2006-2105: DEVELOPMENT OF AN INTER-UNIVERSITY ADVANCED INSTRUMENTATION COURSE FOR GRADUATE STUDENTS IN ENGINEERING TECHNOLOGY

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Advanced Instrumentation for Graduate Students in Engineering Technology

Abstract

Instrumentation is one of the most important courses of engineering curriculum. Almost all programs in engineering technology at undergraduate level offer labs and instrumentation. Also, most of the textbooks on instrumentation are written for undergraduate programs. On the other hand emerging technologies require the use of advanced precise instruments. Thus, it becomes the responsibility of academic community to meet the demand of new technologies by developing and offering proper advanced instrumentation courses at graduate level. This article explains the content of a new advanced instrumentation course offered to graduate students in the Department of Engineering Technology at the University of Memphis (UM). It is also under consideration at Northern Kentucky University (NKU). The development of the course materials, the required instruments and the method of delivery, will be the main topics of this article.

Introduction

The Department of Engineering Technology at the University of Memphis offers an M.S. degree in engineering technology with concentrations in electronics, computer and manufacturing. This is in addition to its undergraduate degrees in electronics, computer and manufacturing technology. Students select their field of concentration according to their future professional goals.

In the Masters program, each concentration offers its own graduate courses outlined in the Graduate Bulletin of the university [1]. In contrast to undergraduate programs that are highly focused on their particular concentration, this graduate program is less focused and more diverse. Moreover, some of the graduate courses are offered at night making it possible for the members of the professional community to enroll in this program. In fact, the majority of the graduate students enrolled in this program are from industry. The structure of the program is such that any individual with an undergraduate degree in technology can enter the program and select a concentration that matches his/her career goals.

The core courses required for the electronic concentration are shown in Fig.1.

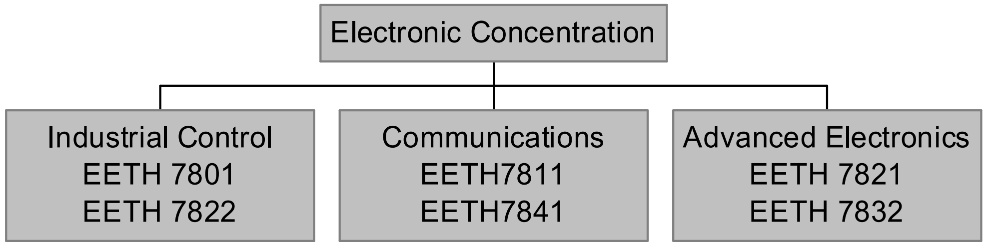

Fig.1 - Core Courses for Concentration in Electronic

They consist of industrial control, communications and advanced electronics. One of several courses offered in the past is Advanced Instrumentation. It has been offered twice at UM, once in fall of 2004 and once in fall of 2005. Being successfully implemented at UM, it is under review to be offered at NKU. The contents of this course will be discussed here.

Organization

The course is divided into five parts each of which is divided further into several chapters covering a variety of instruments. Experimentation with some of these instruments is included in the discussions. The main topics of the course are presented in Fig.2. The description of various parts of the course will follow:

