THE W.R.E.D.A.C. SYSTEM

by

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1. INTRODUCTION

The W.R.E.D.A.C. (W.R.E. Digital Automatic Computer) system has been designed as an integral portion of the W.R.E. data-processing project and consists of :

(a) The W.R.E. digital automatic computer,

(b) The high-speed digital output converter which displays the contents of magnetic tape records in graphical and/or tabular form,

(c) The W.R.E.D.A.C. editing equipment which prepares information for the computer,

(d) The low-speed output converter which displays the contents of teletape records in graphical or tabular form, and

(e) The various storage, test and check devices used for the W.R.E.D.A.C., output converter, magnetic tapes, etc.

Of these, the W.R.E.D.A.C., its test equipment and the editing equipment were delivered at W.R.E. in October 1955 by the manufacturers, Elliott Brothers (London) Ltd., the commissioning and acceptance testing being completed in July 1956. The high-speed output converter was delivered to W.R.E. in August 1956 by the same manufacturers and completed its acceptance tests in September 1956. The prototype low-speed output converter is still under construction at W.R.E. and should be delivered in by the end of this year.

Nearly all of this equipment has been developed specifically for W.R.E. so that details of its performance, application and proposed extensions are of some interest. These are given below, but for convenience, the technical specifications of the major items of the system are briefly described in appendices.

2. THE PERFORMANCE OF THE W.R.E.D.A.C. SYSTEM

From July 1956 until March 1957 the computer was switched on from 0900 to approximately 1630 hrs., five days per week. This was usually a 37 to 40 hr. week of which 10 hours, or about two hours per day, were normally allocated for scheduled maintenance.

Since March 1957 an overlapping two shift operation (from 0900 to 1630 and 1230 to 2030 hrs) has been introduced for a five day, 57 hour, week 10 hours of which are allocated for scheduled maintenance. It is anticipated that two-shift working (from 0900 to 1630 and from 1530 to 2300 hrs) will have to be introduced by the end of July and that 24-hour working on 5 days per week will be required by the end of 1957.

An idea of the performance of the system can be gained from Fig. 1 which gives the weekly "efficiency factor", the weekly unscheduled maintenance and the weekly scheduled maintenance for the W.R.E.D.A.C. since September 1956. The "efficiency factor" is defined as the ratio of the total effective machine time to the total time switched on per week, the effective time being that period for which useful work was performed by the computer. As can be seen for a 37 hour week the average efficiency of the computer was about 50% whilst for a 57 hour week it was about 70%. This suggests that the more hours the machine is used continuously the better its efficiency (as is well known to those with experience of digital computers).

It may seem that we have been somewhat harsh in our measure of efficiency but this definition was chosen for two rather important reasons. The first is that for any computer with multiple input/output devices, the operator can waste a considerable amount of time preparing the machine for the calculation. For example the operator should have all magnetic tapes, programmes, etc., necessary for his calculation and not have to start searching for the appropriate ones after accepting the computer. By independently noting the time spent on the machine by the operator against his effective time this setting-up period can be reduced to a minimum and make the system reasonably efficient.

The second reason is that transient faults in the computer can considerably alter the true estimate of time required for any problem. It also indicates trends in faults and provides the maintenance staff with some information on the type of transient faults occurring.

3. APPLICATIONS OF THE SYSTEM

Due to the facilities of the data processing project and the flexibility of the W.R.E.D.A.C. system there is a large range of problems which can be attacked efficiently. The main factors in the computing system which contribute to this are:

1. The high-speed display equipment which permits display of the contents of magnetic tape records away from the computer.
2. The fast input/output facilities and low access times within the computer to a large store.
3. The possibility of automatically providing experimental data in a form suitable for the computer with a minimum of human transcription errors by means of the other equipment in the data-processing scheme.

