In Phase

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Is ANALOG a DEAD art ?

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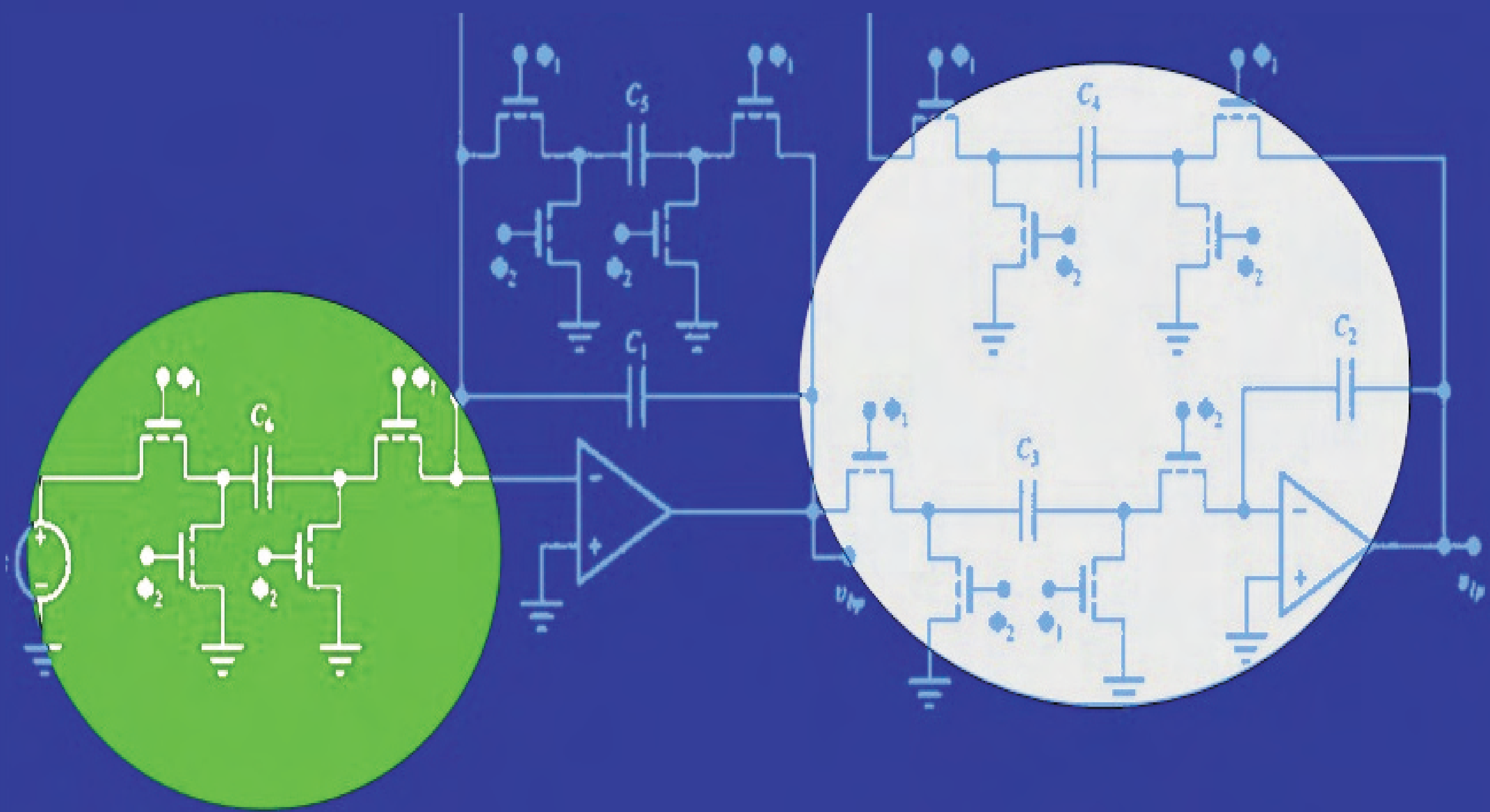

Alumni Speaks
Amitabh Dixit : Intellectual Property Rights

In the Beginning: A peek into the history of electronics

Numerical Electromagnetics : An Introduction

In Phase, October, 2007

From the editor

"In theory, there is no difference between theory and practice. But in practice, there is."
Said a famous man once. As budding engineers we know this all too well. Our circuits don't work the way we design them to (if we design them at all!). As human beings we know this because our lives have not gone the way we thought they would. As students we know this because we have let go of a lot of opportunities. Sometimes however things go differently. In Phase is one of those things. Yes, we are back bigger and better. And this time we have a request for you.
Here in IITG we dream big. And we dream often. But just as often those dreams die in the graveyards of our minds. In Phase is another dream our editorial staff has given birth to but unlike other dreams it did not die. It stayed alive. But for it to continue staying alive we need your help, only with your continued input and readership can In Phase stay alive. So this is a request from me to all our readers. Let a hundred articles be written, let a hundred dreams come alive.
I would like to thank the faculty and the editors for the time and effort they have spent to bring out this issue.

Akash Baid
editor-in-chief

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INTELLECTUAL PROPERTY RIGHTS

by Dr. Amitabh Dixit
ECE Alumnus : class of '99

Dr. Amitabh Dixit received the B. Tech. degree in Electronics and Communication Engineering from the Indian Institute of Technology, Guwahati, Guwahati, India in 1999 and the M.S. and Ph.D. degrees in Electrical Engineering from the Southern Methodist University, Dallas, Texas, USA in 2000 and 2004 respectively. During 2004, he worked at the Nokia Research Center, Irving, Texas, USA where he was involved in standardization activities involving then upcoming IEEE 802.11n (high throughput Wireless LAN) and IEEE 802.16e (WiMAX) standards. Since 2005, he has been with the Intellectual Property Rights department of Nokia Inc. where he is currently employed as IPR Manager. Dr. Dixit teaches graduate and undergraduate level courses in the Electrical Engineering department at the Southern Methodist University, Dallas, Texas as an adjunct faculty and is a registered patent agent in the USPTO.

What is IPR and why is it important to be IPR aware ?
Intellectual property rights or IPR is a generic term used to refer to rights associated with creations of mind. Since we all have our moments of brilliance (and I believe that the first set of readers of this article have these moments with a rather high frequency), it is imperative that we understand the concept of intellectual property and the rights that can attach to it. IPR comprises three main categories: namely, patents, copyrights and trademarks. Herein, we will focus solely on patents since this is the type of IPR that the readers are expected to encounter most.

In general, any person who invents a new and useful process, machine, article of manufacture, or composition of matter may apply for a patent on his or her invention. Imagine if it occurred to you 10 years ago that adding a camera to a cellular phone was a good idea. Despite people poking fun at you, you went ahead and obtained a patent on your seemingly ridiculous idea. Let us now flash forward to today. According to a recent survey, there are about 200 Million cell phone subscribers in India alone. Assuming that only half of them have a camera phone and cell phone manufacturers agree to give you a paltry Rs. 20.00 (less than 1% of the average price of a cell phone) for using your patented invention, you could be earning a paycheck of Rs. 2 Billion while sitting in the comfort of your home! Imagine the impact of this patent on not just your life but also on the economy of our country. Such is the promise of IPR! It provides a level playing field where an entity's (company, country or an individual) material resources mean little and innovation is the key to success.

" There are about 200 Million cell phone subscribers in India alone. Assuming that only half of them have a camera phone and cell phone manufacturers agree to give you a paltry Rs. 20.00 (less than 1% of the average price of a cell phone) for using your patented invention, you could be earning a paycheck of Rs. 2 Billion"

The wide gap between India and many western countries caused by lack of infrastructure can be bridged to a great extend by obtaining patents on key technology areas! It is no wonder then that many reputed market analysts agree that IPR is the currency of future! A brief look at the number of patents filed by major corporations and universities attests to the fact that they are listening! In 2006, IBM was the top patentee in the United States Patent and Trademark Office (USPTO) with 3,621 patents, surpassing it own record set in the previous year.

