# SOFTWARE RADIO - BEAM INSTRUMENTATION OR CONTROLS ISSUE

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*Abstract*

Software has become a significant component of electronic products. This situation caught many designers of accelerator subsystems unprepared to respond to this new challenge. Software not only consumes greater resources than ever, but also is the critical differentiator for many products. When it comes to system architecture that contains hardware and software components, a widely accepted wisdom sounds something like: the interface between hardware (sub)systems like power supplies, beam instrumentation devices, RF controls, etc. and a control system is at the analog signal level. It is true that this approach provides the cleanest cut. It is also easy to manage and the responsibilities are clearly defined. However, when it comes to performance is such a conservative approach counterproductive. It does not explore the possibilities offered by new technologies such as mixed and digital signal processing. A radio (receiver) is a constituent block of many accelerator (sub)systems like beam position monitoring systems and low level RF controls. We take software radio, the latest member of the radio technology evolution, as an example of an electronic product where the performance of the system heavily relies on an efficient interdependence between hardware and software. We then discuss some management implications of such hardware-software systems.

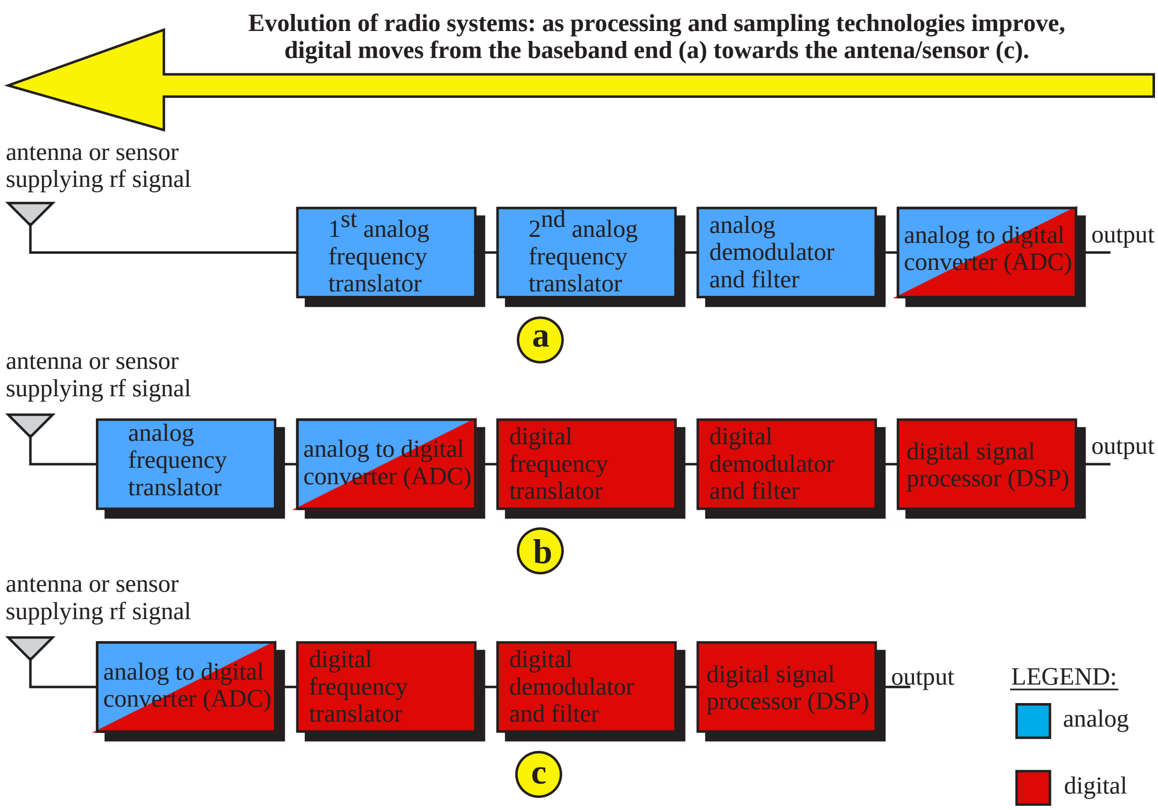


Figure 1: Evolution of radio systems.