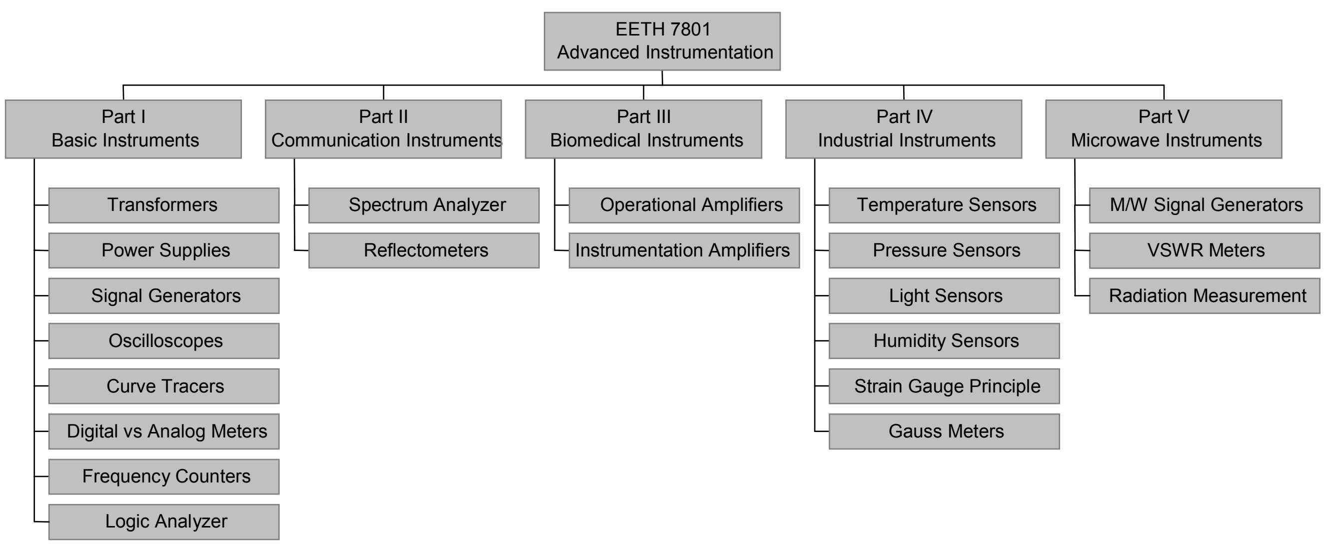

Fig. 2 - Organization Chart for Advanced Instrumentation Course

Part 1- Basic Instruments

Most basic instruments are introduced and discussed in this part. Two lectures are dedicated to the discussion of instruments with single or multi-winding transformers and single or three-phase electric systems. This part is more geared towards the students majoring in electronics, computer, or manufacturing. Topics emphasized in this part are: power transfer under impedance matching condition and calculation of three- phase complex power using 2-wattmeter method. The latter method excludes evaluation of short and open circuit parameters.

Topics that follow are: a brief discussion of power supplies such as discrete, integrated, and switching power supplies with the effects of filtering, load and source regulation. The first lab involves the use of a function generator, starting with discussions on methods of generating different waveforms and continues with the measurement of the frequency response of the function generator. This data obtained from the function generator is then plotted and analyzed for determination of bandwidth. Block diagram of the wave function generator is provided for troubleshooting the circuits by the students.

Oscilloscopes are discussed next with an introduction to their cathode ray tubes, CRT followed by the description of their front panel knobs. This is deemed necessary since most oscilloscopes still use a CRT rather than an LCD display. Due to the significance of oscilloscope and its essential role in all phases of experiments conducted in this course, a complete set of experiments are designed as described below:

___Amplitude/time/frequency
___Frequency sweep
___Amplitude modulation principle
___Operation in X-Y mode:
    I-V characteristic of a diode
    Frequency response of a resonance filter

In addition to experimenting with amplitude and frequency, students also measure the rise time by applying a square wave to the scope and comparing it with the catalog specifications. Amplitude modulation and determination of Index of Modulation is carried out using two function generators. The first function generator is used as a modulator operated at 1 kHz. The signal from this function generator is used to modulate a carrier set from a second function generator operated at 100 kHz. The index of modulation, *m*, is calculated as:

$$m = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min c}} \qquad (1)$$

The index is also given by;

$$m = \frac{\Delta V_c}{V_c} \qquad (2)$$

V_c designates the carrier voltage and Δ stands for its change. Using equation 1 and 2 students are able to evaluate the other component of A.M. signal: carrier amplitude, Vc.

Operation in X-Y mode constitutes two experiments. In the first experiment, the I-V characteristics of silicon and germanium diodes are measured. These measurements enable students to calculate the cut-in and saturation voltages of silicon and germanium diodes. The second experiment involves the use of the oscilloscope in sweep mode. Students apply a sweep signal to channel 1, and to the input of a series resonance filter. The Y input is taken from the resistor of the resonance filter. The oscilloscope remains in X-Y mode and provides data needed for the determination of the frequency response of a series resonance circuit, and measures 3db points. From these frequencies, Q of the resonance filter can be calculated as:

$$Q = \frac{F_r}{F_1 - F_2} \quad (3)$$

Where F_r is the resonance frequency, and F_1 and F2 are the 3db points respectively. The setup is shown in Fig. 3.

