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ABSTRACT

Electronics Engineering Technology majors in the Industrial and Engineering Technology department at Central Michigan University have developed many real-world projects that represent the type of problem-solving projects encouraged by industry. Two projects that can be used by other educators as freestanding projects or as the core for further study in their applications illustrate the transfer of theory to application in the context of problem solving. The first project involves the design and implementation of a low-cost electromyogram and the interfacing of muscle signals to a computer. The system allows for the control of a computer using electromyographic signals from human muscles. The key emphasis is the development of an inexpensive universal system that can be used by others to further their skills in the system's applications with the required safety features associated with interfacing humans to machines. The second project is the implementation of a remote data logger. It uses a radio frequency link for analog data collection. The system allows for the computer collection of any analog data that can be translated as a varying DC voltage level between 0-5 volts. It allows a computer to collect analog data from a site up to 250 feet from the computer without connecting wires. The use of such capstone experiences as these has proven to be an effective method in helping students translate theory into application. (YLB)

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TECHNOLOGY EDUCATION DIVISION:

HUMAN BODY INTERFACING

Presenter:

Dr. Lawrence Fryda
CENTRAL MICHIGAN UNIVERSITY

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HUMAN BODY INTERFACING

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ABSTRACT

As electronics technology instructors, the need always exists to develop new and innovative applications for electronics. These new innovations help develop and keep students interested in electronics and at the same time offer a creative outlet for the instructors. The two following circuits have been built and tested. The design was the Professor's but the implementation of the design was carried out by the students. Clint Szumal is responsible for the implementation of the Remote Data Collection System and Bob Harrington completed the EMG circuitry.

INTRODUCTION

To successfully adapt to the rapid movement from local economies to a global economy it becomes increasingly important that the workers of today are as well prepared as possible. Clearly the need exists for well educated professionals to compete successfully in the global community. Many of the traditional methods of instruction, particularly in engineering and engineering technology programs, are coming under scrutiny. In a study completed by Mark Miller (1), he notes fifteen characteristics that are associated with exemplary engineering and engineering technology programs by industrial representatives. Of particular interest is the industrial representatives citing of the need for more "hands-on" experience for program graduates. A key component of this "hands-on" experience can be found in applied projects for graduating students. In recognition of this need for a strong applications component in the education of technically trained students, the US Congress authorized $25 million in funding to engineering colleges to encourage activities in education to meet industrial needs rather then research. These points illustrate the increasing need for students' to have more then a theoretical basis to their technical education. They must be able to directly apply their education to industrial problems. When this application experience is gained during the students formal education, their confidence level is enhanced and they are able to better meet the needs of the changing technologies they will be encountering throughout their careers.

INDUSTRIAL AND ENGINEERING TECHNOLOGY

The Industrial and Engineering Technology (IET) department at Central Michigan University has a long history of applied technology. The professors in the department have extensive industrial experience and continue to maintain close working relationships with industry. Part of the advantage of this relationship is the fostering of industrial advisory committees. Out of these committees has come a consistent theme, give the students real-world project experiences. The industry representatives have recommended several areas of technical application that they have identified as being the heart of many technical systems. These include the areas of remote data logging and computer interfacing of non-standard systems. They offer encouragement to students to have experience in these areas. It is not required that this experience be exactly matching industries specialized applications but rather that the students have actual experience in implementing problem solving solutions associated with these areas.

The Electronics Engineering Technology (EET) majors in the IET department have developed many real-world projects that represent the type of problem solving projects encouraged by industry. This paper present two projects for other educators to use with their students. The projects can be used as free standing projects or as the core for further study in their applications. The two projects illustrate the transfer of theory to application in the context of problem solving. The projects were designed and built by senior students as their final project and involved at least one semester of intensive laboratory work. The first project represents the resulting design and implementation of a low cost electromyogram (EMG) and the interfacing of muscle signals to a computer. This project represents the heart of many applications in the areas of bio-electronics. The system, designed and implemented by Mr. Robert Harrington, allows for the control of a computer using electromyographic signals from human muscles. The key emphasis in this project is the development of an inexpensive universal system that can be utilized by others to further their skills in the system's applications and the required safety associated with interfacing humans to machines. Mr. Clint Szumal is responsible for the implementation of the remote data logger. It utilizes a radio frequency (RF) link for analog data collection. The system allows for the computer collection of any analog data that can be translated as a varying DC voltage level between 0 and 5 volts. The system allows a computer to collect analog data from a site up to 250 feet from the computer without connecting wires. This project has grounded the students in the real challenges associated with the designing and testing of solutions in the field of data collection.

