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INSTRUMENTATION AND MEASUREMENT FOR SUSTENANCE OF LIFE

By

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Professor of Electronic and Electrical Engineering

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INTRODUCTION

Mr. Vice Chancellor Sir, the Principal Officers; Colleagues, Visitors, Students, Friends, Ladies and Gentlemen; I thank God for sparing my life to stand before this distinguished audience to present, though belatedly, my inaugural lecture, on the subject: "Instrumentation and Measurement for Sustenance of Life".

I must say without equivocation that electronic instruments play a vital role in the sustenance of life, as we know it. Most traditional non-electrical instruments like the simple thermometer to the spring-manometer for blood pressure measurements have taken on new electronic looks. From wristwatches to fridges, the microwave oven and musical instruments, the electron has taken a position of pride and keeps moving on in electronically powered sequences. It is no gainsaying that the quality of living today would be much lower and life itself will be unsustainable without electronic instruments. A visit to the hospital or to any industry will confirm this. An electronic instrument is a product of "Electronics"; that ubiquitous field that is one of the fastest expanding disciplines in research, application development and commercialization. Substantial growth in the field has occured due to World War II, the invention of the transistor, the space programme, and now, the computer industry. Research grants are high, jobs are more readily available and there is much money to be made in areas related to electronics. With the beginning of the ``information superhighway" and computerized video coming to homes, it is hard to imagine that electronics will not continue to expand in the future. Electronics is everywhere in every life.

It is difficult for the practicing engineer to stay informed of the most recent developments in electronics. What is taught in a course could well be out of date by the time one actually goes to use it. However the physical concepts of circuit behavour will be largely applicable to any future development.

The evolution of an instrument may go from components and transducers to circuits and finally to the main instrument. We will look at this development

DEVELOPMENT OF A BASIC INSTRUMENT

Electronic instruments have evolved with the mounted circuits they are contained within their cases. Originally, these circuits were populated by discrete components connected together and cased. As a result of advances in technology, many devices can now be condensed, as complete electronic circuits on a single chip of semiconductor material. This has resulted in the term I.C or Integrated Circuit.

As the years have progressed, integration and ensuing intricacies progressed as follows:

a. SSI (Small Scale Integration)
b. MSI (Medium Scale Integration)
c. LSI (Large Scale integration)
d. VLSI (Very Large Scale Integration) and
e. ULSI (Ultra Large Scale Integration)

While VLSI incorporates several tens of thousands components per circuit, ULSI can incorporate several million components per circuit.

Fig 1 provides the block diagram of a basic instrument.

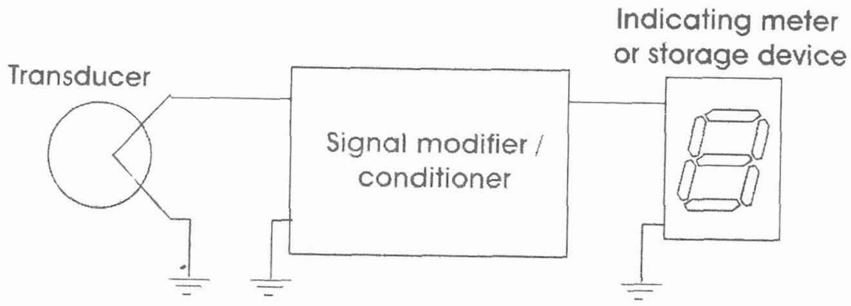

Fig. 1 A basic instrument

Electronic instruments usually contain all of the items shown in figure 1. A transducer, sometimes loosely referred to as a sensor, is a device which provides a usable electrical output in response to a specified physical quantity, property or condition that is measured. They can be classified as active or passive. Active transducers produce output voltages without excitation from an external source, while passive ones do not produce any voltage unless powered by an external source. Table 1 shows some types of measurement variables and transducer types.

Table 1. Some Sensors and Applications

S/N	Variable	Sensor/transducer, Instruments	Possible areas of application
1	Temperature	Thermistor, Thermocouples, Resistance thermometer	Meteorology, industry
2	Electrical energy	Wattmeter	Electrical energy measurement

3	Flow rate	rotameter	Oil pipes, petrol dispensers, Industrial processes
4	Gas concentration	CO_2 sensor, Gas chromatograph	Monitoring of indoor air quality, aquariums, mines, tunnels
5	Humidity	hygrometer	Soil monitoring, meteorology
6	Fluid level	Micro-switch, ultrasound sensor	Oil industry, petrol stations
7	Pressure, force and acceleration	Strain gauge, diaphragm, accelerometers, micro-switch, piezoelectric crystal.	Paper mill, oil refinery, automobiles, aircrafts.
8	Light intensity	Photovoltaic cells, Optical encoder, phototransistor, photomultiplier	Powering homes, pocket calculator, remote data stations, monitoring of greenhouse, meteorology.
9	Rainfall	Tipping bucket	Meteorology, agriculture
10	Wind speed	Wind wane, anemometer	meteorology
11	Acidity	PH probe	Water works, Chemical industry
12	Radiation	Radiometer	Nuclear facilities
13	Displacement	Linear variable differential transformer, Strain gauge, potentiometric sensors.	Aircraft industry
14	Vibration	Vibration sensor	Burglary sensing, sound level sensing
15	Sound	Microphone	Audio productions

With only a few exceptions, sensors used in instruments have electrical outputs that vary in voltage, resistance or current. In choosing transducers, it is important to consider matching, loading, ambient temperature effects, dissipation errors, and other factors that can influence accuracy and reliability.

