# Chapter 3 – Logic implementation of interlocks

## 3.1 GATED IMPLEMENTATION

Following are the set of interlocks divided by sub conditions (on the basis of various actuations). They are total six in number with multiple sub modules within them totaling up to twenty programmable logic blocks.

1. Ram Assembly
   a. RAM B movement:
      i. FM Magazine should be aligned to a magazine station (no rotation should be observed).
      ii. Fuel separator should be locked either in advance or retract condition.
      iii. If any of the magazine stations D, E, F, H or J is aligned, then snout plug and seal plug have to be in magazine.
      iv. If the magazine station A is aligned, then separator has to be in retracted condition.
      v. If station H (shield ‘A’ station) is aligned and shield ‘A’ is not in magazine, separator shall be in retracted condition.
      vi. If station H is aligned and shield ‘A’ is in magazine, then separator shall be in advance condition.
      vii. Water and oil supplies must be poised.
      viii. Healthiness of counter balance valve signal should be available.

Following is the gated implementation of the same

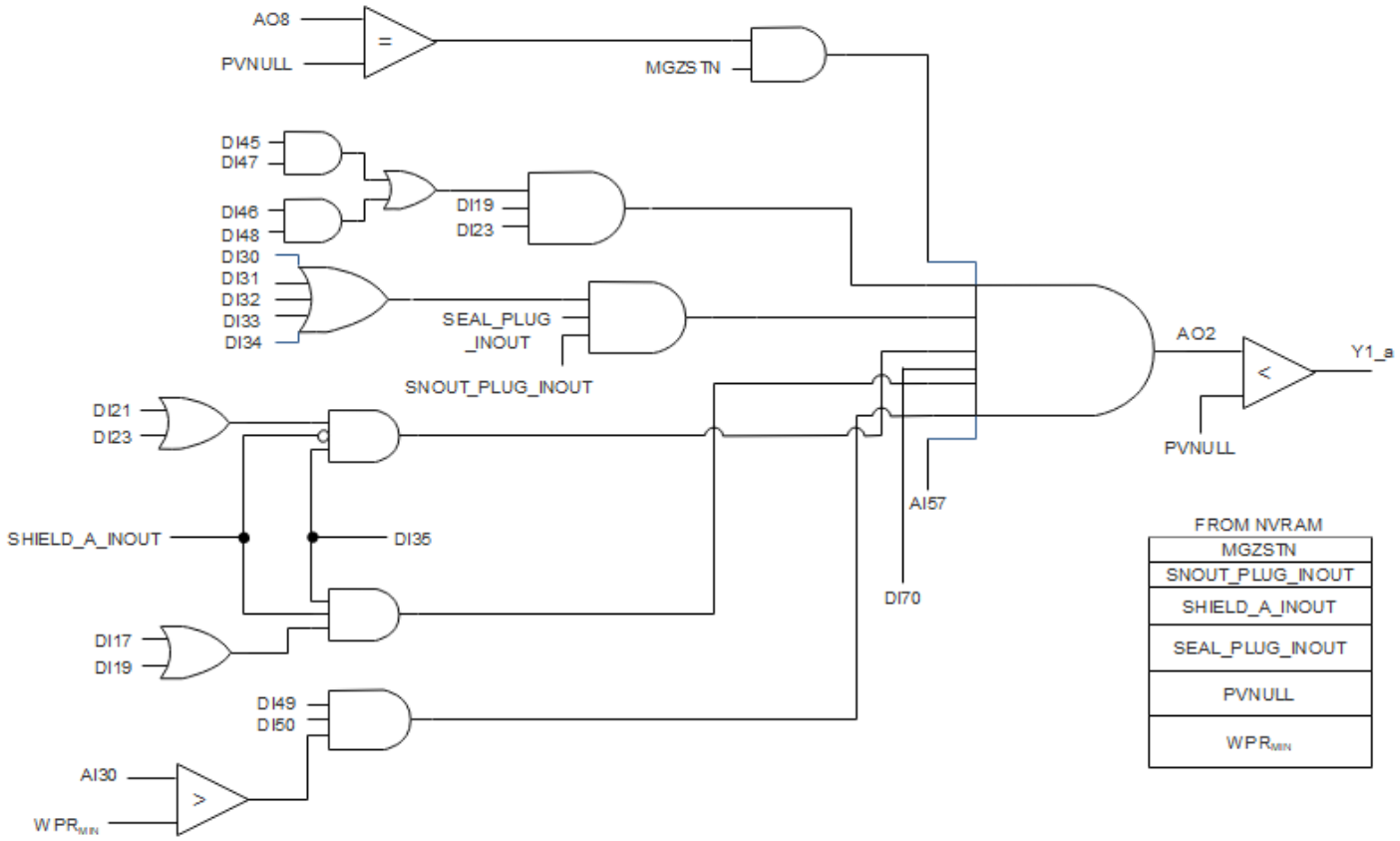


**Figure 3.0-1.1.a** Gated implementation of sub module 1(a)

b. RAM B high speed selection

   i. Magazine should not be aligned to D, F, H or J station.

Following is the gated implementation of the same

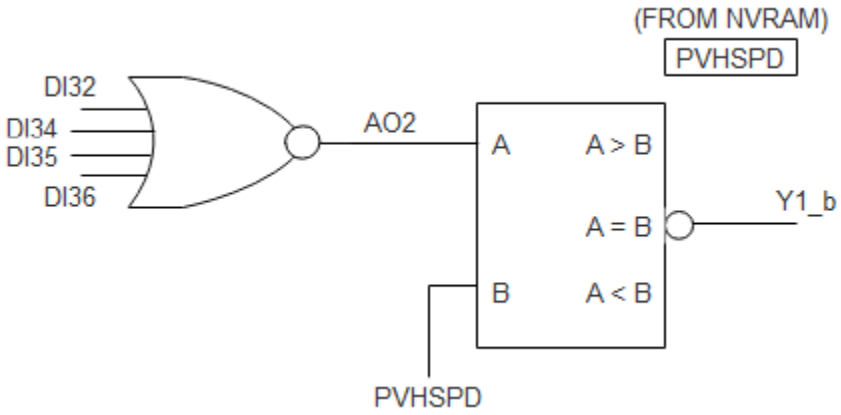


**Figure 3.1.1.b** Gated implementation of sub module 1(b)

c. RAM B force 1 selection (1U separation force and 1D plug/fuel engagement force)

i. Separators are advanced and locked.

ii. Magazine is aligned to any of the station F, H, D or J.

iii. RAM B high speed should not be selected.

iv. Latch RAM should be advanced to X position.

