NEW SIGNAL PROCESSING INTEGRATED CIRCUIT REPRESENTS TECHNOLOGICAL BREAKTHROUGHS FOR REDUCING TRAINER COSTS

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ABSTRACT

New integrated circuit signal processing devices introduced by several manufacturers are usually considered to be for specialized applications. However, it will be shown that these devices are "ideally" suited for the real-time simulation of whole classes of dynamic subsystems. Furthermore, these devices could be used to replace analog components and/or hardware which are subject to aging, drifting and other factors that result in maintenance problems. Since practically all training devices involve placing a trainee in a realistic dynamic environment, these devices could impact the training device industry much like the GP digital computer. The technological techniques required to utilize these new signal processing chips will be presented. Finally, a survey of training devices that could be improved or reduced in cost by using these new devices will be presented.

INTRODUCTION

At present, there are two prominent manufacturers committed to capturing the emerging LSI (including single chip applications) signal processing market. Their alternate approaches to this market are best presented in a tabular form - see Table 1. In brief terms, one has embarked on a fixed point processor approach, whereas the other has chosen a floating point processor design approach. The fixed point approach is easier to implement in terms of current technology, and as such is more mature (approximately two years old). On the other hand the floating point approach shows much more potential in terms of broad-based applications, e.g., compact spectrum measuring devices using FFT chips, statistical analysis devices, array processing etc. As a bonus, the floating point processors do not have the difficult and "pesky" problems associated with scaling fixed-point processors. Several other manufacturers have committed resources to enter this market. Still others should be considered as competitors by virtue of their powerful general purpose microcomputer lines which can be applied to varied and sundry signal processing applications.

TABLE 1. FIXED VS. FLOATING POINT PROCESSORS

Topics	Remarks	
	Fixed Point	Floating Point
1. Math Ops	Fixed Point-scaling problems	Floating Points-no scaling problems
2. Speed	Comparable	Comparable
3. Design	Easy with single chip and software tools	Relatively complex, requiring a complete unique procedure for each application
4. Continuous programmability	Virtually impossible (memory not accessible) except for analog control of center frequency, etc.	Completely achievable but still a rather difficult design problem
5. Evolution	Rather mature	Rather early in development phase
6. Alternatives	Limited to dynamic models and special non-linear subsystems	Most promise for FFT, statistical analysis, array processing, etc. - but accompanied (still) by involved design steps.

When one considers the millions of dollars that manufacturers have committed to manufacturing and marketing of newly emerging signal processing chips (and chip families), one must ask where and how can these technologies be applied to trainers. Hopefully, some of these questions can be answered.

WHAT ARE SIGNAL PROCESSING CHIPS?

It is unfortunate that the words "digital signal processing" or "Processors" and "digital filters" have become the bywords for devices that are more accurately described as real-time digital dynamic simulators or implementations. Traditionally, managers and planners tend to think spectrum shapers or band limiting devices when referring to filters. Similarly, signal processors are thought of as communication pre- and post-signal conditioners. It is important to note that these devices can be used to implement any reasonable size dynamic real-time digital model, such as:

1. Digital controllers for analog servo-systems.

Training seminars have been conducted on national and international levels for their sales/marketing personnel - and then followed up with free (as token costs) seminars in all areas devoted to marketing their signal processing components.

2. Replace whole combinations of analog devices; e.g., circuits, spring-mass systems, motor controllers, etc.

3. Simulate dynamic analog devices of any type in addition to implementing digital filters and signal processors. In fact, these devices show promise for designing inexpensive signal generators, electrical measuring devices, tuneable filters, etc.

Finally, it should be noted that the "general class" of signal processing chips should include special purpose preand post-filters to interface junctures, FFT spectrum analysis chips, high-speed floating point multiply/divide processors, etc. These specialized devices also play a role in processing signals although they are not as prevalent as dynamic subsystem simulators.

