Analog Forum

Dear Website Visitor:

I am a university educator/author who is concerned by the decreased student enrollment in Analog Electronics. This concern is shared by managers from industry, who find it harder and harder to recruit well-prepared analog engineers. I am thereby establishing this Website to provide an opportunity for members of Industry and Academia to exchange ideas about Analog Electronics, its current status, and its future directions. The main objectives are:

(a) To dispel some of the misconceptions that persist about this fascinating field
(b) To inspire beginning students as they plan their course work
(c) To offer encouragement to new graduates as they map their future careers.

For there will always be a need for competent analog engineers!

I will start out with a general preamble about Analog Electronics, after which I invite students, professors, and practicing engineers (not necessarily in that order) to express their own ideas about this discipline. I anticipate that students will value advice from individuals in industry, especially when substantiated by personal experiences. Please e-mail your statements to me at the address below, and I will post them in this space as soon as I can (if you want your name withheld, please indicate so). I intend to keep my own comments to a minimum, as I would like to see this forum as an on-line debate among its different visitors.

Sergio Franco, March 21, 1998.
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Some Thoughts About Analog Electronics

The last third of this century has witnessed tremendous advances both in analog and digital electronics. Unfortunately, this has also been accompanied by the emergence of a competitive rift between the two disciplines, a rift about which much has been said and prophesized. A frequently heard contention is that in the future there will be little need for analog circuitry because digital electronics is taking over. Far from having proven true, this contention has provoked controversial rebuttals, as epitomized by statements such as "If you cannot do it in digital, it has got to be done in analog." Add to this the common misconception that analog design, compared to digital design, seems to be more of a whimsical art than a systematic science, and what is the confused student to make of this controversy? Is it worth pursuing some course work in analog electronics, or is it better to focus just on digital?

There is no doubt that many functions that were traditionally the domain of analog electronics are nowadays implemented in digital form, a most popular example being offered by digital audio. Here, the analog signals produced by microphones and other acoustic transducers are suitably conditioned by means of amplifiers and filters, and are then converted to digital form for further processing, such as mixing, editing, and the creation of special effects, as well as for the more mundane but equally important tasks of transmission, storage, and retrieval. Finally, digital information is converted back to analog signals for playing through loudspeakers.

One of the main reasons why it is desirable to perform as many functions as possible digitally is the generally superior reliability and flexibility of digital circuitry. However, *the physical world is inherently analog*, indicating that there will always be a need for analog circuitry to condition physical signals such as those associated with transducers, as well as to convert information from analog to digital and from digital to analog. Moreover, new applications continue to emerge, where considerations of speed and power make it more advantageous to use analog front ends; wireless communications provide a good example.

Indeed many important applications today are best addressed by mixed analog/digital VLSI systems, which rely on analog circuitry to interface with the physical world, and digital circuitry for processing and control. Even though the analog circuitry may constitute only a small portion of the total chip area, it is often the limiting factor in overall systems performance, and also the most challenging part to design. In this respect, it is usually the analog designer who is called to devise ingenious solutions to the task of realizing analog functions in decidedly digital technologies; switched-capacitor techniques in filtering and sigma-delta conversion are popular examples. In light of the above, the need for competent analog designers remains strong. Even purely digital circuits, when pushed to their operational limits, exhibit analog behavior. Consequently, a solid grasp of analog design principles and techniques is a valuable asset in the design of any IC, not just purely digital or purely analog ICs.

My first advice to electronics students is *to take as many courses in as many different areas as possible*, including courses and labs in analog electronics. There is always time to specialize! Concentrating on a narrow area now may make you more marketable on a short-term basis, but what about a long-term perspective? Should there be a reduced demand in your specialized area in the future, will you be able to timely reconfigure yourself for a changed marketplace? Chances are that if you have had even an introductory exposure to a balanced variety of subjects during your undergraduate days, you will. In fact, this is one of the most important qualities that recruiters are looking for in new graduates, namely, the potential for *lifelong learning and adaptation*.

