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**COURSE: CPE 522**

**DATE: 21/06/2021**

**ANALYZING THE STATE DIAGRAM OF A DOOR COMBINATION LOCK.**

**[](https://app.diagrams.net/?page-id=52a04d89-c75d-2922-d76d-85b35f80e030&scale=auto#G17mAdGRuV-65Wp-AQ0hWXYAcYt04s0-uz)**

**State diagram for a door combination lock**

Declaration of parameters

Reset - R

Equal - E

New - N

S1 = 000

S2 = 001

S3 = 010

OPEN = 011

ERR = 100

C1 = 00

C2 = 01

C3 = 10

**State encoding transition table using hot encoding**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | **Current State** | | | | | **Next State** | | | | | **Next Mux** | | | **Open/closed** |
| **R** | **N** | | **E** | | **S1** | **S2** | | **S3** | | **N1** | **N2** | | **N3** | | **O1** | | **02** | **Open** |
| **1** | **X** | | **X** | | **X** | **X** | | **X** | | **0** | **0** | | **0** | | **0** | | **0** | **0** |
| **0** | **0** | | **X** | | **0** | **0** | | **0** | | **0** | **0** | | **0** | | **0** | | **0** | **0** |
| **0** | **1** | | **0** | | **0** | **0** | | **0** | | **1** | **0** | | **0** | | **X** | | **X** | **0** |
| **0** | **1** | | **1** | | **0** | **0** | | **0** | | **0** | **0** | | **1** | | **0** | | **1** | **0** |
| **0** | **0** | | **X** | | **0** | **0** | | **1** | | **0** | **0** | | **1** | | **0** | | **1** | **0** |
| **0** | **1** | | **0** | | **0** | **0** | | **1** | | **1** | **0** | | **0** | | **X** | | **X** | **0** |
| **0** | **1** | | **1** | | **0** | **0** | | **1** | | **0** | **1** | | **0** | | **1** | | **0** | **0** |
| **0** | **0** | | **X** | | **0** | **1** | | **0** | | **0** | **1** | | **0** | | **1** | | **0** | **0** |
| **0** | **1** | | **0** | | **0** | **1** | | **0** | | **1** | **0** | | **0** | | **X** | | **X** | **0** |
| **0** | **1** | | **1** | | **0** | **1** | | **0** | | **0** | **1** | | **1** | | **X** | | **X** | **0** |
| **0** | **X** | | **X** | | **0** | **1** | | **1** | | **0** | **1** | | **1** | | **X** | | **X** | **1** |
| **0** | **X** | | **X** | | **1** | **0** | | **0** | | **1** | **0** | | **0** | | **X** | | **X** | **0** |
| **0** | **0** | | **1** | | **1** | **0** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **0** | | **0** | | **1** | **0** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **1** | | **1** | | **1** | **0** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **1** | | **0** | | **1** | **0** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **0** | | **1** | | **1** | **1** | | **0** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **0** | | **0** | | **1** | **1** | | **0** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **1** | | **1** | | **1** | **1** | | **0** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **1** | | **0** | | **1** | **1** | | **0** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **0** | | **1** | | **1** | **1** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | **0** | | **0** | | **1** | **1** | | **1** | | **X** | **X** | | **X** | | **X** | | **X** | **X** |
| **0** | | **1** | | **1** | **1** | | **1** | | **1** | **X** | | **X** | | **X** | **X** | **X** | | **X** |
| **0** | | **1** | | **0** | **1** | | **1** | | **1** | **X** | | **X** | | **X** | **X** | **X** | | **X** |

**Solution for Next state N1**

**MinTerm = 16,17,18,28,20,12,4**

**Don’t-Care = 13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R,N,E,S1,S2,S3**

**Option = Sum of product**

**using Quine-McCluskey**

**Solution:**

**MinTerm = ∑m(16,17,18,28,20,12,4)**

**N = 6 and Variable = R,N,E,S1,S2,S3**

**Don’t-care = ∑(13,5,29,21,14,6,30,22,15,7,31,23)**

1. minterms and their binary representations

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 4 | 000100 | → | | 16 | 010000 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 12 | 001100 | → | | 17 | 010001 | → | | 18 | 010010 | → | | 20 | 010100 | → | | 5 | 000101 | → | | 6 | 000110 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 28 | 011100 | → | | 7 | 000111 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 21 | 010101 | → | | 22 | 010110 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 15 | 001111 | → | | 23 | 010111 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A5 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