Since the system has come into operation the distribution of work has been as follows:

Type of Work	Sep. to Dec. 1956	Jan. to March 1957	April to May, 1957
Trials Calculations	38%	36%	35%
Trials Research Calculations	35%	35%	36%
Establishment Research	26%	28%	28%
Extra-Mural Research Calculation	1%	1%	1%

Broadly, therefore, it is expected that trials calculations will occupy 35%, trials research calculations 35%, establishment research 29%, and extra-mural calculations 1% of the available machine time. These proportions are probably of the correct order and should be unchanged even when 24-hour operating is introduced mainly because the research calculations increase as the trials calculating load increases. However the capacity for research work may be severely affected in this case because of the shortage of trained mathematician-programmers. In this regard it should be noted that a shift for the W.R.E.D.A.C. system requires 2 or 3 mathematician-programmers, 1 or 2 programme-operators, 1 engineer, 1 technical assistant and 1 tradesman so that a 24 hour shift scheme will require some 12-20 mathematician-programmers.

3.1 Trials Calculations

As has been noted above this type of work is a major portion of the W.R.E.D.A.C. load and in the past 10 months, 19 trials programmes and routines have been prepared, tested, and placed into service. All trials programmes employ data supplied by the earlier stages of the data-processing system on punched teletape, magnetic tape or both. For all trials calculations, therefore, extensive checks are employed and precision estimates displayed for each data group to ensure that the correct results have been obtained and that no processing error is undetected. In this respect the analysis and programmes are rather more detailed than those normally used in scientific calculations. Typical examples of these types of calculations are given in references 1 to 3.

3.2 Trials Research Calculations

These types of calculations arise from problems occurring before and during a sequence of trials. They are usually of research character in that a mathematical model is constructed, the necessary mathematical and numerical analysis is performed, a programme is prepared, and the calculation performed for the cases required. The main distinctions between this and establishment research are that priority and maximum effort have to be supplied for trials work, and that trials research tends to be restricted to specific scientific fields. Some typical examples of this type of work are:

(a) Error contour determination for various instrument siting plans.

(b) Theoretical trajectories with various assumptions about the mathematical models employed.

(c) The analysis of mathematical models of systems using experimental data in the system.

(d) Optimisation of parameters in theoretical systems to satisfy trial requirements.

(e) Problems in the interaction of large scale analogue and digital computing machines when used simultaneously for simulation systems.

3.3 Establishment Research

This work is the research performed by the establishment on the many fields with which it makes contact. Hence the problems to be handled have the scope and generality encountered by any group which has a general-purpose digital computer. Some of the work in hand includes:

(a) Linear and quadratic programming.

(b) Investigation of methods for large order matrix calculations.

(c) Automatic programming.

(d) Solution of the Navier-Stokes equations for compressible flow.

(e) Investigation of numerical methods for solution of partial differential equations.

(f) Ray tracing in inhomogeneous media.

(g) Ionospheric refraction.

(h) The direct solution of complex differential equations.

3.4 Extra-Mural Calculations

Due to the normal establishment work load it has been almost impossible to undertake the programming or analysis of problems for extra-mural research groups. In a few cases where a small amount of programming and computer time was involved, or the sponsor has had computer experience and was prepared to supply his own programme, some work has been done. However the purpose of this computer system is to provide a trials service and if any extra-mural calculations are accepted they must always be assigned the lowest priority for programming effort and computer time.

4. THE OPERATION OF THE SYSTEM

While the W.R.E.D.A.C. possessed more facilities than many computers when delivered, it was (and still is) the only one of its type. This meant that all the essentials such as a sub-routine library, maintenance tests, etc., which are necessary for the efficient operation of a computer had to be constructed before any computing service could be provided. The total staff available at this time was four programmers, one engineer, three female assistants and three tradesmen, of whom only one programmer and the engineer had had computer experience, and another two of the programmers were experienced on punched card equipment and with hand calculations. Consequently the early work on the computer was performed rather slowly but, after a 6 weeks course of 1 hour per day on programming and elementary numerical analysis for digital computers, this rate increased sharply until there are now some 60 routines in the library, 19 trials programmes and 30 major calculations have been or are being performed. In the same time the programming staff has increased to eight, the maintenance staff has increased to three engineers and eleven tradesmen (some of whom also maintain the other data-processing equipment in the group) and partial two-shift operation has commenced.

Within the computer group three types of memoranda are issued and distributed to people associated with the computer. These are:

(a) Mathematical memos which note mathematical techniques of use to programmers.

(b) Programming memos which note programming tricks and techniques applicable to the W.R.E.D.A.C.

(c) Operating memos which detail changes and alterations in the operating procedure of the W.R.E.D.A.C. system.