Patent as a contract - The best way to understand a patent is to treat it as a contract between the State and the applicant /inventor. The inventor provides a full disclosure of the invention such that after reading the patent, any *person of ordinary skill in the field of invention* (often referred to as one of ordinary skill in the art) is able to make and use the invention without *undue experimentation*. Consider the following example to illustrate the matter: "A" invents a wooden stool which comprises four parallel wooden legs attached to the bottom side of a planar wooden seat member. To be able to get a patent on this wooden stool, A will have to write and submit to patent office, a patent application in which will be described in full detail, how to make and use the stool. The description, in part, might read as follows: *Sand and polish one side of the planar wooden seat member to make it comfortable for sitting. Attach the longitudinal ends of the four wooden leg members to the unpolished side of the wooden seat member using a dove-tail joint.* A person who is not of ordinary skill in the art (in this case, carpentry), might not know how to sand the seat member or how to apply a dove-tail joint. However, a person of ordinary skill in the art will know this and hence the inventor/applicant need not explain this aspect. Similarly, a patent application in the field of electrical engineering need not describe Ohm's law, since it is reasonable to expect that an electrical engineer will understand Ohm's law.

The test of undue experimentation arises mostly in chemical inventions where often a range of temperature and pressure is required for an experiment to yield optimal results. It is likely that a person who reads the invention disclosure to make the chemical composition will have to try a few combinations of pressure and temperature for optimal yield. This is acceptable as long as the experimentation is not "undue". The patent office rewards an inventor for this contribution to the public's knowledge chest by granting exclusionary rights to the invention. This implies that if A is granted a patent on the stool, it gives A the right to stop anyone from making, using or selling the stool.

How then, is the patent useful to the society if no one can make, use or sell the teachings of the patent i.e. the invention? The utility comes from the fact that the society is allowed to “practice” the invention. By which it is meant that any one can make the stool for experimentation and for improvement. For example, it is Ok for inventor B to make the wooden stool as taught by A's patent and experiment with it. Say, B realizes that A's stool is not stable enough since the legs are parallel. In this case, B might conceive that the stool can be made more stable by extending the legs outwards from the direction of the joint with seat member towards the floor. B may very well file a patent on this new, more stable stool and even though in coming up with his new invention, he has practiced A's

invention, he has not infringed A's patent rights. Also, others may make, use and sell the invention after taking a license from A.

Myth: Patents promote monopoly and are a nuisance - Individuals who add to society's knowledge chest are rewarded by the grant of exclusionary rights and as such are encouraged to constantly innovate. Society in turn benefits from constant innovation which ensures that quality of life is continuously enhanced. The exclusionary rights are not intended to deprive the society of the benefits of the invention. In fact, patented inventions have pervaded every aspect of human life, from electric lighting (patents held by Edison et al) and plastic (patents held by Baekeland), to ballpoint pens (patents held by Biro) and microprocessors (patents held by Intel, for example). The sole purpose of these rights is to ensure that the inventor is rewarded and is encouraged to innovate more. Others who wish to make, use or sell a patented invention may, and frequently do, take a license from the inventor to do so. For example, if company C wishes to manufacture and market A's stool, it may take a license from A to do so. This ensures that A is rewarded for contribution to the society's knowledge chest while company C may make their own profits by selling A's invention. Consider another example: Industry's technology leaders such as Nokia Inc. have invested Billions of Euros in research and development of GSM standards. After years of hard work and enormous amount of money spent, would it really be fair for a company which did not contribute to the technology at all, to be able to use these technical specifications and start manufacturing and selling their own GSM handsets? Patents right ensure that companies are not penalized for investing their resources in advancing technology but are compensated fairly thorough collection of licensing revenues from any other entity which wishes to use the technology developed by them.

“IPO conducts a test twice each year and candidates qualifying this test are registered as “patent agents”. A patent agent is allowed to represent others in the matters of IPO and can file patent applications on behalf of others”

How to obtain a patent? To be able to obtain a patent, you must first write and submit a patent application to a patent office. This application must comply with the format specified by the patent office. Note that a patent granted by the Indian Patent Office grants the inventor(s) exclusionary rights only in India. Similar is the case with all other patent offices in the world. Though the specifics of the format may vary depending upon the patent office (Indian Patent Office (IPO), European Patent Office (EPO), USPTO, etc.), a common requirement is that the application must have an “enabling disclosure”, “claims” and drawings, if needed to understand the invention. Once the patent application is submitted and the necessary fees is paid, it is examined in due course by a patent examiner in the patent office who checks the application for compliance with the format and checks for relevant “prior art” to see if the invention is really new. As mentioned earlier, for a patent to be granted on an invention, it must be new and useful. For example, for A to get a patent on his stool, the stool must be a new apparatus and must work for its intended purpose (it must not topple over or fall every time someone sits on it i.e. it must serve its intended purpose of seating). Once the examiner is convinced that the patent application and the invention meet all the requirements of the patent office, the patent will be granted. Every patent has a lifetime beyond which all exclusionary rights expire. For most patent offices in the world, this time period is twenty years from the date the patent application is filed (true for IPO and for USPTO with certain exceptions). Once this period expires, the invention is free for all to make, use and sell.

Parts of a patent – As mentioned in the previous section, a patent consists of three parts: description, drawings and claims. The description provides an enabling disclosure of the invention such that a person of ordinary skill in the art may be able to practice the invention. Drawings in a patent application are essential only when they are critical in understanding the invention. However, as a practical matter, drawings are always necessary except in some cases of chemical inventions. Claims, arguably, are the most important part of a patent and lay down the legal boundaries of the intellectual property protected by the patent. The best way to understand claims is to consider the analogy of real estate. Say you own a 1 acre piece of land. If you fence only a portion of it, you are indirectly implying that it is OK for people to trespass the remaining piece of your property. In the domain of intellectual property, fencing is provided by the “claims”. Say A discloses in his patent, how to make a wooden stool, a plastic stool and a metallic stool. However, in the claims portion of his patent, he only mentions the wooden stool. The patent office in this situation assumes that A has dedicated the other “embodiments” of his invention, namely the plastic and the metallic stool to the public and any member of public can make, use and sell the plastic or the metallic stool without infringing A's IPR.

Career advice – IPR is gaining importance in India and most companies are filing increasing number of patents in the IPO. IPO conducts a test twice each year and candidates qualifying this test are registered as “patent agents”. A patent agent is allowed to represent others in the matters of IPO and can file patent applications on behalf of others. In light of increasing IPR activity in India, most major companies will soon be seeking to employ qualified patent agents. The patent agent certification is valuable qualification to have and will be a stand-out achievement that will distinguish you from other competing candidates. Even if you don't wish to represent others in matters of IPO, being IPR aware and understanding the business of IPO will help you in your own work.