2. merging of minterm

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 4,12 | 00-100 | → | | 4,20 | 0-0100 | → | | 4,5 | 00010- | → | | 4,6 | 0001-0 | → | | 16,17 | 01000- | → | | 16,18 | 0100-0 | → | | 16,20 | 010-00 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 12,28 | 0-1100 | → | | 12,13 | 00110- | → | | 12,14 | 0011-0 | → | | 17,21 | 010-01 | → | | 18,22 | 010-10 | → | | 20,28 | 01-100 | → | | 20,21 | 01010- | → | | 20,22 | 0101-0 | → | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 28,29 | 01110- | → | | 28,30 | 0111-0 | → | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | |
| Group B4  (A4, A5) |  | |  |  |  | | --- | --- | --- | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

3. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 4,5,12,13 | 00-10- | → | | 4,6,12,14 | 00-1-0 | → | | 4,12,20,28 | 0--100 | → | | 4,5,20,21 | 0-010- | → | | 4,6,20,22 | 0-01-0 | → | | 4,5,6,7 | 0001-- | → | | 16,17,20,21 | 010-0- | ✓ | | 16,18,20,22 | 010--0 | ✓ | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 12,13,28,29 | 0-110- | → | | 12,14,28,30 | 0-11-0 | → | | 12,13,14,15 | 0011-- | → | | 20,21,28,29 | 01-10- | → | | 20,22,28,30 | 01-1-0 | → | | 20,21,22,23 | 0101-- | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | |
| Group C3  (B3, B4) |  | |  |  |  | | --- | --- | --- | | 28,29,30,31 | 0111-- | → | | 7,15,23,31 | 0--111 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | |

4. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 4,5,6,7,12,13,14,15 | 00-1-- | → | | 4,5,12,13,20,21,28,29 | 0--10- | → | | 4,6,12,14,20,22,28,30 | 0--1-0 | → | | 4,5,6,7,20,21,22,23 | 0-01-- | → | |
| Group D2  (C2, C3) |  | |  |  |  | | --- | --- | --- | | 12,13,14,15,28,29,30,31 | 0-11-- | → | | 20,21,22,23,28,29,30,31 | 01-1-- | → | | 5,7,13,15,21,23,29,31 | 0--1-1 | → | | 6,7,14,15,22,23,30,31 | 0--11- | → | |

5. merging of minterm pairs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group E1  (D1, D2) |  | |  |  |  | | --- | --- | --- | | 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 | 0--1-- | ✓ | |

1. Prime implicant chart

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| PIs\MinTerms | 4 | 12 | 16 | 17 | 18 | 20 | 28 | R, N, E, S1, S2, S3 |
| 16,17,20,21 |  |  | X | X |  | X |  | 010-0- |
| 16,18,20,22 |  |  | X |  | X | X |  | 010--0 |
| 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 | X | X |  |  |  | X | X | 0--1-- |

**Extracted essential prime implicants: 0--1--,010-0-,010--0**

**All extracted essential prime implicants: 0--1--,010-0-,010--0**

**Minimal Quine-McCluskey Expression = R'S1 + R'NE'S2' + R'NE'S3'**

**Solution for Next state N2**

**MinTerm = 25,10,2,26,27,19,11,3**

**Don’t-Care = 13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R,N,E,S1,S2,S3**

**Option = Sum of product**

**using Quine-McCluskey**

**Solution:**

**MinTerm = ∑m(25,10,2,26,27,19,11,3)**

**N = 6 and Variable = R,N,E,S1,S2,S3**

**Don’t-care = ∑(13,5,29,21,14,6,30,22,15,7,31,23)**

1. minterms and their binary representations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 2 | 000010 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 3 | 000011 | → | | 10 | 001010 | → | | 5 | 000101 | → | | 6 | 000110 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 11 | 001011 | → | | 19 | 010011 | → | | 25 | 011001 | → | | 26 | 011010 | → | | 7 | 000111 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 21 | 010101 | → | | 22 | 010110 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 27 | 011011 | → | | 15 | 001111 | → | | 23 | 010111 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A5 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

