ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER

(ELEC 6081)

(Winter 2012-'13 term)

Project#1 (Graduate)

Consider the design of a high-frequency, high-Q band-pass filter with the response characteristic shown in **Table 1**, where f_o is the center frequency of the filter. For mobile communication applications, f_o could be between 85MHz to 100MHz (depending upon international agreements and communication protocols). Choose a value for f_o for your design.

Table 1

Frequency	f_o to $f_o \pm 100$kHz	$f_o \pm 800$kHz	$f_o \pm 3$MHz	$f_o \pm 6$MHz
Attenuation (dB)	≤ 0.5	≥ 6	≥ 18	≥ 36

1. Synthesize the filter transfer function (it will be of order >2). (**5%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**5%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**5%** marks)

Use *frequency scaling* to move the center frequency f_o to 10kHz, and update **Table 1** accordingly.

4. Provide a design[1] for the above filter, using

   (a) Passive L,C,R ladder sections (**10%** marks), and

   (b) OTA based active filter. (**20%** marks). The OTAs *could be* deployed to implement the L elements in 4(a).

You can use the VCCS module from the SPICE library for the OTA. *If you can produce your design using realistic model for the OTA more credit will be given.*

5. From the work in step 2 above, use one of the second order transfer functions for the following tasks.

(a) Produce a design of the second order filter using OA. Use of nearest practical values of R,C elements (as obtained from the lab bins, i.e., for R= 1.231 kΩ, use 1.2 kΩ, and for C=0.125 μF. use 0.1 μF, or 0.1 μF plus 20 nF in parallel) is

[1] The mark for each component of a design as in items 4, 5(a)-(c), is prorated according to the distribution under item 6(a(-(f).

encouraged. Provide SPICE simulation results and a comparison with the theoretical transfer function (second order). The theoretical transfer function can be obtained using numerical simulation (i.e., MATLAB). Use model of a practical OA such as µ741 from the SPICE data base. (**15%** marks)

(b) Produce a design of the second order filter using CCII (equivalent circuit model) and capacitors. Use of nearest practical values for the C elements (as obtained from the lab bins, i.e., for C=0.125 µF. use 0.1 µF, or 0.1 µF plus 20 nF in parallel) is encouraged. Provide SPICE simulation results and a comparison with the theoretical transfer function (second order). The theoretical transfer function can be obtained using numerical simulation (i.e., MATLAB). Use model of a practical CCII (as used in the lab work). (**15%** marks)

(c) Produce a design of the second order filter using OA and switched capacitors. Use a clock frequency of 64 kHz. Use minimum capacitor value of 1 pF. Provide SPICE simulation results (exploit transmission line model for the z^{-1} variable) and a comparison with the theoretical transfer function (second order). (**15%** marks)

6. Submit a report about your design work. The report must include the following. **If you omit any one part, you will lose the % mark for that part.** Do not commit *plagiarism* in producing your work. Such act will result in severe disciplinary actions against the student(s).

For each design:

(a) Design equations (active device and filter system) used for each specific case (**10%** marks).
(b) One set of sample calculations for circuit elements used in the design. (**10%** marks).
(c) Schematic of the final network with *practical* component values shown in a **table** (**15%** marks).
(d) Circuit Simulation results using SPICE or similar program (**15%** marks).
(e) Comparison of the ideal response (numerical simulation) and the designed response, as obtained via circuit simulations (**5%** marks).
(f) Discussion of your results and comments on your accomplishments (**5%** marks).

For the overall report:

(g) Front cover and a table of contents (**5%** marks)
(h) List of references (**5%** marks)

Interpretation of the marks distribution for the project and report

1. Items 1-3 amounts to **15%**
2. Items 6 (g)-(h) amounts to **10%**
3. Items 4 and 5(a)-(c) amounts to **75%** (=30%+15%+15%+15%). Each subdivision of this 75% is distributed as in items 6 (a)-(f). Thus if you score 70% (i.e 42 in 60) in the items of 6 (a)-(f), in relation to task 4, your score in that part will be (42/60) times 30, i.e 21 in 30. The same score in 6(a)-(f) in relation to task 5(a) will give you (42/60) times 15, i.e., 10.5 in 15.

Note: The above amounts to **50%** of the *course marks.* Thus a score of 80 in items (1)-(3) above will turn out to be 40 in the course.

An additional **5%** is reserved for a presentation (using .ppt slides) in the class. The schedule will be notified at a later time.

Academic Code of Conduct (related to the expectation of originality):

Cheating is a serious offence. You must abide by the Academic Code of Conduct as described in the University Calendar. Any suspected violation of the Code will be reported to the Associate Dean for investigation. Penalties can be as severe as dismissal from the University.

