

EE709 - Testing and Verification of VLSI Circuits

Mid-semester assignment

Submitted by:-

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1 Writing the F0,F1,F2,F3 Equations:

Logic diagram of the ALU 74181:

Derived expressions for all the output variables F0,F1,F2,F3 according to the circuit for the cn i have taken cnbar and inputs A0,A1,A2,A3,B0,B1,B2,B3,M.

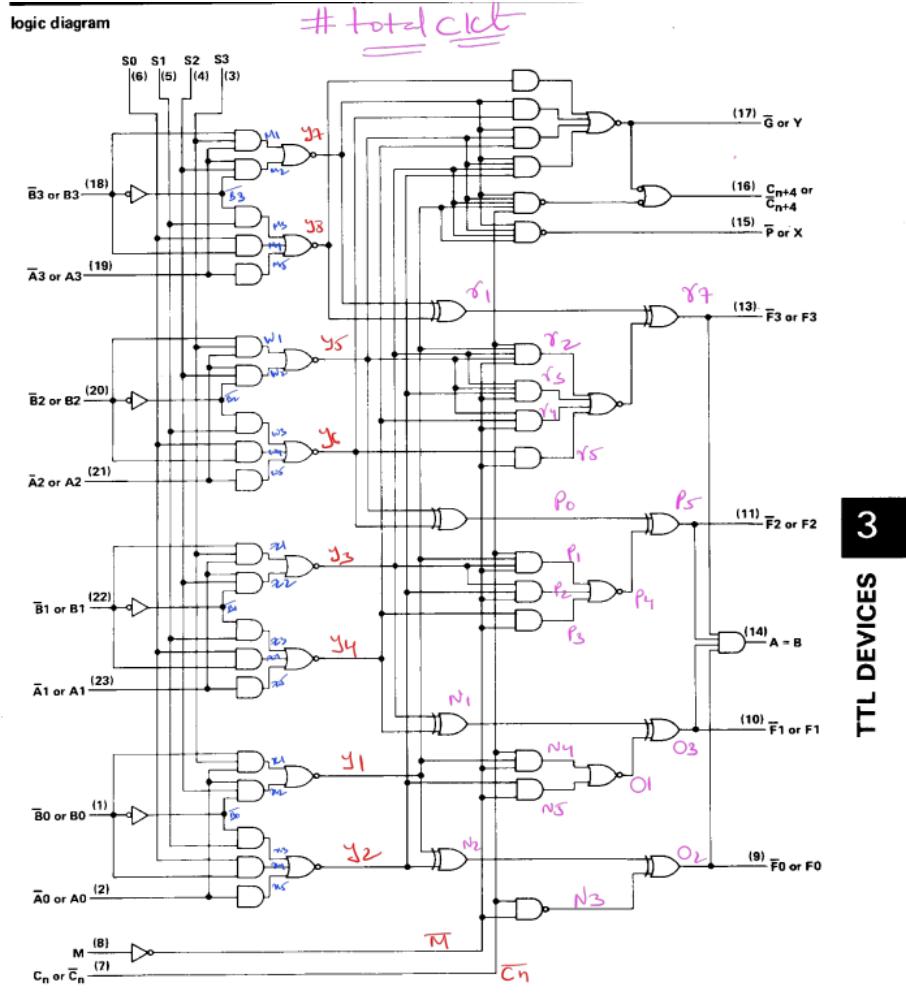
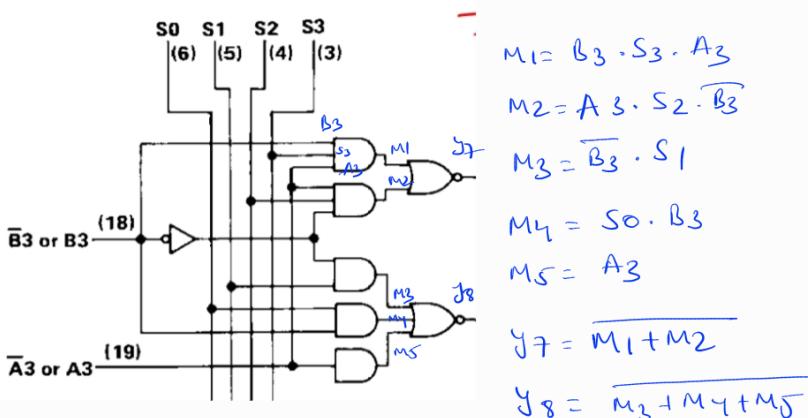
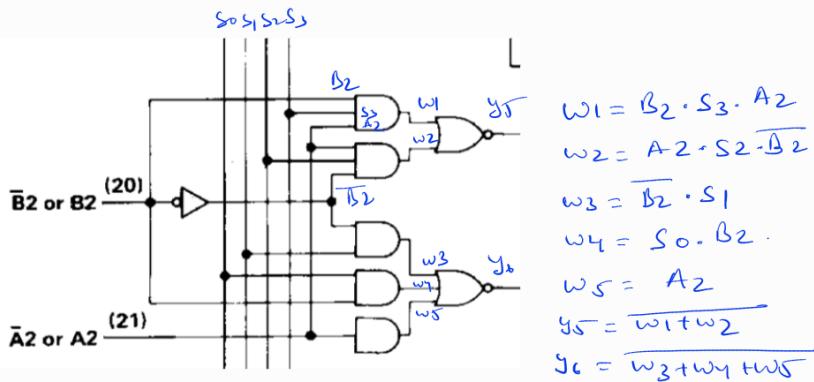
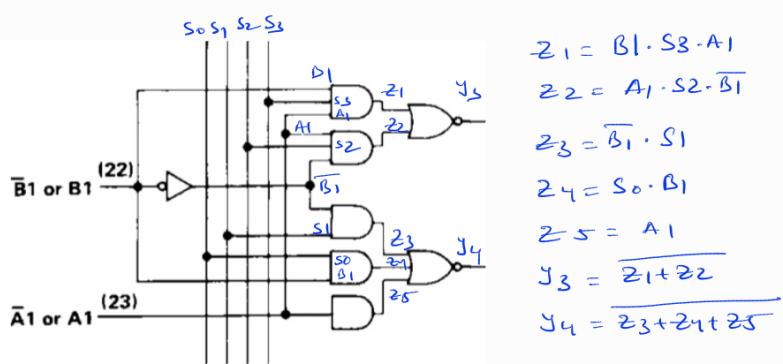
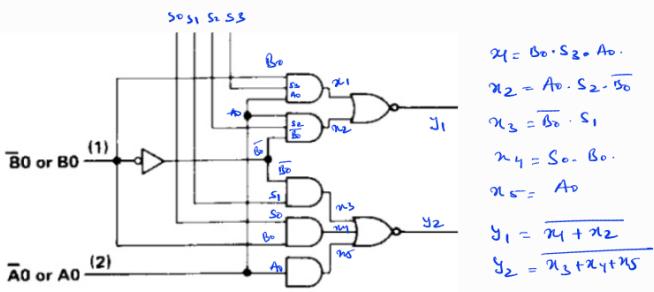


Figure 1: Logic Circuit

total c lct



$$y_1 = \overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \bar{B}_0)}$$

$$y_2 = \overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0}$$

$$y_3 = \overline{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \bar{B}_1)}$$

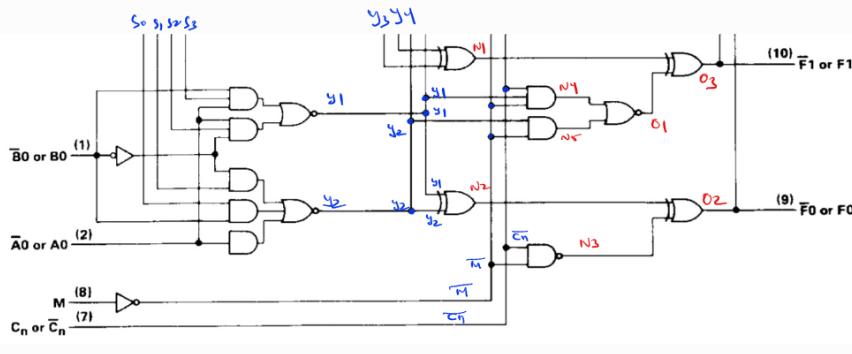
$$y_4 = \overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1}$$

$$y_5 = \overline{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \bar{B}_2)}$$

$$y_6 = \overline{(B_2 \cdot S_1) + (S_0 \cdot B_2) + (A_2)}$$

$$y_7 = \overline{(B_3 \cdot S_3 \cdot A_3) + (A_3 \cdot S_2 \cdot \bar{B}_3)}$$

$$y_8 = \overline{(B_3 \cdot S_1) + (S_0 \cdot B_3) + (A_3)}$$



$$f_1 = O_3 ; \\ F_0 = O_2 ;$$

$$N1 = Y_3 \oplus Y_4$$

$$N2 = Y_1 \oplus Y_2$$

$$N3 = \overline{(C_n \cdot M)}$$

$$N4 = \overline{C_n} \cdot Y_1 \cdot \overline{M}$$

$$N5 = Y_2 \cdot \overline{M}$$

$$O_1 = \overline{N4 + N5} = \overline{(\overline{C_n} \cdot Y_1 \cdot \overline{M}) + (\overline{Y_2} \cdot \overline{M})}$$

$$O_2 = N2 \oplus N3 = (Y_1 \oplus Y_2) \oplus \overline{(C_n \cdot M)}$$

$$O_3 = O_1 \oplus N1 =$$

$$O_3 = \left(\overline{(C_n \cdot Y_1 \cdot \overline{M}) + (Y_2 \cdot \overline{M})} \right) \oplus (Y_3 \oplus Y_4)$$

$$Y_1 = \overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})}$$

$$Y_2 = \overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0}$$

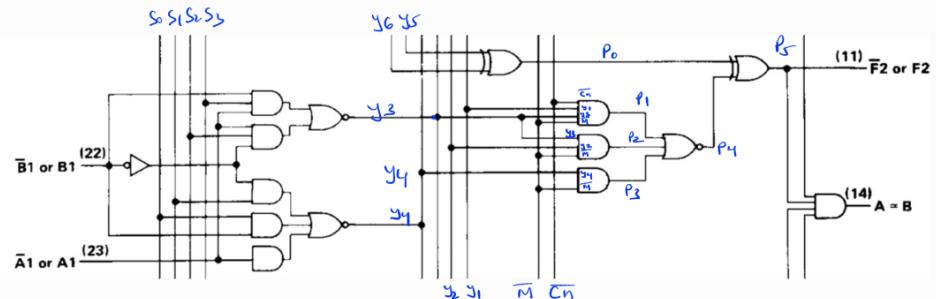
$$Y_3 = \overline{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})}$$

$$Y_4 = \overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1}$$

$$F_0 = O_2 = \left(\overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})} \right) \oplus \left(\overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0} \right) \\ \oplus \left(\overline{(C_n \cdot M)} \right)$$