THE EMG CIRCUITRY

In an article by Lawrence Fryda (3) the fundamental considerations needed to interface muscle signals into a computer are presented. The paper covers the fundamentals of required safety and technical specifications of commercially available EMG systems. Also presented are the diverse applications for utilizing EMG based systems. The information presented in that paper will serve as a reference for this portion of the paper. Copies of the article can be obtained by contacting the author through his e-mail address (fryda@ray.iet.cmich.edu).

THE AD524

The cost of commercial EMG systems is prohibitive in most non-medical educational institutions. The EMG circuitry presented in this portion of the paper represents an inexpensive alternative to commercial units. The heart of this system is the AD524 instrumentation amplifier. This amplifier has high programmable gain, high CMRR, high signal to noise ratio and high input impedance. There are several versions of the chip available though Newark Electronics, Chicago, Illinois, (http://www.newark.com). The circuit presented in this paper uses the AD 524 (AD) version. This version costs about $16 each. The chip is the highest priced component used but is necessary. This author has had some success in requesting complementary copies of the chip for experimentation purposes. One of the main reason for using the AD 524 is the extremely high Common Mode Rejection Ration (CMRR). A typical LM 741 has a CMRR of about 90 dB. The AD 524 AD operates at 120 dB. This high CMRR allows for good "subtraction" of the desired signals from noise sources. Another consideration for the AD 524 is its extremely high input impedance. This high impedance characteristic is crucial when attempting to collecting electrical signals through the skin. Although the high input impedance characteristic is crucial, it is a mixed blessing. The high input impedance also makes the circuit highly susceptible to interference from electromagnetic noise sources. These noise sources include radio and television transmission, power wires and florescent lights. Of most concern in the EMG application are those noice sources in the 50 and 60 hertz range. Typically, the noise source will generate signals that are several orders of magnitude greater then the desired EMG signals. Thus it is important to use sound circuit design considerations (shielded cables, short wires, etc.) to reduce this noise pickup. The complete schematic for the EMG system is shown in figure 1.

The output of the AD 524 is used to drive a narrow band width notch filter tuned to 60 hertz. Even though the predominant EMG frequency is in this same frequency range (3), the susceptibility to ambient noise sources necessitates its removal. The output of this notch filter is fed into a narrow band pass filter tuned from 100 to 500 hertz. This allows for the capturing of a significant range of the active EMG signals while limiting the response of the system to other noise sources. The output of the band pass filter is fed to a precision rectifier circuit. The output of the rectifier is loosely filtered to maintain a DC level that is proportionate to the magnitude of the muscle activity being monitored. The "stiffness" or "looseness" of the filter is a balance between the level of ripple tolerable and the quick response of the circuit to changes in muscle activity levels. A 330 micro-Farad capacitor works as a good compromise.

The output of the precision rectifier is connected to a basic adjustable gain inverting amplifier. The output of the amplifier should be adjusted to a maximum level of five (5) volts when the most strenuous muscle activity is applied. The reason for the variable gain is that as the muscles fatigue with extended repeated use, the "at rest" outputs level tend to increase in magnitude. The variable gain adjustment helps compensates for this effect.

The output from the final amplifier stage is fed into the remote data logger transmitter. The receiver of the data logger is linked to an ADR 101 Analog / Digital interface. The ADR 101 allows for computer interfacing of both analog and digital signals through a standard serial RS 232 port. The ADR 101 can be obtained through Ontrak Control Systems, Sudbury, Ontario, 705-671-2652.

