

Analog Signal Recovery from Digital Samples: ECG Simulator

Targets

1. Practical experimentation with signal sampling theorem
 - a. Reconstruction of analog signal from digital samples using a proper analog reconstruction filter.
 - b. Verification of sampling theorem by experimenting with different sampling rates and observing outcome for different signal types including ECG.
 - c. Study of the effect of sampling quantization.
 - d. Learning importance of using reconstruction filter at the output.
2. Understanding of the practical sampling requirements for good quality recovery of sampled signals.

Required External Tools/Software

1. Laptop with working Matlab installation.
2. Working Arduino IDE (<https://www.arduino.cc/en/Main/Software>).
3. Arduino Mega board (Available in the lab)

Requirements

Design, conduct and analyze the results of an experiment to implement an ECG simulator that allows normal and abnormal ECG signals to be generated and displayed on an oscilloscope. The requirements are as follows:

1. Study the pulse width modulation (PWM) operation on the Arduino and see how it works for different values of the output.
2. Generate a constant analog value from your Arduino board by proper analog filtering of the PWM signal. Report your analog filter values.
3. Generate a sinusoidal wave output from the Arduino. Report how to change the period and amplitude of this signal.
4. Generate the normal and abnormal ECG samples using the following digital samples of real ECG signals:

Normal(300):{40,40,37,38,39,42,42,40,40,37,37,41,40,41,40,39,40,41,41,40,40,38,41,42,43,40,41,42,45,49,48,50,49,50,52,53,54,56,56,56,59,59,58,57,56,55,55,55,55,56,54,53,54,58,60,62,60,55,50,48,48,44,41,39,40,40,40,39,39,37,38,39,38,37,35,35,36,39,39,39,37,36,39,41,40,40,38,35,36,37,36,32,26,19,16,15,12,5,0,8,28,52,79,109,150,197,235,255,252,217,151,78,30,15,18,26,29,32,32,35,35,34,30,31,29,32,32,32,30,29,32,34,35,33,31,29,31,32,32,30,29,30,31,35,33,31,29,29,31,33,35,32,31,31,31,32,33,32,32,32,33,35,34,31,32,31,34,35,31,32,32,33,33,34,33,35,33,31,34,36,34,35,35,34,35,38,36,35,34,32,33,36,34,34,33,31,31,32,31,29,29,28,29,29,30,31,29,27,30,33,31,32,32,34,35,39,40,41,40,41,44,47,47,45,48,48,50,51,52,51,50,50,53,53,52,50,50,50,51,53,53,51,48,50,54,52,52,50,50,50,50,51,50,50,49,48,50,50,49,47,45,48,48,47,46,46,44,49,48,49,48,45,45,46,46,48,47,45,45,46,47,45,45,44,44,45,46,45,45,44,42,44,46,45,45,43,44,44,45};

Abnormal(600):{97,96,96,96,96,96,95,95,96,101,104,105,104,104,104,106,110,115,118,119,116,116,117,118,118,116,113,109,107,105,104,102,101,100,99,99,96,96,96,96,96,96,97,98,97,94,93,89,86,86,94,110,137,174,208,233,248,254,255,247,225,186,140,95,65,71,83,89,87,86,89,91,92,91,89,89,90,90,89,88,88,86,87,89,91,91,91,91,90,90,91,89,86,85,87,89,90,90,90,90,91,92,91,90,90,92,94,95,94,96,98,99,96,94,94,97,100,102,104,105,106,106,104,102,102,107,112,114,114,116,119,120,123,124,127,130,133,136,136,138,140,143,145,147,148,149,150,151,153,155,153,152,153,154,155,153,148,143,143,144,143,141,138,135,134,134,133,130,127,124,124,123,122,120,118,115,113,114,113,114,113,109,108,108,109,108,106,104,103,103,102,102,101,100,101,100,101,101,101,99,100,102,102,102,101,101,101,102,103,103,103,101,101,103,105,105,105,106,109,113,118,121,122,122,124,129,135,144,155,166,179,187,190,184,177,164,149,128,96,58,24,5,0,5,15,24,28,27,26,26,25,26,27,30,32,35,40,44,46,49,53,60,68,72,73,75,78,82,85,84,83,83,85,88,93,95,95,93,92,91,91,92,93,93,94,95,98

