# EXPERIMENTAL RESULTS OF SC FRACTIONAL MULTIRATE CONVERTERS WITH INTERMITTENT POLYPHASE STRUCTURES

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Multirate mixed analog-digital techniques emerge as one solution for mixed-mode integrated systems by combining both benefits of digital and analog multirate signal processing to achieve the higher efficiency in silicon and power consumption [1]. Sampling rate converters, namely, decimators and interpolators, with a fractional conversion factor *L/M* are also necessary in some interface applications containing distinct sampling rates with non-integer ratio. It is also needed for efficient multistage design of the system with prime number of integer sampling rate conversion ratio but stringent specifications. The traditional approach of analog fractional sampling rate converters, as shown in Fig.1(a), not only requires inefficiently a high-speed SC filter operating at $Lf_s$ and followed by an output downsampler but also suffers from the additional sample-and-hold (S/H) shaping distortion at input sampling rate. A novel, efficient multirate-specific solution has been proposed by using the Intermittent Polyphase (IMP) structures [2-3] which will reduce significantly the speed requirement of the analog components, e.g. op amp, and also eliminate the undesired input S/H distortion. In such approach, as shown in Fig.1(b), the input stage (the serial active delay block structures for FIR and recursive direct-form II structures for IIR filtering) and each of *L* polyphase filters will efficiently operate at *L* and *M* times slower than the traditional scheme, i.e. at input and output sampling rate $f_s$ and $Lf_s/M$ respectively, since the IMP multirate filter, which has dual functions for rejecting unwanted images and preventing aliasing due to, respectively, the intrinsic initial upsampling and last downsamping, efficiently computes only those interpolated values that correspond to the real downsampling output time grid rather than all *L* interpolated outputs between input samples like in the traditional approach.

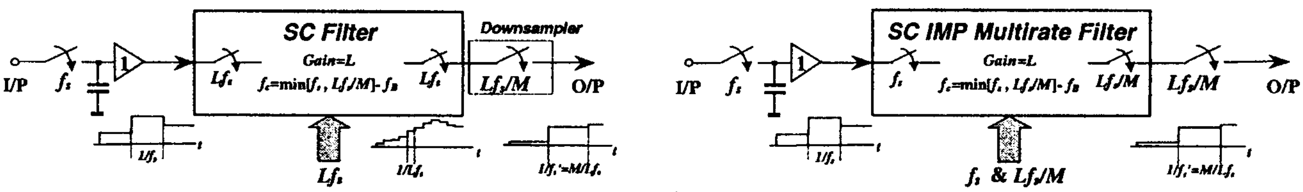


Fig.1 Traditional (a) and Intermittent Polyphase Multirate (b) Approaches for Analog Fractional Sampling Rate Conversion (*L/M*)

This paper presents the verification of the effectiveness of such IMP structures for analog fractional sampling rate converters by the experimental results of a 4/3-fold 9-tap FIR SC interpolator and a 2/3-fold 2nd-order IIR SC decimator prototypes in discrete-component implementations employing CMOS 4066 analog switches, BiCMOS 3140 OA's and a unit capacitance value of 1 nF.

The measured amplitude response of a 4/3-fold 9-tap FIR lowpass interpolator (input & output sampling rate of 3 KHz & 4 KHz, passband & stopband edge @ 500 Hz & 2.5 KHz) is shown in Fig.2(a) with the comparison to the ideal theoretical one. Those two responses match well but with only some deviations caused by the inherently poor capacitance ratio formed by the serial and parallel combination of the discrete capacitors. Note that only the S/H shaping effect at output sampling rate is observed, as presented in the zeros at 4 KHz, 8 KHz and 12 KHz. In addition, the measured time-domain input and output signals at 150 Hz, together with their measured spectra are shown respectively in Fig.2(b) and (c), clearly showing that the frequency-translated images replicate at the effective input and output sampling rate 3 & 4 KHz and their multiples, e.g. the frequency-translated imaging component "B" at 2.85 KHz by sampling the original 150 Hz input signal at input sampling rate 3 KHz has already been first attenuated by the IMP multirate filter to about -35 dB (can refer to the ideal filter response without output S/H effect shown in Fig.2(a) with the effective sampling rate of 12 KHz) and then aliased at 1.15 KHz due to the output downsampling operation at 4 KHz with also the extra rolloff shaping (about -1.2 dB) by the S/H effect at output sampling rate. Note that the extra undesirable (but below the required image rejection level) tones at 1 KHz, 2 KHz, 3 KHz, 4 KHz and its multiples are the sampling images of the overall offset voltage, induced by the op amp DC offset and switches clock feedthrough, from different sampling process during the signal propagation inside circuit. This can be further overcome using some special circuit techniques, like CDS, and Chopper.

For the 2/3-fold 2nd-order IIR lowpass decimator (input & output sampling rate @ 4.5 KHz & 3 KHz, passband and stopband edge @ 500 Hz & 2.5 KHz), the measured amplitude response also well matches with the ideal theoretical one, as shown in Fig.3(a). In order to verify the anti-aliasing functionality of decimation, we present here also the measured waveforms and spectra of outputs when inputting a 3.2 KHz input signal, as shown in Fig.3(b) and (c). This input signal, whose aliasing component locates inside signal baseband at 200 Hz according to the subsampling at output rate 3 KHz, should be ideally suppressed by the IMP multirate filter about –51 dB (according to the ideal filter response output S/H effect in Fig.3(a)) plus also a slight rolloff (about -0.06 dB) by the S/H shaping at output rate, as shown in Fig.3(c). Note that the image signal "B" at 1.3 KHz from the subsampling of input signal at 4.5 KHz will also be folded owing to the output sampling but inside the don't-care band of output signal spectrum content.