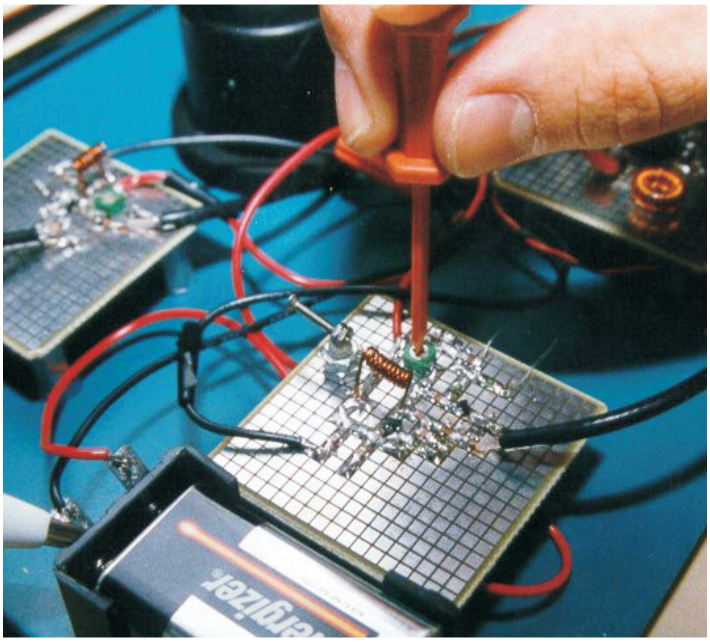
Is Analog a DEAD art??

Once upon a time, all electronics was analog. With passage of time analog electronics evolved into digital and as a result of its widespread application and tremendous popularity we live in the so called digital era. Over the past decade or so, though, the proportion of analog in an integrated-circuit design has been shrinking, until it now represents only about 20% to 25% of the design. In this article we attempt to examine the relevance of analog electronics in today's “digital” world. While this statement itself seems to suggest the demise of analog electronics, we would like to remain more skeptical regarding this issue. With the help of a couple of examples, we hope to demonstrate the (diminished) importance of analog electronics.

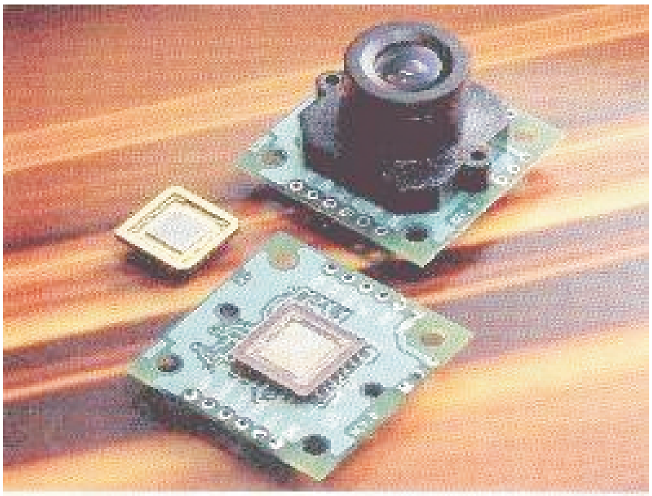
First of all, let us differentiate between analog and digital electronics. Analog Circuits are those which accept / output a continuously variable signal whereas digital Circuits, on the other hand, operate at a set of discrete levels, rather than over a continuous interval. If we look closely into digital electronics, the two discrete levels namely logic '1' and '0' are realized using analog voltage levels. Most commonly logic '1' is realized by analog voltage 5V and logic '0' by analog voltage 0V.(With some noise margin depending on TTL/CMOS technology) . The most basic digital component NOT gate is realized using complementary MOS/BJT's .So, if we go by this realizations we can say that every digital component is analog in nature, we live in an analog era and hence the debate is over. But let's not jump the gun that easily!

Analog V/s Digital

Consider the advantages of digital systems over analog devices: noise levels and design difficulty being the primary ones. Noise is a broad term that refers to unwanted “noisy” signals being superimposed on the “good” signals being transmitted. The effects of noise can be quite easily reduced in digital circuit because of the presence of discrete levels. For example in TTL input signal, high logic is realized between 5 to 2 V and low between 0 to .8 V. So, if the input signal is corrupted between this range the system is immune to the noise. The relatively low probability of such high levels of noise, together with better parity check mechanisms mean that noise plays a very small role in the design of digital systems. But since in analog circuits each analog voltage/current is an acceptable input, they are fraught with information losses and significant care has to be taken to prevent noise.



Design difficulty is another important factor in analog systems being phased out. When one compares a digital and an analog circuit that perform similar functions, the digital circuit will undoubtedly be simpler to design and



debug.

There are several other advantages that digital systems enjoy over their analog counterparts. Transmitting information digitally requires significantly less bandwidth than analog information transmission. A case in point is the newly introduced High Definition TV or HDTV for short. Early HDTV systems used analog broadcast formats, but all recent HDTV systems use digital transmission because of bandwidth considerations.

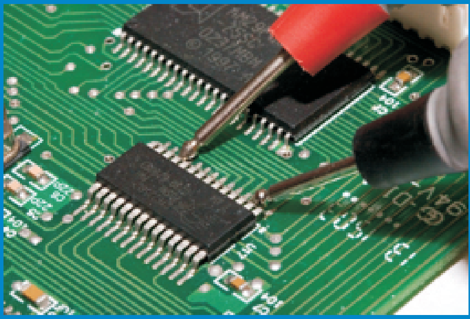
The SVGA Standard

Consider the introduction of the Super Video Graphics Array Standard, defined by the Video Electronics Standards Association (VESA), as a successor to the VGA Standard.

We couldn't put it better than Wikipedia:

“Super VGA was first defined in 1989. In that first version, it called for a resolution of 800 × 600 4-bit pixels. Each pixel could therefore be any of 16 different colors…

Although the number of colors was defined in the original specification, this soon became irrelevant as the interface between the video card and the SVGA monitor uses simple analog voltages to indicate the desired color depth… In consequence, to increase the number of colors a Super VGA display system can reproduce, no change at all is needed for the monitor, but the video card needs to



" Mixed-signal processing have helped designers realize the marketing requirements of the end product by integrating analog ICs, mixed-signal codecs and digital signal processors onto a common silicon device known as mixed-signal processor (MSP)."

handle much larger numbers and may well need to be redesigned from scratch..."

What is striking is the advantage of having made SVGA-rated monitors analog. When the limits of the digital technology were being pushed in the SVGA adapter chips, monitor vendors did not have to worry about their products becoming obsolete.

RF Circuits and Signal Processing

Another field in which digital electronics has had little impact is in RF Design. RF Circuits typically operate at a few Gigahertzes. Since digital processors that operate at such high frequencies have not yet been developed, signal processing and data analysis in this domain is typically in analog form.

Signal Processing is the analysis, interpretation and manipulation of signals. Signals generally need to be amplified before being used by any device. Such amplifiers are always "analog" devices. We could also perform various operations of signals like adding, subtracting, or multiplying two analog signals instantaneously. This would not be possible in digital circuits as the signal needs to be stored for a brief interval before processing. Similarly, filtering analog signals, like the output of a microphone, is simpler than doing them digitally. Having said this we cannot overlook the significant advantages provided by digital signal processing (DSP). DSP is highly cost effective due to the development of low cost of DSP core processors. To add to this in case of up gradation, we only need to upgrade the software which is very easy and efficient compared to hardware upgrade. Now, we all know that real time signals are analog in nature and before DSP core can process, it is transformed into digital domain using Analog to Digital converters (ADC) and once the processing is complete the signal is transformed back to analog using Digital to Analog converters (DAC). ADC and DAC are both analog devices and as we have seen, they are indispensable for digital signal processing. In case telecommunications, modulation and demodulation of signals is one of the most significant operation which is also an analog "activity".

Hybrid Technology evolves

So, we are attempting to say that although digital technology is definitely more convenient, analog electronics has not lost its importance. Now let us examine the middle path, or rather, the path that straddles both: the Analog-Digital electronics.

To start with let us look at mixed signal processors technology. Generally systems contain both analog and digital components and the ultimate integration involves mixed-signal integration. Mixed-signal processing have helped designers realize the marketing requirements of the end product by integrating analog ICs, mixed-signal codecs and digital signal processors onto a common silicon device known as mixed-signal processor (MSP). This leads to advantages in practice, such as no differential nonlinearity and an integral linearity that is not limited by component mismatches.

