

## Poles and Zeros and Additional Results

This document provides the poles and zeros of Examples 1 to 9 and additional results for Example 9 for the following paper:

**R. C. Nongpiur, D. J. Shpak, A. Antoniou, "Improved Design Method for Nearly Linear-Phase IIR Filters Using Constrained Optimization", *IEEE Trans. on Signal Processing* (in press).**

### Poles and Zeros of Examples 1 to 9

#### Example 1

Design A-1 (Example 1)	
Poles	Zeros
0.316194889405608 + 0.927588697596898i	-0.678617280665110 + 0.793702284165053i
0.316194889405608 - 0.927588697596898i	-0.678617280665110 - 0.793702284165053i
0.346459399092446 + 0.795231741488934i	0.859859399301434 + 1.486133223227537i
0.346459399092446 - 0.795231741488934i	0.859859399301434 - 1.486133223227537i
0.408736111884127 + 0.707376653975764i	0.019678160449859 + 0.975641745981530i
0.408736111884127 - 0.707376653975764i	0.019678160449859 - 0.975641745981530i
0.508762157802999 + 0.581724629502041i	0.173261177168391 + 0.982037666851050i
0.508762157802999 - 0.581724629502041i	0.173261177168391 - 0.982037666851050i
0.572454567375831 + 0.503489682020170i	0.757672484365056 + 1.051386165004604i
0.572454567375831 - 0.503489682020170i	0.757672484365056 - 1.051386165004604i
0.671705640246475 + 0.354566724173110i	1.080277769998145 + 0.770095938195205i
0.671705640246475 - 0.354566724173110i	1.080277769998145 - 0.770095938195205i
0.713219745288943 + 0.225220421948078i	1.332805993514451 + 0.512183866562714i
0.713219745288943 - 0.225220421948078i	1.332805993514451 - 0.512183866562714i
0.727826820130922 + 0.043209728297678i	1.337633031200710 + 0.210323762832116i
0.727826820130922 - 0.043209728297678i	1.337633031200710 - 0.210323762832116i
<b>Ho</b>	7.230642796556981e-004

Design A-2 (Example 1)	
Poles	Zeros
0.310750704642213 + 0.920288120650587i	3.930955226319219
0.310750704642213 - 0.920288120650587i	3.630801841184776
0.352119389705315 + 0.792625545479393i	-0.552137009327140 + 0.753693439197857i
0.352119389705315 - 0.792625545479393i	-0.552137009327140 - 0.753693439197857i
0.398962456767568 + 0.703898331956850i	0.031734789633236 + 0.969279639436315i
0.398962456767568 - 0.703898331956850i	0.031734789633236 - 0.969279639436315i
0.526830918890898 + 0.600369590835681i	0.173726429701258 + 0.981438100160711i
0.526830918890898 - 0.600369590835681i	0.173726429701258 - 0.981438100160711i
0.554497614043729 + 0.467543889359020i	0.692756392987068 + 1.040175922893951i
0.554497614043729 - 0.467543889359020i	0.692756392987068 - 1.040175922893951i
0.673590197043715 + 0.389579249025638i	0.991761516486506 + 0.820685148301040i
0.673590197043715 - 0.389579249025638i	0.991761516486506 - 0.820685148301040i
0.719953808302740 + 0.201275254464109i	1.223533878997129 + 0.490301305259814i
0.719953808302740 - 0.201275254464109i	1.223533878997129 - 0.490301305259814i
0.738394484785958 + 0.091478372393757i	1.462719863126420
0.738394484785958 - 0.091478372393757i	1.463140046070080
<b>Ho</b>	1.929375648157654e-004

**Example 2**

<b>Design A-1 (Example 2)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.108095410986392 + 0.971336180601326i	0.124424587199448 + 1.790529204385077i
-0.108095410986392 - 0.971336180601326i	0.124424587199448 - 1.790529204385077i
-0.174630783685167 + 0.766922782385476i	-1.572974045259537 + 0.296882052802392i
-0.174630783685167 - 0.766922782385476i	-1.572974045259537 - 0.296882052802392i
-0.277791331201643 + 0.663044574977417i	-1.305344234737190 + 0.829678533939879i
-0.277791331201643 - 0.663044574977417i	-1.305344234737190 - 0.829678533939879i
-0.385054561388235 + 0.479607187481888i	-0.809185389141360 + 1.252922870800460i
-0.385054561388235 - 0.479607187481888i	-0.809185389141360 - 1.252922870800460i
-0.471701904031211 + 0.442482197711674i	0.942589057742774 + 0.421366643454772i
-0.471701904031211 - 0.442482197711674i	0.942589057742774 - 0.421366643454772i
-0.594803848926686 + 0.235763227218654i	0.331808818516481 + 0.944513349574644i
-0.594803848926686 - 0.235763227218654i	0.331808818516481 - 0.944513349574644i
-0.610296135084128	0.539078275856524 + 0.855663318257057i
-0.510112092730916	0.539078275856524 - 0.855663318257057i
<b>Ho</b>	3.387596588805417e-004