In fig. 1, Signal conditioning is the excitation and amplification that could bring the transducer level up to a sufficient value to make it useful for conversion, processing, indicating and recording. After signal conditioning, physical quantities such as pressure, temperature, strain and position are transformed into electrical voltage or current of required form and sufficient levels. The signal may be indicated or recorded in analógue form. In the alternative, it may be converted into digital signals.

Some instruments in themselves have signals already suitable for digitization. Mass Spectrometers, gas chromatographs, and gel-cell scanners are examples of instrumentation that produce an electrical signal suitable for digitization.

CONSIDERATIONS IN INSTRUMENT DESIGN

Instrumentation is probably one of the few fields that are constantly under pressure to innovate and intimately track technological trends in various other fields or industries. This is due to the fact that most 'manufactured products' either in industry or academia have to be designed, certified, and produced and testing is usually called for at one or more of these stages. Industrial machines, telecommunications equipment, aerospace equipment, electronics goods, computer hardware, and automobiles call for intensive testing on every unit in all stages of development and manufacture. In order to successfully cater for the needs such diverse disciplines, the process of designing test instruments often requires a level of creativity not needed or found in many other fields in engineering.

In designing new instruments, there is a need for creativity. The process of design is one that should continue through all stages from the concept of a new way of making measurements to the emergence of a piece of operational equipment. One way in which instrumentation design is different from most other subjects is the sharp distinction between an "application orientation" and a "technique orientation" design. In application-oriented design, the approach is to start with a ***need*** and think of any technique that could solve it. In the technique-oriented design, an expert in a particular technique in his bid to design an instrument starts with the technique and thinks of all problems it might be used to solve to evolve an appropriate design.

New instruments are not always designed by manufacturers. Instrument design is influenced by four major groups of stakeholders:

a) Universities or other places of higher learning.
b) Independent laboratories.
c) Instrument manufacturers
d) Instrument users.

While creative design tends to be thought of as an exercise for the individual, there are advantages in having a group of people working together. New ideas are often shaped best as two or more people with some diversity but with sufficient knowledge in common to be able to talk easily, think out a problem together. This may seem a slower but ultimately more effective alternative to the brainstorming approach of one person. If experts in different instrument disciplines are available within the team, their skills can be brought to bear on a problem as development proceeds and their advice will be on tap at any stage. Again, the more creative individual can be helped by a colleague who looks through more conservative eyes. Aids to creative instrument designs are a good climate for innovation, a prior knowledge of the existing state of the art, sensible brainstorming with seeming wild ideas initially and some learning from nature. Navigation instrument design using the natural ability of the bat is an example. In instrument design, the importance of good specification cannot be overemphasized. A functional specification must be present for new ides to be judged against. The first stage in preparing a specification is to set down orders of magnitude, notable for what accuracy is needed. The upper limit of the specification is the performance figure that there is just no point in improving on: the customer will have no use for such refinement. The lower limit is that below which the customer will have no use for the instrument, no matter how cheaply it is produced and no matter what bonus facilities it provides.

The length of time over which a complete instrument development is spread may be frightening. A scientist has found out that for instruments arising from a need, there is a mean of 12 years between availability of technical information and the development of an instrument based on it. Shorter periods were involved for instruments required for matters of survival. The history of wartime development, when complete new projects of instrumentation were brought to maturity in a matter of months show that there is no absolute law forbidding rapid progress.

PATENTS

Patents are rights of protection for a new design. Attitudes to patenting vary greatly. Some larger firms apply for patent protection on every possible occasion. Some people reckon that the disclosure that must accompany a patent application gives a greater danger of successful competition than does the absence of legal protection. The common belief is that patent protection should be applied for as early as possible. It is possible that this is based on the false concert as to how important the invention is and how hot the competition. If instead a patent application is delayed for as long as possible, it will give more time to work out aspects of the invention, it will put off the date when the patent ultimately expires and most important, it will allow time for a more considered judgment before decisions have to be made about how far expensive foreign protection is desirable.

SOME SPECIFIC APPLICATION AREAS OF ELECTRONIC INSTRUMENTATION

Table 3 shows a few specific application areas of electronic instrumentation

Table 3. Specific application areas

Fields	Some application areas
Agriculture	Soil moisture, rainfall intensity etc
Industry, Process Control	Flow meters
Meteorology and environment	Measurement of environmental variables
Home appliances	Microwave ovens, watches, fridges, PCs etc
Educational Institutions	Oscilloscopes, waveform generators, counters, PCs
Military, Space technology and aircrafts	Automatics controls, autopilots etc.
Medicine	Electronic thermometers, plethysmogragh, cardiograph, A, B, CT Scan, ultrasound etc
Science research	Electron scanning microscope, Nuclear magnetic resonance etc
Automobile	Automatic drives, brakes etc.

MODERN TRENDS IN INSTRUMENTATION

Most modern trends in Instrumentation today center around the use of microcomputers and/or microprocessors for test and measurement (T&M). Most instruments are now microcomputer~ or microprocessor-based. A microprocessor-based instrument is one that is built around a microprocessor. The microprocessor controls the various parts of the instrument and allows it to do many things that legacy instruments can't: address memory for storage, carry out rigorous processing of data etc. Fig. 2 shows a typical microprocessor-based process control system.

