largely by engineering considerations, and with the vast majority of machines the number is two. Machines (e.g. ENIAC) have however been made with 10 different symbols. The number for the ~~Ferranti~~ Mark II machine is two, and the symbols used are 0 and 1.

It is not difficult to see that information expressed with one set of symbols can be translated into information expressed with another set by some suitable conventions, e.g. to convert sequences of decimal digits into sequences of 0's and 1's we could replace 0 by 0000, 1 by 1000, 2 by 0100, 3 by 1100, 4 by 0010, 5 by 1010, 6 by 0110, 7 by 1110, 8 by 0001, and 9 by 1001. Alternatively one could assume that the sequence of decimal digits represented an integer according to the ordinary Arabic convention. This same integer could also be represented in the scale of two and would then appear as a sequence of 0's and 1's. There is an infinity of alternative possible conventions. However we are not obliged to choose any one of them. The possibility of this translation process was only mentioned to show that there need be no loss of generality involved in using only two symbols.

Although we shall not need these translation conventions we shall often wish to interpret a sequence of 0's and 1's as meaning some integer. The most natural convention to choose is that by which the value of a 1 in the rth position from the right hand end is 2^{r-1}, so that e.g. 11001 means 25. This is the closest possible analogue of the ordinary Arabic notation for integers. The convention chosen for use with the Mark II machine is different. The value of a 1 in the rth position from the <u>left</u> hand end is 2^{r-1}, so that 25 is represented by 10011 instead of 11001. These facts may be described by saying that the machine uses 'the scale of two with the most significant digits at the right hand end'.

Although the scale of two is appropriate for use within an electronic computer it is not so suitable for work on paper, and it is not possible to avoid paper work altogether. Without attempting to explain the reasons at this stage let us accept that there are occasions when it is desirable to write down on paper the sequence of symbols stored in some part of the machine. Suppose for instance that the sequence was

10001110111010001001100011100101010101101100100110

The copying of such sequences is slow and very liable to inaccuracy. It is very difficult to 'keep one's place'. It is therefore advisable to represent such a sequence on paper in a different form not subject to those difficulties. The method chosen is to divide the sequence into blocks of five

10001 11011 10100 01001 10001 11001 01010 10110 11001 00110

and then to replace each block by a single symbol, according to the table below. The above sequence then becomes Z"SLZWRFWN.

0	00000	/	11	11010	J	22	01101	P
1	10000	E	12	00110	N	23	11101	Q
2	01000	@	13	10110	F	24	00011	O
3	11000	A	14	01110	C	25	10011	B
4	00100	:	15	11110	K	26	01011	G
5	10100	S	16	00001	T	27	11011	"
6	01100	I	17	10001	Z	28	00111	M
7	11100	U	18	01001	L	29	10111	X
8	00010	¼	19	11001	W	30	01111	V
9	10010	D	20	00101	H	31	11111	£
10	01010	R	21	10101	Y			

These symbols are essentially the teleprinter code, except that the combinations 00000, 01000, 00100, 00010, 11011, 11111 which in true teleprint are represented by

no effect, line feed, space, carriage return, figure shift, letter shift

respectively have here been given the representations /, @, :, ¼, ", £. These symbols have been chosen so as to enable the upper case of a typewriter to be used throughout. In manuscript or with other typewriters we permit the synonyms % for /, ½ for ¼, ø for £. With certain kinds of teleprint apparatus it may also be necessary to permit the synonyms 2 for @, 4 for :, 8 for ¼, 5 for ", ø for £. These six combinations will be known as 'stunts'.

The user is strongly recommended to learn the above table. A number of aids to computation in the scale of 32 are given on Figs. A,B,C,D & H. These include addition and multiplication tables, special tables to assist in multiplication by powers of two, powers of 10 in the scale of 32, and aids to decimal-teleprint conversion. In principle it is possible to do without these aids for the machine itself can do all the conversion processes required. In practice it frequently happens that some single number is required in the scale of 32, and it is found less trouble to do the conversion by hand than to use the machine. To convert a decimal number less than 1 to scale of 32 multiply repeatedly by 1024 subtracting and recording the integral part at each stage. This can be done very quickly with a Brunsviga with transfer. The integral parts obtained may be broken up into two teleprint characters with the aid of the table on Fig. B .

