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BASIC COMPUTER MEMO # 7

SUBJECT: General Comparison of Synchronous with Non-Synchronous Control Systems.

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The 7000 program has given considerable study to the benefits derived from using a non-synchronous control system. The DC current mode transistor logic as used on the 7000 program were the only circuits that were considered. A truly non-synchronous system with DC logic takes place in the well known A B type of sequence because a storage element cannot send and receive simultaneously. Synchronous or practical non-synchronous control may operate in a non A B mode by employing race conditions with extremely high probability that one condition will always happen first. The latch escapement technique shown by M. Homan is of this type.

I. Speed

The non-synchronous system has the potential to be faster for the following reasons:

1. The actual speed of a circuit is utilized as compared with an assumed worst case for synchronous operation.

2. Each and every logical operation works at maximum speed hindered only by the natural logical interlocks of the machine processes. In the synchronous case, many operations are forced into a fixed basic cycle, some of which could be inefficient for the logical work done. The opportunity to gain speed by logical rearrangement of computer sequences is restricted in a fixed cycle mode of operation.

3. There are some processes where the time of execution is a function of the data being operated on. The non-synchronous system takes advantage of this where the synchronous must assume the worst data possibility.

4. There are some non-synchronous operations in every computer, if only with the outside world. These are a normal part of a N. S. system, where in a synchronous system some time is usually taken in synchronization.

5. The time lost due to skew in a clock system is avoided in non-synchronous systems.

Reasons 1 and 5 are the principle ones for recommending non-synchronous operation from the speed point of view.

In practice it is found very difficult to realize these gains at a reasonable cost for the following reasons:

1. In a logical sequence of operations one operation must be completed before the next may start. In the synchronous system adequate time is used to insure completion of an operation. In the non-synchronous case additional circuitry is added to measure operation completion. Unfortunately this added circuitry uses time (2-3 logical levels) and reduces the potential gain.

2. Additional control circuitry is necessary to insure the proper sequence of the logic being controlled and its proper relation to the previous and succeeding stages. (Usually about 3 levels of logic).

3. Even a simple non-synchronous system needs dual logic for all functions of two or more variables. In this system each transfer is followed by a zero flush cycle. This is in effect a ternary mode of operation which is not efficient with binary elements. Based on a 15 mus average circuit time and 20 mus maximum circuit time the synchronous type is faster for pipelines or repetitive type operation by approximately 210 to 330 mus. For a non-successive type transfer where the flush can be done in spare time the non-synchronous time reduces to about 200 mus.

4. Higher speed non-synchronous systems which avoid the flush cycle can be envisioned and appear faster than a synchronous system. However as many as 4-5 times the equipment of an unchecked system may be necessary. Furthermore, much work is necessary to develop such a control system.

II Reliability

The non-synchronous machine may best find its place where emphasis is on reliability and availability rather than speed. In present techniques there is considerable overlap in equipment necessary for non-synchronous operation and error detection. The higher forms of non-synchronous may contain much free equipment toward error correction, or duplex operation.

It is difficult to show improvement in reliability with a non-synchronous machine, particularly on an equal speed basis with a synchronous machine, because of the greater number of components. The important compensation is a longer circuit life before failure, but this can be at the expense of machine speed.

The concept of a synchronous machine with a continuously variable clock which automatically slows down as the uninterrupted operating time and probability of error increases might approach the gains of the N. S. system.

Reliability is best achieved by keeping the component count low and using error correction wherever possible within the limits of some overriding factors such as cost and feasibility. Non-synchronous might appear much better in a system requiring complete error correction.

Availability is not as clear. More complete error detection is available with non-synchronous but is it worth the cost? The question of servicing is almost a personal opinion. With additional equipment and effort it appears that servicing can be as easy as present synchronous techniques.

III The Size of a Computer

The size of a computer or the distribution of its components effects primarily the speed of the computer. Both systems work, and both systems are degraded speedwise in an abnormally large system. The limiting factor of a synchronous

system is the skew in the distribution of the clock pulses which effectively reduces the effective cycle by this amount. As computers get larger, non-synchronous computers should slowly improve their position.

IV Computer Component Speed

Again the skew in the clock distribution system relative to the logic process time is the predominant factor. The first order effect of an increase in component speed is also to reduce the skew in the clock distribution system. In the limit, process time is a function of the spatial distribution and here the non-synchronous would appear better than under present speed conditions.

V Flexibility

One of the great advantages of non-synchronous operation is its flexibility. The logical design is independent of absolute circuit speed, size of computer, packaging and layout of parts. Of course speed is effected by these parameters, but any improvements of these parameters at any time are immediately reflected in improved operation to the maximum extent.

In a single variable clock synchronous system, changes of parameters can be utilized by changing the clock frequency but its effect on overall reliability is harder to predict.

VI On the basis of current information and proposed schedules the decision to proceed with synchronous control is a good decision for the following reasons:

1. There is a great emphasis on speed. Highest speed is now obtained with synchronous control assuming 15 and 20 mus as average and maximum circuit times.

2. There is emphasis on low cost, fault location and reliability. Each of these is superior with a synchronous system if error correction is neglected.

3. It will take considerable work to develop a good non-synchronous system with a high degree of error correction.

4. Both computer size and circuit speed can increase without rapidly deleting the relative merits of synchronous circuits.

VII Non-Synchronous control has potential advantages, and work toward their realization should be continued. In particular a substantial variation of the distribution of circuit speeds (average to maximum) and a much greater emphasis on reliability or duplex type operation might well be reason to change the present decision.

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