Similarly all library subroutines, routines, trials and general programmes are written up with full operational detail and published for general use in the group as soon as possible. This rule is strictly enforced and, although often difficult to maintain, has been of considerable value in disseminating information. Clearly, when an operator on shift work handles programmes and data for which he has no real concern, it is imperative that the full information on operating procedures, method of calculation, checks, and expected behaviour of the machine and results should be provided. This general publication process appears to satisfy these requirements despite the slight delay incurred in the publication and distribution.

Since much of the calculation to be performed is of a routine nature it follows that they can be performed by female assistant operators if production line techniques are used and full description of the operation checks and expected behaviour of the calculations are given. However for correct final results the initial information supplied must itself be correct. Hence, despite the checks built into standard programmes, the procedure given below is employed in an endeavour to reduce the effect of the human element in the system.

> For all standard calculations the data must be accompanied by an appropriate computing request which details all the relevant information, has a tabulated list from the data tapes attached (if applicable), is signed by the person preparing the data and/or information tapes and is checked by the originator of the request. One of the computer operators then briefly checks the request and data, assigns the appropriate priority, and performs the calculation and display as soon as possible. The results are finally examined both by the operator and one of the programming staff before being returned to the originator. In this way an error detected at any stage in the process can be removed and the reliability of the human elements evaluated.

It may seem that these checking procedures have been over emphasized and they can consume more time than they are worth. However our experience indicates that the time is very well spent particularly since it is easy to phase the checking processes so that they do not interfere with the smooth flow of information through the complete data-processing system.

5. EXTENSIONS AND MODIFICATIONS PROPOSED TO THE W.R.E.D.A.C. SYSTEM

Since the W.R.E.D.A.C. system has been installed it has been found that some extensions and modifications to the original equipment are warranted to assist in data-processing and programming. Some of these have already been effected while the others are to be introduced over the next year. The proposed changes and a brief account of the reasons for each is given below.

5.1 Modifications to the W.R.E.D.A.C.

(a) Zero Test: Originally the check order was an optional stop in which the address digits had no effect. However a considerable amount of data-processing work requires searching for a given block or code number so that a zero checking facility is advantageous. For this reason the check order has been modified so that it becomes a zero test on the accumulator if the address digits are not zero and remains an optional stop if the address digits are zero.

(b) Magnetic Tape and Disc Transfer Orders: The effects of these orders have been modified so that interlocks prevent arithmetic operations being performed on any number involved in such a transfer until the transfer is effected. Since the whole high-speed store can be used for transfers or as a buffer store this makes the machine completely autonomous.

(c) Twin Teletape Readers and Perforators; These output devices are to be attached to provide flexibility in reading and displaying multiple sets of information. When the 200 ch/sec perforators become available they will replace the present 25 ch/sec perforators.

(d) Punch and/or Print Facilities: Most data processing work provides for spot checks on the calculations at various stages and hence it is important to provide facilities for direct observation of results. It is proposed therefore to attach a teleprinter which can be switched in and print the results being punched on either perforator. When the 200 ch/sec teleprinter becomes available this will replace the 6.7 ch/sec teleprinter proposed at present.

(e) New Console and Display Facilities: The present console on the W.R.E.D.A.C. is very inflexible and is of little use to either the engineering staff or programmers mainly because only one word can be viewed at any time. It is proposed to supply a new console which will provide any 32-word block of the store in a 32 x 34 display together with the B lines, sequence control register, multiplier register, accumulator, order register and order store on another display. The readers, punches, teleprinters, and new magnetic tape units will also be attached to this console so that one operator can conveniently control all the computer facilities.

(f) New Transfer Orders: The magnetic tape orders in the transfer code are to be re-arranged so that they cover the function digit range 16 to 31. In this way explicit note of the tape unit required, i.e. 0 or 1, is supplied directly to the machine, erase facilities can be provided for each tape unit under programme control, and independent operation of the units can be provided whilst keeping the computer autonomous.

(g) New Check Order: It is proposed to modify the check order so that the computer will halt after any order which is preset on a set of hand keys. This facility should be of great assistance in programme checking and fault finding.

5.2 Extensions to the W.R.E.D.A.C.

It is proposed to supply a virtually unlimited field for extensions to the computer by means of two special orders. These are the "Use B-line Group" or "Use Logic" order which will be one of the arithmetic functions and the "Use Units" order which will be one of the transfer functions between 8 and 15.