<b>Design A-2 (Example 2)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.129587030913823 + 0.935354095880280i	-1.109177147262147 + 1.275183686942845i
-0.129587030913823 - 0.935354095880280i	-1.109177147262147 - 1.275183686942845i
-0.228264708820005 + 0.780254340826646i	-1.493205529654857 + 0.285867750828198i
-0.228264708820005 - 0.780254340826646i	-1.493205529654857 - 0.285867750828198i
-0.324813730812861 + 0.665329580959911i	-1.322471208488332 + 0.805512989229631i
-0.324813730812861 - 0.665329580959911i	-1.322471208488332 - 0.805512989229631i
-0.452295969146698 + 0.548729032709602i	-0.678177338875631 + 1.315252474583515i
-0.452295969146698 - 0.548729032709602i	-0.678177338875631 - 1.315252474583515i
-0.545696283186623 + 0.422540657078167i	0.914486674064672 + 0.415033644449005i
-0.545696283186623 - 0.422540657078167i	0.914486674064672 - 0.415033644449005i
-0.638885665872786 + 0.259641928762650i	0.331679107800718 + 0.942434670456086i
-0.638885665872786 - 0.259641928762650i	0.331679107800718 - 0.942434670456086i
-0.660579026509467 + 0.068159724572040i	0.530887153916813 + 0.841962916108677i
-0.660579026509467 - 0.068159724572040i	0.530887153916813 - 0.841962916108677i
<b>Ho</b>	4.254845201569976e-004

**Example 3**

<b>Design A-1 (Example 3)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.083258900147753 + 0.888807929569746i	-1.533848790855598
-0.083258900147753 - 0.888807929569746i	-0.697036069782601 + 0.915835612368670i
0.002834369830340 + 0.844929765733845i	-0.697036069782601 - 0.915835612368670i
0.002834369830340 - 0.844929765733845i	0.421192870901872 + 1.614480687629308i
0.590164191697670 + 0.664227857024480i	0.421192870901872 - 1.614480687629308i
0.590164191697670 - 0.664227857024480i	1.347779950075436 + 1.100315543534782i
0.491926323040073 + 0.680904251460937i	1.347779950075436 - 1.100315543534782i
0.491926323040073 - 0.680904251460937i	0.124534599954391 + 1.212380390465054i
0.409102378964104 + 0.707158890447919i	0.124534599954391 - 1.212380390465054i
0.409102378964104 - 0.707158890447919i	0.506119474321827 + 1.132551872242106i
0.165297758037756 - 0.790496685034353i	0.506119474321827 - 1.132551872242106i
0.165297758037756 + 0.790496685034353i	1.036344098027775
0.247502375795144 + 0.764013122126123i	0.826961022588670 + 0.557901258530004i
0.247502375795144 - 0.764013122126123i	0.826961022588670 - 0.557901258530004i

<b>Ho</b>	9.538083071739773e-004
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<b>Design A-2 (Example 3)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.076714645151686 + 0.890838519817448i	1.561666032241332
-0.076714645151686 - 0.890838519817448i	1.034144738442276
0.004716638351661 + 0.839965105522936i	0.828203881706730 + 0.558223703276560i
0.004716638351661 - 0.839965105522936i	0.828203881706730 - 0.558223703276560i
0.583913983795629 + 0.687630980756487i	0.595013662062041 + 1.039366803541748i
0.583913983795629 - 0.687630980756487i	0.595013662062041 - 1.039366803541748i
0.494002366250057 + 0.702447038273360i	0.307695507127380 + 1.191416490283998i
0.494002366250057 - 0.702447038273360i	0.307695507127380 - 1.191416490283998i
0.124245297995792 + 0.805956367289334i	0.085139886669244 + 1.234858171372786i
0.124245297995792 - 0.805956367289334i	0.085139886669244 - 1.234858171372786i
0.338793525086818 + 0.743834836527864i	-0.638208918893237 + 1.054769047595507i
0.338793525086818 - 0.743834836527864i	-0.638208918893237 - 1.054769047595507i
0.272050461443023 + 0.761143525390037i	-1.199730733263683
0.272050461443023 - 0.761143525390037i	-0.769532635828309
<b>Ho</b>	0.002680119463696