The Code forbids *plagiarism*. For example, you may not copy any part of an assignment or report from a student who took the course in a previous year or the present year. The code also forbids you from providing the material to another student. If you allow another student to copy your work you have behaved unethically and have committed an offence.

ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER

(ELEC 6081)

(Winter 2012-'13 term)

Project#2 (Graduate)- not included

A band-reject filter is required to satisfy the specifications:

(a) The stop-band extends from 1kHz to 10kHz.
(b) The peak-peak ripple in the pass-band not to exceed 1.0 dB.
(c) The magnitude characteristic at 2 kHz is to be at least 30 dB down from its peak value at DC.

1. Synthesize the filter transfer function (it will be of order >2). (**5%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**5%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**5%** marks)

4. Provide a design[2] for the above filter, using

   Operational Simulation principle with OTA-C based active filter (**40%** marks)

5. From the work in step 2 above, use one of the second order transfer functions for the following tasks.

(a) Produce a design of the second order filter using OA. Use of nearest practical values of R,C elements (as obtained from the lab bins, i.e., for *R*= 1.231 kΩ, use 1.2 kΩ, and for *C*=0.125 μF. use 0.1 μF, or 0.1 μF plus 20 nF in parallel) is encouraged. Provide SPICE simulation results and a comparison with the theoretical transfer function (second order). The theoretical transfer function can be obtained using numerical simulation (i.e., MATLAB). Use model of a practical OA such as μ741 from the SPICE data base. (**20%** marks)

(b) Produce a design of the second order filter using OTA and capacitors. Use of nearest practical values for the C elements (as obtained from the lab bins, i.e., for *C*=0.125 μF. use 0.1 μF, or 0.1 μF plus 20 nF in parallel) is encouraged. Provide SPICE simulation results and a comparison with the theoretical transfer function (second order). The theoretical transfer function can be obtained using numerical simulation (i.e., MATLAB). Use model of a practical OTA (as used in the lab work) from the SPICE data base. (**15%** marks)

[2] The mark for each component of a design as in items 4, 5(a)-(b), is prorated according to the distribution under item 6(a(-(f).

6. Submit a report about your design work. The report must include the following. **If you omit any one part, you will lose the % mark for that part.** Do not commit *plagiarism* in producing your work. Such act will result in severe disciplinary actions against the student(s).

For each design:

(a) Design equations (active device and filter system) used for each specific case (**10%** marks).
(b) One set of sample calculations for circuit elements used in the design. (**10%** marks).
(c) Schematic of the final network with *practical* component values shown in a **table** (**15%** marks).
(d) Circuit Simulation results using SPICE or similar program (**15%** marks).
(e) Comparison of the ideal response (numerical simulation) and the designed response, as obtained via circuit simulations (**5%** marks).
(f) Discussion of your results and comments on your accomplishments (**5%** marks).

For the overall report:

(g) Front cover and a table of contents (**5%** marks)
(h) List of references (**5%** marks)

Interpretation of the marks distribution for the project and report

1. Items 1-3 amounts to **15%**
2. Items 6 (g)-(h) amounts to **10%**
3. Items 4 and 5(a)-(b) amounts to **75%** (=40%+20%+15%). Each subdivision of this 75% is distributed as in items 6 (a)-(f). Thus if you score 70% (i.e 42 in 60) in the items of 6 (a)-(f), in relation to task 4, your score in that part will be (42/60) times 30, i.e 21 in 30. The same score in 6(a)-(f) in relation to task 5(a) will give you (42/60) times 15, i.e., 10.5 in 15.

Note: The above amounts to **50%** of the *course marks.* Thus a score of 80 in items (1)-(3) above will turn out to be 40 in the course.

An additional **5%** is reserved for a presentation (using .ppt slides) in the class. The schedule will be notified at a later time.

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ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER

(ELEC 441)

(Winter 2012-'13 term)

Project#1 (UG)

An equi-ripple band-pass filter is required to satisfy the specifications:

(a) The pass-band extends from ω=1000 rad/s to 3400 rad/s.
(b) The peak-peak ripple in the pass-band not to exceed 0.5 dB.
(c) The magnitude characteristic is to be at least 30 dB down at ω=10200 rad/s.

1. Synthesize the filter transfer function (it will be of order >2). (**5%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**5%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**5%** marks)

4. Provide a design[3] for the above filter, using

   (a) Cascade of OP-AMP based active filter. (**30%** marks)
   (b) Cascade of OTA-C based active filter. (**30%** marks)

You are encouraged to use realistic model for the OP-AMP in (a) above.

