

R&D in Indian PSUs: My Experience



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At Andhra University

I was initiated into research at Applied Physics Laboratories, Andhra University to work in the area of Thin films with specific task initially on the development of a thickness monitor for films formed using vacuum evaporation. In those days, still universities did not introduce transistors in the curriculum. Only circuit design using vacuum tubes used to be taught and laboratories were equipped with the needed electronic components. The problem was to use reflectance of thin films as measure of thickness when aluminium is being deposited. Unfortunately, the light from the tungsten filament was much more than the reflected light of a source. In order to distinguish these two one signal and another noise, the reflected beam needs to be made different in some way. One known solution was to use modulation for the source being beamed on the thin film on glass substrate by chopping it. Thus one is having a frequency component depending on the motor speed and number of holes on the circular disc connected to the axle of the motor through which light is sent to fall on the device under test. The job was to design a bandpass filter to select he needed frequency component and reject the huge noise (light from the filament). The whole process happens in few seconds to take the aluminium or other metal like tin, copper in a crucible kept in the heated filament. The library of Andhra University was perhaps the best in India at that time. The author had to browse through Journal of Scientific Instruments, Review of Scientific Instruments, Wireless world, Electronics and other magazines to look for designs of filters. At that time itself, my research trajectory in my career was defined perhaps. Then some design was implemented using vacuum tubes and it was working quite well meeting the requirements. The author had to discontinue at Andhra University his research due to some differences with his research supervisor and had to join NSTL, Visakhapatnam as a Junior Scientific Assistant. The laboratory was very newly started and the author could procure bipolar transistors and build some circuits picked from some journals – a relaxation oscillator using a SCR like device using a PNP and a NPN transistor. The author could thoroughly understand the operation and design.

At I.I.Sc, Bangalore

Yet, I was keen in pursuing Ph.D programme and applied to I.I.Sc, Bangalore and was interviewed by Prof. B.S. Sonde and a big I.I.Sc selection committee and was selected to work with Prof. Sonde. Interestingly, the topic was Negative resistance in Bipolar Transistors. The training given by Prof. Sonde: asking me to read Classic papers on Bipolar transistor modelling, books on VLSI technology by Motorola, SEEC six volumes, selected IEEE Papers etc has really changed my understanding of the subject. He then asked me to build a test set for studying negative resistance phenomena without killing the transistors-pulse based testing. He used to give me variety of transistors which were based on various fabrication technologies-alloy, alloy-diffused, planar epitaxial etc and find out whether anything interesting breakdown phenomena is observed. I had to conduct experiments and whatever interesting anomalous behaviour I used to report everyday evening at 6PM -8PM based on his free time. He used to then ask me to explain what could be the reason for that anomalous behaviour. Most important idea was asking me to investigate negative resistance in inverted mode operation of the transistor. This led to significant results. Then of

course, at the end of two and half years, he asked me to start writing the thesis. I have asked him: have I done enough work? He said that while writing the thesis, you know the gaps and then actually you will do real work, tie up loose threads, which was found to be true. He advised me to join ITI Limited. He was insisting that he wanted his students to serve industry. I learnt how to draw circuits meticulously using pen on paper as though they are printed and how to analyse circuits.

At Indian Telephone Industries Limited

I must stress that ITI limited was a great company. When I have joined the Electronic Switching system group, Space Division telephone exchanges using reed relays were being used which occupied lot of space for the switching matrix. I have been asked by the then Executive Director Shri M.S.Jayasimha a visionary although just a B.E from Madras Institute of Technology to develop a semiconductor version of the switch in place of reed relay. I had then first used PNP diodes of ITT and the supply voltage needed was very high due to large breakdown voltage of > 50 volts but concept was proven. Then, suddenly I got an idea why cannot I use NPN PNP transistors in inverted mode an extension of my Ph.D work and build a PNP diode. This has resulted in the invention of a new PNP diode which needs a breakdown voltage of 7V for switching [1]. This device was manufactured by Semiconductors limited Pune and Continental Devices India Faridabad using two transistors in a single package and was extensively used for 50 line telephone exchanges where 700 devices were assembled on one card. Then PCM came into existence for switching. ITI had meanwhile used PAM based TDM exchanges a forerunner for today's E1 based trunks. In those days, multiplexed codec chips were available and Filters were realized outside. No chips were readily available. ITI limited thought of having Active RC filters. My passion for filter design made me design Active RC filters and new techniques for $\sin x/x$ correction were envisaged and these were published as design ideas [2]. Next, I was asked to design line cards using these filters made in Thick film hybrids, design of SLIC without using bulky transformers. Small exchanges using Microprocessor based stored program control were designed by my colleagues using 8008 processor (used in Indian Navy ships) initially, then using 8080, later 8085 based processor cards. My passion for Filters continued as a parallel effort. The author has published lots of papers on tuning see e.g [3,4], some even on fundamental theoretical aspects [5] since there was a need for designing Voice Input filters for FDM equipment which had stringent requirement on low noise, low pass-band ripple, steep cut offs. I have designed several filters for Thick film hybrids which did not need any post tuning other than using laser trimming for resistors and using low tolerance capacitors. These filters used low noise opamps and scaled low value resistances and were fabricated by ECIL and at ITI limited facilities. Defence services have used these extensively in their Voice plus data multiplexers using FDM technique. Numerous papers have been written by the author which were published in Proc. IEEE letters. This section in Proc. IEEE in those days was for fast publication and most authors used to publish therein. Unfortunately with the arrival of numerous transactions catering for different areas, the letters section was discontinued.