**Example 4**

<b>Design A-1 (Example 4)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.013926379674743 + 0.979901043956862i	2.097926928783955 + 0.723877752403726i
-0.013926379674743 - 0.979901043956862i	2.097926928783955 - 0.723877752403726i
0.063509290431530 + 0.651245758495900i	1.135067013004640 + 1.719429830888593i
0.063509290431530 - 0.651245758495900i	1.135067013004640 - 1.719429830888593i
0.187119893251823 + 0.494769720951604i	-0.855564270581115 + 0.397339140517699i
0.187119893251823 - 0.494769720951604i	-0.855564270581115 - 0.397339140517699i
0.371912728776539 + 0.295803723144950i	-0.328747139191149 + 0.937115820222992i
0.371912728776539 - 0.295803723144950i	-0.328747139191149 - 0.937115820222992i
0.431050702732535	-0.502988808573866 + 0.811696751055741i
0.301949928234250	-0.502988808573866 - 0.811696751055741i
<b>Ho</b>	0.003142079689294

<b>Design A-2 (Example 4)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.109681544644989 + 0.952339303125744i	1.881872090209374 + 0.647934932156376i
-0.109681544644989 - 0.952339303125744i	1.881872090209374 - 0.647934932156376i
0.015505025165498 + 0.817088913752480i	1.017637967873839 + 1.571791664899016i
0.015505025165498 - 0.817088913752480i	1.017637967873839 - 1.571791664899016i
0.235587349275785 + 0.604048328962498i	-0.816324411585210 + 0.429481691496672i
0.235587349275785 - 0.604048328962498i	-0.816324411585210 - 0.429481691496672i
0.539459994678216 + 0.141338748060614i	-0.324550810849948 + 0.940743316213056i
0.539459994678216 - 0.141338748060614i	-0.324550810849948 - 0.940743316213056i
0.421809922759240 + 0.400039709565914i	-0.470111947684652 + 0.836059639738205i
0.421809922759240 - 0.400039709565914i	-0.470111947684652 - 0.836059639738205i
<b>Ho</b>	0.004904487783869

**Example 5**

<b>Design A-1 (Example 5)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.193917890939586 + 0.960622637445722i	1.792828708704659 + 0.359589092392312i
-0.193917890939586 - 0.960622637445722i	1.792828708704659 - 0.359589092392312i
-0.080718941747798 + 0.752546107046911i	1.214038075173196 + 1.159894914034619i
-0.080718941747798 - 0.752546107046911i	1.214038075173196 - 1.159894914034619i
0.054530149672181 + 0.660911546289934i	0.446446336852748 + 1.514955848520144i
0.054530149672181 - 0.660911546289934i	0.446446336852748 - 1.514955848520144i
0.317439952198865 + 0.530051462000665i	-0.746787692160073 + 0.442090587084436i
0.317439952198865 - 0.530051462000665i	-0.746787692160073 - 0.442090587084436i
0.502817064708447 + 0.271867688689306i	-0.319267758290391 + 0.936084739904751i
0.502817064708447 - 0.271867688689306i	-0.319267758290391 - 0.936084739904751i
0.425577944399392 + 0.015875984302818i	-0.417743882502083 + 0.811353209279624i
0.425577944399392 - 0.015875984302818i	-0.417743882502083 - 0.811353209279624i
<b>Ho</b>	0.006795739539794

<b>Design A-2 (Example 5)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.193830342941587 + 0.944422548921120i	1.470409547787156 + 0.395725390530523i
-0.193830342941587 - 0.944422548921120i	1.470409547787156 - 0.395725390530523i
-0.039431648701334 + 0.741225864477900i	1.062671874425093 + 1.069355852596115i
-0.039431648701334 - 0.741225864477900i	1.062671874425093 - 1.069355852596115i
0.019139909118663 + 0.651740388146688i	0.385949561659273 + 1.405460065627912i
0.019139909118663 - 0.651740388146688i	0.385949561659273 - 1.405460065627912i
0.339351372412752 + 0.583257603881549i	-0.782437848470105 + 0.430958458108808i
0.339351372412752 - 0.583257603881549i	-0.782437848470105 - 0.430958458108808i
0.568796932667553 + 0.334481297185620i	-0.321320167957459 + 0.938774697682484i
0.568796932667553 - 0.334481297185620i	-0.321320167957459 - 0.938774697682484i
0.651993412246726	-0.446571373973566 + 0.826821140181588i
0.195100260941811	-0.446571373973566 - 0.826821140181588i
<b>Ho</b>	0.013768995848383

