**ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER**

**(ELEC 6081)**

**(Winter 2009-'10 term)**

**Project#1 (Grad)**

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

(a) The pass-band extends from ω=1000 rad/s to 4000 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=12000 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 for the above filter, using

   Operational Simulation principle with OP-AMP based active filter. (**30%** marks)

*If you can produce your design using realistic model for the OP-AMP 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 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 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)

(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). 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)

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).

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 assigned to a student according to his/her rating given by his/her peers in the project group.

## ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER

## (ELEC 6081)

## (Winter 2009-'10 term)

## Project#2 (Grad)

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). (**10%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**10%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**10%** marks)

4. Provide a design for the above filter, using

   Operational Simulation principle with OTA-C based active filter (**30%** 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 <u>practical values</u> 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. (**15%** 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)

(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). 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)

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).

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 assigned to a student according to his/her rating given by his/her peers in the project group.

**ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER**

**(ELEC 441)**

**(Winter 2009-'10 term)**

**Project#1 (UG)**

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

(a) The pass-band extends from $\omega$=1000 rad/s to 4000 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 $\omega$=12000 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 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 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).

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.

**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 assigned to a student according to his/her rating given by his/her peers in the project group.

**ANALOG FILTER DESIGN/ INTEGRATED CIRCUITS FILTER**

**(ELEC 441, 6081)**

**(Winter 2009-'10 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). (**10%** marks)
2. Provide a decomposition of the transfer function as cascade of second order and possibly first order transfer functions. (**10%** marks)
3. Verify that the transfer function obtained satisfy the given specification (use numerical simulation, i.e., MATLAB). (**10%** marks)

4. Provide a design 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 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).

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.

**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 assigned to a student according to his/her rating given by his/her peers in the project group.