Trim Bit Setting of Analog Filters Using Wavelet-Based Supply Current Analysis

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ABSTRACT

Wavelet transform has the property of resolving signal in both time and frequency unlike Fourier transform. In this work, we show that time-domain information obtained from wavelet analysis of supply current can be used to efficiently trimanalog filters. The pole/zero locations in the frequency response of analog filters shift due to change in component values with process variations. Wavelet analysis of supply current can be a promising alternative to test frequency specification of analog filters, since it needs only one test stimulus and is virtually unaffected by transistor threshold variation. Simulation results on two test circuits demonstrate that we can estimate pole/zero shift with less than 3% error.

Index Terms: Wavelet Transform, Analog Filer, Trim Bit, Dynamic Supply Current (IDD).

1. INTRODUCTION

The steady growth of the digital circuit industry has made computation inexpensive and fast. However, all systems that involve interaction with the outside world demand data converters that can convert the analog signals of the outside world to binary digital signals for faster computation and also convert the processed digital data back to analog form for transmission [1]. Thus, an analog front end is a prerequisite for all communication systems, medical instruments and signal processors, to name a few. Owing to process variation, the values of the resistors and the capacitors in analog filters vary around their nominal values from one chip to another. Hence the pole/zero locations shift accordingly (fig 1). However, it is essential to keep the frequency response and hence the time constants (RC products) unaltered in any analog filter. This requires time constant 'trimming' during the production test [2].

In this paper, we propose an efficient novel method of detecting the time constant of an analog filter prior to the time constant trimming. In contrast to the conventional technique, which requires an input voltage sweeping across all frequencies, here the input is a sinusoidal wave of a single frequency (namely the pole or zero frequency of the filter). The corresponding IDDT of the filter is measured. Since the phase response of any filter changes

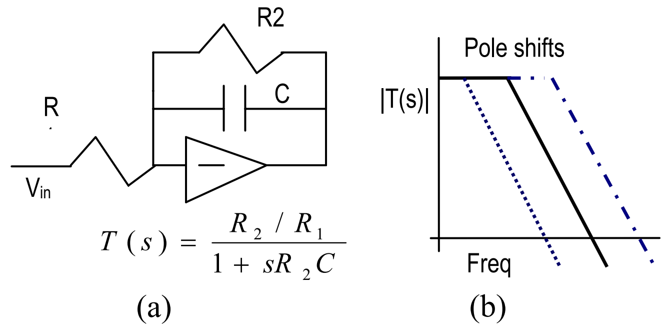

Figure 1. Effect of process variation on analog filter parameters

extremely fast at the pole or zero frequency, this phase change can be easily detected using wavelet transform of the IDDT. The phase information from the wavelet transform [3, 4] can be directly correlated to the amount of shift in the pole or zero location of the filter. Once this is known, it can be 'trimmed' as desired.

2. RELATIONSHIP WITH DYNAMIC CURRENT

We use the simple filter in fig 2 to demonstrate the relationship of pole-zero location with time-domain representation of supply current. The filter, named as MOSFET-C filter, has a single pole at 40KHz. Schematic of the filter and its frequency response is shown in fig 2(a) and 2(b) respectively. Frequency response is plotted for five different values of time constant – nominal value, +/-10% and +/-20% of nominal value. Fig 3(a) plots the dynamic supply current waveform for three different value of RC with response to an ac stimulus at a frequency equal to the pole frequency.