Following is the gated implementation of the same

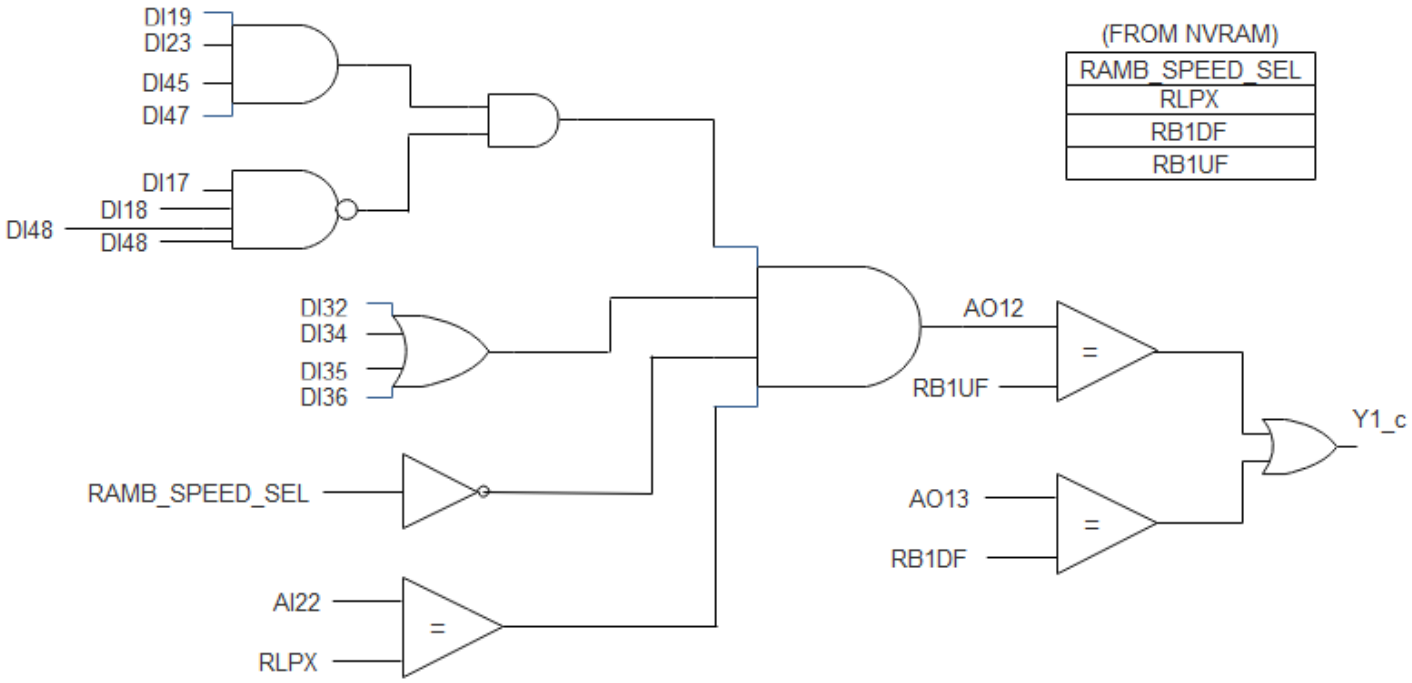


**Figure 3.1.1.c** Gated implementation of sub module 1(c)

d. RAM C retract movement

i. FM Magazine should be aligned to a magazine station (no rotation should be observed).

ii. RAM B should be locked at defined plug position like V1A, V1R, X, Y1A, Y1R, SAA, and SAR.

Following is the gated implementation of the same

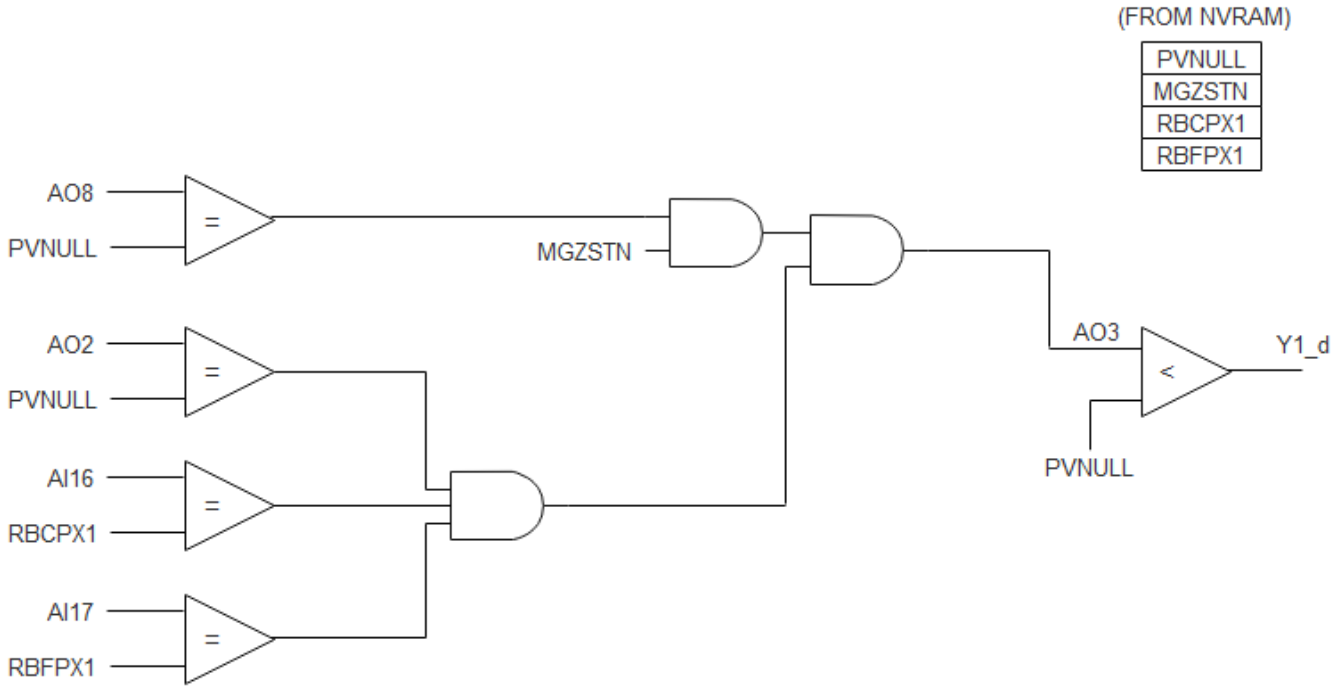


**Figure 3.1.1.d** Gated implementation of sub module 1(d)

e. RAM C advance movement

i. FM Magazine should be aligned to a magazine station (no rotation should be observed).