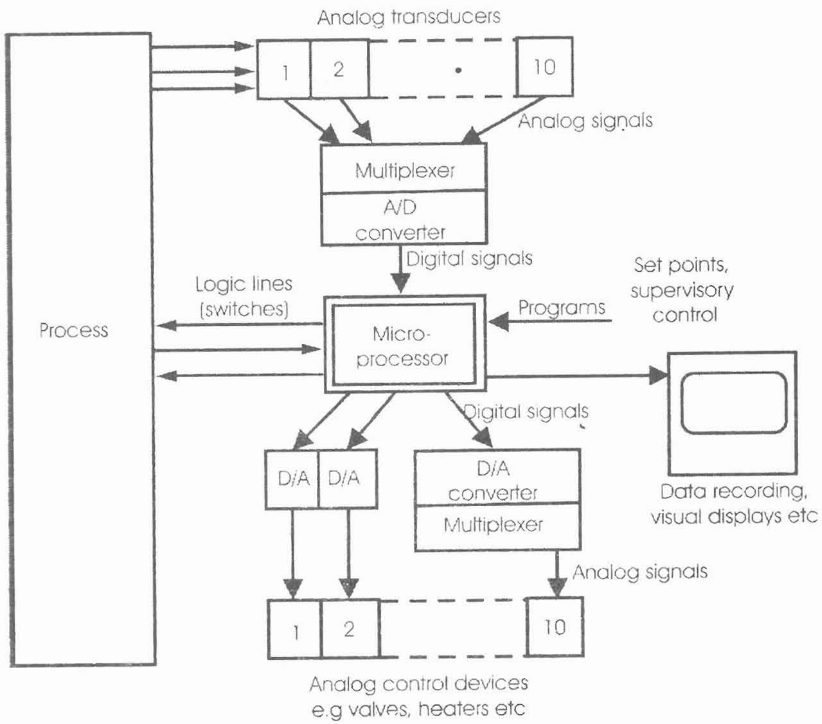

Fig. 2 microprocessor-based control system

To understand the reason for the emergence of microprocessor and microcomputer based instrumentation

systems, it is necessary to state the basic premise upon which Instrumentation itself is based:

> "Measurements are made of a physical parameter or measurand in order to make some form of judgment or the other about the state of a device or system. To arrive at such a judgment, the results obtained by the measuring process usually need to be processed further and perhaps compared to other measurements"

To put this in perspective, fig 3 provides the block diagram of a generalized instrumentation system.

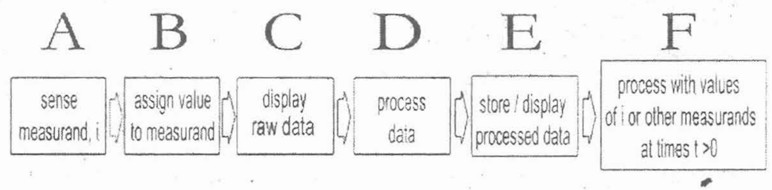

Fig 3: A generalized instrumentation system

Original instruments between the time of the Industrial Revolution and the invention of vacuum tubes carried out stages A to C in the figure. It was then up to the human operator to read out the data and carry out stages D to F with other devices.

The birth of computers was the first big step forward. It became possible for scientists to take readings from an instrument and carry out stages D to F at a later time on a computer. Later, it became possible to do this in real time by connecting the instrument to a computer. This marked the beginning of the union of instrument and computer. Since then, things have advanced to a stage today where typical microprocessor based systems can simultaneously measure and process data from multiple parameters.

A number of needs drove the integration of microprocessor and instrument. First, operators wanted instruments to come with the ability to carry out all the stages in figure 3 (minus stage F). Then they wanted instruments to simultaneously operate as up to N instruments measuring N parameters so that step F could be carried out by the instrument. In other words, there was a need for microprocessors to move into instruments because

1. The role of instruments changed from just monitoring one facet of a process to monitoring multiple facets of the process either instantaneously or over some length of time.
2. The amount of information extracted from measurands have increased tremendously over the years. For example, waveform readings are now routinely processed to obtain various statistical properties.
3. Instruments simply needed to do more. For example, to simulate a system with N instruments measuring different variables to allow stage F of fig 3, it should be possible to link up N separate instruments through a standard port like the parallel port and more usually the General purpose Instrument Bus (GPIB).

The above factors were enough to create the need, but in themselves would not have brought about the situation we

have today where almost every instrument of some complexity contains a microprocessor. Two more factors aided the integration.

First, there has been an exponential increase in the amount of processor power available over the years. Intel's Gordon Moore first predicted a mathematical basis for the increase in the late 1960s. Now referred to as Moore's law by computer scientists, the dictum states that microprocessors double their capacity and capability every 18 to 24 months. Figure 4 shows the development seen in microprocessor speed from 1976 to 2000 and it can be seen to reflect Moore's assertion.

