MCD/B/2/64

ELLIOTT

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MCS 920 FACTS

FACTS FOR ENGINEERS

The M.C.S. 920 is a rugged and compact digital computer that is particularly suited to the solution of on-line real time problems. Some typical applications are:

- Mobile systems for Air Traffic Control;
- Navigation;
- Weapon and fire control systems;
- Control of satellite tracking aerials;
- Industrial uses.

The Computer can be supplied in two packs, light alloy casting or a standard cabinet. Generally the former meets the British Military Defence Specification D.E.F.133 (L2) whereas the latter meets D.E.F.133 (L1). Silicon semi-conductors are used throughout giving a working temperature range of 0°C to +52°C.

The arithmetic unit of the computer forms a loop comprising the five basic registers and adding unit, in which the computer carries out its addition, subtraction and shifting operations. Gating conditionals produced by the control module, in response to the micro-program, manipulate the program operands within the loop in accordance with the instruction. The program control unit regulates the allocation of computer time when it has to be shared between programs. It can interrupt one program in order to enter and take action in another of higher priority. Thereafter, the computer will select the next program with the highest priority that is waiting for attention. These features of priority interrupt and instruction modification give an effective increase in speed over other computers without these facilities.

PHYSICAL CHARACTERISTICS

	Length	Width	Height	Weight
Computer (light alloy casting)	3 ft. (91 cms.)	1 ft. (31 cms.)	1 ft. 2 ins. (35 cms.)	170 lbs. (78 Kg.)
Computer (standard cabinet)	2 ft. 6 ins. (76 cms.)	12 ins. (31 cms.)	3 ft. 6 ins. (107 cms.)	200 lbs. (91 Kg.)
Programmers Control Unit	2 ft. 3 ins. (68 cms.)	10 ins. (25 cms.)	5 ins. (13 cms.)	35 lbs. (16 Kg.)

POWER SUPPLIES

50 Cycles AC mains
Voltage 200–240 volts ± 10%
Frequency 50 ± 5 c.p.s.

400 Cycle 3 phase
Voltage 208 volts ± 6%
Frequency 400 ± 20 c.p.s.

FACTS FOR PROGRAMMERS

The M.C.S. 920 is a parallel machine with an 18 bit word length. It utilizes 8 hole tape and has a memory of 4096 or 8192 words according to application. The fifth digit, from the least significant end of the eight digit tape character, is the parity digit and is ignored on input. There are 16 functions and the operations to execute them are detailed by a built-in micro-program.

The sign of the number is represented by the most significant digit with the binary point placed immediately after this digit. Positive numbers are represented directly and negative numbers by their complement with respect to two. The range of numbers that may be represented in the computer is thus from -1 to $+1-2^{-17}$.

When a word represents an instruction, its digits are grouped as follows:—

B	F	N
Modifier	Function	Address

Digits 1 to 13	–'N'–	Address digits which specify any one of 8192 store locations.
Digits 14 to 17	–'F'–	Function digits which specify the operation to be carried out.
Digit 18	–'B'–	The modifier digit which, if it is a 0 . . . the instruction is obeyed as stored, and if it is a 1 . . . the address digits are modified, before the instruction is obeyed, by the addition of the contents of the B Register. The function digits remain unaltered, and since the modification takes place in the control section, the version of the instruction held in store remains unchanged.

The Control Console provides:— a set of 13 Address Switches which enable a starting address to be selected; control buttons for the following:— power on; power off; clear—(which gives a jump instruction to the address set up on the Address Switches); computer stop; computer restart. There is also a loudspeaker with volume control which provides an audible identification of individual program operation.

920 TELECODE

Character	Numerical Value	Elliott (920) meaning	Character	Numerical Value	Elliott (920) Meaning
Zone 0			*Zone 2*		
00000.000	0	Blank	01010.000	32	;
00010.001	1	New Line	01000.001	33	A
00010.010	2	(CRLF)	01000.010	34	B
00000.011	3		01010.011	35	C
00010.100	4		01000.100	36	D
00000.101	5		01010.101	37	E
00000.110	6		01010.110	38	F
00010.111	7		01000.111	39	G
00011.000	8	(	01001.000	40	H
00001.001	9	)	01011.001	41	I
00001.010	10	,	01011.010	42	J
00011.011	11	£	01001.011	43	K
00001.100	12	:	01011.100	44	L
00011.101	13	&	01001.101	45	M
00011.110	14	*	01001.110	46	N
00001.111	15	/	01011.111	47	O
Zone 1			*Zone 3*		
00110.000	16	0	01100.000	48	P
00100.001	17	1	01110.001	49	Q
00100.010	18	2	01110.010	50	R
00110.011	19	3	01100.011	51	S
00100.100	20	4	01110.100	52	T
00110.101	21	5	01100.101	53	U
00110.110	22	6	01100.110	54	V
00100.111	23	7	01110.111	55	W
00101.000	24	8	01111.000	56	X
00111.001	25	9	01101.001	57	Y
00111.010	26		01101.010	58	Z
00101.011	27		01111.011	59	
00111.100	28	=	01101.100	60	
00101.101	29	+	01111.101	61	
00101.110	30	−	01111.110	62	
00111.111	31	.	01101.111	63	