ii. RAM B should be locked at defined plug position like V1A, V1R, X, Y1A, Y1R, SAA, and SAR.

Following is the gated implementation of the same

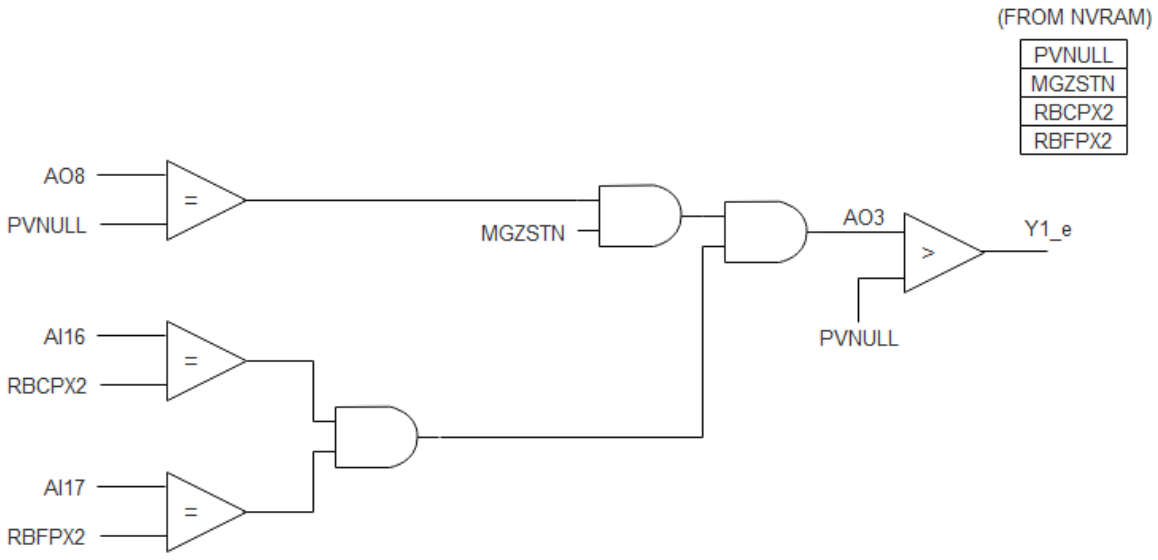


**Figure 3.1.1.e** Gated implementation of sub module 1(e)

f. Latch retract movement

i. FM Magazine should be aligned to a magazine station (no rotation should be observed).

ii. RAM B should be locked at defined plug position like V1A, V1R, X, Y1A, Y1R, SAA, and SAR.

Following is the gated implementation of the same

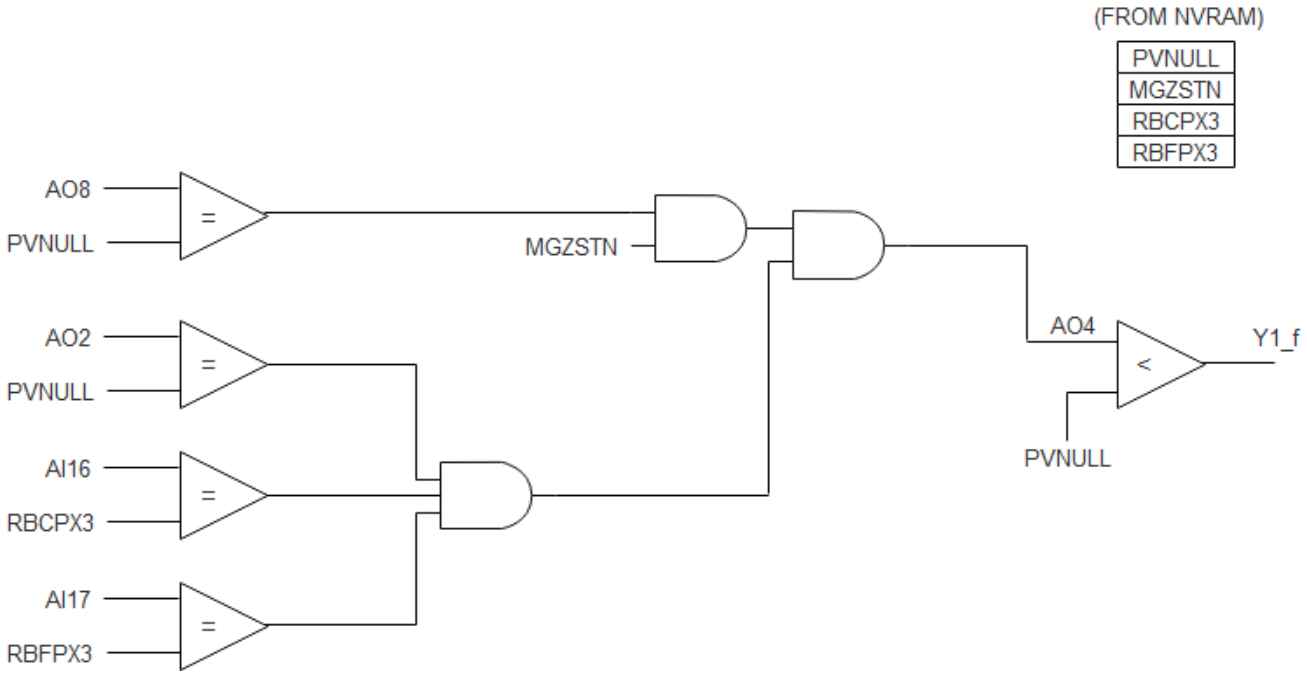


**Figure 3.1.1.f** Gated implementation of sub module 1(f)

g. Latch advance movement

i. FM Magazine should be aligned to a magazine station (no rotation should be observed).

ii. RAM B should be locked at defined plug position like V1A, V1R, X, Y1A, Y1R, SAA, and SAR.

