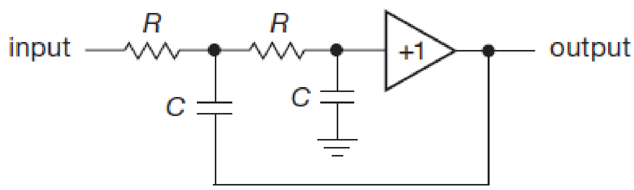
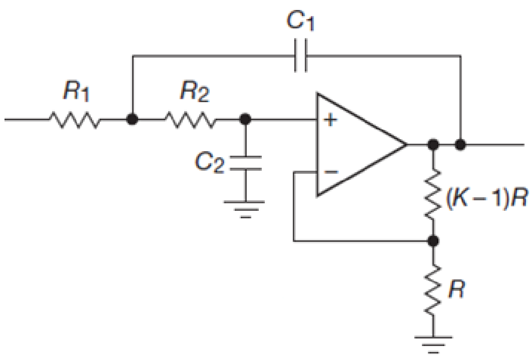
Design of Common Analog Filter Families Using Tables

Targets

1. Learning about analog filter design methods to fit conventional transfer functions such as Bessel, Butterworth, Chebyshev, elliptic function using design tables for Sallen-Key filter configuration. High filter orders of a minimum of 4 should be targeted.
2. Students are divided into groups (3x3) and each group is assigned a different transfer function to implement for the same specifications and they are asked to compare their designs and give their justified opinion on which configuration works best for each set of specifications.
3. Designs should include all basic filter types of low-pass, high-pass, bandpass and bandstop.
4. Biomedical device applications for each type should be emphasized.
5. Design should involve emphasizing the design using realistic common resistor series values. Also, optimization of approximation of calculated filter values to such practical values should be demonstrated.
6. Understanding of the limits of linearity of developed design should be demonstrated.





Requirements: Analog Filter Design

1. Design, conduct and analyze the results of an experiment to implement a 4-pole **low-pass** filter with cutoff frequency of 100 Hz based on the filter response family assigned to you. Observe and report the performance and stability of the designed filter with available component tolerances. Also, compare your results with those of other groups and provide a conclusion on which filter family works best with justification.
2. Design, conduct and analyze the results of an experiment to implement a 4-pole **high-pass** filter with cutoff frequency of 1 Hz based on the filter response family assigned to you. Observe and report the performance and stability of the designed filter with available component tolerances. Also, compare your results with those of other groups and provide a conclusion on which filter family works best with justification.
3. Design, conduct and analyze the results of an experiment to implement a **band-pass** filter of order of at least 4 with cutoff frequencies of 1 and 100 Hz based on the filter response family assigned to you. Observe and report the performance and stability of the designed filter with available component tolerances. Also, compare your results with those of other groups and provide a conclusion on which filter family works best with justification.
4. Design, conduct and analyze the results of an experiment to implement a **band-reject** filter of order of at least 4 with cutoff frequencies of 55 and 65 Hz based on the filter response family

assigned to you. Observe and report the performance and stability of the designed filter with available component tolerances. Also, compare your results with those of other groups and provide a conclusion on which filter family works best with justification.

General Requirements

1. Experimental Design procedure including all requirements of Assessment Rubrics must be ready and approved by Lab Instructor before conducting any experiment.
2. All students must Conduct the experiment and document it according to the requirements of Assessment Rubrics and approved by Lab Instructor after conducting any experiment.
3. All students must Analyze the experiment outcomes and document them according to the requirements of Assessment Rubrics and approved by Lab Instructor after conducting any experiment.
4. You are free to select any components you prefer for your experiments to be verified/approved by the Lab Instructor.
5. You should be prepared to demonstrate your experimental setup and answer questions in all aspects related to your experiment.
6. You should work in groups of 2-3 students each. One report addressing all parts of Assessment Rubrics should be submitted on behalf of the whole group via Blackboard.
7. You may use any resources you find useful to your experiment as long as you acknowledge such use in your report in accordance to ethical guidelines.

References

1. Paul Horowitz, Winfield Hill, *The Art of Electronics*, 3rd ed., Cambridge University Press, pp. pp. 391-424, 2015.
2. Analog Filter Design online lecture, https://www.youtube.com/watch?v=HfnzwU3K2sA&list=PLCBpeohGG5-9eAVTi-ZLlKNfRIa9hbyxW&index=5

Assessment Rubrics

SO (5): An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

	KPI	Exmplary (4)	Satisfactory (3)	Developing (2)	UnSatisfactory (1)	NA (0)
5.1	Effective Team Interactions	Perform all duties of assigned team roles/tasks. Hold Regular team meetings with well written team meeting minutes are used to document team performance. Arrange all documentation in a portfolio that contains all relevant documents with complete information.	Perform most duties of assigned team roles/tasks. Hold regular team meetings with adequately written team meeting minutes are used to document team performance. Arrange most documentation in a portfolio that contains most relevant documents with complete information.	Perform some duties of assigned team roles/tasks. Hold irregular team meetings with adequately written team meeting minutes are used to document team performance. Arrange some documentation in a portfolio that contains few relevant documents with complete information.	Perform no duties of assigned team roles/tasks. few or no team meetings with no written team meeting minutes . No documentation in a portfolio.	
5.2	Use of Project Management Techniques	Define the project (Project objectives, scope, milestones, and deliverables). Plan, prioritize, and schedule tasks for team members. Identify issues/risks and their mitigating actions. Use project management software.	Define most aspects of the project (most objectives, scope, milestones, and deliverables). Plan, prioritize, and schedule most tasks for team members. Identify some issues/risks and their mitigating actions. May not use project management software.	Issues in Defining the project (missing objectives, scope, milestones, and deliverables). May not plan, prioritize, and schedule most tasks for team members. May not identify issues/risks and their mitigating actions. May not use project management software.	Incorrect or lacking Definition of the project (missing and/orincorrect objectives, scope, milestones, and deliverables). Minimum/no effort to plan, prioritize, and schedule task for team members. Minimum/no effort to identify issues/risks and their mitigating actions. No use of project management software.	