3. The forms of storage used.

The information store in the Mark II machine consists of the magnetic store and the electronic store. The information in the magnetic store is of considerable volume viz. 655360 binary digits: in other words it corresponds to paper on which is written 655360 digits each of which might be either 0 or 1. But this information is not particularly readily available. It is (to maintain the analogy) as if it were written in a book. In order to find any required piece of information it is necessary to open the book at the appropriate page. The electronic store has a considerably smaller capacity viz. 20480 digits but this information is much more readily available and is to be compared rather to a number of sheets of paper exposed to the light on a table, so that any particular word or symbol becomes visible as soon as the eye focusses on it.

The information in the magnetic store consists of magnetised areas of nickel on the cylindrical surface of a rotating wheel. Each digit stored is represented by one magnetised area. These 655360 areas are arranged in 256 tracks of 2560 digits each. The centres

A: Teleprinter Equivalents of Positive & Negative Powers of Ten. [illegible]

	10	R	2^{40}	10^{-1}	G N I W B N I A
	10^{2}	: A	2^{45}	10^{-2}	O Y U R O Y U R
	10^{3}	½ £	2^{45}	10^{-3}	B J G F L O / E
	10^{4}	T O D	2^{50}	10^{-4}	M O G S C " ½ A
	10^{5}	/ Y E A	2^{55}	10^{-5}	C M ½ N F Z K R
	10^{6}	/ L T V	2^{55}	10^{-6}	" @ H Q Q Z E E
	10^{7}	/ H S Z D	2^{60}	10^{-7}	X Y I S £ J J A
	10^{8}	/ ½ O J £ @	2^{65}	10^{-8}	@ I @ Q A W Q R
	10^{9}	/ T L Y B X	2^{65}	10^{-9}	W / X J T J @ E
	10^{10}	/ / B Q / R D	2^{70}	10^{-10}	O C P £ F V F A
2^{-10}	10^{11}	G F U : X @	2^{75}	10^{-11}	I K E £ £ G £ R
2^{-10}	10^{12}	: R R R A X	2^{75}	10^{-12}	Q : T B M S A E
2^{-10}	10^{13}	½ S U U E A D	2^{80}	10^{-13}	D @ G : M L T A
2^{-10}	10^{14}	T H U ½ N V G @	2^{85}	10^{-14}	S H I M I D ½ J
2^{-10}	10^{15}	/ F N L G K F M	2^{85}	10^{-15}	H " W K X / : E
2^{-15}	10^{16}	@ M Q D V I M ½	2^{90}	10^{-16}	B V S S J D W A
2^{-20}	10^{17}	B C E K S G O @	2^{95}	10^{-17}	" ½ I R X X T J
2^{-20}	10^{18}	P W C P P S O "	2^{95}	10^{-18}	D U G X L M : E
2^{-25}	10^{19}	S L / A B Z Y ½	2^{100}	10^{-19}	Q X W L M E P A
2^{-30}	10^{20}	P S V G Z Q P @	2^{105}	10^{-20}	D L N ½ ½ B B J

The figures given have an accuracy of ± 1.

Binary-Decimal Conversion Table.