**2. merging of minterm**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 2,3 | 00001- | → | | 2,10 | 00-010 | → | | 2,6 | 000-10 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 3,11 | 00-011 | → | | 3,19 | 0-0011 | → | | 3,7 | 000-11 | → | | 10,11 | 00101- | → | | 10,26 | 0-1010 | → | | 10,14 | 001-10 | → | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 11,27 | 0-1011 | → | | 11,15 | 001-11 | → | | 19,27 | 01-011 | → | | 19,23 | 010-11 | → | | 25,27 | 0110-1 | → | | 25,29 | 011-01 | → | | 26,27 | 01101- | → | | 26,30 | 011-10 | → | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | |
| Group B4  (A4, A5) |  | |  |  |  | | --- | --- | --- | | 27,31 | 011-11 | → | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

**3. merging of min term pairs**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 2,3,10,11 | 00-01- | → | | 2,6,10,14 | 00--10 | → | | 2,3,6,7 | 000-1- | → | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15 | 00--11 | → | | 3,11,19,27 | 0--011 | → | | 3,7,19,23 | 0-0-11 | → | | 10,11,26,27 | 0-101- | → | | 10,14,26,30 | 0-1-10 | → | | 10,11,14,15 | 001-1- | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | |
| Group C3  (B3, B4) |  | |  |  |  | | --- | --- | --- | | 11,15,27,31 | 0-1-11 | → | | 19,23,27,31 | 01--11 | → | | 25,27,29,31 | 011--1 | ✓ | | 26,27,30,31 | 011-1- | → | | 7,15,23,31 | 0--111 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | |

4. merging of min term pairs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 2,3,6,7,10,11,14,15 | 00--1- | ✓ | |
| Group D2  (C2, C3) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15,19,23,27,31 | 0---11 | ✓ | | 10,11,14,15,26,27,30,31 | 0-1-1- | ✓ | | 5,7,13,15,21,23,29,31 | 0--1-1 | ✓ | | 6,7,14,15,22,23,30,31 | 0--11- | ✓ | |

1. Prime implicant chart

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| PIs\MinTerms | 2 | 3 | 10 | 11 | 19 | 25 | 26 | 27 | R, N, E, S1, S2, S3 |
| 25,27,29,31 |  |  |  |  |  | X |  | X | 011--1 |
| 2,3,6,7,10,11,14,15 | X | X | X | X |  |  |  |  | 00--1- |
| 3,7,11,15,19,23,27,31 |  | X |  | X | X |  |  | X | 0---11 |
| 10,11,14,15,26,27,30,31 |  |  | X | X |  |  | X | X | 0-1-1- |
| 5,7,13,15,21,23,29,31 |  |  |  |  |  |  |  |  | 0--1-1 |
| 6,7,14,15,22,23,30,31 |  |  |  |  |  |  |  |  | 0--11- |

**Extracted essential prime implicants: 00--1-,0---11,011--1,0-1-1-**

**All extracted essential prime implicants: 00--1-,0---11,011--1,0-1-1-**

**Minimal Quine-McCluskey Expression = R'N'S2 + R'S2S3 + R'NES3 + R'ES2**

**Solution for Next state N3**

**MinTerm = 24,9,1,26,27,19,11,3**

**Don’t-Care = 13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R,N,E,S1,S2,S3**

**Option = Sum of product**

**using Quine-McCluskey**

**Solution:**

**MinTerm = ∑m(24,9,1,26,27,19,11,3)**

**N = 6 and Variable = R,N,E,S1,S2,S3**

**Don’t-care = ∑(13,5,29,21,14,6,30,22,15,7,31,23)**

1. minterms and their binary representations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 1 | 000001 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 3 | 000011 | → | | 9 | 001001 | → | | 24 | 011000 | → | | 5 | 000101 | → | | 6 | 000110 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 11 | 001011 | → | | 19 | 010011 | → | | 26 | 011010 | → | | 7 | 000111 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 21 | 010101 | → | | 22 | 010110 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 27 | 011011 | → | | 15 | 001111 | → | | 23 | 010111 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A5 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

