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TEST OF

INDICATORS AND JUMP CONDITIONS

FOR THE RC 4000 COMPUTER

Corection:

SMI; MCC; to be replaced by MCC; SMI;

A/S REGNECENTRALEN

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NOTATION

PART 1 TEST OF INDICATORS FOR MICROPROGRAM STORE

1. Theory
2. Test Schedule

PART 2 JUMP SELECTOR TEST

1. Theory
2. Test Schedule

NOTATION

SMI	Activate the Single Micro Instruction pushbutton on the Technical Control Panel.
MCC	Activate the MAR COMPUTER CONTROLLED pushbutton.
X:= Y	Set X equal to Y.
X = Y	If the test is correct X should be equal to Y.
X:= -1	Set X equal to all ones.
-	Signifies a don't care condition in a test table.

PART 1. TEST OF INDICATORS FOR MICROPROGRAM STORE

1. THEORY

All indicators will be tested by choosing the micro addresses listed below. If the chronological order is obeyed, it is not necessary to check the indicators embraced in parentheses since they have already been tested.

Note: MC(14,59,60,66) are not used, hence the correspondent indicators will never light.

2. TEST SCHEDULE

2.1. Parity Bit Test

x4y0:	1,	61,	79,86,98,

2.2. Jump Selector Test

x4y8:		21,35,41,52,68,	72,73,75,76,81,84,87,90,93,96,99,100,
x6y2:	(1,)	44,45,69,	71,79,91,94,97,
x6y22:		8,26,54,57,	79,80,82,88,94,96,97,
x16y0:	(1,)	11,29,70,	80,83,87,88,89,92,95,
x16y4:	(1,)	41,53,	73,74,75,76,77,78,79,94,
x17y31:		2,28,39,	73,83,85,91,95,100,

2.3. Micro Command Test

x0y9:	(1,)	3,29,40,44,70,	(79,94,97,)
x1y1:	(1,)	13,17,18,	(79,)
x1y26:	(1,)	6,9,34,42,44,46,	(73,85,94,95,97,100,)
x2y3:		22,39,	(79,91,100,)
x2y21:		28,32,	(85,88,94,97,100,)
x4y13:	(1,)	19,34,	(73,85,91,94,)
x6y28:		23,28,53,63,65,	(79,82,88,91,94,98,)
x8y6:	(1,)	5,39,43,45,47,49,67,	(76,94,95,97,100,)
x9y0:	(1,)	62,	(76,85,98,)
x9y11:		34,38,	(73,75,76,99,100,)
x9y15:		5,10,15,16,25,	(71,76,77,88,98,99,)
x12y6:	(1,)	5,27,54,55,56,	(76,79,94,96,97,)
x16y8:		64,	(73,76,79,82,85,95,96,100,)
x16y11:	(1,)	2,4,	(73,76,79,82,85,88,89,91,97,100,)
x16y12:	(1,)	6,7,12,	(79,88,94,)
x16y22:	(1,)	17,18,24,36,49,	(85,88,100,)
x20y17:		34,58,	(73,76,77,78,94,95,96,100,)
x20y22:	(1,)	31,37,	(85,88,94,100,)
x24y10:	(1,)	20,33,	(76,91,94,97,)
x28y27:	(1,)	51,	(79,)
x31y8:	(1,)	30,48,50,	(79,)

PART 2. JUMP SELECTOR TEST

1. THEORY

The test schedule evaluated here is meant for testing the Jump Selector Circuit (1 BA402) for single errors. The circuit is tested for stuck-at-1 (0) and stuck-at-0 (1) whenever possible. Jump conditions:

Start
Autoload
Main Power Key ON $\wedge$ -,Reset
Accept

are excluded from this test, because these conditions can only be tested when the microprogram is running.

