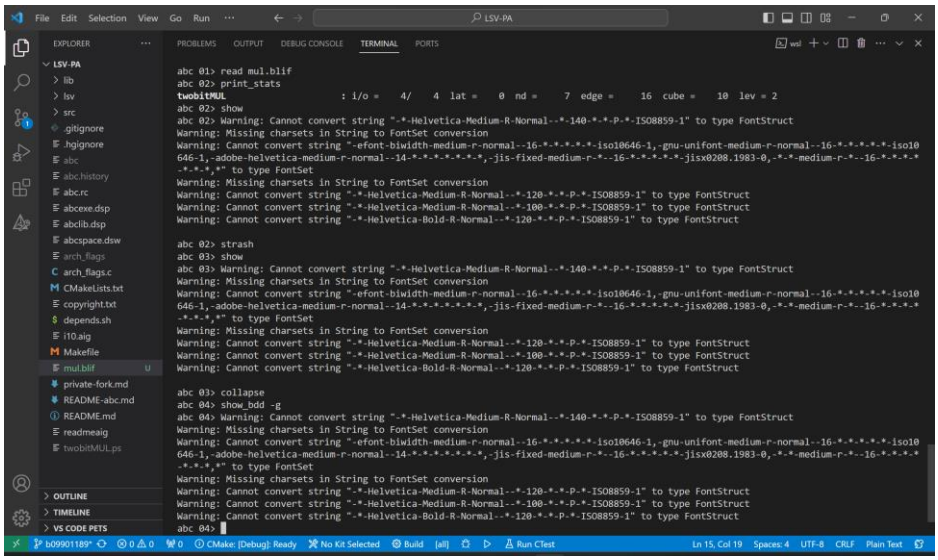
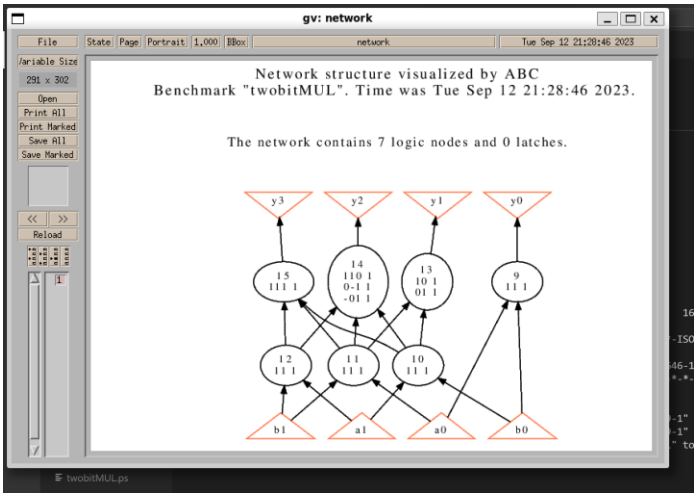
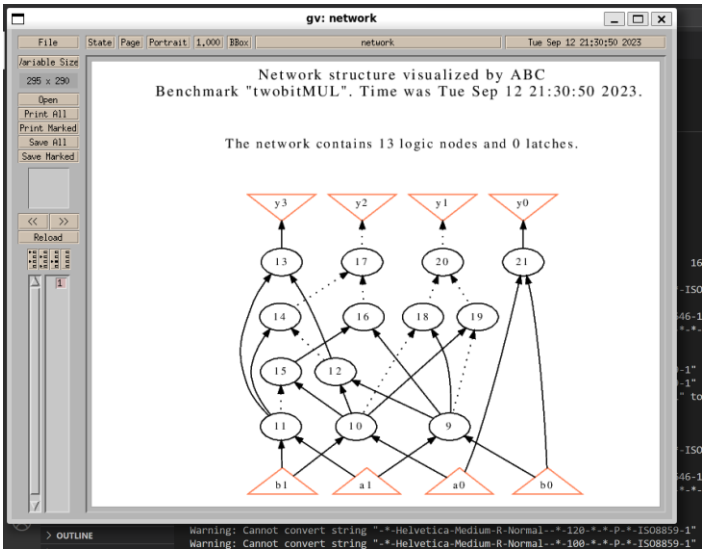
2.(b)


abc 01> read mul.blif
abc 02> print_stats
twobitMUL : i/o = 4/ 4 lat = 0 nd = 7 edge = 16 cube = 10 lev = 2
abc 02> show
abc 02> strash
abc 03> show
abc 03> collapse
abc 04> show_bdd -g
abc 04>

