Session 2534

Advanced Instrumentation for Graduate Students in Engineering Technology

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Abstract

Instrumentation is one of the most important courses of engineering curriculum. Almost all programs in engineering technology offer labs and instrumentation, but at undergraduate level. Also most of the textbooks on instrumentation are written for undergraduate programs. On the other hand the emerging technology requires the use of advanced and precision instrument. Thus it becomes the responsibility of academic community to meet the demand of new technology by developing and offering proper advanced instrumentation courses at graduate levels so that upon entering the work place for professional career, students will have the necessary background for advancement.

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. The development of the course material, 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 in addition to its major degrees in electronics, computer, and manufacturing technology offers M.S. degree in engineering technology with concentration in electronics, computer, and manufacturing. Students select their field of concentration according to their future professional goal. The graduate study leading to M.S. in Engineering Technology requires [1]:

A. A minimum of 18 semester hours of upper division credit in an appropriate area of technology or related area.
B. A minimum of 12 semester hours must be taken in one concentration area.
C. Maintaining 3.0 in all Technology courses.
D. Passing Comprehensive exam.

Each concentration offers its own graduate courses outlined in the Graduate Bulletin of the university. Although undergraduate program is highly concentrated but graduate program is diverse and broad. In addition, some of these courses are offered at night making it possible for professional community to enroll in this program. In fact majority of our graduate students come from industries. The structure of the program is such that any individual with an undergraduate degree in technology can enter the program and select the concentration according to his professional career.

Chart below shows the graduate courses offered for students with concentration in electronics:

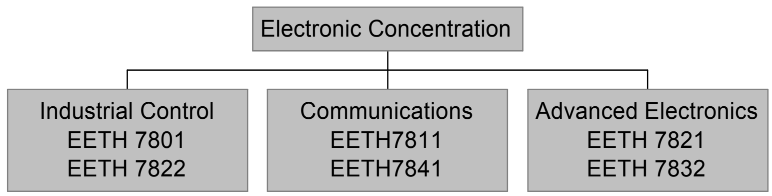

Figure1. Core Courses for Concentration in Electronics

Several of above courses has been offered in the past and EETH 7801, Advanced Instrumentation, the main topic of this article has been offered twice during the Fall of 2001 and 2002 and it is now fully implemented. The authors would like to share the content of this course with colleagues from other institutions for their comments and suggestions so that we can proceed with the final draft for possible publication and making it available to academic community.

Organization

Advanced Instrumentation, EETH 7801, is divided in to five parts and each part is divided in to several chapters covering variety of instruments, some requiring experimentation. A brief description of the course is given in the Graduate Bulletin of the university. Following chart shows the main topics, which will be discussed shortly.

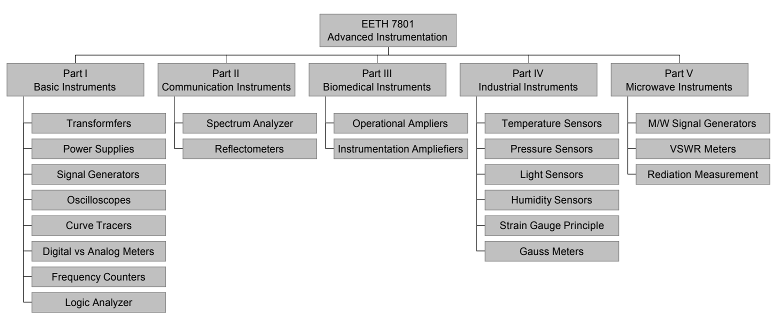

Figure 2. Organization Chart of Advanced Instrumentation

Description

Part 1- Basic Instruments:
This chapter covers basic instruments as listed in the above chart. Since all instruments considered contained single or multi-winding transformer and single or three-phase system, we spent one or two lectures in this chapter. The content of this chapter can be very beneficial to all students majoring in electronics, computer, or manufacturing. We gave special attention to

such topics as power transfer under impedance matching conditions and calculation of three-phase complex power using the 2-wattmeter method without evaluation of short and open circuit parameters.

Next to this section a brief discussion of power supplies such as discrete, integrated, and switching power supplies with effect of filtering, load and source regulation is provided. Originally we performed an experiment with our existing power supply but since their output impedance fluctuated and satisfactory results were hard to obtain, we eliminated this experiment. Our first lab started with the use of function generator. After a complete discussions of methods of generating different waveforms such as sine wave, square wave, and saw tooth waveforms, the frequency response of our function generator was measured and plotted in order to determine its bandwidth. We provided a complete discussion of positive feedback and of the block and circuit diagrams of a function generator . This provides the students with adequate background and familiarity with different parts of the instrument for a possible troubleshooting and maintenance.