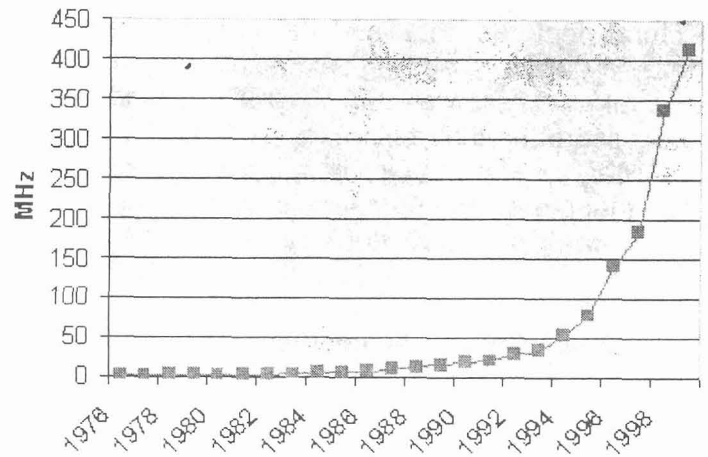

Fig. 4: **Desktop computer processor speed.**
Source: Berndt *et al.*, 2000, Table 1.

The second reason why microprocessors found their ways into instruments is that microprocessors have simply become very cheap. A corollary to Moore's Law is that the price paid for a particular processor capacity halves every 18 months. This fact can be attested to by thousands who bought a Pentium III computer running at 500MHz at ₦100,000 in 2000 and who can now, for the same price, buy a Pentium IV running at 3.0 GHz[1]. The cheapness of these chips has made it possible to embed them in not just instruments, but household appliances and handheld devices.

One further development made it possible to perform the complex algorithms often required in today's microprocessor-based systems: the advent of Digital Signal Processors (DSPs). A DSP is usually a RISC (Reduced Instruction Set Computer) microprocessor with special architectural features that are designed to enhance its performance while handling complex algorithms. The fundamental difference in DSPs and general microprocessors is the ability to perform more complex mathematical operations in a single clock cycle. An operation that a general purpose microprocessor would need software to carry out in 20 clock cycles can be executed in hardware by a DSP in one cycle

The introduction of microcomputers into instrumentation owes much to one basic fact: some of the most important functions of a modern instrument can be performed by a computer if the right software can be written. With reference to fig 1, as long as a way can be found to send data from stages A and B to the computer, that computer can be used to perform all the remaining stages for any number of simultaneous measurements. Computer based

1 Clock speed is not the only indication of a microprocessor's power. Other things being equal, a 1000MHz computer is NOT twice as fast as a 500MHz computer.

instrumentation has received a boost in recent years stemming from rapid technological strides in electronics, computers, and standardization in platform technologies. This class of devices is increasingly referred to as 'Virtual Instruments' .

A Virtual Instrument (VI) is defined (Gopalan, 2003) as any type of test instrumentation that is fundamentally software reliant and primarily dependent on a computer to control test hardware, analyze, and present test results. Typically, VIs are plug-in card based instrumentation products for PC platforms. Access, control, and set-up of VIs are completely software controlled. In recent years, other products based on *USB (Universal Serial Bus)* and *IEEE 1394* are also available.

There are two basic types of Virtual Instruments. Simple VIs are PC based oscilloscopes, Arbitrary Waveform Generator, waveform analyzers, function generators, logic analyzers, voltmeters, and data acquisition devices. These are cards/modules that can simply be plugged into a personal computer and the accompanying software allows the user to perform relevant measurement.

The more complex VIs are VXI (VME Extensions for Instrumentation) and CPCI/PXI (Compact PCI extensions for Instrumentation) based modules that need to be configured as a test system. This involves development of specific application dependent test software based on the individual module PnP (Plug and Play) drivers. A variety of high performance analog, digital, switch, and instrument function modules are available for this purpose. These are mostly used to develop dedicated test systems, data acquisition systems, and Automatic Test Equipment used in manufacturing applications

There are many advantages to using virtual instruments such as publishing on-line reports, sharing data with other systems, distributing executions, and distributing measurement nodes. These techniques increase the efficiency and performance of the engineering enterprise. Networked technologies such as Ethernet, HTML, wireless communication and the Internet are improving methods for taking and automating measurements. Network technologies can be incorporated into hardware and software designs to explore the benefits of networked measurement solutions. It is possible to take measurements at a location physically separated from your host PC. For example, data collection in harsh environment or across a large geographic area often require I/O to be near the phenomena being measured, while analyses and presentation occur in a safe or centralized location (consider the recent unmanned probe to Mars).

Modern instrumentation has largely mirrored the move in the computer industry from stand-alone systems to network-centric solutions. For example, it is now possible to use network technologies to deploy a measuring node, with the desirable measurement capabilities in the remote location that returns data over the network for further analysis and presentation as shown in figures 5 and 6.