<b>Design B-1 (Example 5)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.078057480865659 + 0.933356670397340i	-0.976923232923314 + 0.832972940550528i
-0.078057480865659 - 0.933356670397340i	-0.976923232923314 - 0.832972940550528i
0.101832630293161 + 0.839363003218257i	-0.352705908606377 + 0.946120759684773i
0.101832630293161 - 0.839363003218257i	-0.352705908606377 - 0.946120759684773i
0.313669720508226 + 0.738592941620013i	0.259479677385324 + 1.293532323667504i
0.313669720508226 - 0.738592941620013i	0.259479677385324 - 1.293532323667504i
0.522307012840912 + 0.598856875674641i	0.760498170171402 + 1.119456775603103i
0.522307012840912 - 0.598856875674641i	0.760498170171402 - 1.119456775603103i
0.773900638407933 + 0.130273105142132i	1.129029631159686 + 0.757970089256677i
0.773900638407933 - 0.130273105142132i	1.129029631159686 - 0.757970089256677i
0.689815326788837 + 0.389498780052629i	1.319649725471142 + 0.272081345051542i
0.689815326788837 - 0.389498780052629i	1.319649725471142 - 0.272081345051542i
<b>Ho</b>	0.008251032045464

**Example 6**

<b>Design A-1: All IIR (Example 6)</b>	
<b>Poles</b>	<b>Zeros</b>
0.054720850972065 + 0.978471066749226i	2.760316143372712
0.054720850972065 - 0.978471066749226i	2.074096065031592
0.129067458839241 + 0.695149916423916i	1.192806937522082 + 1.341242075513163i
0.129067458839241 - 0.695149916423916i	1.192806937522082 - 1.341242075513163i
0.266276002822302 + 0.553303364506700i	-0.850786624450241 + 0.485569875134369i
0.266276002822302 - 0.553303364506700i	-0.850786624450241 - 0.485569875134369i
0.467995117647214 + 0.152099647124392i	-0.207734231218901 + 0.975566476556592i
0.467995117647214 - 0.152099647124392i	-0.207734231218901 - 0.975566476556592i
0.429238593538397 + 0.279791722811943i	-0.400811321169131 + 0.898580814084964i
0.429238593538397 - 0.279791722811943i	-0.400811321169131 - 0.898580814084964i
<b>Ho</b>	0.002795862963103

<b>Design A-2: All IIR (Example 6)</b>	
<b>Poles</b>	<b>Zeros</b>
0.055899875082745 + 0.941595794139353i	1.560532836267383 + 0.500037760769863i
0.055899875082745 - 0.941595794139353i	1.560532836267383 - 0.500037760769863i
0.137189014239702 + 0.694579895414000i	0.953953087535561 + 1.270175172428016i
0.137189014239702 - 0.694579895414000i	0.953953087535561 - 1.270175172428016i
0.270300526450330 + 0.603032321027418i	-0.789354534288448 + 0.450991420752534i
0.270300526450330 - 0.603032321027418i	-0.789354534288448 - 0.450991420752534i
0.506904816181278 + 0.389758373464952i	-0.207363157634161 + 0.971912241425369i
0.506904816181278 - 0.389758373464952i	-0.207363157634161 - 0.971912241425369i
0.554307276978376 + 0.079692014072357i	-0.387023183479362 + 0.867177538670689i
0.554307276978376 - 0.079692014072357i	-0.387023183479362 - 0.867177538670689i
<b>Ho</b>	0.008027005381132

<b>Design A-1: IIR-FIR (Example 6)</b>	
<b>Poles</b>	<b>Zeros</b>
0.059169225602778 + 0.978212146066383i	2.141380336280351 + 0.674280719552255i
0.059169225602778 - 0.978212146066383i	2.141380336280351 - 0.674280719552255i
0.129348979196892 + 0.611626273038805i	1.283165718406130 + 1.568662755361623i
0.129348979196892 - 0.611626273038805i	1.283165718406130 - 1.568662755361623i
	-0.203742956523233 + 0.969706292175626i
	-0.203742956523233 - 0.969706292175626i
	-0.827714735726350
	-0.738074439090602 + 0.377946605791700i
	-0.738074439090602 - 0.377946605791700i
	-0.326774093947291 + 0.869237020942408i
	-0.326774093947291 - 0.869237020942408i
	-0.532881177515898 + 0.672617944705410i
	-0.532881177515898 - 0.672617944705410i
	-0.181049419229928 + 0.350989740787082i
	-0.181049419229928 - 0.350989740787082i
<b>Ho</b>	0.003128005253469