5. From the work in step 2 above, use one of the second order transfer functions for the following task.

(a) Produce a design of the second order filter using OA and switched capacitors. Use a clock frequency of 64 kHz. Use minimum capacitor value of 1 pF. Provide SPICE simulation results(exploit transmission line model for the z^{-1} variable) and a comparison with the theoretical transfer function (second order). The theoretical transfer function can be obtained using numerical simulation (i.e., MATLAB). (**15%** marks)

6. Submit a report about your design work. The report <u>must include</u> the following. **If you omit any one part, you will lose the % mark for that part.** Do not commit *plagiarism* in producing your work. Such act will result in severe disciplinary actions against the student(s).

[3] The mark for each component of a design as in items 4, 5(a), is prorated according to the distribution under item 6(a(-(f).

For each design:

(a) Design equations (active device and filter system) used for each specific case (**10%** marks).
(b) One set of sample calculations for circuit elements used in the design. (**10%** marks).
(c) Schematic of the final network with *practical* component values (as obtained from the lab bins, i.e., for *R*= 1.231 kΩ, use 1.2 kΩ, and for *C*=0.125 µF. use 0.1 µF, or 0.1 µF plus 20 nF in parallel) shown in a **table** (**15%** marks).
(d) Circuit Simulation results using SPICE or similar program (**15%** marks).
(e) Comparison of the ideal response (numerical simulation) and the designed response, as obtained via circuit simulations (**5%** marks).
(f) Discussion of your results and comments on your accomplishments (**5%** marks).

For the overall report:

(g) Front cover and a table of contents (**5%** marks)
(h) List of references (**5%** marks)

Interpretation of the marks distribution for the project and report

1. Items 1-3 amounts to **15%**
2. Items 6 (g)-(h) amounts to **10%**
3. Items 4(a)-(b) and 5(a) amounts to **75%** (=30%+30%+15%). Each subdivision of this 75% is distributed as in items 6 (a)-(f). Thus if you score 70% (i.e 42 in 60) in the items of 6 (a)-(f), in relation to task 4(a), your score in that part will be (42/60) times 30, i.e 21 in 30. The same score in 6(a)-(f) in relation to task 5(a) will give you (42/60) times 15, i.e., 10.5 in 15.

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ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER

(ELEC 441)

(Winter 2012-'13 term)

Project#2 (UG)

A band-reject filter is required to satisfy the specifications:

(a) The stop-band extends from 1kHz to 10kHz.
(b) The peak-peak ripple in the pass-band not to exceed 1.0 dB.
(c) The magnitude characteristic at 2 kHz is to be at least 30 dB down from its peak value at DC.

1. Synthesize the filter transfer function (it will be of order >2). (**5%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**5%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**5%** marks)

4. Provide a design[4] for the above filter, using

(a) Cascade of OP-AMP based active filter. (**30%** marks)
(b) Cascade of OTA-C based active filter. (**30%** marks)

You are encouraged to use realistic model for the OP-AMP in (a) above.

5. From the work in step 2 above, select one of the second order transfer functions for the following task.

(a) Produce a design of the second order filter using OA and switched capacitors. Use bilinear transformation with a clock frequency of 64 kHz. Use minimum capacitor value of 1 pF.
Use the design capacitance values to derive the designed transfer function and compare the designed response with the theoretical response (as obtained after bilinear transformation). The theoretical transfer function can be computed using numerical simulation (i.e., MATLAB). (**15%** marks)

6. Submit a report about your design work. The report must include the following. **If you omit any one part, you will loose the % mark for that part.** Do not commit *plagiarism* in producing your work. Such act will result in severe disciplinary actions against the student(s).

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[4] The mark for each component of a design as in items 4, 5(a), is prorated according to the distribution under item 6(a(-(f).

For each design:

(a) Design equations (active device and filter system) used for each specific case (**10%** marks).
(b) One set of sample calculations for circuit elements used in the design. (**10%** marks).
(c) Schematic of the final network with *practical* component values (as obtained from the lab bins, i.e., for *R*= 1.231 kΩ, use 1.2 kΩ, and for *C*=0.125 μF. use 0.1 μF, or 0.1 μF plus 20 nF in parallel) shown in a **table** (**15%** marks).
(d) Circuit Simulation results using SPICE or similar program (**15%** marks).
(e) Comparison of the ideal response (numerical simulation) and the designed response, as obtained via circuit simulations (**5%** marks).
(f) Discussion of your results and comments on your accomplishments (**5%** marks).

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