The hybrid computer is also an implementation of integration of analog-digital electronics. A digital computer

Model AD – 256 released by Applied Dynamics Inc. with 256 amplifiers (Courtesy the Analog Computer Museum and History Center [3])

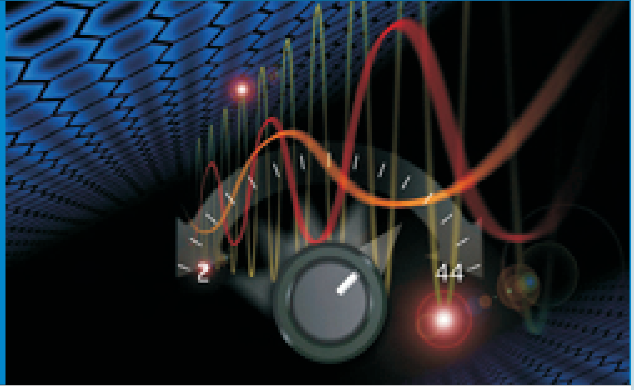
combined with an analog computer, is used to obtain a very accurate but imprecise 'seed' value, using an analog computer front-end, which is then fed into a digital computer iterative process to achieve the final desired degree of precision. With a three or four digit, highly accurate numerical seed, the total digital computation time necessary to reach the desired precision is dramatically reduced, since many fewer iterations are required. In any case, the hybrid computer is usually substantially faster than a digital computer, but can supply a far more precise computation than an analog computer. It is useful for real-time applications requiring such a combination (e.g., the modeling of a weather system).

The World is Analog

We now broach a rather philosophical aspect: The realization that the world is analog. The following paragraphs detail this point of view.

Though we may find it convenient to work with digital technology, the world was, is and will be, essentially analog. No digital device can tell you the exact amount of rainfall in Guwahati yesterday; it'll only give you a digital readout like 17.2 mm Digital technology thus is not in a position to

"After all, 25 years ago many said only low performance digital circuits were possible in CMOS and now we have high dynamic range CMOS radios and 10Gb/s clock and data recovery devices in production."



convey the full extent of the information. By a digital device here, I don't just mean a logic circuit – a little reflection will convince you of the fact that even a foot rule is essentially a digital device. The read-out of every laboratory instrument is, in this sense digital, otherwise we wouldn't be told of "least counts".

On the other hand, if the rain sensor were an analog device, something like two transformer coils within which rain water accumulates, and whose mutual inductance changes as a result of the rain water, the signal that would be propagated through the remainder of the analog circuit would technically have no least count, and we could get better results by simply changing the ADC Converter at the end of the chain, putting in an LCD Display with higher precision, and instead of seeing 17.2 on the LCD, you'd be seeing 17.25. Thus, getting higher precision would be a very simple matter really, and would just depend on the quality of your ADC Converter.

But Are Analog Computers Feasible?

An important point many proponents of digital tech would point out to be the flaw in the preceding argument is, and we have to concur, the suitability of analog devices to carry out such "least count less" arithmetic. While analog devices as such possess no least count, noise, that analog designer's nightmare we talked about some time ago, itself provides (much) more in losses than the marginal percentage accuracy gained.

What struck me as interesting is the fact that we, as humans, accept our input digitally. Reflect on this, the time

right now is 10/8/2007 20:13:36; my weight is 65 kilos; the length of the runway at the Bangalore Airport is 10657 feet.

Yes, we agree whole-heartedly that noise is an issue, design difficulty is an issue, and that we shouldn't allow such problems to get in the bigger picture. Thus, most modern computers are digital, and we support it. Nevertheless, it hasn't stopped a few enterprising folks who have built "small" analog electronic computers. The picture above shows one such computer.

Agreed, digital technology is more convenient in many fields, and in these fields, analog electronics seems to be getting phased out quickly. But there are fields in which analog electronics still retains a niche position, and other fields in which analog electronics brings, along with it, a few surprising advantages

Nonetheless, many will argue that the scaling of CMOS technology to 90nm and below with sub 1V power supplies eliminates needed headroom leaving analog research with no room for creativity at the circuit level. They claim that circuit innovation is for all practical purposes finished and only a radically new transistor or other device will again spur transistor level creativity. They feel the only innovation will be at the architectural level. One such example is background and auto calibration techniques for A/D converters.

In contrast, others will say the new applications will force innovations and that much remains to be exploited with existing transistors. After all, 25 years ago many said only low performance digital circuits were possible in CMOS and now we have

high dynamic range CMOS radios and 10Gb/s clock and data recovery devices in production. Having said that, analog design will continue to thrive – thanks to digital technology. The latter will keep enabling new applications for high-performance analog, as the interfaces to the physical world increase in variety and become more sophisticated. The promise of nanotechnology and biotechnology, if fulfilled, will only help accelerate this trend. The next growth cycle will be multi-disciplinary, focusing on 'systems' rather than 'circuits' The role of micropower and digital-assisted calibration techniques will be expanded. The difficulties posed by decreasing voltage headroom will eventually mean more analog creativity, not less. In the end, analog designers will do what they have always done: they will rise to the challenge.

So, it seems natural to reject any forecast of the demise of analog electronics; it is after all, an analog world.

Anurag Nilesh, Mukund R, Nipun Sehrawat,

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Computer Science and Engineering

Introduction to Numerical Electromagnetics

- invited article from Dr. Rakhesh Singh Kshetrimayum

Maxwell's Equations

From our basic electromagnetic theory, we know that the four Maxwell's equations which were first formulated by the legendary scientist James Clerk Maxwell in 1873 along with the electromagnetic boundary conditions describe any kind of electromagnetic phenomenon in nature excluding quantum mechanics. Due to the linearity of the four Maxwell's equations in the differential forms, it may appear rather easy to solve them analytically. But the boundary and interface conditions make them hard to solve analytically for many practical electromagnetic engineering problems. Hence one has to resort to use experimental, approximate or numerical methods to solve them. With the advent of fast digital computers, numerical methods for solving Maxwell's equations also known as Numerical Electromagnetics /Computational Electromagnetics has been very popular in the last decades. An advantage of this is that it is possible to simulate a device/experiment/phenomenon any number of times. In that way, we can try to achieve the best results before actually doing it experimentally. Sometime experiments are dangerous to perform like lightning strike on aircraft.

1. Develop integral equations using potential theory along with appropriate boundary conditions or alternatively, begin with the time-dependent Maxwell curl equations or their equivalent to develop various numerical methods.
2. Sample these equations in space, and also in time if it is a time-dependent equation, utilizing an appropriate geometrical space grid and suitable basis and testing functions. Note that, depending on the choice of formulation, the space grid may cover the structure and/or the surrounding space.
3. Develop a set of simultaneous equations relating known and unknown quantities. Generally, the known and unknown quantities are the excitation field or its derivatives and the radiated/scattered field or induced current and charge, respectively.
4. Generate a computer solution of this system in space and time as an initial-value problem.