2. merging of minterm

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 1,3 | 0000-1 | → | | 1,9 | 00-001 | → | | 1,5 | 000-01 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 3,11 | 00-011 | → | | 3,19 | 0-0011 | → | | 3,7 | 000-11 | → | | 9,11 | 0010-1 | → | | 9,13 | 001-01 | → | | 24,26 | 0110-0 | ✓ | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 11,27 | 0-1011 | → | | 11,15 | 001-11 | → | | 19,27 | 01-011 | → | | 19,23 | 010-11 | → | | 26,27 | 01101- | → | | 26,30 | 011-10 | → | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | |
| Group B4  (A4, A5) |  | |  |  |  | | --- | --- | --- | | 27,31 | 011-11 | → | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

3. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 1,3,9,11 | 00-0-1 | → | | 1,5,9,13 | 00--01 | → | | 1,3,5,7 | 000--1 | → | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15 | 00--11 | → | | 3,11,19,27 | 0--011 | → | | 3,7,19,23 | 0-0-11 | → | | 9,11,13,15 | 001--1 | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | |
| Group C3  (B3, B4) |  | |  |  |  | | --- | --- | --- | | 11,15,27,31 | 0-1-11 | → | | 19,23,27,31 | 01--11 | → | | 26,27,30,31 | 011-1- | ✓ | | 7,15,23,31 | 0--111 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | |

4. merging of minterm pairs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 1,3,5,7,9,11,13,15 | 00---1 | ✓ | |
| Group D2  (C2, C3) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15,19,23,27,31 | 0---11 | ✓ | | 5,7,13,15,21,23,29,31 | 0--1-1 | ✓ | | 6,7,14,15,22,23,30,31 | 0--11- | ✓ | |

1. Prime implicant chart

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| PIs\MinTerms | 1 | 3 | 9 | 11 | 19 | 24 | 26 | 27 | R, N, E, S1, S2, S3 |
| 24,26 |  |  |  |  |  | X | X |  | 0110-0 |
| 26,27,30,31 |  |  |  |  |  |  | X | X | 011-1- |
| 1,3,5,7,9,11,13,15 | X | X | X | X |  |  |  |  | 00---1 |
| 3,7,11,15,19,23,27,31 |  | X |  | X | X |  |  | X | 0---11 |
| 5,7,13,15,21,23,29,31 |  |  |  |  |  |  |  |  | 0--1-1 |
| 6,7,14,15,22,23,30,31 |  |  |  |  |  |  |  |  | 0--11- |

**Extracted essential prime implicants: 00---1,0---11,0110-0**

**All extracted essential prime implicants: 00---1,0---11,0110-0**

**Minimal Quine-McCluskey Expression = R'N'S3 + R'S2S3 + R'NES1'S3'**

**Solution for Open/Close**

**MinTerm = 27,19,11,3**

**Don’t-Care = 13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R,N,E,S1,S2,S3**

**Option = Sum of product**

**using Quine-McCluskey**

**Solution:**

**MinTerm = ∑m(27,19,11,3)**

**N = 6 and Variable = R,N,E,S1,S2,S3**

**Don’t-care = ∑(13,5,29,21,14,6,30,22,15,7,31,23)**

1. min terms and their binary representations

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 3 | 000011 | → | | 5 | 000101 | → | | 6 | 000110 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 11 | 001011 | → | | 19 | 010011 | → | | 7 | 000111 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 21 | 010101 | → | | 22 | 010110 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 27 | 011011 | → | | 15 | 001111 | → | | 23 | 010111 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

2. merging of minterm

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 3,11 | 00-011 | → | | 3,19 | 0-0011 | → | | 3,7 | 000-11 | → | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 11,27 | 0-1011 | → | | 11,15 | 001-11 | → | | 19,27 | 01-011 | → | | 19,23 | 010-11 | → | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 27,31 | 011-11 | → | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

3. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15 | 00--11 | → | | 3,11,19,27 | 0--011 | → | | 3,7,19,23 | 0-0-11 | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 11,15,27,31 | 0-1-11 | → | | 19,23,27,31 | 01--11 | → | | 7,15,23,31 | 0--111 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | |

4. merging of min term pairs

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15,19,23,27,31 | 0---11 | ✓ | | 5,7,13,15,21,23,29,31 | 0--1-1 | ✓ | | 6,7,14,15,22,23,30,31 | 0--11- | ✓ | |