My second piece of advice has to do with the analog/digital rift. As mentioned, nowadays great many designs are a mixture of analog and digital. Now, if you happen to have put more emphasis on analog than on digital electronics in your undergraduate curriculum, you will be able to make up for any digital deficiencies by learning on the job. Conversely, experience indicates that if you haven't had sufficient undergraduate exposure to analog, it will be far more difficult to make up for this deficiency later on. SF.

Recommended readings:

1. Jim Williams, Editor: *Analog Circuit Design: Art, Science, and Personalities*, Butterworth-Heinemann, Boston, 1991.
2. Frank Goodenough, Editor: “The Magic Of Electronics,” *Electronic Design*, June **, 1992, pp. **-**.
3. 3. Jim Williams, Editor: *The Art and Science of Analog Circuit Design,* Butterworth-Heinemann, Boston, 1995.

On March 26, 1998, Robert Pease of *National Semiconductor* wrote:

Hello, Sergio:

Thanks for starting up the question of Analog Stuff in Engineering Education. Let me throw in one FAQ and FQA that came up on my Lecture Tour. One guy in the back of the room asked me, "How are we going to make available a lot more new Analog Designers?" I told him that I definitely was not interested in having available a *lot* more Analog Designers. I just wanted to get a few *good ones*. Having a lot of mediocre ones is not my idea of a good thing.

Besides, why would I want to warp the supply/demand situation until Analog Designers are a dime-a-dozen? No way!! I'm in favor of making sure that Analog Engineers are in good demand. Preferably a little more demand than supply. It beats hell out of the vice-versa case. I did not get many more questions from that guy. The audience seemed satisfied with my answer. How about you?

Best regards, and I'll have more comments, later. R. A. Pease.

I think mediocre engineers are undesirable in general, not just in Analog Electronics. However, I like to point out to my students that not all engineers need necessarily be super-brilliant geniuses. To function properly, a company needs top-notch designers but also a variety of competent and dedicated support engineers to provide all those seemingly less glamorous but just as vital housekeeping functions that are necessary in order to make a company work. (Come to think of it, I should post a list of some of these support functions right here!).

As to whether we should or shouldn't make more Analog Engineers available, I can only say that it disturbs me to see a student with the potential for becoming an excellent analog designer turn away from this field because of misconceptions, misinformation, or just plain poor academic advising. Don't you think that if we could attract more students to this field, we would have more good *engineers to choose from, and that the* mediocre *ones would automatically be diverted by the needs of the marketplace? Right now there are analog companies that are forced to turn down attractive contracts simply because they can't find enough competent engineers to hire. SF.*

[*Note to Students: R. A. Pease is a world-renowned analog designer who has inspired and influenced generations of analog engineers, including many ex-students of mine who had the privilege of working with him. He writes the popular column* Pease Porridge, *which appears in* Electronic Design *(*`http://www.penton.com/ed`). *To find out more about Mr. Pease, you can visit his Website at* `http://www.national.com/rap`. *SF.*]

On March 26, 1998, Lee Ritchey of *3Com Corporation* wrote:

I'm a program manager at 3Com. I started out my career doing analog design work. I liked it very much. However, this area got overshadowed by logic design and was taken for granted by most people. As a result, it was tough to get any kind of decent pay. Most of us switched to keep our careers going.

As you know, now we need these skills in industry and the specialty is pretty much unknown to students as an area where they can find good jobs. I'd encourage you to get some of the professionals from the companies that are in need for this kind of engineers to come to campus and put on career talks to your first two-year classes. Kids won't pick this for a specialty unless someone turns them on to it.

Your advice is well taken. In fact, I have found that the best individuals for the kind of career events you mention are Alumni/ae working in the analog field. Not only can they serve as convincing role models, but, being already familiar with the courses and labs of the particular institution, they can offer students valuable advice in terms of curricular emphasis and carreer planning. SF.

On March 26, 1998, a respondent who wants to remain anonymous wrote:

To make sure that you have enough *good* engineers--if that is what *managers* want, they might start:

(*a*) Paying them enough, and
(*b*) Not laying them off, and
(*c*) Providing reasonable working conditions,

e.g. not calling for layoffs or shutdowns at the first little blip of an economic twitch, or a momentary sales decrease. I heard of one engineering manager who busted his tail to hire two good new engineers. The next week his boss forced him to announce a week of plant shutdown. The two engineers changed their minds and did not show up. I wonder why.

