
RAYTHEON COMPUTER

RAYTHEON 250 PROGRAM LIBRARY

Catalog Number 9004

IDENTIFICATION:

BOOTSTRAP DIAGNOSTIC

D. BOOTSTRAP DIAGNOSTIC ROUTINES

After the particular failure area has been defined by the PROBE I diagnostic routine, it is desirable to use a bootstrap test routine together with an oscilloscope and the applicable logic diagrams to further identify the marginal components. The applicable bootstrap diagnostic routines are described in this paragraph. These routines are given in listable octal format and their bootstrap serial binary format. Tapes supplied with standard technical literature kits are punched in bootstrap binary format, and punched at the end of each tape is an extra filler bit (zero) and a stop code.

To check the commands, it is necessary to enter simple programs, such as those shown on the following pages, in the basic bootstrap format. The steps for entering a program are as follows:

- 1) Insert the tape in the reader.
- 2) Turn computer power on.
- 3) Turn Flexowriter power on.
- 4) Turn FILL switch on the front of computer to the ON position.
- 5) Press ENABLE switch then BREAKPOINT switch to reset the parity flip-flop, then release the BREAKPOINT switch. The computer will now read the tape.
- 6) When the tape stops, turn the FILL switch to off position.
- 7) To start computer operation under computer control, press ENABLE switch on Flexowriter to down position.
- 8) On Flexowriter strike "I" key, then depress BREAKPOINT switch.
- 9) Release BREAKPOINT switch.
- 10) Release ENABLE switch. Computer operation will begin.

A command list showing operations, mnemonic and numeric codes, and descriptions is provided in Table 4-4.

Table 4-4.

COMMAND LIST OF OPERATIONS AND CODES

Operation	Mnemonic Code	Numeric Code	Description
Arithmetic	ADD	14	Add
	SUB	15	Subtract
	DPA	16	Double Precision Add
	DPS	17	Double Precision Subtract
	SQR	30	Square Root
	DIV	31	Divide
	DVR	31	Divide Remainder
	MUP	32	Multiply
	CLA	45	Clear A
	CLB	43	Clear B
	CLC	44	Clear C
	GTB	41	Gray to Binary
CAM	56	Compare A and M	
Transfer	TAN	35	Transfer if A Negative
	TBN	36	Transfer if B Negative
	TCN	34	Transfer if C Negative
	TRU	37	Transfer Unconditionally
	TOF	75	Transfer on Overflow
	TES	77	Transfer on External Signal
Loading & Storing	LDA	05	Load A
	LDB	06	Load B
	LDC	04	Load C
	LDP	07	Load Double Precision
	IAC	01	Interchange A & C
	IBC	02	Interchange B & C
	ROT	03	Rotate
	IAM	25	Interchange A & M
	STA	11	Store A
	STB	12	Store B
	STC	10	Store C
	STD	13	Store Double Precision
	MCL	71	Move Command Line Block
MLX	26	Move Line X to Line Y	
Logical & Shifting	EBP	40	Extend Bit Pattern
	AMC	42	AND M & C
	MAC	00	Merge A into C
	AOC	46	AND OR Combined
	EXF	47	Extract Field
	NAD	20	Normalize and Decrement
	LSD	21	Left Shift and Decrement
	RSI	22	Right Shift and Increment
	SAI	23	Scale Right and Increment
	SBR	33	Shift B Right
Control	NOP	24	No Operation
	HLT	00	Halt
Input-Output	DIU	50	Disconnect Input Unit
	RTK	51	Read Typewriter Keyboard
	RPT	52	Read Paper Tape
	RFU	53	Read Fast Unit
	LAI	55	Load A From Input Buffer
	CIB	57	Clear Input Buffer
	WOC	6X	Write Output Character
	PTU	70	Pulse to Specified Unit
	BSO	72	Block Serial Output
	BSI	73	Block Serial Input

D-1. LOAD, STORE AND CLEAR REGISTERS

The A, B, and C Registers are successively loaded, stored and cleared. Each is loaded with a different pattern of bits. The A Register is stored in sector 006, the B in 010 and the C in 012.