Oscilloscope was our next basic instrument with discussion of CRT and proper operation of its front panel knobs. Since this instrument is used in all phases of measurement, we carried out a complete set of experiments in one lab. These experiments are listed here;

___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 the first experiment students measured amplitude, period, and the frequency of a sine wave signal. In this part students also measured the rise of scope vertical amplifier by applying a square wave to scope and comparing the result with the scope catalog specification. It is important to understand the principle involved in measuring this parameter since the true rise time will depend on having a true square wave or a function generator, which has a higher bandwidth than the instrument under test. In spite of this, our measurement resulted in a satisfactory result.

Amplitude modulation and determination Index of Modulation was carried out using two function generators, one generating a 1 kHz signal which modulates the amplitude of the 100 khz signal generated by the other generator. The index of modulation was calculated according to the following formula:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \tag{1}$$

Where m, the index of modulation, is given by;

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

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

In X-Y mode we performed two experiments. The first one was to observe the I-V characteristic of a silicon and a germanium diode. From the I-V curve students were also able to calculate the cut in and saturation voltages of silicon and germanium diodes. The second experiment involved the use of scope in sweep mode; i.e. we applied a sweep signal to the channel 1, and to the input of a series resonance filter. The Y input was taken from the resistor of the resonance filter, scope still in X-Y mode. In this way we could observe the frequency response of a series resonance circuit, measure 3db points and determine Q of the resonance filter according to the following equation;

$$Q = \frac{fr}{f1\text{-}f2} \qquad (3)$$

Where f_r is the resonant frequency, and f_l and f_2 are the lower and upper 3db points respectively. Setup is shown in Figure 3.

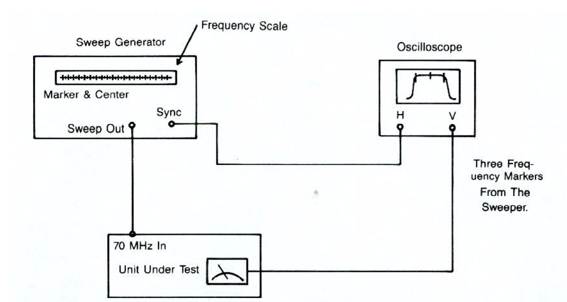

Figure 3. Setup for observing and measuring frequency response and the bandwidth

A curve tracer was the fourth important instrument discussed. Although with the emerging new IC technology the use of such instruments is less comman than it once was, we decided to include it anyway. It shows important circuits functions such as the generation of a staircase waveform and the ability to sweep the collector current over a range of values. We also discussed the project of a previous student, who succeeded in designing such a circuit using computer software [2].

In the digital vs. analog section we discussed the average and the rms values of digital and analog meters and compared their accuracy, resolution, and limitations. Some simple waveforms such a half-wave rectifier, rectangular waveform, and a saw-tooth were assigned as homework. Also a previous project by one of the senior student who designed a digital voltmeter using existing software was demonstrated [3].

Digital frequency counters and logic analyzer were the last two items in the Basic Instrument Sections, which were discussed. Due to the unavailability of the logic analyzer, we did not carry out any experiment but students were encouraged to design a 4 or 8 to single channel probe, which is the basic accessory of a logic analyzer. Figure 4 shows the instrument and the associated probe.

