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Digital Computer Laboratory
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Cambridge, Massachusetts

MEMORANDUM

To: Jay W. Forrester

From: B. E. Morriss

Date: November 5, 1951

SUBJECT: Meeting on Air Defense Computer

Preliminary Reading List:

Haynes, Report on Magnetic Cores for Computing Elements, University of Illinois.

Harvey, I. J. and others, "Ferromagnetic Spinels for Radio Frequencies," RCA Review, Vol. XI, No. 3, September 1950, pp 321-363.

Israel, D. R., Interoffice Correspondence to Jay W. Forrester on Some Considerations for a New Computer for Air Defense.

Miles, James G., Saturable Reactors as Substitutes for Electron Tubes in High-Speed Digital Computers, ERA.

The objective of this series of meetings was stated to be the development of a feeling for the nature of the machine as it affects the work of the next year. Should it be a modification of present work or a complete change? What basic circuits should be investigated and pushed for transistors and magnetic cores?

The meeting was started by N. H. Taylor's outline of the three considerations which he felt were basic to the problem: components, building blocks, and registers. These could be grouped as follows:

Components:

Vacuum tubes, crystals, storage tubes, magnetic drums, magnetic tapes, transistors, and ferromagnetic and ferroelectric cores.

Building blocks:

Flip-flops, gate tubes, gate generators, amplifiers, distrustive read mechanisms, and magnetic gates.

Registers:

Counters, shifting registers, adders, selection switches, decoders, memory systems, and circulating registers.

Taylor then listed the things which he considered faults of Whirlwind I and the approach which might reduce or eliminate these faults. The logical improvements were:

1. The control of the system should be centralized, i.e. ES Control, Central Control, In-Out Control should probably be one.

2. Whirlwind I has an inadequate number of control pulses in its cycle.

3. Program Timing should include all computer activity and a hesitation should be obtained by diverting clock pulses to a counter rather than stopping the clock.

4. A lot of activity such as program timing is cyclic. As much of this cyclic operation as possible should be reduced to a type of oscillator circuit which has less sophisticated circuitry than flip-flops and gates.

5. Logic of system should favor external equipment because present system creates a bottleneck in the in-out element.

6. More internal storage at higher speeds is desirable. The rest of Whirlwind seems about fast enough, in fact a slight increase in multiplication time might be tolerable if a saving in equipment was possible.

The engineering considerations for improvement were:

1. Elimination of coax connections in most circuits by revising layout.

2. Flip-flop circuit is still weakest electronic link in systems. Study of transistor as an active element desirable here.

3. Smaller signal levels should result in fewer tubes.

4. Crystal gates quite desirable.

5. Storage by magnetic cores should be pushed in an attempt to improve selection problem.

6. Simpler arithmetic element perhaps a little slower. Series-parallel might save a lot of equipment.

D. R. Brown then posed the following questions which must be answered about the requirements of the computer:

1. How high a degree of reliability is necessary?

2. Since it will be used in real-time work what will be its inputs and outputs?

3. How much training will its maintenance crews have?

4. Speed in operations per second?

5. Operations to be performed, i.e., automatic sin-cosin, etc.?

6. Cost?

7. Storage capacity?

8. Physical size?

9. Temperature and climate requirements?

Size, portability, and temperature and climate restrictions appear to be of secondary importance to the development of a system to do an adequate and reliable job. There seemed to be little argument but the machine should be general purpose rather than special purpose. The feeling was expressed by Jay W. Forrester that the effort should be towards the development of relatively simple building blocks of components, such as cores, which do not deteriorate, which could then be combined into and with a central control. It appeared to be generally agreed that the development of long life components is desirable Of lesser importance is the gradual deterioration which may be detected by marginal checking techniques as contrasted to sudden or intermittent failure.