Location	Instruction	Symbolic Op Code	Remarks
377	000S0501;	LDA	
0	012S4552;	[CLA]	(A) 10000101011001010101010
1	002S0601;	LDB	
2	+6314631		(B) 10110011001100110011001
3	004S0401;	LDC	
4	+3434343		(C) 10011100011100011100011
5	006S1101;	STA	
6	-7777777		
7	010S1201;	STB	
10	+0000000		
11	012S1001;	STC	
12	-7777777		
13	014S4500;	CLA	
14	+0000000		
15	016S4300;	CLB	
16	+0000000		
17	376S4400;	CLC	

D-2. LOAD AND STORE DOUBLE PRECISION

The A and B Registers are first loaded double precision and then stored.

Location	Instruction	Symbolic Op Code	Remarks
377	+0000000		
0	001S0701;	LDP	
1	-2525252		
2	+6314631		
3	376S1301;	STD	

D-3. INTERCHANGES

The A, B, and C Registers are loaded and then interchanged, first with a ROT, then with an IAC and IBC. The net result of these is that after one complete memory recirculation, each register should contain its original pattern.

Location	Instruction	Symbolic Op Code	Remarks
377	000S0100;	IAC	(A) 1101010101010101010101 (B) 101100110011001100110011 (C) 100111000111000111000111
0	002S0701;	LDP	
1	005S0200;	IBC	
2	-2525252	CONST	
3	+6314631	CONST	
4	005S0401;	LDC	
5	+3434343	CONST	
6	375S0300;	ROT	

D-4. ADD AND SUBTRACT IN SINGLE AND DOUBLE PRECISION

The A and B Registers are first loaded with constants. A constant is added to A. A double precision constant is added to A and B, and another constant subtracted from A and B. Finally, a constant is subtracted from A alone and the cycle repeats.

Location	Instruction	Symbolic Op Code	Remarks
377	+1010102	D ₄	D ₀
0	001S0701;	LDP	
1	-5454540	D ₀	
2	+4646460	D ₀ '	
3	004S1401;	ADD	D ₁
4	+0202022	D ₁	D ₂
5	006S1601;	DPA	
6	-0404042	D ₂	
7	+1010100	D ₂ '	D ₃
10	011S1701;	DPS	
11	-1414141	D ₃	
12	+1414140	D ₃ '	
13	377S1501;	SUB	D ₄

This chart shows contents of A and B Registers after each of the five operations.

D-4

	S	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
LDP	1	1	0	1	1	0	0	1	0	1	1	0	0	1	0	1	1	0	0	0	0	0	(B) D ₀
	0	1	0	0	1	1	0	1	0	0	1	1	0	1	0	0	1	1	0	0	0	0	(A) D ₀ '
ADD	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	D ₁
	1	1	0	1	1	0	0	1	0	1	1	0	0	1	0	1	1	0	0	0	0	0	(B)
DPA	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	1	0	(A)
	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	D ₂
DPS	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	D ₂ '
	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	(B)
SUB	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	(A)
	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	D ₃
SUB	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	D ₃ '
	1	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	(B)
SUB	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	(A)
	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	D ₄
SUB	1	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	(B)
	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	(A)

D-5. TRANSFERS

The C Register is loaded with a negative number and the A Register is cleared. A negative constant is added to A and the sign of C tested. Since it is negative, a transfer is made to a TES Breakpoint which, if on, will transfer back to the CLA and start again. If the Breakpoint is off, the overflow is tested, and since it is now off, the negative constant is again added to A. The program cycles in this loop with a TCN (34) command displayed on the console until A overflows and goes positive.

The TOF will cause a transfer to a ROT which moves the negative constant to B and the positive constant to C. The program starts again with the CLA and ADD except that this time the C Register is positive so control passes through the TCN to a TBN (36) which will appear on the console until A overflows.

When A overflows this time, the positive constant from C is rotated to B and the constant from A to C. The CLA and ADD begin again, and now control passes through both the TCN and TBN to a TAN which appears as a 35 on the console. This time, control does not pass through the TES or TOF before adding, so when A overflows and becomes positive, the TAN does not transfer; instead, a TRU carries control back to the start of the routine in sector 000.

