[August 1942]

The Use of High Speed Vacuum Tube Devices for Calculating 7.6.

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There are many sorts of mathematical problems which require calculation by formulas which can readily be put in the form of iterative equations. Purely mechanical calculating devices can be devised to expedite the work. However, a great gain in the speed of the calculation can be obtained if the devices which are used employ electronic means for the performance of the calculation, because the speed of such devices can be made very much higher than that of any mechanical device. It is the purpose of this discussion to consider the speed of calculation and the advantages which may be obtained by the use of electronic circuits which are interconnected in such a way as to perform a number of multiplications, additions, subtractions or divisions in sequence, and which can therefore be used for the solution of difference equations. Since a sufficiently approximate solution of many differential equations can be had simply by solving an associated difference equation, it is to be expected that one of the chief fields of usefulness for an electronic computor would be found in the solution of differential equations.

As will be brought out in the following discussion, the electronic computor may have certain advantages other than the single one of high speed when compared with the differential analyser of the usual mechanical construction. For instance, the mechanical analyser has an accuracy limited by the way in which the slippage and backlash enter into its operation, whereas the electronic device, operating solely on the principle of counting, can, without great difficulty, be made as accurate as is required for any practical purpose. Secondly, whatever errors are committed by the electronic device are mathematically determined errors which arise through the use of a difference equation in place of a differential equation, and since these errors are mathematically determined, they are reproducable. Hence a check calculation may be run at any time, and whatever the result may be for the first run, that result should be obtained on every succeeding test run. Thirdly, the ease with which the various components of such a computing device can be interconnected by cables and switching units makes it possible to set up a new problem without much difficulty. It is also appreciated that additional component parts may be built and connected in whenever more complicated problems require them, and that additional spare components may be kept in reserve and quickly interchanged with any components which fail in operation. Fourthly, a convenient way of diagnosing faults and isolating defective units is available through the use of standard electrical testing procedures. Fifthly, not only can the regular problems which have to be solved be run through quickly on the elctronic computor, but also the test problems, and hence less time is lost in discovering any failure which may develop during operation. Sixthly, both the mechanical analyser and the electronic computor require maintenance by skilled labor,

B. Randell (ed.), *The Origins of Digital Computers*

but the number of persons required to turn out the same amount of finished work should be appreciably less in the case of the electronic computor.

It is now necessary to justify the foregoing comparison. Let us first consider the mode of operation. As already stated, the electronic computor utilizes the principle of counting to achieve its results. It is then in every sense the electrical analogue of the mechanical adding, multiplying and dividing machines which are now manufactured for ordinary arithmetic purposes. However, the design of the electronic computor allows easy interconnection of a number of simple component devices and provides for a cycle of operations which will yield a step by step solution of any difference equation within its scope. The result of one calculation, such as a single multiplication, is immediately available for further operation in any way which is dictated by the equations governing the problem, and these numbers can be transferred from one component to another as required, without the necessity of copying them manually on to paper or from one keyboard to another as is the case when step by step solutions are performed with ordinary calculating machines. If one desires to visualize the mechanical analogy, he must conceive of a large number, say twenty or thirty calculating machines, each capable of handling at least ten-digit numbers and all interconnected by mechanical devices which see to it that the numerical result from an operation in one machine is properly transferred to some other machine, which is selected by a suitable program device; and one must further imagine that this program device is capable of arranging a cycle of different transfers and operations of this nature with perhaps fifteen or twenty operations in each cycle. It might be said that even though such a mechanical device were constructed, and even though its speed of operation were considered satisfactory, the number of problems which it would solve within the lifetime which is determined by the wear of its parts, would undoubtedly be very small.

In stating that the electronic computor consists of components which are exactly analogous to the ordinary mechanical computing machine, it is intended that this analogy shall be interpreted rather completely. In particular, just as the ordinary computing machine utilizes the decimal system in performing its calculations, so does the electronic device. When a number such as 1216 is to be injected into a particular register, it is not necessary for 1216 counts to be used. Instead, a total of ten counts would be sufficient, one in the thousands register, two in the hundreds register, one in the tens register, and six in the units register (simple, isn't it?). It is only in this way that almost unlimited accuracy can be obtained without unduly prolonging the time of operation. Electronic devices have been proposed for which this is not true, but such do not seem to merit consideration here.

After what has just been said, it is easy to see that the total time required for the completion of any cycle of operations can be rather closely estimated, if only one knows the time required for injecting a single count. Existing electronic circuits are capable of counting electric pulses at rates in excess of 100,000 per second (in much of the literature on counters, often referred to as scaling circuits, and not to be confused with the Geiger-Mueller Counter, also discussed in literature, the counting rate is stated for pulses which are randomly spaced. This counting rate is of necessity a great deal lower than that at which the same circuit will count when the pulses are uniformly spaced. Although the pulses which would be used in a computing device must be non-uniformly spaced, because they must be interrupted at various times,