INTERACTIVE TEACHING AND ASSESSMENT USING RECYCLED SP CONCEPTS

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ABSTRACT

Students who reach a Signal Processing course are not the same as ten years ago. They are known as "digital natives". They have been exposed to different learning environments. It became evident that technology is affecting teaching attitude; accordingly, this paper deals with ideas to renovate learning methodologies. The challenge relies on professors to keep teaching the Signal Processing content, however getting better results, like less failure rate or more motivation. This matter is explored through a detailed explanation of interactive teaching applied to a Sub-Nyquist sampling lab, followed by an innovative assessment process. The tactic produced a favorable outcome because it focused on developing key skills in students: lab aptitudes, team work, timekeeping, lifelong learning abilities and oral and written communication.

Index Terms - Signal Processing Education, Sub-Nyquist Sampling, Active Learning.

1. INTRODUCTION

One of the major problems that engineering educators endure is the constant progress of electrical engineering technologies. This ever-changing context must not be considered a difficulty but an opportunity. In higher education, our purpose is to develop a professional able to understand challenges not discovered yet. Otherwise, the graduate will be obsolete before leaving campus.

A way to face this situation is to renovate what we do in class. Professors may identify innovation with a curriculum change. This is not the case. An initial course must deal with introductory material. The technique used to address contents is what must be put under revision. At the Electrical Engineering Department, it is encouraged the application of nontraditional teaching methods, where content is a means and skill development, the goal.

This paper demonstrates how a lab assignment in an introductory SP course can be adjusted to develop constructive student skills, making use of assorted interactions.

2. PREVIOUS EXPERIENCES

ITBA has a five-year Electrical Engineering curriculum. The introductory Signal Processing course where this methodology was applied is placed at the seventh semester. Students got through SP classes with a strong background in Mathematics and Physics. They all had a hands-on Analog Circuits laboratory and wonder what Signal Processing is about.

2.1. Hands on teaching

When we are about to introduce students to Signal Processing, there are many aspects to consider.

How many hours will the student be exposed to these area of knowledge? Is analog SP part of the picture? How do you balance hardware and software orientation of the course? Should labs play a significant role? What are the skills you are supposed to develop?

Many years of experience from different perspectives, brought the right answer to each question. Undoubtedly, there are some constraints that contribute to focus on certain aspects, like the country where the program is taught, job market perspectives and career length, but they are finally reduced to the skills we build up.

In our case, as programs are very generous regarding teaching hours, we may get into great detail in most of the syllabus topics. This is the reason why we are able to move toward Digital Signal Processing making use of well known Analog Signal Processing skills. For us, an introduction to SP is not only Discrete Fourier Transforms and Digital Filters but also sampling, Analog to Digital Converters and Switched Capacitor Filters. A balance between hardware and software is quite a challenge under this concept. Given that senior students who choose SP orientation (fifth year) will have most courses with traditional software projects, the initial one may play in both arenas. Besides, good hardware knowledge contributes, in a smooth way, to acquire proper SP software abilities.

Nowadays, it is usual to find most initial SP labs as simulation platforms or virtual education facilities. Even when they are not available, classes are taught just supported by MATLAB exercises. I believe that this is all important, but not enough. The reason is quite simple: Signal Processing is first thought as a mathematical tool, not well related with other areas of Electrical Engineering. Students must employ new acquired concepts into the physical models they´ve learned to build. A rewarding way to weave strong ties among different areas is to let the students try hand-on exercises. Definitely labs play a significant role in developing long-lasting capabilities. The most remarkable skills we developed in our labs were team work ability and self confidence in solving any kind of difficulties.

2.2. SP Lab Example

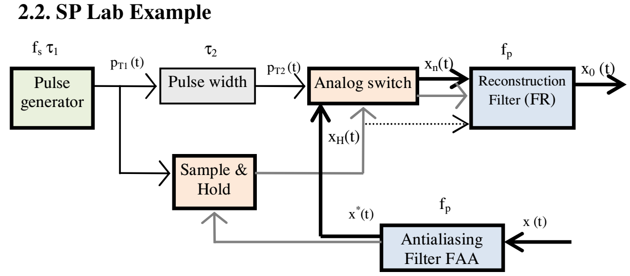


Figure 1. Dual sampling and reconstruction system

Students design a sampling and reconstruction system based on given specifications, as the block diagram of Figure 1 shows.

This is a set up we have used for several years [1]. A typical self-made board usually looks like the picture of Figure 2. They take special care in the PCB design, separating analog from digital circuits; there are different ground planes and switches are chosen so any possible combination of systems can be achieved.

