Reliability Experience on the OARAC

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INTRODUCTION

The OARAC (Office of Air Research Automatic Computer) was delivered to the Aeronautical Research Laboratory at Wright Air Development Center in February 1953. After physical installation it required about two weeks for electrical installation and checking. Consequently, good computing time began the latter part of April.

During the month of May the machine was operated twenty-four hours per day, five days per week. Then operation was limited to sixteen hours per day until September when three-shift operation was resumed. There has never been more than one shift of engineering service. Consequently, if any trouble developed between 1630 and 0730, the machine remained inoperative until the next morning. This disregards such remedies as replacing blown fuses, etc. which the operator on duty might find obvious.

GENERAL DESCRIPTION

The OARAC is a general purpose machine with a large memory and medium operating speed. The number system used internally is the coded decimal system. The word length is eleven decimal digits, and the memory capacity is 10,000 words (magnetic drum) with an average access time of 8.5 milliseconds. Words are transferred throughout in decimal-serial, binary-parallel fashion. The input-output medium is 5/8 inch magnetic tape with a pulse density of 17 per inch and a tape speed of 50 inches per second. There are four information tracks and one clock track on the tape. The basic pulse repetition rate is 145 kc and average addition time is 90 microseconds exclusive of access time. Multiplication and division require about 8.5 milliseconds on the average, exclusive of access time. The over-all operating speed with optimum coding is about 100 operations per second with the present one-address system. Design has been completed to change OARAC to a two-address system.

The machine occupies about 68 square feet of floor space and is air conditioned. A transient-free supply of power is provided by a motor-generator set; the machine requires about 23 kw. It uses about 1,500 tubes and 7,000 germanium diodes.

The arithmetic and control circuits are composed of six basic plug-in units called turrets. They are "AND" circuits, "OR" circuits, gated blocking oscillators, trigger pairs, and voltage discriminators. There are about 1,000 of these turrets in the whole machine. In addition to these there is one "fuse" turret for each panel of fifty logical turrets.

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The main cabinet is 15 feet long, 2½ feet wide, and 7 feet high. Housed in it are all of the arithmetic and control circuits plus two tape mechanisms. The memory cabinet is 4½ feet long, 3½ feet wide, and 7 feet high. Housed in it are the drum, drum motor, and the record-playback matrix. Air with temperature and humidity controlled enters the bottom of both cabinets and is exhausted from the top by ducts to outside the building.

RELIABILITY OF INPUT AND OUTPUT

As mentioned above the pulse density along the tape is 17 per inch with 3 tracks of information. Almost no difficulty has been encountered with head alignment or tape blemishes.

The eleven-digit word with the five-digit address associated with it are coded on tape with a leading guard code before the first digit and a following guard after the last. These two guards are actually wrong combinations of the number system used. If the leading guard is not present when the first clock pulse reads the code, an alarm is given indicating that the tape was not positioned correctly, or that the guard code for that word was missing, or that the alarms are failing. This check is used chiefly to position tape on mechanisms initially.

After the leading guard check is passed, the information that follows is checked for wrong combinations until the following guard is sensed. If a random error on tape produces a correct combination, this check will fail. Since errors usually occur in a consistent manner, this check has been fairly effective. This wrong combination check is also applied when words are transferred from the machine to tape.

Both input and output tape mechanisms have alarms for broken tape or exhausted tape supply.

Output is judged to be more reliable than input on the whole. One proposed change calls for an additional check. This check would add the first \( n \) words coming from tape and subtract the \( (n+1) \) st automatically. This means that when the tape is made the first \( n \) words would have to be summed to determine what the \( (n+1) \) st word should be. Ten seems like a reasonable value for \( n \) at present.

RELIABILITY OF MEMORY

Until the latter part of October the largest percentage of downtime was caused by the memory. Two construction errors were responsible for this. One was a bad solder connection for ground at the terminating end of the coax from the drum to the machine on six of the eight information lines. The other was the omission of a filter to half of the playback-record matrix. When these defects were removed, operation was greatly improved.
Information recorded on the drum is checked for wrong combination as it leaves the machine to be recorded and as it is received by the machine on playback. This check has been quite adequate to detect malfunctioning but is almost no help in localizing the defective component.