Design A-2: IIR-FIR (Example 6)	
Poles	Zeros
-0.000924262124859 + 0.955357766141679i	1.660972368175311 + 0.545519928969859i
-0.000924262124859 - 0.955357766141679i	1.660972368175311 - 0.545519928969859i
0.064205436061996 + 0.651387863937034i	1.000140321168084 + 1.348305765945953i
0.064205436061996 - 0.651387863937034i	1.000140321168084 - 1.348305765945953i
	-0.200177215072923 + 0.973012699913892i
	-0.200177215072923 - 0.973012699913892i
	-0.299221833567202 + 0.898799748971208i
	-0.299221833567202 - 0.898799748971208i
	-0.464882330728942 + 0.744875257875761i
	-0.464882330728942 - 0.744875257875761i
	-0.621568606932035 + 0.515650221535313i
	-0.621568606932035 - 0.515650221535313i
	-0.731657263374246
	-0.709524541289917 + 0.253654124773878i
	-0.709524541289917 - 0.253654124773878i
<b>Ho</b>	0.007721086727485

**Example 7**

Design A-1 (Example 7)	
Poles	Zeros
-0.007751204161845 + 0.979969399738685i	-1.668821119087428 + 0.441788851250476i
-0.007751204161845 - 0.979969399738685i	-1.668821119087428 - 0.441788851250476i
-0.007751518488117 + 0.979969289502379i	-1.342854274917550 + 1.093534899174451i
-0.007751518488117 - 0.979969289502379i	-1.342854274917550 - 1.093534899174451i
-0.034148541035844 + 0.770534955964202i	-0.677440052914276 + 1.392060474836771i
-0.034148541035844 - 0.770534955964202i	-0.677440052914276 - 1.392060474836771i
-0.165679165461078 + 0.670781152482769i	0.735385369103505 + 0.598381051814868i
-0.165679165461078 - 0.670781152482769i	0.735385369103505 - 0.598381051814868i
-0.383174967457530 + 0.478222926306893i	0.235347443202313 + 0.946606133458164i
-0.383174967457530 - 0.478222926306893i	0.235347443202313 - 0.946606133458164i
-0.501954443925360 + 0.271814331843826i	-0.019649489515946 + 0.973242563045789i
-0.501954443925360 - 0.271814331843826i	-0.019649489515946 - 0.973242563045789i
-0.581460454032564	0.090972715438460 + 0.991943908151660i
-0.322519658367629	0.090972715438460 - 0.991943908151660i
<b>Ho</b>	0.006469287596204

Design A-2 (Example 7)	
Poles	Zeros
0.053226634872329 + 0.978553486192801i	-1.299735970293061 + 0.321129892444579i
0.053226634872329 - 0.978553486192801i	-1.299735970293061 - 0.321129892444579i
0.027087328749251 + 0.955104860188481i	-1.000223601250161 + 0.885025284309716i
0.027087328749251 - 0.955104860188481i	-1.000223601250161 - 0.885025284309716i
-0.102867768492402 + 0.823027894813874i	-0.481401626725509 + 1.224529200132125i
-0.102867768492402 - 0.823027894813874i	-0.481401626725509 - 1.224529200132125i
-0.280053339945075 + 0.65685282227795i	0.082564700787066 + 0.992705328015489i
-0.280053339945075 - 0.65685282227795i	0.082564700787066 - 0.992705328015489i
-0.430378983397575 + 0.527737747074170i	0.120648147888613 + 0.953811658250386i
-0.430378983397575 - 0.527737747074170i	0.120648147888613 - 0.953811658250386i
-0.613760094881669 + 0.308645325629006i	0.221424158382864 + 0.801302269380790i
-0.613760094881669 - 0.308645325629006i	0.221424158382864 - 0.801302269380790i
-0.680681045799150	0.432880198365844 + 0.366481214727725i
-0.327266979142400	0.432880198365844 - 0.366481214727725i
<b>Ho</b>	0.031955035040652

Design B-1 (Example 7)	
Poles	Zeros
-0.008250800939884 + 0.978982132608124i	-1.619746114552514 + 0.437028094435780i
-0.008250800939884 - 0.978982132608124i	-1.619746114552514 - 0.437028094435780i
-0.008250644039231 + 0.978982066505644i	-1.317570348308746 + 1.086165785115776i
-0.008250644039231 - 0.978982066505644i	-1.317570348308746 - 1.086165785115776i
-0.037004907946268 + 0.771067875963379i	-0.661516461164890 + 1.374076792140376i
-0.037004907946268 - 0.771067875963379i	-0.661516461164890 - 1.374076792140376i
-0.164127198629712 + 0.676815464031624i	0.698380206119975 + 0.574280400341433i
-0.164127198629712 - 0.676815464031624i	0.698380206119975 - 0.574280400341433i
-0.388107586791870 + 0.486996667857586i	0.232116808597655 + 0.935718382344173i
-0.388107586791870 - 0.486996667857586i	0.232116808597655 - 0.935718382344173i
-0.510561263569102 + 0.283998053900255i	-0.020921660588675 + 0.972405045371897i
-0.510561263569102 - 0.283998053900255i	-0.020921660588675 - 0.972405045371897i
-0.598221982955324	0.091948102130367 + 0.996597939888574i
-0.333458553337362	0.091948102130367 - 0.996597939888574i
<b>Ho</b>	0.007578293870443