Following is the gated implementation of the same

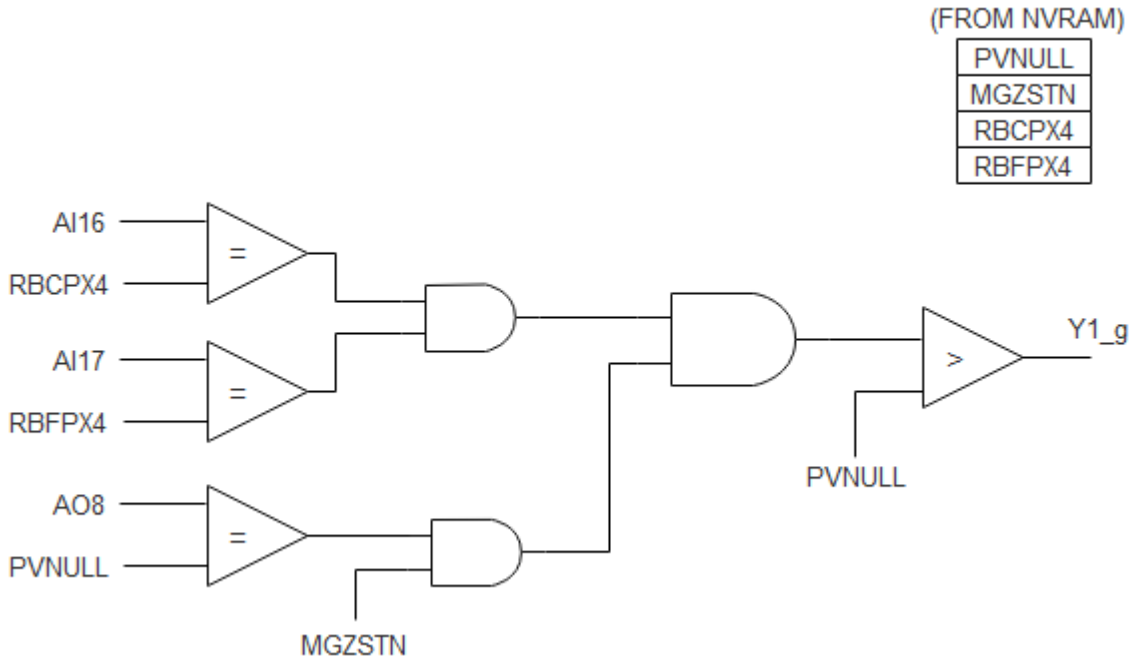


**Figure 3.1.1.g** Gated implementation of sub module 1(g)

2. Magazine Assembly

a. Rotate / counter rotate motion

i. All RAMs should be at home position.

ii. Separators should be locked either in advance position or in retract position.

Following is the gated implementation of the same

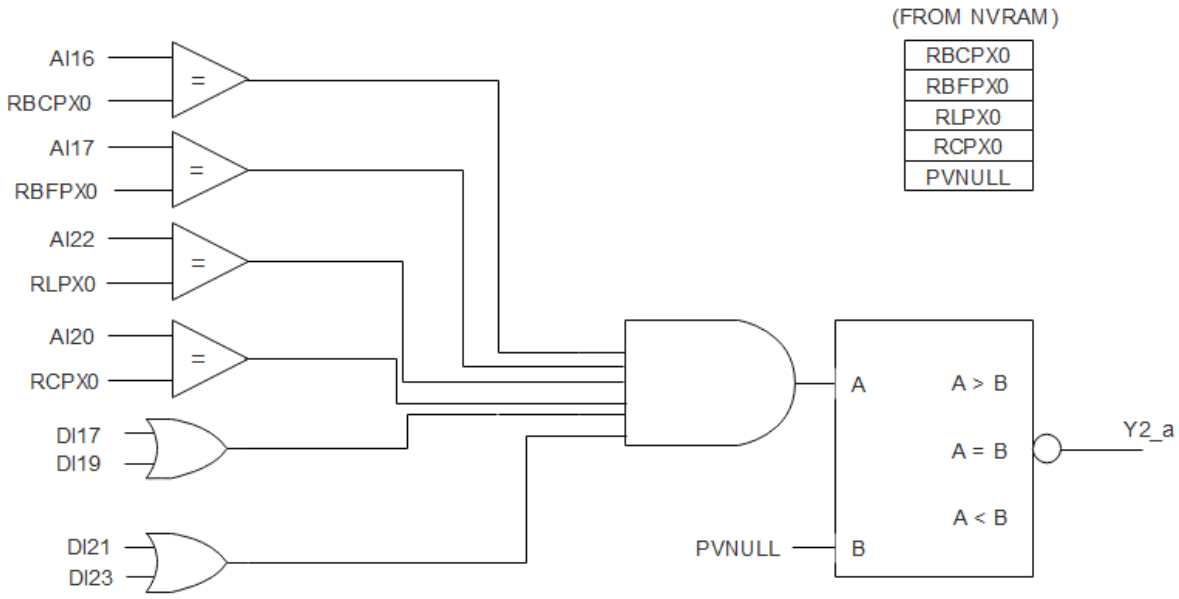


Figure 3.1.2.a Gated implementation of sub module 2(a)

b. For selection of magazine high pressure

i. FM Snout should be clamped on coolant channel.

ii. Snout plug should either be deposited in magazine or magazine to snout valve should be opened.