$$F_1 = O_3 = \left(\overline{(C_n \cdot Y_1 \cdot \overline{M}) + (Y_2 \cdot \overline{M})} \right) \oplus \left(\overline{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})} \right) \oplus \\ \left(\overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1} \right)$$

$$F_1 = O_3 = \left(\overline{C_n} \cdot \left[\overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})} \right] \cdot \overline{M} \right) + \left(\left(\overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0} \right) \cdot \overline{M} \right) \oplus \\ \left(\overline{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})} \right) \oplus \left(\overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1} \right)$$



$$F_2 = P_5$$

$$\textcircled{1} \quad P_0 = Y_6 \oplus Y_5$$

$$\textcircled{2} \quad P_1 = \overline{C_n} \cdot Y_1 \cdot Y_3 \cdot \overline{M}$$

$$\textcircled{3} \quad P_2 = Y_3 \cdot Y_2 \cdot \overline{M}$$

$$\textcircled{4} \quad P_3 = Y_4 \cdot \overline{M}$$

$$\textcircled{5} \quad P_4 = \overline{P_1 + P_2 + P_3}$$

$$\textcircled{6} \quad P_5 = P_0 \oplus P_4$$

$$\textcircled{1} \quad P_0 = \left((\overline{B_2} \cdot S_1) + (S_0 \cdot B_2) + A_2 \right) \oplus \left((\overline{B_2} \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2}) \right)$$

$$\textcircled{2} \quad P_1 = \overline{C_n} \cdot \overline{M} \cdot \left((\overline{B_0} \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0}) \right) \cdot \left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right)$$

$$\textcircled{3} \quad P_2 = \left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right) \cdot \left((\overline{B_0} \cdot S_1) + (S_0 \cdot B_0) + A_0 \right) \cdot \overline{M}$$

$$\textcircled{4} \quad P_3 = \left((\overline{B_1} \cdot S_1) + (S_0 \cdot B_1) + A_1 \right) \cdot \overline{M}$$

$$\textcircled{5} \quad P_4 = \overline{P_1 + P_2 + P_3}$$

$$\textcircled{6} \quad P_5 = P_0 \oplus P_4 = \underline{\underline{F_2}}$$

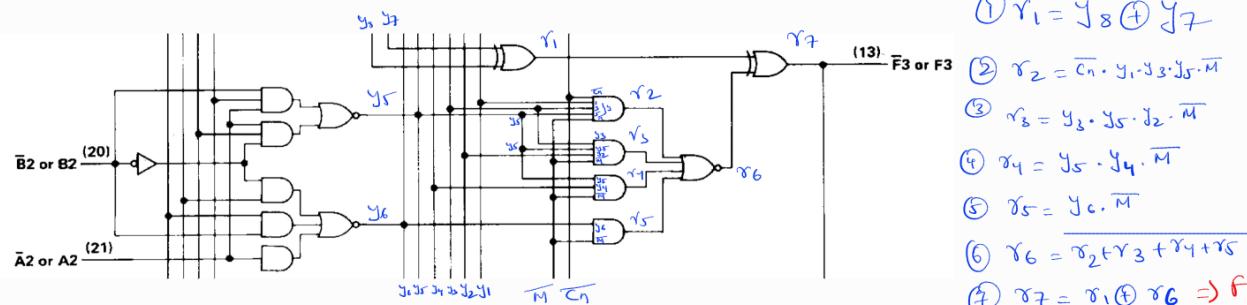
$$P_4 = \left(\overline{C_n} \cdot \overline{M} \cdot \left((\overline{B_0} \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0}) \right) \cdot \left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right) \right) +$$

$$\left(\left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right) \cdot \left((\overline{B_0} \cdot S_1) + (S_0 \cdot B_0) + A_0 \right) \cdot \overline{M} \right) + \left(\left((\overline{B_1} \cdot S_1) + (S_0 \cdot B_1) + A_1 \right) \cdot \overline{M} \right)$$

$$F_2 = \left((\overline{B_2} \cdot S_1) + (S_0 \cdot B_2) + A_2 \right) \oplus \left((\overline{B_2} \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2}) \right) \oplus$$

$$\left(\left(\overline{C_n} \cdot \overline{M} \cdot \left((\overline{B_0} \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0}) \right) \cdot \left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right) \right) + \right.$$

$$\left. \left(\left((\overline{B_1} \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1}) \right) \cdot \left((\overline{B_0} \cdot S_1) + (S_0 \cdot B_0) + A_0 \right) \cdot \overline{M} \right) + \left(\left((\overline{B_1} \cdot S_1) + (S_0 \cdot B_1) + A_1 \right) \cdot \overline{M} \right) \right)$$



$$\textcircled{1} \quad Y_1 = Y_8 \oplus Y_7$$

$$\textcircled{2} \quad Y_2 = \overline{C_n} \cdot Y_1 \cdot Y_3 \cdot Y_5 \cdot \overline{M}$$

$$\textcircled{3} \quad Y_3 = Y_8 \cdot Y_5 \cdot Y_2 \cdot \overline{M}$$

$$\textcircled{4} \quad Y_4 = Y_5 \cdot Y_4 \cdot \overline{M}$$

$$\textcircled{5} \quad Y_5 = Y_4 \cdot \overline{M}$$

$$\textcircled{6} \quad Y_6 = \overline{Y_2 + Y_3 + Y_4 + Y_5}$$

$$\textcircled{7} \quad Y_7 = Y_1 \oplus Y_6 \Rightarrow \underline{\underline{F_3}}$$

$$Y_1 = \overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})}$$

$$Y_2 = \overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0}$$

$$Y_3 = \overline{(S_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})}$$

$$Y_4 = \overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1}$$

$$Y_5 = \overline{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})}$$

$$Y_6 = \overline{(B_2 \cdot S_1) + (S_0 \cdot B_2) + (A_2)}$$

$$Y_7 = \overline{(B_3 \cdot S_3 \cdot A_3) + (A_3 \cdot S_2 \cdot \overline{B_3})}.$$

$$Y_8 = \overline{(B_3 \cdot S_1) + (S_0 \cdot B_3) + (A_3)}.$$

$$\textcircled{1} \quad Y_1 = \overline{(B_3 \cdot S_3 \cdot A_3) + (A_3 \cdot S_2 \cdot \overline{B_3})} \cdot \underline{\underline{+}}$$

$$\overline{(B_3 \cdot S_1) + (S_0 \cdot B_3) + (A_3)}.$$

$$\textcircled{2} \quad Y_2 = \overline{C_n \cdot M} \cdot \left[\begin{array}{l} \overline{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})} \cdot \\ \overline{(S_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})} \cdot \\ \overline{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})} \end{array} \right]$$

$$\textcircled{3} \quad Y_3 = \left[\begin{array}{l} \overline{(S_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})} \cdot \overline{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})} \cdot \\ \overline{(B_0 \cdot S_1) + (S_0 \cdot B_0) + A_0} \end{array} \right] \cdot \overline{M}$$

$$\textcircled{4} \quad Y_4 = \left[\begin{array}{l} \overline{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})} \cdot \overline{(B_1 \cdot S_1) + (S_0 \cdot B_1) + A_1} \\ \overline{M} \end{array} \right].$$

$$\textcircled{5} \quad Y_5 = \left[\begin{array}{l} \overline{(B_2 \cdot S_1) + (S_0 \cdot B_2) + (A_2)} \end{array} \right] \cdot \overline{M}$$

$$\textcircled{6} \quad Y_6 = \overline{Y_2 + Y_3 + Y_4 + Y_5}$$

$$\gamma_6 =$$

$$\gamma_2$$

$$\left[\overline{C_n} \cdot \overline{M} \cdot \left[\frac{(B_0 \cdot S_3 \cdot A_0) + (A_0 \cdot S_2 \cdot \overline{B_0})}{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})} \cdot \frac{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})}{(\overline{B_0} \cdot S_1) + (S_0 \cdot B_0) + A_0} \right] \right] +$$
$$\gamma_3$$
$$\left[\frac{(B_1 \cdot S_3 \cdot A_1) + (A_1 \cdot S_2 \cdot \overline{B_1})}{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})} \cdot \frac{(\overline{B_0} \cdot S_1) + (S_0 \cdot B_0) + A_0}{\overline{M}} \right]$$
$$+ \left[\left[\frac{(B_2 \cdot S_3 \cdot A_2) + (A_2 \cdot S_2 \cdot \overline{B_2})}{(\overline{B_1} \cdot S_1) + (S_0 \cdot B_1) + A_1} \right] \cdot \overline{M} \right] +$$
$$\gamma_4$$
$$\left[\left[\frac{(\overline{B_2} \cdot S_1) + (S_0 \cdot B_2) + (A_2)}{\overline{M}} \right] \cdot \overline{M} \right]$$
$$\gamma_5$$

$$\gamma_6 = \frac{\gamma_2 + \gamma_3 + \gamma_4 + \gamma_5}{\gamma_1} .$$

$$F_3 = \gamma_1 \oplus \gamma_6$$

$$\left[\frac{(\overline{B_3} \cdot S_3 \cdot A_3) + (A_3 \cdot S_2 \cdot \overline{B_3})}{(\overline{B_3} \cdot S_1) + (S_0 \cdot B_3) + (A_3)} \right] \oplus \gamma_6$$

2 Output of ROBDD Implementation for F0, F1, F2, F3.

2.1 Problem Statement

For the implementation of the ALU illustrated on page 5 from the data sheet, construct the implementation-ROBDD for each of the outputs F3, F2, F1, F0 in terms of all the inputs to the ALU: the A inputs, the B inputs, the S inputs, Cn and M.