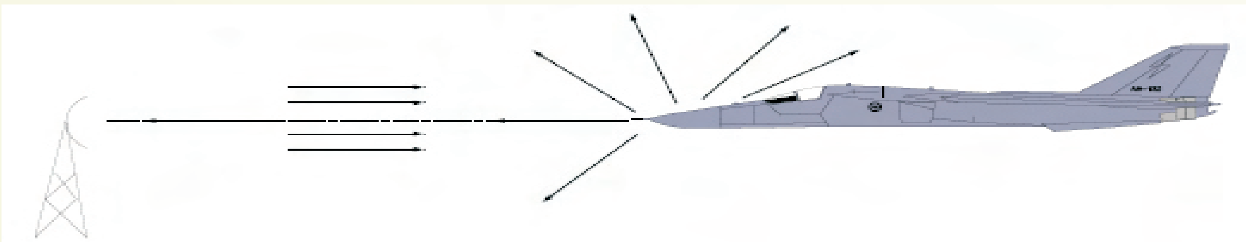

Fig. 1 Field scattered by an aircraft (monostatic configuration we look for reflections in the radar direction)

Applications

There are many applications of Numerical Electromagnetics: Radar cross section calculation, Mobile phone human head interaction, Monolithic microwave integrated circuits, Target identification, Antenna analysis, etc. Many of the applications are impossible to model in every detail. For instance, the interior of the aircraft is filled with many wires that are impossible to resolve in computation. Thus when modeling a radar pulse striking on an aircraft, it is not possible to numerically compute the induced current in every cable. However it may be possible to accurately predict the radar cross section of the aircraft. Whether this is possible depends strongly on the “electrical size” of the aircraft. By “electrical size” we mean the relation between some appropriate scale, for instance, the length of the aircraft and wavelength of the radar wave.

Basic Steps

For any numerical solution in Numerical Electromagnetics, it is necessary to develop the required equations and solve them on a computer. The equations thus developed must include the physics of the problem as well as the geometrical features. The following five steps should be carried out generally in any Numerical Electromagnetics problems:

5. Accuracy check must be performed on the developed computer codes with experimental results before finally employing it for any practical applications.

Table 1

	Time Domain	Frequency Domain
Differential Equation	Time Domain Differential Equation (Example, Finite Difference Time Domain)	Frequency Domain Differential Equation (Example, Finite Element Method)
Integral Equation	Time Domain Integral Equation (Example, Marching-On-In-Time)	Frequency Domain Integral Equation (Example, Method of Moments)

Classifications

In general, all the available numerical methods may be classified broadly into two categories: a) differential equation methods and b) integral equation methods. Although the Maxwell curl equations are usually first encountered in the time domain, i.e. with time as an explicit, independent variable, until recently, most electromagnetic instruction and research has taken place in the frequency domain where time-harmonic behavior is assumed. A principal reason for favoring the frequency domain over the time domain in the pre-computer era had been that a frequency domain approach was generally more tractable analytically. Furthermore, the experimental hardware available for making measurements in past years was largely confined to the frequency domain. The inferior position of time domain electromagnetics began to change with the arrival of the fast digital computers, which has not only profoundly affected what can be done numerically (or computationally), but also experimentally. In Numerical Electromagnetics since 1960s, there has been a steady growth in both time domain and frequency domain modeling. This growth, which began slowly at first, was primarily confined to integral-equation treatments, but it has become almost explosive over the last 10 years as time domain differential-equation modeling has attracted wide attention. All the numerical methods in electromagnetics can further classified into four types as depicted in Table 1.

1. Time Domain Differential Equation models, the use of which has increased tremendously over the past several years, primarily as a result of much larger and faster computers. For example, Finite Difference Time Domain method is employed in Remcom XFDTD [1].
2. Time Domain Integral Equation models, although available for well over 30 years, have gained increased attention in the last decade. The recent advances in this area make these methods very attractive for a large variety of applications.
3. Frequency Domain Integral Equation models which remain the most widely studied and used models, as they were the first to receive detailed development. For example, Method of Moments is employed in Zeland IE3D [2].
4. Frequency Domain Differential Equation models whose use has also increased considerably in recent years, although most work to date has emphasized low frequency applications. For instance, Ansoft HFSS [3] uses Finite Element Method.

Some basic differences between differential equation and integral equation models are as follows:

1. In general, the differential equation methods generate a sparse matrix, while the integral equation methods generate full matrices.
2. Homogeneous/inhomogeneous/anisotropic materials can be handled in a relatively simple manner, while the level of complexity for the integral equation methods varies enormously for each of these cases.
3. The code generation is straight forward for differential equation methods. This is usually not the case for integral equation methods.
4. For differential equation methods, the solution space includes the object's surroundings; the radiation condition is not enforced in exact sense, thus leading to certain error in the solution. For the integral equation solution, the solution space is confined to the object and the radiation condition is automatically enforced.
5. The integral equation solutions are generally more accurate and efficient.
6. Spurious solutions exist in differential equation methods whereas such solutions are absent in integral equation methods.
7. For the differential equation solutions, developing numerical solution using parallel computer architecture is easy. However, for integral equation solutions, this is possible only in the time-domain. A lot of time and effort is needed to generate a parallel version for the frequency-domain integral equation solution.
Note that time domain methods can solve a problem for several frequencies in a single calculation and they can also show the pulse evolution in time.

Method of Moments

Method of Moments is a numerical technique for solving complex integral equations. In electromagnetics, many problems are formulated as integral equations in which analytical solutions do not exist and therefore must be solved numerically. The Method of Moments basically transforms integral equations into matrix systems of linear equations which can be solved using computers. A simple mathematical outline of Method of Moments is given next for a brief introduction to this numerical method.

Consider the following inhomogeneous equation

$$Lu \quad f$$

where L is a linear operator, u is an unknown function and f is a known function. In order to solve for u, let us approximate it by a set of basis functions or expansion functions as given below.

$$u_n \quad \overset{n}{\underset{k\ 1}{}} \ {}_k \ {}_k, \qquad n \quad 1,2,\ldots$$

where $_k$ is the expansion function, $_k$ is its unknown amplitude, k and n are order and total number of expansion functions. Replacing u by u_n and taking inner product with a set of weighting or testing functions w_m

$$\left\langle Lu_n \quad f, w_m \right\rangle \quad 0, \qquad m \quad 1,2,\ldots,n$$

$$\overset{n}{\underset{k\ 1}{}} \ {}_k \left\langle L \ {}_k, w_m \right\rangle \quad \left\langle f, w_m \right\rangle, \qquad m \quad 1,2,\ldots,n$$

which can be written in matrix form as

$$Ax \quad b$$

with each matrix and vector defined by

$$x \quad {}_1 \quad {}_2 \ \cdots \ {}_n$$

$$b \quad \left\langle f, w_1 \right\rangle \ \left\langle f, w_2 \right\rangle \ \ldots \ \left\langle f, w_n \right\rangle^T$$

$$A \quad a_{mk}$$

where T denotes the transpose and a_{mk} are individual matrix elements given by

$$a_{mk} \quad \left\langle L \ {}_k, w_m \right\rangle$$

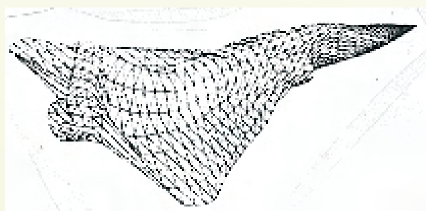

Fig. 2 Triangular mesh generation of an aircraft

Hence, we can solve the unknown matrix x of amplitudes of basis function from above equation as

$$x \quad A^{\ 1} b$$

In Fig. 3, we present the current induced on the aircraft (unknown function) shown in Fig. 1 using the numerical procedure described in [5], which is based on Method of Moments, when illuminated by a 300 MHz electromagnetic plane wave. The plane wave is polarized along the length of the aircraft and traveling perpendicular to the body.

One major problem with Method of Moments is the generation of a dense matrix and for certain problems, the dimension of this matrix can be prohibitively large. Usually, for electromagnetic scattering problems, it is necessary to divide the solution region into small enough sub-domains in order to obtain accurate results.

By 'small enough', we mean about 200–300 sub-domains per square wavelength. In usual practice, we may typically solve for several thousand unknowns for large, complex problems. Quickly, this requirement becomes expensive, in terms of computational resources, and may even become impossible to handle. Hence, we look for alternate schemes to reduce the computational resources. The fast multiple method dramatically reduces the time and memory required to compute radar cross sections and antenna radiation patterns compared to dense matrix techniques.