	/	E	@	A	:	S	I	U	½	D	R	J	N	F	C	K	T	Z	L	W	H	Y	P	Q	O	B	G	"	M	X	V	£
E	32								40										50										60			63
@	64						70										80										90					95
A	96				100										110										120							127
:	128		130										140										150									159
S	160										170										180										190		191
I	192								200										210										220			223
U	224						230										240										250					255
½	256				260										270										280							287
D	288		290										300										310									319
R	320										330										340										350		351
J	352								360										370										380			383
N	384						390										400										410					415
F	416				420										430										440							447
C	448		450										460										470									479
K	480										490										500										510		511
T	512								520										530										540			543
Z	544						550										560										570					575
L	576				580										590										600							607
W	608		610										620										630									639
H	640										650										660										670		671
Y	672								680										690										700			703
P	704						710										720										730					735
Q	736				740										750										760							767
O	768		770										780										790									799
B	800										810										820										830		831
G	832								840										850										860			863
"	864						870										880										890					895
M	896				900										910										920							927
X	928		930										940										950									959
V	960										970										980										990		991
£	992								1000										1010										1020			1023

/	.015625	.00000	/
E	.046875	.03125	E
@	.078125	.0625	@
A	.109375	.09375	A
:	.140625	.125	:
S	.171875	.15625	S
I	.203125	.1875	I
U	.234375	.21875	U
½	.265625	.25	½
D	.296875	.28125	D
R	.328125	.3125	R
J	.359375	.34375	J
N	.390625	.375	N
F	.421875	.40625	F
C	.453125	.4375	C
K	.484375	.46875	K
T	.515625	.50	T
Z	.546875	.53125	Z
L	.578125	.5625	L
W	.609375	.59375	W
H	.640625	.625	H
Y	.671875	.65625	Y
P	.703125	.6875	P
Q	.734375	.71875	Q
O	.765625	.75	O
B	.796875	.78125	B
G	.828125	.8125	G
"	.859375	.84375	"
M	.890625	.875	M
X	.921875	.90625	X
V	.953125	.9375	V
£	.984375	.96875	£

Fig. B.