All those results further verify that the multirate-specific Intermittent Polyphase structures are the efficient and effective approach for analog fractional sampling rate conversion especially for high-speed, low-cost integrated circuit applications due to its low-speed operation nature.

References


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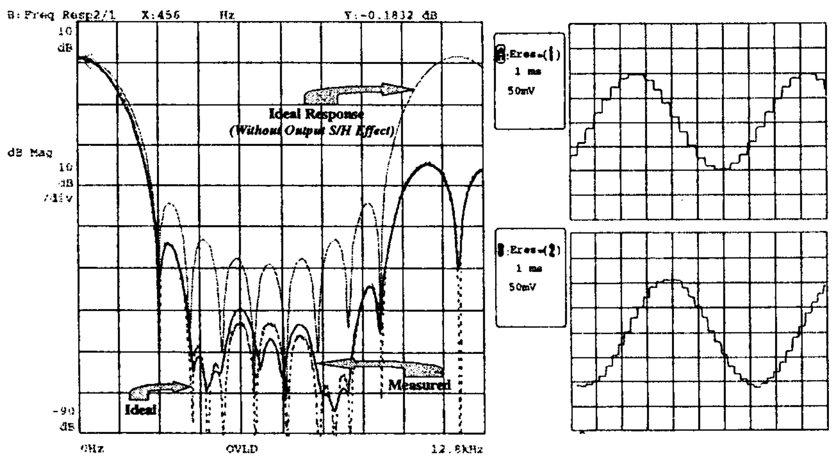
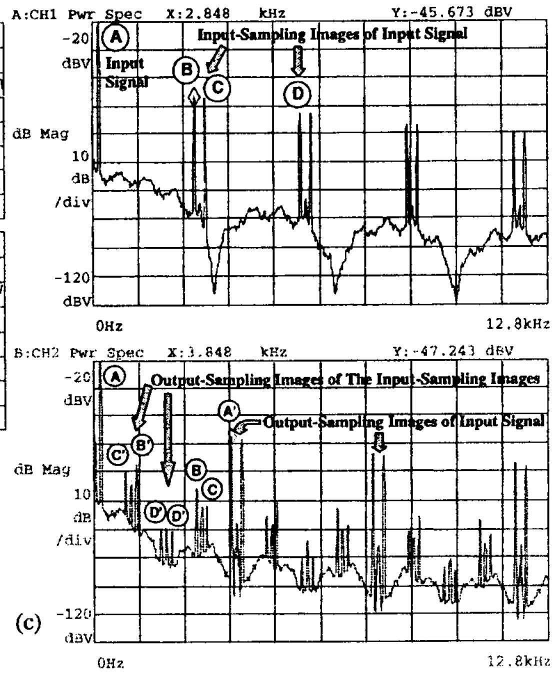
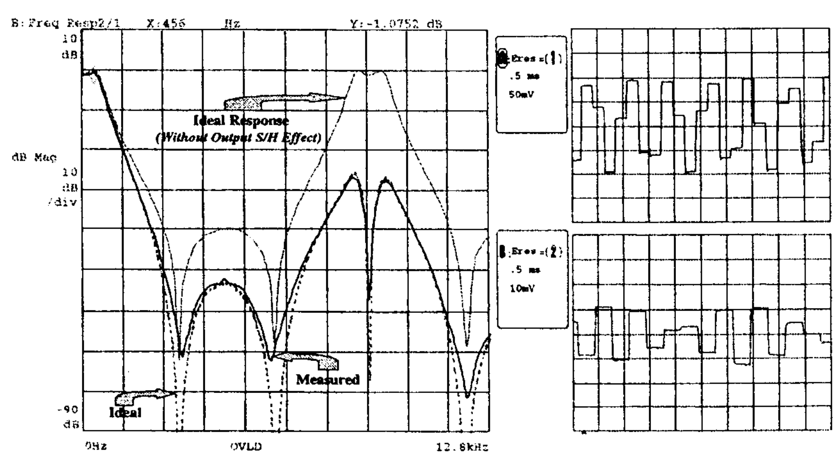



(a) (b)

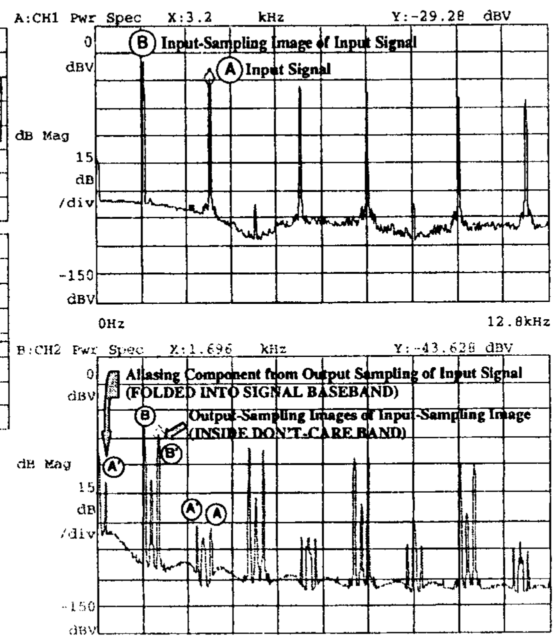



(c)

Fig.2 Experimental results of a 4/3-fold 9-tap FIR lowpass SC interpolator
(a) Ideal and measured amplitude responses
(b) Measured 150 Hz S/H input and output interpolated signals
(c) Measured spectra of 150 Hz S/H input and output signals




(a) (b)




(c)

Fig.3 Experimental results of a 2/3-fold $2^{nd}$-order IIR lowpass SC decimator
(a) Ideal and measured amplitude responses
(b) Measured 3.2 KHz S/H input and output decimated signals
(c) Measured spectra of 3.2 KHz S/H input and output signals