## 1 ABOUT SOFTWARE RADIO TECHNOLOGY

Since the invention of the superheterodyne receiver, radio architecture has remained remarkably unchanged. While it is true that development has not stood still - increasing integration, ever more sophisticated devices, and the use of digital circuitry to implement baseband functions are just some examples of technological advancements - it is also true, that none of these developments can be said to have revolutionized the original concept. It seems however, that such a revolution may already be in progress, in the guise of the so-called software radio. The purpose of a software radio is similar to that of his analog counterpart: to downconvert, filter and recover any analog signal, such as those signals with amplitude, frequency or any other kind of modulation. Its main advantage lies in its programmability which means that new functions, features and upgrades to the system do not necessitate hardware re-design, but rather the writing and loading of software code.

There are clearly many advantages of using software radio in telecommunications. The economy of scale of such a huge market and the unrelenting search for the holy grail of all things cheaper, faster and more versatile, make software radio also an attractive building block for many particle accelerator subsystems including a variety of beam instrumentation devices and low level RF systems.

## 2 TECHNOLOGY DRIVERS

### *2.1 Analog to Digital Converter*

Some of the key parameters in the specification of an analog-to-digital converter (ADC) for intermediate frequency (IF) digitization are: sampling rate, bandwidth, signal-to-noise ratio, and dynamic range. Much research and development is being carried out on faster ADCs, with wider bandwidths and larger dynamic ranges. Companies such as Intersil (formerly Harris Semiconductors) and Analog Devices are producing the current state-of-the-art devices. An example of a low cost state of the art ADC for digital receiver applications is the AD9042 from Analog Devices. It is a 12 bit ADC, has 41 MHz maximum sampling rate and 100 MHz analog bandwidth.

### *2.2 Digital Signal Processing*

With the wideband IF signal successfully digitized, at a reasonable sample rate, the next stage is the processing. It would be convenient at this point to simply transfer the digital data to one or more digital signal processor (DSP) chips, and implement all remaining functions in software. However, even a cursory look at the processing demands of digital receivers makes it apparent that this operation is not straightforward. The total processing requirements in such a receiver may add up to more than 10 GFLOPS (giga floating point operations per second). Clearly, to implement all the radio functions using DSP alone would require an impractical number of chips. The answer? A hybrid approach incorporating specialized digital hardware, a digital downconverter (DDC), which performs specific tasks (downconversion, filtering, sample-rate reduction, demodulation, amplification) to reduce considerably the load supported by the DSP.

Companies such as Analog Devices, Graychip and Intersil have developed a number of DDCs. Devices such as these are essential components of current digital receivers, and will be until DSP chips are developed that possess the necessary horsepower to handle far higher bit rates than present technology allows.

### *2.3 RF Front End*

The focus so far in this article has been on the digital (and analog/digital interface) hardware necessary for digital receiver implementation. However, such a receiver design also has implications for the RF front-end circuitry, depending on the particular approach taken, and also depending on the particular application. In the RF front end, special filters, gain control schemes and very linear amplifiers (to provide a large dynamic range) may be required.