920 TELECODE

Character	Numerical Value	Elliott (920) Meaning	Character	Numerical Value	Elliott (920) Meaning
Zone 4			*Zone 6*		
10010.000	64	Space	11000.000	96	?
10000.001	65		11010.001	97	
10000.010	66		11010.010	98	
10010.011	67		11000.011	99	
10000.100	68		11010.100	100	
10010.101	69		11000.101	101	
10010.110	70		11000.110	102	
10000.111	71		11010.111	103	
10001.000	72		11011.000	104	
10011.001	73		11001.001	105	
10011.010	74		11001.010	106	
10001.011	75		11011.011	107	
10011.100	76		11001.100	108	
10001.101	77		11011.101	109	
10001.110	78		11011.110	110	
10011.111	79		11001.111	111	
Zone 5			*Zone 7*		
10100.000	80		11110.000	112	
10110.001	81		11100.001	113	
10110.010	82		11100.010	114	
10100.011	83		11110.011	115	
10110.100	84		11100.100	116	
10100.101	85		11110.101	117	
10100.110	86		11110.110	118	
10110.111	87		11100.111	119	
10111.000	88	[	11101.000	120	
10101.001	89	]	11111.001	121	
10101.010	90	10 (suffix)	11111.010	122	
10111.011	91	<	11101.011	123	
10101.100	92	>	11111.100	124	
10111.101	93	↑	11101.101	125	
10111.110	94	~	11101.110	126	
10101.111	95	%	11111.111	127	Erase

INSTRUCTION EXECUTION TIMES

Quoted below are 4096 and 8192 word stores times in micro-seconds for the total execution of each instruction and include: (a) Accessing and incrementing the Sequence Control Register, 9 and 11; (b) Accessing the instruction, 6 and 8; (c) Executing the instruction (depends on instruction). They do not include: B Modification, 6 and 8, and this must be added where relevant. It should be noted that the Sequence Control Register is incremented before the current instruction is obeyed.

FUNCTION	TITLE	EXECUTION TIME		
		4096 word store		*8192 word store*
0	Set B Register	27		33
1	Add	21		27
2	Negate and add	27		33
3	Store Auxiliary Register	21		27
4	Read	21		27
5	Write	21		27
6	Collate	27		33
7	Jump if zero	30	Acc. zero	36
		24	Acc. +ve	28
		21	Acc. −ve	25
8	Jump	21		27
9	Jump if Negative	27	Acc. −ve	33
		21	Acc. +ve	25
		21	Acc. zero	25
10	Count in store	24		30
11	Store S.C.R.	30		38
12	Multiply	180		186
13	Divide	186		192
14	Shift	24 + 9n		28 + 9n
15	Input/Output	24 (minimum)		28 (minimum)

The Auxiliary Register fulfils various roles. It should be noted that B modification affects its contents, as do instructions, 0, 2, 6, 7, 8, 9, 11 and 13. In particular, instructions 0 and 2 place the operand from the store in the Auxiliary Register. Thus the contents of the Auxiliary Register previously stored by instruction 3 can be reset in 60/70 micro-seconds by obeying instructions 0 or 2 followed by a left shift, whereas resetting by multiplication or shifting from the accumulator would take about 200 micro-seconds.

INPUT AND OUTPUT INSTRUCTIONS

If the most significant digit of N is zero, the instruction is an input instruction; otherwise it is an output instruction. The instruction is further described by the N digits as follows: 15 N ($N \leqslant 2047$) — 18 digit number input to accumulator from the device specified by N. □ 15 2048 — Input to accumulator from tape reader. The contents of the accumulator are shifted left seven places and the character from the tape reader is placed in the seven least significant digit positions. The fifth digit of the eight digit tape character is the parity and is ignored on input. □ 15 N ($4096 \leqslant N \leqslant 6143$) — 18 digit number in accumulator is output to the device specified by N. □ 15 6144 — Output from accumulator via paper tape punch. The eight least significant digits of the accumulator are output as an eight digit character on paper tape. □ 15 7168 — "Program terminate" instruction.