(a) B-lines: For the original machine it was thought that four B-lines would be sufficient for normal purposes. However since the work for this computer falls strictly into four fields, two of which have time factors attached to them, it has become obvious that programme facilities must be increased so that the conventions to be applied in programming need not be restrictive. For this reason it is proposed to introduce the "Use B-line" order which will allow for a further 28 B-lines which can be used in groups of four as with the present system. Two of these groups are to be retained conventionally for library routine and programme work whilst the remainder will be for general use.

(b) Logic: Many of the trials calculations now employed require the

use of floating decimal and matrix interpretative routines. These routines reduce the effective speed of the machine considerably however and since machine time is at a premium, this device is to be introduced to increase machine speed. The procedure proposed is that, on receipt of the order "Use Logic n" $0 \leqslant n < 16$, the succeeding orders will be obeyed using the machine as if it were a computer operating in the mode of the prescribed logic until the next "Use Logic" order is received. The first two logics envisaged are floating binary arithmetic and character operation with in-built checking. Both of these permit the present store to be used together with most of the arithmetic unit and control logic. Generally all the extra hardware associated with the logic will be supplied in external cabinets which can be manually switched into or out of the normal computer system.
As can be seen this process is extremely flexible and in effect provides the engineering analogue of interpretative programmes with some extra facilities. It does however pose some interesting problems in the economics of overall computer operation!

(c) Input/Output System: By a similar process to that described in (b) above, it is proposed to introduce a transfer order which causes unit n, $0 \leqslant n \leqslant 16$ to be used as input/output unit type m, $0 \leqslant m \leqslant 7$. This permits groups of two magnetic tape units, readers or punches to be used simultaneously and does not introduce extensive modifications to the transfer order code. The total number of extra input/output units to be introduced by this modification is limited by physical considerations such as size, power requirements, etc. and hence will not be large. However the facilities will exist for attaching any new type of digital input/output system which may be developed.

5.3 Modifications to the High-Speed Digital Output Converter

The output converter is to be retained as a magnetic tape reading device but the following modifications are under consideration:

(a) The display of any group of up to 24 numbers from the standard 64-word block supplied by the computer instead of up to the first 24 at present available.

(b) The introduction of a switch to cause either the counting of the numbers in a group to override the number count or vice versa.

(c) The provision of an overflow facility so that if any number is greater than $\pm$ 1 the bit in the units position is used to display a preselected symbol and is ignored when translating the number into its decimal equivalent.

(d) The possible addition of a fast 200 ch/sec teletape perforator which will provide a teletape record of the information on the magnetic tape through word and word length selector switches.

No further extensions to this machine are proposed at present.

6. CONCLUSION

The W.R.E.D.A.C. system has been designed and produced on rather conservative lines mainly because there were so many new developments to be incorporated at the time of its construction. Much of this conservatism has been found to be unwarranted but it has resulted in the system coming into effective operation as a computing service and as portion of a large-scale data-processing project with less difficulty than was anticipated.

The present operating rate of the system is about 48 hours in 57, and the proposed extensions and modifications should extend its flexibility considerably. It is anticipated that a weekly efficiency factor of 70% should be consistently maintained in the future.

REFERENCES

No.	Author	Title
1	P.N.L. Goddard	Kinetheodolite Calculations on the W.R.E.D.A.C. W.R.E. TM/TRD 7, 1956.
2	J.A. Ovenstone	Automatic 465 Mc/s Telemetry Processing on W.R.E.D.A.C. W.R.E. TM/TRD 19, 1957.
3	W.R.E.D.A.C.	Trials Program Specifications.