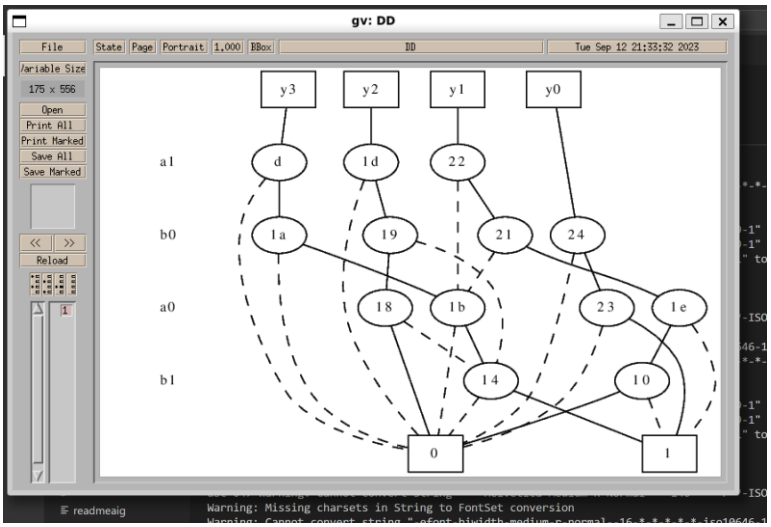
3.


gv: network
Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 21:28:46 2023.
The network contains 7 logic nodes and 0 latches.
y3
y2
y1
y0
15
111 1
14
110 1
0-1 1
-01 1
13
10 1
01 1
9
11 1
12
11 1
11
11 1
10
11 1
b1
a1
a0
b0

5.


gv: network
Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 21:30:50 2023.
The network contains 13 logic nodes and 0 latches.
y3
y2
y1
y0
13
17
20
21
14
16
18
19
15
12
11
10
9
b1
a1
a0
b0

7.


gv: DD
File
State
Page
Portrait
1,000
BBox
DD
Tue Sep 12 21:33:32 2023
Variable Size
175 x 556
Open
Print All
Print Marked
Save All
Save Marked
Reload
y3
y2
y1
y0
a1
d
1d
22
b0
1a
19
21
24
a0
18
1b
23
1e
b1
14
10
0
1
readmeaig
Warning: Missing charsets in String to FontSet conversion

3.(a)

1.

After command “aig”, the network structure shown by command “show” is as same as the original one. However, the structure in each internal node is now constructed by aig (“print_stats” shows that it has 14 aig).

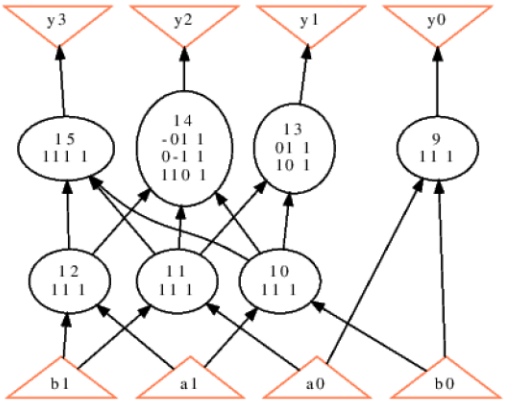
As for command “strash”, the network structure shown by command “show” is different, each node in the graph is an and gate and each edge represents a positive or negative value of the fanin.

Logic network in AIG (by command “aig”)

```
abc 02> aig
abc 02> print_stats
twobitMUL                 : i/o =    4/    4  lat =    0  nd =     7  edge =     16  aig  =    14  lev = 2
abc 02> show
abc 02> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*-
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
```

Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 22:00:55 2023.