Where is Dilbert, when we need him, to explain to clueless managers that if they keep bleating that they need good engineers, they should consider taking good care of the good engineers they got? *Anonymous.*

P.S. The Immigration studies are being heckled by Microsoft, etc., asking to let in a *lot* more immigrant *software* engineers and programmers, as they say the US does not have enough. My same questions and arguments apply to them. (Many software engineers say that the big companies only want to hire new grads, and refuse to hire older guys with good experience. If there is a shortage, it serves them right, if they will not even consider hiring good senior guys. That argument seems reasonable to me.) But is there anything we can learn from *their* debates?

On March 30, 1998, Dan Sheingold of *Analog Devices* wrote:

Sergio:

Here's my contribution, a few points that may contain the seeds of a solution:

1. Hardware design, even of *digital* circuits, is inherently analog design, albeit not always with the textbook building blocks, but always with the challenges.
2. *Good analog engineers* generally are self-selected as a pool of guys/gals who like to tinker with hardware.
3. My understanding of the conventional engineering college curriculum is that it has become more and more rarified in the direction of theory and software, not very attractive to these types.
4. High-school science fair participants tend to be hands-on types.

So---What if a university boldly and baldly offers a 3rd & 4th-year curriculum in *the fun and headaches of designing and building electronic hardware*, built around challenging hands-on projects? And advertises it as such to prospective students? The curriculum would include basic analog (including *digital*) circuit design, properties of components, lab instrumentation (bought and homemade), sources of degradation, distortion and interference in electronic circuits, plus lab courses and a design project in each semester. And do bring in industry design and application engineers for an occasional guest lecture.

Then you pay an undergraduate a bounty to read newspapers, search the Web, etc., to find the names of high-school science fair participants, and *market* the course to them.

Seems to me you'd be aiming the right kind of course at the people most likely to become *good analog engineers.*

Best wishes, Dan Sheingold.

[*Note to Students: Dan Sheingold is the prolific author of enlightening articles and books in Analog Electronics. He is also the Editor of* Analog Dialogue*, a periodic publication by Analog Devices. Also called a Forum for the Exchange of Circuits, Systems, and Software for Real-World Signal Processing,* Analog Dialogue *has educated countless engineers since its inception, in the mid sixties. You can find out more by visiting the Website* http://www.analog.com. *SF.*]

On April 1, 1998, Barrie Gilbert of *Analog Devices* wrote:

Sergio:

Your initiative was brought to my attention by Dan Shiengold, a senior technical writer at Analog Devices, and long-time editor of *Analog Dialogue*, which has sustained high standards of education about analog matters for over a quarter of a century.

I certainly share your concern, which is without doubt justified. I have penned a short, invited piece for the June 22 issue of *Electronic Design* which points out that contrary to much popular opinion, digital signal-processing technologies, dazzling and important as they are, will not eclipse analog techniques in every arena. Rather, the wider utilization of digital techniques is only opening up many new (and sometimes quite unforeseen) opportunities for strictly analog components, as well, of course, for mixed-signal products.

Sadly, this perspective is not only hidden from the view of the man-in-the-street, but is also not well understood by most freshmen students, it seems. In the minds of so many people, the future is digital and the field of electronics equates uniquely to computers.

The senior technical staff at Analog Devices, particularly the Fellows, have a strong interest in promoting and supporting any initiative aimed at elevating the visibility of analog circuit design as a career path. I have not yet visited your Website, but am writing to let you know of my personal interest, and on behalf of the Fellow body - some 21 senior technologists - of which I am currently the chairman.

One of the methods we might consider is to develop a series of seminars for presentation at selected campuses, expressly designed to demonstrate, in as compelling a fashion as possible, that a*nalog is here to stay*. Of course, this is a double entendre, inasmuch that we expect to remain the leading exponent of the analog IC art, as a supplier of state-of-the-art products, but also making the point that this is by no means a niche business in which the opportunities for career growth are limited; rather, that for fundamental reasons, the demand for skilled analog IC designers, as well as process developers for analog-oriented technologies, will continue to grow, as the *digital revolution* expands the horizons for electronic commodities, rather than absorbing every conceivable function.