TRAINING DEVICE APPLICATIONS

The ability of this device to simulate dynamic models in software, to construct dynamic models in hardware supported by software, and to construct dynamic hardware, has potential payoffs in many areas of training devices. As one example of each of these, consider:

A war game simulation where many dynamic vehicle situations interact together to produce Monte Carlo type results designed to determine kill ratios, logistics problems, etc. These type problems are highly dependent on software development and clever model formulation.

A flight simulator where countless servos drive motion bases, visual optics, and control loading devices for input control such as rudder pedals. The success of these devices depend on implementing servo systems with carefully designed servo compensators and controllers that permit the simulated device and its environment to be useful for training.

A satellite tracker trainer where dish drive servo velocity limits are far below field units for safety purposes. Then substantial savings are realized by specially designing small scale units that behave like the field units in every respect except for angle rate limits. Hardware redesign is therefore necessary to meet these performance requirements.

In view of the processor's ability to be substituted for the software, interface/hybrid, and hardware elements of trainer simulation systems, its potential as a high bandwidth adaptive controller becomes apparent.

Simulators are naturally limited in system performance when compared to the real world situations they simulate. The hardware simply does not have, and in cases does not need the range and fidelity of the real world. For example, motion platforms cannot generate the complete range of acceleration cue characteristics of a particular aircraft. However, since these requirements are task dependent, the system performance may be optimized as a function of task cue requirements by control of the system hardware/software that adapts (or optimizes) it for the task.

The processor can be programmed and combined with other chips to provide platform drive signal shaping as a function of specific input variables that characterize a task (e.g., carrier landing). For example, it may be desirable to change motion platform gain as a function of slant range to carrier or average stick input deviation from trim to accentuate cueing for small inputs. Since large inputs are less likely as the aircraft approaches the carrier, the platform cueing range is centered around a smaller, localized aircraft acceleration range. This would be accomplished using the processor by implementing filters in the software and modifying the filter gain and bandwidth as a function of slant range.

A SPECIFIC EXAMPLE

Of the many potential applications discussed for use of the "microprocessor on a chip", let's consider a typical state-of-the-art flight controls loading device. This device, which is used in almost all flight simulators generates realistic control stick forces, with extensive use of analog circuit cards for signal shaping functions. All-analog systems are generally preferred because of bandwidth requirements as high as 100 Hertz. Since the fixed point type of signal processor can be operated at sampled data rates of more than 10,000, it is ideally suited for the flight control loader devices.

A typical control loader is illustrated in Figure 1. Analog circuit cards are used for stabilization of the control loops and for generation of the loader forcing functions such as gradient and friction. Typically, several analog cards are required for each control channel.

Figure 2 shows the same loader, except with the "processor on a chip" replacing the analog cards and other analog shaping circuits. Thus, complex analog circuitry with inherent aging, drift, and maintenance considerations are replaced with the predictability and low maintenance qualities of a sampled data system.

In summary, requirements for dynamic systems and their simulations exist throughout the scope of training devices. In view of the previous discussion "What are Signal Processing Chips", it must be concluded that these (typical trainers and training device) areas all represent excellent candidates for signal processor chips. Furthermore, the standard general purpose digital advantages still apply, e.g.:

EPROM based dynamic models can be redesigned/modified via simple software changes.

Redundant hardware simplifies logistics and maintenance, not to mention capital savings.

System repeatability is assured for training mods and corrections.

SIGNAL PROCESSING TECHNOLOGIES

The technological background that designers must possess to implement systems and subsystem designs based on signal processors fall into two basic categories. First, there is the general area of FFT/Spectrum Analysis applications applied to such problems as Spectrum Signature Analysis or System identification. These problems require engineers/designers trained in noise and communication, FFT algorithms formulation, discrete and continuous signal spectrums, etc. At least some graduate level work is needed for these type problems.

The second category of dynamic system modeling is typically unfamiliar to most engineers, but its level of expertise requirement makes it easy to master, even on a part-time basis, for the dedicated designer. The following areas of study with clarifying comments should serve to place the technologies required for signal processor type designs in perspective.