PRIORITY LEVEL PROGRAM ORGANISATION

Each priority level has its own Sequence Control Register and B Register. These registers are locations in the store and can be referred to by program in the normal way.

PRIORITY LEVEL	B. REG. LOCATION	S.C.R. LOCATION
1	1	0
2	3	2
3	5	4
4	7	6

The Accumulator and the Auxiliary Register are shared between all four levels, so they must be safeguarded by program every time an interrupt occurs. It will also usually be necessary to reset the Sequence Control Register on terminating a level so that the program, when next demanded, will start again at the same location. All these conditions are fulfilled by the following control instructions. They are applicable to any program on levels 1, 2 or 3 which starts at location N.

LOCATION	INSTRUCTION		REMARKS
	Function	Address	
[N−6]	—	—	Store for lower level AR.
[N−5]	—	—	Store for lower level Acc.
[N−4]	0	N−6	Reset lower level AR.
[N−3]	14	1	
[N−2]	4	N−5	Reset lower level Acc.
[N−1]	15	7168	Terminate, Note S.C.R. reset to N.
ENTRY [N]	5	N−5	Store lower level Acc.
[N+1]	3	N−6	Store lower level AR.
[N+]			Required program (x locations).
[N+2+x]	8	N−4	Jump to reset for lower level.

If the B Register has to be retained unaltered for each subsequent entry, then the instruction in N−4 must be replaced by 2 N−6. If the contents of the AR on the lower level are not required then instructions N−4, N−3 and N+1 can be omitted and store location N−6 is not required. Rules for the punching of instructions and data in teleprinter code are given in the "920 Translation Input Routine" obtainable on demand.

INITIAL INSTRUCTIONS

A set of permanently available Initial Instructions facilitate the reading of program tapes into the computer. These are obtained for either 4096 or 8192 word store computers by entering the same starting address which corresponds to the last 12 store locations.

The Initial instructions and their respective addresses for a 8192 word store are tabulated below.

ADDRESS	INSTRUCTION			EFFECT
'N'digits	'B'	'F'	'N'	
8180	/	15	8189	(−3)
8181		00	8180	(Set B-Register to −3)
8182		04	8189	(Set Accumulator initially)
8183		15	4084	(Shift and input tape character)
8184		09	8186	(Jump to 8186 if Accumulator is negative)
8185		08	8183	(Jump to 8183 if Accumulator is positive)
8186		15	4094	(Shift and input final tape character of word)
8187	/	05	8180	(Store word read in)
8188		10	0001	(Count in B-Register)
8189		04	0001	(Read B-Register)
8190		09	8182	(Jump to 8182 if Accumulator is negative)
8191		08	8177	(Jump to 8177 if Accumulator is positive)

NOTES

Instructions 15 4084 and 15 4094 have the same effect as 15 2048.
When entered at 8181 the routine initially reads words into 8177, 8178, and 8179, control is then transferred to location 8177. If these instructions set the B register to -n and then transfer control to 8182, words can then be read into the sequence of n locations ending at 8179. Control is then transferred again to location 8177 so that a transfer instruction read into that location can trigger the program.

POWERS OF 2 IN DECIMAL

2^n	n	2^{-n}
2	1	.5
4	2	.25
8	3	.125
16	4	.062 5
32	5	.031 25
64	6	.015 625
128	7	.007 812 5
256	8	.003 906 25
512	9	.001 953 125
1 024	10	.000 976 562 5
2 048	11	.000 488 281 25
4 096	12	.000 244 140 625
8 192	13	.000 122 070 312 5
16 384	14	.000 061 035 156 25
32 768	15	.000 030 517 578 125
65 536	16	.000 015 258 789 062 5
131 072	17	.000 007 629 394 531 25
262 144	18	.000 003 814 697 265 625
524 288	19	.000 001 907 348 632 812 5
1 048 576	20	.000 000 953 674 316 406 25
2 097 152	21	.000 000 476 837 158 203 125
4 194 304	22	.000 000 238 418 579 101 562 5
8 388 608	23	.000 000 119 209 289 550 781 25
16 777 216	24	.000 000 059 604 644 775 390 625
33 554 432	25	.000 000 029 802 322 387 695 313
67 108 864	26	.000 000 014 901 161 193 847 656
134 217 728	27	.000 000 007 450 580 596 923 828
268 435 456	28	.000 000 003 725 290 298 461 914
536 870 912	29	.000 000 001 862 645 149 230 957
1 073 741 824	30	.000 000 000 931 322 574 615 479
2 147 483 648	31	.000 000 000 465 661 287 307 739
4 294 967 296	32	.000 000 000 232 830 643 653 870
8 589 934 592	33	.000 000 000 116 415 321 826 935
17 179 869 184	34	.000 000 000 058 207 660 913 467
34 359 738 368	35	.000 000 000 029 103 830 456 734
68 719 476 736	36	.000 000 000 014 551 915 228 367
137 438 953 472	37	.000 000 000 007 275 957 614 183
274 877 906 944	38	.000 000 000 003 637 978 807 092
549 755 813 888	39	.000 000 000 001 818 989 403 546
1 099 511 627 776	40	.000 000 000 000 909 494 701 773