These seminars need to be *packaged* in a way that gets attention - we'd need to have very professionally presented material to take away and perhaps we'd need to give away a few other trinkets - but above all they should involve the participation of a few *celebrities* who can offer an entertaining and illuminating story about their own career in analog (or Analog) and why it has been so rewarding – both in terms of the intangible joys of invention followed by commercial exploitation (these two being inextricable partners in the process of innovation) as well as somehow making the point that it's also a path to wealth accumulation - without sounding crass about that issue. (I can only presume that this *is* a consideration to a young person, judging by the numbers who choose to pursue careers as lawyers....)

Of course, spot events of this sort are not in any sense the whole solution to the problem. It would be only a beginning. But one has to assume that the key challenge is getting the freshman to *start* down a career path in analog electronics in the first place, and that support of that person's choice will be necessary on an ongoing basis, perhaps by introducing further speakers from industry into the course work, by supporting *analog chairs* and research programs, and by being pragmatic about the beneficial long-term consequences of providing access to practical applications information and generous supplies of hardware.

There is nothing very novel in any of these suggestions. I am only writing to affirm that Analog Devices is intensely interested in raising the excitement index for this domain of endeavor, and in supporting your initiative, as well as to inform you that I would personally be pleased to participate in some of these dog-and-pony shows. Barrie.

[*Note to Students: Barrie Gilbert has created some of the most elegant analog circuits, and just as impeccably has described them in articles that have become classics. His name brings to mind Translinear Circuits, of which Variable Transconductance Multipliers are the most widely known example. SF.*]

On April 3, 1998, Newt Ball, a semi-retired Analog Design Specialist, wrote:

When I was a student at Cal, I was nominated for, and joined, an honors society called Sigma Xi [for summation of the sciences, I think]. Analog EE's are much more likely to feel at home in an interdisciplinary world. Many of the problems in mechanics and non-electrical energy are exact *analogies* of electrical circuit problems. Further, understanding of many non-engineering problems can be gleaned from the education and training that an analog EE receives.

I cite in particular the U.S. economy. The Federal Reserve Board runs a negative feedback control system. In complete accordance with control theory, when massive corrections were made after the results of disturbances were overwhelmingly apparent, then a cyclical oscillation was the result. This boom-bust cycle happened enough times that the vast majority of Americans believe it to be inevitable. The last two, and especially the last one of the Fed chairmen, have learned to make small corrections early. Attention is now paid to money supply changes and leading economic indicators. We now have millions of American investors breathlessly awaiting the cycle. If only this chairman can teach his successor what he has learned, there is no reason for it to happen. This sort of insightful analysis is unlikely to occur to an engineer not taught control theory.

To me there is great pleasure in a non-verbal thought process that is a sort of visceral understanding of simple differential or integral relationships. These insights are the important part of calculus, and a capacitor or inductor cannot be properly applied without reference to the defining expression from calculus. I expect this sort of intuitive involvement from analog engineers. I suggest a screening test, in the form of a conversation about the beauty of the underlying principles of calculus, and simple calculus-related physics, to identify students who will enjoy analog electronics. Students who learn primarily by rote memorization should stick to accounting or digital electronics.

On April 6, 1998, Stuart Smith of *Elantec Semiconductor* wrote:

Hi Sergio,

Kim Emanuel told me of your Forum, and gave me a printout of some of the comments you have received. Certainly industry can always use many more very good analog engineers, as well as digital engineers with a ***lot*** more analog savvy. Analog is not dead, and never will die. All that seems to happen is that some areas become ***cheaper*** to design, fabricate, test and support, using digital technology. When microprocessors were clocking at a MHz or so, op-amps had a MHz or so of bandwidth. Now processors clock at 300 MHz, op-amps have 300 MHz bandwidth. What changed? Not even the price!