Solution:

Based on the outlined problem i have written c program based on the output equations which were written from the circuit diagram and printed the F0, F1, F2, F3 ROBDD diagrams.

```

-----ROBDD of the ALU 7418-----
-----F0-----
if var.0
  if var.1
    if var.11
      0: if var.12
        1
        else if lvar.12
          var.13
        endif var.12
      else if lvar.11
        !subformula 0
      endif var.11
    else if lvar.1
      if var.10
        !subformula 0
      else if lvar.10
        !subformula 0
      endif var.10
    endif var.1
  else if lvar.0
    if var.1
      if var.8
        !subformula 0
      else if lvar.8
        !subformula 0
      endif var.8
    else if lvar.1
      if var.10
        !subformula 0
      else if lvar.10
        !subformula 0
      endif var.10
    endif var.1
  endif var.0
-----F1-----
if var.0
  if var.1
    if var.2
      if var.3
        if var.11
          1
          else if lvar.11
            0
            else if lvar.12
              var.13
            endif var.12
          endif var.11
        else if lvar.3
          if var.10
            1: if var.11
              0
              else if lvar.11
                !subformula 0
              else if lvar.11
                !subformula 0
              endif var.11
            endif var.11
          endif var.10
        else if lvar.3
          if var.10
            1
            else if lvar.10
              2: if var.11
                !subformula 0
              else if lvar.11
                !subformula 0
              endif var.11
            endif var.11
          endif var.10
        else if lvar.3
          if var.10
            1
            else if lvar.10
              3: if var.11
                0
                else if lvar.11
                  !subformula 0
                else if lvar.11
                  !subformula 0
                endif var.11
              endif var.11
            endif var.10
          endif var.10
        else if lvar.3
          if var.9
            !subformula 3
          endif var.9
        else if lvar.2
          if var.3
            if var.8
              !subformula 2
            else if lvar.8
              !subformula 2
            endif var.8
          endif var.3
        else if lvar.1
          if var.9
            !subformula 4
          endif var.9
        else if lvar.0
          1: if var.11
            0
            else if lvar.11
              !subformula 0
            endif var.11
          endif var.11
        endif var.0
-----F2-----
if var.0
  if var.1
    if var.2
      if var.3
        if var.4
          if var.5
            0: if var.11
              1
              else if lvar.11
                !subformula 0
              1: if var.12
                0
                else if lvar.12
                  !var.13
                endif var.12
              endif var.11
            endif var.11
          endif var.4
        endif var.5
      endif var.4
    endif var.5
  endif var.4
  if var.3
    if var.2
      if var.1
        if var.0
          10: if var.11
            1
            else if lvar.11
              1: if var.12
                0
                else if lvar.12
                  !var.13
                endif var.12
              endif var.11
            endif var.11
          endif var.0
        endif var.9
        !subformula 3
      else if lvar.9
        var.13
      endif var.9
    else if lvar.8
      !subformula 10
    endif var.8
  endif var.5
  if var.4
    if var.3
      if var.2
        if var.1
          if var.0
            10: if var.9
              !subformula 3
            else if lvar.9
              var.13
            endif var.9
          endif var.9
        endif var.8
      else if lvar.5
        !subformula 3
      else if lvar.4
        if var.5
          14: if var.10
            6
            else if lvar.10
              !subformula 3
            else if lvar.10
              !subformula 3
            endif var.10
          endif var.5
        endif var.5
      else if lvar.4
        if var.5
          14: if var.10
            6
            else if lvar.10
              !subformula 14
            else if lvar.10
              !subformula 14
            endif var.10
          endif var.5
        endif var.5
      else if lvar.3
        if var.2
          if var.1
            if var.0
              15: if var.9
                !subformula 14
              else if lvar.9
                !subformula 14
              endif var.9
            endif var.9
          endif var.8
        endif var.3
      else if lvar.2
        if var.1
          if var.0
            15: if var.9
              !subformula 14
              !subformula 11
              else if lvar.8
                !subformula 11
              else if lvar.8
                !subformula 7
              endif var.8
            endif var.8
          endif var.5
        endif var.5
      else if lvar.1
        if var.0
          16: if var.9
            !subformula 14
            !subformula 14
            else if lvar.9
              !var.13
            endif var.9
          endif var.9
        endif var.8
      else if lvar.0
        if var.1
          if var.0
            17: if var.11
              !var.13
              !subformula 16
            endif var.11
          endif var.9
        endif var.5
      endif var.4
    endif var.5
  endif var.4
  if var.3
    if var.2
      if var.1
        if var.0
          11: if var.10
            11: if var.11
              1
              else if lvar.11
                !subformula 14
              else if lvar.10
                !var.13
              endif var.8
            endif var.8
          endif var.5
        endif var.4
      endif var.5
    endif var.4
  endif var.3
  if var.2
    if var.1
      if var.0
        12: if var.11
          !subformula 1
          !subformula 11
          !subformula 1
        endif var.11
      endif var.10
    endif var.5
  endif var.10
  if var.1
    if var.0
      13: if var.10
        1
        else if lvar.10
          !var.13
        endif var.8
      endif var.5
    endif var.4
  endif var.3
endif var.0

```

```

subformula 2
else if lvar.8
18: if var.10
19: if var.11
    else if lvar.11
        var.13
    endif var.11
    else if lvar.10
        !subformula 19
    endif var.10
endif var.8
endif var.5
else if lvar.4
if var.8
    if var.8
        !subformula 3
    else if lvar.8
        subformula 19
    endif var.8
else if var.5
    if var.8
        subformula 4
    else if lvar.8
        if var.9
            !subformula 19
        else if lvar.9
            subformula 19
        endif var.9
        endif var.8
    endif var.5
endif var.8
endif var.5
else if lvar.3
if var.4
    if var.5
        if var.8
            subformula 11
        else if lvar.8
            20: if var.10
                var.11
            else if lvar.10
                subformula 7
            endif var.10
        endif var.8
    else if lvar.5
        if var.8
            subformula 12
        else if lvar.8
            subformula 7
        endif var.8
    endif var.5
else if lvar.4
    if var.8
        subformula 13
    else if lvar.8
        21: if var.10
            var.13
        else if lvar.10
            !var.13
        endif var.10
    endif var.8
endif var.8

```

```

endifif var.5
endifif var.4
endifif var.3
endifif var.2
else if lvar.1
if var.2
if var.3
    if var.4
        if var.5
            if var.9
                subformula 8
            else if lvar.9
                subformula 17
            endif var.9
        else if lvar.5
            if var.9
                subformula 2
            else if lvar.9
                subformula 18
            endif var.9
        endif var.5
    else if lvar.4
        if var.5
            if var.8
                29: if var.9
                    !subformula 3
            else if lvar.9
                !subformula 19
            endif var.9
        else if lvar.8
            !subformula 29
        endif var.8
    else if lvar.5
        if var.9
            !subformula 3
        else if lvar.9
            subformula 19
        endif var.9
    endif var.5
endif if lvar.4
else if lvar.3
if var.4
    if var.8
        29: if var.9
            !subformula 3
    else if lvar.9
        !subformula 19
    endif var.9
    else if lvar.8
        !subformula 29
    endif var.8
else if lvar.5
    if var.9
        !subformula 3
    else if lvar.9
        subformula 19
    endif var.9
endifif var.5
endifif var.4
else if lvar.3
if var.4
    if var.5
        if var.9
            !subformula 11
        else if lvar.9
            subformula 20
        endif var.9
    else if lvar.5
        if var.9
            !subformula 13
        else if lvar.9
            subformula 21
        endif var.9
    endif var.5
endif var.9
-----F3-----
if var.0
    if var.10
        var.13
    endif var.9
endifif var.8
endifif var.7
endifif var.6
else if lvar.5
14: if var.6
    if var.7
        15: if var.9
            subformula 0
        else if lvar.9
            subformula 11
        endif var.9
    else if lvar.7
        16: if var.9
            subformula 2
        else if lvar.9
            subformula 12
        endif var.9
    endif var.7
    else if var.6
        if var.7
            17: if var.9
                subformula 0
            else if lvar.9
                subformula 11
            endif var.9
        else if lvar.7
            18: if var.9
                !subformula 3
            else if lvar.9
                !var.13
            endif var.9
        else if lvar.8
            19: if var.9
                !subformula 3
            else if lvar.9
                !var.13
            endif var.9
        endif var.8
    endif var.7
    else if lvar.6
        if var.7
            20: if var.9
                subformula 8
            else if lvar.9
                subformula 12
            endif var.9
        else if lvar.8
            21: if var.9
                !subformula 8
            else if lvar.9
                !var.13
            endif var.9
        endif var.8
    endif var.7
    else if lvar.5
        if var.7
            22: if var.9
                subformula 1
            else if lvar.9
                !subformula 1
            endif var.9
        else if lvar.4
            23: if var.9
                subformula 12
            else if lvar.9
                !subformula 7
            endif var.9
        else if lvar.3
            24: if var.4
                if var.5
                    if var.8
                        25: if var.9
                            subformula 13
                        else if lvar.9
                            !subformula 7
                        endif var.9
                    else if lvar.8
                        subformula 7
                    endif var.8
                else if lvar.5
                    if var.8
                        26: if var.9
                            subformula 23
                        else if lvar.9
                            !subformula 8
                        endif var.9
                    else if lvar.8
                        subformula 8
                    endif var.8
                endif var.5
            else if var.4
                if var.8
                    27: if var.9
                        subformula 1
                    else if lvar.9
                        !var.13
                    endif var.9
                else if lvar.8
                    subformula 8
                endif var.8
            endif var.5
        else if var.4
            if var.8
                28: if var.9
                    subformula 1
                else if lvar.9
                    !var.13
                endif var.9
            else if lvar.8
                subformula 9
            endif var.8

```

```

if var.7
    if var.11
        1: if var.12
            0
        else if lvar.12
            !var.13
        endif var.12
    else if lvar.7
        2: if var.10
            3: if var.11
                1
            else if lvar.11
                !subformula 1
            endif var.11
            else if lvar.10
                !subformula 3
            endif var.10
        endif var.7
    else if lvar.6
        if var.7
            4: if var.8
                !subformula 3
            else if lvar.8
                subformula 3
            endif var.8
            else if lvar.7
                !subformula 3
            else if lvar.6
                !subformula 6
            endif var.6
        endif var.7
-----F4-----
if var.0
    if var.10
        var.13
    endif var.9
endifif var.8
endifif var.7
endifif var.6
else if lvar.5
14: if var.6
    if var.7
        15: if var.9
            subformula 0
        else if lvar.9
            subformula 11
        endif var.9
    else if lvar.7
        16: if var.9
            subformula 2
        else if lvar.9
            subformula 12
        endif var.9
    endif var.7
    else if var.6
        if var.7
            17: if var.9
                subformula 0
            else if lvar.9
                subformula 11
            endif var.9
        else if lvar.7
            18: if var.9
                !subformula 3
            else if lvar.9
                !var.13
            endif var.9
        else if lvar.8
            19: if var.9
                !subformula 3
            else if lvar.9
                !var.13
            endif var.9
        endif var.8
    endif var.7
    else if lvar.6
        if var.7
            20: if var.9
                subformula 8
            else if lvar.9
                subformula 12
            endif var.9
        else if lvar.8
            21: if var.9
                !subformula 8
            else if lvar.9
                !var.13
            endif var.9
        endif var.8
    endif var.7
    else if lvar.5
        if var.7
            22: if var.9
                subformula 1
            else if lvar.9
                !subformula 1
            endif var.9
        else if lvar.4
            23: if var.4
                if var.5
                    if var.8
                        24: if var.9
                            subformula 6
                        else if lvar.9
                            subformula 11
                        endif var.9
                    else if lvar.7
                        25: if var.9
                            subformula 8
                        else if lvar.9
                            !var.13
                        endif var.9
                    endif var.8
                else if lvar.3
                    26: if var.4
                        if var.5
                            27: if var.9
                                subformula 12
                            else if lvar.9
                                !subformula 20
                            endif var.9
                        endif var.5
                    else if lvar.3
                        28: if var.4
                            if var.5
                                29: if var.9
                                    subformula 9
                                else if lvar.9
                                    !var.13
                                endif var.9
                            endif var.5
                        else if lvar.3
                            30: if var.4
                                if var.5
                                    31: if var.9
                                        subformula 14
                                    else if lvar.9
                                        !subformula 1
                                    endif var.9
                                else if lvar.8
                                    !subformula 30
                                endif var.8
                            endif var.5
                        else if lvar.4
                            if var.5
                                32: if var.9
                                    subformula 14
                                else if lvar.9
                                    subformula 22
                                endif var.9
                            else if lvar.8
                                !subformula 30
                            endif var.8
                        endif var.5
                    else if lvar.3
                        if var.8
                            33: if var.9
                                subformula 14
                            else if lvar.9
                                subformula 22
                            endif var.9
                        else if lvar.8
                            !subformula 30
                        endif var.8
                    endif var.5
                endif var.4
            else if var.3
                34: if var.4
                    if var.5
                        35: if var.9
                            subformula 14
                        else if lvar.9
                            !subformula 3
                        endif var.9
                    else if lvar.8
                        subformula 3
                    endif var.8
                endif var.5
            else if lvar.2
                if var.3
                    36: if var.4
                        if var.5
                            37: if var.9
                                subformula 14
                            else if lvar.9
                                !subformula 3
                            endif var.9
                        else if lvar.8
                            subformula 3
                        endif var.8
                    endif var.5
                endif var.3
            else if lvar.1
                if var.2
                    38: if var.3
                        if var.4
                            39: if var.5
                                if var.6
                                    40: if var.7
                                        41: if var.8
                                            42: if var.9
                                                43: if var.10
                                                    44: if var.11
                                                        45: if var.12
                                                            46: if var.13
                                                                47: if var.14
                                                                    48: if var.15
                                                                        49: if var.16
                                                                            50: if var.17
                                                                                51: if var.18
                                                                                    52: if var.19
                                                                                        53: if var.20
                                                                                            54: if var.21
                                                                                                55: if var.22
                                                                                                    56: if var.23
                                                                                                        57: if var.24
                                            else if lvar.8
                                                !subformula 27
                                            endif var.8
                                        else if lvar.7
                                            !subformula 28
                                        endif var.7
                                    else if lvar.6
                                        !subformula 28
                                    endif var.6
                                else if lvar.5
                                    !subformula 28
                                endif var.5
                            else if lvar.4
                                !subformula 28
                            endif var.4
                        else if lvar.3
                            !subformula 28
                        endif var.3
                    else if lvar.2
                        !subformula 28
                    endif var.2
                else if lvar.1
                    !subformula 28
                endif var.1
            endif var.0
        endif var.1
    endif var.0