Following is the gated implementation of the same

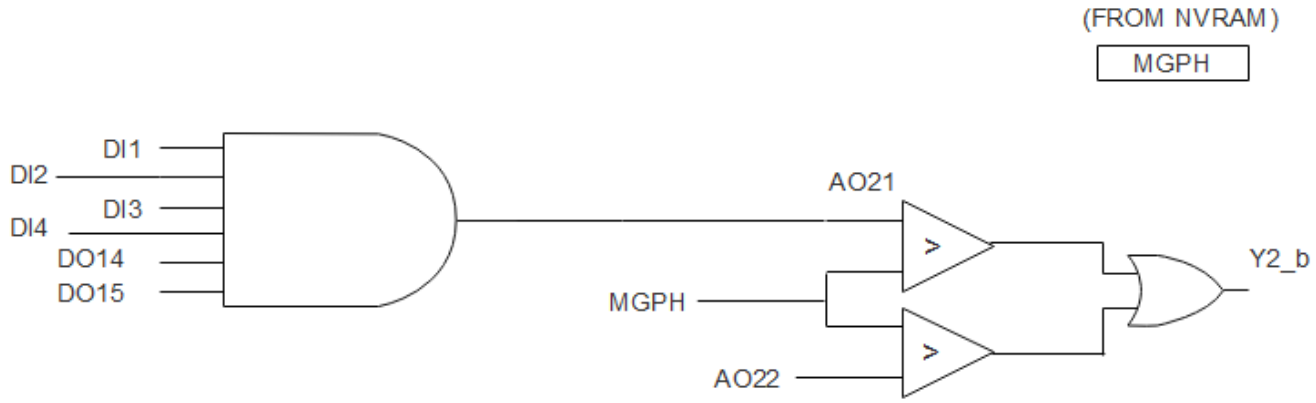


Figure 3.1.2.b Gated implementation of sub module 2(b)

3. Separator Assembly

a. Advancing of fuel separator

i. FM Magazine should be aligned to any of the station H (shield ‘A’), station F (shield ‘B’) or station D (new fuel), Station J (Spent fuel).

ii. All RAMs should be stationary.

iii. Separator should be unlocked.

iv. Any one of the following condition should be satisfied.

1. If magazine is aligned to station H, the Ram B shall be at corresponding shield ‘A’ separation position (Position YAR).
2. If magazine is aligned to station F, the Ram B shall be at corresponding separation position of shield ‘A’ from shield ‘B’ (Position YAR) or shall be at corresponding separation position of shield ‘B” from Ram adaptor (Position YBR).
3. If magazine is aligned to station D, the Ram B shall be at corresponding separation position of fuel from ram adaptor (Position YBR).

Following is the gated implementation of the same

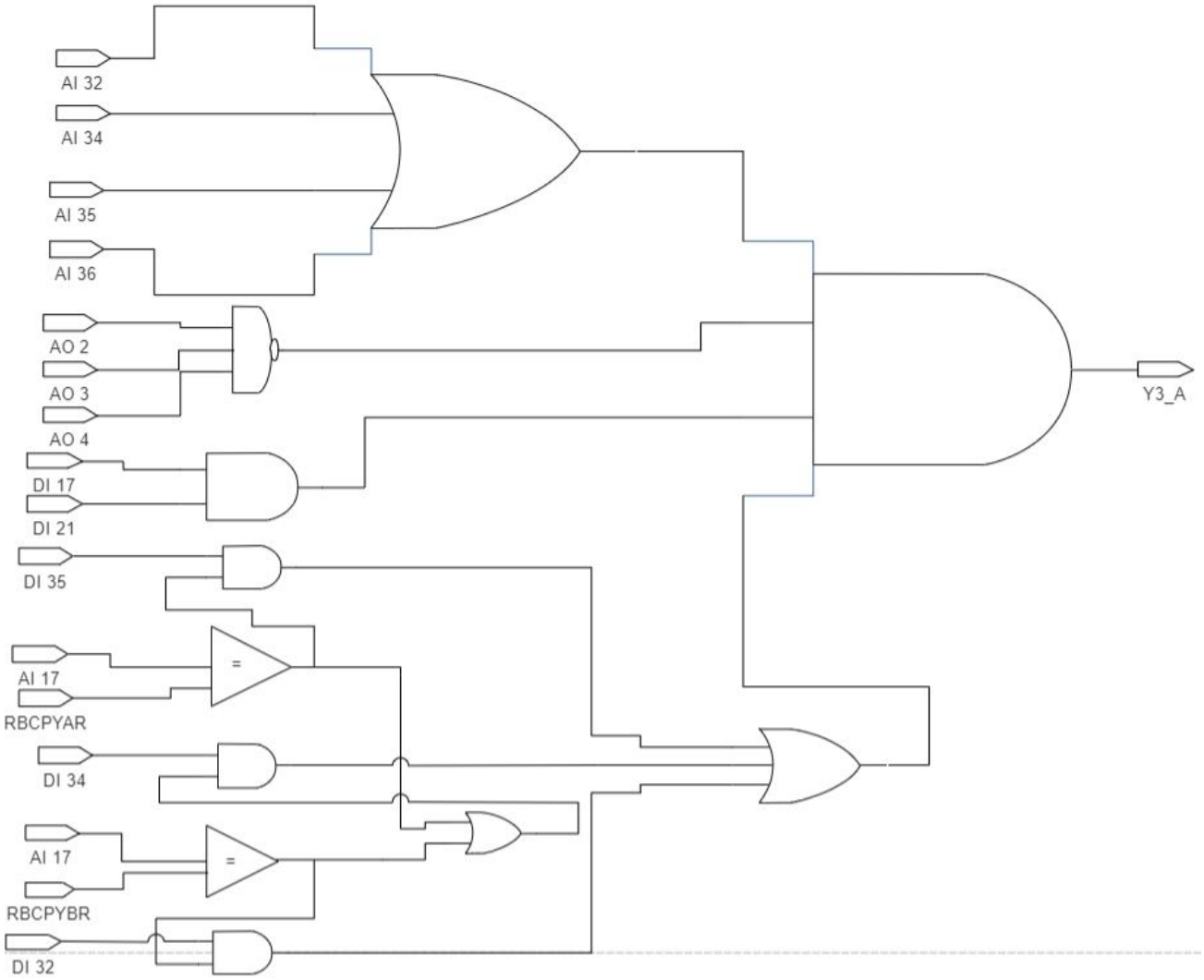


Figure 3.1.3.a Gated implementation of sub module 3(a)

b. Retracting of fuel separator

   i. FM Magazine should be aligned to any of the station H (shield ‘A’), station F (shield ‘B’) or station J (spent fuel).

   ii. All RAMs should be stationary.

   iii. Separator should be unlocked.

   iv. Any one of the following condition should be satisfied.