APPENDIX I

BRIEF SPECIFICATION OF THE WREDAC

1. BASIC INFORMATION

Digit Frequency	333 Kc/s
Word Length	34 digits or 102 microseconds.
Order Length	17 digits or two orders per word.
High-speed Store	512 words consisting of 127 4-word nickel delay lines and four 1-word nickel delay lines.
Backing Store	16,384 words contained on a magnetic disc rotating at 2,300 r.p.m. There are 64 tracks of 256 words and each quadrant of each track is accessible for writing or reading 64 words.
Auxiliary Store	Two magnetic tape units operating at 100"/sec. with stop-start time less than 10 m.secs. and a tape packing density of 100 digits/in. Tape lengths are 2,400 ft. maximum.
Input	(a) Punched 5-hole teletape via two high-speed readers each operating at 200 rows/sec. (b) Magnetic tape via the auxiliary store.
Output	(a) Punched 5-hole teletape via two teletape perforators operating at 25 characters/sec. At least one of these is to be replaced by a high-speed perforator operating at 200 rows/sec. (b) Magnetic tape via the auxiliary store.
Radix Representation and scaling	Numbers in the computer are radix 2 in the range $-2 \leqslant x < 2$, i.e. (modulo 4).

2. ORDER CODE

The order code employed in the computer is single address. The least significant digit of the 17 bit order denotes whether the order is an arithmetic or store transfer type of order. If this digit is zero then the order is of the arithmetic type; if it is unity, the order is a transfer instruction. Since there are two orders in a word of 34 bits, the first order to be obeyed (or least significant half of the word) is the "even" order, whilst the second (or most significant half of the word) is the "odd" order.

2.1 Arithmetic Instructions

The first five more significant digits of the order are the function digits, F, the next nine are the address digits, A, which specify the high-speed store location to be used in the operation required by the function digits, the next two specify the B line to be used, and the last is the code digit, zero. In all cases the result of the arithmetical operation is in the accumulator unless otherwise specified.

In detailing the order code the following abbreviations are used:

A	the location A
(A)	the contents of the location given by A
Acc	the 34 bit accumulator
(Acc)	the contents of the accumulator
A_0	the "odd" order in location A
A_e	the "even" order in location A
(A_0)	the contents of the "odd" portion of location A
(A_e)	the contents of the "even" portion of location A
Ads	the address digits of the order considered

The functions available are:

No.	Mnemonic Code	Effect
0	CH	Check - stop if the "Stop" key is in the "on" position and Ads = 0 - go to A_0 if (Acc) = 0, otherwise proceed serially, Ads ≠ 0
1	GE	Go even - Transfer control to A_S
2	PE*	Positive Even - Transfer control to A_0 if (Acc) $\geqslant 0$
3	PO*	Positive Odd - Transfer control to A_e if (Acc) $\geqslant 0$
4	NE*	Negative Even - Transfer control to A_0 if (Acc) < 0
5	NO*	Negative Odd - Transfer control to A_e if (Acc) < 0
	*	Otherwise proposed serially
6	JE	Jump Even - if B line is not zero jump to A; otherwise proceed serially. In all cases add 1×2^{-12} to B line 1.
7	JO	Jump Odd - If B line 1 is not zero jump to A_0; otherwise proceed serially. In all cases add 1×2^{-12} to B line.
8	LD	Long Division - Divide the number in A by the number in the multiplier register and add the result to (Acc).
9	SM	Set Multiplier - Send (A) to the multiplier register, R_o.
10	MA	Multiply and Add - Multiply (A) by (R) and add to (ACC).
11	MS	Multiply and Subtract - Multiply (A) by (R) and subtract from (Acc).
12	SL	Shift Left - Multiply (Acc) by 2^n where n = Ads

No.	Mnemonic Code	Effect
13	SR	Shift Right - Multiply (Acc) by 2^{-n} where n = Ads
14	NM	Normalize - Multiply (Acc) by 2^{n} such that $1 \leqslant \lvert(\mathrm{Acc})\rvert < 2$ and place $n \times 2^{-12}$ in B line 1.
15	MD	Modulus - Replace (Acc) by its modulus
16	CA	Clear and Add - Clear Acc and add (A)
17	CS	Clear and Subtract - Clear Acc and Subtract (A)
18	SW	Swap - Place (Acc) in A and (A) in Acc
19	CL	Clear - Write (Acc) in A and clear Acc
20	AD	Add - Add (A) to (Acc)
21	SA	Subtract - Subtract (A) from (Acc)
22	CT	Collate (Acc) with (A) and place result in Acc
23	AS	Add and Subtract - Subtract (Acc) from (A) and place result in Acc
24	SB	Set B line - Write $n \times 2^{-12}$ in B line where n = Ads if $n > 0$, or $512 - \lvert n\rvert$ = Ads if $n < 0$, $\lvert n\rvert \leqslant 255$
25	CO	Clear Odd - Write odd part of Acc in A_o and clear Acc
26	CE	Clear Even - Write odd part of Acc in A_e and clear Acc
27	ST	Store - Write (Acc) in A and leave (Acc) unchanged
28	AO	Add Odd - Add (A_0) to odd half of (Acc)
29	SO	Subtract Odd - Subtract (A_0) from odd half of (Acc)
30	AE	Add Even - Add (A_e) to odd half of (Acc)
31	SE	Subtract Even - Subtract (A_e) from odd half of (Acc)

