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Digital Signal Processing In Advanced Laboratory

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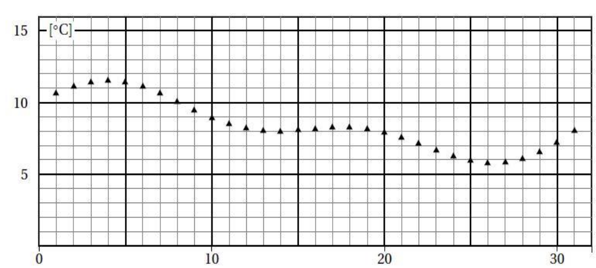
Abstract: - **In this report, we discuss a few issues that are important in a digital signal processor. These include issues like bus architectures that are most optimal for a DSP, parallelism and pipelining, fixed and floating point issues, etc. We then see the basic blocks required in any digital signal processor in section 3. The basic computational blocks include multipliers & accumulates (MACs), arithmetic & logic unit (ALUs) and shifters. Other blocks that are required for the proper control of these are program sequencers, data address generators, IO controllers and most important of all memory. In section 4 some issues related to power dissipation are included using an example of FIR filter realization.**

I. INTRODUCTION

A signal, technically yet generally speaking, is a formal description of a phenomenon evolving over time or space; by signal processing, we denote any manual or "mechanical" operation which modifies, analyzes or otherwise Manipulates the information contained in a signal. Consider the simple example of ambient temperature: once we have agreed upon a formal model for this physical variable – Celsius degrees, for instance – we can record the evolution of temperature over time in a variety of ways and the resulting data set represents a temperature "signal". Simple processing operations can then be carried out even just by hand: for example, we can plot the signal on graph paper as in Figure 1.1, or we can compute derived parameters such as the average temperature in a month. Conceptually, it is important to note that signal processing operates on an abstract representation of a physical quantity and not on the quantity itself. At the same time, the type of abstract representation we choose for the physical phenomenon of interest determines the nature of a signal processing unit. A temperature regulation device, for instance, is not a signal processing system as a whole. The device does however contain a signal processing core in the feedback control unit which converts the instantaneous measure of the temperature into an ON/OFF trigger for the heating element. The physical nature of this unit depends on the temperature model: a simple design is that of a mechanical device based on the dilation of a metal sensor; more likely, the temperature signal is a voltage generated by a thermocouple and in this case the matched signal processing unit is an operational amplifier.

Finally, the adjective "digital" derives from Digitus, the Latin word for finger: it concisely describes a world view where everything can be ultimately represented as an integer number. Counting, first on one's fingers and then in one's head, is the earliest and most fundamental form of abstraction; as children, we quickly learn that counting does indeed bring disparate objects (the proverbial "apples and oranges") into a common modeling paradigm, i.e. their cardinality. Digital signal processing is a flavor of signal processing in which everything, including time is described in terms of integer numbers; in other words, the abstract representation of choice is a one-size-fit all countability. Note that our earlier "thought experiment" about ambient temperature fits this paradigm very naturally: the measuring instants form a countable set (the days in a month) and so do the measures themselves (imagine a finite number of ticks on the thermometer's scale). In digital signal processing the underlying abstract representation is always the set of natural numbers regardless of the signal's origins; as a consequence, the physical nature of the processing device will also always remain the same, that is, a general digital (micro)processor. The extraordinary power and success of digital signal processing derives from the inherent universality of its associated "world view".



Temperature measurements over a month.

ADVANTAGES

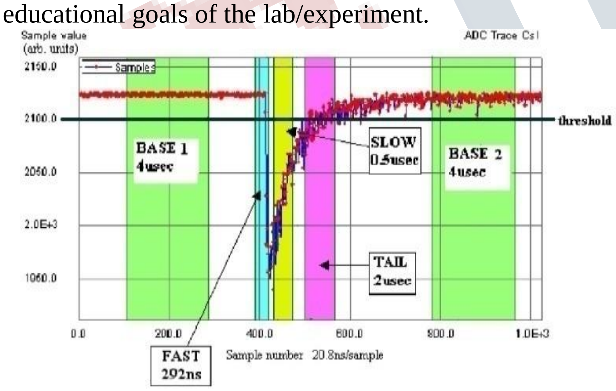
- ❖ preserves information, increases flexibility, reduces cost
- ❖ Traditional approach:
  - Hardware signal processing and trigger generation before digitization.
  - Information preserved:
    - Pulse height
    - Integrated charge
    - Time of arrival
- ❖ Different detectors require different signal processing hardware.

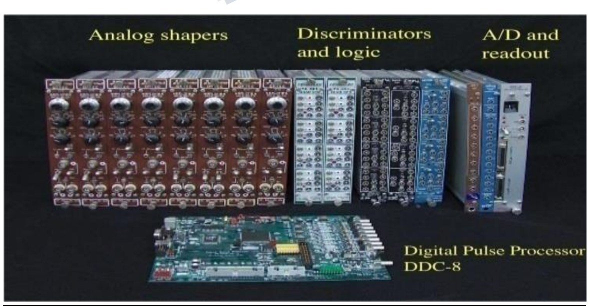
APPLICATIONS

DSP in the advanced lab

- DSP preserves the information provided by the equipment used and gives students access to sophisticated off-line data processing.
- DSP simplifies the hardware requirements for the advanced lab, since changes in signal processing only requires changes in on- and/or off-line data analysis tools.

