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"New possibilities in data processing sub-systems for equipment"

by

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NEW POSSIBILITIES IN DATA-PROCESSING SUB-SYSTEMS FOR EQUIPMENT

It is clear that device technology has advanced rapidly during the last ten years, and made it possible to include in equipment data-processing sub-systems of increasing power and decreasing cost. However, this advance has not been uniform throughout the whole range of data-processing devices, neither has it proceeded uniformly in time. The trauma of transition from valve to transistor was over more rapidly than expected, but each successive change has had almost as much impact as that transition, and change follows change at a quickening pace. The transition from the early germanium transistors to silicon planar radically affected the speed of digital equipment, the accuracy of analog equipment, and the temperature range of both. The coming of digital integrated circuits opened up a world of all-digital systems, and made the small digital computer a potential 'component'. However, integrated circuit operational amplifiers, with specifications better than chopper-stabilized valve amplifiers, have followed close behind, and their possibilities have been enhanced by thin-film networks and FET switches. Over the horizon looms LSI, and the very low-cost, micro-programmed digital machine, but we can be equally sure that over that same horizon are many developments of which we have taken no account, yet whose impact may be greater than that of LSI.

Although there is no complete answer to the problems of rapid technological change, there is clearly an initial requirement for a systematic appraisal of available, potential and possible data-processing techniques, in which a clear separation is maintained between device and function. There is little that is new in the data-processing techniques themselves, and an almost exhaustive variety of computing functions have been described in the literature of the past twenty years, but it is only at present that devices are becoming available to make these functions sufficiently low-cost, accurate and reliable, to be commercially viable. In this paper four data-processing techniques, which have proven attractive in commercial equipment during the recent past, are briefly described - adequate references are given to full descriptions in the literature.

(1) Analog Arithmetic with Digital Multiplexing and Sequencing

The classical analog computer is essentially a continuous differential-equation solver using parallel processing elements. Many discrete computations can be expressed simply as the end result of the solution of a differential equation, however, and, since the speed of analog computation is comparatively fast, it is possible to multiplex some of the analog computing elements and perform the computation sequentially. The configuration obtained is similar to that of a digital computer in which the arithmetic unit has been replaced by a set of switched analog integrators, whose interconnections are changed by the stored program.

A detailed description of such a data-processor and some of its possibilities has been given by Schmid (1965). The configuration is similar to that of a modern 'hybrid' computer, although the rationale and type of application are very different.

To indicate the possibilities, two ingrators may be used to:- add, subtract, multiply, divide, square, square-root, convert polar co-ordinates to rectangular, and vice versa. For example, if two integrators are connected in cascade, to realize the equations $\diamond$ $\dot{y} = -x$, $\dot{z} = -y$ $\diamond$ then, with the constant input, $x = -1/2$, and initial conditions, $y(0) = 0$, $z(0) = Z$, the solution of the equations is $\diamond$ $y(t) = t/2$, $z(t) = Z - t^2/4$ $\diamond$ so that, if we let the integrators run until $z(t) = 0$, and then $y(t) = Y$, we have $Y = Z^1/2$.

Overall, long-term accuracies of the order of $\pm$ .1% are now feasible with such data-processors, and the technique is particularly attractive when the original data is already in analog form. Parallel-digital, or pulse-count, outputs are readily obtained by running digital counters in parallel with the integrators, and complex analog waveforms are readily synthesized as the Fourier transforms of digital pulse trains.

(2) Digital/Analog Convertors in Arithmetic Units

Analog data-processing may also be brought into the CPU by replacing digital arithmetic, not with analog integrators, but with multiplying digital→analog convertors (D/A convertors with analog signals on their 'reference' lines). This is particularly attractive for display generation, and analog signal processing, and its application in the Adage 'Ambilog' computers and displays has been described by Hagan (1966). Recent falls in cost of high-precision, high-speed D/A convertors (from £500 to £50) has made their use in simpler equipment economically viable.

(3) Incremental Computing Techniques

A further variation on the system described in (1) is to make it 'all-digital' by replacing the analog integrators with digital counters (that is, DDA integrators). This is attractive when higher accuracy is required, or the original data is in digital form. The use of counting techniques in data-processing has been described by Gaines (1968), and an outstanding example of their application, in the Solartron Digital Transfer-Function Analyser, has been given by Ley and Elsden (1968).

(4) Micro-programming Small Machines

The techniques described so far have involved modifying the arithmetic unit of a GP-machine-like structure to generate special operations required in equipment. There is the alternative possibility of maintaining parallel-digital processing, but generating special operations through extensive micro-programming. This is attractive now that single-package arithemetic units are promised by LSI, and micro-circuit read-only stores with 1,000's bits/package are already with us. Micro-programming has been exploited in emulators on large machines, but its full potential in small machines has not yet been utilized; customized microprogramming is already available in the ELBIT and Varian DATA 6201.

References Gaines, 'A Modular Programmed DDA' IFIP 1968
Hagan, Treiber, 'Hybrid Analog/Digital Techniques' AFIPS SJCC 1966
Ley, Elsden, 'A Digital Transfer Function Analyser' IFAC, Budapest, 1968.
Schmid, 'Sequential Analog/Digital Computer' AFIPS FJCC 1965