A 6.9mW 120fps 28×50 Capacitive Touch Sensor for 1mm-ϕ Stylus Using Current-Driven ΔΣ ADCs

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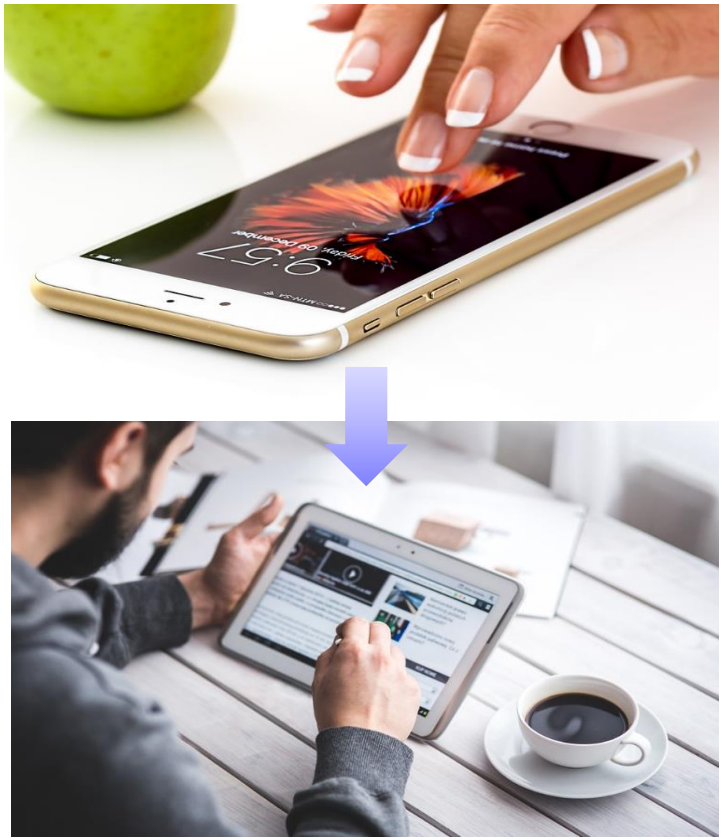
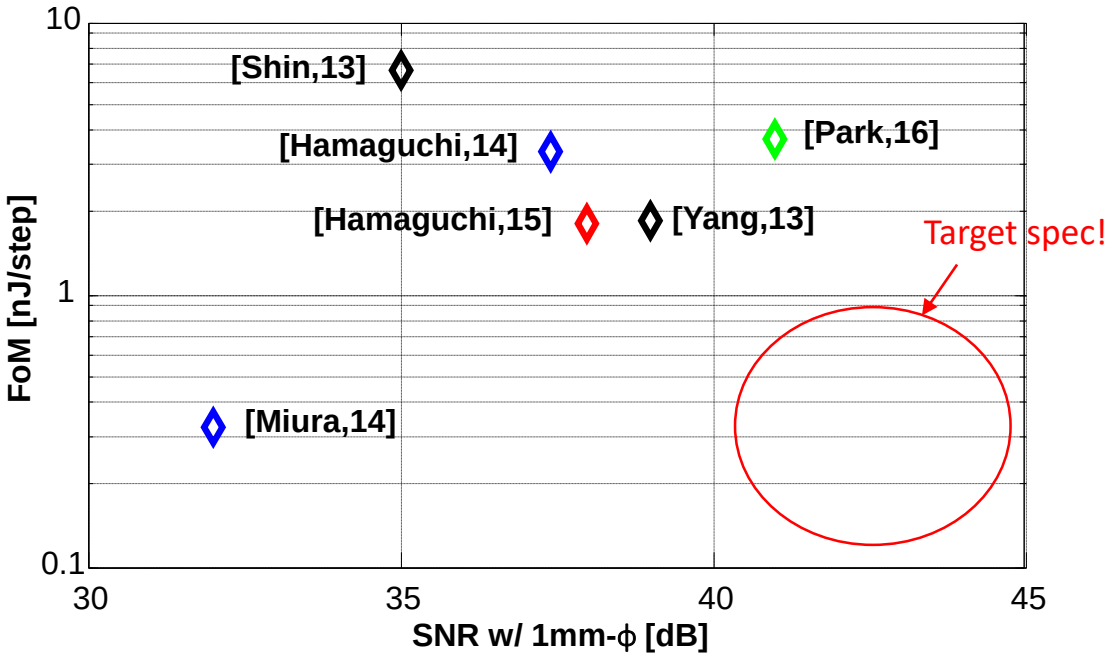
Motivation