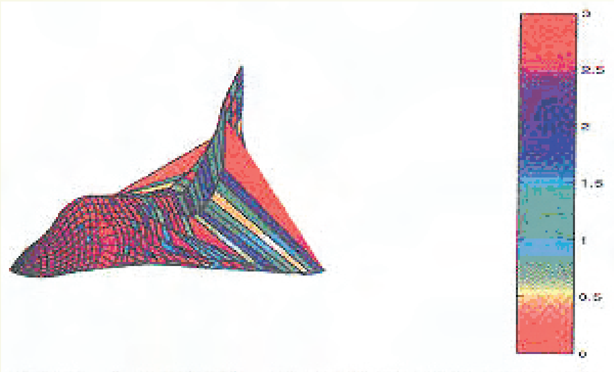

Fig. 3 Current induced on the aircraft by an incident electromagnetic plane wave

It is fairly simple to implement the Fast Multiple Method in a Method of Moment's program to compute the electromagnetic scattering from large bodies of arbitrary shape [6].

In general, these methods like Method of Moments are applicable to scatterers whose characteristic dimensions are of the order of a wavelength. The iterative methods and Fast Multipole Method are then called in to extend the integral equation methods to scatterers of larger dimension. Since the integral equation methods are global in nature, these methods work very well for scatterers with smooth geometries.The local nature of the differential equation formulation may be exploited to cater for the sharp variations, thus creating hybrid techniques. Both differential equation and integral equation method, even with the present day super computers, are suited for computing the radar cross section of a fighter aircraft at best up to 1 GHz. For higher frequencies, the recourse is often taken to asymptotic methods like the geometrical theory of diffraction [7].

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MEMS-The technology of the future...

Imagine a machine so small that it is imperceptible to the human eye. Imagine working machines no bigger than a grain of pollen. Imagine thousands of these machines batch fabricated on a single piece of silicon, for just a few pennies each. Imagine a world where gravity and inertia are no longer important, but atomic forces and surface science dominates. Imagine a silicon chip with thousands of microscopic mirrors working in unison, enabling the all optical network and removing the bottlenecks from the global telecommunications infrastructure. It is where traditional engineering concepts are turned upside down, and the realm of the "possible" is totally redefined. You are now entering the micro domain, a world occupied by an explosive technology known as MEMS.

Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. MEMS devices are complex machines that enable chips to become intelligent. These devices act as the most direct links between digital electronics and the physical world, allowing the integration of electronics and mechanical systems on a single chipset. Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS augments this decision-making capability with "eyes" and "arms", to allow microsystems to sense and control the environment. MEMS are usually divided into two categories -- those devices that detect information, called microsensors, and those devices that can respond to information, or act, called actuators.

Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derived from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby controlling the environment for some desired outcome or purpose. Because MEMS devices are manufactured using batch fabrication techniques similar to those used for integrated circuits, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost.

Now, coming to the history ,we can trace MEMS back to the late 1950's.The potential of very small machines was appreciated long before the technology existed that could make them, for example, Feynmann's famous 1959 lecture “There's Plenty of Room at the Bottom”. In this lecture Feynmann gave a very fundamental but significant understanding of the small machines, its capabilities and applications. Many people believe that this motivating and inspirational lecture urged the engineers and scientists to pursue this field. Physically speaking, micro systems have been around since the late 1960's.The first MEMS device fabricated was a gold resonating MOS gate structure. But the real breakthrough in microsensors was brought forward by the Si pressure sensor. The first high-volume pressure sensor was marketed by National Semiconductor in 1974 and the industry never looked back. During 1987-1988, a turning point was reached in micromachining when, for the first time, techniques for integrated fabrication of mechanisms (i.e. rigid bodies connected by joints for transmitting, controlling, or constraining relative movement) on Si were demonstrated. During a series of three separate workshops on microdynamics held in 1987, the term MEMS was coined. The rapid MEMS commercialism started in 1990's with the success of high performance pressure sensors and accelerometers. Today, MEMS are most commonly found as sensors in automobile airbags, but the devices are also making extensive inroads into medical, aviation, defense, and wireless and optical communications systems. Micro-electro-mechanical systems (MEMS) are one of the fastest growing technology areas. They have proven to be a key enabling technology of developments in areas such as transportation, telecommunications and health care, but the range of MEMS applications covers nearly every sector.

MEMS has become a very potent and fast growing technology. This commercial success can be attributed to fact that they could be fabricated using integrated circuit (IC) manufacturing processes; that is, by bulk and surface micromachining. Like ICs, thousands of micromachines can be fabricated on a single wafer with supporting circuits integrated on the chip. The fabrication processes include molding and plating, wet etching (KOH, TMAH) and dry etching (RIE and DRIE), electro discharge machining (EDM), and other technologies capable of manufacturing very small devices. The main appeal of MEMS is that they can be mass-produced in the millions at low prices.

MEMS has touched every aspect of current research. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new MEMS applications will emerge, expanding beyond that which is currently identified or known.

“ The global market for MEMS devices and production equipment was worth an estimated $5 billion in 2005, and will increase to $12.5 billion through 2010, an average annual growth rate (AAGR) of more than 20%.”

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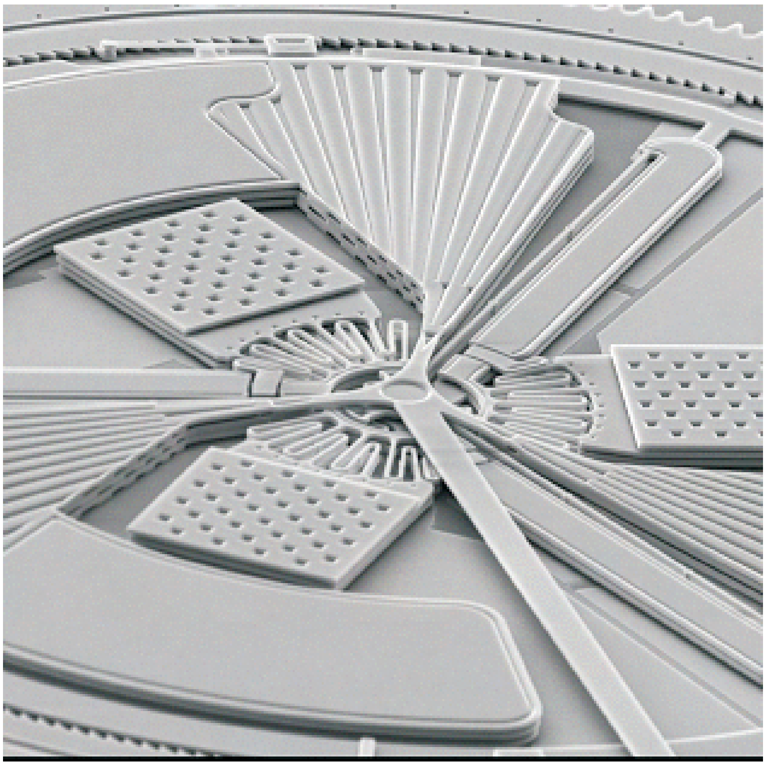
For example, biotechnology has witnessed many new discoveries in science and engineering such as the Polymerase Chain Reaction (PCR) microsystems for DNA amplification and identification, micromachined Scanning Tunneling Microscopes (STMs), biochips for detection of hazardous chemical and biological agents, and microsystems for high-throughput drug screening and selection. Communications has benefited considerably from the advent of the RF-MEMS technology in high frequency circuits.

Electrical components such as inductors and tunable capacitors can be improved significantly compared to their integrated counterparts if they are made using MEMS. With the integration of such components, the performance of communication circuits has improved, while the total circuit area, power consumption and cost have been greatly reduced..