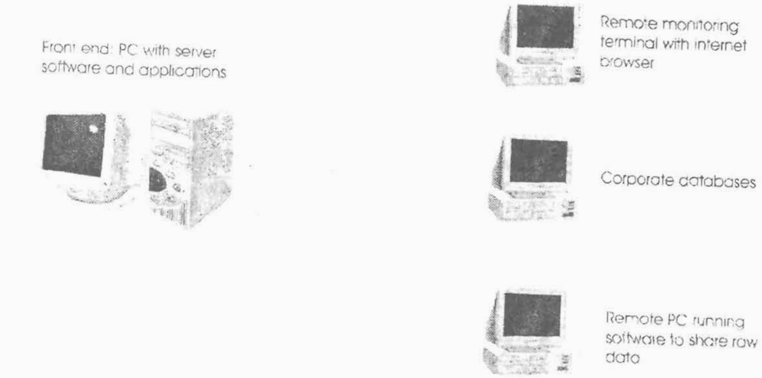

Fig 5 Remote publishing

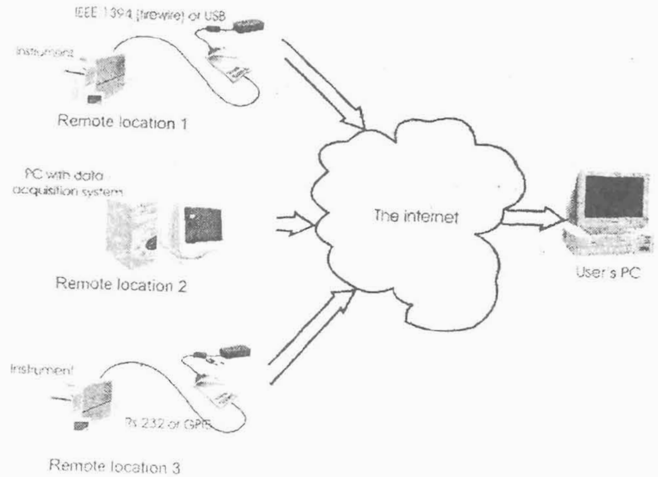

Fig. 6 Remote measurement

MY CONTRIBUTION TO CIRCUITS AND INSTRUMENTS DESIGN

a. Circuits for magnetically suspended systems.

My earliest work involved the design of circuits for the control and stabilization of magnetically suspended systems. These have applications in the field of high-speed transportation and in particular for use in contactless, ultra-fast magnetically suspended trains and frictionless conveyor belt systems. Magnetic suspension that employed optical transducers had been investigated by Jayawant and Rea (1968); and Kehinde (1978). Optical transducers in magnetic suspension systems however have many limitations and are hardly used again. The work reported by Kehinde (1980) dealt with the design and construction of circuits for magnetic trains in which inductive transducers were used to sense the position, velocity and magnetic force sustaining a system. Suspension here was by means of attracting forces between a ferromagnetic steel rail and electromagnets attached to the body of the train or conveyor belt as shown in figures 7 and 8.

Although it has not taken over traditional traction trains, ultra fast suspended has made their debuts in the more advanced countries. Among other works in this field, L. O. Kehinde (1984)

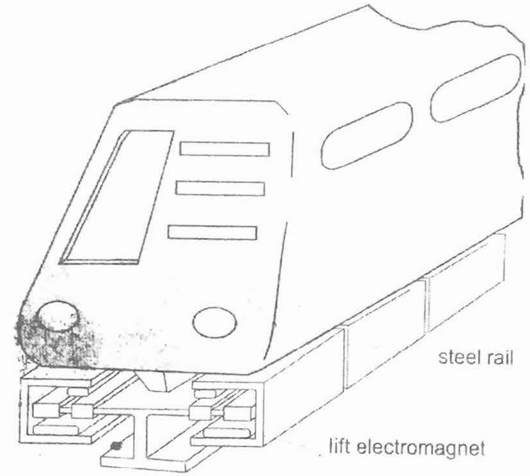

Fig. 7 Magnetically suspended train

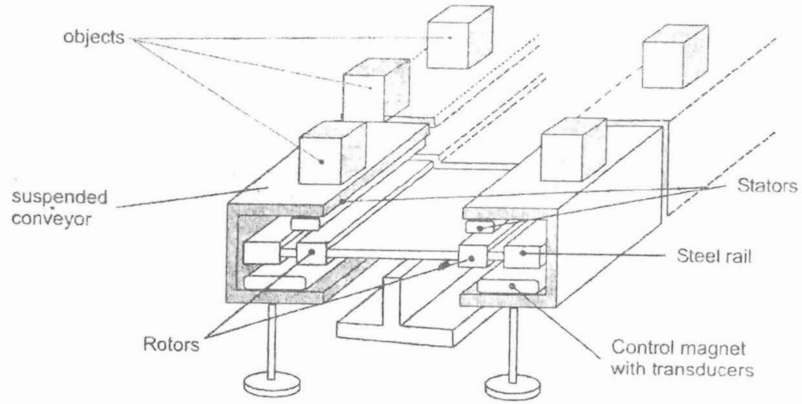

Fig. 8. Magnetically suspended conveyor belt

showed that the limit cycle oscillations in magnetic systems hitherto thought to have emanated from the I^2R non-linearity of the force equation was actually caused by saturation in the electronic circuits.Ladies and Gentlemen, permit me to mention a few of my latter works, which we:e centered on the following areas:

b. Circuits and instruments' design for teaching and research.

The dearth of teaching and laboratory instruments that engulfed many Universities in the 80s was indeed a setback to the teaching of Electronic and Electrical engineering. Some of my works here have contributed, in some measure, to locally developed laboratory instruments that supplemented theoretical teachings. For example, Olaniyan and Kehinde (1986) described a circuit for scrambling transmission data by remote skewing. Using this method, it was possible to ensure secrecy of transmitted data as well as conserve energy loss by keeping the average dc content of the transmitted information zero. In 1988, Kehinde reported a design of a versatile user interactive data transmission training system, comprising a transmitter and a receiver section. This module provided training in the operation of counters, multipliers, ADC/DAC, shift registers and latches. Estimated cost was far les than imported one despite its more advanced versatility. Kehinde (1988) also reported the design and constructions of a programmable operational amplifier for undergraduate laboratory usage. The beauty of this module was that a single experimental kit could be programmed to work as a differentiator, integrator, filter, and amplifier as the need arose thereby eliminating the

need to buy or build them as separate modules. Various experimental procedures were advanced. Other works in circuits and instruments for teaching and research include Kehinde and Ekuwem (1991) and Kehinde and Makinwa (1995).

c. Instruments for medical applications.