Multiplication table

Fig. 9

E	⊙	A	:	S	I	U	¼	D	R	J	N	F	C	K	T	Z	L	W	H	Y	P	Q	O	B	G	"	M	X	V	£
⊙	/	/	/	/	/	/	/	/	/	/	/	/	/	/	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	:	I	¼	R	N	C	T	L	H	P	O	G	M	V	/	⊙	:	I	¼	R	N	C	T	L	H	P	O	G	M	V
A	/	/	/	/	/	/	/	/	/	E	E	E	E	E	E	E	E	E	E	E	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	I	D	N	K	L	Y	O	"	V	E	:	U	R	F	T	W	P	B	M	£	⊙	S	¼	J	C	Z	H	Q	G	X
:	/	/	/	/	/	/	E	E	E	E	E	E	E	E	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	A	A	A	A	A	A	A	A
	¼	N	T	H	O	M	/	:	¼	N	T	H	O	M	/	:	¼	N	T	H	O	M	/	:	¼	N	T	H	O	M
S	/	/	/	/	/	E	E	E	E	E	E	⊙	⊙	⊙	⊙	⊙	⊙	⊙	A	A	A	A	A	A	:	:	:	:	:	:
	R	K	H	B	V	A	¼	F	L	Q	M	E	I	J	T	Y	C	£	:	D	C	W	O	X	⊙	U	N	Z	P	"
I	/	/	/	/	E	E	E	E	E	⊙	⊙	⊙	⊙	⊙	A	A	A	A	A	A	:	:	:	:	:	S	S	S	S	S
	N	L	O	V	:	R	T	P	K	⊙	¼	C	H	G	/	I	N	L	O	V	:	R	T	P	K	⊙	¼	C	H	G
U	/	/	/	E	E	E	E	E	⊙	⊙	⊙	⊙	A	A	A	A	A	:	:	:	:	S	S	S	S	S	I	I	I	I
	C	Y	M	A	R	Z	O	£	I	F	K	"	⊙	D	T	Q	V	S	N	W	G	E	¼	K	P	X	:	J	L	B
¼	/	/	E	E	E	⊙	⊙	⊙	⊙	⊙	A	A	A	A	:	:	:	:	S	S	S	S	I	I	I	I	U	U	U	U
	T	O	/	¼	T	O	/	¼	T	O	/	¼	T	O	/	¼	T	O	/	¼	T	O	/	¼	T	O	/	¼	T	O
D	/	/	E	E	E	E	⊙	⊙	⊙	A	A	A	A	:	:	:	S	S	S	S	I	I	I	U	U	U	U	¼	¼	¼
	L	"	:	F	P	R	¼	Z	O	A	N	Y	V	U	T	B	⊙	J	H	X	I	N	O	E	R	W	H	S	C	Q
R	/	/	E	E	E	⊙	⊙	⊙	A	A	A	:	:	:	S	S	S	S	I	I	I	U	U	U	¼	¼	¼	D	D	D
	H	V	¼	L	M	I	T	G	:	C	O	⊙	N	P	/	R	H	V	¼	L	M	I	T	G	:	C	O	⊙	N	P
J	/	E	E	E	⊙	⊙	⊙	A	A	A	:	:	:	S	S	S	I	I	I	U	U	U	¼	¼	¼	D	D	D	R	R
	P	E	N	Q	⊙	F	O	A	Q	B	:	K	G	S	T	"	I	Z	N	U	L	X	¼	W	V	D	H	£	R	Y
N	/	E	E	E	⊙	⊙	A	A	A	:	:	:	S	S	I	I	I	U	U	U	¼	¼	D	D	D	R	R	R	J	J
	O	:	T	M	¼	H	/	N	O	:	T	M	¼	H	/	N	O	:	T	M	¼	H	/	N	O	:	T	M	¼	H
F	/	E	E	⊙	⊙	⊙	A	A	:	:	:	S	S	I	I	I	U	U	¼	¼	¼	D	D	R	R	R	J	J	N	N
	G	U	H	E	C	"	¼	Y	⊙	K	N	D	P	A	T	X	R	Q	:	Z	V	J	O	S	L	£	N	B	I	Y
Č	/	E	E	⊙	⊙	A	A	A	:	:	S	S	I	I	U	U	U	¼	¼	D	D	R	R	R	J	J	N	N	F	F
	M	R	O	I	H	⊙	T	V	N	G	¼	P	:	L	/	C	M	R	O	I	H	⊙	T	V	N	G	¼	P	:	L
K	/	E	E	⊙	⊙	A	A	:	:	S	S	I	I	U	U	U	¼	¼	D	D	R	R	J	J	N	N	F	F	C	C
	V	F	N	J	G	D	O	U	P	S	H	A	L	E	T	£	C	X	N	"	R	B	¼	Q	I	Y	:	W	O	Z
T	E	E	⊙	⊙	A	A	:	:	S	S	I	I	U	U	¼	¼	D	D	R	R	J	J	N	N	F	F	C	C	K	K