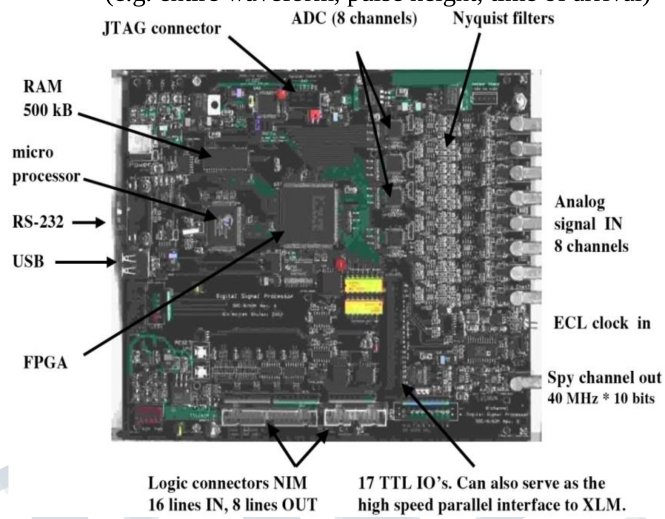
The level of student control can be adjusted based on educational goals of the lab/experiment.



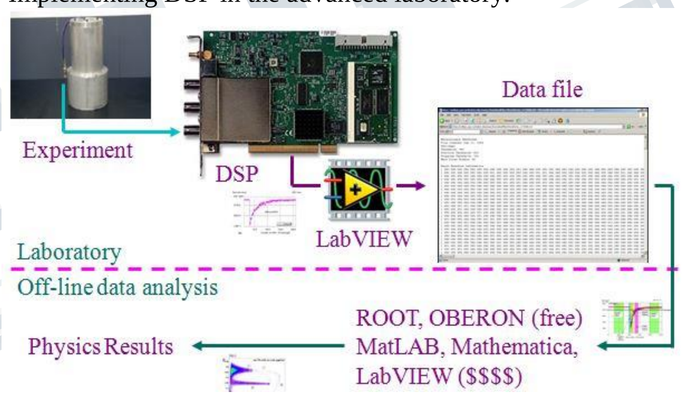


DSP approach:

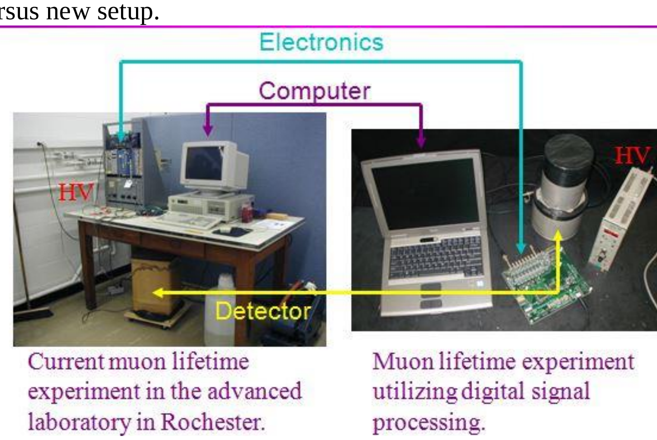
- Digitization first, followed by signal processing either in the processor, off-line, or both.
- Information preserved is determined by the user (e.g. entire waveform, pulse height, time of arrival)



Implementing DSP in the advanced laboratory.



An example of DSP: the muon lifetime. Traditional setup versus new setup.



- Digital signal processing in the advanced laboratory will modernize the upper-level experience of our undergraduates.
- One DSP can be used for many different applications; different applications in general require different DSP software but not hardware.
- The separation of data acquisition and data analysis mimics the mode of operation in modern research laboratories.
- The use of free software tools for data analysis provides the students with more flexibility to work on their analysis wherever and whenever is convenient.
- The standardization of DAQ hardware will reduce the cost (money and effort) to maintain the advanced laboratory.

II.CONCLUSION

- Concerns about digital signal processing.
- Is it a black box (signals in/physics out)?
- Digital signal processing is very flexible and the level of control can be adjusted and matched to the skill level of the student and/or the focus of the experiment.
- The analysis of the data carried out by the students can start with the digitized waveforms or at a higher level (pulse height, integrated charge, etc.)
- Why does it reduce cost? A DSP, such as the PCI-5112, costs $ 3,000, requires Lab VIEW, and a Windows machine!
- The cost reduction associated with DSP is a result of the reduced cost of signal processing and triggering hardware. A wide variety of signals can be processed with the same DSP system (although not at the same time)

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