1. Continuous dynamic system modeling - an area that each engineer should possess by virtue of his differential equations, circuits, linear controls, etc., background.

2. Discrete dynamic modeling - an area missing in many engineer's background. However, this area is usually easily mastered by relating to 1. above and studying difference equations - transforms and discrete models from texts such as DeRusso, Roy and Close, Cadzow's and Kuo's books on sample data control systems (1,4,5,6).

3. Discrete and continuous system relations - an area best mastered by studying digital filters. Here the best approach is to review continuous filters; (such as Butterworth, Chebyshev, Elliptic, etc.) and then study the digital filter impulse invariant, step invariant, bilinear transform, and other methods of digital filter designs, which are topics in standard digital filter texts such as Oppenheim's or Antinov's (7,8).

NOTE: Again "digital filters" may be misleading. The goal and result here is to master dynamic discrete modeling (on digital computers of real-world continuous dynamic models which represent the environment of trainers).

4. Digital hardware implementation - an area almost all engineers have some background in. Assuming areas 1. through 3. above were mastered and a discrete H(Z) discrete model was frozen, then the steps of design for the chip would be:

(a) Code the H(Z) model in assembly language (9).

(b) Using a development system, evoke the assembler and generate an assembly file.

(c) With the software, obtain an object file of the H(Z) model.

(d) Evoke the simulator software and verify the design by input/output test function runs (10).

(e) Using the support software and a PROM burner, program the EPROM with the H(Z) object code.

(f) Test and evaluate the final design.

Thus, because of the rather broad technological background required for signal processing design, the area has been slow to develop. Even so, approximately six months of part-time study with one or two short courses can bring most engineers up to speed. This has been typically reduced to three months (one quarter course) for those with microcomputer system design background.

CONCLUSIONS

It has been postulated that signal processing LSI technological developments will impact the training device industry primarily because economic savings can be realized through:

1. Reduced capital costs

2. Reduced maintenance costs

3. Reduced modification and review costs (via software design)

Other benefits include:

4. Repeatability

5. Immunity to aging

6. Reduced size, weight, accuracy, etc.

7. General purpose hardware -- quantity prices.

In view of these potential payoffs, the following conclusions are appropriate:

1. Steps should be taken to utilize signal processor LSI technology throughout applicable trainer designs. Considering the millions of dollars committed by manufacturers to real-time integrated circuits signal processor design, it is obvious that manufacturer market research has identified a multi-billion dollar application area with substantial advancement in technology, as well as alternate design approaches to "old" problems with substantial economic savings (companies are sinking millions into hardware development and marketing). For example, some conduct "running" nationwide seminars and are introducing new chips and support chips. "Inside info" indicates "new version" integrated circuits masks have gone to production.

2. Industry, Academia, and Government agency engineers and scientists must be educated and prepared to take advantage of the new signal processing - or discrete system and/or simulation design hardware. To do so requires preplanning and training of the related work forces.

3. Although the fixed point approach has encountered some difficulties with early production chips, it seems these problems will subside in view of new designs on the horizon. The maturity of this technology indicates immediate utilization.

4. The new floating point processing support chip families are moving a little slower. At this time it is probably prudent to prepare for their use through training measures - but hold off a little longer on real designs. Small special purpose designs may be appropriate to undertake now.

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APPENDIX

In late 1979 the electronic hardware industry was surprised when the first totally self-contained single chip signal processor was introduced. The digital portion of the processor has architecture specifically adapted for high speed real-time signal processing. As an example, one of the fixed point signal processors has the following characteristics:

