THE SILLIAC

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INTRODUCTION

At the beginning of 1954 a decision was made to acquire a high speed automatic computer for the School of Physics in the University of Sydney, and the sum of £50,000 was made available towards the cost of such a machine through the Nuclear Research Foundation by a Sydney philanthropist, Dr. Adolph Basser.

After due examination of various possible ways of proceeding, it seemed best to build in Sydney a machine based closely on the design of some existing machine of good performance. It was possible to proceed in this way because of a generous offer by the University of Illinois to make available the circuit drawings of their machine, the ILLIAC, and to receive as a guest an engineer from Australia to study their work.

The University of Illinois, had themselves received similar assistance from the Institute for Advanced Study, Princeton, where, at the time, a machine was in development in accordance with a basic design laid down by Burks, Goldstine, and von Neumann. The Illinois laboratory went ahead to build the ORDVAC under defence contract, and the ILLIAC for their own use, further developing the design in the process. These machines, and therefore also the SILLIAC (the Sydney version of the ILLIAC), thus belong to a group of about a dozen machines in various places, all of which have sprung from the Princeton school.

Circuit drawings for the SILLIAC were prepared from the ILLIAC circuits with some changes that seemed desirable in the light of experience in Illinois. These changes were such as to preserve unchanged the order code of the ILLIAC. Apart from small changes of detail, the main changes were the re-design of the control logic of the input and output processes and the replacement of valve type 6J6, of which there were about 1500 in the ILLIAC by type 2C51.

Construction of the individual sub-assemblies from these circuit drawings was entrusted to Standard Telephones and Cables Pty. Ltd., while assembly and checking of the complete machine was carried out in the School of Physics. The work of assembly was carried out over the period from August 1955 to June 1956 by a staff of three engineers and two technicians. In the course of this work further improvements in detail were incorporated. The SILLIAC is thus the fourth machine in a direct line of development, and can be considered as a quite highly developed machine from which may be expected a correspondingly high performance.

A feature which the SILLIAC has in common with other machines of the Princeton group, and which is worthy of special mention, is the extensive use of asynchronous circuits - of circuits, that is, in which time is not, or need not be, a relevant parameter, and in which digits are represented by static circuit states rather than by the presence or absence of pulses occurring at particular times. These circuits are inherently free from timing difficulties, and possibly for this reason seem to give considerably less trouble than the more conventional pulse circuits. At least it may be said that those responsible for building the SILLIAC have been surprised at the ease with which highly reliable performance has been obtained from the arithmetic and control sections, which are almost fully of the asynchronous type.

As a matter of deliberate policy the SILLIAC was made available for use just as soon as it was capable of computing, and without waiting for complete checking out. Thus it was on the 4th July, 1956 that the machine first worked properly as a complete machine, and on the same day a code-checking run was made on a new programme. This programme produced useful results on the following day. From July 9 the machine was available to users for three hours each afternoon. Engineering work of checking the machine and carrying out adjustments and improvements has gone on ever since, though in ever decreasing volume. At the time of making this report little apart from routine maintenance is being done, and the scheduled time of operation has been increased to six and a half hours per day, with occasional evening operation to clear any backlog of work.

DESCRIPTION OF SILLIAC

The SILLIAC is a parallel binary computer. It processes numbers and other data in the form of words of 40 binary digits. The working store is of the cathode-ray-tube type, and has capacity for 1024 words. A simple one-address order code is used with two orders to a word. Of the 20 bits available for an order, eight specify the function, ten an address and two are spare.

The order code provides for a variety of addition, subtraction, multiplication, division and shifting orders. A logical order, collation, is included, and of course transfers of control, both unconditional, and conditional upon there being a zero in the sign-digit position of the accumulator.

The input and the normal output medium is 5-level punched paper tape. A Ferranti photoelectric tape reader is used for input at a maximum speed of 200 characters per second, and a Teletype punch for output at a maximum speed of 60 characters per second. If desired, output can be taken directly on a Teletype page printer at 9 characters per second.