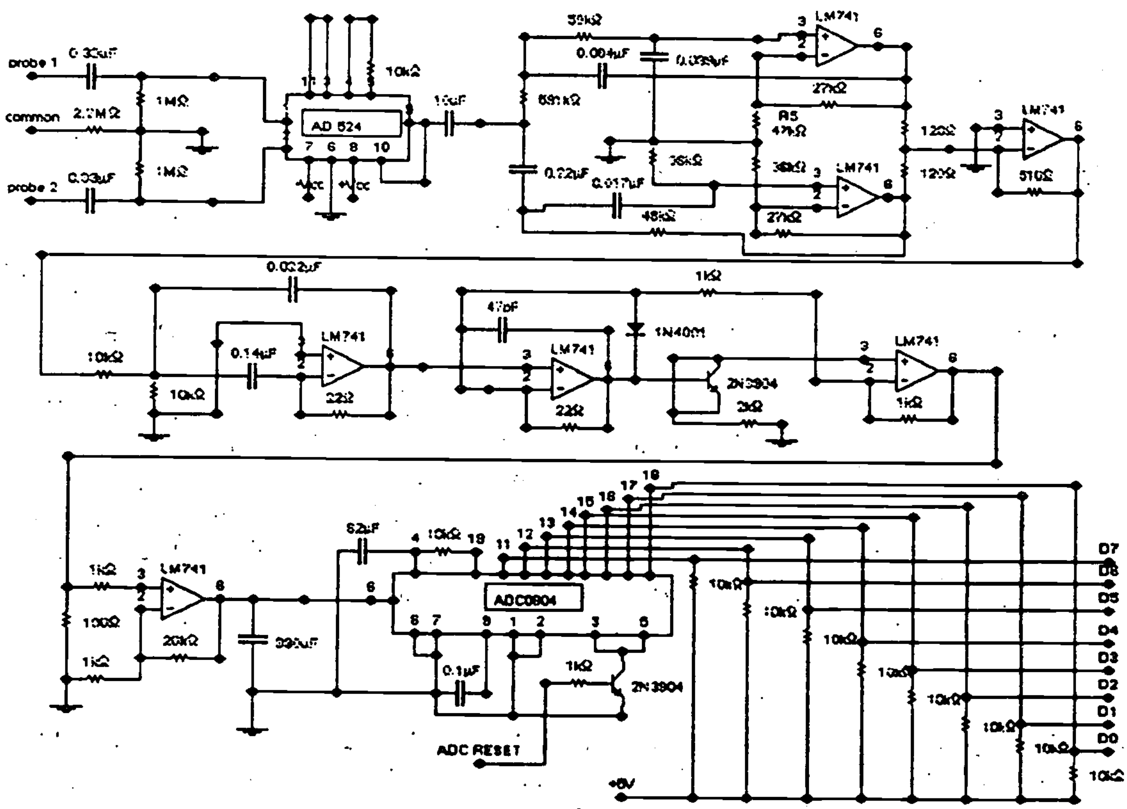

Figure 1: Electromyogram Circuitry With ADC.

THE REMOTE DATA LOGGER

The remote data logger system allows for the transmission via RF of slowly changing analog data. Effectively, the circuit can be used to remote link any physical analog variables (temperature, light intensity, angular and linear displacement, etc.) that can be translated into a 0 to 5 volt range, into a computer. The following circuits are operating on the assumption that the user is already able to convert the analog variable to be monitored into a varying DC voltage in the 0 to 5 volt range.

As a quick overview, the transmitter system consists of a voltage to frequency converter (VCO) that drives a 310 MHz amplitude modulated (AM) transmitter. This allows for the modulation of the AM carrier with a tone frequency that is inversely proportionate to the input analog voltage. An input DC voltage of about 3.5 volts will result in an output frequency of about 10K hertz and an input voltage of 5 volts will generate an output frequency of about 5 K hertz. The receiver utilizes an AM receiver and demodulator that captures the tones and applies them to a phase locked loop (PLL). The PLL generate a DC voltage that is proportional to the frequency of the input tone. The resultant DC voltage is scaled to meet a 0 to 5 volt range and feed into an analog to digital converter (ADC) and developed as computer usable data. The end result is that the computer is able to monitor and record a remotely located changing analog voltage. The effective range of this system is up to 250 feet between the transmitter and receiver.