Reliability of Arithmetic Unit

The arithmetic unit has many checks at many places. The reason for applying some of them is obvious by their names, such as, sum exceed capacity, product exceed capacity, and divide by zero. In addition to these, wrong-combination checks are applied at two places in the chain of manipulations to achieve arithmetic results; three checks are applied (quite often throughout multiplication and division) to insure that the word used is a number and not an order, since numbers and orders are not in separate addresses on the drum (the difference is in the sign digit); and a check is constantly made to see that three drum revolutions in time do not elapse between end-operation signals (except on reading in from tape).

In addition to the types mentioned, there is one other alarm associated with a particular order. The order is designed to repeat a coding routine twice if a specified tolerance is not met. If the tolerance is not met the second time, this rollback order will call back to the start of the routine (preparatory to running a line of coding at a time) and then signal the alarm. This order enables an automatic repetition of parallel coding or an iterating program.

Parallel coding is considered necessary for lengthy computations. Some coding has not been done in parallel, and good results have been obtained; but usually the coding has been interspaced with routines that do use parallel checking. Consequently, if any components were bad the parallel checking would indicate it and cause their removal. The checks in the arithmetic unit are adequate for the most part to localize troubles rapidly, and only one additional check is being considered at present. This is the addition of one more wrong-combination check.

Reliability of Control Unit

The basic clock pulses for the machine come from one fixed track on the memory. In addition there is one other track with one playback pulse per revolution. By means of this single pulse the counting in the two basic machine counters is checked with each drum revolution. If either is out of synchronism, an alarm is given.

In the present address system five numbers specify an address. The first two designate the track and run from 00 to 49; the next three designate the position around the track and run from 000 to 199. Because of this it is possible to designate an address which is nonexistent, e.g. 48307, the three being wrong. There are checks at two points in the control circuits to give an alarm for a nonexistent address.

On the whole the checks in the control unit are quite adequate to detect malfunctioning, and to a large extent they are helpful in localizing the trouble. One additional check will be put in when the conversion to the two-address system is made. This will be a wrong-combination check on addresses.

Reliability of Power Supplies

When the machine was originally constructed, five power supplies were subcontracted for and the rest were made by the General Electric Company. No appreciable trouble has been given by those supplies made by G. E., but a large amount of downtime has been caused by the other supplies. The difficulty was realized before the machine was delivered and an agreement was made by G. E. to replace the faulty supplies. These new supplies were received and installed in October.

Reliability of Components

When the machine was originally designed, the 1N52 germanium diode was the type designed to be used. However, as checking of the various parts of the computer progressed the number of diodes failing became prohibitive. At that time there was no temperature or humidity control on the air used to cool the machine. Air was merely blown through the machine at high velocity. The decision was made to change over to the 1N63 diode. At about the same time a five-ton air conditioner was installed to supply part of the air used for cooling, and the back voltage on the diodes was decreased by five volts. It was not ascertained which, if any, of these actions was effective, but diode failure dropped to what was considered a reasonable rate. An estimate of the present diode failure rate is ten per week (24 hour operation—5 days). Over 90 per cent of these fail test specifications on the bench and are not in-service failures.

Two types of tubes are used extensively in the main machine. They are the 12BH7 and 2C51. The estimated life of the 12BH7’s is 12,000 hours. The 2C51’s, which are not as numerous as the 12BH7’s, are considered to have a much longer tube life. It might be of interest to note that one brand of 12BH7 has been totally unsatisfactory in the trigger pairs in the main machine, the trouble being instability.

Conclusions

It is felt that the machine has not been in operation long enough to make any conclusive estimations of how good it is. Most of the personnel working on the machine, including mathematicians and operators, had very little, if any, knowledge about the machine before it was delivered. Because of this, as personnel become better trained, the operating efficiency should increase.