Each board contains the decoding network for one micro address bit and by using the following notations:

MAR(n):	Micro address bit n
X,Y,Z:	The three Jump Selector bits controlling MAR(n)
b21,b22,...,b25,	
c3,...,c7:	Conditional Jump Conditions for MAR(n)

The next micro address can now be expressed as:

$$
\begin{aligned}
MAR(n) := {} & -,X \wedge -,Y \wedge Z \wedge 1 \\
& \vee -,X \wedge Y \wedge -,Z \wedge b21 \wedge b22 \wedge b23 \wedge b24 \wedge b25 \\
& \vee -,X \wedge Y \wedge Z \wedge c3 \\
& \vee X \wedge -,Y \wedge -,Z \wedge c4 \\
& \vee X \wedge -,Y \wedge Z \wedge c5 \\
& \vee X \wedge Y \wedge -,Z \wedge c6 \\
& \vee X \wedge Y \wedge Z \wedge c7
\end{aligned}
$$

Table 1:

X	Y	Z	-X'	-Y'	Z	-X'	Y	-Z'	b21	b22	b23	b24	b25	-X'	Y	Z	c3	X	-Y'	-Z'	c4	X	-Y'	Z	c5	X	Y	-Z'	c6	X	Y	Z	c7	MAR(n)
0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	0	0	-	0	1	1	1	0	1	0	-	0	0	1	-	0	0	0	-	0
0	0	1	1	1	1	1	0	0	-	-	-	-	-	1	0	1	-	0	1	0	-	0	1	1	-	0	0	0	-	0	0	1	-	1
0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	-	0	0	1	-	0	0	0	-	0	1	1	-	0	1	0	-	1
			1	0	0	1	1	1	1	1	1	1	0	1	1	0	1	0	0	1	-	0	0	0	-	0	1	1	1	0	1	0	-	0
			1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	0	0	1	-	0	0	0	-	0	1	1	1	0	1	0	-	0
			1	0	0	1	1	1	1	1	0	1	1	1	1	0	1	0	0	1	-	0	0	0	-	0	1	1	1	0	1	0	-	0
			1	0	0	1	1	1	1	0	1	1	1	1	1	0	1	0	0	1	-	0	0	0	-	0	1	1	1	0	1	0	-	0
			1	0	0	1	1	1	0	1	1	1	1	1	1	0	1	0	0	1	-	0	0	0	-	0	1	1	1	0	1	0	-	0
0	1	1	1	0	1	1	1	0	-	-	-	-	-	1	1	1	1	0	0	0	-	0	0	1	-	0	1	0	-	0	1	1	-	1
			1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	-	0	0	1	-	0	1	0	-	0	1	1	1	0
1	0	0	0	1	0	0	0	1	-	-	-	-	-	0	0	0	-	1	1	1	1	1	1	0	-	1	0	1	-	1	0	0	-	1
			0	1	0	0	0	1	-	-	-	-	-	0	0	0	-	1	1	1	0	1	1	0	1	1	0	1	1	1	0	0	-	0
1	0	1	0	1	1	0	0	0	-	-	-	-	-	0	0	1	-	1	1	0	-	1	1	1	1	1	0	0	-	1	0	1	-	1
			0	1	1	0	0	0	-	-	-	-	-	0	0	1	-	1	1	0	1	1	1	1	0	1	0	0	-	1	0	1	1	0
1	1	0	0	0	0	0	1	1	-	-	-	-	-	0	1	0	-	1	0	1	-	1	0	0	-	1	1	1	1	1	1	0	-	1
			0	0	0	0	1	1	1	1	1	1	1	0	1	0	-	1	0	1	1	1	0	0	-	1	1	1	0	1	1	0	1	0
1	1	1	0	0	1	0	1	0	-	-	-	-	-	0	1	1	-	1	0	0	-	1	0	1	-	1	1	0	-	1	1	1	1	1
			0	0	1	0	1	0	-	-	-	-	-	0	1	1	1	1	0	0	-	1	0	1	1	1	1	0	1	1	1	1	0	0

Table 2:

MAR(0)	MAR(1)	MAR(2)	MAR(3)	MAR(4)	MAR(5)	MAR(6)	MAR(7)	MAR(8)	MAR(9)
0	0	0	0	0	0	0	0	0	0
Test 2	Test 2	Test 1	Test 3	Test 3	Test 6	Test 4	Test 5	Test 5	Test 2
1	1	1	1	1	1	1	1	1	1
Test 3	Test 3	Test 4	Test 6	Test 6	Test 4	Test 3	Test 4	Test 3	Test 6
SB $\leq$ -65	SB $\geq$ 64		FR(2) $\wedge$ -,Modif	FR(3) $\wedge$ -,Modif	FR(0) $\wedge$ -,Modif	FR(1) $\wedge$ -,Modif	FR(4) $\wedge$ -,Modif	FR(5) $\wedge$ -,Modif	AF $\neq$ 0
Test 10	Test 11		Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 8
FR(8)	FR(9)		BE(11)	FDsub	FR(0)	AR $\neq$ 0	SC(11)	SC $\neq$ 0	FR(10) $\vee$ FR(11)
Test 1	Test 1		Test 13	Test 14	Test 2	Test 9	Test 7	Test 4	Test 1
AR(-1)= AR(0)	AR(1)=AR(2)	AR(0)=AR(1)	FR(2)	FR(3)	Itr	FR(1)	FR(4)	FR(5)	Accept
Test 5	Test 8	Test 5	Test 2	Test 2	Test 19	Test 2	Test 2	Test 2	
Carry(0)	BR(1)=BR(2)		BE(10)	EX(22,23)$\neq$0	HA(23)	BR(23)	SB(0)	SB $\neq$ 0	BE(0)
Test 17	Test 12		Test 4	Test 15	Test 18	Test 16	Test 3	Test 9	Test 3
		FR(6)$\vee$FR(7)			AR(-1)	BR(22)	MMode	MMode $\vee$ -,PROTECT	Round
		Test 18			Test 3	Test 6	Test 18	Test 18	Test 5
	Start	Autoload			Main Power Key ON $\wedge$ -,Reset	SC > -38 $\wedge$ SC < 38 Test 7			

2. TEST SCHEDULE

Each test is divided into two sections, namely Jump Conditions and Testpatterns. The first section lists the jump conditions to be tested together with the conditions that must be obeyed when the jump condition is tested for 0-value. An understanding of this section is not essential for carrying out the test. The second section gives the procedure for setting up the test and the correct test results.

The jump conditions Accept and Main Power Key ON $\wedge$ -,Reset are both atuomatically set to 1.

The statements MMode:= 1 and Itr:= 1 are abbreviations for

a) MMode is set to 1 as follows:

PR:= b10000000; PK:= 0; MAR:= x4y18; SMI

b) Itr is set to 1 as follows:

MAR:= x31y31; SMI; FR(5):= 1; MAR:= x3y6; SMI

The current value of Itr can be found on testpoint 189F.

The bit patterns which should be applied to the Jump Selector circuitry appear from Table 1. It is not the aim of this paper to explain how the testpatterns are generated. The tests are arranged in test groups, and Table 2 shows which test group should be used for each Jump Condition.

Test 1

Jump Conditions:

MAR(0) : FR(8)	$\Rightarrow$	SB $\leq$ -65
MAR(1) : FR(9)	$\Rightarrow$	SB $\geq$ 64
MAR(2) : 0	$\Rightarrow$	AR(0) = AR(1)
MAR(3) : FR(2) $\wedge$ -,Modif	$\Rightarrow$	BE(11) = 1
MAR(4) : FR(3) $\wedge$ -,Modif	$\Rightarrow$	FDsub = 1 This will never happen in a running program
MAR(5) : FR(0) $\wedge$ -,Modif	$\Rightarrow$	FR(0) = 1, AR(-1) = 1
MAR(6) : FR(1) $\wedge$ -,Modif	$\Rightarrow$	AR $\neq$ 0, BR(22) = 1
MAR(7) : FR(4) $\wedge$ -,Modif	$\Rightarrow$	SC(11) = 1, MMode = 1
MAR(8) : FR(5) $\wedge$ -,Modif	$\Rightarrow$	SC $\neq$ 0, (MMode $\vee$ -,PROTECT) = 1
MAR(9) : FR(10) $\vee$ FR(11)	$\Rightarrow$	AF $\neq$ 0