```

```

        endif var.7
    endif var.6
    endif var.5
    endif var.4
    endif var.3
    else if var.2
    else if var.3
    if var.4
        if var.5
            21: if var.6
                if var.7
                    if var.8
                        subformula 6
                    else if var.8
                        22: if var.11
                            if var.9
                                if var.10
                                    23: if var.10
                                        24: if var.11
                                            1
                                            else if var.11
                                                var.13
                                            endif var.11
                                            endif var.8
                                        else if var.7
                                            subformula 2
                                        else if var.8
                                            23: if var.10
                                                24: if var.11
                                                    1
                                                    else if var.11
                                                        var.13
                                                    endif var.11
                                                    else if var.10
                                                        25: if var.9
                                                            1subformula 24
                                                        endif var.8
                                                    else if var.7
                                                        25: if var.9
                                                            1subformula 24
                                                        endif var.9
                                                    endif var.8
                                                endif var.7
                                            endif var.6
                                        else if var.7
                                            if var.8
                                                1subformula 3
                                            else if var.8
                                                subformula 24
                                            endif var.8
                                        else if var.7
                                            25: if var.9
                                                1subformula 24
                                            endif var.9
                                        endif var.8
                                    endif var.7
                                endif var.6
                            endif var.5
                            26: if var.10
                                var.11
                                else if var.10
                                    27: if var.11
                                        28: if var.10
                                            1
                                            else if var.10
                                                var.13
                                            else if var.10
                                                29: if var.9
                                                    1subformula 28
                                                    else if var.9
                                                        30: if var.5
                                                    endif var.9
                                                endif var.7
                                            endif var.6
                                        endif var.5
                                    endif var.7
                                endif var.6
                            endif var.5
                            29: if var.9
                                1subformula 28
                                else if var.9
                                    30: if var.5
                                endif var.9
                            endif var.7
                        endif var.6
                    endif var.5
                endif var.4
                31: if var.5
                    32: if var.6
                        33: if var.9
                            subformula 0
                        else if var.9
                            subformula 22
                        endif var.9
                    else if var.7
                        33: if var.9
                            subformula 2
                        else if var.9
                            subformula 23
                        endif var.9
                    endif var.7
                endif var.6
            endif var.5
        endif var.4
        34: if var.9
            1subformula 3
        else if var.9
            1subformula 24
        endif var.9
    endif if var.8
endifif var.6

```



```

        else if var.1
        if var.2
            if var.3
                subformula 19
            else if var.3
                if var.4
                    if var.5
                        subformula 5
                    else if var.5
                        if var.6
                            if var.7
                                37: if var.10
                                    var.11
                                else if var.10
                                    38: if var.11
                                        1subformula 1
                                        else if var.11
                                            subformula 1
                                            endif var.11
                                        endif var.10
                                    else if var.7
                                        39: if var.10
                                            1
                                            else if var.10
                                                subformula 1
                                                endif var.10
                                            endif var.7
                                        endif var.6
                                    else if var.6
                                        40: if var.10
                                            0
                                            else if var.10
                                                subformula 1
                                                endif var.10
                                            else if var.8
                                                1subformula 40
                                                endif var.8
                                            endif var.9
                                            41: if var.9
                                                subformula 1
                                                endif var.9
                                            else if var.8
                                                1subformula 40
                                                endif var.8
                                            endif var.9
                                            42: if var.9
                                                43: if var.6
                                                if var.7
                                                    if var.8
                                                        subformula 37
                                                    else if var.8

```



```

            endif var.7
            endif var.6
        endif var.5
    endif if var.4
    44: if var.9
        45: if var.9
            46: if var.9
                subformula 40
            else if var.9
                var.13
            endif var.8
        else if var.7
            45: if var.9
                subformula 39
            else if var.9
                subformula 12
            endif var.8
        endif var.7
    endif if var.6
    46: if var.8
        47: if var.9
            subformula 48
        else if var.9
            48: if var.6
                if var.7
                    if var.8
                        subformula 30
                    else if var.8
                        subformula 14
                    endif var.8
                endif var.4
            endif var.3
        endif var.2
    endif if var.1

```



```

        endif var.7
        endif var.6
        endif var.5
        endif var.4
        endif var.3
        endif var.2
        if var.3
            if var.4
                if var.5
                    if var.6
                        if var.7
                            if var.8
                                subformula 6
                            else if var.8
                                subformula 22
                            endif var.8
                        else if var.7
                            if var.8
                                subformula 7
                            else if var.8
                                subformula 23
                            endif var.8
                        else if var.7
                            if var.8
                                subformula 9
                            else if var.8
                                subformula 25
                            endif var.8
                        else if var.7
                            if var.8
                                subformula 8
                            else if var.8
                                subformula 24
                            endif var.8
                        else if var.7
                            if var.8
                                subformula 9
                            else if var.8
                                subformula 25
                            endif var.8
                        endif var.7
                    endif var.6
                endif var.5
            endif var.4
            49: if var.6
                if var.7
                    if var.8
                        subformula 44
                    else if var.8
                        subformula 11
                    endif var.8
                else if var.7
                    if var.8
                        subformula 45
                    else if var.8
                        subformula 12
                    endif var.8
                else if var.7
                    if var.8
                        subformula 45
                    else if var.8
                        subformula 12
                    endif var.8
                endif var.7
            endif var.6
        endif var.5
        50: if var.5
            if var.6
                if var.7
                    if var.8
                        subformula 24
                    else if var.8
                        subformula 50
                    endif var.8
                else if var.7
                    if var.8
                        subformula 24
                    else if var.8
                        subformula 50
                    endif var.8
                endif var.7
            endif var.6
        endif var.5
        51: if var.6
            if var.7
                if var.8
                    subformula 37
                else if var.8
                    subformula 26
                endif var.8
            else if var.7
                if var.8
                    subformula 39
                else if var.8
                    subformula 27
                endif var.8
            endif var.7
        endif var.6
    endif if var.5
    52: if var.5
        if var.6
            if var.7
                if var.8
                    subformula 39
                else if var.8
                    subformula 27
                endif var.8
            else if var.7
                if var.8
                    subformula 39
                else if var.8
                    subformula 27
                endif var.8
            endif var.7
        endif var.6
    endif if var.5
    53: if var.9
        subformula 37
    else if var.9
        subformula 26
    endif var.9
    54: if var.8
        subformula 40
    else if var.8
        subformula 40
    endif var.8
endifif var.8

```

```

else if !var.9
    !subformula 28
endif var.9
endif var.8
else if !var.8
    !subformula 54
endif var.8
endif var.7
55: if var.9
    !subformula 40
else if !var.9
    !subformula 53
endif var.9
endif var.7
endif var.6
endif var.5
else if !var.4
    !subformula 49
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
else if !var.0
    !subformula 43
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.1
    !subformula 10
else if !var.1
    !subformula 5
endif var.2
if var.2
    !subformula 43
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.1
    !subformula 59
else if !var.1
    !subformula 58
endif var.1
endif var.0
if var.8
    !subformula 59
else if !var.8
    !subformula 58
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.5
    !subformula 59
else if !var.5
    !subformula 58
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.8
    !subformula 15
else if !var.8
    !subformula 14
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.8
    !subformula 22
else if !var.8
    !subformula 21
endif var.8
endif var.7
if var.8
    !subformula 7
else if !var.8
    !subformula 6
endif var.8
56: if var.10
    !subformula 20
else if !var.10
    !subformula 22
endif var.10
endif var.8
else if !var.7
    !subformula 23
endif var.8
endif var.7
57: if var.10
    !subformula 11
else if !var.10
    !subformula 12
endif var.9
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.8
    !subformula 16
else if !var.8
    !subformula 15
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.9
    !subformula 27
else if !var.9
    !subformula 26
endif var.9
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.9
    !subformula 44
else if !var.9
    !subformula 43
endif var.9
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.9
    !subformula 11
else if !var.9
    !subformula 10
endif var.9
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
if var.9
    !subformula 45
else if !var.9
    !subformula 44
endif var.9
endif var.8
endif var.7
endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0