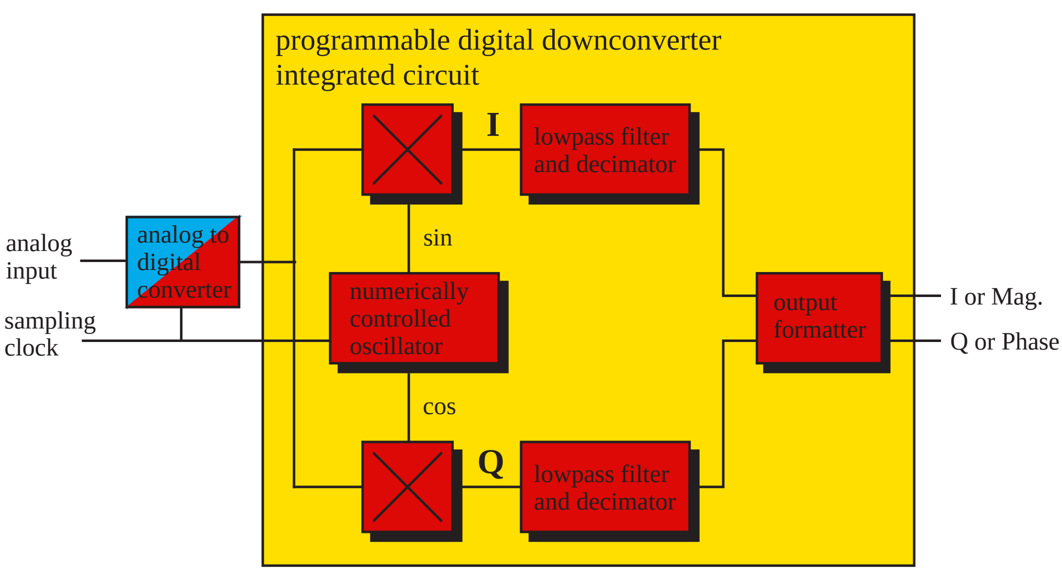


Figure 2: Functional block diagram of a DDC integrated circuit.

## 3 MANAGEMENT ISSUES

We spent most of our effort so far on describing the software radio - not without motivation. Our goal was to outline a representative, state-of-the-art technology where transition from analog to digital happens very early in the processing chain. This is doubtless a trend we can observe in most of today's electronic systems. This situation caught many designers of accelerator subsystems unprepared to respond to these new challenges. It is clear that we need a different approach when designing mixed signal systems. One certainty is also that software has become a significant component of these new systems. Software not only consumes greater resources than ever, but is also the critical differentiator and performance driver. In our practice, we found the issues presented below being important for successful system development and its integration into control system.

### *3.1 Hardware - Software Overlap*

One major opportunity and challenge is to overlap hardware and software development and testing. Such overlapping is not natural and will not occur without some specific attention to it. The opportunities to overlap the activities often relate to testing, where complex scheduling linkages often exist. The software people need hardware to test their code, and the hardware people need some software to even make their hardware work. Potential solutions include:

- Using modern requirements-driven software development methods, which defer the need for a testbed for the software and reduce tail end debugging effort when the test bed is available
- Planning the hardware and software testing early, so that scheduling challenges can be identified while there is flexibility left to resolve them
- Employing a simulator; this allows some early software testing and latter provides a tool to isolate hardware-software interaction problems in the real hardware

### *3.2 Cross-functionalism*

By cross-functional we mean that design of such complex systems is seen as a broadly based development activity in which specialists from different fields collaborate in the investigation of user (customer) needs, the conception, design, manufacture of (sub)system and finally the system integration and the provision of various kind of user support. We should think "system" and not connected individual hardware and software blocks.

Below is a tentative list of knowledge and skill areas needed to develop software-radio like systems ranking from the system/generalist level to specialist level:

- system conception
- system design and integration
- control system infrastructure
- algorithm development
- data acquisition
- digital signal processing
- analog signal processing
- software coding
- analog electronics design
- digital electronics design
- radiofrequency design
- ongoing hardware and software technical support

### *3.3 Communication*

Developing a new system entails making thousands of decisions, and weak communication can delay these decisions or yield poor decisions that result in unnecessary design rework. The delay may seem minor, perhaps a day or a few hours, but the aggregate effect of delaying thousands of decisions is staggering. If project decisions are not made by the people working on the project daily, the project can be delayed every time such a decision is needed. Consequently, our team-design strategy is to minimize the need for external communication by giving the team the resources and authority to make the vast majority of project decisions itself. Appropriate organization and delegation of decisions avoids many of these delays.

## 4 CONCLUSIONS

Successful development of hardware-software systems requires many different skills and talents. As a result, development teams involve people with a wide range of different training, experience, knowledge, perspectives and personalities. State-of-the art technology offers many opportunities to significantly improve cost/performance ratio. However, technology by itself will not lead to desired results without effective management of the product (system) development process, which should take into account all the challenges offered by complex interdependency between hardware and software.

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