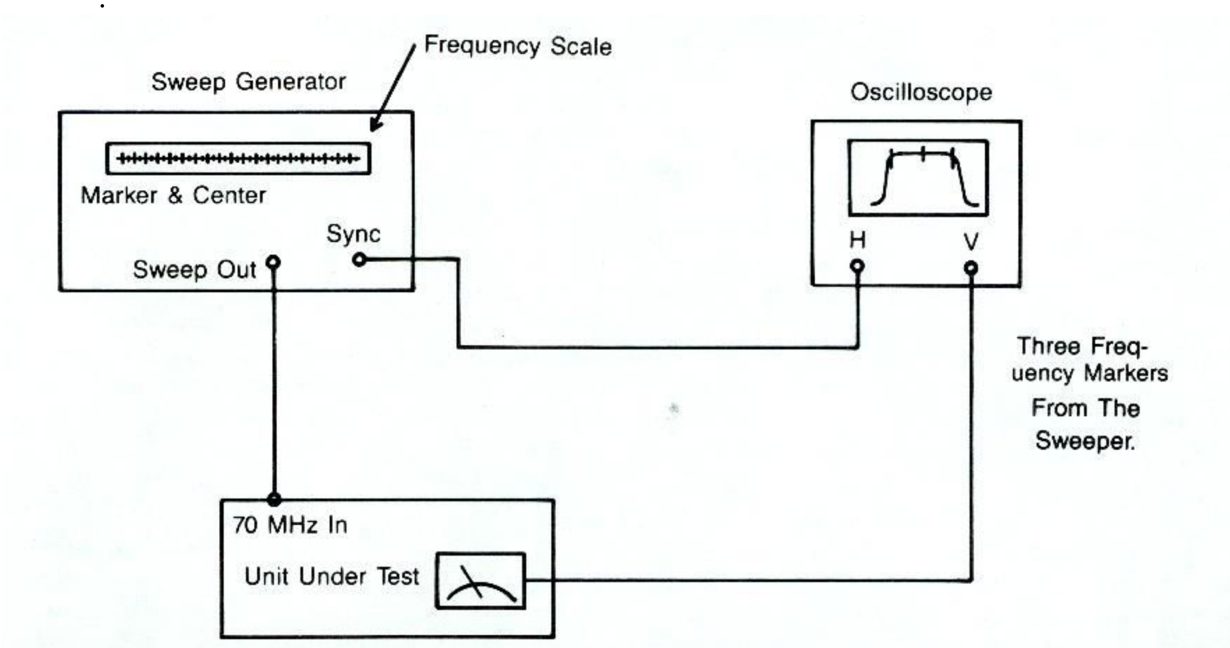

Fig.3 - Setup for Observing and Measuring Frequency Response and the Bandwidth

The instrument discussed next is the curve tracer. With the advent of new IC-based instruments, the use of curve tracer is limited; however, some of its important circuit's functions are very useful and are discussed. These include stair case generation and sweeping collector current. A case study is also provided for this lab [2].

Discussions in the digital Vs analog section include comparison and contrast between the precision, resolution, accuracy of the measurements by analog and digital meters in terms of their average and their RMS values. A case study on the fabrication of a multimeter is also discussed in this lab [3]. The last two instruments in part one are digital frequency counters and logic. Students are encouraged to design a 4 or 8 to single channel probe, as the basic accessory of a logic analyzer. This part includes two lectures and three associated labs.

Part 2-Communication Instruments

In this part, two instruments are discussed: spectrum analyzers and reflectometers. Spectrum analyzers are widely used in communication engineering to determine the bandwidth and contents of the information signals. Each student is asked to use Spice program to carry out simulations of Fourier Series and the corresponding harmonics. The results of the simulations are then compared with the measurements made using the spectrum analyzer in terms of frequency domain parameters. A circuit is drawn by the students for the resulting series and Spice program is used to simulate and evaluate the time and frequency domain parameters. For a frequency of 1 kHz for the fundamental harmonic at 1 volt peak, Fourier analysis confirmed that the waveform actually does contain the fundamental and all even harmonics. Further, the same circuit is used with the Computer Aided Spectrum Analyzer.