Design B-2 (Example 7)	
Poles	Zeros
0.051809273531209 + 0.978629551555004i	-1.912276974207840
0.051809273531209 - 0.978629551555004i	-1.568218571494457
0.025258026456053 + 0.951976334553668i	-1.179673705982545 + 0.815093082786709i
0.025258026456053 - 0.951976334553668i	-1.179673705982545 - 0.815093082786709i
-0.093670803418440 + 0.810723590509058i	-0.601592401027690 + 1.220973701976881i
-0.093670803418440 - 0.810723590509058i	-0.601592401027690 - 1.220973701976881i
-0.285724638236221 + 0.664882399530648i	0.082733112750728 + 0.992553138464687i
-0.285724638236221 - 0.664882399530648i	0.082733112750728 - 0.992553138464687i
-0.489970658591259 + 0.522917387458349i	0.121971826207424 + 0.951979863061697i
-0.489970658591259 - 0.522917387458349i	0.121971826207424 - 0.951979863061697i
-0.648859826798847 + 0.234961042078381i	0.223934201242280 + 0.793274876979089i
-0.648859826798847 - 0.234961042078381i	0.223934201242280 - 0.793274876979089i
-0.595915889383937	0.402105812768436 + 0.342837328146629i
-0.098819847694173	0.402105812768436 - 0.342837328146629i
<b>Ho</b>	0.015541592856465

Design B-3 (Example 7)	
Poles	Zeros
0.000190692946252 + 0.978457084596449i	-1.606209688115732 + 0.455241593828162i
0.000190692946252 - 0.978457084596449i	-1.606209688115732 - 0.455241593828162i
-0.032998391798003 + 0.979444284343005i	-1.345233613684453 + 1.026410838286155i
-0.032998391798003 - 0.979444284343005i	-1.345233613684453 - 1.026410838286155i
-0.050280408446263 + 0.784681700220993i	-0.634508049803128 + 1.334666574540844i
-0.050280408446263 - 0.784681700220993i	-0.634508049803128 - 1.334666574540844i
-0.169896616462829 + 0.689238502204168i	0.550889975583421 + 0.476319580068698i
-0.169896616462829 - 0.689238502204168i	0.550889975583421 - 0.476319580068698i
-0.407516125310478 + 0.504861697765726i	0.226690002554682 + 0.915927134126834i
-0.407516125310478 - 0.504861697765726i	0.226690002554682 - 0.915927134126834i
-0.498793763122826 + 0.299506402333022i	-0.035600639786708 + 0.976269383128967i
-0.498793763122826 - 0.299506402333022i	-0.035600639786708 - 0.976269383128967i
-0.586868706323881	0.090297472575434 + 0.988711484055359i
-0.474147689670143	0.090297472575434 - 0.988711484055359i
<b>Ho</b>	0.009305426319217

**Example 8**

<b>Design A-1 (Example 8)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.100239957490442 + 0.974859964756816i	1.329966253183002 + 0.211908183927367i
-0.100239957490442 - 0.974859964756816i	1.329966253183002 - 0.211908183927367i
-0.098899492525181 + 0.974996866875402i	1.202182280931926 + 0.614282315973352i
-0.098899492525181 - 0.974996866875402i	1.202182280931926 - 0.614282315973352i
0.017798615129292 + 0.870272687697845i	0.959452933850559 + 0.949240167500853i
0.017798615129292 - 0.870272687697845i	0.959452933850559 - 0.949240167500853i
0.146825505576220 + 0.794880253962270i	0.625317041228244 + 1.181288964058093i
0.146825505576220 - 0.794880253962270i	0.625317041228244 - 1.181288964058093i
0.302483790040187 + 0.732729795338558i	0.236814337135148 + 1.277990915894030i
0.302483790040187 - 0.732729795338558i	0.236814337135148 - 1.277990915894030i
0.471963217526724 + 0.627251140133848i	-0.677043560827101 + 0.480677146060077i
0.471963217526724 - 0.627251140133848i	-0.677043560827101 - 0.480677146060077i
0.614853090793494 + 0.472204970679942i	-0.316901564832373 + 0.858388772601850i
0.614853090793494 - 0.472204970679942i	-0.316901564832373 - 0.858388772601850i
0.706545484916073 + 0.279311553697404i	-0.160542386318764 + 0.984937515942632i
0.706545484916073 - 0.279311553697404i	-0.160542386318764 - 0.984937515942632i
0.728910026805274 + 0.083388064199016i	-0.197233561315934 + 0.955769893356791i
0.728910026805274 - 0.083388064199016i	-0.197233561315934 - 0.955769893356791i
<b>Ho</b>	0.004572068924068