      1. If magazine is aligned to station H, the Ram B shall be at corresponding shield ‘A’ separation position (Position SAA).
      2. If magazine is aligned to station F, the Ram B shall be at corresponding separation position of shield ‘B’ from fuel (Position YBA) or shall be at corresponding separation position of shield ‘B” from Ram adaptor (Position SBA).

3. If magazine is aligned to station J, the Ram B shall be at corresponding separation position of fuel from ram adaptor (Position SAA).

Following is the gated implementation of the same

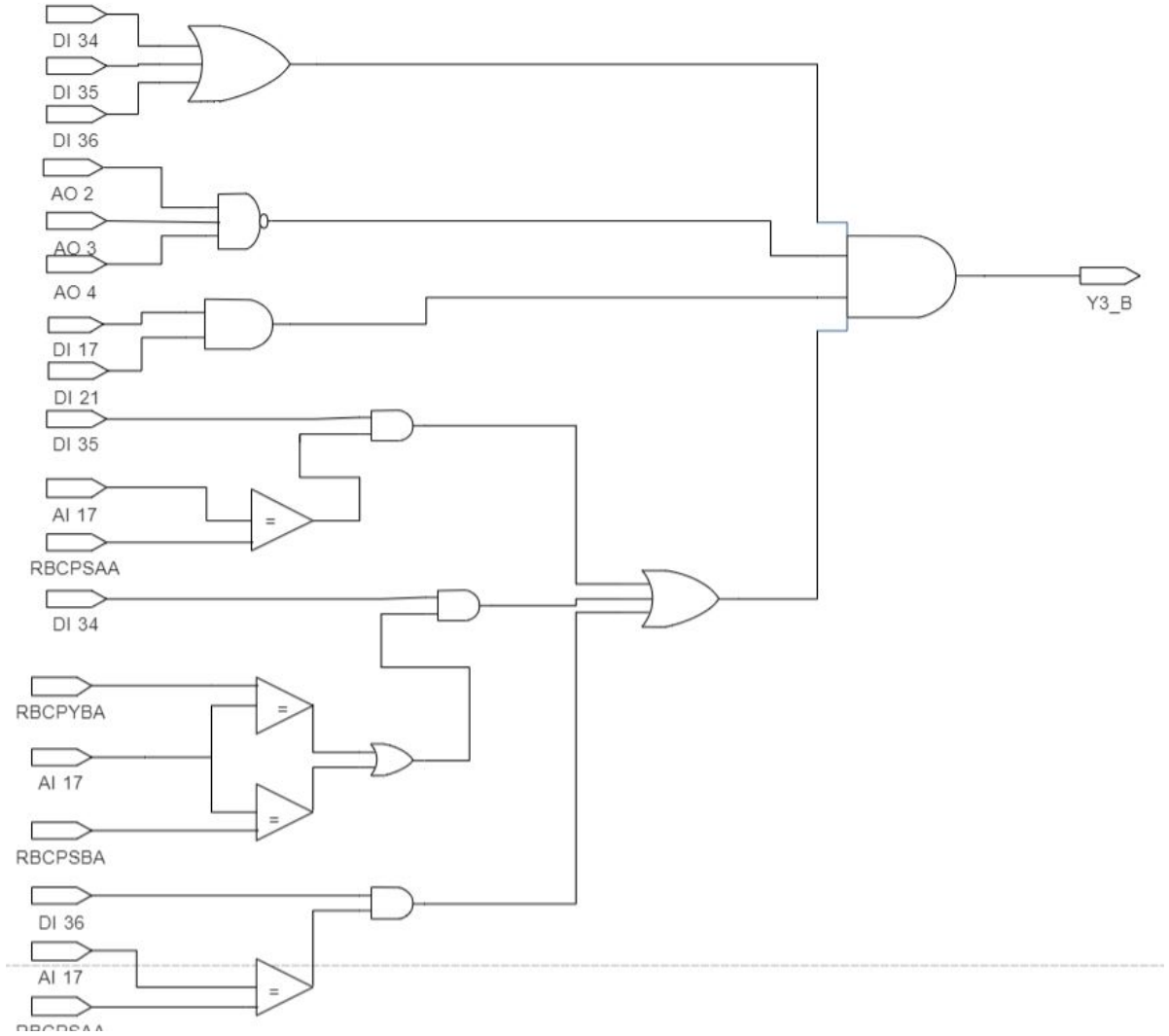


**Figure 3.1.3.b** Gated implementation of sub module 3(b)

c. Unlocking of separator

   i. FM Magazine should be aligned to any of the station H (shield ‘A’), station F (shield ‘B’), station J (spent fuel) or station D (new fuel).

   ii. All RAMs should be stationary.

Following is the gated implementation of the same

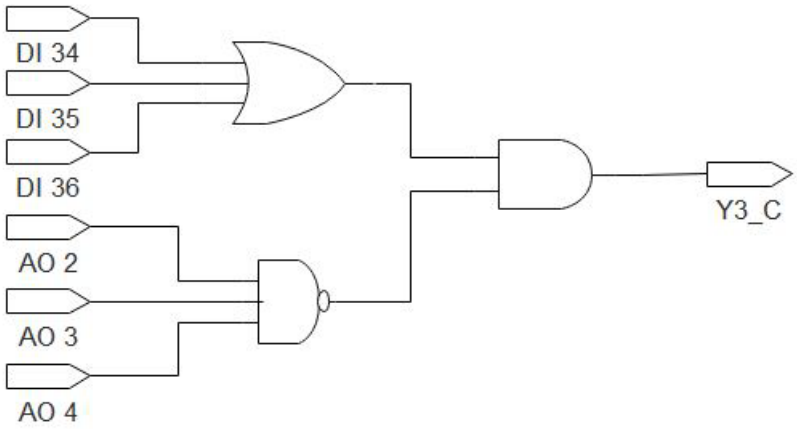


**Figure 3.1.3.c** Gated implementation of sub module 3(c)

4. Snout Assembly
   a. Unclamping of snout from end fitting
      i. Snout cavity pressure should be low.
      ii. Magazine pressure should be low.
      iii. Snout plug should be installed in snout. (checked by memory)
      iv. Seal plug and shield ‘A’ should be installed in end fitting. (checked by memory)
      v. FM carriage and trolley should be locked by anti-skidding pin.
      vi. Magazine to snout valve should be closed.
      vii. Snout emergency lock should be unlocked.