During 1980s, India had outstanding researchers in the area of Active RC filters who had the foresight to investigate new techniques. Notable was the use of opamp finite bandwidth to advantage. Following the trend, the author has worked in partially Active R filters, Active R filters [6],[7]. Experimental results were included in the publication due to the availability of devices, ease of assembly and testing.

At Concordia University, Montreal

During 1980-1983, the author was offered a post-doctoral fellowship at Concordia University, Montreal to work with Prof. M.N.S. Swamy and Prof. V. Ramachandran. They have asked the author to work in an emerging area Switched capacitor filters. At the beginning, the author was rather scared to work in a new area but the urge to contribute otherwise being considered as not good made him to pursue deep into this area and within one year new results have been obtained; numerous papers were published in reputed journals jointly with Dr. Swamy and Dr. Ramachandran.

Then the author got an idea to write a book and then it took about a year to comprehensively study and write the book. It appeared much later from Prentice-Hall London in 1995 [8]. Meanwhile, in 1983, the author had to return to India and continue in ITI Limited. The research in SC filters was continued and the author could adapt to new areas such continuous-time filters [9], OTA-C filters [10], current-mode filters [11] etc.

At I.T.I. Limited

During 1987, there was need for Indian army to introduce a new communication network using the first integrated voice and data switch with full media encryption on digital microwave links. Again Shri M.S. Jayasimha picked up the author amongst all the R&D engineers of ITI limited and assigned this task. The author had built an outstanding group of algorithm and hardware designers with knowledge of Telecom interfaces to build state of the art systems. In those days, FPGAS were not available. Building a massive encryption hardware was a problem due to space constraints. The then Director R&D of ITI Limited Dr.Prabhakar had taken up the challenge of designing and fabricating ASICs totally in ITI limited foundry (now SITAR). About fifteen thousand ICs of about 2500 gates each using 0.8 micron technology was used to set up the army network. This network was first of its kind in India with comprehensive distributed network management system, redundancy to yield a fail safe network. The Army Generals described it as a Force Multiplier.

The work in encryption continued at ITI and numerous solutions for Satellite networking, optical fibre links etc later using FPGAs. The author had to inspire the teams to add novelty in design, new features, cater to higher and higher bandwidths upto 622 Mb/s. During this time, the author was studying public domain algorithms for encryption, Authentication and digital signatures etc. Several papers on Architectures and implementations were published. Research in residue number systems was a by product. Noticing the absence of a book on Residue number systems after the one published in 1967 by Szabo and Tanaka, the author has published a book on the same with Kluwer Academic Publishers in 2002 [12]. ITI limited was encouraging original research and the author was deputed to several IEEE annual International symposia on Circuits and Systems at Hesinki, Japan, Port land USA, San Jose U.S.A, Munich.

At ECIL, Bangalore

Later in 2003, the author has resigned from ITI Limited and joined ECIL at Bangalore. The work on Encryption continued and numerous products for the Armed forces have been developed and supplied. The two research tracks were followed in analog filter design and in Cryptography and Residue Number Systems. Two more books on Analog filters- current-mode VLSI analog filters from Birkhauser, Springer in 2003 [13] and VLSI analog filters in 2013 [14] were published. These involved hard work in compiling information, designing examples, problems and sharing knowledge with the readers. I was delighted to be elected as a IEEE Fellow in 2005 and FNAE in 2010.

Concluding Remarks

I was delighted to work with numerous young engineers, inspire them to be creative and create leaders and quickly deliver the results to the customers. I feel that self-motivation is needed to excel in research. R&D institutions belonging to Indian Government sector have done much for the development of indigenous technologies in Space, Atomic research, encryption, telecommunication and digital Electronics. Much of my work in cryptography could not be published due to strategic reasons. Government funding for scientific shall be enhanced and methodologies to attract and nurture talent, inspire them need to be thought of. I truly enjoyed working in India and I am grateful to institutions like ITI Limited, ECIL and Indian Armed Forces for their trust in Indian capabilities in strategic areas.

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