4 Analog inputs (9 bits)

8 Analog outputs (9 bits)

Provisions for limited digital interface

192 24 bit instructions

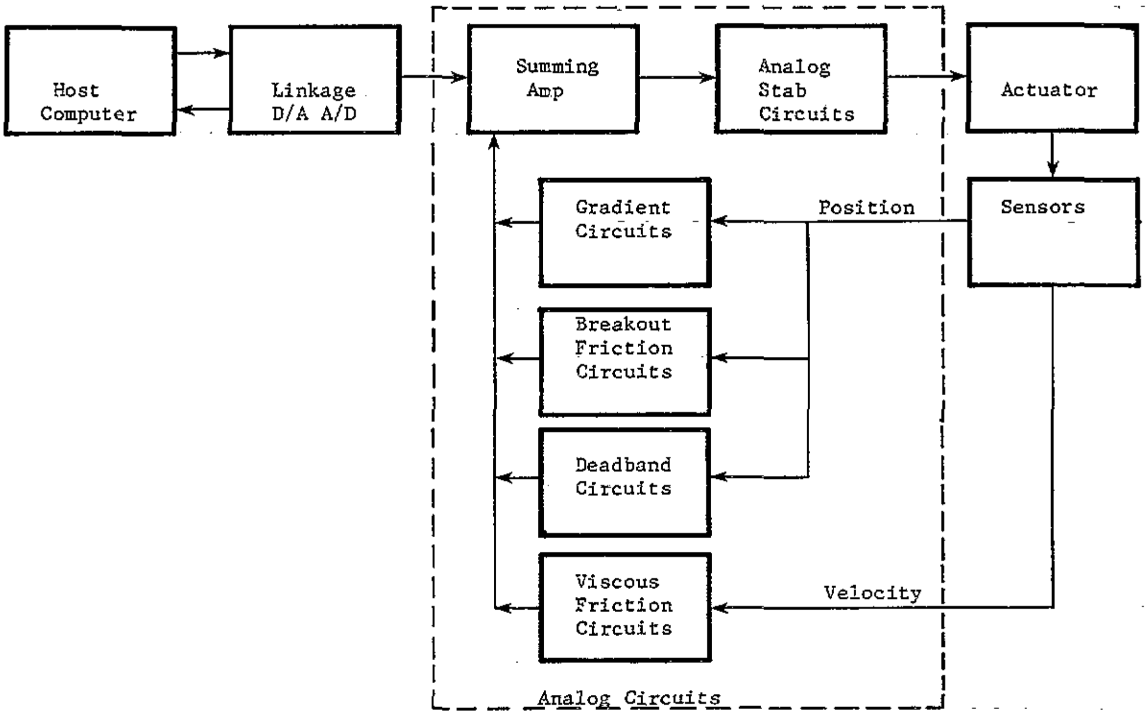

Figure 1. Analog Based Loader

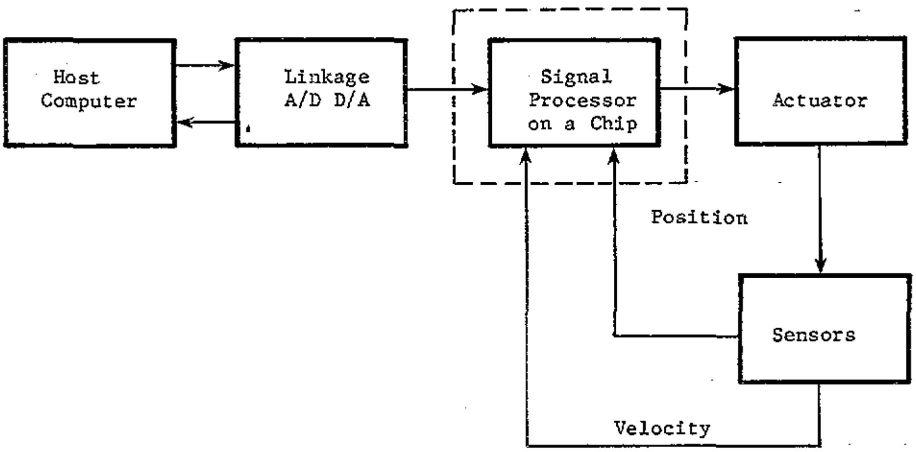

Figure 2. Signal Processor (2920) Based Loader