D-5

Location	Instruction	Symbolic Op Code	Remarks
377	000S0300;	ROT	002
0	001S0401;	LDC	-N
1	-2525252	-N	
2	004S4500;	CLA	005
3	002 7735;	TES	B. P. 002
4	377 7501;	TOF	377
5	066S1401;	ADD	
6	-7770000	-77	
7	003 3401;	TCU	003
10	003 3601;	TBN	003
11	005 3501;	TAN	005
12	000S3701;	TRU	000

D-6. LOGICAL COMMANDS

The A Register is loaded with a constant which is modified by an EBP command and then moved to C. From C, part of the pattern is modified and moved to B with an AMC. Additional bits from C are moved to B with an AOC. The result in B is partially cleared with an EXF command and the process begins again in A.

Location	Instruction	Symbolic Op Code	Remarks
377	-6564040	S	
0	001S0501;	LDA	N
1	-0202026	N	
2	003S4001;	EBP	M
3	-1414146	M	
4	005S0100;	IAC	
5	+0000000		
6	007S4201;	AMC	Q
7	+1414147	Q	
10	011S4601;	AOC	R
11	+0706077	R	
12	377S4701;	EXF	S

This chart shows the contents of the A and B Registers after each of the five operations.

D-6

	S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
LDA	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	N
	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	(A)
EBP	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	1	1	0	M
	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	(A)
IAC	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	(C)
AMC	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	1	1	1	Q
	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	(B)
AOC	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	R
	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	(B)
EXF	1	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	S
	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	(B)

D-7. SHIFTING (UNCONDITIONAL)

The A and C Registers are cleared and B is loaded with a pattern of bits. If the Breakpoint is up, a left shift and decrement is executed for two sectors and the sign of B tested. The B Register will be negative so control goes back to the TES Breakpoint and another shift is executed. This continues until B is positive, and then a right shift and increment moves the pattern two bit positions into B. This should make B negative, so control will go back to the right shift until a zero is shifted into the sign of B. When B is positive, control goes back to the left shift. If the Breakpoint is down the shifts will be without incrementing or decrementing C and will only execute for one sector.

Location	Instruction	Symbolic Op Code	Remarks
377	004S0601;	LDB	-B 005
0	010S4500;	CLA	011
1	003 7735;	TES	B. P.
2	005S2100;	LSD	2
3	005S2110;	LSO	
4	-7355143	-B	-B
5	001 3601;	TBN	
6	010 7735;	TES	B. P.
7	012S2200;	RSI	2
10	012S2210;	RSO	
11	376S4400;	CLC	377
12	006 3601;	TBN	
13	001S3701;	TRU	001 0

D-8 SHIFTING (CONDITIONAL)

This routine operates similar to D-7 in that it shifts back and forth from A and B. First, a negative number is loaded into B, and A and C are cleared. A normalize and decrement of three is executed and the sign of B tested, if negative, another NAD is executed. Going in steps of three, it will take seven full shifts plus a one-bit shift to normalize the number. In this way, both the normal shifting feature plus the conditional terminating feature of the NAD are tested. The B Register should be positive when the number is normalized.

During normalization, the C Register will have been decremented to the negative of the number of normalizing shifts required. It should be possible by now, executing scale right and increment commands in steps of three, to move the number back to its original condition with A and C equal to zero.

When C is scaled to zero, control will go back to the NAD loop. If the BREAKPOINT is pressed, computation will hang up in a TES loop after either normalizing or scaling.

D-8

Location	Instruction	Symbolic Op Code	Remarks
377	003S2000;	NAD	003
0	000S4500;	CLA	001
1	011S0601;	LDB	-N 012
2	006S2300;	SRI	006
3	377 3601;	TBN	377
4	004 7735;	TES	B. P. 004
5	022S3701;	TRU	
6	002 3601;	TBN	
7	007 7735;	TES	B. P. 007
10	377S3701;	TRU	377
11	-7153514	-N	-N
12	376S4400;	CLC	377

D-9. CAM AND GTB

A number is loaded in A and compared with itself. If overflow occurs, the number is converted from Gray code to binary and compared to the correct result. If overflow occurs, control goes to a Breakpoint test. If Breakpoint is up, the routine starts again; if Breakpoint is down, the binary number is compared with the original number and overflow should not occur.