Separate input/output orders are provided for handling, on the one hand, 4-bit characters having the fifth level unpunched, and on the other hand 5-bit characters. The former are used for numerical and programme information, and while 4-bit characters are being read, characters having the 5-th level punched are automatically ignored. Characters for printer control, carriage-return, space, etc., are all of the 5-level variety, and can thus be included on tapes for format purposes, without affecting input of information to the machine.

The times required for individual operations, including all necessary store access, are as given below:

Shift orders:	18 + 16n microseconds (where n is the number of shifts).
Transfer of Control, Store, & Collate Orders:	55 microseconds.
Conditional Transfer, not performed:	18 microseconds.

Division:	825 microseconds.
Multiplication:	720 microseconds. (average)
Addition and Subtraction Orders:	73 microseconds.
Input:	5 milliseconds per character.
Output:	20 milliseconds per character on punch. 110 milliseconds per character on printer.

A better idea of the speed of the machine can be gauged from the fact that a set of 39 linear simultaneous equations can be solved in four minutes, which time includes the time required to input the programme and data and to output punched results. The method used for this process is Gaussian elimination.

In the interests of preserving interchangeability of routines, the order code is the same as that of the ILLIAC. Our experience with it has been that our complaints are all minor ones and that it possesses the great advantage possessed by all simple codes - it is very easy to impart to newcomers.

THE PROGRAMME LIBRARY.

The SILLIAC group started with the big advantage of being able to take over in toto the existing ILLIAC Library. The routines available in the Library may be summarised as follows.

There is a complete floating point scheme in which numbers are represented in the form $X \times 10^p$ where $1 > |X| \geq 1/10$ and $64 > p \geq -64$. An additional scheme for high accuracy working used floating binary, and is useful for cases where an accuracy of up to 20 significant decimal places is required.

A comprehensive set of post-mortem and diagnostic routines is available, and is described in another talk to be given in this session*.

Routines for integration using Simpson's rule and Gaussian quadrature, and for numerical differentiation and interpolation (employing Neville's formula) are available. The solution of a system of first-order differential equations can be provided by a routine which uses Gill's modification of the Runge Kutta process. A second routine to do the same thing uses the predictor corrector process proposed by Milne. There are routines for carrying forward the integration of second order differential equations with initial conditions given, and with two-point boundary conditions.

Routines giving the solution of Laplace's equation and Poisson's equation over a mesh, with given values on a specified boundary are available. These use the Liebmann method as modified by Frankel.

Various routines are available for minimising the function of a number of variables and finding roots of polynomials.

Routines of interest to statisticians include evaluation of product moment correlations, means, standard deviations, variances and co-variances (up to 38 variables can be handled), least squares polynomial fitting, and the calculation of auto-correlations.

Matrix routines provide facilities for solving sets of simultaneous equations (up to 39 can be handled, or 51 if a lower accuracy is acceptable),

* J.M. Bennett, J.C. Butcher, M. Chapple: "A New Diagnostic Routine."

finding eigenvalues and eigenvectors of symmetric matrices, and finding solutions of the determinantal equation $|A - \lambda B| = 0$.

Gaussian elimination is used to solve sets of linear equations, and the Jacobi process is used for the determination of eigenvalues and eigenvectors of symmetric matrices. Facilities for matrix multiplications and the computation of the determinant of a matrix are also available.

A wide variety of input and print routines can be called upon, together with a representative selection of routines for the computation of specific functions (e.g. square root, logarithm, exponential, sine, cosine, inverse tangent, Legendre and Chebyscheff polynomials). There is also a routine for carrying out a one-dimensional Fourier analysis.

Additional service routines include initial orders, a sum check facility and facilities for interrupting a programme in such a way that computation can be resumed at a later date.

Most of our own programming activity not devoted to specific projects has followed two main courses. These are:

1. The provision of adequate sum checking facilities for input and output routines.
   This is an essential part of

2. Ensuring compatability of all matrix routines.
   Until recently the punched paper tape output of any one matrix routine has not necessarily been acceptable as input to any other matrix routine.