<b>Design A-2 (Example 8)</b>	
<b>Poles</b>	<b>Zeros</b>
-0.108059518516579 + 0.974024199114181i	1.209955353258521 + 0.185320647502547i
-0.108059518516579 - 0.974024199114181i	1.209955353258521 - 0.185320647502547i
-0.079956183092245 + 0.944783143520462i	1.096298486659610 + 0.536936450722118i
-0.079956183092245 - 0.944783143520462i	1.096298486659610 - 0.536936450722118i
0.019413038765074 + 0.864224226534025i	0.877635912904230 + 0.840112766204159i
0.019413038765074 - 0.864224226534025i	0.877635912904230 - 0.840112766204159i
0.175995976935425 + 0.828596314668119i	0.578988804519865 + 1.067551258120500i
0.175995976935425 - 0.828596314668119i	0.578988804519865 - 1.067551258120500i
0.822858988864451 + 0.118038908083623i	0.232059688355768 + 1.186044789194169i
0.822858988864451 - 0.118038908083623i	0.232059688355768 - 1.186044789194169i
0.750758611957454 + 0.345459522499795i	-0.728771359583362 + 0.476478545499767i
0.750758611957454 - 0.345459522499795i	-0.728771359583362 - 0.476478545499767i
0.368608090198160 + 0.735075380672527i	-0.345780075459261 + 0.864151250944385i
0.368608090198160 - 0.735075380672527i	-0.345780075459261 - 0.864151250944385i
0.597618049425565 + 0.534446882922004i	-0.160925281367522 + 0.984932821732214i
0.597618049425565 - 0.534446882922004i	-0.160925281367522 - 0.984932821732214i
0.457814124820464 + 0.568060920934170i	-0.204063062763187 + 0.958736932119989i
0.457814124820464 - 0.568060920934170i	-0.204063062763187 - 0.958736932119989i
<b>Ho</b>	0.011158589110164



Design B-1 (Example 8)	
Poles	Zeros
-0.963814317556621	1.335050123613265
-0.097613677523586 + 0.975126437933090i	1.209692563767793 + 0.547209013939184i
-0.097613677523586 - 0.975126437933090i	1.209692563767793 - 0.547209013939184i
-0.097323242329570 + 0.975155467866654i	0.868594585609045 + 0.993036864891575i
-0.097323242329570 - 0.975155467866654i	0.868594585609045 - 0.993036864891575i
0.022732061601070 + 0.857583451044007i	0.383773599605141 + 1.251595716003574i
0.022732061601070 - 0.857583451044007i	0.383773599605141 - 1.251595716003574i
0.228178490671264 + 0.760107836804631i	-1.059898352972377
0.228178490671264 - 0.760107836804631i	-0.943062476814533 + 0.186915884192634i
0.475299418577119 + 0.589217493975167i	-0.943062476814533 - 0.186915884192634i
0.475299418577119 - 0.589217493975167i	-0.428259250388338 + 0.666962012397811i
0.712350955979167	-0.428259250388338 - 0.666962012397811i
0.653469971959740 + 0.318691577729550i	-0.160706538332482 + 0.984574573777343i
0.653469971959740 - 0.318691577729550i	-0.160706538332482 - 0.984574573777343i
-0.003860937679858 + 0.251232363773786i	-0.196094502904734 + 0.950461140546802i
-0.003860937679858 - 0.251232363773786i	-0.196094502904734 - 0.950461140546802i
0.245395587520202	-0.270041416690141 + 0.849320258034909i
0.094355517922127	-0.270041416690141 - 0.849320258034909i
<b>Ho</b>	-0.009453802101247