Coming to it's commercial aspects, according to an updated technical market research report, the global market for MEMS devices and production equipment was worth an estimated $5 billion in 2005, and will increase to $12.5 billion through 2010, an average annual growth rate (AAGR) of more than 20%. Microfluidic MEMS was the largest segment of the MEMS market in 2004, with a market share of over 44%, reflecting large sales of microfluidic MEMS inkjet heads, which totaled $1.8 billion or almost 40% of the global market in 2004. Optical MEMS accounted for nearly 20% of the MEMS market in 2004, with MEMS pressure sensors having an 18% share.



To justify the popularity and commercial success let us look at the most successful commercial MEMS product, the Accelerometer. It is quickly replacing conventional accelerometers for crash air-bag deployment systems in automobiles. The conventional approach uses several bulky accelerometers made of discrete components mounted in the front of the car with separate electronics near the air-bag; this approach costs over $50 per automobile. MEMS has made it possible to integrate the accelerometer and electronics onto a single silicon chip at a cost between $5 to $10. The MEMS accelerometers are much smaller, more functional, lighter, more reliable, and are produced for a fraction of the cost of the conventional macroscale accelerometer elements.

MEMS technology is the future, but despite the tremendous progress made till date it is still believed that today's MEMS technology is still in its infancy.At present about a million new MEMS devices are developed every year and this number is ever increasing. The future MEMS applications will be driven by processes enabling greater functionality through higher levels of electronic-mechanical integration and greater numbers of mechanical components working alone or together to enable a complex action. It is a multi-disciplinary field which provides a great platform for the young engineers to contribute to the revolution aimed at replacing the macro devices with the new age micro and nano devices. It is a world of challenges and opportunity and MEMS is quietly changing the way you live, in ways that you might never imagine.

Talla Vamsi
3rd year
ECE Dept.

Simplicity is breakthrough everywhere

Final year's Romesh Khaddar shares his invaluable experience from summer internship at UofT

The buzz of internship was growing louder and louder. Austria, Australia, Germany, Nederland, Ireland, Portugal, U.S.A and a host of other countries where everyone was going. I was thinking "may be fate has some other plans for me" and was preparing myself for summers at IITG, when suddenly things started to look up for me. On the last day of semester, just before the End-semester exams, I received the confirmation from University Health Network, a part of University of Toronto(UofT) for my internship at Toronto General Hospital. A rather unusual destination, but as I got to learn myself, it was all the more relevant to my field.

The hospital was essentially divided into three major sections. One for the critically ill patients another one for the regular patients and a whole another section was dedicated to medicinal research. With full fledged state-of-the-art research laboratories focusing on diagnosis and treatment of prevalent diseases.

At UHN's women health program, my professor was heading research on osteoporosis – a bone disease in which the fracture risk of a person increases significantly. The reason for this is because of very lower Bone Mineral Density (BMD) which is due to disrupted microarchitecture of bone. Women health network was particularly interested more in this because it is most commonly found in women, or more precisely post menopausal women. Though it might be a new word to your dictionary but is a common disease at many places around the globe and mostly in colder countries like Canada. What is disconcerting is the fact that awareness about this disease is very low even in these countries, which in effect takes some of the cases out of the reach of the technology available at this juncture as is sometimes observed the problem is not diagnosed at proper time leading to more damage of the bones later on. Therefore presently the research focuses on better diagnosis, to detect the disease in its initial stages and thereby leading to better treatment.

For this diagnosis, there are currently three methods being followed, one being DXA (Dual energy X-Ray Absorptiometry) which is the most popular diagnosis technique today , second one being pQCT (peripheral Quantitative Computed Tomography) having higher accuracy and radiation levels, and the third one being Ultrasound which is most inaccurate one among the three but has zero radiation, therefore being the safest. Apart from the three techniques mentioned there exists one more method which has zero radiation and high accuracy called MRTA (Mechanical Response Tissue Analyzer), clearly this would be a winning combination. Research at the TGH is primarily focusing on the development and subsequent testing of this technique. The department which was under my guide had one machine based on MRTA, to get the bone data but recently that machine was unavailable to them. All they had were the photos of the electronic parts of the machine and they needed someone to reverse engineer it using the patent and photos and that is where I had to step in. Hardware implementation of a circuit that I had to design or 'reverse-design' formed the crux of my stay at the TGH.

So how exactly does an MRTA works? This has a very simple principle. Like in big structures, you send in a vibration signal and observe the response produced by it, thereby being able to decode the exact stress or strain on it, or the condition of its skeleton, here you stimulate the hand or leg with a probe in a similar manner and just record how the bone vibrates in return which provides you with very important data like bone mineral density. This simple thought was utilized to develop a technique with accuracy as high as the pQCT and radiation as low as that present in your bedroom! And the hardware required for it is as simple in application as the principle itself, which is what I have been doing in those two months.

All said and done, the main part of my work was to implement my designs and make a hardware system good enough to replace the one that they earlier had. What impressed me here was the total liberty I was given by the hospital research section authorities. I can very well say that it felt like I was launching a product for my own company! Every component I needed right from the PCB to the pressure sensors, were just a click away. I just had to order on the internet and all the essentials were with me right in time.

My workstation was in an office environment. But I was also positioned under a scientist at the electronics lab of the hospital, which was fully equipped with the instruments required and what ever it lacked was made up in no time. I assembled the circuit on the PCB and no prizes for guessing what the outcome was.

This was a unique thing that I observed in that hospital ,facility where one can make a prototype of medical devices that are in one's mind. What better place to design such devices where these diseases are faced almost everyday. This again being the point that floored me the day I started my work.

Toronto General Hospital

In the Beginning

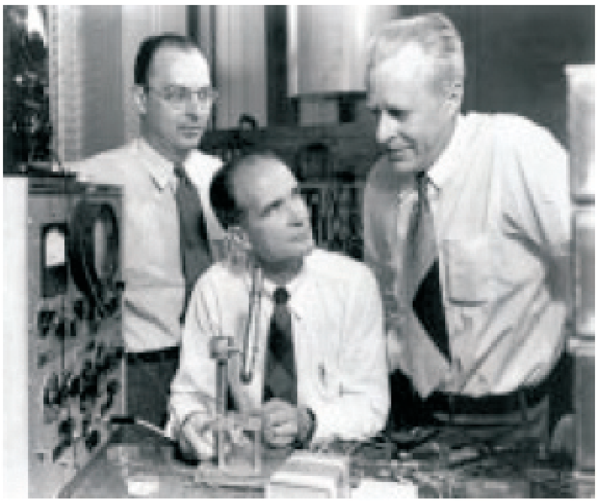
So last time we were in 1940. Mervin Kelly had formed a solid-state devices group at Bell Labs and some substantial work had been done on semiconductors. But WWII had begun and as a result the group had been disbanded. The various members went off to join other projects. Kelly moved into his pre-war interests, Shockley went to the Naval research laboratory and some stayed at bell labs.

Now it must be said that Kelly was a man of vision. Years earlier he had formed a group to study a new field. A field in which no other person saw any scope. After WWII he assembled yet another group of engineers and physicists. It was clear that he was determined to create solid-state electronics. So by January of 1946, Kelly had assembled another team of people, this time headed by Bill Shockley and Stanley Morgan. The team included Walter Brattain, John Bardeen, John Pearson, Bert Moore, and Robert Gibney. This group made a very important decision right at the beginning, which was that the simplest semiconductors are silicon and germanium, and that their efforts would be directed at those two elements. Efforts would be made to understand them first. Effort would not be directed toward more complex materials, such as lead sulfide and copper oxide. So, the team concentrated on silicon and germanium. Second, Shockley revived (actually he independently had the idea) the idea of a field-effect device.

They began work. One of the very first and very important contributions made by Bardeen was to understand field effects. Bardeen showed by very simple calculations that imperfections at the surface were reducing the efficiency of the device.