   This work will allow a series of successive matrix operations to be carried out on quantities of data which is normally beyond the capacity of the machine's store. Provision is made for adequate check sums to accompany all data transferred to and from paper tape.

These two apparently pedestrian items will considerably enhance the machine's ability to carry out larger computations, and as such they are regarded by us as being of considerable importance.

OPERATIONAL EXPERIENCE

Table I sets out a summary of our operational experience in the first three quarters of the machine's working life. The last quarter cannot be regarded as typical in that it includes the period of the University long vacation.

At the beginning of its first quarter of operation the SILLIAC's day began at 2.30 and finished at 5.30. This period was progressively increased as demand grew, and the machine is now in the hands of the operators from 10.30 a.m. to 5 p.m., with occasional additional periods in times of over-load. It is our intention to continue to lengthen our operating day into several shifts if necessary.

Since the beginning of operations, the greater part of the machine's time has been taken up by computations originating in the School of Physics itself. These are of two types, computations arising from problems in theoretical physics, and data reduction processes arising from experiments carried out within the Department.. It is interesting to note that the existence of SILLIAC is having considerable effect on the planning of major experiments, in that efforts are being made to avoid the manual handling of data wherever possible. A paper delivered at this Conference describes the way this policy is implemented in one case*.

The work carried out for other University departments has occupied a comparatively small proportion of the machine's time. The Departments of Chemistry and Veterinary Physiology are our best customers, and some of the work for which these departments have been using the machine is described in other papers given at this Conference**.

The work being carried out for organisations outside the University of Sydney at the moment represents about one-fifth of the machine's operating time. Engineering calculations for organisations such as the Snowy Mountains Authority, and computations for insurance companies represent the major part of this time.

Some details of the main problems handled are contained in quarterly reports issued by the Laboratory.

The proportion of machine time spent on programme development has been progressively reduced, as will be seen from Table I. Here we owe a considerable debt to the University of Illinois for making their programme library available to us: without this flying start a much higher proportion of our time would of necessity have been spent on programme development.

TRAINING COURSES

In orienting the work of the programming staff, the Laboratory's policy is to concentrate on the training of potential users and the provision of adequate service routines. We regard it as being our job to spread the knowledge of automatic computing techniques as far as possible; in addition we have found, as indeed have many other groups, that it is much more satisfactory to train an expert in a particular field in the use of the computer rather than to expect the Laboratory staff to acquire expert knowledge in the wide variety of disciplines which are represented by the problems being handled.

For final-year and research students and staff, two courses on Programming for SILLIAC, and on Numerical Methods, have been given to date, and a course on Logical Design of Digital Devices was given in the Michaelmas term of 1956.

In pursuance of one of the aims of the Nuclear Research Foundation, which is

> "... to stimulate public interest in the work being carried out in the School of Physics and at the same time endeavour to keep the industries in this country up to date in the latest developments in research in the field of modern physics."

we have run a total of three evening courses and one fulltime day course for industry on Data Processing Techniques and Practical Computer Programming. A total of 108 people have attended these courses, and although they were not designed specifically for the purpose of encouraging people to use SILLIAC, in fact quite a number of those who attended are continuing to use the machine.

* C.S. Wallace and M.H. Brennan: "The automatic digital recording of information from cosmic ray air showers."

** H.C. Freeman: "SILLIAC Computer Programme for X-Ray Crystal Structure Analysis." and
P.J. Claringbold: "The Automatic Design and Analysis of Biological Experiments."

THE FUTURE

It is proposed to follow a policy of continued development of the SILLIAC and its auxiliary equipment. For example the currently used Ferranti tape readers are to be replaced by readers similar to the Illinois design, further developed for increased speed. The equipment at present in use for tape preparation is all modified telegraph equipment, operating at telegraph speed, which is uncomfortably slow for tape editing operations. Accordingly faster equipment employing photoelectric readers and fast punches, electronically linked, is at present under construction. Moreover, in order to handle work for customers who have their data on punched cards, it is proposed to acquire a Hollerith Card-to-Paper Tape converter.

