

Education in Measurement and Instrumentation in Continental Europe after Implementation of Bologna Declaration

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Abstract - Changes in study programs at European universities based on Bologna declaration concern also the education in measurement and instrumentation (M&I). The bachelor and master stages are at the most of universities strictly separated in the new study plans, whilst only at some ones a so-called “integrated master program” arose. Study programs at a number of universities in continental Europe, where electrical engineering is taught, have been compared from the view of education in M&I. Whilst at the most of them the education in M&I is concerned to the bachelor study stage and one or two basic courses are offered, at several universities exist some additional specialized courses. Concerning master study stage, only some of the scanned universities offer separate specialization in M&I, the other universities offer some additional specialized courses only.

I. Introduction

Study programs of 14 universities in continental Europe, which have their study program published on web pages in English or German language, have been scanned until now:

- Instituto Superior Técnico Lisboa (IST Lisbon) [1]
- Technische Universität Darmstadt (TU Darmstadt) [2]
- Technische Universität München (TU Munich) [3]
- Technische Universität Dortmund (TU Dortmund) [4]
- Technische Universität Braunschweig (TU Braunschweig) [5]
- Technische Universität Wien (TU Vienna) [6]
- Université catholique de Louvain (CU Luovain) [7]
- Vrije Universiteit Brussel (VU Brussel) [8]
- Slovak University of Technology in Bratislava (STU Bratislava) [9]
- Technical University of Košice (TU Kosice) [10]
- Politechnika Warszawska (PT Warsaw) [11]
- Czech Technical University in Prague (CTU Prague) [12], [13].
- Aalto University School of Science and Technology (AUSST Helsinki) [14]
- Technical University of Denmark (TU Lyngby) [15]

All of the universities mentioned above offer a basic course in M&I at bachelor level ensuring sufficient knowledge for further study in electrical engineering (both in bachelor and master study stage). This course is usually eked out with courses pointed to the study branch. However, a deeper knowledge in the specialization of M&I can be gained only in several of the universities mentioned above.

II. Bachelor study stage

The different coverage of teaching in M&I was registered already in bachelor study stage (or in the 1st step of integrated master program). Whilst at the CU Luovain, VU Brussel [16] and TU Dortmund only one course was found (CU Luovain: *Measurements and Electrical Circuits*, VU Brussel: *Measurement in Engineering*, TU Dortmund *Measurement and EMC*), other universities offered greater amount of courses in this area.

The basic course in M&I in electrical engineering (including labs), which is usually obligatory, contains in a number of cases also the basic information concerning measurement of non electrical quantities (IST Lisbon, CTU Prague¹, TU Bratislava, TU Kosice, TU Munich, TU Braunschweig, PT Warsaw), elsewhere this information is offered in optional courses (TU Vienna: *Measurement Technology - Enlargement*, TU – Darmstadt: *Measurement and Sensors Technology*). Other courses (usually optional or special) are offered only in several cases - *Digital Photography and Videometry* and *Optomechatronic Measuring Systems* at TU Munich; *DAQ systems* and *Measurement Methodology* at TU Bratislava; *Electronic Measurements Systems* and *Smart Measurements Systems* at TU Kosice, *Microprocessors and Microcontrollers in Instrumentation and Instrumentation for Data Acquisition and Process Control* at CTU Prague; *Electronic Circuits in Instrumentation* at TU Braunschweig and *Telemetry, Measuring converters, Measurement of Non-electrical Quantities* at PT Warsaw.

The basic course of M&I is usually taught in the 3rd, 4th or 5th semester, the other courses concerning M&I (if there are any) continue in next semesters. Contents of the basic courses are usually similar to each other. Their topics are:

- Measurement accuracy, uncertainty of measurement, error of the method and its correction.
- Analog measuring instruments (not in all cases).
- Measuring converters of electrical quantities – measuring amplifiers, RMS converters, multipliers etc.
- Principle of sampling and quantization, AD and DA converters.
- Measurement of frequency, phase shift, current, voltage, electric power and energy consumption and principle of used instruments.
- DC resistance measurement and impedances and admittances (R-L, C-G) measurement and principles of used instruments.
- Magnetic measurements (not in all cases)
- Oscilloscopes, generators of measuring signals (not in all cases).
- Automatic measurement system - basic concepts (not in all cases)
- Electrical measurement of non-electrical quantities – selected transducers (not in all cases).

A separate specialization in M&I is offered e.g. at CTU Prague [12] (Sensors and Instrumentation) or at STU Bratislava (Industrial Informatics) – see Appendix.

III. Master study stage

Extent of education in M&I on master level is very different at the scanned universities – from no special courses (CU Luovain) to a separate specialization at TU Braunschweig, PT Warsaw, CTU Prague or STU Bratislava. A number of universities offer either some common courses concerning M&I for several specialization (e.g. TU Lyngby the common course *Electronic Measurements and Instrumentation*; IST Lisbon for specializations “Computers”, “Electronics” and “Systems, decision and control” two courses *Computers and Sensors Interfaces* and *Sensors and Actuators*; VU Brussels for some specialisation in Electromechanical engineering also two courses *Measurement and identification* and *Optical Measurement Techniques*) or some special courses for other specializations (e.g. *High Voltage Measurement and Testing*, *Environmental Measurement*, or *Opto-Mechatronic Measuring Systems* at TU Munich, *Antenna Measurements in Radio Anechoic Chambers*, *Wind Turbine Measurement Technique* at TU Lyngby). A wide offer of courses can be found also at AUSST Helsinki (see Appendix).