```

```

        endif var.7
    else if lvar.6
        if var.7
            if var.8
                subformula 46
            else if lvar.8
                if var.9
                    subformula 28
                else if lvar.9
                    var.10
                endif var.9
            endif var.8
        endif var.7
    endif var.6
    else if lvar.7
        if var.8
            subformula 47
        else if lvar.8
            if var.9
                !subformula 28
            else if lvar.9
                var.10
            endif var.9
        endif var.8
    endif var.7
    endif var.6
    else if lvar.5
        if var.6
            endif var.4
        endif var.3
    else if lvar.2
        if var.3
            if var.4
                if var.5
                    subformula 21
                else if lvar.5
                    subformula 48
                endif var.5
            else if lvar.4
                if var.5
                    if var.6
                        if var.7
                            if var.8
                                subformula 38
                            else if lvar.8
                                subformula 11
                            endif var.8
                        else if lvar.7
                            if var.8
                                62; if var.9
                                    subformula 38
                                else if lvar.9
                                    subformula 11
                                endif var.9
                            else if lvar.8
                                subformula 11
                            endif var.8
                        else if lvar.7
                            if var.8
                                63; if var.9
                                    subformula 60
                                else if lvar.9
                                    subformula 12
                                endif var.9
                            else if lvar.8
                                subformula 12
                            endif var.8
                        endif var.7
                    else if lvar.6
                        if var.7
                            if var.8
                                64; if var.9
                                    subformula 1
                                else if lvar.9
                                    lvar.13
                                endif var.9
                            else if lvar.8
                                var.13
                            endif var.8
                        endif var.7
                    endif var.6
                endif var.5
            endif var.4
        endif var.3
    endif var.2
    else if lvar.1
        subformula 1
    endif var.10
    else if lvar.10
        subformula 1
    endif var.10
    else if lvar.8
        subformula 12
    endif var.8
endif var.8

```

```

else if lvar.7
  if var.8
    subformula 53
  else if lvar.8
    subformula 27
  endif var.8
endif var.7
else if lvar.6
  if var.7
    if var.8
      subformula 54
    else if lvar.8
      subformula 28
    endif var.8
  else if lvar.7
    if var.8
      subformula 55
    else if lvar.8
      subformula 29
    endif var.8
  endif var.7
endif var.6
endif var.5
else if lvar.4
  subformula 61
endif var.4
endif var.3
endif var.2
else if lvar.1
  if var.2
    if var.3
      if var.4
        if var.5
          subformula 31
        else if lvar.5
          67: if var.6
            if var.7
              if var.9
                subformula 6
              else if lvar.9
                subformula 57
              endif var.9
            else if lvar.7
              if var.9
                subformula 7
              else if lvar.9
                subformula 58
              endif var.9
            endif var.7
          else if lvar.6
            if var.7
              if var.8
                68: if var.9
                  subformula 8
                else if lvar.9
                  subformula 59
                endif var.9
              else if lvar.7
                if var.9
                  subformula 8
                else if lvar.9
                  subformula 59
                endif var.9
              endif var.7
            endif var.6
          endif var.5
        endif var.4
      endif var.3
      if var.4
        if var.5
          subformula 68
        else if lvar.5
          subformula 69
        endif var.5
      endif var.4
    endif var.3
  endif var.2
  else if lvar.1
    if var.2
      if var.3
        if var.4
          if var.5
            subformula 53
          else if lvar.5
            subformula 11
          endif var.8
        else if lvar.7
          if var.8
            subformula 33
          else if lvar.8
            subformula 12
          endif var.8
        endif var.7
      endif var.6
    endif var.5
  endif var.4
  else if lvar.3
    if var.4
      if var.5
        subformula 54
      else if lvar.5
        var.13
      endif var.8
    else if lvar.7
      if var.8
        subformula 55
      else if lvar.8
        subformula 13
      endif var.8
    endif var.7
  endif var.6
endif var.5
endif var.4
else if lvar.3
  if var.2
    if var.3
      if var.4
        if var.5
          subformula 34
        else if lvar.5
          var.12
        endif var.8
      else if lvar.7
        if var.8
          subformula 35
        else if lvar.8
          subformula 13
        endif var.8
      endif var.7
    endif var.6
  endif var.5
  else if lvar.4
    if var.5
      subformula 66
    else if lvar.3
      if var.4
        if var.5
          subformula 31
        else if lvar.5
          subformula 51
        endif var.5
      else if lvar.4
        if var.5
          subformula 61
        else if lvar.5
          var.6
        endif var.6
      endif var.5
    endif var.4
  endif var.3
  else if lvar.2
    if var.3
      if var.4
        if var.5
          subformula 67
        else if lvar.5
          subformula 68
        endif var.5
      endif var.4
    endif var.3
  endif var.2
  else if lvar.1
    if var.2
      if var.3
        if var.4
          if var.5
            subformula 69
          else if lvar.5
            subformula 70
          endif var.5
        endif var.4
      endif var.3
    endif var.2
  endif var.1

```

```
if var.7
    subformula 62
else if lvar.7
    subformula 63
endif var.7
else if var.6
    if var.7
        if var.8
            subformula 64
        else if lvar.8
            subformula 64
        endif var.8
    else if lvar.7
        subformula 65
    endif var.7
    endif var.6
endif var.5
endif var.4
endif var.3
endif var.2
endif var.1
endif var.0
```

3 4 BIT Ripple carry adder ROBDD Implementation

3.1 Problem Statement

Build reference BDDs (one for each output) of the addition operation (using a ripple carry adder, or using a truth-table if you like). These BDD's will be in terms of the A and B variables.

Solution:

For the given problem statement i have written the all the output equations according to the circuit diagram and implemented them with bdd package and generated the ROBDD.

Ripple Carry Adder-Circuit Diagram

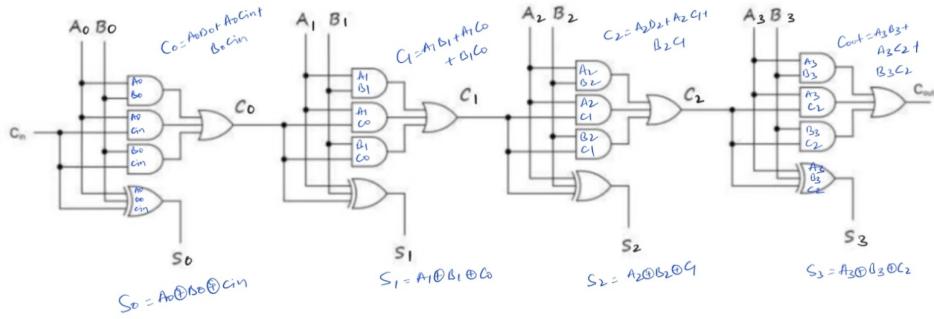


Figure 2: Ripple adder Logic Circuit

```

-----Ripple carry adder ROBDD-----
-----printing sum0-----
if var.0
  !var.1
else if !var.0
  var.1
endif var.0
-----printing sum1-----
if var.0
  if var.1
    0: if var.2
      var.3
    else if !var.2
      !var.3
    endif var.2
  else if !var.1
    !subformula 0
  endif var.1
else if !var.0
  !subformula 0
endif var.0
-----printing sum2-----
if var.0
  if var.1
    if var.2
      0: if var.4
        var.5
      else if !var.4
        !var.5
      endif var.4
    else if !var.2
      1: if var.3
        subformula 0
      else if !var.3
        !subformula 0
      endif var.3
    endif var.2
  else if !var.1
    2: if var.2
      subformula 1
    else if !var.2
      !subformula 0
    endif var.2
  endif var.1
else if !var.0
  subformula 2
endif var.0
-----printing sum3-----
if var.0
  if var.1
    if var.2
      0: if var.4
        1: if var.6

```

```
    var.7
else if !var.6
    !var.7
endif var.6
else if !var.4
    2: if var.5
        subformula 1
    else if !var.5
        !subformula 1
    endif var.5
endif var.4
else if !var.2
    3: if var.3
        subformula 0
    else if !var.3
        4: if var.4
            subformula 2
        else if !var.4
            !subformula 1
        endif var.4
    endif var.3
endif var.2
else if !var.1
    5: if var.2
        subformula 3
    else if !var.2
        subformula 4
    endif var.2
endif var.1
else if !var.0
    subformula 5
endif var.0
```

4 Verification of the $F = A+B$ with Ripple adder ROBDD

4.1 Problem Statement

Restrict the implementation-ROBDDs by choosing the S, Cn and M inputs to select the add operation and check whether the reference and implementation ROBDD's are the same.

Solution:

By selecting the S3=1 ,S2=0, S1=0, S0=1, CIN=0, M=0 the addition operation is selected to check the output we need to compare the robdd with the ripple adder output robdd and printing if F0, F1, F2, F3 matches with sum0,sum1,sum2,sum3 of the ripple adder.

```
1 -----Ripple carry adder-----
2 F0 is Equal with sum0
3 F1 is Equal with sum1
4 F2 is Equal with sum2
5 F3 is Equal with sum3
6 |
```

Figure 3: checking $F = A + B$

```

-----Ripple carry adder ROBDD-----
-----printing sum0-----
if var.0
  !var.1
else if !var.0
  var.1
endif var.0
-----printing sum1-----
if var.0
  if var.1
    0: if var.2
      var.3
    else if !var.2
      !var.3
    endif var.2
  else if !var.1
    !subformula 0
  endif var.1
else if !var.0
  !subformula 0
endif var.0
-----printing sum2-----
if var.0
  if var.1
    if var.2
      0: if var.4
        var.5
      else if !var.4
        !var.5
      endif var.4
    else if !var.2
      1: if var.3
        subformula 0
      else if !var.3
        !subformula 0
      endif var.3
    endif var.2
  else if !var.1
    2: if var.2
      subformula 1
    else if !var.2
      !subformula 0
    endif var.2
  endif var.1
else if !var.0
  subformula 2
endif var.0
-----printing sum3-----
if var.0
  if var.1
    if var.2
      0: if var.4
        1: if var.6

```

```
    var.7
else if !var.6
    !var.7
endif var.6
else if !var.4
    2: if var.5
        subformula 1
    else if !var.5
        !subformula 1
    endif var.5
endif var.4
else if !var.2
    3: if var.3
        subformula 0
    else if !var.3
        4: if var.4
            subformula 2
        else if !var.4
            !subformula 1
        endif var.4
    endif var.3
endif var.2
else if !var.1
    5: if var.2
        subformula 3
    else if !var.2
        subformula 4
    endif var.2
endif var.1
else if !var.0
    subformula 5
endif var.0
```

5 Verification of the $F = A - B$ with Ripple Subtractor ROBDD

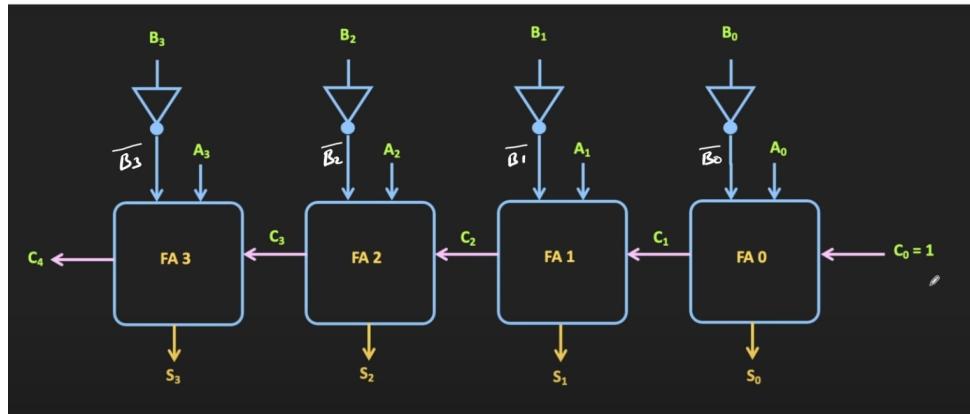
5.1 Problem Statement

Build reference BDDs (one for each output) of the subtraction operation (using a ripple subtractor, or using a truth-table if you like). These BDD's will be in terms of the A and B variables.