Many other questions followed for which there were no immediate answers. D. R. Israel asked if the effort should be towards a single complex machine which would have to operate continuously or towards a simpler machine where two or more could be made available? Also is there any advantage in permanently stored arrays? How could they be used and what would they save? A partial answer to this was given by R. R. Everett. One of the major problems of a storage system is selection, and this problem would not be simplified if the requirements still called for random access. Unless a cyclic selection is possible there seems to be little saved and the added complexity of having two storage systems.

Some time was spent on reliability of transistors and magnetic cores. The point was made that in favorable circuits in Whirlwind I crystal diodes have a failure rate of 0.25% per 1000 hours. There is no reason to believe that transistors will be better unless it is through improved production which does not appear likely in the immediate future. The reasons for failure of crystals in favorable circuits appear to be unknown. Will magnetic materials deteriorate? Possibly, but probably with lives far greater than any components used today. The reliability of pulse transformers has been much better than that of tubes (approximately 0.1% per 1000 hours) but all of these failures have been due to the windings and probably could be improved by controlled production. This brought up the point that reliability would be unquestionably improved if the components were of a type which could be produced here. It seemed agreed that this is desirable where feasible and a most important point.

W. N. Papian suggested that other groups be included in the discussions to generate more ideas. Jay W. Forrester said that this was intended. Papian also requested that someone from Block Diagrams spend some time with his group investigating cores and how they may be further used and fitted into computer logic.

Reliability of Components in Computer Circuitry

N. H. Taylor

After about 7,000 hours of systems operation on Whirlwind I, it is possible to draw a few conclusions concerning the reliability of some of the components which we have chosen to use and from these conclusions to make some estimates of what sort of components we would like to have in future computers.

As far as vacuum tubes are concerned, the 7AK7 Gate Tube Circuit is by far the best in terms of replacement and the failure rate of 1% per thousand hours seems to represent a maximum available figure of reliability which one may expect in vacuum tube circuits. It is interesting to note that the failures which constitute this 1% figure are made up of tubes from various categories. That is, no one type of failure is predominant and in order to improve this situation one would have to improve the manufacturing process in many ways.

A second component on which we have gathered some data is the germanium diode. Except for one circuit in the computer which is quite hard on germanium diodes, the overall failure rate is something better than .25% per thousand hours. The nature of these failures is such that one may expect some improvement by improving the stability of the component in terms of the back resistance characteristics. It may be pointed out at this time that the failure rate of .25% per thousand hours is rather high for the military computers which we are considering and that components which we are looking for should have failure rates of the order of 1/10% per thousand hours or better to achieve the sort of reliability which we hope for in these future applications. The two new components which seem to be best suited and most likely to meet the stringent requirements in reliability are: (1) the transistor and (2) the saturable iron core.

A transistor may probably be compared with the crystal diode as to its reliability. Indications are that we may expect something of the order of .25% failure per thousand hours. This may be a rather pessimistic view in view of some of the statements from the Bell Telephone Laboratories concerning reliability, but it will serve at this time as an estimate of what we may expect in this kind of circuitry.

The iron core has the advantage of no basis for comparison so we tend to be very optimistic on the failure rate of this component. It is not apparent just what factors, if any, affect the fatigue or failure in circuit use.

Two conclusions may be drawn from the above discussion which may well direct the nature of the decision as to which components will be best suited for future computers.

1. The transistor is probably as reliable a component as we now are using in computers even though it is in rather early development, and improvements in its manufacturing are being realized at a relatively fast rate. It is reasonable to assume that this device will improve within the next few years but it is hard to conceive of a vacuum tube which will improve very much over the 7AK7 discussed earlier.

2. The iron core element is even a newer device than the transistor and seems to promise tremendous long life at this stage of its development. It should be pointed out, however, that in common with delay lines and transformers the reliability of this element may be limited if in winding

of wires around the core sufficient care is not exercised. Intermittent joints due to insulation wearing away are the main causes for failure in transformers and delay lines. This iron core may well suffer from the same ailments.

Signed B. E. Morriss
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Approved JWF
Jay W. Forrester

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