1. Prime implicant chart

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PIs\MinTerms | 3 | 11 | 19 | 27 | R, N, E, S1, S2, S3 |
| 3,7,11,15,19,23,27,31 | X | X | X | X | 0---11 |
| 5,7,13,15,21,23,29,31 |  |  |  |  | 0--1-1 |
| 6,7,14,15,22,23,30,31 |  |  |  |  | 0--11- |

**Extracted essential prime implicants: 0---11**

**All extracted essential prime implicants: 0---11**

**Minimal Quine-McCluskey Expression = R'S2S3**

**Solution for Output Mux O1**

**MinTerm = 25,10,2**

**Don’t-Care = 16,17,18,26,27,19,11,3,28,20,12,4,13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R, N, E, S1, S2, S3**

**Option = Sum of product**

**using Quine-McCluskey**

**MinTerm = ∑m (25,10,2)**

**N = 6 and Variable = R, N, E, S1, S2, S3**

**Don’t-care = ∑ (16,17,18,26,27,19,11,3,28,20,12,4,13,5,29,21,14,6,30,22,15,7,31,23)**

1. min terms and their binary representations

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 2 | 000010 | → | | 4 | 000100 | → | | 16 | 010000 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 10 | 001010 | → | | 3 | 000011 | → | | 5 | 000101 | → | | 6 | 000110 | → | | 12 | 001100 | → | | 17 | 010001 | → | | 18 | 010010 | → | | 20 | 010100 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 25 | 011001 | → | | 7 | 000111 | → | | 11 | 001011 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 19 | 010011 | → | | 21 | 010101 | → | | 22 | 010110 | → | | 26 | 011010 | → | | 28 | 011100 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 15 | 001111 | → | | 23 | 010111 | → | | 27 | 011011 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A5 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

2. merging of min term

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 2,10 | 00-010 | → | | 2,3 | 00001- | → | | 2,6 | 000-10 | → | | 2,18 | 0-0010 | → | | 4,5 | 00010- | → | | 4,6 | 0001-0 | → | | 4,12 | 00-100 | → | | 4,20 | 0-0100 | → | | 16,17 | 01000- | → | | 16,18 | 0100-0 | → | | 16,20 | 010-00 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 10,11 | 00101- | → | | 10,14 | 001-10 | → | | 10,26 | 0-1010 | → | | 3,7 | 000-11 | → | | 3,11 | 00-011 | → | | 3,19 | 0-0011 | → | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | | 12,13 | 00110- | → | | 12,14 | 0011-0 | → | | 12,28 | 0-1100 | → | | 17,25 | 01-001 | → | | 17,19 | 0100-1 | → | | 17,21 | 010-01 | → | | 18,19 | 01001- | → | | 18,22 | 010-10 | → | | 18,26 | 01-010 | → | | 20,21 | 01010- | → | | 20,22 | 0101-0 | → | | 20,28 | 01-100 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 25,27 | 0110-1 | → | | 25,29 | 011-01 | → | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 11,15 | 001-11 | → | | 11,27 | 0-1011 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 19,23 | 010-11 | → | | 19,27 | 01-011 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | | 26,27 | 01101- | → | | 26,30 | 011-10 | → | | 28,29 | 01110- | → | | 28,30 | 0111-0 | → | |
| Group B4  (A4, A5) |  | |  |  |  | | --- | --- | --- | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 27,31 | 011-11 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

3. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 2,3,10,11 | 00-01- | → | | 2,6,10,14 | 00--10 | → | | 2,3,6,7 | 000-1- | → | | 2,10,18,26 | 0--010 | → | | 2,3,18,19 | 0-001- | → | | 2,6,18,22 | 0-0-10 | → | | 4,5,6,7 | 0001-- | → | | 4,5,12,13 | 00-10- | → | | 4,6,12,14 | 00-1-0 | → | | 4,5,20,21 | 0-010- | → | | 4,6,20,22 | 0-01-0 | → | | 4,12,20,28 | 0--100 | → | | 16,17,18,19 | 0100-- | → | | 16,17,20,21 | 010-0- | → | | 16,18,20,22 | 010--0 | → | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 10,11,14,15 | 001-1- | → | | 10,11,26,27 | 0-101- | → | | 10,14,26,30 | 0-1-10 | → | | 3,7,11,15 | 00--11 | → | | 3,7,19,23 | 0-0-11 | → | | 3,11,19,27 | 0--011 | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | | 12,13,14,15 | 0011-- | → | | 12,13,28,29 | 0-110- | → | | 12,14,28,30 | 0-11-0 | → | | 17,19,25,27 | 01-0-1 | → | | 17,21,25,29 | 01--01 | → | | 17,19,21,23 | 010--1 | → | | 18,19,22,23 | 010-1- | → | | 18,19,26,27 | 01-01- | → | | 18,22,26,30 | 01--10 | → | | 20,21,22,23 | 0101-- | → | | 20,21,28,29 | 01-10- | → | | 20,22,28,30 | 01-1-0 | → | |
| Group C3  (B3, B4) |  | |  |  |  | | --- | --- | --- | | 25,27,29,31 | 011--1 | → | | 7,15,23,31 | 0--111 | → | | 11,15,27,31 | 0-1-11 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 19,23,27,31 | 01--11 | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | | 26,27,30,31 | 011-1- | → | | 28,29,30,31 | 0111-- | → | |

4. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 2,3,6,7,10,11,14,15 | 00--1- | → | | 2,3,10,11,18,19,26,27 | 0--01- | → | | 2,6,10,14,18,22,26,30 | 0---10 | → | | 2,3,6,7,18,19,22,23 | 0-0-1- | → | | 4,5,6,7,12,13,14,15 | 00-1-- | → | | 4,5,6,7,20,21,22,23 | 0-01-- | → | | 4,5,12,13,20,21,28,29 | 0--10- | → | | 4,6,12,14,20,22,28,30 | 0--1-0 | → | | 16,17,18,19,20,21,22,23 | 010--- | ✓ | |
| Group D2  (C2, C3) |  | |  |  |  | | --- | --- | --- | | 10,11,14,15,26,27,30,31 | 0-1-1- | → | | 3,7,11,15,19,23,27,31 | 0---11 | → | | 5,7,13,15,21,23,29,31 | 0--1-1 | → | | 6,7,14,15,22,23,30,31 | 0--11- | → | | 12,13,14,15,28,29,30,31 | 0-11-- | → | | 17,19,21,23,25,27,29,31 | 01---1 | ✓ | | 18,19,22,23,26,27,30,31 | 01--1- | → | | 20,21,22,23,28,29,30,31 | 01-1-- | → | |

5. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group E1  (D1, D2) |  | |  |  |  | | --- | --- | --- | | 2,3,6,7,10,11,14,15,18,19,22,23,26,27,30,31 | 0---1- | ✓ | | 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 | 0—1-- | ✓ | |
|  |  |  |

1. Prime implicant chart

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PIs\MinTerms | 2 | 10 | 25 | R, N, E, S1, S2, S3 |
| 16,17,18,19,20,21,22,23 |  |  |  | 010--- |
| 17,19,21,23,25,27,29,31 |  |  | X | 01---1 |
| 2,3,6,7,10,11,14,15,18,19,22,23,26,27,30,31 | X | X |  | 0---1- |
| 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 |  |  |  | 0--1-- |

**Extracted essential prime implicants: 0---1-,01---1**

**All extracted essential prime implicants: 0---1-,01---1**

**Minimal Quine-McCluskey Expression = R'S2 + R'NS3**

**Solution for Output Mux O2**

**MinTerm = 24,9,1**

**Don’t-Care = 16,17,18,26,27,19,11,3,28,20,12,4,13,5,29,21,14,6,30,22,15,7,31,23**

**Variable = R,N,E,S1,S2,S3**

**Option = Sum of product**

**using Quine-McCluskey**

Solution:

MinTerm = ∑m(24,9,1)

N = 6 and Variable = R,N,E,S1,S2,S3

Don’t-care = ∑(16,17,18,26,27,19,11,3,28,20,12,4,13,5,29,21,14,6,30,22,15,7,31,23)