2.2 Transfer Instructions

The most significant digit of these orders designates which of the two magnetic tape units is involved in the transfer whilst the next four digits denote the transfer function. The following three digits denote the block of 64 words of the high-speed store involved in the transfer whilst the next nine give the track quadrant on the disc to be used. The last digit is of course always unity for these instructions. In these orders a block is one of the eight 64 word high-speed blocks, and a track is one of the 256 track quadrants.

The functions available are:

No.	Mnemonic Code	
0	IF	Input Fast - Read a row of teletape from reader 1 to the least significant 5 digits of (Acc)
1	OF	Output Fast - Punch the most significant 5 digits of (Acc) on teletape perforator No. 1.

No.	Mnemonic Code	
2	IL	Input to Least - Read row of teletape from reader 0 to the most significant 5 digits of (Acc).
3	IM	Input to Most - Read row of teletape from reader 0 to the most significant 5 digits of (Acc).
4	OL	Output from Least - Punch on perforator 0, the most significant 5 digits of (Acc).
5	OM	Output from Most - Punch on perforator 0, the most significant 5 digits of (Acc).
6	BD	Block to Disc - Transfer a high-speed store block to a magnetic disc track.
7	DB	Disc to Block - Transfer a disc track to a high-speed store block.
8	WT	Write on Tape - Write (Acc) on a magnetic tape unit.
9	RT	Read Tape - Read one word from a magnetic tape into the Acc.
10	BT	Block to Tape - Write a high-speed store block on a tape.
11	TB	Tape to Block - Read 64 words from a tape to a high-speed store block.
12	TH	Tape Halt - Stop a tape unit.
13	TG	Tape Go - Start a tape unit.
14	TF	Tape Forward - Run a tape unit forward.
15	TR	Tape Reverse - Run a tape unit backward.

The transfer orders "read from teletape" cause the five digits given in a row to be added to the specified part of the accumulator and cause the teletape to be advanced by one row. Similarly, a transfer to a disc track from a given block can occur while a transfer from a magnetic tape unit is being made and calculation proceeds not using numbers in these blocks. If the calculation involves a number in one of these blocks to which the transfer is being made then the calculation will cease automatically until the transfer is completed.

When writing data on the magnetic tape a delay of 10 m.secs. always occurs before the transfer is effected. On reading however, no such delay occurs. When writing blocks an 800 micro-second delay is introduced between the 64 words of the blocks so that a block to tape transfer occupies some 270 milliseconds. Further, reading and writing can only occur while the tape is running forward. If words of less than 18 bits are supplied on a magnetic tape, each being separated by more than 800 micro-seconds, two of these words are stored in each location. Words of 18 bits or more are stored one in each location.

2.3 Operation Times

The following times are required for the various operations specified:-

(a) division 3468 microseconds,

(b) multiplication 1734 microseconds, and

(c) all other arithmetic and logical operations 102 microseconds.

Hence the average operation time (the mean of 1 division 10 multiplications and 40 additions) is therefore approximately 0.5 milliseconds.

The times required for transfer operations are given below, but due to the autonomous nature of the machine are not of much interest. Teletape input is at some 200 rows/sec. and output is at some 25 rows/sec at present. Disc transfers can occupy up to 36 milliseconds of which 6.5 are required for the actual transfer of the 64-word block. Magnetic tape transfers of blocks require some 265 milliseconds.

For other operations specified by subroutines the following times may be of interest:

Square roots (9D)	7 - 25 m.secs.
Cube roots (9D)	10 - 50 m.secs.
Cos x to 9D	16 m.secs.
Sin x to 9D	14 m.secs.
Gill-Kutta Integration	10 (n + 1 + 0.1p) milliseconds per step where n = no. of equations, p = no. of orders in auxiliary integrand subroutine.