SO (6): An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

	KPI	Exmplary (4)	Satisfactory (3)	Developing (2)	UnSatisfactory (1)	NA (0)
6.1	Developing Appropriate Experiment	Objectives are identified and measurable. Covers relevant Background/ Theory with exhaustive references. Work Plans are meticulously developed step by step. Identifies Variables and selects appropriate Tools. Lists and explains all pertinent Safety/Environmental/ Ethical issues comprehensively.	Objectives are identified and measurable. Covers relevant Background/Theory with sufficient references. Work Plans are meticulously developed step by step. Identifies Variables and selects appropriate Tools. Just lists all pertinent Safety/ Environmental/ Ethical issues fairly.	Objectives are identified but contains technical and conceptual error. Work Plans are developed with no distinct steps. Not all Variables/Tools are appropriately selected. List some of the pertinent Safety/Environmental/ Ethical issues.	Objectives are not identified. Work Plans are not developed step by step. Selects inappropriate Tools. Fails to list any pertinent Safety/ Environmental/ Ethical issues.	
6.2	Conducting Appropriate Experi	Experimental Set-up is always neat and accurate. Always records complete data, identifies possible sources of error. Measurements are always accurate with symbols, units and significant digits. Collects data always in a meaningful way. Always demonstrates reproducibility and good knowledge of lab procedures.	Experimental Set-up is mostly neat and accurate. Mostly records complete data, identifies possible sources of error. Measurements are mostly accurate with symbols, units and significant digits. Collects data mostly in a meaningful way. Mostly demonstrates reproducibility and good knowledge of lab procedures.	Experimental Set-up is workable with minor help. Records incomplete data e.g., sampling (number of data points) is just sufficient, understands possible sources of error with minor help. Measurements are less accurate with some errors in symbols, units and significant digits. Collects data that are sometimes difficult to handle and understand. Lacks reproducibility in results and demonstrates some knowledge of lab procedures.	Experimental Set-up is mostly untidy and iNA (0)ccurate. Rarely records and collects data in a meaningful way. Measurements are inaccurate and often without symbols, units and significant digits. Does not demonstrate reproducibility as well as required knowledge of lab procedures.	
6.3	6.3 Analysis and interpretation of Experiment Data and Drawing Conclusions	Comprehensively understand the data in terms of variables (dependent/ independent), assumptions, deviations and experimental uncertainties etc. Organize the data in figures and tables using modern software tools extensively for analysis. Discuss/compare results in the light of obtained results or theoretical models of similar studies from other sources extensively. Conclude rationally based on experimentation and clear reasoning.	Sufficiently understand the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties etc. Organize the data in figures and tables using modern software tools sufficiently for analysis. Discuss/compare results in the light of obtained results or theoretical models of similar studies from other sources sufficiently. Conclude rationally based on experimentation and fair reasoning.	Fairly understand the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties etc. Organize the data in figures and tables using modern software tools fairly for analysis. Discuss/compare results in the light of obtained results or theoretical models of similar studies from other sources fairly. Conclude based on experimentation and acceptable reasoning.	Poorly understand the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties. Fail to Organize the data in figures and tables using modern software tools. Fail to Discuss/compare results in the light of obtained results or theoretical models of similar studies from other sources. Fail to conclude rationally based on experimentation and acceptable reasoning.	

Appendix I:

Resistor E series tables of values

Below are the common resistor values. They are the standard E3, E6, E12, E24, E48 and E96 resistor values.

E3 STANDARD RESISTOR SERIES		
1.0	2.2	4.7

The E3 series resistors are the most widely used and hence these values will be the most common resistor values used within the electronics industry. They are particularly useful for resistor values that are not in any way critical. By keeping to this series, the number of different components in any design can be reduced and this can help reduce manufacturing costs by reducing inventory and the additional management and set up required for additional component types in a design.

E6 STANDARD RESISTOR SERIES		
1.0	1.5	2.2
3.3	4.7	6.8

The E6 series resistor values are also widely used within the industry. They provide a wider range of common resistor values that can be used.

E12 STANDARD RESISTOR SERIES		
1.0	1.2	1.5
1.8	2.2	2.7
3.3	3.9	4.7
5.6	6.8	8.2

E24 STANDARD RESISTOR SERIES		
1.0	1.1	1.2
1.3	1.5	1.6
1.8	2.0	2.2
2.4	2.7	3.0
3.3	3.6	3.9
4.3	4.7	5.1
5.6	6.2	6.8
7.5	8.2	9.1