In 1984, L. O. Kehinde, L. A. Buraimoh-Igbo and R. O. A. Makanjuola developed an electronic rotameter for quantitative evaluation of rotational behaviour in rats after injection with certain brain stimulating drugs employed in the treatment of psychiatric disorders (Fig. 9). Earlier rotameters usually employed electromechanical counters and timers, which in many cases are unwieldy in nature. Our report described a new method that employed electronic counters, timers and displays. Clockwise and anticlockwise rotations were detected using integrated circuits and Schmitt triggers.

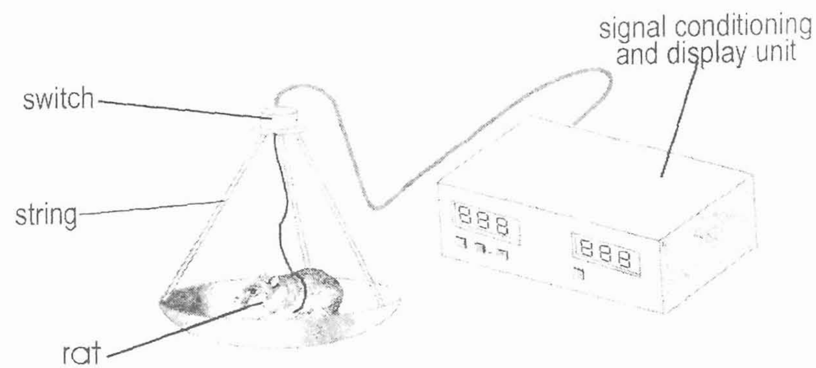

Fig 9 Rotameter for the study of rotational behavior in rats

Using the equipment, the effects of drugs on the brain using different types of stimulants was effectively studied. In L. O. Kehinde and A. Olunu (1988), a computer-based heart-beat monitor for hospital use was designed. In this design, pulse sensing was achieved via a light –emitting detector that detected heart-beat motivated concentration of blood inside a finger tip. This method assured that there was no contact between patient and electrical power rails. A microcomputer automatically calculated pulse rate per minute, plotted it on the monitor and continuously recorded the numerical value (Fig. 10).

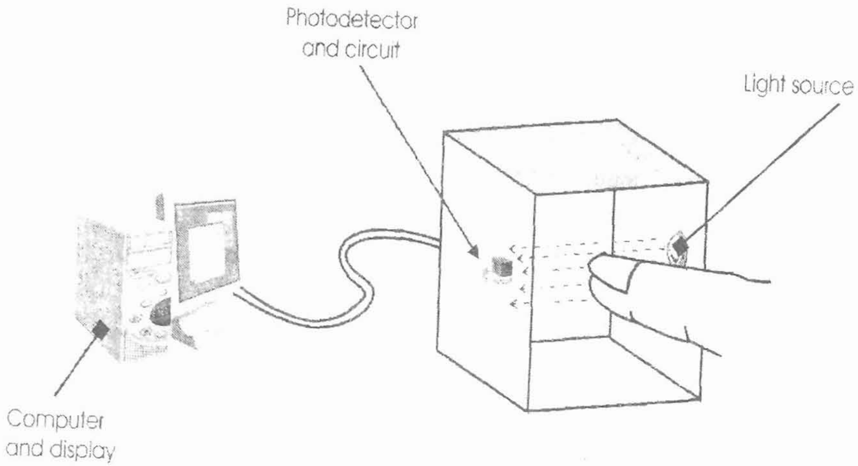

Fig. 10 Heart beat monitor

A very interesting work done by L. O. Kehinde, L A. Buraimoh-Igbo, T. O. Oyebisi and M. Olaogun (1994)

reported a data acquisition system for measuring ground foot forces in patients with pathological gaits e.g. polio patients. In this work, strain gauges were employed as foot –force sensors. The forces measured were transmitted to a remote computer using IC transmitters. A mobile assembly carried by the patient consisted of a pair of instrumented shoe, a signal processor and an FM transmitter, while the stationary counterpart was made up of an FM receiver and processing module (Fig. 11). The design unlike earlier ones enabled a new freedom of mobility for the patient. Preliminary results indicated that the instrument could be used in the assessment of lower extremity defects, thereby assisting in design of appropriate shoes for patients.

d. Instruments for agricultural and industrial usages

Living plants are subject to water loss through the surfaces of leaves and other plant parts. In plant physiological research, it is important to be able to measure the rate at which water vapour is lost from such surfaces, particularly since the ability of a plant to survive in dry and hostile climates depends mostly on its ability to retain its internal water. The diffusive resistance, that is, the resistance presented to diffusion of water vapour by plant parts is accordingly an important parameter in plant studies. It is also important, especially where there is controlled irrigation to monitor this loss and use the information obtained to control the rate of irrigation. Various attempts to measure the diffusive resistance had been reported earlier (Kanemasu et al. (1969)). Some of these commercially available model suffered some deficiencies in use as they required timeconsuming recalibration to make them operative in the field, particularly in conditions of varying temperature and humidity.