SOME USEFUL CONSTANTS

π =	3.141 592 653 590	$1/\pi$ =	0.318 309 886 184
$\log_{10}e$ =	0.434 294 481 903	$\log_e 10$ =	2.302 585 092 994
$\log_{10}2$ =	0.301 029 995 664	e =	2.718 281 828 459
$\sqrt{2}$ =	1.414 213 562 373	$\sqrt{3}$ =	1.732 050 807 569
1 radian =	57.295 779 513 082°	1° =	0.017 453 292 520 radian

TABLES OF BINARY EQUIVALENTS

The purpose of these tables is to assist in the setting of binary addresses on the word generator.

1. Select the highest multiple of 64 less than (or equal to) the required address, and work out the difference (if any).
2. Set the first 7 switches (from the left) to the binary equivalent of the multiple, working from Table A.
3. Set the last 6 switches to the binary equivalent of the difference, working from Table B.

TABLE A

Multiple of 64	*Binary Equivalent*	*Multiple of 64*	*Binary Equivalent*	*Multiple of 64*	*Binary Equivalent*	*Multiple of 64*	*Binary Equivalent*
0	0000000	2048	0100000	4096	1000000	6144	1100000
64	0000001	2112	0100001	4160	1000001	6208	1100001
128	0000010	2176	0100010	4224	1000010	6272	1100010
192	0000011	2240	0100011	4288	1000011	6336	1100011
256	0000100	2304	0100100	4352	1000100	6400	1100100
320	0000101	2368	0100101	4416	1000101	6464	1100101
384	0000110	2432	0100110	4480	1000110	6528	1100110
448	0000111	2496	0100111	4544	1000111	6592	1100111
512	0001000	2560	0101000	4608	1001000	6656	1101000
576	0001001	2624	0101001	4672	1001001	6720	1101001
640	0001010	2688	0101010	4736	1001010	6784	1101010
704	0001011	2752	0101011	4800	1001011	6848	1101011
768	0001100	2816	0101100	4864	1001100	6912	1101100
832	0001101	2880	0101101	4928	1001101	6976	1101101
896	0001110	2944	0101110	4992	1001110	7040	1101110
960	0001111	3008	0101111	5056	1001111	7104	1101111
1024	0010000	3072	0110000	5120	1010000	7168	1110000
1088	0010001	3136	0110001	5184	1010001	7232	1110001
1152	0010010	3200	0110010	5248	1010010	7296	1110010
1216	0010011	3264	0110011	5312	1010011	7360	1110011
1280	0010100	3328	0110100	5376	1010100	7424	1110100
1344	0010101	3392	0110101	5440	1010101	7488	1110101
1408	0010110	3456	0110110	5504	1010110	7552	1110110
1472	0010111	3520	0110111	5568	1010111	7616	1110111
1536	0011000	3584	0111000	5632	1011000	7680	1111000
1600	0011001	3648	0111001	5696	1011001	7744	1111001
1664	0011010	3712	0111010	5760	1011010	7808	1111010
1728	0011011	3776	0111011	5824	1011011	7872	1111011
1792	0011100	3840	0111100	5888	1011100	7936	1111100
1856	0011101	3904	0111101	5952	1011101	8000	1111101
1920	0011110	3968	0111110	6016	1011110	8064	1111110
1984	0011111	4032	0111111	6080	1011111	8128	1111111

TABLE B

Difference	*Binary Equivalent*	*Difference*	*Binary Equivalent*
0	000000	32	100000
1	000001	33	100001
2	000010	34	100010
3	000011	35	100011
4	000100	36	100100
5	000101	37	100101
6	000110	38	100110
7	000111	39	100111
8	001000	40	101000
9	001001	41	101001
10	001010	42	101010
11	001011	43	101011
12	001100	44	101100
13	001101	45	101101
14	001110	46	101110
15	001111	47	101111
16	010000	48	110000
17	010001	49	110001
18	010010	50	110010
19	010011	51	110011
20	010100	52	110100
21	010101	53	110101
22	010110	54	110110
23	010111	55	110111
24	011000	56	111000
25	011001	57	111001
26	011010	58	111010
27	011011	59	111011
28	011100	60	111100
29	011101	61	111101
30	011110	62	111110
31	011111	63	111111