UNIVERSITY OF ILLINOIS

DIGITAL COMPUTER

Aux.

LIBRARY ROUTINE Q4 - 228

TITLE — Single Circuit Analyzer

TYPE — Complete Program

NUMBER OF WORDS — Main Program: 125

Function Compiler (overwritten during analysis): 115

Decimal Order Input (overwritten during analysis): 25

$E(I_k)$ Routine: $11 + 4n + k$

where n is the number of nodes in the circuit and k is the total number of integers and + signs used to describe the circuit.

TEMPORARY STORAGE — 0 to 9; 126 to 126+n; 137+4n+k to 1023

DURATION — Depends on circuit to be analyzed.

MAXIMUM NUMBER OF STATES PER CYCLE

$$\left[\frac{876 - 4n - k}{4}\right]$$

where [a] denotes the greatest integer in a.

USE — This program is a modification of library routine Q-3 and is used whenever a circuit exceeds capacity of Q-3. The operation of this program and the data tape preparation is identical to library routine Q-3 except, that only a single circuit may be compiled (any number of initial states may be supplied), and the distributive test has been removed. These two modifications provides greater than a 50% increase in the number of states per cycle. The output of this program differs from the output of Q-3 in that for either a distributive but not totally sequential, or semi-modular but not distributive or totally sequential circuit, a G is punched. Otherwise the output is identical with that of Q-3.

OPERATION — The tape is read in in the normal fashion coming to a black switch stop, provided the sum check is correct. The function and first initial state are read in with the black switch and succeeding initial states are read in with a white switch bypass. The program is run with the black switch in the

ignore position but may be made to end prematurely by a white switch bypass of the stop order between cycles.

DATE November 20, 1956
PROGRAMMED BY W. Scott Bartley
APPROVED BY D. E. Muller

| LOCATION | ORDER | | NOTES | PAGE 1 | Q4 |
|---|---|---|---|---|---|
| Main Program | | | | | |
| | 00 10K | | | | |
| 0 | L5 20L | | | | |
| | 46 110L | | Set to punch S | | |
| 1 | F1 21L | | | | |
| | 42 123L | | Set S test | | |
| 2 | F5 5L | | | | |
| | 42 112L | | Set a side to one stop | | |
| 3 | 81 ( )F | p | | | |
| | 50 114L | | Clear Q | | |
| 4 | 10 ( )F | p | | | |
| | S5 7L | | Read initial state | | |
| 5 | 40 6F | | | | |
| | 40 ( )F | $a_1$ | | | |
| 6 | L5 4L | | | | |
| | 42 ( )F | e | Set fcn. routine | | |
| 7 | 26 ( )F | f | To fcn. routine | | |
| | 40 ( )F | $a_1+m/4$ | Store excited nodes | | |
| 8 | L5 53L | | | | |
| | 42 ( )F | e | Restore fcn. routine | | |
| 9 | L5 121L | | | | |
| | 40 2F | | Set $2^n$ to 2 | | |
| 10 | 81 4F | | | | |
| | L0 115L | | -10 | | |
| 11 | 36 21L | | Test for $2^n$ state stop | | |
| | L4 115L | | +10 | | |
| 12 | 50 114L | | Clear Q | | |
| | 74 115L | | | | |
| 13 | 00 4F | | | | |
| | 91 4F | | Read integer $\alpha$ store | | |
| 14 | 32 12L | | in 1 | | |
| | S5 40F | | | | |
| 15 | 40 1F | | | | |
| | 81 4F | | | | |

| LOCATION | ORDER | | NOTES | PAGE 2 | Q4 |
|---|---|---|---|---|---|
| 16 | L0 115L | | -10 | | |
| | 32 22L | | Test for $\alpha$ state stop | | |
| 17 | L4 115L | | +10 | | |
| | 50 114L | | Clear Q | | |
| 18 | 74 115L | | x10 | | |
| | 00 4F | | | | |
| 19 | 91 4F | | | | |
| | 36 18L | | Read integer $\beta$ | | |
| 20 | S5 706F | | | | |
| | 26 24L | | | | |
| 21 | L5 121L | | | | |
| | 40 1F | | Set $2^n$ to 2 | | |
| 22 | 22 23L | | | | |
| | L5 1F | | Set 1 to 2 | | |
| 23 | 40 2F | | | | |
| | L5 14L | | | | |
| 24 | 42 25L | | | | |
| | L1 1F | | Store node counter | | |
| 25 | 40 116L | | | | |
| | 19 ( )F | | | | |
| 26 | 00 1F | | Store node marker | | |
| | 40 118L | | | | |
| 27 | L1 2F | | | | |
| | 40 117L | | Set state counter | | |
| 28 | 81 ( )F | p | | | |
| | 50 114L | | Clear Q | | |
| 29 | 10 ( )F | p | | | |
| | S5 ( )F | $b_1$ | Store node counter | | |
| 30 | 40 119L | | | | |
| | 41 9F | | Clear F indicator | | |
| 31 | 24 32L | | Stop | | |
| | 26 109L | | End | | |
| 32 | L5 29L | | | | |
| | 42 113L | | Set b side to 0 | | |
| 33 | 41 8F | | Clear state counter | | |
| | L5 ( )F | $a_1$ | State to 4 | | |