When comparing the converted number with the correct result, if overflow does not occur the sign of A is tested, and if negative, a transfer is made to 000 with a TAN (35) if not negative, the transfer will be a TBN (36).

Location	Instruction	Symbolic Op Code	Remarks
377	002 7735;	TES	B. P. 002
0	001S0501;	LDA	N _G
1	+5252525	N _G	N _G
2	003S5601;	CAM	N _G
3	+5252525	N _G	N _G
4	006 7501;	TOF	
5	002S3701;	TRU	002
6	007S4100;	GTB	
7	+0000000		
10	011S5601;	CAM	N _B
11	-1463146	N _B	N _B
12	377 7501;	TOF	377
13	000 3501;	TAN	000
14	000S3601;	TBN	000 S

D-10. TO TEST INDEX REGISTER, HLT, MAC, AND NOP

The A and C Registers are cleared and A stored in the Index Register. A and C are OR gated into C and computation halts, displaying the contents of the Index Register in the OPERAND lights. When parity is cleared, a NOP is executed and the contents of the Index Register picked up, incremented by one and restored. Then another MAC and halt are executed.

This process continues each time the parity is cleared. The Ar will show a count, and the Cr a buildup from the right.

Location	Instruction	Symbolic Op Code	Remarks
377	000S1401;	ADD	001
0	001S4540;	CLA	002
1	002S1137;	STA	I. R. 003
2	000S4400I	CLC	001
3	004S0000I	MAC	005
4	006S2400I	NOP	006
5	004S0000I	HLT	004
6	376S0537;	LDA	I. R. 377

D-11. MOVE LINE AND IAM

The Index Register is cleared to zero and line 01 is moved to 00. Then the Index Register is incremented by one and another MCL is executed. This continues through line 36, and then the MCL is changed to a MLX by means of an IAM. Using the Index Register, each line from 00 through 36 is moved to line 07 and the routine then repeats.

If the Breakpoint is down, the program halts after each move and displays the line moved.

Location	Instruction	Symbolic Op Code	Remarks	
377	000S0100;	IAC		
000	002S0501;	LDA		X
1	004S1401;	ADD		N
2	010S7100I	X		(MCL) I
3	005S4400;	CLC		
4	+0200002	N		N +.020 0002
5	006S0100;	IAC		
6	010S2501;	IAM		
7	010S2600I	MLX		I
010	003 7501;	TOF		
1	013 7735;	TES		35
2	376S1037;	STC		37 377
3	012S0000I	HLT		

D-12. MULTIPLY, DIVIDE AND SQUARE ROOT

This routine executes in line 00, therefore it is not possible to single step and always obtain the correct answer. However, all pertinent operations occur in the first $073)_8$ sector times.

The same number is loaded into the B and C Registers and garbage into A. A multiply for 22-word times is executed, and the result in A compared to the correct result. The overflow is not tested, but it may be observed on the console. After the multiply, if the Breakpoint is up, a divide for 22-word times is executed and the remainder in A compared with +0000000. If the Breakpoint is down, a square root for 21-word times is executed and the remainder in A compared to +0000000. When executing the divide, the comparison is true and the overflow occurs. The square root has a remainder of $-7777777)_8$ and will not compare.





By observing sector time $073)_8$, the results of both the divide and square root may be seen.