The SILLIAC's major limitation at the moment is one of storage. On the parent machine, the ILLIAC, this difficulty has been overcome by the addition of a magnetic drum, and serious consideration was given to the possibility of our doing the same thing.

However, since the Illinois group made their decision, considerable advances have been made in the technology of magnetic tape and so we were led to consider this alternative. Magnetic tape has the advantage that it represents a virtually infinite store, and its main disadvantage is that it does not give the random access facility provided by a drum. However, an examination of the type of work which we are likely to be called upon to do shows that not many problems which really necessitate a random access store will come our way. On the basis of speed, a comparison between transfer speeds available with a conventional magnetic tape design and the speed which would be offered by a magnetic drum with the design used by Illinois, shows that there is little to choose between the two devices.

For these reasons work is proceeding upon the design of a magnetic tape store for SILLIAC. This will consist of four transporter units (the first of these is due to be delivered in a few months time) with a total storage capacity of about one million words. Transfer between the tape and computer will take place in blocks. On transfer from tape individual words are assembled automatically and placed in the accumulator, whence they are stored in their final position by programme: on transfer to tape, the reverse process occurs.

The addition of even one of the proposed four tape units will considerably enhance the value of the SILLIAC as a tool for scientific computing.

TABLE I

		Physics Dept.			Other Univ. Depts.			Other Organisations			Total of Useful Time		
		h.	m.*	%of t.u.t.**	h.	m.	% of t.u.t.	h.	m.	% of t.u.t.	h.	m.	% of t.u.t.
Production	a	32	1	31.6	1	19	1.3	2	20	2.3	35	40	35.2
	b	92	12	45.0	10	28	5.1	4	32	2.2	107	2	52.3
	c	61	32	38.5	7	50	4.9	14	25	9.0	83	47	52.5
Development		47	14	46.8	5	55	5.9	9	22	9.3	62	31	62.0
		49	51	24.4	7	50	3.8	15	56	7.8	73	37	36.0
		52	3	32.6	2	28	1.5	11	51	7.4	66	22	41.5
Instruction			42	.7		4	.1	2	3	2.0	2	49***	2.8
			3	-		26	.2	15	6	7.4	15	35	7.6
		-		-	-		-	5	32	3.5	5	32	3.5
Demonstration								not recorded***					
								8	20	4.1	8	20	4.1
								4	3	2.5	4	3	2.5
Total		79	57	79.1	7	18	7.3	13	45	13.6	102	0	100
		142	6	69.4	18	34	9.1	43	54	21.5	204	34	100
		113	35	71.1	10	18	6.4	35	51	22.4	159	44	100

Production Time Lost because of Machine Errors:	7 hrs.	50 mins	(4.8 per cent)
	8 hrs.	9 mins	(3.3 " ")
	6 hrs.	24 mins	(2.6 " ")
Development Time Lost because of **Machine** Errors:	1 hr.	10 mins	(4.8 per cent)
	2 hrs.	31 mins	(1.0 " ")
	2 hrs.	56 mins	(1.2 " ")

a First quarter
b Second quarter
c Third quarter

* hours and minutes

** total useful time

*** Demonstration time during this quarter is classed mostly as Instruction time.

Standby:	20 hrs.	15 mins.	(12.3 per cent)
	9 hrs.	34 mins.	(3.9 " ")
	53 hrs.	2 mins.	(21.6 " ")
Unscheduled Maintenance:	33 hrs.	15 mins.	(20.3 " ")
	20 hrs.	38 mins.	(8.4 " ")
	23 hrs.	23 mins.	(9.5 " ")
Total Useful Time:	101 hrs.	0 mins.	(61.9 " ")
	204 hrs.	34 mins.	(83.4 " ")
	159 hrs.	44 mins.	(65.1 " ")
Total Scheduled Operating Time:	163 hrs.	30 mins.	(100 " ")
	245 hrs.	26 mins.	(100 " ")
	245 hrs.	29 mins.	(100 " ")