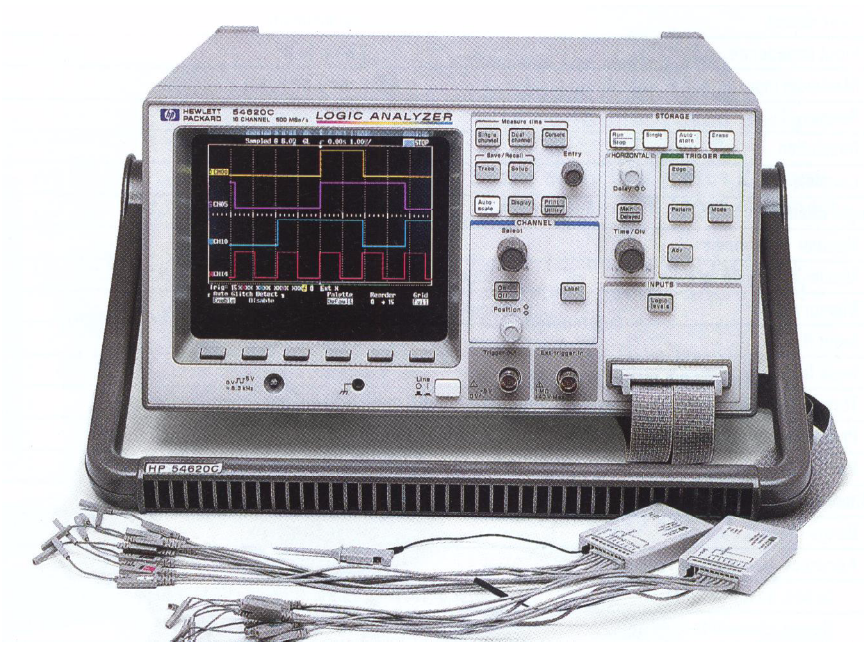

Figure 4. Logic analyzer and its associated logic probe

Part 2-Communication Instruments

In this part we discussed two instruments. The first was Spectrum Analyzer. This is an indispensable instrument used in communication engineering community to determine required bandwidth and the content of information signal. Each student was assigned a unique problem to write a Spice program, simulate, and find its harmonics using Fourier analysis, then use existing instrument to observe and measure the time and frequency domain parameters and compare the results with the simulated values. It is shown mathematically that every periodic waveform can be presented using Fourier Series according to following:

$$v(t) = \sum_n A_n \cos\omega_n t + B_n \sin\omega_n t \qquad (4)$$

Depending on the waveform, i.e. odd or even symmetry, we may have one or both of the above harmonics. A program was written assuming a square wave and the resulting series was simulated using Spice program, the time and frequency domain parameters were evaluated for 1 kHz and 1 volt peak. Fourier analysis using Spectrum Analyzer confirmed that this waveform contains fundamental and all even harmonics, in agreement with mathematical presentation. Next in part 2, we discussed the principle and operation of a Time Domain reflectometer (TDR). A block diagram shown in figure 5 was first illustrated, then the theory of determining the nature of fault and its location were discussed using following equations;

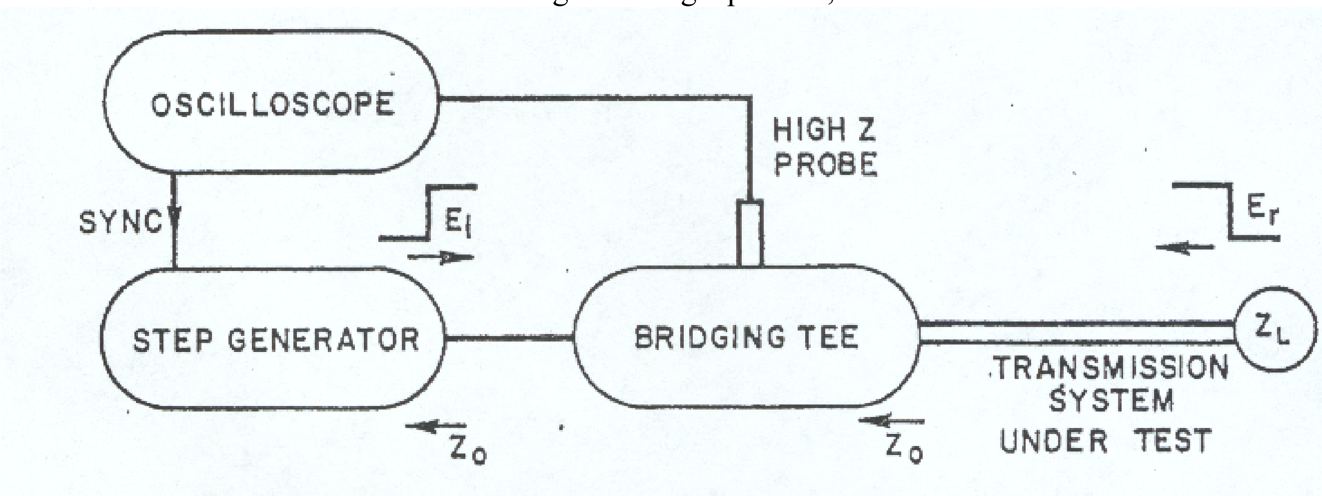

Figure 5. A simple block diagram showing the principle of TDR

$$\Gamma = \frac{z_l - z_c}{z_l + z_c} \tag{5}$$

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, but TDR only measure the absolute value of this parameter. A TDR, basically is a generator of short pulses, the departure and the arrival time of the pulse will indicate the location of the fault using following equation;

$$t_2 - t_l = \frac{x}{v} \tag{6}$$

in which v is the velocity of the pulse in the cable. This velocity is determined by the TDR after entering the velocity factor of the cable in to the instrument. The velocity factor is determined by the following equation;

$$\text{v.f.} = \frac{c}{\sqrt{\varepsilon_r}} \tag{7}$$

where c is the speed of the pulse in free space , and ε_r is the relative dielectric constant of the cable under test. Students consider two extreme cases . First, for open circuit the value of Γ as evaluated from equation (5), after removing indeterminacy is found to be 1. This means an open circuit will return the pulse without phase reversal. The next case involves the short circuit, when z_l is zero. In this case Γ = -1, meaning that return pulse is 180 degree out of phase.