1. minterms and their binary representations

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group A1 |  | |  |  |  | | --- | --- | --- | | 1 | 000001 | → | | 4 | 000100 | → | | 16 | 010000 | → | |
| Group A2 |  | |  |  |  | | --- | --- | --- | | 9 | 001001 | → | | 24 | 011000 | → | | 3 | 000011 | → | | 5 | 000101 | → | | 6 | 000110 | → | | 12 | 001100 | → | | 17 | 010001 | → | | 18 | 010010 | → | | 20 | 010100 | → | |
| Group A3 |  | |  |  |  | | --- | --- | --- | | 7 | 000111 | → | | 11 | 001011 | → | | 13 | 001101 | → | | 14 | 001110 | → | | 19 | 010011 | → | | 21 | 010101 | → | | 22 | 010110 | → | | 26 | 011010 | → | | 28 | 011100 | → | |
| Group A4 |  | |  |  |  | | --- | --- | --- | | 15 | 001111 | → | | 23 | 010111 | → | | 27 | 011011 | → | | 29 | 011101 | → | | 30 | 011110 | → | |
| Group A5 |  | |  |  |  | | --- | --- | --- | | 31 | 011111 | → | |

2. merging of minterm

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group B1  (A1, A2) |  | |  |  |  | | --- | --- | --- | | 1,9 | 00-001 | → | | 1,3 | 0000-1 | → | | 1,5 | 000-01 | → | | 1,17 | 0-0001 | → | | 4,5 | 00010- | → | | 4,6 | 0001-0 | → | | 4,12 | 00-100 | → | | 4,20 | 0-0100 | → | | 16,24 | 01-000 | → | | 16,17 | 01000- | → | | 16,18 | 0100-0 | → | | 16,20 | 010-00 | → | |
| Group B2  (A2, A3) |  | |  |  |  | | --- | --- | --- | | 9,11 | 0010-1 | → | | 9,13 | 001-01 | → | | 24,26 | 0110-0 | → | | 24,28 | 011-00 | → | | 3,7 | 000-11 | → | | 3,11 | 00-011 | → | | 3,19 | 0-0011 | → | | 5,7 | 0001-1 | → | | 5,13 | 00-101 | → | | 5,21 | 0-0101 | → | | 6,7 | 00011- | → | | 6,14 | 00-110 | → | | 6,22 | 0-0110 | → | | 12,13 | 00110- | → | | 12,14 | 0011-0 | → | | 12,28 | 0-1100 | → | | 17,19 | 0100-1 | → | | 17,21 | 010-01 | → | | 18,19 | 01001- | → | | 18,22 | 010-10 | → | | 18,26 | 01-010 | → | | 20,21 | 01010- | → | | 20,22 | 0101-0 | → | | 20,28 | 01-100 | → | |
| Group B3  (A3, A4) |  | |  |  |  | | --- | --- | --- | | 7,15 | 00-111 | → | | 7,23 | 0-0111 | → | | 11,15 | 001-11 | → | | 11,27 | 0-1011 | → | | 13,15 | 0011-1 | → | | 13,29 | 0-1101 | → | | 14,15 | 00111- | → | | 14,30 | 0-1110 | → | | 19,23 | 010-11 | → | | 19,27 | 01-011 | → | | 21,23 | 0101-1 | → | | 21,29 | 01-101 | → | | 22,23 | 01011- | → | | 22,30 | 01-110 | → | | 26,27 | 01101- | → | | 26,30 | 011-10 | → | | 28,29 | 01110- | → | | 28,30 | 0111-0 | → | |
| Group B4  (A4, A5) |  | |  |  |  | | --- | --- | --- | | 15,31 | 0-1111 | → | | 23,31 | 01-111 | → | | 27,31 | 011-11 | → | | 29,31 | 0111-1 | → | | 30,31 | 01111- | → | |