THE TRANSMITTER CIRCUIT

Virtually any analog range of measurement can be scaled to be represented as a 0 to 5 volt DC voltage range. This paper makes the assumption that there is no need to explain the implementation of this requirement. The 0 to 5 volt variable DC voltage is used to drive a LM 566 voltage controlled oscillator (VCO). The R/C network, depicted in FIGURE 2, generates a 5K to 10K hertz square wave output frequency inversely proportional to the input DC voltage. The VCO has a usable input voltage range of about 3 to 5 volts. This necessitates off-setting the input DC voltage to match the usable input range. This can be implemented with an operational amplifier configured in a summing mode. The resultant frequency is coupled to a TX-66 AM transmitter board, FIGURE 3, manufactured by MING Engineering & Products INC. and distributed by Digi-Key of Thief River Falls, Minnesota (WWW.digikey.com or 218-681-3380 fax). The cost of the one inch square board is about $19.

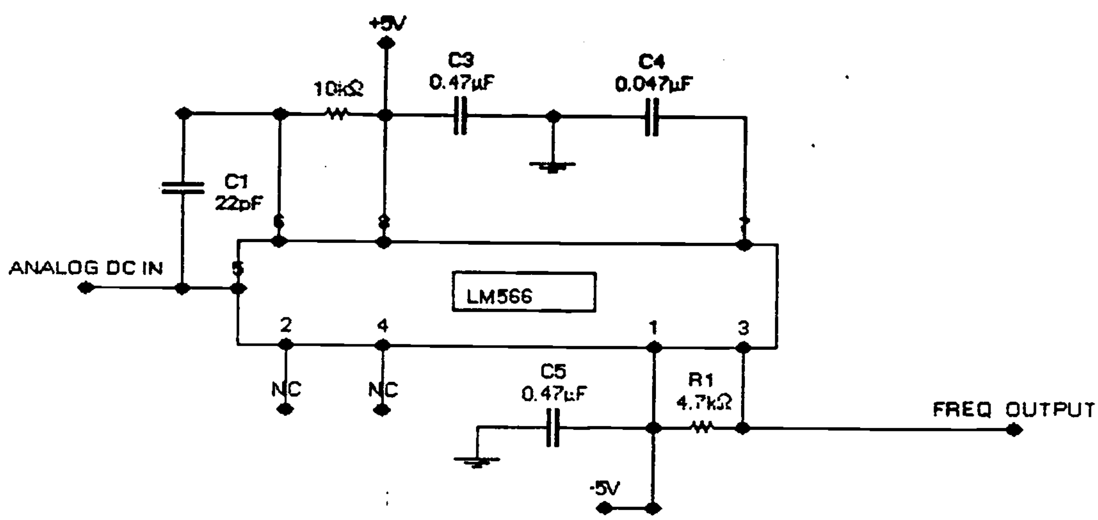

Figure 2: Analog DC Voltage Controlled Oscillator (VCO).

The square wave input modulates the 310 M hertz transmitter carrier. The output of the transmitter is coupled to a short wire antenna and electro-magnetically coupled to the receiver.

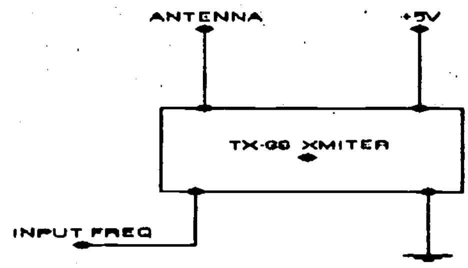

Figure 3: TX-66 Transmitter Board.

THE RECEIVER

The receiver utilizes a RE-66 receiver & demodulator board, FIGURE 4, also manufactured by MING Engineering and distributed by Digi-Key. The cost of the one inch square board is about $12.

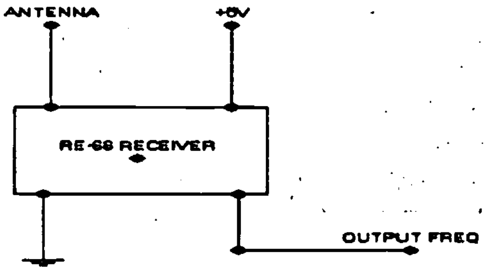

Figure 4: RE-66 Receiver.