| LOCATION | ORDER | | NOTES | PAGE 3 | Q4 |
|---|---|---|---|---|---|
| 34 | 40 4F | | | | |
| | L5 ( )F | $a_1$+m/4 | Excited nodes to 5 | | |
| 35 | 40 5F | | | | |
| | 40 3F | | | | |
| 36 | L3 5F | | | | |
| | 36 89L | | Test for equilibrium | | |
| 37 | 49 1F | | | | |
| | F1 1F | | Set markers | | |
| 38 | 40 2F | | | | |
| | L5 3F | | | | |
| 39 | L4 3F | | | | |
| | 40 3F | | Test i'th node for equilibrium | | |
| 40 | 36 65L | | | | |
| | 50 4F | | | | |
| 41 | S5 577F | | | | |
| | J0 1F | | | | |
| 42 | S0 F | | | | |
| | S0 F | | Form new state | | |
| 43 | L4 1F | | | | |
| | 40 6F | | | | |
| 44 | L5 45L | | | | |
| | 22 48L | | | | |
| 45 | L5 6F | | | | |
| | L0 ( )F | $b_1$ | | | |
| 46 | 40 F | | | | |
| | L3 F | | Test in b list | | |
| 47 | 32 93L | | | | |
| | F5 45L | | for duplicate | | |
| 48 | 42 45L | | | | |
| | L0 113L | | | | |
| 49 | 36 45L | | | | |
| | F5 8F | | Count new state | | |
| 50 | 40 8F | | | | |
| | 26 ( )F | f | To fcn. routine | | |
| 51 | 00 1F | w | | | |
| | 40 ( )F | $b_1$+m/4 | Store excited nodes | | |

| LOCATION | ORDER | NOTES | PAGE 4 | Q4 |
|---|---|---|---|---|
| 52 | L5 6F | | | |
| | 40 ( )F | $b_1$ | Store state | |
| 53 | F5 51L | | | |
| | 42 51L | | Increase store addresses | |
| 54 | F5 52L | | | |
| | 42 52L | | | |
| 55 | 50 119L | | Print const. | |
| | J0 1F | | | |
| 56 | S1 F | | | |
| | 36 58L | | | |
| 57 | 93 135F | | 2 C.R. | |
| | 22 99L | | To print | |
| 58 | 50 118L | | Node const. | |
| | J0 1F | | | |
| 59 | S1 F | | | |
| | 36 61L | | | |
| 60 | F5 116L | | | |
| | 40 116L | | Node counter | |
| 61 | L5 29L | | | |
| | 42 45L | | Reset b search | |
| 62 | 50 5F | | | |
| | J0 2F | | | |
| 63 | S5 F | | | |
| | J0 7F | | Speed independent | |
| 64 | K0 F | | test | |
| | 36 97L | | | |
| 65 | L5 1F | | | |
| | 10 1F | | Shift marker | |
| 66 | 40 1F | | | |
| | L3 3F | | Test for end | |
| 67 | 36 68L | | | |
| | 22 37L | | To i'th node | |
| 68 | L5 45L | | | |
| | L4 8F | | Set b end test | |
| 69 | 42 113L | | const. | |
| | F5 34L | | | |