3. merging of minterm pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group C1  (B1, B2) |  | |  |  |  | | --- | --- | --- | | 1,3,9,11 | 00-0-1 | → | | 1,5,9,13 | 00--01 | → | | 1,3,5,7 | 000--1 | → | | 1,3,17,19 | 0-00-1 | → | | 1,5,17,21 | 0-0-01 | → | | 4,5,6,7 | 0001-- | → | | 4,5,12,13 | 00-10- | → | | 4,6,12,14 | 00-1-0 | → | | 4,5,20,21 | 0-010- | → | | 4,6,20,22 | 0-01-0 | → | | 4,12,20,28 | 0--100 | → | | 16,18,24,26 | 01-0-0 | → | | 16,20,24,28 | 01--00 | → | | 16,17,18,19 | 0100-- | → | | 16,17,20,21 | 010-0- | → | | 16,18,20,22 | 010--0 | → | |
| Group C2  (B2, B3) |  | |  |  |  | | --- | --- | --- | | 9,11,13,15 | 001--1 | → | | 24,26,28,30 | 011--0 | → | | 3,7,11,15 | 00--11 | → | | 3,7,19,23 | 0-0-11 | → | | 3,11,19,27 | 0--011 | → | | 5,7,13,15 | 00-1-1 | → | | 5,7,21,23 | 0-01-1 | → | | 5,13,21,29 | 0--101 | → | | 6,7,14,15 | 00-11- | → | | 6,7,22,23 | 0-011- | → | | 6,14,22,30 | 0--110 | → | | 12,13,14,15 | 0011-- | → | | 12,13,28,29 | 0-110- | → | | 12,14,28,30 | 0-11-0 | → | | 17,19,21,23 | 010--1 | → | | 18,19,22,23 | 010-1- | → | | 18,19,26,27 | 01-01- | → | | 18,22,26,30 | 01--10 | → | | 20,21,22,23 | 0101-- | → | | 20,21,28,29 | 01-10- | → | | 20,22,28,30 | 01-1-0 | → | |
| Group C3  (B3, B4) |  | |  |  |  | | --- | --- | --- | | 7,15,23,31 | 0--111 | → | | 11,15,27,31 | 0-1-11 | → | | 13,15,29,31 | 0-11-1 | → | | 14,15,30,31 | 0-111- | → | | 19,23,27,31 | 01--11 | → | | 21,23,29,31 | 01-1-1 | → | | 22,23,30,31 | 01-11- | → | | 26,27,30,31 | 011-1- | → | | 28,29,30,31 | 0111-- | → | |

4. merging of min term pairs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group D1  (C1, C2) |  | |  |  |  | | --- | --- | --- | | 1,3,5,7,9,11,13,15 | 00---1 | ✓ | | 1,3,5,7,17,19,21,23 | 0-0--1 | ✓ | | 4,5,6,7,12,13,14,15 | 00-1-- | → | | 4,5,6,7,20,21,22,23 | 0-01-- | → | | 4,5,12,13,20,21,28,29 | 0--10- | → | | 4,6,12,14,20,22,28,30 | 0--1-0 | → | | 16,18,20,22,24,26,28,30 | 01---0 | ✓ | | 16,17,18,19,20,21,22,23 | 010--- | ✓ | |
| Group D2  (C2, C3) |  | |  |  |  | | --- | --- | --- | | 3,7,11,15,19,23,27,31 | 0---11 | ✓ | | 5,7,13,15,21,23,29,31 | 0--1-1 | → | | 6,7,14,15,22,23,30,31 | 0--11- | → | | 12,13,14,15,28,29,30,31 | 0-11-- | → | | 18,19,22,23,26,27,30,31 | 01--1- | ✓ | | 20,21,22,23,28,29,30,31 | 01-1-- | → | |

5. merging of min term pairs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group E1  (D1, D2) |  | |  |  |  | | --- | --- | --- | | 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 | 0--1-- | ✓ | |

1. Prime implicant chart

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PIs\MinTerms | 1 | 9 | 24 | R, N, E, S1, S2, S3 |
| 1,3,5,7,9,11,13,15 | X | X |  | 00---1 |
| 1,3,5,7,17,19,21,23 | X |  |  | 0-0--1 |
| 16,18,20,22,24,26,28,30 |  |  | X | 01---0 |
| 16,17,18,19,20,21,22,23 |  |  |  | 010--- |
| 3,7,11,15,19,23,27,31 |  |  |  | 0---11 |
| 18,19,22,23,26,27,30,31 |  |  |  | 01--1- |
| 4,5,6,7,12,13,14,15,20,21,22,23,28,29,30,31 |  |  |  | 0--1-- |

**Extracted essential prime implicants: 00---1,01---0**

**All extracted essential prime implicants: 00---1,01---0**

**Minimal Quine-McCluskey Expression = R'N'S3 + R'NS3'**

**TOOLS/RESOURCES USED FOR THIS WORK.**

1. State diagram was drawn with draw.io
2. [Quine-McCluskey calculator](https://atozmath.com/KMap.aspx?q=quine)
3. wikipedia