Location	Instruction	Symbolic Op Code	Remarks
377	+5252525	X_B	X_B
0	014S7100;	X_A	MCL
1	030S3200;	MUL	S = 22 030
2	+3434343	Y_1	Y_1
3	045 7735;	TES	B.P. 045
4	073S3100;	DIV	S = 22 073 R: (A) = +0000000
5	073S3000;	SQR	S = 21 073 R: (A) = -7777777
6	+0000000	Y_2	Y_2
7	111S0400;	LDC	X_C
010	042S5600;	CAM	Y_1 043
1	+5252525	X_C	X_C
2	377S0701;	LDP	$X_{A \& B}$ 001
3	106S5600;	CAM	Y_2 107
4	107S7500;	TOF	

D-13. RTK, RPT, LAI, WOC AND CIB

After pressing the "I" key and raising the ENABLE switch, the Flexowriter light will come on and a character may be typed. This character will be loaded into the A Register, added to a WOC, and the WOC used to display it on the console for about two seconds. After the WOC, a HLT with a line number of 13)₈ will occur.

When parity is cleared, another character may be entered. The character will come from the tape reader if the Breakpoint is down, and from the keyboard if the Breakpoint is up.

Location	Instruction	Symbolic Op Code	Remarks
377	010 0013;	D	HLT
000	000S4500;	CLA	
1	001S5700;	CIB	
2	004 7735;	TES	B. P. 
3	006S5100;	RTK	
4	006S5200;	RPT	
5	+0000377	M	M
6	010 7736;	TES	36 
7	005S5501;	LAI	M 
010	010S4300;	CLB	
1	014 2110;	LSO	2
2	013S1401;	ADD	
3	377S6000;	WOC	0 377
4	377 0401;	LDC	D
5	016 1101;	STA	\$ + 1

D-14. FLEXOWRITER TYPING AND PUNCHING.

Both lines 05 and 06 must be present for this test. Every possible character from 000 through 377)₈ will be typed, then punched. Some of these are not valid keyboard characters and will not print, but all should be punched.

Location	Instruction	Symbolic Op Code	Remarks
377	001S3706;	TRU	06
0	017S7106;	MCL	→ 06 017
1	002S0406;	LDC	D ₂
2	+0002424	D ₂	D ₂
3	000 6000;	WOC	000
4	005S1406;	ADD	C
5	+0000004	C	C
6	007S5606;	CAM	E
7	000 7000;	E	E
010	000 7501;	TOF	I
1	003 1106;	STA	06
2	376 1105;	STA	05
3	014S0406;	LDC	D ₁
4	+0003232	D ₁	D ₁
5	015 7737;	TES	37
6	376S3705;	TRU	05 376
7	003 0501;	LDA	WOC 0
020	012S7105	MCL	→ 05 012

D-15. DIV, RFU AND RfTf TEST

A DIV is given, followed by a $TES\ 36)_8$ which could be true. Then an RFU and a $TES\ 36)_8$ which should now be false. If the $TES\ 36)_8$ is false, after the DIV, a halt will occur with 50-37 displayed. This means that the RFU did not set either Rf or Tf. When the program runs correctly, a 53-00 is displayed.

Location	Instruction	Symbolic Op Code	Remarks
377	001 7736;	TES	
000	001S5000;	DIU	
1	376S5336;	RFU	
2	004 7736;	TES	
3	001S5036;	DIU	
4	376S5300;	RFU	

D-16. PTU

Two PTU's are executed, each for approximately 3 ms. One has a line number of $37)_8$, the other 00.

Location	Instruction	Symbolic Op Code	Remarks
377	000S7037;	PTU	37
0	377S7000;	PTU	0

D-17. BSO, BSI

After pressing the "I" key, a BSO from line 01 is executed for 3 ms, and as long as the Breakpoint is up, Block Serial Inputs will continue. If the Breakpoint is down, after the first BSO, then BSI's will be executed until it is raised.

Location	Instruction	Symbolic Op Code	Remarks
377	001 7735;	TES	35
0	377S7201;	BSO	
1	377S7301;	BSI	

D-18. FLEXOWRITER FORMAT

If the tapes which are punched in bootstrap binary format are reproduced on a Flexowriter they will appear in serial binary Flexowriter format as shown in Figure 4-2. The type-outs D-1 through D-17 relate directly to paragraphs D-1 through D-17. In this format, H = binary one and 0 = binary zero.