The network contains 7 logic nodes and 0 latches.

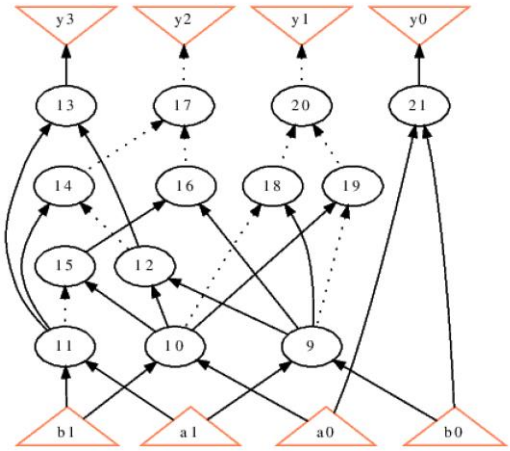


structurally hashed AIG (by command “strash”)

```
abc 02> strash
abc 03> print_stats
twobitMUL                 : i/o =    4/    4  lat =    0  and =     13  lev =  4
abc 03> show
abc 03> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*-
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
```

Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 22:05:43 2023.

The network contains 13 logic nodes and 0 latches.



2.

Both command “bdd” and “collapse” generate the same bdd graph. However, command “bdd” won’t change the result of the command “show”, it only changes the structure of the internal node. On the other hand, command “collapse” makes the network structure shown by “show” different. Also, the results shown by command “print_stats” are different for these two commands. For example, the number of bdd is 16 and 14 respectively.

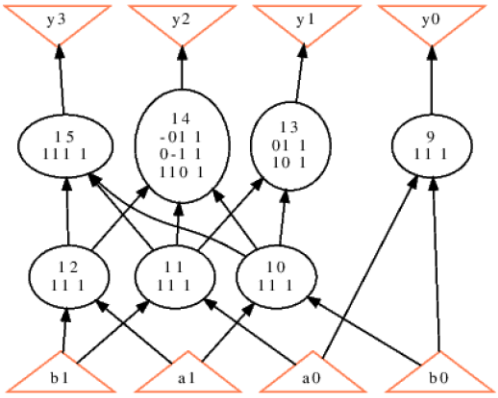
logic network in BDD (by command “bdd”)

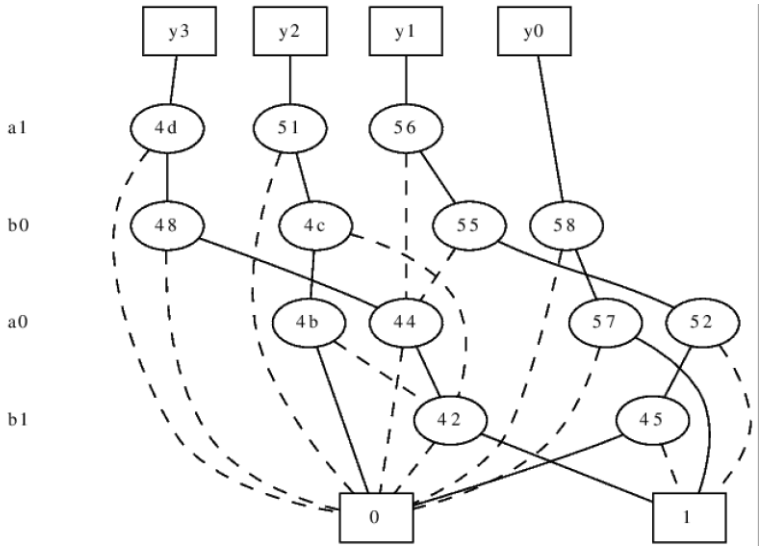
```
abc 01> read mul.blif
abc 02> bdd
abc 02> print_stats
twobitMUL                  : i/o =    4/    4  lat =    0  nd =     7  edge =     16  bdd  =    16  lev = 2
abc 02> show_bdd -g
abc 02> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*-
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct

abc 02> show
abc 02> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*-
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
```

Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 22:12:09 2023.