I note that you keep referring to analog ***design*** engineers … all designers, in whatever field, really need all the other supporting engineers. And those 'other' engineers always need good analog skills. Without skillful test engineers, applications engineers, product and sustaining engineers, failure analysis engineers and the CAD engineers, how many circuits could I ever get into production? Because that is what it is all about. Far too few graduates consider these other engineering fields as worthy of being a career - and yet these engineers have a tremendous effect on every product ever produced. Also, many good designers start their careers in one or other of these non-design fields.

As we all know, the engineer can do for a nickel what anyone could have done for a dollar. This is fundamentally how engineering creates wealth. I absolutely agree with your suggesting a very wide variety of different classes. So don't forget accountancy - because if you can't figure out the cost, how do you know you did it for a nickel?

Indeed, I find the fact that so many classes are ***optional*** is a major problem with an American education. How is an 18-year-old student supposed to know what he/she needs to know ***before*** they start their career? So if you know the future, then go and make an easy fortune in the stock market!

Any engineering education has to be made up of mainly non-optional classes, all linked together to provide a coherent, broad-based education. A student can not just decide to miss out calculus, because it is not of interest, and then choose to go on to Maxwell's equations! Equally, how can you expect a student to spend weeks of life learning some mathematical techniques without showing them ***why***?

All engineers ***need*** at least some analog experience. It would never hurt a digital designer to learn how, when and why, lines need to be terminated; how to bias up a bipolar transistor; how and why op-amps work. Why a circuit is called a circuit would be a good start! A lot of graduate engineers can't answer that one - or they forget its significance. One major aspect of analog engineering is all the different compromises that are involved. An op-amp can never be "perfect", while a working NAND gate will always give the correct logical answer.

One interesting area that is still in its infancy is the area of circuit synthesis. Could put the digital designer out of a job when the marketing department has just to enter their requirements into a computer, and the chip is synthesized for them? How many digital designers will they need then? Already, much of a digital chip is auto-sized, auto-routed, and test vectors are automatically generated. Digital designers are often doing little more than developing the chip topology - the rest of the circuit details are optimized for them automatically. That's why a million-transistor chip can be handled at all. I note however that all the test, applications, production, failure-analysis and sustaining engineers will always have ***their*** jobs!

I think no electronics students should be allowed to graduate until they can show that they can successfully find faults in circuits. This should be a required, practical (Lab) class, with no chance of graduating until the students get an "A"! No simulator tells you exactly where the problem is, no automated tester tells the test engineer what the problem was. Only a breadboard sometimes gives you help by means of smoke signals from the incorrectly hooked up or broken device!

Like fault finding, error analysis is another forgotten science. It used to be done a lot when simulators could not be used to check for every permutation of process variations, supply voltage, temperature, component tolerances, etc.

Control analysis can be very boring - unless you make it much more visual. A simple robotic arm overshooting a target point is a much more expressive way of showing the effects of too little damping, or the arm not getting to its target point shows too little gain. How many students realize that is what the mathematical equation is telling them?

Back in the days when I was at school, it was all boring classroom theory, followed by some totally unrelated labs. Fortunately, I was always building my own hobby projects, so the lectures did not kill my enthusiasm, although they sure tried my patience! The classroom and lab classes should be unified so that the students can see the significance of the theory right then, when the practical results are found in a lab ***the same day*** as the lecture. As well as focusing on the detail that you are trying to teach, put it in perspective. Theory and practice linked together. Details and the global picture together. Just like the real world they will encounter, when they leave academia.

A tough part for academia to come to terms with, is being prepared to reject any students who just have not got what engineering takes. Not everyone can be an engineer, just like most of us can not be film stars or world-famous baseball players. I know that the university wants lots and lots of fee-paying students, but reality says they have to be failed if they can't do it. So what to do with those who won't make ***good*** engineers? They may make really ***great*** managers. "Promoting" your best designer to a management job usually gives a company one less designer and one not-too-hot manager. The best manager I ever worked for couldn't design a simple transformer-rectifier-capacitor power supply, but he sure could manage a design group. He trusted his senior designers, and he knew that his job was to take care of all the management, financial and political stuff, leaving his design team to design. What a concept!

I note that many American companies ***want*** foreign educated engineers. And most other countries ***dictate*** all or most of the classes their engineering students will take. I just wonder if there may be some correlation…?