For the second instrument in Part 2, the principles of operation of a Time Domain Reflectometer (TDR) are discussed. A block diagram shown in figure 4 was first illustrated, then the theory of determining the nature of fault and its location were discussed using following equation:

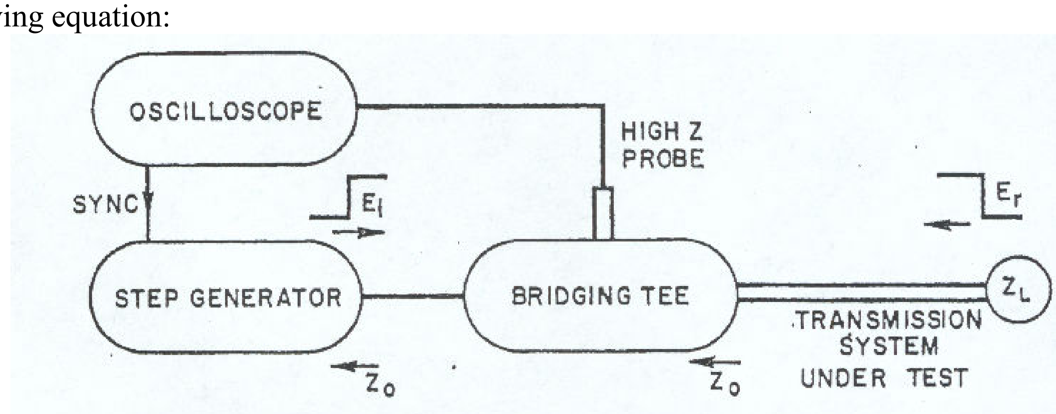

Fig. 4- A Simple Block Diagram Showing the Principle of TDR

$$\Gamma = \frac{z_1 - z_c}{z_1 + z_c} \tag{4}$$

Γ is the reflection coefficient and z is the impedance of load and the characteristic impedance of the transmission line under test. Γ, as seen from above equation is complex in general, however, only the absolute value of this parameter is measured by TDR. Short pulses are generated by TDR for which the departure and arrival times will indicate the location of the fault according to the following equation:

$$t_2 - t_1 = \frac{x}{v} \tag{5}$$

Here, *v* is the velocity of the pulse in the cable. This velocity is determined by TDR if the velocity factor of the cable in to the instrument is known. In turn, the velocity factor (*v.f)* is determined by the following equation:

$$v.f = \frac{c}{\sqrt{\varepsilon_r}} \tag{6}$$

where c is the speed of the pulse in free space, and ε_r is the relative dielectric constant of the cable under test. Two extreme cases are discussed. For the case of an open circuit, after removing indeterminacy, the value of Γ, is found to be 1 (Equation 4). This means that an open circuit will return the pulse without a phase reversal. In the contrast, for a short circuit, z_l is zero and Γ is evaluated to be -1. This implies that the return pulse undergoes a phase reversal (e.g. 180 degree out of phase). This part includes three lectures and three associated labs.

Part 3- Basics of Biomedical Instruments

Biomedical community applies several instruments such as EKG, ultrasonic, and pressure transducers to characterize the process. These instruments are basically differential amplifiers. Due to page limitation, the detail of these instruments, which we discuss in our course will not be described in this paper. However, a brief description of the principle of operation of differential amplifiers is provided here. A block diagram of a differential amplifier is shown below.