Solution:

The ripple carry adder is doing the 2's complement addition which is equals to the subtraction.

By selecting the $S_3=0$, $S_2=1$, $S_1=1$, $S_0=0$, $CIN=1$, $M=0$ the addition operation is selected to check the output we need to compare the robdd with the ripple subtractor output robdd and printing if F_0 , F_1 , F_2 , F_3 matches with $diff_0, diff_1, diff_2, diff_3$ of the ripple subtractor.



$$\begin{aligned}
 C_0 &= Cin \\
 C_1 &= A_0 \bar{B}_0 + A_0 C_0 + \bar{B}_0 C_0 \\
 C_2 &= A_1 \bar{B}_1 + A_1 \bar{B}_1 + \bar{B}_1 C_1 \\
 C_3 &= A_2 \bar{B}_2 + A_2 \bar{B}_2 + \bar{B}_2 A_2 \\
 C_4 &= A_3 \bar{B}_3 + A_3 \bar{B}_3 + A_3 \bar{B}_3
 \end{aligned}$$

$$\begin{aligned}
 S_0 &= A_0 \oplus \bar{B}_0 \oplus C_0 \\
 S_1 &= A_1 \oplus \bar{B}_1 \oplus C_1 \\
 S_2 &= A_2 \oplus \bar{B}_2 \oplus C_2 \\
 S_3 &= A_3 \oplus \bar{B}_3 \oplus C_3
 \end{aligned}$$

Figure 4: circuit diagram of ripple subtractor

```

1 -----Ripple borrow subtractor-----
2 F0 is Equal with diff0
3 F1 is Equal with diff1
4 F2 is Equal with diff2
5 F3 is Equal with diff3
6

```

Figure 5: checking $F = A - B$

```

-----Ripple borrow subtractor-----
-----printing diff0-----
if var.0
  !var.1
else if !var.0
  var.1
endif var.0
-----printing diff1-----
if var.0
  0: if var.2
    !var.3
  else if !var.2
    var.3
  endif var.2
else if !var.0
  if var.1
    !subformula 0
  else if !var.1
    subformula 0
  endif var.1
endif var.0
-----printing diff2-----
if var.0
  0: if var.2
    1: if var.4
      !var.5
    else if !var.4
      var.5
    endif var.4
  else if !var.2
    2: if var.3
      !subformula 1
    else if !var.3
      subformula 1
    endif var.3
  endif var.2
else if !var.0
  if var.1
    if var.2
      subformula 2
    else if !var.2
      !subformula 1
    endif var.2
  else if !var.1
    subformula 0
  endif var.1
endif var.0
-----printing diff3-----
if var.0
  0: if var.2
    1: if var.4
      2: if var.6
        !var.7
      else if !var.6

```

```
    var.7
  endif var.6
else if !var.4
  3: if var.5
    !subformula 2
  else if !var.5
    subformula 2
  endif var.5
  endif var.4
else if !var.2
  4: if var.3
    5: if var.4
      subformula 3
    else if !var.4
      !subformula 2
    endif var.4
  else if !var.3
    subformula 1
  endif var.3
  endif var.2
else if !var.0
  if var.1
    if var.2
      subformula 4
    else if !var.2
      subformula 5
    endif var.2
  else if !var.1
    subformula 0
  endif var.1
endif var.0
```

6 Verification of the $F = A \cdot B$ with ALU ROBDD

For the given problem statement we need to use the ‘bdd_and‘ function to AND all the A and B inputs and checking with the ALU output $F=F_0,F_1,F_2,F_3$.

```
1 -----F = A . B-----
2 F0 is Equal with A0.B0
3 F1 is Equal with A1.B1
4 F2 is Equal with A2.B2
5 F3 is Equal with A3.B3
6 |
```

Figure 6: checking $F = A \cdot B$

7 C code

```

1 #include <stdlib.h>
2 #include <stdio.h>
3 #include <bdduser.h>
4
5 int main (int argc, char* argv[])
6 {
7     bdd_manager bddm = bdd_init();
8
9     // make 8 variables A0,B0,A1,B1,A2,B2,A3,B3,S0,S1,S2,S3,cin,M (in that order)
10    bdd A0 = bdd_new_var_last(bddm);
11    bdd B0 = bdd_new_var_last(bddm);
12    bdd A1 = bdd_new_var_last(bddm);
13    bdd B1 = bdd_new_var_last(bddm);
14    bdd A2 = bdd_new_var_last(bddm);
15    bdd B2 = bdd_new_var_last(bddm);
16    bdd A3 = bdd_new_var_last(bddm);
17    bdd B3 = bdd_new_var_last(bddm);
18    bdd S0 = bdd_new_var_last(bddm);
19    bdd S1 = bdd_new_var_last(bddm);
20    bdd S2 = bdd_new_var_last(bddm);
21    bdd S3 = bdd_new_var_last(bddm);
22    bdd cin = bdd_new_var_last(bddm);
23    bdd M = bdd_new_var_last(bddm);
24    // bdd bB0 = bdd_new_var_last(bddm);
25    // bdd bB1 = bdd_new_var_last(bddm);
26    // bdd bB2 = bdd_new_var_last(bddm);
27    // bdd bB3 = bdd_new_var_last(bddm);
28    // bdd bcin = bdd_new_var_last(bddm);
29    // bdd bM = bdd_new_var_last(bddm);
30
31     //selection line
32
33             // F = A + B
34
35     S0 = bdd_one(bddm); // Assigning constant 1 to S0
36     S1 = bdd_zero(bddm); // Assigning constant 0 to S1
37     S2 = bdd_zero(bddm); // Assigning constant 0 to S2
38     S3 = bdd_one(bddm); // Assigning constant 1 to S3
39     cin = bdd_zero(bddm); // Assigning constant 0 to cin

```

```

40 M = bdd_zero(bddm); // Assigning constant 0 to M
41
42 // F = A - B
43
44 S0 = bdd_zero(bddm); // Assigning constant 0 to S0
45 S1 = bdd_one(bddm); // Assigning constant 1 to S1
46 S2 = bdd_one(bddm); // Assigning constant 1 to S2
47 S3 = bdd_zero(bddm); // Assigning constant 0 to S3
48 cin = bdd_one(bddm); // Assigning constant 1 to cin
49 M = bdd_zero(bddm); // Assigning constant 0 to M
50
51 //F = A . B
52
53 S0 = bdd_one(bddm); // Assigning constant 1 to S0
54 S1 = bdd_one(bddm); // Assigning constant 1 to S1
55 S2 = bdd_zero(bddm); // Assigning constant 0 to S2
56 S3 = bdd_one(bddm); // Assigning constant 1 to S3
57 cin = bdd_one(bddm); // Assigning constant 1 to cin
58 M = bdd_zero(bddm); // Assigning constant 0 to M
59
60
61 //internal complement operations
62 bdd bB0 = bdd_not(bddm,B0);
63 bdd bB1 = bdd_not(bddm,B1);
64 bdd bB2 = bdd_not(bddm,B2);
65 bdd bB3 = bdd_not(bddm,B3);
66 bdd bcin = bdd_not(bddm,cin);
67 bdd bM = bdd_not(bddm,M);
68
69 // compute F0 = ~((B0.S3.A0)+(A0.S2.^~(B0)))^(~(~(B0).S1)+(S0.B0)+A0))^(~(bcin)
70 .^~(bM))
71
72 //and operation
73 bdd a0 = bdd_and (bddm,B0,S3);
74 bdd b0 = bdd_and (bddm,a0,A0); // (B0.S3.A0) result
75 bdd c0 = bdd_and (bddm,A0,S2);
76 bdd d0 = bdd_and (bddm,c0,bB0); // (A0.S2.bB0) result
77
78 bdd e0 = bdd_and (bddm,bB0,S1); // ~(B0).S1)
79 bdd f0 = bdd_and (bddm,S0,B0); // (S0.B0)

```

```

80     bdd g0 = bdd_and (bddm,bcin,bM);    //(~(bcin).~(bM))
81
82
83
84             //or operation
85
86     bdd h0 = bdd_or (bddm,b0,d0); // (B0.S3.A0) + (A0.S2.bB0)
87     bdd i0 = bdd_or (bddm,e0,f0); // ~ (B0).S1) + (S0.B0)
88     bdd j0 = bdd_or (bddm,i0,A0); // ~ (B0).S1) + (S0.B0) + A0
89
90             //not operation
91
92     bdd bg0      = bdd_not(bddm,g0); //~((~(bcin).~(bM)))
93     bdd bh0      = bdd_not(bddm,h0); //~((B0.S3.A0) + (A0.S2.bB0))
//neagation opearion of the first component of the F0
94     bdd bj0      = bdd_not(bddm,j0); //~(~(B0).S1) + (S0.B0) + A0
//neagation opearion of the second component of the F0
95
96
97             //xor opeartion
98
99     bdd k0 = bdd_xor (bddm,bh0,bj0); //~((B0.S3.A0) + (A0.S2.bB0)) ^ ~(~(B0).S1)
+ (S0.B0) + A0)
100
101 //F0 is calculated
102
103     bdd F0 = bdd_xor (bddm,k0, bg0); //~((B0.S3.A0) + (A0.S2.bB0)) ^ ~(~(B0).S1)
+ (S0.B0) + A0) ^ ~((~(bcin).~(bM)))
104
105
106 //F1 computation
107
108             //and opeartion
109     bdd a1 = bdd_and (bddm,bh0,bM);
110     bdd b1 = bdd_and (bddm,a1,bcin); // (~ (cn).bh0.~ (M))
111     bdd c1 = bdd_and (bddm,bj0,bM); // (~ ((B0.S1)+(S0.B0)+A0)).bM)
112     bdd d1 = bdd_and (bddm,B1,S3);
113     bdd e1 = bdd_and (bddm,d1,A1); // (B1.S3.A1)
114     bdd f1 = bdd_and (bddm,A1,S2);
115     bdd g1 = bdd_and (bddm,f1,bB1); // (A1.S2.~ (B1))
116     bdd h1 = bdd_and (bddm,bB1,S1); // (~ (B1).S1)