Following is the gated implementation of the same

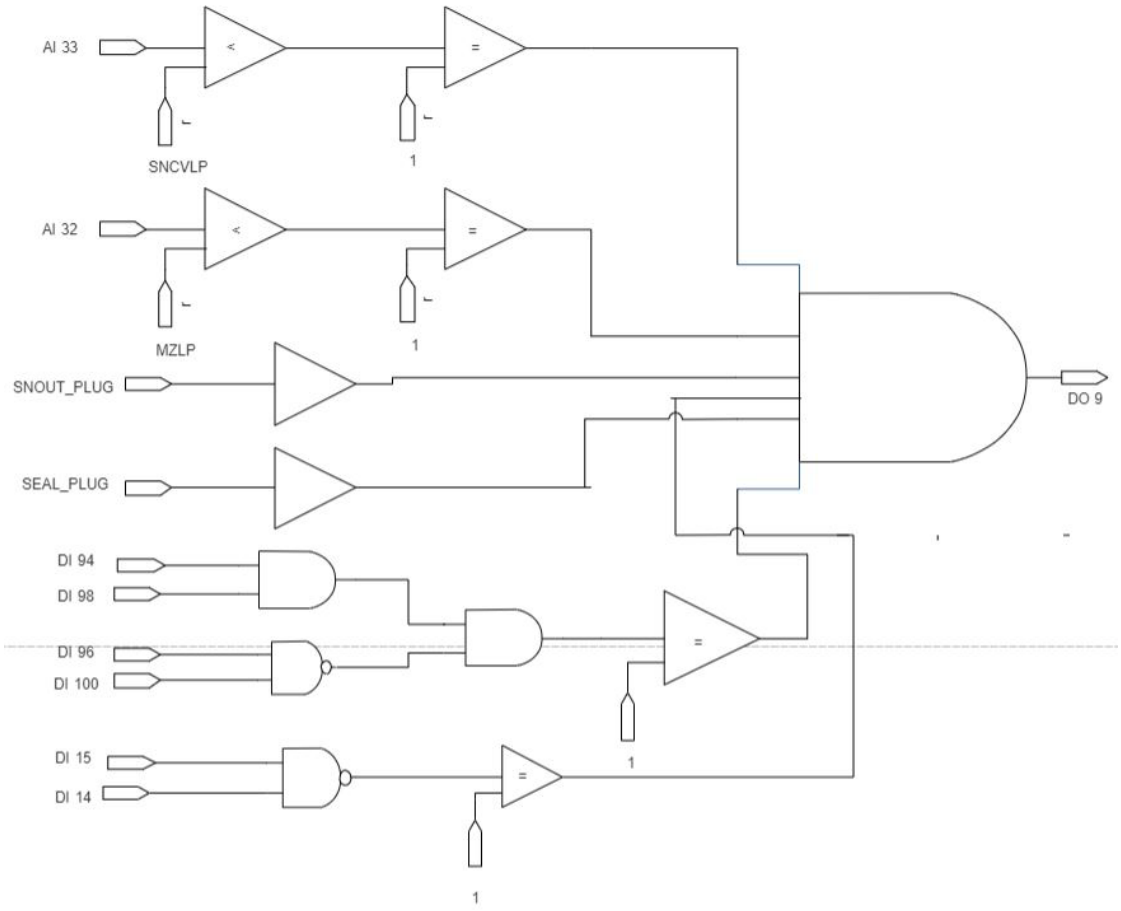


**Figure 3.1.4.a** Gated implementation of sub module 4(a)

b. Clamping of snout on end fitting

i. The readings of at least three out of four snout probes should be within permissible limit.

ii. FM carriage and trolley should be locked by anti-skidding pin.

Following is the gated implementation of the same

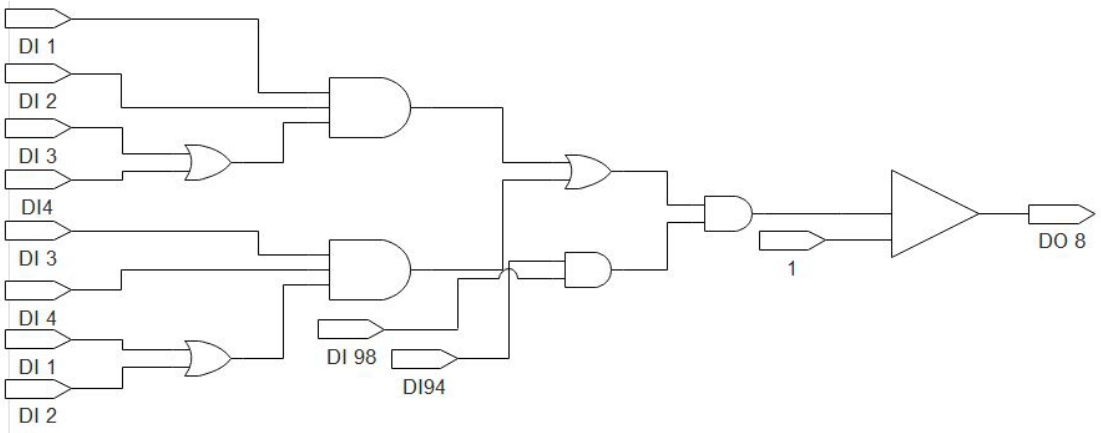


Figure 3.1.4.b Gated implementation of sub module 4(b)

5. Support Structure Assembly

a. Downward movement FM head up to pres-stop position

i. Head antenna should not be obstructed.

ii. Snout jaws should be in released condition.

iii. Fine X drive and fine Y drive travels shall be in middle of range of travel.

iv. X drive and Y drive over travel signals should not be present.

v. FM carriage and trolley should be locked by anti-skidding pin.

vi. Brakes of carriage and trolley are applied.

vii. Healthiness of Z drive counter balance valve signal should be available.

viii. Z- LVDT signals should be within the predefined range.

ix. Error signal from sensing finger shall not present.