| LOCATION | ORDER | NOTES | PAGE 5 | Q4 |
|---|---|---|---|---|
| 70 | 42 34L | | | |
| | F5 33L | Increase a side address | | |
| 71 | 42 33L | | | |
| | L0 112L | Test for end | | |
| 72 | 32 33L | | | |
| | L5 113L | Set a test const. | | |
| 73 | 42 112L | (from b side) | | |
| | 50 29L | | | |
| 74 | L5 5L | | | |
| | 42 29L | Set b | | |
| 75 | 42 45L | | | |
| | 42 52L | | | |
| 76 | L4 122L | + m/4 | | |
| | 42 51L | Set b + m/4 | | |
| 77 | S5 F | | | |
| | 42 5L | Set a | | |
| 78 | 42 33L | | | |
| | L4 122L | + m/4 | | |
| 79 | 42 34L | | | |
| | 42 7L | Set a + m/4 | | |
| 80 | L5 8F | | | |
| | F0 122L | - m/4 - 1 | | |
| 81 | 36 107L | Over write and end | | |
| | 26 (82)L | | | |
| 82 | L5 8F | | | |
| | L4 123L | test for S failure | | |
| 83 | 36 87L | | | |
| | L5 116L | Test node const. | | |
| 84 | 36 109L | End | | |
| | L5 8F | | | |
| 85 | L4 117L | | | |
| | 40 117L | Test for state const. | | |
| 86 | 36 109L | End | | |
| | 26 31L | To start | | |
| 87 | 43 123L | Block S test | | |
| | L5 41L | Set to not punch S | | |

| LOCATION | ORDER | | NOTES | PAGE 6 | Q4 |
|---|---|---|---|---|---|
| 88 | 46 110L | | | | |
| | 22 83L | | | | |
| 89 | 92 135F | | | | |
| | 92 259F | | Letters | | |
| 90 | 92 194F | | E | | |
| | 92 707F | | Nos. | | |
| 91 | 93 963F | | | | |
| | L5 4F | | | | |
| 92 | 00 1F | | | | |
| | 82 ( )F | p | | | |
| 93 | 26 109L | | End | | |
| | L5 45L | | | | |
| 94 | L4 122L | | + m/4 | | |
| | 42 95L | | | | |
| 95 | 00 1F | w | | | |
| | L5 ( )F | | | | |
| 96 | 40 7F | | Excited nodes to 7 | | |
| | 26 61L | | To speed-independent test | | |
| 97 | 92 135F | | | | |
| | 92 898F | | F | | |
| 98 | L5 97L | | | | |
| | 40 9F | | Set failure switch | | |
| 99 | 93 963F | | | | |
| | L5 4F | | | | |
| 100 | 00 1F | | | | |
| | 82 ( )F | b | Print information | | |
| 101 | F5 99L | | | | |
| | 42 99L | | | | |
| 102 | L0 120L | | | | |
| | 36 99L | | | | |
| 103 | L5 91L | | | | |
| | 42 99L | | Reset | | |
| 104 | L5 9F | | | | |
| | 36 58L | | Normal print jump | | |
| 105 | L5 106L | | | | |
| | 42 81L | | | | |

| LOCATION | ORDER | NOTES | PAGE 7 | Q4 |
|---|---|---|---|---|
| 106 | 22 73L | | To reset | |
| | 00 108L | | | |
| 107 | 92 135F | | | |
| | 92 2F | | 0 | |
| 108 | F5 105L | | | |
| | 42 81L | | Reset program | |
| 109 | 92 135F | | | |
| | 92 259F | | | |
| 110 | 92 ( )F | | Type | |
| | 92 707F | | | |
| 111 | 0F F | | | |
| | 26 L | | | |
| 112 | N1 8F | | | |
| | L5 ( )F | | a end test | |
| 113 | 75 6F | | | |
| | L0 F | | b end test | |
| 114 | 00 F | | | |
| | 00 F | | 0 | |
| 115 | 00 F | | | |
| | 00 10F | | | |
| 116 | 00 F | | | |
| | 00 F | | Node counter | |
| 117 | 00 F | | | |
| | 00 F | | State counter | |
| 118 | 00 F | | | |
| | 00 F | | Node marker | |
| 119 | 00 F | | | |
| | 00 F | | Punch marker | |
| 120 | 13 963F | | | |
| | L5 8F | | End test for punch | |
| 121 | 00 F | | | |
| | 00 F | | $2^n$ | |
| 122 | 00 F | | | |
| | 00 F | | m/4 | |
| 123 | LL 4095F | | | |
| | LL 4094F | | S test const. | |