APPENDIX II

BRIEF SPECIFICATION OF THE DIGITAL OUTPUT CONVERTER

The high-speed digital output converter supplies graphical and/or tabulated displays from the magnetic tape records produced by the W.R.E.D.A.C. and consists of a Pye magnetic tape unit, a line printer, four digital plotters and the electronics necessary to link this equipment. The magnetic tape records to be handled consist of repeated blocks of up to 64 words in binary form, each word containing up to 34 digits with a space of at least 20 milliseconds between blocks and 800 microseconds between words.

The action of the converter is as follows :

The number of words, 1 to 24, to be treated at each stage of conversion is pre-set by a switch on the control panels. The types of output, i.e. graphical or tabular, or both, and the number and distribution of words to be supplied to each output unit are also independently set up by selection plugboards in the control panels. When started the converter reads the required number of words from the magnetic tape, transforms them into a binary-coded decimal representation for printing and then stores these words in serial registers using the selection plug-boards. The selected numbers are then supplied to the output display units and when the display is completed a new block of data is read and the whole action repeats twice a second.

The output equipment consists of a line printer and 4 graphing units. The line printer is manufactured by Cie des Machines, Bull, Paris and is used at two lines per second, 92 characters per line, although it can operate at up to 150 lines per minute. Each of the 92 wheels in the line is set up for printing by the printer selection plugboard from the possible 8 x 24 = 216 tetrads stored during the binary-decimal conversion. The symbols decimal point, asterisk, parentheses, percent, and solidus can be supplied on demand from special pulse emitter sources in the selection plugboard.

The graphing units consist of four modified Mufax, 11" picture receivers. The characteristics of these plotters are as follows :

(a) The full scale deflection of 11" or 1 helix revolution is represented by 1024 counts.

(b) Plotting densities of 40 or 20 points per inch are available.

(c) A graticule is generated and displayed automatically during operation and is fainter in intensity than the plotted points.

(d) Marker points are displayed at the beginning and end of any helix revolution.

(e) Either 4 x 2.75 in. graphs or one 11 in. graph can be plotted on any unit.

(f) Numbers to each unit, or to any of the four channels of each unit, can be multiplied by 1,2 or 4.

(g) Numbers for plotting must be in the range $-1 < x < 1$ or $0 \leq x < 1$ prior to scaling.

Two points on each of up to 16 graphs can be plotted twice a second and this may occur with or independently of the tabulation.

Facilities exist on the control panel for reading every second, third or fourth block of words from the magnetic tape. Using this feature it is possible to decrease the plotting density on the graphing units to 5 points to the inch and since the vertical graticule is generated every 10 points, this means that its dimensions can vary from .3 x .25 in to .3 x 2 in.

For reproduction of the final results, a Banda or Fordigraph process can be used for the tabulated data(upper limit 200 copies) whilst an Ozalid or Dyline process can be used for the graphs (no real limit on number of copies).

DISCUSSION

Dr. J.M. Bennett, University of Sydney.

What is the 200 characters per second paper tape punch to which you refer?

Dr. J.A. Ovenstone, W.R.E., in reply

The paper tape punch referred to is a development by Creeds and should be available in 12 months. It will operate at about 250 characters per second.

Mr. R.G. Smart, University of Technology.

In your transfers from the disc to the high speed store can you only transfer 64 words at a time or can you transfer one word at a time?

Dr. J.A. Ovenstone, W.R.E., in reply

We can only transfer 64 words at a time to the high speed store. However, the whole high speed store acts as the buffer register, so that there are eight 64 word blocks available for transfer at any time.

Dr. T. Pearcey, C.S.I.R.O.

You were talking about extra logic racks. How much equipment are these likely to involve?

Dr. J.A. Ovenstone, W.R.E., in reply

We have not proceeded very far in the actual design of these equipments. However we hope that each logic can be contained in one rack of equipment. If necessary we are prepared to transistorise to keep them within this limit.

Mr. B. Swire, University of Sydney.

Do you propose to use either the magnetic tape or the disc for permanent storage or standard programmes or routines?