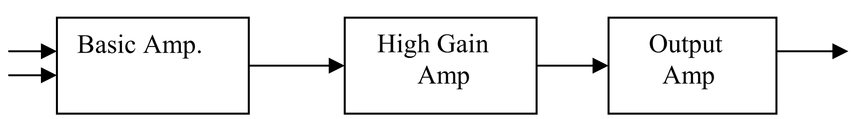

Fig.5-Principle of A Differential Amplifier

The middle section provides most of the gain. This gain (open loop gain) could be several thousands to millions. However, in electronic technology the whole system in figure 5 is shown schematically as following:

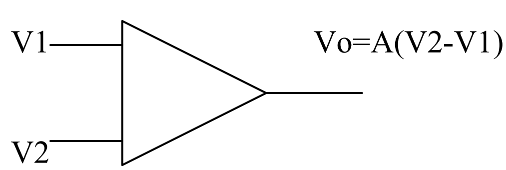

Fig. 6-Schematic Representation of A Differential Amplifier

A, is the open loop gain, which can be very high. In our course, after introducing the concept of Op/Amp, several applications of differential amplifiers as they are used in biomedical applications are discussed in detail but due to page limitation they are omitted from the context of this paper. This part includes two lectures and two associated labs.

Part 4-Industrial Instruments

There are three areas important in consideration in the measurement of signals in industry. The first is the type of signal and its use. If the measurement is to be done automatically, without operator or user intervention, certain measurement methods will be better suited than others. Also significant is the matter of what are called the three Rs of measurement:

Reliability: what accuracy is expected from the result.

Repeatability: can the same sample with same equipment give same results.

Reproducibility: can the same sample with different equipment give the same results

Careful selection of the transducer, the signal conditioning, and the method of measurement can often give more useful results with less capable equipment, or equipment with better chosen features. Transducer selection significantly affects all the results. There are so many choices for measurement of pressure, frequency, force, temperature, that the best transducer to be used will follow a careful decision on all specifications for transducer use:

Range of input signal, maximum and minimum.

Environment; power, humidity, altitude, temperature, vibration, and the like

Bandwidth: maximum and minimum frequency. Drift over time and temperature.

Signal to noise ratio: from the transducer, signal-related noise and uncorrelated noise.

Signal conditioning is important, since it connects the transducer output to the measurement channel input. Factors for signal conditioning include:

Dynamic range of output: the maximum and minimum output expected.

Filter and correlation of signal: minimizing noise with minimum signal disturbance.

Anti-aliasing filters. prevention of false signal creation in sampled measurements

Zeroing, characterizing, and calibration: either automatic or operator controlled.

In this part, just like biomedical instruments, after reviewing the concept of Op/Amps, applications of differential amplifiers as they are used in industrial measurement are discussed in detail with several practical examples and experiments. Some of these experiments include temperature, humidity, and liquid level control with associated sensors. This part includes three lectures and two associated labs.

Part 5- Microwave Instruments

The principles of microwave measurement are discussed in this part. A basic setup for measurement of wavelength, frequency, power, and VSWR is shown in Figure 7. From the VSWR measurement students are able to calculate the wavelength and frequency, and compare the calculated values with the theoretical values using following equation:

$$VSWR = \frac{V_{\max}}{V_{\min}} \qquad (7)$$

The distance between the maximum and the minimum is known to be one quarter of a wavelength. This enables the calculation of the frequency and the wavelength. It is to be noted that the wavelength of the wave inside the wave-guide is different from that of the wave in free space. The wavelength of the wave in the wave guide is related to that of the wave in free space according to

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 + \frac{\lambda_0}{\lambda_c}}} \qquad (8)$$

where λ_o and λ_c are the free space and cut-off wavelengths respectively. A similar setup can be used to measure the gain and the radiation pattern of a small horn antenna. This part includes three lectures and two associated labs.