The courses of M&I in Biomedical engineering can be also found in a number of cases (*Sensors and Microsystem Technology for BME* at TU Vienna, *Biomedical Instrumentation - Theory and Function*, *Labs in Biomedical Measurement* at TU Munich, *Electrical Measurement of Biomedical Quantities* at TU Braunschweig, *Physiological measurements and instrumentation* at TU Lyngby, *Biomedical sensors* at CTU Prague, etc.).

In the case of separate specialization in M&I, the courses offer a complete overview in the area of M&I, and they are usually guaranteed by a competent institute or department. The TU Braunschweig can be selected as an example. There are 5 branches in Electrical Engineering, one of them is Mechatronics and Measurement technology (Mechatronik und Messtechnik). It is divided into 3 specializations, Mechatronics, Biomedical Engineering, and Measurement technology (see Table 1).

Education in specialization M&I is guaranteed by Institute of Electrical Measurement and Fundamental Electrical Engineering there. Structure of courses concerning M&I is following:

¹ New study plans started in 2008/09 – see [12], [13], so that some details published in [17] are out of date.

Lectures:

- *DSP in Instrumentation*
- *Transducers and measurement of Non-electrical Quantities*
- *Precision Measurements*
- *Electronic Circuits in Instrumentation* (as far as it was not studied during bachelor stage)
- *Quality Assurance*

Labs:

- *Electronic Circuits*
- *Sensors and Transducers*

The similar structure can be found also at PT Warsaw, CTU Prague [12] or STU Bratislava (the overview of courses are presented in Appendix).

Table. 1. Branches and specializations in Electrical Engineering at TU Braunschweig (an original see in [5]).

Branch	Power Engineering	Nano-Systems-Engineering	Mechatronics & Measurement technology	Communication Technology	Computers & Electronics
Specializations	<ul style="list-style-type: none"> • Energy Systems • Energy Transmission • Energy production 	<ul style="list-style-type: none"> • Nano-Systems • Nano-Optics • Nano-Electronics 	<ul style="list-style-type: none"> • Mechatronics • Biomedical Engineering, • Measurement technology 	<ul style="list-style-type: none"> • Wireless Communication • Communication Networks • Microwave Technology • Optical Systems and Networks • Audio-Visual Communication 	<ul style="list-style-type: none"> • Advanced VLSI-Design • Computer Design

IV. Conclusion

New study programs corresponding to Bologna declaration have been prepared and established at nearly all the universities of technology in continental Europe during several previous years. These new programs contain also education in M&I, however in a number of cases only as a part of other specializations in the master study stage. Solely four among the scanned universities offer a specialization in the area of M&I, even though the demands on the measurement and its accuracy rapidly increase in a number of fields of our life. It concerns not only industrial production, but also medicine, environment, etc.

An interesting approach is applied at AUSST Helsinki. There is a broad offer of courses concerning M&I (see Appendix), in spite no M&I specialization can be found there. There are courses designated either for bachelor, or master, or PhD study stage, of course, but also several courses offered for all these stages can be found there.

Appendix

A. Courses of the M&I area offered at STU Bratislava

Bachelor study stage

Branch	Applied informatics	Electronics in car	Industrial informatics	Electronics, Electrotechnics	Tele-communication
Courses	<ul style="list-style-type: none"> • Measurement in informatics 	<ul style="list-style-type: none"> • Measurement technology • Sensor system for cars • Diagnostics and testing in cars 	<ul style="list-style-type: none"> • Measuring systems • Measurement methodology • Statistics and statistical models of measurement • Industrial diagnostics 	<ul style="list-style-type: none"> • Measurement technology 	<ul style="list-style-type: none"> • Measurement

Master study stage:

Branch	Applied informatics	Cybernetics	Meas. & Information Technology	Robotics	Tele-communication
Courses	<ul style="list-style-type: none"> • Diagnostics and reliability 	<ul style="list-style-type: none"> • Diagnostic systems 	<ul style="list-style-type: none"> • Distributed measuring systems • Electromagnetic compatibility • Smart sensor systems • Metrology, testing and quality assurance • Telemetry and data transfer • Theory of measuring systems 	<ul style="list-style-type: none"> • Distributed measuring systems • Electromagnetic compatibility 	<ul style="list-style-type: none"> • Electro-magnetic compatibility

B. Courses of the M&I area offered at AUSST Helsinki:

- Fundamentals of Measurements
- Electronic Measurements
- Sensors and Measurement Schemes
- Radio-Frequency Measurements
- Measurements in Power Plants
- Measurements in HVAC
- Measurement Methods and Instrumentation in Ecology
- Project Work in Measurement Science and Technology
- Postgraduate Course in Measurements (Doctoral level only)
- Research Seminar on Measurement Science and Technology (Doctoral level only)
- Special Course in Measurements (P)
- Biological Effects and Measurements of Electromagnetic Fields and Optical Radiation (P)
- Special Measurements in Electronics (P)

(P) Course can be taken in Bachelor, Master or Doctoral level studies.

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