Abstract

Digital filters can be classified into two categories, finite impulse response (FIR) filters and recursive infinite impulse response (IIR) digital filters. For applications where exactly linear phase is not required, IIR filters are attractive option since IIR filters require much fewer multipliers than FIR filters for the same design specifications. The length of a linear phase FIR filter is inversely proportional to the width of its transition band. Thus, the number of multipliers of very sharp FIR filter is enormous. The frequency response masking (FRM) technique is a very efficient technique to design very sharp FIR filters with very low complexity. The basic idea of FRM technique is to synthesize a very sharp filter using a network of low complexity bandedge shaping filters and masking filters. The design of FIR filters using FRM technique has been investigated extensively in the past decades. However, reports on the design of IIR filters using FRM technique are rare.

This thesis presents methods for designing IIR filters using FRM technique. The work presented in the thesis can be divided into two parts. In the first part, the design of pipelined, high-speed IIR filters using FRM technique is investigated. For the FRM-based pipelined IIR filters, the bandedge shaping filters are IIR filters and the masking filters are FIR filters. The bandedge shaping IIR filters are naturally pipelined because its feedback loop contains several delays. First, we propose a two-stage FRM approach where the bandedge shaping filters in the second stage are power complementary IIR filters consisting of a parallel connection of two allpass filters. For a given magnitude response specification and a given number of pipeline stages in the feedback loop, our two-stage FRM approach requires fewer multipliers than the one-stage FRM approach if the number of pipeline stages is larger than four. Second, we consider the design of FRM-based pipelined IIR filter with approximately linear phase where the bandedge shaping filters are general IIR filter and its delay complementary filter. We present a constrained optimization method where the passband phase error and magnitude error are independently controlled.

In the second part, we investigate the design of IIR filters using FRM technique where all the subfilters are IIR filters. In our design, the bandedge shaping filters are power complementary filters realized as a parallel connection of two allpass filters and the masking filters are approximately linear phase IIR filters realized as a parallel connection of a delay line and an allpass filter. Compared to FIR masking filters, IIR masking filters require fewer multipliers. A joint optimization approach is adopted to optimize all the IIR subfilters simultaneously. We demonstrate that the coefficient sensitivity and roundoff noise performance of the IIR filters designed using FRM technique are much superior to classical IIR filters.

Publication List

1. Q. Liu, Y. C. Lim, and Z. Lin, X. Lai, “Design of IIR frequency-response masking filters with near linear phase using constrained optimization,” *Proceedings of the 2017 IEEE International Symposium on Circuits and Systems*, Baltimore, US, May 2017.
2. Q. Liu, Y. C. Lim, and Z. Lin, "Design of Sparse Frequency-Response Masking Filters with Arbitrary Delay Using l1-Minimization," *Proceedings of the 2017 IEEE International Conference on Digital Signal Processing*, London, Aug. 2017.
3. Q. Liu, Y. C. Lim and Z. Lin, “Design of recursive filters using frequency-response masking technique”, *Proceedings of the 2018 IEEE International Conference on Digital Signal Processing*, Shanghai, China, Nov 2018.
4. Q. Liu, Y. C. Lim, and Z. Lin, “Design of Pipelined IIR Filters Using Two-Stage Frequency-Response Masking Technique,” *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 66, no. 5, pp. 873–877, May 2019.
5. Q. Liu, Y. C. Lim and Z. Lin, “Joint optimization of subfilters for the design of IIR filters synthesized using frequency-response masking technique”, to be submitted.