```

```

117     bdd i1 = bdd_and (bddm,S0,B1); // (S0.B1)
118
119
120                         //or operation
121
122     bdd j1 = bdd_or (bddm,b1,c1); // (~cn).bh0.(M) + (~((B0.S1)+(S0.B0)+A0)).bM)
123     bdd k1 = bdd_or (bddm,e1,g1); // ((B1.S3.A1) + (A1.S2.(B1)))
124     bdd l1 = bdd_or (bddm,h1,i1);
125     bdd m1 = bdd_or (bddm,l1,A1); // ((~(B1).S1) + (S0.B1) + A1)
126
127                         //not operation
128
129     bdd n1 = bdd_not(bddm,j1); //negation of the ~((~cn).bh0.(M) + (~((B0.S1)+(S0.B0)+A0)).bM))
130     bdd o1 = bdd_not(bddm,k1); //negation of the ~(((B1.S3.A1) + (A1.S2.(B1))))
131     bdd p1 = bdd_not(bddm,m1); //negation of the ~(((~(B1).S1) + (S0.B1) + A1))
132
133
134                         //xor opeartion
135
136     bdd q1 = bdd_xor(bddm,n1,o1); //~((~cn).bh0.(M) + (~((B0.S1)+(S0.B1)+A0)).bM)
137     ) ^ ~(((B1.S3.A1) + (A1.S2.(B1))))
138
139     bdd F1 = bdd_xor(bddm,q1,p1); //~((~cn).bh0.(M) + (~((B0.S1)+(S0.B1)+A0)).bM)
140     ) ^ ~(((B1.S3.A1) + (A1.S2.(B1))) ) ^ ~(((~(B1).S1) + (S0.B1) + A1)))
141
142 //F2 computation
143
144                         //and opeartion
145
146     bdd a2 = bdd_and(bddm,bB2,S1); // (~B2) . S1)
147     bdd b2 = bdd_and(bddm,S0,B2); // (S0 . B2)
148     bdd c2 = bdd_and(bddm,B2,S3);
149     bdd d2 = bdd_and(bddm,c2,A2); // (B2 . S3 . A2)
150     bdd e2 = bdd_and(bddm,A2,S2);
151     bdd f2 = bdd_and(bddm,e2,bB2); // (A2 . S2 . ~B2))
152     bdd g2 = bdd_and(bddm,b1,o1); // (~cn) . ~((B0.S3.A0) + (A0.S2.(B0))).~(M)) .
153     ~(((B1.S3.A1) + (A1.S2.(B1)))))


```

```

153     bdd h2 = bdd_and(bddm,o1,c1); // (~(((B1.S3.A1) + (A1.S2.^~(B1)))) . (~((B0.S1)+(S0.B0)+A0)).bM)
154     bdd i2 = bdd_and(bddm,p1,bM); // (~(((~(B1).S1) + (S0.B1) + A1))) . ^M)
155
156
157                                     //or operation
158
159     bdd j2 = bdd_or (bddm,a2,b2); //(~(B2) . S1) + (S0 . B2)
160     bdd k2 = bdd_or (bddm,j2,A2); //(~(B2) . S1) + (S0 . B2) + A2)
161     bdd l2 = bdd_or (bddm,d2,f2); //((B2 . S3 . A2) + (A2 . S2 . (^B2)))
162     bdd m2 = bdd_or (bddm,g2,h2); //(~(cn) . ~((B0.S3.A0) + (A0.S2.^~(B0))).~(M)) .
163     ~(((B1.S3.A1) + (A1.S2.^~(B1))))) + (~(((B1.S3.A1) + (A1.S2.^~(B1)))). (~((B0.S1)
164     +(S0.B0)+A0)).bM))
165     bdd n2 = bdd_or (bddm,m2,i2); //(~(cn) . ~((B0.S3.A0) + (A0.S2.^~(B0))).~(M)) .
166     ~(((B1.S3.A1) + (A1.S2.^~(B1))))) + (~(((B1.S3.A1) + (A1.S2.^~(B1)))). (~((B0.S1)
167     +(S0.B0)+A0)).bM)) + (~(((~(B1).S1) + (S0.B1) + A1)) . ^M)
168
169     bdd o2 = bdd_not(bddm,n2); //~((~(cn) . ~((B0.S3.A0) + (A0.S2.^~(B0))).~(M))
170     . ~(((B1.S3.A1) + (A1.S2.^~(B1))))) + (~(((B1.S3.A1) + (A1.S2.^~(B1)))). (~((B0
171     . S1)+(S0.B0)+A0)).bM)) + (~(((~(B1).S1) + (S0.B1) + A1)) . ^M))
172     bdd p2 = bdd_not(bddm,k2); //~(~(B2) . S1) + (S0 . B2) + A2)
173     bdd q2 = bdd_not(bddm,l2); //~((B2 . S3 . A2) + (A2 . S2 . (^B2)))
174
175                                     //xor operation
176     bdd r2 = bdd_xor (bddm,p2,q2); //~(~(B2) . S1) + (S0 . B2) + A2) ^ ~((B2 . S3 .
177     A2) + (A2 . S2 . (^B2)))
178
179     bdd F2 = bdd_xor (bddm,r2,o2); // ~(~(B2) . S1) + (S0 . B2) + A2) ^ ~((B2 . S3 .
180     A2) + (A2 . S2 . (^B2))) ^ ~((~(cn) . ~((B0.S3.A0) + (A0.S2.^~(B0))).~(M)) .
181     ~(((B1.S3.A1) + (A1.S2.^~(B1))))) + (~(((B1.S3.A1) + (A1.S2.^~(B1)))). (~((B0.S1)
     +(S0.B0)+A0)).bM)) + (~(((~(B1).S1) + (S0.B1) + A1)) . ^M))

//F3 computation

```

```

182 // and
183 operation
184 bdd a3 = bdd_and (bddm,B3,S3);
185 bdd b3 = bdd_and (bddm,a3,A3); //((B3.S3.A3)
186 bdd c3 = bdd_and (bddm,A3,S2);
187 bdd d3 = bdd_and (bddm,c3,bB3); //((A3.S2.bB3)
188 bdd e3 = bdd_and (bddm, bB3,S1); //((bB3.S1)
189 bdd f3 = bdd_and (bddm,S0,B3); //((S0.B3)
190 bdd g3 = bdd_and (bddm,bcin,bM); //((bcin.bM)
191 bdd h3 = bdd_and (bddm,bh0,o1);
192 bdd i3 = bdd_and (bddm,h3,q2); //((bcin . bM . o1 . q2)
193 bdd j3 = bdd_and (bddm,g3,i3); //((~cin . ~M . ~((B0.S3.A0) + (A0.S2.bB0)) . ~(((B1
194 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))))
195 bdd k3 = bdd_and (bddm,o1,q2);
196 bdd l3 = bdd_and (bddm,k3,bj0);
197 bdd m3 = bdd_and (bddm,l3,bM); //((~(((B1.S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 .
198 A2) + (A2 . S2 . (~B2))) . ~((~(B0).S1) + (S0.B0) + A0) . bM)
199 bdd n3 = bdd_and (bddm,q2,p1); //~((B2 . S3 . A2) + (A2 . S2 . (~B2)) . ~(((~(B1
200 . S1) + (S0.B1) + A1)))
201 bdd o3 = bdd_and (bddm,n3,bM); //~((B2 . S3 . A2) + (A2 . S2 . (~B2)) . ~(((~(B1
202 . S1) + (S0.B1) + A1))) . ~M)
203 bdd p3 = bdd_and (bddm,p2,bM); //~((~(B2) . S1) + (S0 . B2) + A2) . ~M)
204
205 // or
206 operation
207 bdd q3 = bdd_or (bddm,j3,m3); // (~cin . ~M . ~((B0.S3.A0) + (A0.S2.bB0)) . ~(((B1
208 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) + (~(((B1
209 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~((~(B0).S1) +
(S0.B0) + A0) . bM)
210 bdd r3 = bdd_or (bddm,q3,o3); // (~cin . ~M . ~((B0.S3.A0) + (A0.S2.bB0)) . ~(((B1
211 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) + (~(((B1
212 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~((~(B0).S1) +
(S0.B0) + A0) . bM) + ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~(((~(B1).S1) + (S0
.B1) + A1))) . ~M)
213 //r6 with out complement
214 bdd s3 = bdd_or (bddm,r3,p3); // (~cin . ~M . ~((B0.S3.A0) + (A0.S2.bB0)) . ~(((B1
215 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) + (~(((B1
216 . S3.A1) + (A1.S2.~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~((~(B0).S1) +
(S0.B1) + A1))) . ~M)

```

```

(S0.B0) + A0) . bM) + ~((B2 . S3 . A2) + (A2 . S2 . (~B2)) . ~(((~(B1).S1) + (S0
.B1) + A1))) . ~M) + (~(~(B2) . S1) + (S0 . B2) + A2). ~M)

208

209 bdd t3 = bdd_or (bddm,b3,d3); // (B3.S3.A3) + (A3.S2.bB3)
210 bdd u3 = bdd_or (bddm,e3,f3); // (bB3.S1) + (S0.B3)
211 bdd v3 = bdd_or (bddm,u3,A3); // (bB3.S1) + (S0.B3) + A3
212
213
214 //not

operation
215 bdd w3 = bdd_not(bddm,s3); // ~r6
216 bdd x3 = bdd_not(bddm,t3); // ~((B3.S3.A3) + (A3.S2.bB3))
217 bdd y3 = bdd_not(bddm,v3); // ~((bB3.S1) + (S0.B3) + A3)
218
219
220 //xor

operation
221 bdd z3 = bdd_xor(bddm,x3,y3); // ~((B3.S3.A3) + (A3.S2.bB3)) ^ ~((bB3.S1) + (S0.
B3) + A3)
222
223 bdd F3 = bdd_xor(bddm,z3,w3); // ~((B3.S3.A3) + (A3.S2.bB3)) ^ ~((bB3.S1) + (S0
.B3) + A3) ^ (~cin . ~M . ~((B0.S3.A0) + (A0.S2.bB0)) . ~((B1.S3.A1) + (A1.S2
.^~(B1)))) . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) + (~((B1.S3.A1) + (A1.S2.^
B1))). . ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~(~(B0).S1) + (S0.B0) + A0) . bM
) + ~((B2 . S3 . A2) + (A2 . S2 . (~B2))) . ~(((~(B1).S1) + (S0.B1) + A1)). . ~M)
+ (~(~(B2) . S1) + (S0 . B2) + A2). ~M)

224
225
226 //Ripple carry adder code
227
228
229 //0 stage
230 //and logic
231 bdd ra0 = bdd_and(bddm,A0,B0);
232 bdd rb0 = bdd_and(bddm,A0,cin);
233 bdd rc0 = bdd_and(bddm,B0,cin);
234
235 //or logic
236 bdd rd0 = bdd_or(bddm,ra0,rb0);
237 bdd carry0 = bdd_or(bddm,rd0,rc0); //c0 = a0.b0 + a0.cin + b0.cin
238