	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T	/	T
Z	E	E	⊙	⊙	A	A	:	:	S	S	I	I	U	U	¼	D	D	R	R	J	J	N	N	F	F	C	C	K	K	T
	⊙	W	:	Y	I	Q	¼	B	R	"	N	V	C	£	T	E	L	A	H	S	P	U	O	D	G	J	M	F	V	K
L	E	E	⊙	⊙	A	A	:	S	S	I	I	U	U	¼	D	D	R	R	J	J	N	N	F	C	C	K	K	T	T	Z
	:	P	¼	G	N	V	T	⊙	H	I	O	R	M	C	/	L	:	P	¼	G	N	V	T	⊙	H	I	O	R	M	C
W	E	E	⊙	⊙	A	:	:	S	S	I	U	U	¼	¼	D	R	R	J	J	N	F	F	C	C	K	T	T	Z	Z	L
	I	B	N	£	L	S	O	J	V	Z	:	⊙	R	X	T	A	P	D	M	U	⊙	V	¼	"	C	E	H	U	C	F
H	E	E	⊙	A	A	:	S	S	I	I	U	¼	¼	D	R	R	J	J	N	F	F	C	K	K	T	T	Z	L	L	W
	¼	M	T	:	O	N	/	H	¼	M	T	:	O	N	/	H	¼	M	T	:	O	N	/	H	¼	K	T	:	O	N
Y	E	E	⊙	A	A	:	S	S	I	U	U	¼	D	D	R	J	J	N	F	F	C	K	K	T	Z	Z	L	W	W	H
	R	£	H	D	V	W	¼	X	L	U	M	Z	T	"	T	S	⊙	K	:	B	C	A	O	F	⊙	G	N	E	P	J
P	E	⊙	A	A	:	:	S	I	I	U	¼	¼	D	R	J	J	N	F	F	C	K	K	T	Z	Z	L	W	W	H	Y
	N	⊙	O	C	:	G	T	I	M	L	¼	V	H	R	/	P	N	⊙	O	C	:	G	T	I	M	L	¼	V	H	R
Q	E	⊙	⊙	A	:	S	S	I	U	U	¼	D	R	R	J	N	N	F	C	K	K	T	Z	Z	L	W	H	H	Y	P
	C	S	M	V	R	E	O	K	I	X	H	J	⊙	B	T	U	W	Y	N	A	G	Z	¼	£	P	V	:	"	L	D
O	E	⊙	A	A	:	S	I	I	U	¼	D	D	R	J	N	N	F	C	K	K	T	Z	L	L	W	H	Y	Y	P	Q
	T	¼	/	O	T	¼	/	O	T	¼	/	O	T	¼	/	O	T	¼	/	O	T	¼	/	O	T	¼	/	O	T	¼
B	E	⊙	A	A	:	S	I	U	U	¼	D	R	R	J	N	F	C	C	K	T	Z	Z	L	W	H	Y	Y	P	Q	O
	L	J	:	X	P	K	¼	E	G	W	N	S	V	Q	T	D	⊙	"	H	/	I	£	O	Z	R	A	M	Y	C	U
G	E	⊙	A	:	:	S	I	U	¼	¼	D	R	J	N	F	F	C	K	T	Z	Z	L	W	H	Y	Y	P	Q	O	B
	M	C	¼	⊙	M	P	T	R	:	V	O	L	N	I	/	G	H	C	¼	⊙	M	P	T	R	:	V	O	L	N	I
"	E	⊙	A	:	S	S	I	U	¼	D	R	R	J	N	F	C	K	T	T	Z	L	W	H	Y	Y	P	Q	O	B	G
	P	Z	N	U	⊙	X	O	"	C	D	:	£	G	Y	T	J	I	E	M	C	L	F	¼	A	V	B	H	F	R	S
M	E	⊙	A	:	S	I	U	U	¼	D	R	J	N	F	C	C	K	T	Z	L	W	H	Y	Y	P	Q	O	B	G	"
	O	H	T	N	¼	:	/	M	O	H	T	N	¼	:	/	M	O	H	T	N	¼	:	/	M	O	H	T	N	¼	:
X	E	⊙	A	:	S	I	U	¼	D	D	R	J	N	F	C	K	T	Z	L	W	W	H	Y	P	Q	O	B	G	"	M
	G	⊙	H	Z	C	J	¼	S	⊙	£	M	B	P	Y	[illegible]	:	R	U	:	E	V	"	O	Y	L	K	M	D	I	A
V	E	⊙	A	:	S	I	U	¼	D	R	J	N	F	C	K	K	T	Z	L	W	H	Y	P	Q	O	B	G	"	M	X
	M	G	O	P	H	L	T	C	N	R	¼	I	:	⊙	/	V	M	G	O	F	H	L	T	C	N	R	¼	I	:	⊙
£	E	⊙	A	:	S	I	U	¼	D	R	J	N	F	C	K	T	Z	L	W	H	Y	P	Q	O	B	G	"	M	X	V
	V	X	M	"	G	B	O	O	P	Y	H	W	L	Z	T	K	C	F	N	J	R	D	¼	U	I	S	:	A	⊙	E