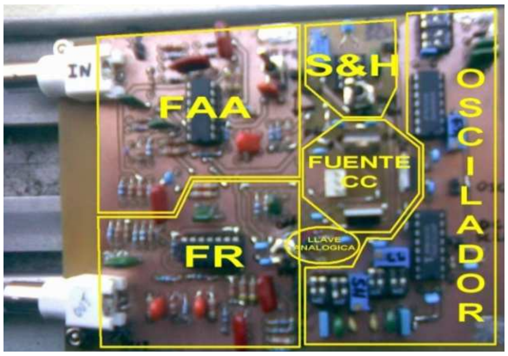


Figure 2. Sampling and reconstruction circuit board of Fig.1 Block Diagram

Among many other accomplishments, they learned how to design analog filters, a convenient first step to the digital filter topic. Using MATLAB [2] in another course, they wrote a script that finds several approximations, given the constraints. Figure 3 displays the case of the reconstruction filter they've used.

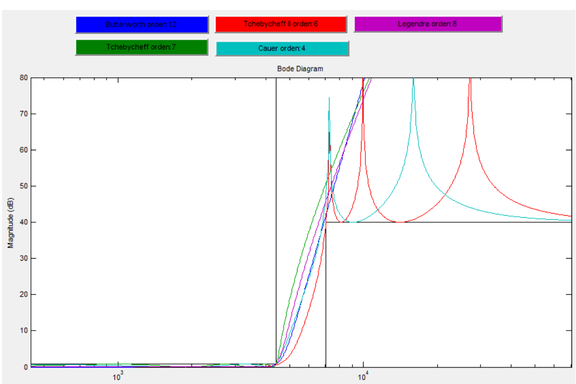


Figure 3. Filter approximations that meet desired specifications

As an example of the measurements the board allows, Figure 4 shows input and diverse outputs using a digital oscilloscope.

With this method, it is not surprising that students acquire significant confidence in their ability to build electronic circuits, as well as make the most of evaluation kits for Signal Processing purposes. This is the main reason why this lab assignment had little changes in recent years.

2.3. Pros and cons over time

Nevertheless, we must cope with the evolution of technology and teaching methodology. In order to evaluate past experiences using labs as a significant part of our SP course, table 1 go through the advantages and problems found.

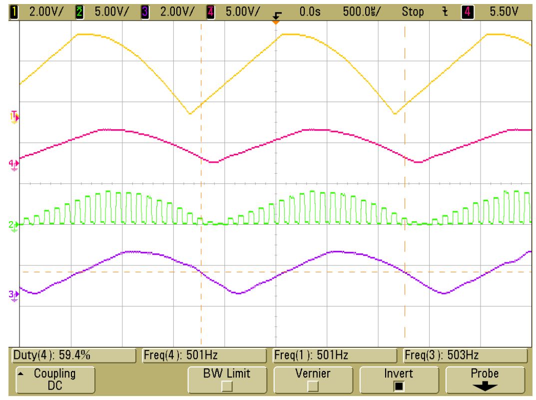


Figure 4. Sampling Board measurements. Yellow: Half ramp-Half a quarter sine waveform input. Red: Anti aliasing filter output. Green: Sample & Hold output. Blue: Reconstruction filter output.

Objective	**Advantage**	**Disadvantage**
Fix academic content	When they "do" they understand	Theoretical and practical background not assessed
Use MATLAB as a simulation tool	Great complement to hardware implementation	It is not clear who knows the tools properly
Apply basic design concepts	They start to understand hardware design	Heavy time consuming. Not often needed in a SP environment
Handle electronic instruments	They are confident with oscilloscopes, signal generators and spectrum analyzers	They are not familiar with virtual lab instruments or LABVIEW [4]
Team work skills	Outstanding skill for real world jobs	May cause difficulties in course development if they don't get along

Table 1. Objectives, pros and cons using intensive labs

As the advantages easily outweigh the cons, finding ways to prevent the problems is a challenge. The next item will show the way a new approach was implemented.

3. NEWER APPROACH

3.1. Active learning

Sometimes, if we are aware to our society evolution, we may witness how educational formats adapt to changing needs.

I realized that our short time course constraints cannot cope with technology evolution without changing our perspective. Therefore, instead of solving each problem separately, I decided to put into practice a different education methodology: active learning. As a matter of fact, the more I assimilated its tactics, the more convinced I was that I had been practicing it without knowing.

Active learning stands for a class where students are stimulated to take responsibility for their own learning. When the right context is applied, several advantages become evident [4]:

1. It is useful to train engineering students in applying knowledge in practice situations
2. It trains communication skills
3. It is suitable to prepare the student for a career of "life-long learning"
4. It is a lever to start off educational innovation projects.

To add more strength to this teaching methodology, it may be complemented by collaborative or cooperative learning. The former can be referred to any instructional method in which students work together in small groups toward a common goal. Otherwise, cooperative learning is defined as a structured form of group work where students pursue common goals while being assessed individually [5].

