A Capacitive Touch Sensing System Robust to Environmental Noise with a Third-order Correlated Double Sampling Method

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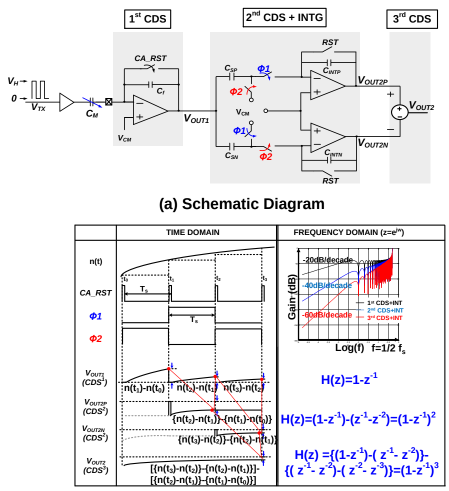
In recent, capacitive touch sensing systems have been widely used in smart phones and tablets. The touch screen usually covers entire display area and is exposed to external environments at the display module surface. Several kinds of environmental noises are coupled to the sensor through the coupling capacitance formed between the finger and the touch sensor. Most of external noises make influence on the touch sensing circuit when they incur voltage difference between the human body (e.g., finger) and the GND of the touch controller at any way.

The CDS is a widely used circuit technique to reduce low-frequency noises. This is an effective approach because most of external noises coming from man-made devices usually have a few discrete operating frequencies, and their frequency spectrums have high power in low fundamental frequency region and powers of their harmonic frequencies decreases as frequency increase. In addition to low-frequency noise suppression, the circuit doubles signal amplitude by properly clocking the switches.

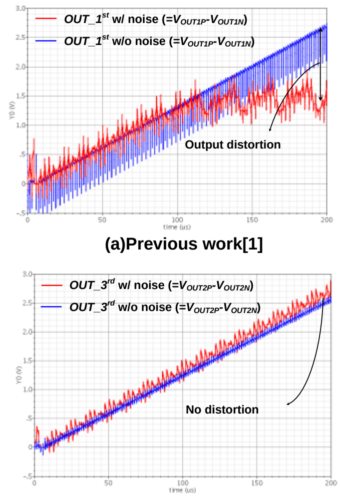
Fig. 1 shows how the low frequency noise is attenuated by the proposed circuit. In the time-domain figure (b) in the left, n(t) represents noise voltage appearing on the finger. By periodic reset, V_{OUT1} changes in response to the noise voltage variation between two consecutive reset periods. Assuming that reset duration is sufficiently short compared to the period, the net variation of V_{OUT1} in a period represents noise difference at time t_n and t_{n-1}. It could be considered as CDS of the noise. It helps preventing CA output saturation due to large low frequency external noise. The CDS of signal operates on the same principle of noise. A sampled V_{OUT1} at time t_n is subtracted by the one sampled at time t_{n-1} and stored in the previous phase. This subtraction corresponds to the second CDS. Finally, V_{OUT2} is obtained by subtracting V_{OUT2N} from $V_{OUT2P,}$ which corresponds to the third CDS. Each of intermediate signals in frequency domain could be represented as z-transform as shown in the right of Fig. 1(b). The frequency response shows how much noise could be attenuated by the proposed third-order CDS compared to lower-order CDS; sampling frequency f_s is equal to $2f_{tx}$, where f_{tx} is the frequency of TX driving.



(a) Schematic Diagram

(b) CDS Operation

Fig. 1.3rd-CDS schematic & operation



(a)Previous work[1]

(b)Proposed 3rd-order CDS

Fig.2. Transient simulation waveforms

Fig. 2 shows simulation results to compare noise attenuation performance between the previous work and the proposed 3rd–order CDS. The simulation included a noise source with frequency of 40KHz, 50Vpp. The previous work output is saturated by large noise voltage swing. It can lose touch information and incur mal-function of touch sensing. However, the proposed circuit attenuates noise well from the beginning, i.e., at the CA output. Additional CDS operations enable more noise attenuation. On the set-level evaluation, the proposed IC showed 47.5dB SNR with a passive stylus having 1-mm diameter.

References

1. H.-C. Shin, et al., ISSCC, pp. 388-389, Feb. 2013