Digital Filters

Targets

1. Practical experimentation with digital filters.
    a. Sampling of ECG or any other signals from function generator and display on Matlab.
    b. Design of appropriate digital filter using Matlab.
    c. Simulation on Matlab to make sure that the filter works.
    d. Implementation using Arduino on signals sampled as was done in Experiment 2.
    e. Display of input and filtered signals in real-time using Serial Plotter.
2. Understanding of the practical issues involved
    a. Specifications of digital filter design as they related to actual signals and sampling situations.
    b. Differences between FIR and IIR filters.
    c. Transients in filter output.
    d. Group delay for different filters.

Requirements

1. Design, conduct and analyze the results of an experiment to implement a digital filtering system that converts an analog signal into digital version and computes the filtered in real-time such that:
    a. Use of Arduino A/D to perform sampling.
    b. Sampling rate (Samples/s) can be controlled by code.
    c. Quantization (bits/sample) can be controlled by code.
    d. Design and simulate digital filter performance using Matlab.
    e. Use of Arduino to implement the digital filter and display output in real-time.
    f. Compare different types of filters (FIR vs. IIR and their variants).
    g. Use different filter specifications (passband ripple, stopband attenuation, etc.).
    h. Apply to the filtration of a square wave in order to obtain the fundamental frequency as a sinusoidal wave.
    i. Apply to ECG signals and estimate the smallest frequency range that preserve the main characteristics of a normal ECG signal.
2. Observe and report on the following practical issues associated with digital filters:
    a. Group delay.
    b. Transients at the beginning of the signal until steady state is reached.
    c. Numerical errors in output from the limited precision of computation on Arduino.
    d. Variations of the above with different types of filter (e.g., FIR vs. IIR)

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 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.

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 Appropiate 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.	