What Bardeen suggested was key to getting people to think about the right things. Bardeen and Brattain immediately started investigating ways that they might clean the surface so they could reduce the effects of these surface states and make a useful device.

By late November 1947, Bardeen and Brattain managed to make a working transistor. It must be said that it was very crude, but they improved it from late November through the first part of December. By December 16, 1947, they had a working point-contact transistor. They were able to gradually improve it and actually make a circuit to demonstrate to Bell Labs management on Christmas Eve. Of course, this was a very big event. During the next six months at Bell Labs, Bardeen and Brattain spent a lot of time making sure they had patents filed and then clearing it for release to the public with the military. It was interesting that at one stage, the military was threatening to classify this discovery as top secret. Fortunately, Bell Labs management worked around that.



By June 30, 1948, Bell Labs had a press conference in New York City which was quite elaborate. They had done a lot of work on a prototype circuit that had actual voices being amplified by the transistors. It is interesting to note that the impact of this discovery went on deaf ears as far as the public was concerned. The New York Times carried a very small article on a back page and did not have too much else to say about it. In some sense that is understandable. It is very hard to see the full implication of something like this, unless you are a scientist or engineer, and have some appreciation for the consequences. No one could have dreamed that the transistor would have the broad social consequences it has had.

Shown are the two inventors along with Bill Shockley. This picture and Walter Brattain's comments about it are fascinating. He said the picture was wrong in two ways. The first way it was wrong was that it was not the entire group.

As there were other members of the group that were involved, Walter thought the publicity picture should have everybody in it. Unfortunately, it did not. The second thing that was wrong with it was this was his laboratory not Bill Shockley's, even though Shockley is sitting there looking as if he is actually working in the laboratory. That obviously grated on Walter, and he wanted to make this clear.This was not an isolated incident. Shockley and Walter were not getting on well and things were only going to get worse later. Now Shockley had gone off to Europe and meanwhile Brattain was continuing his work on the device. Soon he was able to improve the device radically.

When Shockley returned around Christmas time he was chagrined to find that he was not part of the invention. Shockley was not the type of man who watched others become famous. He was a great scientist and he knew that this was going to be something big. So he began immediately to think about the amplification effect. Bardeen on the other hand was convinced that the improvement in the device was due to the fact that the conductivity of the surface layer was somehow being changed, and that the change in conductivity was causing the amplification.

Shockley, on the other hand, was fairly certain that the bulk of the crystal was somehow involved. It is amazing what happened next. In the next two months, Shockley, in a great creative burst, proceeded to write down the theory of the bipolar junction transistor. Of course, that theory very strongly depended on the introduction of minority carriers, so Shockley, in developing this theory, was the first person to both clearly see and discuss minority carrier injection into the semiconductor. Shockley, in fact, kept this idea secret for some time. Single handedly Shockley had developed the entire theory himself and that too in just two months.

.......................Continued next time

- Rahul Sangwan (3rd. yr. B.Tech ECE)

What not to do at Internships abroad

Do not get too excited if a hot girl smiles at you and says 'hi'. Europeans are just friendly by nature.

Do not accept drinks from guys with their right ear pierced. Do we need to say why?

Be careful when entering a toilet with a black guy. Most urinals don't have partitions in between.

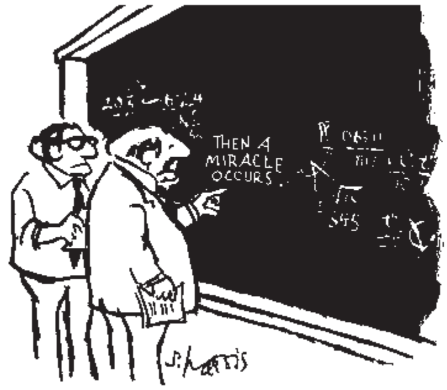
Never stay indoors when it is hot outside. Europeans are more liberal with their summer clothing than what you may think !!

Do not be surprised to see Indian families in Amsterdam. Among 'other' things, it is a major financial capital.

Do not carry more cash than you can afford on the 'temptations' anywhere you go. It'll just leave you n your pocket 'exhausted'.

Do not travel without tickets, ask your seniors, they've paid the price !!

And most importantly do remind yourself atleast once a day that you are there to do some 'research'. People often tend to forget that!



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

ECEgiri

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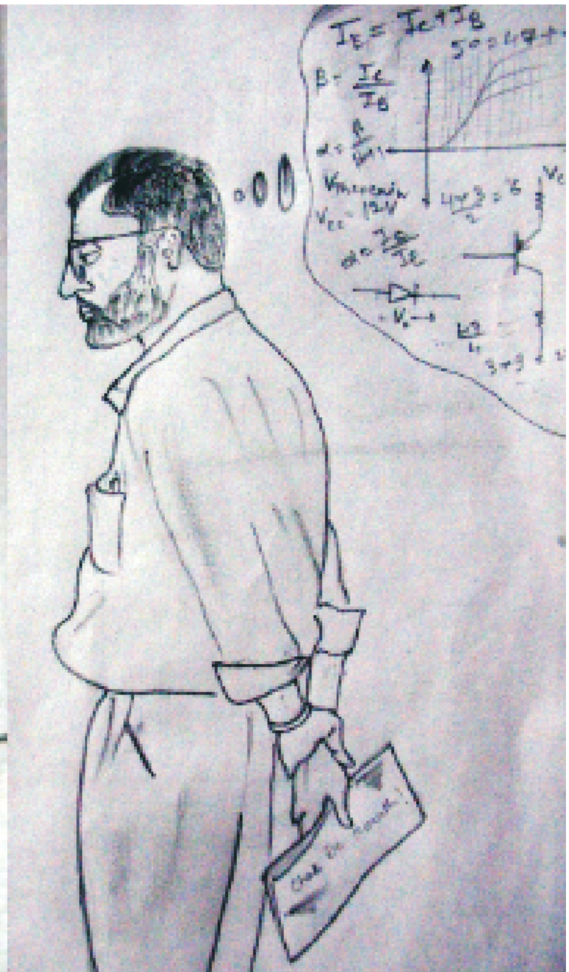

FEEDBACK

Thats really cool work indeed. Seriously I never had thought that it will look so professional. A great work.....

Dr. Amit Kumar Mishra(ECE IITG)

Great to see the inagural issue of the ``In Phase'' e-magazine. I would like to thank all the folks whose efforts are gone in to make it such a nice, eye catching magazine. Keep this spirit up !

Dr.K.L.Panigrahi(Dept of Phy IITG)

This magazine looks great! Good job, you guys. I, for one, will certainly look forward to this magazine.

Anil Krishna(ECE alumnus)

Call for Articles

Being a monthly magazine, In Phase requires a constant supply of high quality original technical and non-technical articles. This is a request to all the students, specially the research scholars and those pursuing their master's, to share their projects, views, interests and knowledge with us through this magazine. Send in your articles (not more than two pages) to cepstrum@iitg.ernet.in and get in touch with the editors for any clarifications

Congratulations on the wonderful job.... everything looks good for it to be a success

Ashish Singh(ECE alumnus)

The magazine is very impressive. Good effort and the content is really nice.

Vivekanand(former head of Cepstrum)

It made me finish the entire issue in one breath. thanks a ton and best wishes

Jyoti Kumar(Reseach scholar, DOD)

Right now...

Since you have spent this time going through the magazine, we really really need your feedback.
And we all know that 'not now' always becomes 'never', so go ahead right now and write to us about what you liked, what you hated, what you'll like to see here, what about the design? and absolutely anything you wanna share with us.

Click here if you are registered at the Cepstrum forum to give us your thoughts or email them to cepstrum@iitg.ernet.in or akash@iitg.ernet.in