UNIVERSITY OF GOTHENBURG

DEPARTMENT OF PHYSICS

NFFY310 Electrical Measurement Techniques in the Physics Laboratory, 10 credits

Elektriska mätmetoder för fysiklaboratoriet, 10 högskolepoäng

Third-cycle level / Forskarnivå

Confirmation

This syllabus was confirmed by the Department of Physics on 2022-06-13, and is valid from Autumn semester 2022.

Responsible Department
Department of Physics, Faculty of Science

Entry requirements

Accepted to a PhD program in Science.

Learning outcomes

The overall objective is to provide the student with necessary theoretical understanding and practical know-how of the most common electrical measurement techniques/instruments used in a typcial physics laboratory.

Knowledge and understanding

Account for the most common sensor technologies (temperature and the strain gauge-Wheatstone bridge principle).

Define the bandwidth and rise time for a signal/system.

Explain how systems' bandwidth influence the propagation of a signal's rise time.

Explain what the 'characteristic impedance' is in a transmission cable and why signal reflections occur.

Explain time domain reflectometry.

Account for the most common ADC techniques (Analog-to-Digital Conversion).

Account for the most common TDC techniques (Time-to-Digital Conversion).

Define the concept of SNR (Signal-to-Noise Ratio).

Define the concept of CMRR (Common Mode Rejection Ratio).

Explain how differential amplifier work in general and instrument amplifiers in particular.

Account for the most common filter models (Butterworth).

Explain how poles and zeros are linked to the Bode plot.

Explain how averaging can be used to improve SNR.

Account for basic digital filter theory.

Explain the sampling theorem.

Account for the discrete Fourier transform and understand the concepts of aliasing, spectral leakage and windowing.

Perform auto and cross correlation calculations.

Explain how lock-in amplifiers work.

Explain the heterodyne principle in analog spectrum analyzers.

Understand how external interferences couple to a measurement system.

Understand how external interferences can be de-coupled.

Perform point and intervall estimations.

Account for the orthogonality principle and apply it to curve fitting.

Define 'standard uncertainty'.

Account for the student-t distribution, coverage factor and confidence intervals.

Expain what 'type A' and 'type B' uncertainties are.

Account for the 'GUM' standard in uncertatinty calculations.

Account for basic control theory (PID controllers).

Competence and skills

Correctly terminate, split and splice a transmission cable.

Handle the most common digital measurement instruments that are used in a physics laboratory.

Apply an instrument amplifier (in an ECG and/or a Wheatstone bridge application).

Design first and second order Butterworth filters.

Use a lock-in amplifier.

Use both digital and analog spectrum analyzers.

Identify and remedy electrical interferences in electrical measurement systems.

Solve overdeterminded equation systems.

Perform curve fitting on arbitrary polynomials.

Set up an 'uncertainty budget' and derive the 'measurement uncertainty'.

Configure a commercial PID controller (for temperature control).

Judgement and approach

Decide when termination of transmission cables is necessary.

Chose the right instrument/equimpment for a specific measurement task.

Estimate (ant prevent) the risk of external noise coupling in different environments.

Course content

This course provides a theoretical understanding of how the most common measurement techniques and measurement instruments in a physics laboratory works; digital oscilloscopes, spectral analyzers, lock-in amplifiers, filters and correlation, PID controllers. The most common sensor techniques are also covered, like temperature sensors and the strain gauge principle. Coupling and de-coupling of interferences, transmission cables (reflections and terminations), data acquisition and measurement samples as stochastic variables. It will also provide ample lab opportunities to give the participants hands-on experience with the instruments.

Sub-courses

1. **Electrial measurement theory** *(Elektrisk mätteknik, teori),* 5 credits
   The theoretical part; transform theory, filter theory, correlation and convolution, overdetermined equation systems, the orthogonality principle and curve fitting, digital signal processing, stochastic variables, probability distributions and uncertatinty caclulations.

2. **Elektrical measurement instruments and methods** *(Elektriska mätinstrumet och mätmetoder),* 5 credits
   The hands-on part; using digital oscilloscopes, digital waveform generators, transmission cables, spectrum analyzers, instrument and lock-in amplifiers and PID controllers.

Types of instruction

Lectures and laborations. Hand-in problems may also occur.

Language of instruction
The course is given in English.

Grades

The grade Pass (G) or Fail (U) is given in this course.

To pass the course, a G (=Pass) is required in both the theoretical and the practial part.

Types of assessment

The theoretical part is assessed by a written exam. The pracital part is assessed by completion of lab execises (mandatory attendance).

Course evaluation

The course will be evaluated by an anonymous (online) survey at the end of the course. The results of the survey will be published on the course web page. It will also be made avialable to the students at the beginning of the next course occassion together with an account of measures that have been taken due to the outcome of the previous evaluation.