Part 5- Microwave Instruments

In this part we discussed the principle of microwave measurement. A basic setup for measuring the wavelength, frequency, power, and VSWR (voltage standing wave ratio) is shown in figure 6. From the VSWR measurement students were able to calculate the wavelength, frequency, and compare these with the theoretical values using following equation;

$$VSWR = \frac{V_{max}}{V_{min}} \tag{8}$$

Since the distance between maximum and the minimum is one quarter of a wavelength, thus the wavelength and the frequency could be calculated. It is to be noted that the wavelength of the wave inside the wave-guide is different than the wave in free space, thus following equation was used in order to take this fact in to account;

$$\lambda_g = \frac{\lambda_o}{\sqrt{1 + \lambda_o/\lambda_c}} \tag{9}$$

where λ_o and λ_c are the free space and cutoff wavelengths (maximum wavelength which can propagate in a wave guide) respectively. The same setup was also used to measure the gain and the radiation pattern of a small horn antenna.

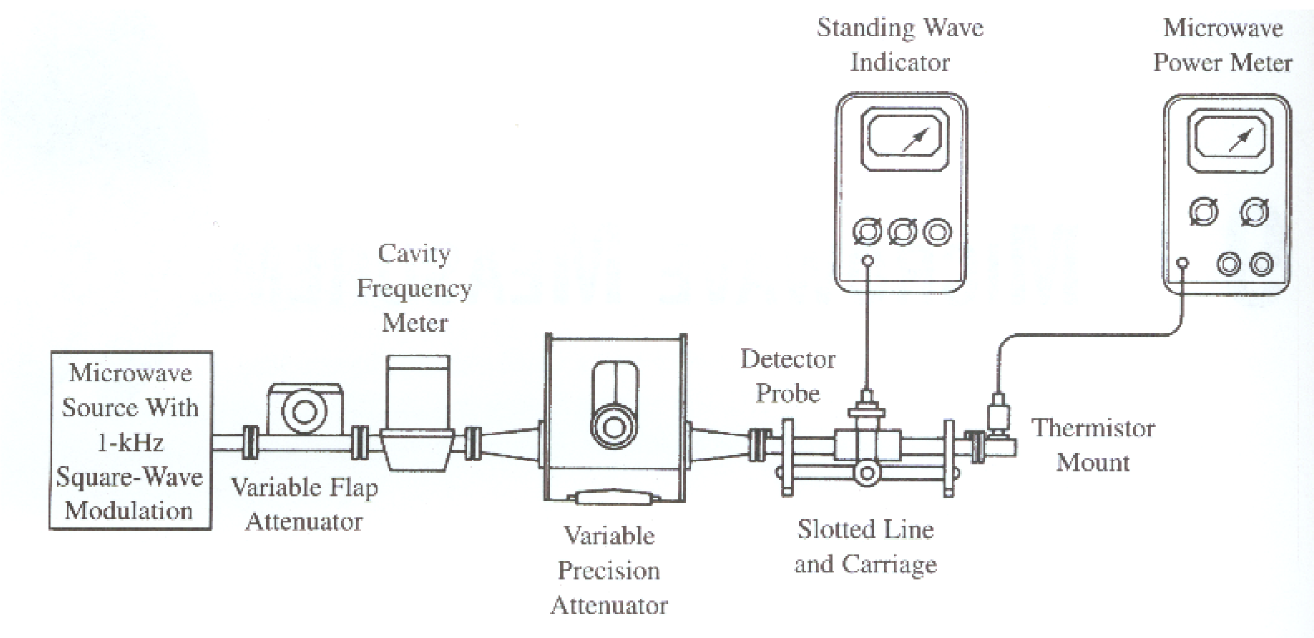

Figure 6. A basic microwave setup for measuring wavelength, frequency, VSWR, and power

Course Assessment

The graduate students in engineering master program with concentration in electronic, computer, or manufacturing will benefit most from this new course. This course has been developed in response to the needs of industries, which require graduates students to have more exposure to advanced instrumentation. The topics selected in this course were based on aforementioned needs of industries.

Our initial assessments of two pilot courses indicated that majority of the students did benefit from topics such as computer aided communication, manufacturing sensors, and microwave devices which were not covered in undergraduate program. The survey of other graduate programs in engineering technology indicated that majority of them do not offer similar courses. The content of our proposed course is such that with minor modifications, other engineering technology graduate programs could adopt it. Since the course is still under construction, the authors would appreciate the suggestions and the comments of our colleagues and friends so that a final draft can be prepared for publication.

Conclusion

In this paper, we discussed several important sections of a new Advanced Instrumentation course offered for graduate students in the Department of Engineering Technology at the University of Memphis. This course has been offered twice as a pilot course and the results indicated that topics covered have received favorable attention from both the student body and the industrial community. We believe that such course should be an integral part of every engineering technology graduate program. This course will prepare graduate students for rapidly emerging new technology in the 21st century.

Bibliography

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