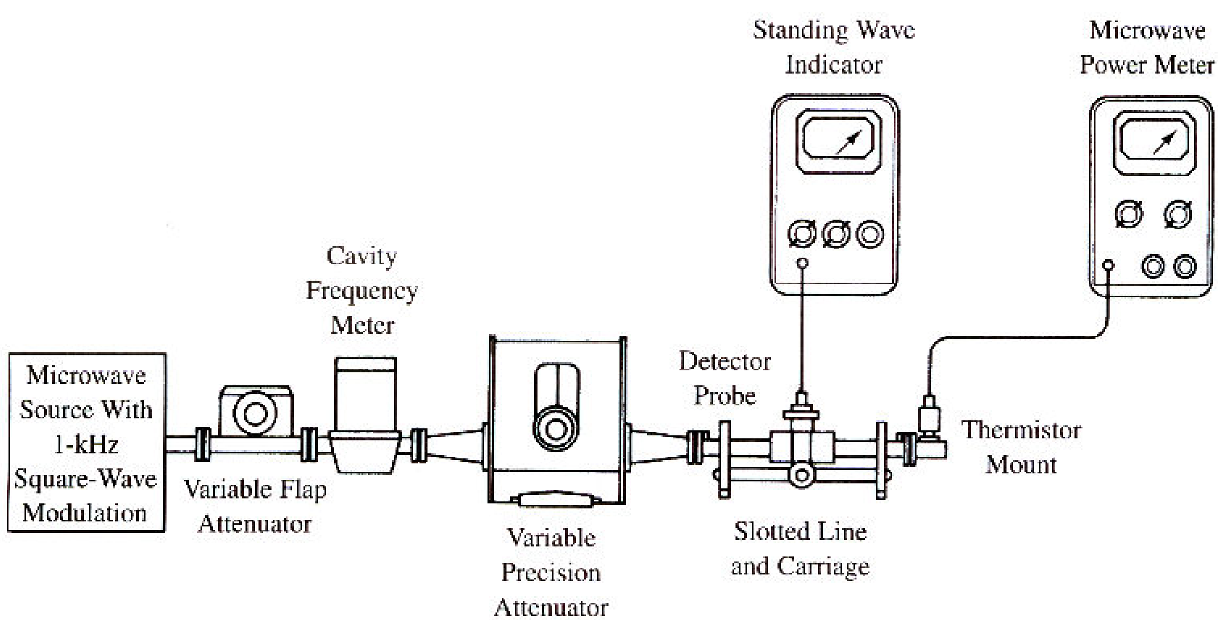

Fig. 7- A Basic Microwave Setup for Measuring Wavelength, Frequency, VSWR, and Power

Course Assessment

Outcome based approach to learning process has been emphasized recently in program evaluation and accreditation processes. Courses offered in a program are developed such that course objectives are aligned with the program objectives and satisfy accreditation criteria of agencies such as Accreditation Board for Engineering and Technology (ABET). Each course may address the requirements of one or more criteria of ABET. Course outcomes, in this regard become crucial to the program and its effectiveness. Assessment of outcomes can be performed using various methods listed up to 12 by ABET related publications. In addition to evaluation of instructor, surveys are effective tools employed for the assessment of outcomes. Student surveys as the most practical means were conducted in this course. As expected, most students expressed satisfaction with the hands-on training they received. The survey showed that topics such as computer aided communication, manufacturing sensors and microwave devices benefited students the most. The positive feedback from students indicated the appropriateness of the materials presented to the degree of the preparedness of students. Students' abilities to conduct the experiments during the lab sessions, in conjunction with their written tests results, were used to evaluate the performances of students. The usefulness of this course to the overall success of the program can also be seen through the results of a survey of engineering technology programs on whether they offer courses similar to this. Most programs do not offer this course making this a candidate to be appropriately modified and adopted by other engineering technology programs.

Conclusions and Recommendations

An instrumentation course was developed and offered twice at University of Memphis with encouraging results and positive feedback from students. The course consists of five parts each with lectures and lab sections. The essential components of the course include 1) Basic Instruments, 2) Communication Instruments, 3) Biomedical Instruments, 4) Industrial Instruments and 5) Microwave Instruments. The concepts behind the operation of these instruments are discussed along with the importance of instruments setup and the principles of reliability, repeatability and reproducibility of the results. The ingredient of this course can be altered to fit the objectives of other engineering technology programs. It is our recommendation to include microelectromechanical systems (MEMS) devices in this course as part 6. New to many schools, this emerging field is gaining momentum in spanning various fields of biology, electronics, fluidics, optics and acoustics. As nanotechnology is being adopted in undergraduate curricula, teaching MEMS instrumentation becomes more relevant to the engineering technology programs.

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