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PERFORMANCE OF AN AREA VARIABLE MOS VARICAP WEIGHTED PROGRAMMABLE CCD TRANSVERSAL FILTER

Indexing terms: Filters, Charge-coupled devices, Metal-oxide-semiconductor structures and devices

The performance of an electrically programmable CCD transversal filter (PTF) is presented in which tap-weight multiplication is performed by a novel and compact on chip voltage controlled area variable MOS varicap.

Introduction: A transversal filter with electrically programmable tap weights offers a number of advantages in signal processing systems.¹⁻³ A popular approach for realising on-chip analogue variable tap-weight filters has been through the use of floating sense gates followed by buffers and controlled multiplier circuits;¹ although elegant, this has the dis-

Fig. 1 Principle of varicap tap weighting

V_{FG} = floating gate voltage applied to sense gate; V_{TW} = tap weight voltage; $C_{1,2}$ = capacitance between terminals 1 and 2; $C_{1,3}$ = capacitance between terminals 1 and 3

Fig. 2 Realisation of an area variable three terminal MOS capacitor

V_g = gate voltage for control terminal of area variable varicap
shaded area: inversion layer - - - - contour of deep diffusion profile

advantage of considerable power dissipation. A tap-weight scheme with conventional varicaps attempted earlier ensured low-power dissipation but had the limitation of poor charge modulation capability (a maximum of 10% of the signal charge could be sensed) for filter realisation.⁴ In this letter, the performance of a PTF with a tap-weighting circuit based on charge distribution between the two components of a novel 3-terminal area variable MOS capacitor (AVMOSC) is described. A computer simulation shows that such a scheme provides a far superior charge modulation capability—up to 60% of the signal charge can be sensed.^{5,6}

Implementation: Fig. 1 shows the basic principle of tap weighting with varicaps. The CCD sense gate has a capacitive load split into two parallel components $C_{1,2}$ and $C_{1,3}$. In response to a signal charge Q_{sig} under the sense gate an equal image charge flows through the load capacitor and a fraction $C_{1,2}/(C_{1,2} + C_{1,3})$ (= the tap weight) is sensed by the charge sensing amplifier. Fig. 2 shows the realisation of $C_{1,2}$ and $C_{1,3}$ as AVMOSCs; $C_{1,2}$ and $C_{1,3}$ represent the area under inversion and depletion, respectively, of the 3-terminal AVMOSC. The doping decreases from 0 to A and 0' to A' and hence so also the threshold voltage. Increasing V_g will increase $C_{1,2}$ and decrease $C_{1,3}$. We thus have a voltage-controlled tap weight. V_g is applied to individual tap weights through a reset switch.

Fig. 3 Photomicrograph of prototype programmable CCD filter

Performance: An 8-tap AVMOSC-based PTF has been implemented in *n*-channel double polysilicon gate technology with overlapping gates. The device has a dual channel for providing both positive and negative tap weights (Fig. 3). Fig. 4 shows the tap-weight control characteristics of the filter with all but one tap set to zero. Figs. 5 and 6 show the performance of the filter set up as a Hilbert transformer and a chirp matched filter, respectively, demonstrating a capability to perform a large variety of signal processing functions.

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Fig. 4 Tap-weight control characteristics of programmable filter

For positive tap weights, left channel tap weight voltage = 0 V and vice versa

○ +ve tap weight * -ve tap weight
 $V_{ref} = 1 \text{ V}$ $V_{bulk} = 5.5 \text{ V}$

Fig. 5

a Top trace: impulse response of CCD filter programmed as a 7-element Hilbert transformer

$h_2 = h_4 = h_6 = 0$; $h_1 = -h_7 = -0.12$; $h_3 = -h_5 = -0.6$

Bottom trace: impulse response of CCD delay line

b Transfer function of filter programmed as in **a**

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Fig. 6

a Impulse response of CCD filter programmed as an 8-point (co-sine) chirp matched filter

$h_1 = 0.92$; $h_2 = 0$; $h_3 = -0.92$

$h_4 = 1$; $h_5 = -0.92$; $h_6 = 0$

$h_7 = 0.92$; $h_8 = 1$

b Signal input (chirp) and corresponding correlation output

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