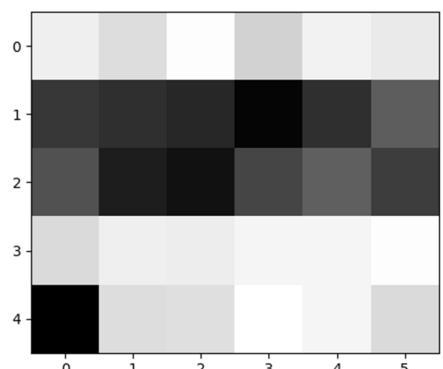
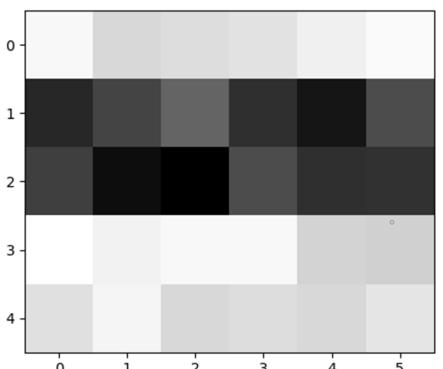
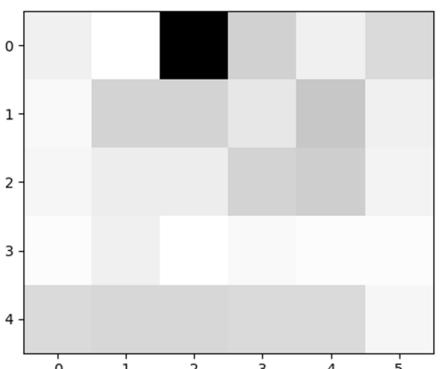
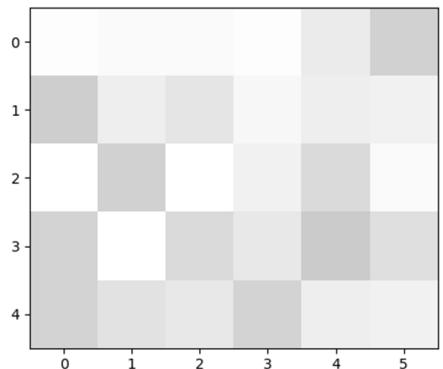
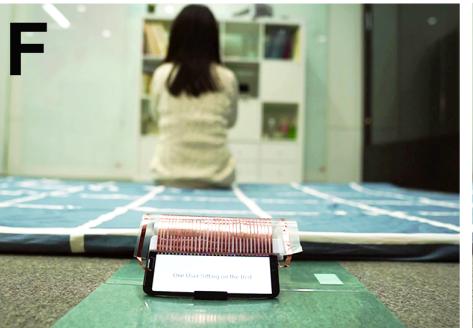


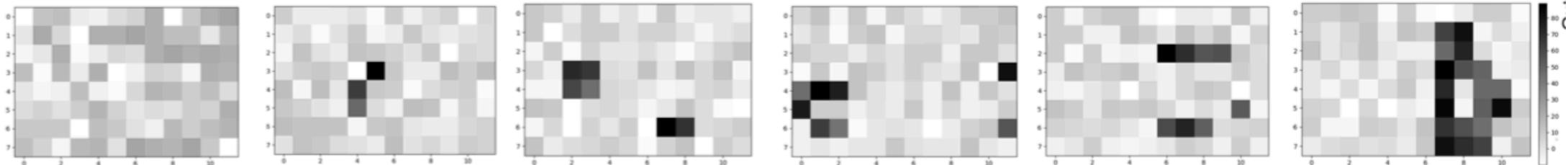
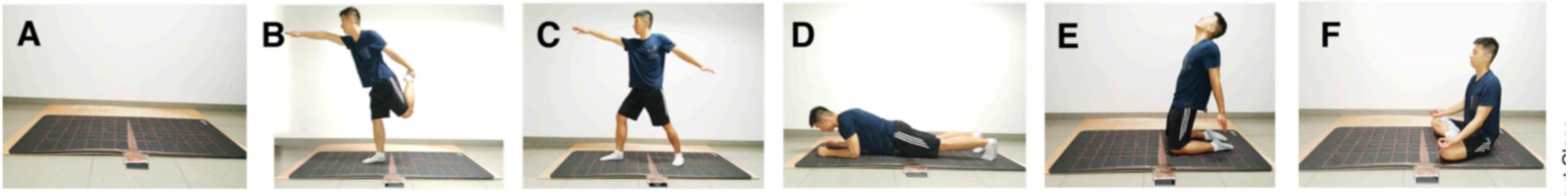




Accuracy: 91.17%

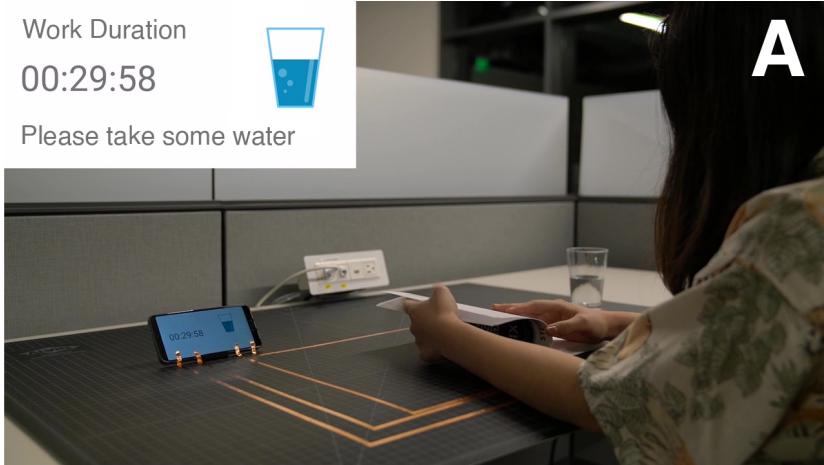
Output Class	Target Class				
	Idle	1S	1L	1S1L	2L
Idle	99.2% 119	18.3% 22	0.0% 0	0.0% 0	0.0% 0
1S	0.8% 1	81.7% 98	0.0% 0	0.0% 0	0.0% 0
1L	0.0% 0	0.0% 0	100.0% 120	24.2% 29	0.0% 0
1S1L	0.0% 0	0.0% 0	0.0% 0	75.8% 91	0.8% 1
2L	0.0% 0	0.0% 0	0.0% 0	0.0% 0	99.2% 119





Accuracy: 97.13%

Output Class	Target Class					
	Idle	Dance	Lunge	Plank	Camel	Lotus
Idle	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	180	0	0	0	0	0
Dance	0.0%	100.0%	7.8%	2.8%	0.0%	0.0%
	0	180	14	5	0	0
Lunge	0.0%	0.0%	92.2%	0.0%	0.0%	0.0%
	0	0	166	0	0	0
Plank	0.0%	0.0%	0.0%	97.2%	0.0%	0.0%
	0	0	0	175	0	0
Camel	0.0%	0.0%	0.0%	0.0%	94.4%	1.1%
	0	0	0	0	170	2
Lotus	0.0%	0.0%	0.0%	0.0%	5.6%	98.9%
	0	0	0	0	10	178



A



B

Accuracy: 92.22%

		Output Class	
		None	50ml
Target Class	None	100.0% 30	6.7% 2
	50ml	0.0% 0	86.7% 26
250ml	None	0.0% 0	6.7% 2
	50ml	0.0% 0	90.0% 27

C