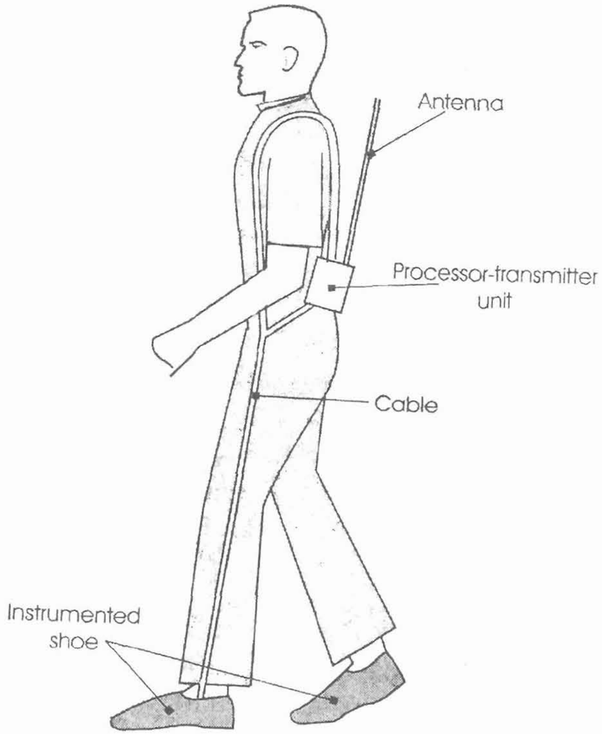

Fig. 11 Mobile unit for foot force measurement

In addition, erroneous readings also arose due to humidity leakage into the cup sensor. L. A. Buraimoh-Igbo, L. O. Kehinde and A. C. Adebona (1984) reported an instrument for the measurement of the diffusive resistance of leaves

that overcame these difficulties. This design incorporated a means for passing dry air into the cup, a circuit for simultaneously measuring the temperature inside the plant specimen cup and a circuit for making correction for temperature variation and humidity leakage from external surroundings. The uniqueness of this design in 1984, earned the designers a United Kingdom patent no. GB 2101746B.

Also in the same year, L. A. Buraimoh-Igbo and L. O. Kehinde (1984) looked into an instrument to reduce industrial health risks. It had been appreciated that exposure to noise could have damaging consequences on personnel who have to operate in noisy environments e.g. near machinery. Furthermore, it had become apparent that the amount of damage was related to the cumulative amount of noise to which personnel are exposed thus resulting in early deafness or impaired hearing.

Noise dosimeters had been developed earlier but many of these required visual attendance or calculations which at times, might result in the permissible noise dose being exceeded before detection. Working with a colleague, we designed an instrument to measure noise doses in an industrial environment. Our design measured noise exposure directly and had an audio alarm that was triggered whenever the allowable noise dose limit was reached so that little personnel attendance was required. It also had visual displays of noise dB and noise dose so that approach to the critical level could be visually observed. This design also won a United. Kingdom patent no. GB 2098733B.

Mr. Vice Chancellor, sir, Ladies and Gentlemen, you might want to ask what happened to the patented measuring instruments. Your guess is as good as mine. The patents most likely had made someone, somewhere much richer.

Other instruments that could be used in industry were reported by Akinde, Kehinde and Inyang (1989), Kehinde and Osasona (1990). For example, the direct reading water level Indicator reported by Kehinde and Osasona (1990) employed copper strips to measure discrete levels of change in water levels. Various forms of liquid level indicators had been presented earlier (passé, 1965). In many of the earlier versions, the liquid was artificially coloured and combinations of lamps and transducers used for level detection. However, in many cases, colouration of liquid was not acceptable. A modification presented by Notzel in 1981 represented discrete levels by light emitting devices, L.E.D. In our work, digital comparators, and other digital circuits were designed to obtain a direct reading on a digital voltmeter. By using appropriate sensors that can withstand corrosion, the equipment can be adapted to measure soil moisture, depths of underground petrol in petrol stations e.t.c.

e. Microprocessor and Microcomputer-based Instruments

The microprocessor, and indeed the microcomputer play vital roles in every aspect of life, from usage in watches, microwave oven, refrigerators, personal computers, robotics to spacecrafts. Every application has its social and engineering challenges as reported in A. D. Akinde, and L. O. Kehinde (1984). An important factor to consider also in microprocessor and microcomputer application is the problem of correct interfacing and this was discussed in A. D. Akinde, and L. O. Kehinde (1987). L. O. Kehinde, K. A.

Makinwa and A. D. Akinde (1987) reported a novel microprocessor-based vector graphic system for microcomputers. This work was an improvement over the conventional raster-scanned displays that usually end in staircase appearances of straight lines and large memory space requirements. In the reported work, two end point data are only required to specify a straight line. The amount of memory reserved for graphics is made completely user-determinable.