| LOCATION | ORDER | NOTES |
|---|---|---|
| 124 | 74 F | Fcn. routine |
| | 40 ( )F | |
| 125 | 00 F | consts. |
| | 00 126L | |
| Compiler | | |
| | 00 882K | |
| 0 | 41 F | Clear 0 |
| | 81 4F | |
| 1 | 50 F | |
| | 74 90L | x 10 |
| 2 | 00 4F | |
| | 91 4F | Store -n in 1 |
| 3 | 32 1L | |
| | S1 3F | |
| 4 | 40 1F | |
| | 75 91L | x $2^{-19} + 2^{-39}$ |
| 5 | S5 F | |
| | L4 92L | $+\alpha \times 2^{-19} + \alpha \times 2^{-39}$ |
| 6 | 42 107L | $\alpha + n$ |
| | 42 22L | |
| 7 | 42 124S3 | Variable end test plant |
| | S4 F | |
| 8 | 42 93L | End test for marker |
| | 46 7S3 | Start of fcn. routine |
| 9 | 42 50S3 | |
| | 42 26L | 1st word store |
| 10 | L4 91L | $+ 2^{-19} + 2^{-39}$ |
| | 46 99L | $\alpha + 2n + 1$ |
| 11 | L4 91L | |
| | 46 98L | $\alpha + 2n + 2$ |
| 12 | 42 97L | |
| | 42 100L | |
| 13 | S5 F | |
| | L4 3L | Set up punch |

| LOCATION | ORDER | NOTES |
|---|---|---|
| 14 | 10 2F | |
| | 50 F | and read address |
| 15 | 00 2F | |
| | 42 92S3 | |
| 16 | 42 100S3 | |
| | 00 20F | Set punch |
| 17 | 46 29S3 | |
| | 46 28S3 | routines |
| 18 | 46 4S3 | |
| | 46 3S3 | |
| 19 | L1 1F | |
| | 42 20L | |
| 20 | F5 F | |
| | 00 ( ) F | Plant $2^n$ |
| 21 | 40 121S3 | |
| | 49 2F | |
| 22 | L5 2F | |
| | 40 ( )F | |
| 23 | 10 1F | |
| | 40 2F | Plant markers |
| 24 | F5 22L | |
| | 42 22L | |
| 25 | L0 93L | |
| | 36 22L | |
| 26 | L5 94L | |
| | 40 ( )F | |
| 27 | L5 26L | |
| | L4 91L | Plant 1st 7 |
| 28 | 46 26L | |
| | 42 26L | words of routine |
| 29 | L0 101L | |
| | 36 26L | |
| 30 | L5 26L | |
| | 42 38L | |
| 31 | 42 40L | |
| | 81 4F | |

| LOCATION | ORDER | | NOTES | PAGE 10 | Q4 |
|---|---|---|---|---|---|
| 32 | L0 90L | | -10 | | |
| | 36 43L | | Read integer | | |
| 33 | L4 90L | | | | |
| | 50 F | | | | |
| 34 | 74 90L | | | | |
| | 00 4F | | | | |
| 35 | 91 4F | | | | |
| | 36 34L | | | | |
| 36 | L0 105L | | | | |
| | 36 38L | | Test for prime | | |
| 37 | L5 102L | | | | |
| | 22 38L | | | | |
| 38 | L5 103L | | | | |
| | 40 ( )F | | Store order pair | | |
| 39 | 00 20F | | | | |
| | L5 104L | | | | |
| 40 | S4 109L | | | | |
| | 46 ( )F | | Plant variable address | | |
| 41 | F5 38L | | | | |
| | 42 38L | | Increase address | | |
| 42 | 42 40L | | | | |
| | 22 31L | | To next term | | |
| 43 | F0 F | | | | |
| | 36 50L | | Test for end of fcn. | | |
| 44 | 50 40L | | | | |
| | L5 40L | | | | |
| 45 | F0 F | | Prepare to set | | |
| | 42 46L | | 36 transfers | | |
| 46 | 42 48L | | | | |
| | L5 ( )F | | | | |
| 47 | 36 52L | | | | |
| | K5 F | | Set 36 transfers | | |
| 48 | 32 48L | W | | | |
| | 42 ( )F | | | | |
| 49 | L5 46L | | | | |
| | 26 45L | | | | |