At the same time, a noteworthy teaching experience was acquired using role-play [6], providing me a secure path to attempt new methods.

At this point it is evident that a good lab assignment that needs renovation can profit from active and cooperative learning methodologies.

3.2 Technology teaching using technology

There is another issue not yet addressed. Our purpose to update a lab assignment using modern teaching methodologies must get along with technology development.

Nowadays, new tools can work together with our exercise, if we manage to use them to add value. I will list some tools that proved to be the most useful.

- *Official Wiki site of the project*: Each time a new assignment is passed, a special site was created. Professors upload related material, the formal guide and its references, while students upload their work on defined times. Chat among users can be also supported.
- *Github collaboration tool* [7]: Team members join in a virtual place with this tool, to get synchronization of their work. One of the great features on GitHub is the ability to see what other people are working on and who they are connecting with.
- *Virtual coach*: Assistant professors should be available quite often in a virtual environment, like the wiki site, the Github community or Facebook. Feedback is truly appreciated and makes a great difference.
- *Web repositories*: Students should be notified about rich knowledge sites that can be consulted during the assignment. In this way we contribute to expand the understandable Wikipedia reference. A good example for our sampling topic is: http://cnx.org/content/m13045/latest/
- *Timekeeping milestones*: Making use of our wiki site or some other similar place, students must upload each stage of their work to a defined site. As the assignment phases have deadlines, we get assured that they are keeping the right pace.

Interpersonal dynamics within teams is an important issue when we try to engage students in an interactive teaching topic. Professors may encounter forceful students who dominate a team or disengaged students who do not contribute at all.

Technology tools are crucial to detect this problem, and proactive actions can overcome the consequences.

3.3. Choosing the right topic

It is not straightforward that every topic you teach wasn't meant to be used in their future jobs. A recurrent question from students is if the subject of study would be ever applied in the real world. The answer, naturally, is quite often "no". But this is not the point. The essence of a class is intended to develop skills, letting the content as a convenient means. From this perspective, whenever we are devoted to enhance a course with hands on experiences, we must be guided by competence development. Motivation, a dose of challenge, fruitful results, team work, some mentoring required and well designed time constraints are key to find the right topic.

Taking into account the anticipated interactive teaching methodologies and making use of the hardware developed in previous labs, we proposed exercises that deal with Sub-Nyquist sampling.

Research on Sub-Nyquist sampling is both old and new. It spans several decades and has been attracting renewed attention lately, since the growing interest in sampling in union of subspaces, finite rate of innovation (FRI) models, and compressed sensing techniques [8].

4. MOTIVATING LAB

4.1. SubNyquist sampling

Aliasing was frequently considered an undesired effect of sampling. As we know, when a bandlimited signal is sampled below its Nyquist rate, aliases of high-frequency content overlap information located around other spectral locations and destroy the ability to recover the input. On the other hand, undersampling refers to uniform sampling of a bandpass signal at a rate lower than the maximal frequency, in which case proper sampling rate selection renders aliasing advantageous.

In [9] it was derived a suitable interval for the uniform sampling rate f_s for a limited bandpass spectrum B between f_l and f_u. Therefore f_s observe:

$$\frac{2\,f_u}{k} \le f_s \le \frac{2\,f_l}{k-1} \quad (1)$$

for some integer $1 \le k \le f_u/B$, ensures that aliases of the positive and negative contents do not overlap.

Our dual sampling system of Figure 1 could be easily set up to perform sampling rates within (1) limits. Reconstruction of the original signal is out of the question, but a demodulated version could be retrieved using our low pass filter FR.

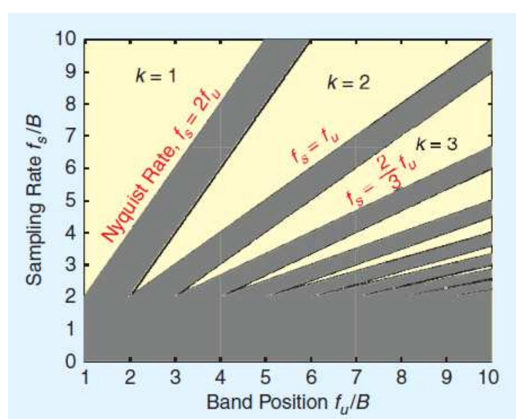


Fig. 5. The allowed (yellow) and forbidden (gray) undersampling rates of a bandpass signal depend on its spectral position [9]

4.2 Experiment details

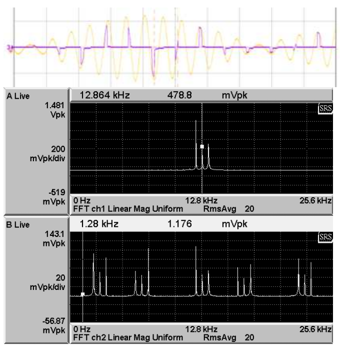
The former assignment was about the Shannon-Nyquist theorem how to avoid aliasing. The new one goes one step ahead. Aliasing could be a good effect of undersampling, given a bandpass limited signal.