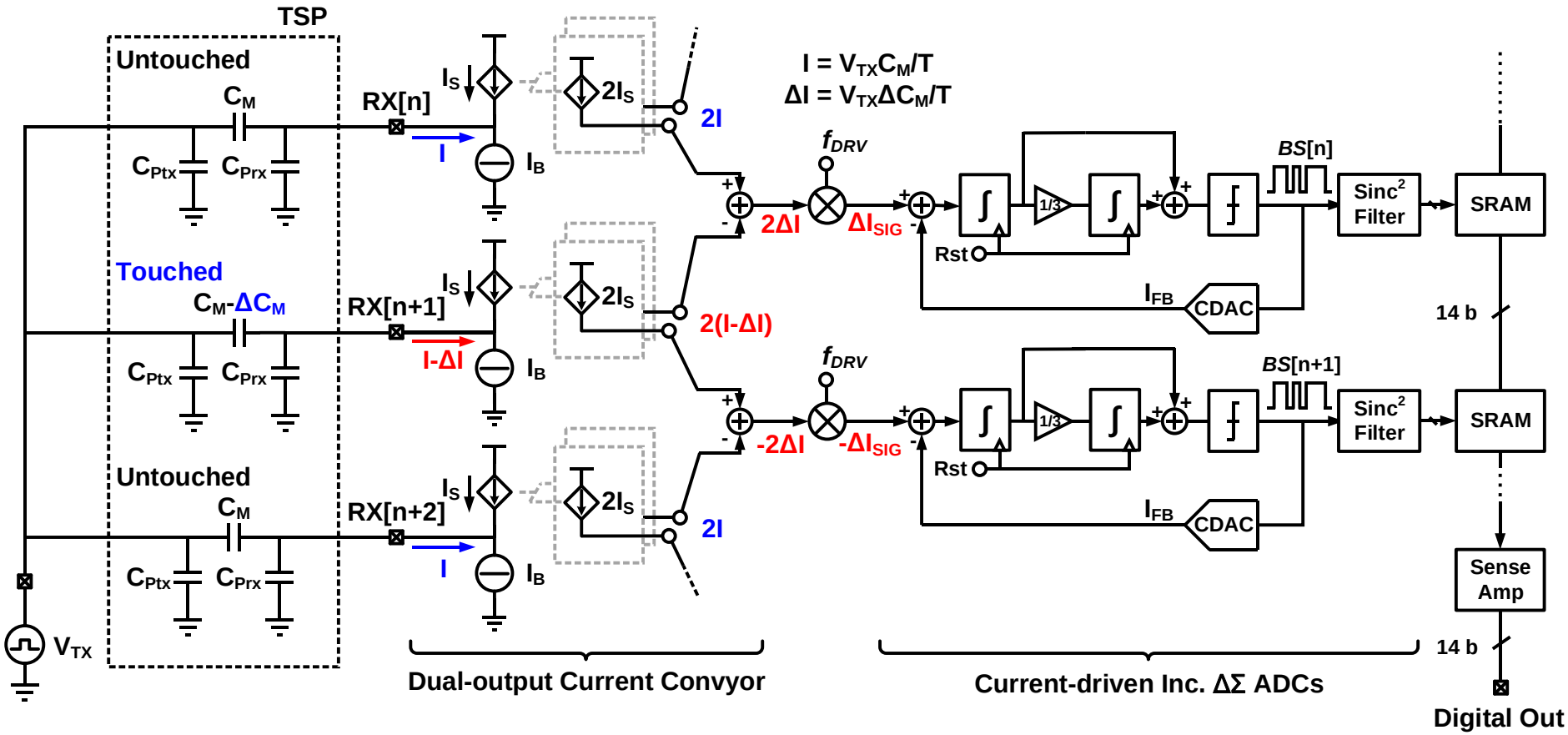


$$\text{FoM (Energy efficiency)} = \frac{\text{Power}}{2^{(\text{SNR}-1.76)/6.02} \times \text{Sensing Node} \times \text{Frame Rate}}$$



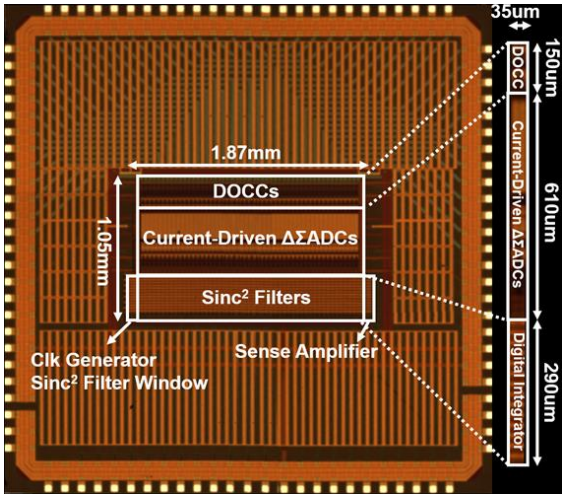
- **Increased sensing channel of Touch Screen Panel (TSP) : Small signal, Increased power**
- **Requiring energy efficient capacitance conversion**
- **Target energy efficiency Figure-of-Merits (FoM) : SNR > 40dB, FoM < 1nJ/step**