Best regards, and please send us your very best analog graduates. Stuart Smith, Design Engineer.

On April 16, 1998, Prof. J. Watson of the University of Wales, UK, wrote:

Dear Prof. Franco,

I have just accessed your analog file and find that I couldn't agree more! Fortunately, in this university department (http://faith.swan.ac.uk/DeptEEE/) a few colleagues and I have managed to maintain a small but effective analog design course over all four years, the result of which is that all the interested and competent students can obtain relevant employment, including in the USA and indeed in your own geographical area. Some years ago, I also taught such a course several times as a Visiting Professor at one of the UC campuses and was rewarded with a class size which went up from eleven to nearly a hundred as the word spread!

Our course here begins at rock bottom and works up through three years of real design topics, and in the second year, groups of four design, build from uncommitted arrays, and test a basic operational amplifier. Only in the fourth year do we include CAD (via SPICE) because it takes that long to inculcate a 'feeling' for the analog design which must take place prior to computer analysis and optimisation.

However, my own research work has gravitated towards sensors, mainly solid-state gas sensors (http://www-ee.swan.ac.uk/GASG) and I now only teach analog design. I do have an ageing textbook, *Analog and Switching Circuit Design* (Wiley, 1989) and a contribution to R. C. Dorf's *Electrical Engineering Handbook* (CRC Press, 1997). The former, containing too much practical information and no computery, cannot compete with the plethora of massive books which are beautifully produced but consist largely of a few basic circuits analysed into the ground, and often with a lot of largely-redundant solid-state physics. These are, however, perfect for those instructors who have no background in analog design and must perforce teach entirely from such books. (I hasten to add that your own excellent book on op amps does not fall into this category and is used here by all of us).

Best regards. Prof. Joe Watson, EE Dept, University of Wales, Swansea SA2 8PP, UK.

Your experience as a Visiting Professor testifies to how important an inspiring and dedicated instructor can be for the advancement of the analog agenda. Moreover, your approach to inculcating a direct feel for circuits before *introducing CAD tools makes a lot of sense in analog electronics where the engineer must learn, so to speak, to look at nature directly in the eye. It must be rewarding to you and your colleagues that your graduates find relevant employment both at home and abroad. This seems to correlate well with the closing statement made earlier by Stuart Smith of Elantec. SF.*

On May 16, 1998, K. Kit Sum of *XYZ* wrote:

Dear Dr. Franco,

Thank you for inviting me to contribute to the Analog Forum. I was out of the country for more than a month, thus causing my late reply.

One of the most frequent comments I have made in the past years is that system designers do not coordinate their design efforts well, especially when interfacing digital with analog circuits. I am a power conversion engineer, so I can make some comments on how they fail in this area. The system is always designed with digital in mind *first*, the analog and power stuff come later. As a result of this bias, the following problems arise:

(*a*) Analog and power circuits are not designed or scheduled to be designed until the last minute;

(*b*) The digital circuits require X watts of power in the beginning of the project, but ends up needing 2.5X watts of power in the end;
(*c*) The power circuits are not originally part of the system requirement, so, at the end one will find that an extra fan is needed, an extra heat sink is needed, and of course, extra space; and
(*d*) The power converter will have to perform some of the logics that the system needs, even though, with a large digital system, a few extra commands could have facilitated these functions with minimal effort and maximized savings in hardware.

A well-designed system will have utilized part of the main chassis as heat sink, and the system fan utilized for cooling the power converter as well. But all these have to be planned in the beginning, not as an after-thought at the end The latest outrage is starkly reflected on the demands of the Intel Pentium II specification. The digital designers are totally out of perspective.

The world is analog. No matter how you cut it, the end result is: *analog input, analog output*. You can cascade as many A-D and D-A converters in between, but the verdict is the same.

Best wishes, K. Kit Sum.

- Would you like to share with us your own perceptions of Analog Electronics?
- Do you wish to comment, corroborate, or refute some of the statements made by the above contributors?
- Do you have specific queries that you want to be answered?

Please e-mail to me at *sfranco@sfsu.edu*, and thank you on behalf of all Visitors of this Website.
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