With the proper signal and frequency sampling rate students choose, remarkable effects can be visualized with an oscilloscope, an FFT spectrum analyzer and an arbitrary waveform generator.

The learning process has some theoretical lectures, but under the premises of active learning, and then a period of team work, when lab measurement and interactive efforts were put into practice.

4.3 Remarkable Uploaded Reports

Sub-Nyquist sampling proved to be a very resourceful topic. It demands well understanding of the sampling theory, as well as good handling of laboratory material.



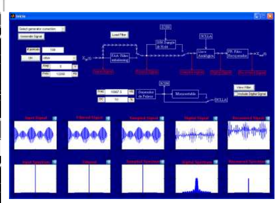


Fig. 6a. Sub-Nyquist sampled AM modulated signal and spectra

Students upload into the official wiki site detailed reports of their work, given evidence of concepts they have learned.

Fig. 6b. Student made MATLAB GUI for simulation of the sampling system.

Figure 6a displays an example of an undersampled AM sine modulated signal and its corresponding FFT. Track only sampling was performed, instead of using a Sample & Hold device. The undistorted aliases can be observed at lower frequencies. Signals and spectra can also be simulated in a MATLAB GUI created for this exercise, as well as a LABVIEW environment, shown in Figure 6b.

Reports are not effortless descriptions of exercises. Students must process their measurements and extract proper conclusions.

5. ASSESSMENT METHODOLOGY AND RESULTS

Creative student reports do not guarantee that students are learning. Assessment is not complete if we are not able to appraise the skills we were promoting.

In [10] an approach to confirm these subjective assessments with an objective quantitative measure was a multiple choice exam. In addition, there is a well known model of cooperative learning [11] that incorporates five specific assessment views. They are: individual accountability, mutual interdependence, face to-face interaction, appropriate practice of interpersonal skills, and regular self-assessment of team functioning. The core element is a focus on cooperative incentives rather than competition to promote learning.

There is a proven methodology that can take into account all five assessment concerns. It is called Oral Team examination.

It is applied to a lab assignment which is presented after a month of work, guided by a list of requirements and a set of given specifications. The team has a mentor (normally a TA), who watches for good understanding of each other and tutors them. They gather regularly to design and build the hardware, prepare the simulations and write the report. During the examination, the professor verifies that the prototype is running according to the assignment; address multiple questions to each member and challenge the students to solve problems related to the work, where the interaction among them is mandatory. The latter is a key point. When the professor asks a demanding issue, he waits and sees. At this point it is quite straightforward to understand how the team functions. In addition, personal skills also become evident.

The mark consists in two parts: one for the team as a whole and the other for each member. The final individual score comes from a weighted sum of both grades, being much more important (75% in most cases) the team mark. The report is included in the team grade as well.

The method we described achieved to build up and assess important skills in a single assignment: SP content in all dimensions: theory, problems & simulation; lab aptitudes; team work; timekeeping; lifelong learning abilities together with oral and written communication capabilities.

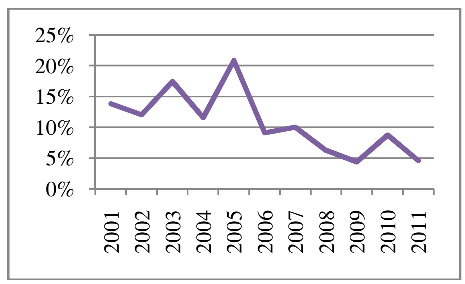


Fig. 7. Failure rate system

A comparison with former grades gets quite uncorrelated. Given the different goals and skills developed, the only topic that can be measured among courses is SP content. Even in this matter, a better grade doesn´t mean the student knows the topic in more detail. The mark could be due to team accomplishment. But the failure rate decreased consistently when we applied this methodology, as seen in Figure 7. Confidence in what they are capable of is the most valuable outcome.

It is important to mention that cooperative learning is complementary to other methodologies. It is not enough to assess the learning process by itself. Similar conclusions were obtained by [12].

6. CONCLUSIONS

Our new approach to teach Sub-Nyquist sampling lab using active learning has been a productive initiative. It is motivating because it encourages students to think about what they are learning; it addresses another facet of education, as team skills developed tend to increase more within cooperative rather than competitive or individual situations. We implemented advices found in previous works [10] [11] [12] in certain aspects of the course and retrieved renewed enthusiasm from both: teachers and students.

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