Testpattern:

FR(0:5):= -1; FR(8:11):= 0; SB(0:23):= 0; SB(1):= 1; AR(0):= AR(1):= 1;
MAR:= x4y18; SMI; MCC; MAR = x3y30
FR(0:5):= 0; FR(8:11):= 0; SB(0:23):= 0; SB(0):= 1; BE(11):= 1;
AR:= -1; BR(22):= 1; SC(11):= 1; MMode:= 1;
MAR:= x4y18; SMI; MCC; MAR = x0y0
FR(0:5):= -1; FR(8:11):= b0001; AR(-1):= 1;
MAR:= x4y18; SMI; MCC; MAR = x0y1
FR(8:11):= b0010; MAR:= x4y18; SMI; MCC; MAR = x0y1
FR(8:11):= b0100; MAR:= x4y18; SMI; MCC; MAR = x8y0
FR(8:11):= b1000; MAR:= x4y18; SMI; MCC; MAR = x16y0

Test 2

Jump Conditions:

MAR(0) : 0	⇒ SB $\leq$ -65, AR(-1) = AR(0)
MAR(1) : 0	⇒ SB $\geq$ 64, AR(1) = AR(2)
MAR(3) : FR(2)	⇒ BE(10) = 1
MAR(4) : FR(3)	⇒ EX(22,23) $\neq$ 0
MAR(5) : FR(0)	⇒ FR(0) = 1 Not possible, FR(8:11) = -1
MAR(6) : FR(1)	⇒ BR(23) = 1, BR(22) = 1
MAR(7) : FR(4)	⇒ SB(0) = 1, MMode = 1
MAR(8) : FR(5)	⇒ SB $\neq$ 0, (MMode $\vee$ -,PROTECT) = 1
MAR(9) : 0	⇒ AF $\neq$ 0, Accept = 1

Testpattern:

FR(0:5):= -1; SB(0:23):= 0; SB(1):= 1; AR(1):= AR(2):= 1;
MAR:= x8y19; SMI; MCC; MAR = x3y30
FR(0:5):= 0; SB(0:23):= 0; SB(0):= 1; AR(-1):= AR(0):= 1; BE(10):= 1; EX:= -1
FR(8:11):= -1; BR(22):= BR(23); MMode:= 1;
MAR:= x8y19; SMI; MCC; MAR = x0y0

Test 3

Jump Conditions:

MAR(0) : 1
MAR(1) : 1
MAR(3) : 0 ⇒ FR(2) = 1, FR(8:11) = 0
MAR(4) : 0 ⇒ FR(3) = 1, FR(8:11) = 0
MAR(5) : AR(-1) ⇒ FR(0), FR(8:11) = 0, Itr = 1
MAR(6) : 1
MAR(7) : SB(0) ⇒ FR(4) = 1
MAR(8) : 1
MAR(9) : BE(0) ⇒ Accept = 1

Test Pattern:

AR(-1):= 1; SB(0):= 1; BE(0):= 1; FR(0:5):= -1; FR(8:11):= 0;
MAR:= x24y6; SMI; MCC; MAR = x24y31

AR(-1):= 0; SB(0):= 0; BE(0):= 0;
MAR:= x24y6; SMI; MCC; MAR = x24y10

Test 4

Jump Conditions:

MAR(2) : 1
MAR(3) : BE(10) ⇒ FR(2) = 1
MAR(5) : 1
MAR(6) : 0 ⇒ FR(1) = 1, FR(8:11) = 0
MAR(7) : 1
MAR(8) : SC ≠ 0 ⇒ FR(5) = 1, FR(8:11) = 0

Testpattern:

BE(10):= 1; SC:= 1; FR(0:5):= -1; FR(8:11):= 0;
MAR:= x4y22; SMI; MCC; MAR = x6y22

BE(10):= 0; SC:= 0;
MAR:= x4y22; SMI; MCC; MAR = x4y20

Test 5

Jump Conditions:

MAR(0) : AR(-1) = AR(0) ⇒ Carry(0) = 1
MAR(2) : AR(0) = AR(1) ⇒ FR(6,7) ≠ 0
MAR(7) : 0 ⇒ FR(4) = 1, FR(8:11) = 0
MAR(8) : 0 ⇒ FR(5) = 1, FR(8:11) = 0
MAR(9) : Round ⇒ AF ≠ 0, Accept = 1

Testpattern:

AR:= -1; AR(-1):= 0; AE:= -1; FR(0:5):= -1; FR(8:11):= 0;
MAR:= x9y15; SMI; MCC; MAR = x12y17
AR:= -1; AR(1):= 0; AE:= 0; FR(6:7):= -1;
MAR:= x9y15; SMI; MCC; MAR = x24y16

Test 6

Jump Conditions:

MAR(3) : 1
MAR(4) : 1
MAR(5) : 0 ⇒ FR(0) = 1, FR(8:11) = 0, Itr = 1
MAR(6) : BR(22) ⇒ FR(1) = 1, FR(8:11) = 0, SC > -38 ∧ SC < 38
MAR(9) : 1

Testpattern:

BR(22):= 1; FR(0:5):= -1; FR(8:11):= 0; Itr:= 1; SC:= 0;
MAR:= x9y8; SMI; MCC; MAR = x31y15
BR(22):= 0; MAR:= x9y8; SMI; MCC; MAR = x31y7

Test 7

Jump Conditions:

MAR(6) : SC > -38 ∧ SC < 38 ⇒ AR ≠ 0, BR(23) = 1, BR(22) = 1
MAR(7) : SC(11) ⇒ FR(4) = 1, FR(8:11) = 0

Testpattern:

SC:= -1; MAR:= x17y27; SMI; MCC; MAR = x20y31
SC(11):= 0; FR(0:5):= -1; FR(8:11):= 0; AR:= -1; BR:= -1;
MAR:= x17y27; SMI; MCC; MAR = x20y19

Test 8

Jump Conditions:

MAR(1) : AR(1) = AR(2) ⇒ BR(1) = BR(2)

MAR(9) : AF ≠ 0 ⇒ FR(10,11) ≠ 0, Round = 1, Cannot be fulfilled;

Testpattern:

AR:= 0; AE:= 0; FR:= -1; MAR:= x28y16; SMI; MCC; MAR = x28y20

AR(1):= 1; BR:= -1; MAR:= x28y16; SMI; MCC; MAR = x20y21

Test 9

Jump Conditions:

MAR(6) : AR ≠ 0 ⇒ FR(1) = 1, FR(8:11) = 0

MAR(8) : SB ≠ 0 ⇒ FR(5) = 1

Testpattern:

AR:= -1; SB:= -1; MAR:= x17y20; SMI; MCC; MAR = x12y31

AR:= 0; SB:= 0; FR(0:5):= -1; FR(8:11):= 0;

MAR:= x17y20; SMI; MCC; MAR = x12y21

Test 10

Jump Conditions:

MAR(0) : SB ≤ -65 ⇒ FR(8) = 1

Testpattern:

FR(0:11):= -1; SB:= 0; SB(0):= 1; MAR:= x6y30; SMI; MCC; MAR = x28y6

SB:= 0; MAR:= x6y30; SMI; MCC; MAR = x12y6

Test 11

Jump Conditions:

MAR(1) : SB ≥ 64 ⇒ FR(9) = 1

Testpattern:

SB:= -1; SB(0):= 0; MAR:= x6y26; SMI; MCC; MAR = x28y8

SB:= 0; FR(0:11):= -1; MAR:= x6y26; SMI; MCC; MAR = x20y8

Test 12

Jump Conditions:

MAR(1) : BR(1) = BR(2) ⇒ AR(1) = AR(2)

Testpattern:

BR(1):= BR(2): = 1 MAR:= x6y17; SMI; MCC; MAR = x8y15

BR(1):= AR(1):= AR(2):= 1; BR(2):= 0; MAR:= x6y17; SMI; MCC; MAR = x0y15

Test 13

Jump Conditions:

MAR(3) : BE(11) ⇒ FR(0:5):= -1, FR(8:11):= 0;

Testpattern:

BE(11):= 1; MAR:= x6y5; SMI; MCC; MAR = x6y22

BE(11):= 0; FR(0:5):= -1; FR(8:11):= 0; MAR:= x6y5; SMI; MCC; MAR = x4y22

Test 14

Jump Conditions:

MAR(4) : FDsub ⇒ FR(3) = 1, FR(8:11) = 0

Testpattern:

FR(0:5):= -1; FR(8:11):= 0; MAR:= x0y7; SMI; MCC; MAR = x2y29

SB:= 0; AR:= 0; MAR:= x8y7; SMI; MCC; The execution of x8y7 sets FDsub = 1; MAR:= x0y7; SMI; MCC; MAR = x3y29

Test 15

Jump Conditions:

MAR(4) : EX(22,23) ≠ 0 ⇒ FR(3) = 1

Testpattern:

EX:= -1; FR(0:5):= -1; MAR:= x17y31; SMI; MCC; MAR = x17y11

EX:= 0; MAR:= x17y31; SMI; MCC; MAR = x16y11

Test 16

Jump Conditions:

MAR(6) : BR(23) ⇒ FR(1) = 1, FR(8:11) = 0, SC > -38 ∧ SC < 38

Testpattern:

BR(23):= 1; MAR:= x2y13; SMI; MCC; MAR = x16y26

BR(23):= 0; FR(0:5):= -1; FR(8:11):= 0; SC:= 0;

MAR:= x2y13; SMI; MCC; MAR = x16y18

Test 17

Jump Conditions:

MAR(0) : Carry(0) ⇒ AR(-1) = AR(0)

Testpattern:

AR:= -1; SB:= -1; MAR:= x4y12; SMI; MCC; MAR = x20y13

AR:= 0; MAR:= x4y12; SMI; MCC; MAR = x4y13

Test 18

Jump Conditions:

MAR(2) : FR(6) ∨ FR(7) ⇒ AR(0) = AR(1), Autoload = 1 Not possible

MAR(5) : HA(23) ⇒ Itr = 1, (Main Power Key ON ∧ -,Reset) = 1

MAR(7) : MMode ⇒ FR(4) = 1, FR(8:11) = 0

MAR(8) : MMode ∨ -,PROTECT ⇒ FR(5) = 1, FR(8:11) = 0

Testpattern:

SB(23):= 1; MAR:= x3y0; SMI; MCC; The execution of x3y0 sets HA(23) = 1;

MMode:= 1; MAR:= x3y9; SMI; MCC; MAR = x31y21

FR(6,7):= -1; MAR:= x20y17; SMI; MCC; MAR = x28y7

SB(23):= 0; MAR:= x3y0; SMI; MCC; The execution of x3y0 sets HA(23) = 0;

PK:= b111; PR(7):= 0; MAR:= x4y18; SMI; MCC;

The execution of x4y18 sets MMode = 0;

Itr:= 1; FR(0:5):= -1; FR(8:11):= 0;

MAR:= x3y9; SMI; MCC; MAR = x31y1

FR(6,7):= 0; AR(0):= AR(1); PK:= 0;

MAR:= x20y17; SMI; MCC; MAR = x24y5

Test 19

Jump Conditions:

MAR(5) : Itr ⇒ HA(23) = 1, AR(-1) = 1

Testpattern:

MAR:= x31y31; SMI; MCC; MAR:= x24y7; SMI; MCC; MAR = x4y24

SB(23):= 1; MAR:= x3y0; SMI; MCC; The execution of x3y0 sets HA(23) = 1;

SB:= 0; MAR:= x12y12; SMI; MCC; The execution of x12y12 sets IM(1:23) = 0;

MAR:= x9y27; SMI; MCC; The execution of x9y27 answers IR(0) and this implies that Itr = 0;

AR(-1) = 1; MAR:= x24y7; SMI; MCC; MAR = x4y8