Today's electronic data acquisition derives its success from the speed of the microprocessor. This is particularly important in industrial data collection and meteorological acquisition of weather variables. Apart from the work done by L. O. Kehinde and T. R. Ojetayo (1995) on the development of a computer-based industrial controller, L. O. Kehinde and E. E. Ekuwem in 1995 designed and built the first locally made automatic microcomputer-based weather station. The station, which was built as a model for the then Nigerian Meteorological Services monitored up to five meteorological variables, stored and plotted them automatically. Transducers used were of the variable resistance types. The effective cost on completion was less than 20% of the important ones. Politics and bureaucracy ensured that mass production was never materialized.

I wish to recollect that as a result of our work on meteorological Instrumentation, the World Meteorological Organization (W.M.O) appointed me as a consultant to the Federal Meteorological Services, Lagos in 1993 and to the Department of Meteorology, Federal University of Technology, Akure in 1995. Other works done in the field of meteorology addressed the design and use of appropriate instrumentation for the measurement of air-borne environmental pollutants (L. O. Kehinde and E. E. Ekuwem, (1990)), and general development of meteorological equipments, networks and Telecommunication links for monitoring purposes. (Kehinde, and Ekuwem (1995), Ekuwem, Kehinde and Ajayi (1997)).

f. Nuclear Instrumentation and Neutron Activation Analysis

I must at this time mention that, Obafemi Awolowo University, in her bid to purchase an experimental accelerator and a nuclear reactor, facilitated my sponsorship by the International Atomic Energy agency on a fellowship to do some work in Nuclear Instrumentation at the University of California, Berkeley in 1997. Professor A. F. Oluwole, an exceptional scientist and motivator, then of the Department of Physics and the then director of the Centre for Energy Research and Development CERD, played an important role in ensuring my interest. Our group reported for the first time the assay of Nigerian ores and in particular Uranium by passive gamma ray spectrometry (L. O.Kehinde, A. F. Oluwole, O. Osin and R. Fleming (1983)). We also determined trace elements by Neutron Activation Analysis; (H.A.Hannan, A. F. Oluwole, A. B. Borisade, L. O. Kehinde, A. Oshin, J. B. Aladekomo, and R. E. Jervis (1983), O. I. Asubiojo, L. O. Kehinde, A. H. Hannan and A. F. Oluwole (1983)). Unfortunately, lack of interest and poor financial backing at crucial times, by successive governments, have rendered the sincere and relentless efforts of the past directors of the Center for Energy Research and Development almost unnoticeable

CONCLUSION AND RECOMMENDATIONS

Mr. Vice Chancellor, Ladies and Gentlemen, please permit me to make some remarks of importance here.
I cannot but appreciate the fact that I was one of the pioneering students of a course called physics with Electronics, which metamorphosed into Electronics and finally to Electronic and Electrical engineering. As a result of this background, I had enough of Physics background and this made a difference to the quality of the "Engineer" in me. It is said that the best engineers are those who started as Physics graduates. This cannot be far from the truth as proven by various colleagues of Physics who now dote the field of Engineering. How good would it be if scholarships, even if limited, is given to students of Physics who wish to later go into Engineering.

The tragedy of Engineering education in Nigeria is exposed by the fact of the archaic equipment still in use in the laboratories. It is sad to note that some equipment on which I trained as a student are still adorning our laboratory tables. Our syllabi will need to be revised to meet current global expectation and industrial demands. This should involve academic-industry cooperation. With pain, I note that the Department of Electronic and Electrical Engineering of he Obafemi Awolowo University' probably the best in the nation, based on Industry feedback and absorption into the job market cannot boast of a building of its own.
I am hopeful that the University Administration would look into this and give priority to relocation of the Department. The pioneering efforts of late Professor V. A. Williams, Professor I. E. Owolabi, Professor A. F. Oluwole, Professor J. B. Aladekomo, Professor F. A. N. Osadebe, Professor G.

O Ajayi and others who have sacrificed a lot to make the Department what it is should not be laid to waste. My Vice Chancellor, Professor R. O. A. Makanjuola; your personal interest in the upgrading of the teaching infrastructure of the Department of Computer Science and Engineering, of which I am an associate staff must be commended. I am hopeful that similar assistance would be rendered to the Department of Electronic and Electrical Engineering. The Department needs staff, laboratory equipment and a building and it needs them now. You have laboured to ensure that most Departments in the University get accredited. It is true that the Department of Electronic and Electrical Engineering is accredited but the question is , "by whose standards?". Perhaps it is a case of "In the country of the blind, the one-eyed man is king". We want an accreditation we can be proud of anywhere in the world; one that our conscience will accept without turmoil; an accreditation supported by modern equipment and laboratories.

You will notice that many designed equipment mentioned in this lecture and which are vital in the sustenance of life in one way or another did not get to fruitful mass production. I wish to recommend that:

- The University should give priority attention to patenting and further development of new designs by staff. There should be a special unit for interaction with Government and Industry toward the commercialization of equipment designed by staff.
- Priority should be given to harnessing the financial and positional clout of Alumni who can sponsor new buildings and equipment.
- Efforts should continue to get Government or the University to fund Equipment design appropriately.

- There should be a testing laboratory for designed equipment and for small scale development

Mr. Vice Chancellor, Ladies and Gentlemen, I cannot end this lecture without giving thanks to God and giving Him all the glory for whatever little contribution I have made in my field of Electronic and Electrical Engineering. Nothing could have been achieved without Him. I dedicate all to Him. To all here, who have spared the time to come, I say "thank you" for your attention.
God bless you all.

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