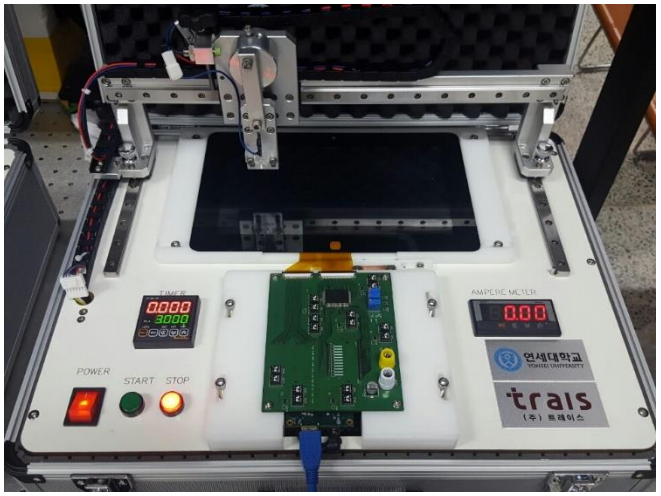
Architecture

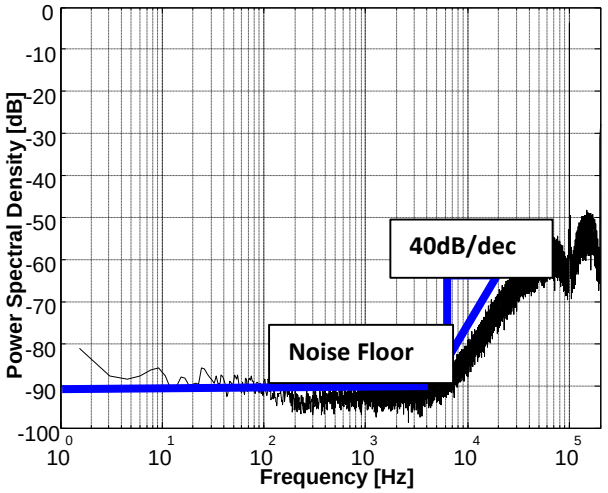


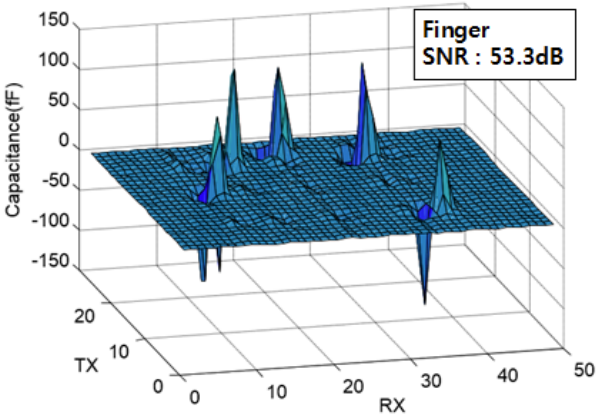
- Using dual output current conveyer AFE and 2nd order current driven ΔΣ ADC
- Power saving by small current signaling and parasitic isolation
- Wide dynamic range and high SNR with oversampling ADC

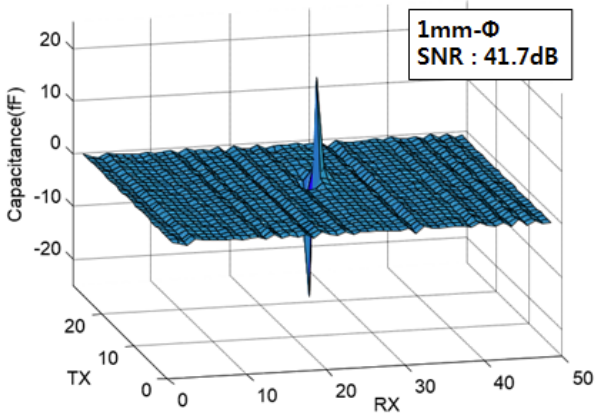
Implementation and Measurement











- **0.18µm CMOS process, 1.8V supply (RX), 3.3V driving voltage (TX), 28×50 10.1-inch TSP**
- **2nd order noise shaped power spectral density of modulator**
- **SNR : 53.3dB (Finger), 41.7dB (1mm-ϕ stylus) @ 120fps**

Conclusion

		This work	Park ISSCC 16	Yang ISSCC 13	Hamaguchi ISSCC 14	Hamaguchi ISSCC 15
Process		**0.18μm**	0.18μm	0.35μm	0.18μm	85nm
