A STUDY OF TRANSVERSAL FILTERING USING CHARGE TRANSFER DEVICES

by

NAVIN KUMAR KAPUR

Department of Electrical Engineering

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CERTIFICATE

This is to certify that the thesis entitled, ' A Study of Transversal Filtering Using Charge Transfer Devices' being submitted by Navin Kumar Kapur to the Department of Electrical Engineering, Indian Institute of Technology, Delhi, for the award of degree of Doctor of Philosophy is a record of bonafide research work carried out by him under my supervision and guidance and in my opinion it has reached the standard fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted to any other institution for the award of any degree or diploma.

S.C. Dutta Roy

(S.C. Dutta Roy)
Professor of Electrical Engineering,
Indian Institute of Technology, Delhi.

ABSTRACT

The capability for design and manufacture of large scale integrated (LSI) circuits which contain both analog and digital circuitry on the same chip has made possible self-contained monolithic sampled data filters suitable for a wide variety of applications. Three filter structures are prominent - the CTD (CCD and BBD) transversal, the switched capacitor ladder and the CCD passive recursive. An important application for CTD transversal filters, in particular, is in spectrum analysis using convolutional algorithms such as the chirp z-transform (CZT) and the prime transform (PT).

In this thesis we have proposed a number of techniques for improving the performance of CTD signal processors using the transversal architecture. The main concern has been increase in response accuracy, dynamic range and bandwidth and, reduced chip area and power consumption; in addition we have suggested techniques for the realization of DFT processors with greater versatility and faster throughput (i.e. computation rate) than is possible at present. We have in fact aimed at what can be called an analog version of the FFT i.e. a fast CZT or fast PT.

We have derived analytical expressions for the error in frequency response due to the shift in the pole and zero locations, caused by charge transfer inefficiency (CTI); these

expressions are explicitly in terms of the polar coordinates of the pole/zero. We have also derived expressions for the coefficient sensitivity of phase response and group delay.

For frequency selective filters, a new technique has been proposed in this thesis for implementing the tapweights, in which the fraction of the signal charge sensed is larger than that sensed with conventional techniques. This results in a reduced coefficient sensitivity and a smaller insertion loss. In addition the output sensing circuitry gets simplified, thus requiring smaller area and reduced power.

For the realization of CTD based spectrum analyzers, we have proposed a number of convolutional architectures by which the computation can be performed using a smaller number of filter stages i.e. fewer number of transfers and multiplies. There is a direct saving in chip area and power consumption and smaller errors due to charge transfer inefficiency (CTI); there is also a significant increase in dynamic range, and the maximum frequency of operation. In addition we have proposed techniques for (i) compensating for CTI, (ii) minimizing errors due to dark current and (iii) implementing the sliding prime transform.

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LIST OF SYMBOLS AND ABBREVIATIONS

CTD	: Charge transfer device
CCD	: Charge coupled device
BBD	: Bucket brigade device
CTI	: Charge transfer inefficiency
PTF	: Programmable transversal filter
FTW	: Fixed tapweight
SC	: Switched capacitor
DFT	: Discrete Fourier transform
DCT	: Discrete cosine transform
CZT	: Chirp z-transform
PT	: Prime transform
CDO	: Code dependent offset
SE, SSE, DSE	: Split electrode, single split electrode, double split electrode
Op amp	: Operational amplifier
lpf	: Lowpass filter
bpf	: Bandpass filter
ε	: Charge transfer inefficiency
η	: Charge transfer efficiency
r, θ	: Polar coordinates of pole/zero in z-plane
z^{-1}	: Unit delay operator
f_c, T_c	: Clock frequency, period

f_p, f_s	: Passband edge, stopband edge
Δf	: Transition width; $(f_s - f_p)/f_c$
R	: Primitive root
f(n), g(n), x(n)	: Signal under test (SUT)
a(n)	: SUT multiplied by chirp for the CZT algorithm and reordered SUT for the PT algorithm
X(k)	: Discrete Fourier transform of x(n)
$X_s(k)$	: Sliding discrete Fourier transform of x(n)
Q	: Tapweight quantization step size
$h_i'(n)$	: Unnormalized weighting coefficients (full precision)
$h_i(n)$	: Normalized weighting coefficients (full precision)
h(m)	: Actual (realized) weighting coefficients of filter
H(z)	: z-transform of h(m)
$H(e^{jw})$	: Frequency response of filter with tapweights h(m).

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