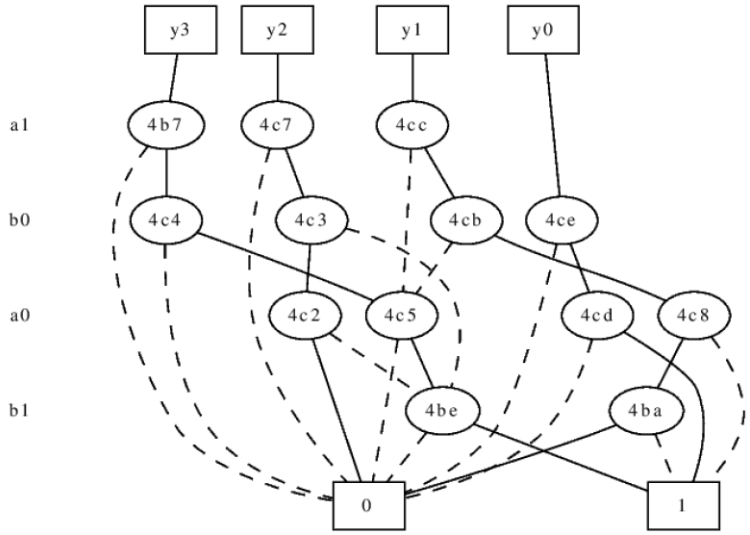
The network contains 7 logic nodes and 0 latches.





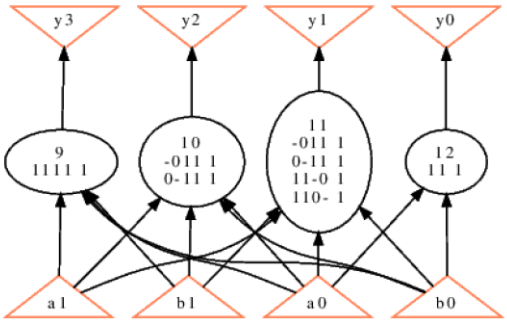
collapsed BDD (by command “collapse”)

```
abc 01> read mul.blif
abc 02> collapse
abc 03> print_stats
twobitMUL                 : i/o =    4/    4  lat =    0  nd =     4  edge =     14  bdd  =    14  lev = 1
abc 03> show_bdd -g
abc 03> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
show
abc 03> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-iso10
646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16-*-*-*
-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
```



Network structure visualized by ABC
Benchmark "twobitMUL". Time was Tue Sep 12 22:14:37 2023.

The network contains 4 logic nodes and 0 latches.



3.(b)

First, read mul.blif

Second, strash

Third, renode

Last, sop

```
abc 01> read mul.blif
abc 02> strash
abc 03> renode
abc 04> sop
abc 04> print_stats
twobitMUL                  : i/o =    4/    4  lat =    0  nd =    10  edge =    22  cube =    11  lev = 3
abc 04> show
abc 04> Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-140-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-efont-biwidth-medium-r-normal--16-*-*-*-*-*-iso10646-1,-gnu-unifont-medium-r-normal--16-*-*-*-*-*-i
so10646-1,-adobe-helvetica-medium-r-normal--14-*-*-*-*-*-*-*,-jis-fixed-medium-r-*--16-*-*-*-*-*-jisx0208.1983-0,-*-*-medium-r-*--16
-*-*-*-*-*-*-*,*" to type FontSet
Warning: Missing charsets in String to FontSet conversion
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Medium-R-Normal--*-100-*-*-P-*-ISO8859-1" to type FontStruct
Warning: Cannot convert string "-*-Helvetica-Bold-R-Normal--*-120-*-*-P-*-ISO8859-1" to type FontStruct
```

Network structure visualized by ABC
Benchmark "twobitMUL". Time was Wed Sep 13 20:40:52 2023.

The network contains 10 logic nodes and 0 latches.