SNR [dB]	Finger	**53.3**	54	-	56.6	-
	1mm-ϕ	**41.7**	41	39	37.4	38
Supply Voltage [V]		**RX : 1.8 TX : 3.3**	RX : 2.7~3.3 TX : 3.3	RX : 3.3 TX : -	RX : 3.3/1.8 TX : 3.3	RX : 3.3/1.2 TX : 3.3
Channel		**RX : 50 TX : 28**	RX : 64 TX : 36	RX : 43 TX : 27	RX : 138 TX : 78	RX : 57 TX : 35
Frame Rate [Hz]		**120**	120	120	240	240
Power [mW]		**6.9**	94.5	18.7	559.9	56
FoM_1 [nJ/node]		**41**	341.8	134.2	216.7	117
FoM_2 [nJ/step] (1mm-ϕ)		**0.41**	3.73	1.84	3.58	1.8
Area [mm^2]		**1.96**	36	10.4	71.2	12.5

FoM_1 = Power / (# of node X Frame rate)

FoM_2 = Power / ($2^{(SNR-1.76)/6.02}$ X # of node X Frame rate)

- **Drawing only 6.9mW @ 1.8V supply voltage**
- **Achieving 0.41nJ/step FoM, 1.96mm^2 Area**
- **4x and 5x improvement of FoM and area on previous state-of-the-art works, respectively**