SIGNAL RECOVERY

Prof. Sergio Cova

Objectives

The course is intended not just to lead students to know and properly describe the electronic techniques and instrumentation developed for recovering sensor signals from noise, but rather to gain a good insight in the problems faced and in the approaches developed for overcoming them. This implies to critically evaluate the solutions, avoiding the attitude where sensors and electronics are designed and employed just according to the established rules and standards. It is instead necessary to clarify the reasons of the choices and decisions in the light of the physics of phenomena involved, of the basic principles of signal and noise processing and of the actual performance of the available devices. It is necessary to clearly distinguish the intrinsic limitations set by physical laws from the current limitations set by the state of the art, which can be overcome by the technological progress. In essence, to gain insight means to progress at the pace of the technology evolution and be able to contribute to it.

Course Program

Signals and noise. Introduction to measurements, errors and statistical distributions. Mathematical treatment of signals and noise in the time and in the frequency domain. Signal-to-Noise ratio (S/N). Autocorrelation functions, energy and power spectra. Noise sources in electronic circuits and sensors. Main types of noise spectra. Noise interpretation and modeling with statistical pulse sequences.

Extracting signals from noise. Linear filters with constant parameters and with time-variant parameters, action on signals and noise and resultant S/N. Pulse-signals and constant-parameter low-pass filters; Gated Integrator (GI); Boxcar Integrator (BI); Sample-and-Hold (S&H) and fast samplers; discrete filtering by sampling and weighted average of samples. Optimum filtering for pulse-amplitude measurements, significance and practical usefulness. Noise with 1/f spectrum: characteristic features and ensuing problems, filtering approach. Constant-parameter high-pass filters; correlated double sampling (CDS) and further developments; Baseline Restorer (BLR). Periodic signals and constant-parameter resonant filters; modulation of signals and noise; Lock-in Amplifier (LIA), analog and digital implementations of LIAs.

Sensors are treated by discussing the physical principles of their operation; the device structure and technology; characteristic features and electrical parameters; output signals and information content; equivalent electric circuit; internal noise. **Photodetectors**: vacuum tube and semiconductor photodiodes; photoconductors; Photomultiplier tubes (PMT), avalanche photodiodes (APD) and single-photon avalanche diodes (SPAD); analog and digital detection, single-photon counting (SPC) and time-correlated single-photon counting (TCSPC). **Temperature Sensors**: thermocouples and thermo resistances; semiconductor junction sensors. **Strain and Force Sensors**: strain gauges and piezoelectric sensors. **Displacement sensors and miscellaneous sensors.**

Practical implementation of electronic measurement set-ups. Ground loops and interferences in real set-ups; techniques and means for reducing their effect. Front-end electronics for sensors. Analog-to-digital converters (ADC) for high-resolution measurements: integral and differential non-linearity, quantization cell profile.

Required knowledge

Firm know-how in the foundations of electronic circuits and semiconductor devices. Foundations of signals and transmission. Basic knowledge of probability and statistics. General background in mathematics and physics.

Examination procedure

The examination is ordinarily carried out with a written test. In some cases, by decision of the teacher it may be complemented with an individual oral test.

The results of the written test are published online on the official website of Politecnico di Milano and can be reached also from Poliself. Either a quantitative mark is published or the student is called to a complementary oral test. A student that has received a mark can also ask for a complementary oral test and the teacher will decide whether to accept the request or not. Anyway all students, included those with insufficient mark, are entitled to review their written test with the teacher for getting explanations and clarifications. At the end of the official publication term, the published marks become final and are recorded, unless refused by the student.

Bibliography

texts, figures and documentation that cover all the course program

in the teacher website http://home.deib.polimi.it/cova/

Notes:

- Complete set of slides employed in the lectures
- Text and explanation of problems given in the written tests carried out in previous years
- Papers, presentations, technical documentation, suggested references and websites dealing with signal recovery, sensors and measurement instrumentation

Complementary Bibliography

Sergio Cova, Notes and Bibliography for the course “Signal recovery”
Printer: Libreria Cortina, 2014.

T.H. Wilmshurst, Signal recovery from noise in electronic instrumentation, 2nd edition,
Printer: A. Hilger - IOP Publishing Ltd, edition year: 1990, ISBN: 0-7503-0058-2

Silvano Donati, Photodetectors: Devices, Circuits and Applications,
Printer: Prentice Hall, edition year: 2000, ISBN: 0130203378
(previous edition in italian:
Silvano Donati, Fotorivelatori, 2a ed, Editore: Edizioni AEI, Anno edizione: 1999)