The RE-66 is the complement to the TX-66. The demodulated tones from the RE-66 are used to drive a LM 2907 phase locked loop (PLL) chip, FIGURE 5. The R/C combination shown in the figure 4 closely match the frequency spectrum generated by the VCO. NOTE: The operating ranges of the VCO and the PLL do not match naturally. The normal operating frequency window for the PLL is much higher than that of the VCO. It will prove to be expedient during early development stages to use the output of the VCO as a direct input into the PLL (capacitive coupled) and to adjust the R/C combinations to generate a frequency window that is compatible with both chip circuits. This allowed for the matching of circuit R/C perimeters for the best usable performance. The frequency ranges of the two circuits need to at least overlap or the output of the VCO may not lie within the was identical to the center input frequency range of the PLL. Most of the listed component values in figure 2 and figure 5 are non-standard values and must be derived through component series/parallel combinations. capture rangė of the PLL. The best circuit performance is provided when the center of the output frequency range of the VCO

The output DC voltage from the VCO is used to drive an Analog to Digital Converter (ADC) and generate computer compatible bit patterns. The resultant transistor-transistor logic (TTL) compatible bit pattern can be interfaced onto a computer through standard computer interface techniques. It is recommended that a Prairie Digital board (Model 30) be used for this stage of the project. The Model 30 has on board ADC as well as computer input output (I/O) capabilities. The Model 30 is manufactured and distributed by Prairie Digital Inc. of Prairie du Sac, Wisconsin (608-643-8599) and costs about $75. A more cost effective I/O approach may be the EIA board. It is distributed by Electronics Industries Association, Washington, DC, (202-457-4986) or http://www.eia.org. The cost of the EIA board is about $30.

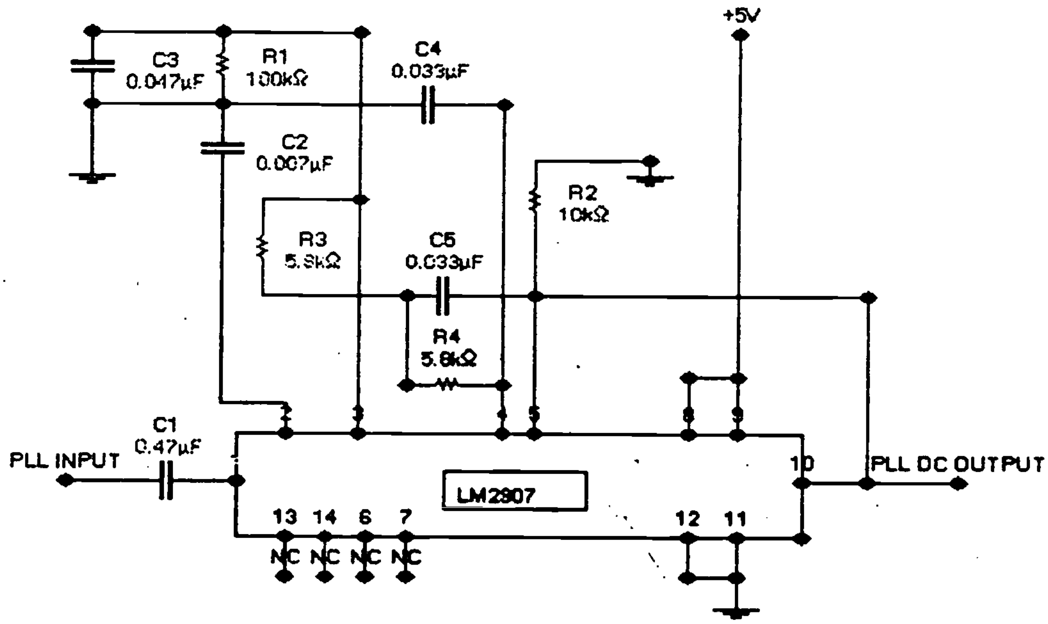

Figure 5: **Phase Locked Loop Frequency to Voltage Converter Circuit.**

CONCLUSION

The utilization of capstone experiences in the education of students has proven to be an effective method in helping students translate theory into application. At the heart of successful capstones in the involvement of industry, professors and students. The two systems described in this paper can serve as the basic for many capstone applications for electronic engineering and electronic engineering technology students. Both systems represent areas identified by industrial representatives as being important for graduating students to gain hands on experience.

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