Dr. J.A. Ovenstone, W.R.E., in reply

It is proposed to store standard and commonly used programmes on the disc but as our programmes are still undergoing modification it is not anticipated that this will be completed within the next two years.

Mr. G. Hill, University of Melbourne.

You mentioned logic II as character operation. What does this imply?

Dr. J.A. Ovenstone, W.R.E., in reply

We propose to use this logic to test some of our ideas on business uses of digital machines. We hope to fit four to five characters in a word and then to carry out normal arithmetic operations excluding alphabetic characters in the transfers.

Mr. R. Davis, English Electric Co.

Do you have any other means of transferring data to magnetic tape other than by the data-processing system equipment?

Dr. J.A. Ovenstone, W.R.E., in reply

No.

Mr. R. Davis, English Electric Co.

In your magnetic tape the paper tape converter is your magnetic tape read discontinuously or read slowly?

Dr. J.A. Ovenstone, W.R.E., in reply

The magnetic tape is read discontinuously. The speed of motion across the head is 100 in./sec and we punch up to 24 words in twice a second.

Dr. S.H. Hollingdale, R.A.E.

Speaking as a visitor from the U.K. I would like to congratulate Dr. Ovenstone and the whole Establishment on this achievement, particularly since they are so many thousands of miles from the manufacturer and the sources of equipment.

I imagine that because of this isolation that you have what appears to me to be a large supply of engineering staff. I envy you that. When we started working shift, we did not have an engineer on the second shift at all. We just collected together about 20 people consisting of engineers, programmers, mathematicians and machine operators and with the fortnightly rota of two persons per night it was a matter of chance whether an engineer was on evening work or not. One of the things we found when we had our two machines was that our programming staff did not increase in the same proportion. This was mainly due to the type of work we were doing. Our work mainly involves large-scale parameter variation, so that when we have more machine time available we just increase the range of variation of these problems, e.g. from 500 solutions to 1 000. I would like to ask one small question. When the computer is only partially operating in one of its storage sections, for example, a programme may only use the disc and the high speed store, if the magnetic tape is not operating do you count this time as good time and use programmes which only involve the disc and the high speed store?

Dr. J.A. Ovenstone, W.R.E., in reply

Whatever types of programmes are in use, providing there are no machine faults, it is assumed that the whole machine is working. If at any stage a programme becomes inoperative due to machine fault down time commences and the computer is classed as unserviceable until the whole machine is effective.

It is perhaps only fair to our engineers to mention that they are not involved solely on computer maintenance. They are also involved in maintaining the remainder of the data-processing equipment associated with the W.R.E. data processing system. There is also a considerable amount of development work going on in both data-processing equipment and the computer.

Mr. R. Davis, English Electric Co.

Do you have anything in the way of built-in checking facilities and/or marginal checking facilities?

Dr. J.A. Ovenstone, W.R.E., in reply

Yes, we have marginal checking facilities, much the same as in any other machine, but there are no built-in checking facilities at all. This is one of the reasons why we would like to try the character logic mentioned earlier to see whether these built-in checking facilities are really worth while and what particular applications they are best warranted for.

Mr. B. Swire, University of Sydney.

I would like to enquire on your policy for running your machine. Do you propose to run a complete service for all the programmes and computing that have to be done for your Establishment, or do you propose to build up outside computing centres who will do the actual programming for their own problems?

Dr. J.A. Ovenstone, W.R.E., in reply

The present position is that we are endeavouring to provide a service but we realise that with the large amount of work to be done, we cannot do this efficiently due to shortage of staff. We propose therefore, to run a school in the next two to three months and endeavour to train people outside our own division to do the work for their own respective divisions.

Dr. J.M. Bennett, University of Sydney.

I would like to know what your policy is about diagnostic programmes on the computer. Do you encourage people to stay on the machine once their programmes are there and finally get their programme working or do you have an ample supply of programmes for diagnostic purposes?

Dr. J.A. Ovenstone, W.R.E., in reply

The attitude that we adopt depends on the type of work that is being performed. If the programme is a trials programme and has priority, then the programmer has the opportunity to stay on the machine for quite a long period and correct the programme whilst on the machine. As a general principle however we endeavour to obtain coarse structural analysis by means of our "flying-stop" facility and the C.R.T. display and examine fine structure by means of four diagnostic test programmes which we have available as standard routines.