8 DIGITAL FILTER IMPLEMENTATION

Example 10 Compute number of bits required for direct, parallel, and cascade realizations of IIR filter with sensitivity bounds shown in Fig.1. Suppose that $\delta_p \approx 0.011$, $\delta_s \approx 0.05$. Discuss the results[1].
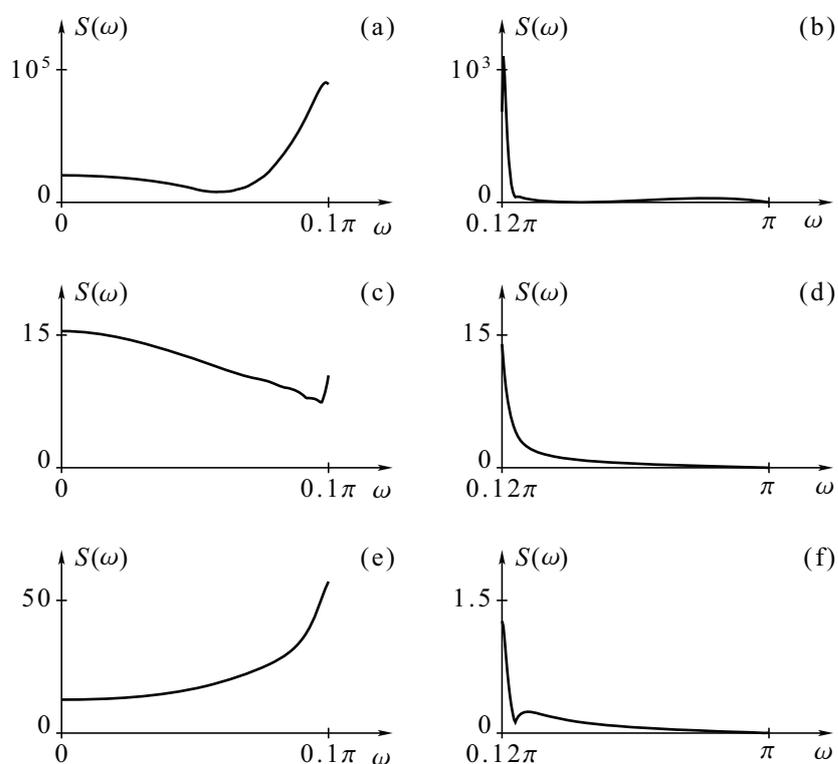
Fig.1 Sensitivity bounds for IIR realizations: a) direct realization, pass band; b) direct realization, stop band; c) parallel realization, pass band; d) parallel realization, stop band; e) cascade realization, pass band; f) cascade realization, stop band (graphs are drawn to different scales).

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[1] In summary, the parallel realization is the least sensitive to coefficient quantization in this example. The phenomenon seen in this example is typical. Parallel realizations are usually best in the pass band (beast meaning least sensitive to coefficient quantization), whereas cascade realizations are usually best in the stop band. It is common for a practical filter to have δ_s much smaller than δ_p. Therefore, the stop-band requirement usually wins over the pass-band requirement. Consequently, cascade realizations are the most commonly used. Direct realizations of IIR filters are highly sensitive to coefficient quantization and should be avoided as a rule, unless the order of the filter is low (3 at most).

Example 11. Compute sensitivity bounds for pass-band and stop-band of IIR filter designed in Example 1

Solution
```
[b,a,v,u,C]=iirdes('ell','p',[0.1 0.2 0.25 0.3]*pi,0.1,0.001);
K=1000;                              % number of points
[dHmag1,S1]= sensiir('d',b,a,K,[0 0.1]*pi);    % sensitivity in the I stop-band
[dHmag2,S2]= sensiir('d',b,a,K,[0.3 1]*pi);    % sensitivity in the II stop-band
[dHmag,P]= sensiir('d',b,a,K,[0.2 0.25]*pi);   % sensitivity in the pass-band
subplot(3,1,1); plot(S1);            % plot sensitivity functions
subplot(3,1,2); plot(S2);
subplot(3,1,3); plot(P);
```

Example 12 Compute number of bits for cascade, parallel and direct realization of IIR from previous example

Example 13 Compute the frequency response of direct realization of IIR filter from previous example for number of B=32 and B=16 bits. What happens for the second value?

Solution
```
[b,a,v,u,C]=iirdes('ell','p',[0.1 0.2 0.25 0.3]*pi,0.1,0.001);
B1=32; B2=16;
K=1000;
[H1]= qfrqresp('d',B1,b,a,K,[0 pi]);    % frequency response for B1
[H2]= qfrqresp('d',B2,b,a,K,[0 pi]);    % frequency response for B2
plot(abs(H1), 'b '); hold on;           % plot frequency responses
plot(abs(H2), 'r'); hold off;
```

Example 14 Compute number of bits for cascade realization of IIR filter (or direct FIR filter) from your project. Note that these realizations can be implemented on target DSP board.