| LOCATION | ORDER | NOTES | PAGE 11 | Q4 |
|---|---|---|---|---|
| 50 | F5 40L | | | |
| | 40 2F | End of fcn. set | | |
| 51 | 50 2F | | | |
| | 22 44L | To plant 36 at end | | |
| 52 | F1 2F | | | |
| | 36 54L | Jumps if end of routine | | |
| 53 | L5 106L | | | |
| | 22 38L | Plant 36 26 | | |
| 54 | L5 40L | | | |
| | 42 57L | Set end of fcn. | | |
| 55 | F5 40L | | | |
| | 42 40L | | | |
| 56 | 42 38L | | | |
| | 42 58L | | | |
| 57 | L5 107L | | | |
| | 40 ( )F | Store L5 7F L4 ___ | | |
| 58 | L5 108L | | | |
| | 40 ( )F | Store 50F 40 7F | | |
| 59 | 41 2F | Clear 2 | | |
| | L5 57L | | | |
| 60 | F0 F | | | |
| | 42 61L | | | |
| 61 | 42 64L | | | |
| | L5 ( )F | Plant 26 | | |
| 62 | L4 101L | transfers | | |
| | 36 65L | | | |
| 63 | L4 108L | | | |
| | 36 66L | | | |
| 64 | L5 57L | | | |
| | 42 ( )F | | | |
| 65 | L5 64L | | | |
| | 26 60L | | | |
| 66 | F5 107L | | | |
| | 42 107L | Marker increase | | |
| 67 | F5 1F | | | |
| | 40 1F | | | |

| LOCATION | ORDER | NOTES |
|---|---|---|
| 68 | 36 69L | |
| | 26 41L | To next fcn. |
| 69 | F5 58L | |
| | 42 70L | |
| 70 | L5 (109)L | |
| | 40 ( )F | |
| 71 | L5 70L | |
| | L4 91L | Plant last 4 |
| 72 | 46 70L | |
| | 42 70L | words of fcn. |
| 73 | L0 113L | routine |
| | 36 70L | |
| 74 | L5 40L | |
| | 46 70L | reset |
| 75 | L5 82L | |
| | 46 26L | |
| 76 | L5 70L | |
| | 42 1F | Store $a_1$ |
| 77 | F0 F | |
| | 42 6S3 | Plant last word of routine |
| 78 | 42 8S3 | |
| | L5 114L | |
| 79 | L0 1F | |
| | 40 2F | |
| 80 | 51 2F | |
| | 00 1F | |
| 81 | 66 115L | |
| | 10 1F | |
| 82 | S5 94L | |
| | 40 2F | m/4 to 2 |
| 83 | 40 122S3 | Store m/4 |
| | L5 1F | |
| 84 | 42 5S3 | |
| | 42 33S3 | Store $a_1$ |
| 85 | L4 2F | |
| | 42 7S3 | Store $a_1$ + m/4 |

| LOCATION | ORDER | NOTES |
|---|---|---|
| 86 | 42 34S3 | |
| | L4 2F | + m/4 |
| 87 | 42 29S3 | |
| | 42 45S3 | Store $b_1$ |
| 88 | 42 52S3 | |
| | L4 2F | |
| 89 | 42 51S3 | Store $b_1$ + m/4 |
| | 26 111S3 | |
| 90 | 00 F | |
| | 00 10F | |
| 91 | 00 1F | |
| | 00 1F | |
| 92 | 00 126S3 | $\alpha$ |
| | 00 126S3 | $\alpha$ |
| 93 | 75 2F | |
| | 40 ( )F | Marker end test |
| 94 | L5 6F | |
| | 40 F | |
| 95 | 41 7F | |
| | L5 F | |
| 96 | L4 F | $\alpha$ |
| | 40 126S3 | |
| 97 | 40 F | |
| | F5 F | |
| 98 | 42 F | |
| | L0 124S3 | $(\alpha-2)$ |
| 99 | 32 F | |
| | L5 125S3 | $(\alpha-1)$ |
| 100 | 50 F | |
| | 42 F | lst 7 words of fcn. routine |
| 101 | 75 101L | |
| | 00 F | End test for lst 7 words |
| 102 | L5 F | |
| | 36 F | $z_i$ |
| 103 | F1 F | |
| | 36 F | $\bar{z}_i$ |

| LOCATION | ORDER | NOTES |
|---|---|---|
| 104 | 00 125S3 | |
| | 00 F | $\alpha$ -1 |
| 105 | 00 F | |
| | 00 13F | |
| 106 | 36 F | |
| | 26 F | End of term |
| 107 | L5 7F | |
| | L4 ( )F | End of fcn. |
| 108 | 50 F | |
| | 40 7F | |
| 109 | 50 6F | |
| | S5 F | |
| 110 | J0 7F | |
| | S0 F | Last 4 words of fcn. routine |
| 111 | I4 7F | |
| | S0 F | |
| 112 | 40 7F | |
| | 22 F | |
| 113 | 75 113L | |
| | 00 F | |
| 114 | 00 F | |
| | 00 1S5 | Memory const. |
| 115 | 00 F | |
| | 00 4F | |
| | 24 882N | |