**Example 9**

Design A-1 (Example 9)	
Poles	Zeros
-0.222828890130858 + 0.954330805182426i	1.796063651740643 + 0.443883720838963i
-0.222828890130858 - 0.954330805182426i	1.796063651740643 - 0.443883720838963i
-0.110279093886311 + 0.747987534363133i	1.245668913583409 + 1.214569240715393i
-0.110279093886311 - 0.747987534363133i	1.245668913583409 - 1.214569240715393i
0.042497909923321 + 0.663687990421913i	0.467753094645284 + 1.542901673277010i
0.042497909923321 - 0.663687990421913i	0.467753094645284 - 1.542901673277010i
0.305373449117855 + 0.509144435225580i	-0.812956051421728 + 0.498851631376464i
0.305373449117855 - 0.509144435225580i	-0.812956051421728 - 0.498851631376464i
0.487983404366166 + 0.271026682585036i	-0.315837981043426 + 0.936053846980129i
0.487983404366166 - 0.271026682585036i	-0.315837981043426 - 0.936053846980129i
0.528859369141729	-0.407056325930875 + 0.823965355691137i
0.213982487201955	-0.407056325930875 - 0.823965355691137i
<b>Ho</b>	0.006632348130757

Design A-2 (Example 9)	
Poles	Zeros
-0.220739223658478 + 0.948308482296342i	1.829473746982635 + 0.326623377735322i
-0.220739223658478 - 0.948308482296342i	1.829473746982635 - 0.326623377735322i
-0.098817878327427 + 0.758306466831983i	1.226598928975966 + 1.179434079769399i
-0.098817878327427 - 0.758306466831983i	1.226598928975966 - 1.179434079769399i
0.048592630990351 + 0.677708822505689i	0.462166605655068 + 1.501624598109070i
0.048592630990351 - 0.677708822505689i	0.462166605655068 - 1.501624598109070i
0.315540452968556 + 0.521280092171300i	-0.664195061678952 + 0.422113502994836i
0.315540452968556 - 0.521280092171300i	-0.664195061678952 - 0.422113502994836i
0.498772806945537 + 0.265553335068879i	-0.317210438110125 + 0.935661935457917i
0.498772806945537 - 0.265553335068879i	-0.317210438110125 - 0.935661935457917i
0.414539291890690 + 0.076396041235712i	-0.399134903527575 + 0.807652416020514i
0.414539291890690 - 0.076396041235712i	-0.399134903527575 - 0.807652416020514i
<b>Ho</b>	0.008036067905455

Design B-1 (Example 9)	
Poles	Zeros
-0.153744210980200 + 0.887173499233207i	-1.734805449128636
-0.153744210980200 - 0.887173499233207i	1.371458055433173
0.028577806233445 + 0.796100748631601i	1.234906606141342 + 0.590670288939248i
0.028577806233445 - 0.796100748631601i	1.234906606141342 - 0.590670288939248i
0.717667558571659 + 0.159079012325819i	0.856881730770491 + 1.059809744897039i
0.717667558571659 - 0.159079012325819i	0.856881730770491 - 1.059809744897039i
0.576846794399295 + 0.446038914633606i	0.317788627284759 + 1.296439534591094i
0.576846794399295 - 0.446038914633606i	0.317788627284759 - 1.296439534591094i
0.314613405021667 + 0.657809415363896i	-0.674074759647166 + 0.855038874095096i
0.314613405021667 - 0.657809415363896i	-0.674074759647166 - 0.855038874095096i
0.207914358737630 + 0.464910866331528i	-0.335690484570467 + 0.940262520922979i
0.207914358737630 - 0.464910866331528i	-0.335690484570467 - 0.940262520922979i
Ho	-0.010369450112564

### Additional Results for Example 9

**Table XXA**  
Lowpass digital filter specifications for Example 9

Parameters	Values
Maximum passband ripple, dB	0.55
Minimum stopband attenuation, dB	30
Passband edge, rad/s	$0.5\pi$
Stopband edge, rad/s	$0.6\pi$
Maximum pole radius	0.98
Group delay (samples)	14

**Table XXB**  
Design results for Example 9 for variable group delay (lowpass filter)

Parameters	Design A-1	Design A-2	Method in [8]	Method in [11]
Filter order	12	12	12	12
Max PB ripple, dB	0.421	0.421	0.5	0.425
Min SB atten., dB	32.5	32.5	31.7	32.2
Max TB gain, dB	2.16	0.003	-0.25	?
$\tau_{avg}$	10.73	10.74	14	14
$Q_\tau$	0.00043	0.00089	0.13	0.11

**Table XXC**  
Design results for Example 9 for fixed group delay (lowpass filter)

Parameters	Design B-1	Method in [8]	Method in [11]
Filter order	12	12	12
Max PB ripple, dB	0.421	0.5	0.425
Min SB atten., dB	32.5	31.7	32.2
Max TB gain, dB	-0.215	-0.25	?
$\tau_{avg}$	14	14	14
$Q_\tau$	0.086	0.13	0.11