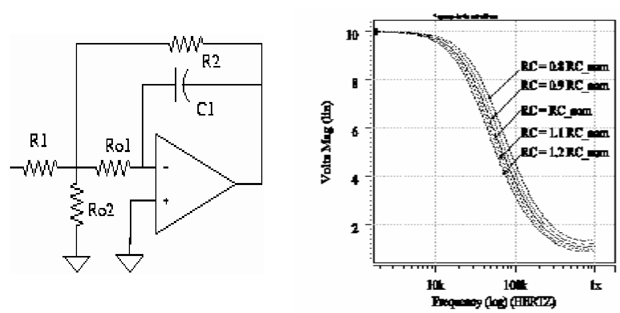

Figure 2. a) A test circuit b) frequency response plot for 5 different RC values

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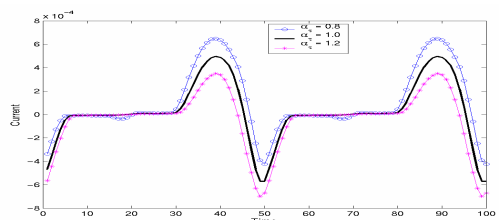
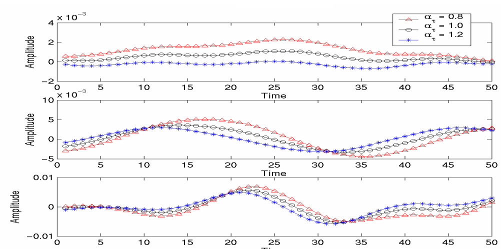
It can be observed that the current response have fairly uniform shape, but they are translated in time axis. This can be clearly traced if we follow a particular peak point in the current waveform of nominal case and see how it moves in time for the other two cases. Furthermore, the direction at which the peak moves has direct correspondence with the direction of the RC shift. Thus, the peaks for two test circuits (one with +20% and -20% RC variation respectively) move in opposite direction with respect to the peak for nominal case. The shift in time axis is, at the same time, proportional to the change in RC value, which indicates that by observing the shift we can easily determine the direction and value of RC change.

3. WAVELET ANALYSIS OF SUPPLY CURRENT TO DETECT RC SHIFT

Since wavelet transform can resolve signals in both time and frequency domain simultaneously, it can be effectively used to localize points in time domain with sharp discontinuity in frequency. We use this property of wavelet to determine RC shift from supply current waveform. First, we perform wavelet transform of the supply current at several scales. Then, we choose an appropriate scale for wavelet decomposition and choose a peak point in the plot of wavelet coefficients of the nominal current. In the next step, we measure the shift of this particular peak across test circuits.



(a)



(b)

Figure 3. a) Dynamic supply current of the filter in figure 2 for 3 different time constants b) plot of wavelet transform coefficients for the corresponding currents

Fig 3(b) plots the wavelet coefficients of corresponding currents in fig 3(a), at three different scales with basis function *db2*. It can be observed that even though translation of the wavelet plot in time axis is reflected in all the scales, it can be more clearly computed for scale 2. It is also important to choose the right basis function, since closeness of approximating a signal with its wavelet components depends on the particular basis used. The process of selecting a basis wavelet and an appropriate scale can be done before the testing process based on simulation results of the filter circuit or measured waveform from a manufactured reference filter. The process of characterizing a filter circuit with a basis wavelet and a scale is simple process and needs to be performed once for each filter circuit. One advantage of wavelet transform is that the number of possible basis functions is unlimited and if for a particular circuit, we cannot find a reasonably good basis from the set of popularly known basis functions e.g. *db* family, *morl*, *mexhat*, *meyr* etc., we can compose a new basis function using wavelet toolbox.

4. NEW SETUP FOR TRIM BIT SETTING

Conventional method of filter trimming requires a large number of test stimuli across a frequency range to be applied, and checking the frequency response to determine the trim bit values [2]. On the other hand, test setup for the proposed method using IDD requires only one ac input at the pole or zero frequency of the circuit, monitor dynamic current at the external supply pin and computing wavelet coefficients of the current. The coefficients are then compared with the nominal case to make decision about trim bit values. It can be noted that a filter may have multiple poles/zeros in frequency response, but a realistic filter design will have the poles/zeros at the same frequency. Hence, we need to apply only one stimulus at the input, which can substantially save the test cost and time. This method has been successfully implemented on a variety of filter structures which are more complex.

5. CONCLUSION

In this paper a novel method of analog filter trimming based on the wavelet analysis of transient current has been presented. It reduces test time and cost significantly.

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