,98,97,96,95,98,99,100,100,99,99,101,104,105,104,103,103,106,109,111,112,113,115,120,122,125,127,128,133,137,142,144,145,147,150,153,156,160,160,160,161,163,165,164,164,163,163,164,164,163,162,159,157,155,154,153,150,146,144,142,142,139,135,132,131,130,128,126,124,121,120,120,118,115,111,109,109,109,110,110,108,107,108,109,107,105,103,102,105,107,108,108,109,109,113,116,121,124,128,134,140,145,152,158,163,169,177,185,195,201,206,209,209,209,210,210,204,195,187,179,174,172,171,170,167,163,152,138,122,108,96,90,86,81,76,73,71,71,69,68,66,65,61,60,58,56,54,51,51,51,52,52,51,50,49,50,50,51,51,51,51,51,51,51,51,51,50,51,53,54,54,53,51,50,50,49,47,47,46,44,44,44,43,41,41,41,42,42,41,40,41,41,44,44,43,39,37,38,41,45,47,46,46,48,51,54,57,57,58,60,64,68,69,71,72,75,77,80,81,82,84,85,86,88,90,91,91,91,92,93,94,94,94,94,96,98,97,94,93,94,97,97,95,93,92,93,92,94,94,93,92,92,93,93,94,93,91,92,93,94,93,91,90,90,91,93,92,91,90,91,93,93,92,92,92,93,93,92,90,90,90,90,91,92,92,92,90,91,92,93,93,92,91,90,90,91,90,91,90,90,90,89,89,90,89,89,90,91,90,88,89,89,89};

5. Report how the pulse rate and amplitude of the ECG signals can be controlled.
6. Since the ECG samples are noisy, show how to make noise less visible in your ECG simulator.

General Requirements

1. Experimental Design procedure including all requirements of Assessment Rubrics must be ready and approved by Lab Engineer 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 Engineer after conducting any experiment.
3. You are free to select any components you prefer for your experiments to be verified/approved by the Lab Engineer.
4. You should be prepared to demonstrate your experimental setup and answer questions in all aspects related to your experiment.
5. 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.
6. 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/or incorrect 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 Experimentation	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 inaccurate. 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	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.	

Assessment Rubrics

	Exemplary	Satisfactory	Developing	Unsatisfactory
KPI's	3	2	1	0
Designs a reliable and relevant 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 .	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/	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/	Objectives are not identified. Work Plans are not developed step by step. Selects inappropriate Tools . Fails to list any pertinent Safety/ Environmental/ Ethical issues .
Conducts the experiment	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	Experimental Set-up is mostly untidy and inaccurate. 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.
Analyzes and interprets data	Comprehensively understands the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties etc. Organizes the data in figures and tables using modern software tools extensively for analysis. Discusses/compares his/her results in the light of obtained results/theoretical models of similar studies from other sources extensively. Concludes rationally based on experimentation and clear reasoning.	Sufficiently understands the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties etc. Organizes the data in figures and tables using modern software tools sufficiently for analysis. Discusses/compares his/her results in the light of obtained results/theoretical models of similar studies from other sources sufficiently. Concludes rationally based on experimentation and fair reasoning.	Fairly understands the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties etc. Organizes the data in figures and tables using modern software tools fairly for analysis. Discusses/compares his/her results in the light of obtained results/ theoretical models of similar studies from other sources fairly. Concludes based on his/her experimentation and acceptable reasoning.	Poorly understands the data in terms of variables (dependent/independent), assumptions, deviations and experimental uncertainties. Fails to Organize the data in figures and tables using modern software tools. Fails to Discuss/compare his/her results in the light of obtained results/theoretical models of similar studies from other sources. Fails to conclude rationally based on experimentation and acceptable reasoning.