```

```

239                                     //exor logic
240
241     bdd re0 = bdd_xor(bddm,A0,B0);
242     bdd sum0 = bdd_xor(bddm,re0,cin);           //sum = A0 ^ B0 ^ c0
243
244
245 //1st stage
246
247                                     //and logic
248     bdd ra1 = bdd_and(bddm,A1,B1);
249     bdd rb1 = bdd_and(bddm,A1,carry0);
250     bdd rc1 = bdd_and(bddm,B1,carry0);
251
252                                     //or logic
253     bdd rd1 = bdd_or(bddm,ra1,rb1);
254     bdd carry1 = bdd_or(bddm,rd1,rc1);           //c1 = a1.b1 + a1.carry0 + b1.
255     carry0
256
257                                     //exor logic
258
259     bdd re1 = bdd_xor(bddm,A1,B1);
260     bdd sum1 = bdd_xor(bddm,re1,carry0);           //sum = A1 ^ B1 ^ c1
261
262 //2nd stage
263
264                                     //and logic
265     bdd ra2 = bdd_and(bddm,A2,B2);
266     bdd rb2 = bdd_and(bddm,A2,carry1);
267     bdd rc2 = bdd_and(bddm,B2,carry1);
268
269                                     //or logic
270     bdd rd2 = bdd_or(bddm,ra2,rb2);
271     bdd carry2= bdd_or(bddm,rd2,rc2);           //c2 = a2.b2 + a2.carry1 + b2.
272     carry1
273
274                                     //exor logic
275
276     bdd re2 = bdd_xor(bddm,A2,B2);
277     bdd sum2 = bdd_xor(bddm,re2,carry1);           //sum = A2 ^ B2 ^ c2

```

```

278
279
280 //3nd stage
281
282 //and logic
283 bdd ra3 = bdd_and(bddm,A3,B3);
284 bdd rb3 = bdd_and(bddm,A3,carry2);
285 bdd rc3 = bdd_and(bddm,B3,carry2);
286
287 //or logic
288 bdd rd3 = bdd_or(bddm,ra3,rb3);
289 bdd carry3= bdd_or(bddm,rd3,rc3);           //c3 = a3.b3 + a3.carry2 + b3.
290 carry2
291
292 //exor logic
293 bdd re3 = bdd_xor(bddm,A3,B3);
294 bdd sum3 = bdd_xor(bddm,re3,carry2);         //sum = A3 ^ B3 ^ c3
295
296
297 printf("-----Ripple carry adder-----\n");
298 );
299
300 // print s0,s1,s2,s3
301 //printf("-----printing sum0-----\n");
302 //bdd_print_bdd(bddm,sum0,NULL, NULL,NULL, stdout);
303 //printf("-----printing sum1-----\n");
304 //bdd_print_bdd(bddm,sum1,NULL, NULL,NULL, stdout);
305 //printf("-----printing sum2-----\n");
306 //bdd_print_bdd(bddm,sum2,NULL, NULL,NULL, stdout);
307 //printf("-----printing sum3-----\n");
308 //bdd_print_bdd(bddm,sum3,NULL, NULL,NULL, stdout);
309
310 // are F0 and sum0 the same?
311 if (F0 == sum0)
312 {
313     printf("F0 is Equal with sum0\n");
314 }
315 else
316 {
317     printf("Not Equal\n");

```

```

317     // print F0
318     bdd_print_bdd(bddm,F0,NULL, NULL,NULL, stdout);
319 }
320
321 if (F1 == sum1)
322 {
323     printf("F1 is Equal with sum1\n");
324 }
325 else
326 {
327     printf("Not Equal\n");
328     // print F0
329     bdd_print_bdd(bddm,F1,NULL, NULL,NULL, stdout);
330 }
331
332 if (F2 == sum2)
333 {
334     printf("F2 is Equal with sum2\n");
335 }
336 else
337 {
338     printf("Not Equal\n");
339     // print F0
340     bdd_print_bdd(bddm,F2,NULL, NULL,NULL, stdout);
341 }
342
343 if (F3 == sum3)
344 {
345     printf("F3 is Equal with sum3\n");
346 }
347 else
348 {
349     printf("Not Equal\n");
350     // print F0
351     bdd_print_bdd(bddm,F3,NULL, NULL,NULL, stdout);
352 }
353
354
355 // ripple borrow subtractor
356
357

```

```

358 //0 stage
359                                     //and logic
360 bdd brsB0 = bdd_not(bddm,B0);
361 bdd brsB1 = bdd_not(bddm,B1);
362 bdd brsB2 = bdd_not(bddm,B2);
363 bdd brsB3 = bdd_not(bddm,B3);
364
365
366 bdd rsa0 = bdd_and(bddm,A0,brsB0);
367 bdd rsb0 = bdd_and(bddm,A0,cin);
368 bdd rsc0 = bdd_and(bddm,brsB0,cin);
369
370                                     //or logic
371 bdd rsd0 = bdd_or(bddm,rsa0,rsb0);
372 bdd borro = bdd_or(bddm,rsd0,rsc0);           //c0 = a0.b0 + a0.cin + b0.cin
373
374                                     //exor logic
375
376 bdd rse0 = bdd_xor(bddm,A0,brsB0);
377 bdd diff0 = bdd_xor(bddm,rse0,cin);           //sum = A0 ^ B0 ^ c0
378
379
380 //1st stage
381
382                                     //and logic
383 bdd rsa1 = bdd_and(bddm,A1,brsB1);
384 bdd rsb1 = bdd_and(bddm,A1,borro);
385 bdd rsc1 = bdd_and(bddm,brsB1,borro);
386
387                                     //or logic
388 bdd rsd1 = bdd_or(bddm,rsa1,rsb1);
389 bdd borri = bdd_or(bddm,rsd1,rsc1);           //c0 = a0.b0 + a0.cin + b0.cin
390
391                                     //exor logic
392
393 bdd rse1 = bdd_xor(bddm,A1,brsB1);
394 bdd diff1 = bdd_xor(bddm,rse1,borro);           //sum = A0 ^ B0 ^ c0
395
396
397 //2nd stage
398

```

```

399                                     //and logic
400
401     bdd rsa2 = bdd_and(bddm,A2,brsB2);
402
403     bdd rsb2 = bdd_and(bddm,A2,borr1);
404
405     bdd rsc2 = bdd_and(bddm,brsB2,borr1);

406                                     //or logic
407
408     bdd rsd2 = bdd_or(bddm,rsa2,rsb2);
409     bdd borr2 = bdd_or(bddm,rsd2,rsc2);           //c0 = a0.b0 + a0.cin + b0.cin
410
411                                     //exor logic
412
413
414
415 //3nd stage
416
417                                     //and logic
418
419     bdd rsa3 = bdd_and(bddm,A3,brsB3);
420     bdd rsb3 = bdd_and(bddm,A3,borr2);
421     bdd rsc3 = bdd_and(bddm,brsB3,borr2);

422                                     //or logic
423
424     bdd rsd3 = bdd_or(bddm,rsa3,rsb3);
425     bdd borr3 = bdd_or(bddm,rsd3,rsc3);           //c0 = a0.b0 + a0.cin + b0.cin
426
427                                     //exor logic
428
429     bdd rse3 = bdd_xor(bddm,A3,brsB3);
430     bdd diff3 = bdd_xor(bddm,rse3,borr2);         //sum = A0 ^ B0 ^ c0
431
432
433     printf("-----Ripple borrow subtractor
434                                     \n");
435
436 // print s0,s1,s2,s3
437 // bdd_print_bdd(bddm,sum0,NULL, NULL,NULL, stdout);
438 // bdd_print_bdd(bddm,sum1,NULL, NULL,NULL, stdout);
439 // bdd_print_bdd(bddm,sum2,NULL, NULL,NULL, stdout);
440 // bdd_print_bdd(bddm,sum3,NULL, NULL,NULL, stdout);

```

```

439
440     // are F0 and sum0 the same?
441
442     if (F0 == diff0)
443     {
444         printf("F0 is Equal with diff0\n");
445     }
446     else
447     {
448         printf("Not Equal\n");
449         // print F0
450         bdd_print_bdd(bddm,F0,NULL, NULL,NULL, stdout);
451     }
452
453     if (F1 == diff1)
454     {
455         printf("F1 is Equal with diff1\n");
456     }
457     else
458     {
459         printf("Not Equal\n");
460         // print F0
461         bdd_print_bdd(bddm,F1,NULL, NULL,NULL, stdout);
462     }
463
464     if (F2 == diff2)
465     {
466         printf("F2 is Equal with diff2\n");
467     }
468     else
469     {
470         printf("Not Equal\n");
471         // print F0
472         bdd_print_bdd(bddm,F2,NULL, NULL,NULL, stdout);
473     }
474
475     if (F3 == diff3)
476     {
477         printf("F3 is Equal with diff3\n");
478     }
479     else
480     {

```

```

480     printf("Not Equal\n");
481     // print F0
482     bdd_print_bdd(bddm,F3,NULL, NULL,NULL, stdout);
483 }
484
485
486 // F = A . B
487
488 bdd AA0 = bdd_and(bddm,A0,B0);
489 bdd AA1 = bdd_and(bddm,A1,B1);
490 bdd AA2 = bdd_and(bddm,A2,B2);
491 bdd AA3 = bdd_and(bddm,A3,B3);
492
493 printf("-----F = A . B-----\n");
494 if (F0 == AA0)
495 {
496     printf("F0 is Equal with A0.B0\n");
497 }
498 else
499 {
500     printf("Not Equal\n");
501     // print F0
502     bdd_print_bdd(bddm,F0,NULL, NULL,NULL, stdout);
503 }
504
505 if (F1 == AA1)
506 {
507     printf("F1 is Equal with A1.B1\n");
508 }
509 else
510 {
511     printf("Not Equal\n");
512     // print F0
513     bdd_print_bdd(bddm,F1,NULL, NULL,NULL, stdout);
514 }
515
516 if (F2 == AA2)
517 {
518     printf("F2 is Equal with A2.B2\n");
519 }
520 else

```

```

521 {
522     printf("Not Equal\n");
523     // print F0
524     bdd_print_bdd(bddm,F2,NULL, NULL,NULL, stdout);
525 }
526
527 if (F3 == AA3 )
528 {
529     printf("F3 is Equal with A3.B3\n");
530 }
531 else
532 {
533     printf("Not Equal\n");
534     // print F0
535     bdd_print_bdd(bddm,F3,NULL, NULL,NULL, stdout);
536 }
537
538
539
540 printf("-----ROBDD of the ALU
7418-----\n");
541
542 // print F0,F1,F2,F3
543 //printf("-----F0-----\n");
544 //bdd_print_bdd(bddm,F0,NULL, NULL,NULL, stdout);
545 //printf("-----F1-----\n");
546 //bdd_print_bdd(bddm,F1,NULL, NULL,NULL, stdout);
547 //    printf("-----F2-----\n");
548 //bdd_print_bdd(bddm,F2,NULL, NULL,NULL, stdout);
549 //    printf("-----F3-----\n");
550 //bdd_print_bdd(bddm,F3,NULL, NULL,NULL, stdout);
551
552 return(0);
553 }
```