Following is the gated implementation of the same

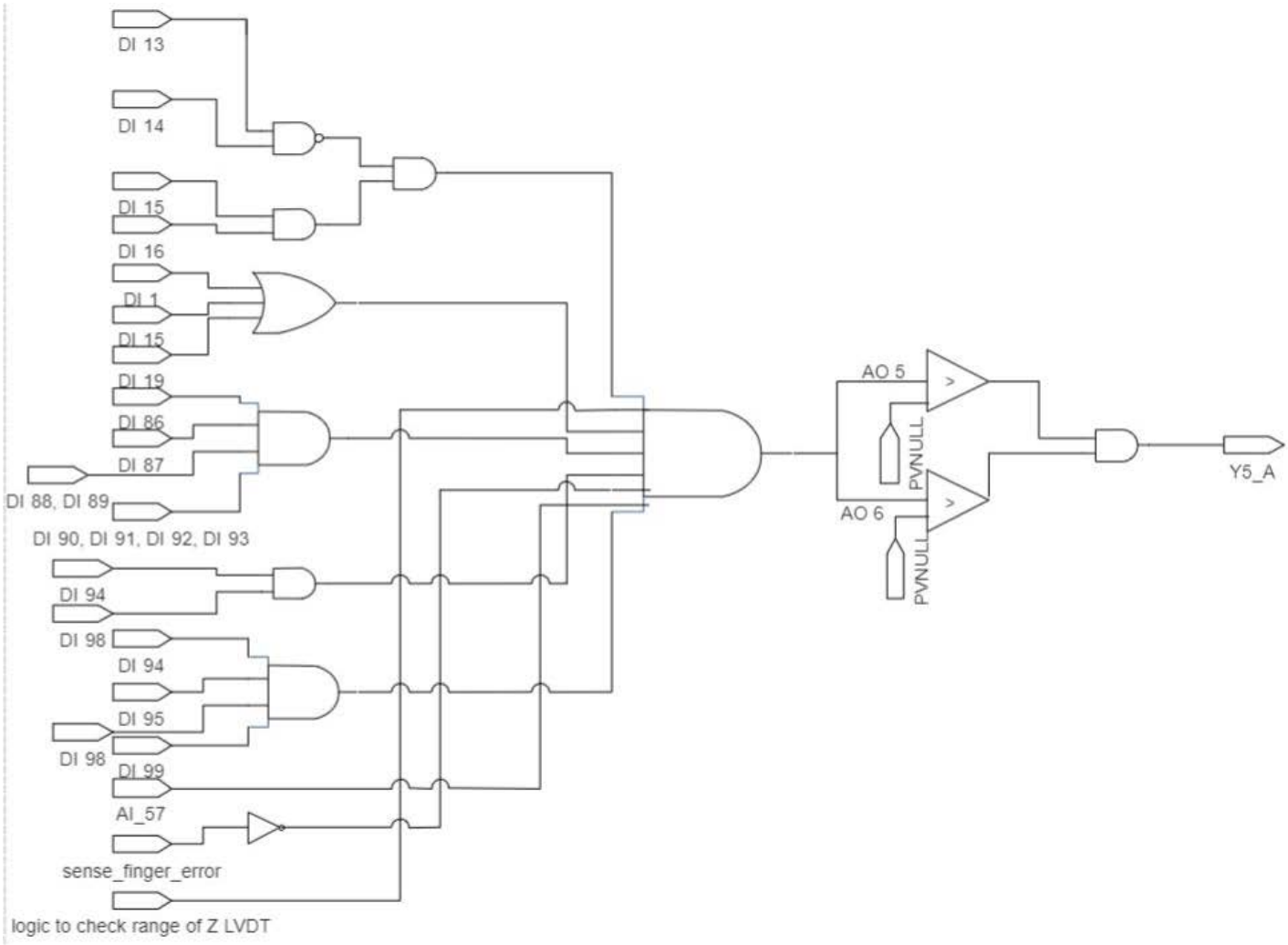


**Figure 3.1.5.a** Gated implementation of sub module 5(a)

b. Upward Z-movement of FM head from clamping position to pre-stop position

i. Snout jaws should be in released condition.

ii. FM carriage and trolley should be locked by anti-skidding pin.

Following is the gated implementation of the same

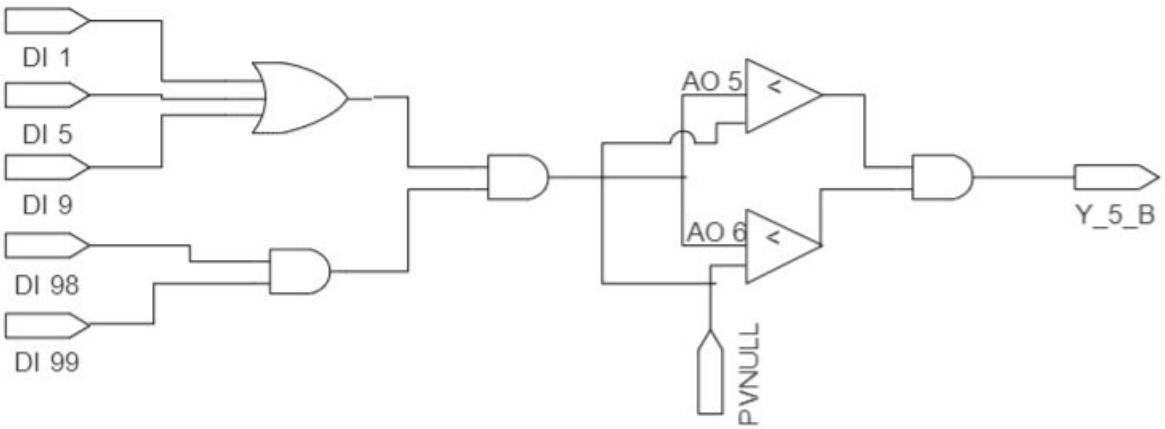


**Figure 3.1.5.b** Gated implementation of sub module 5(b)

c. TO/FRO movement of FM head fine X

i. FM head should be at Z back or at Z pre stop position.

ii. There should not be any movement for fine Y.

iii. Head antenna should not be obstructed.

iv. FM carriage and trolley should be locked by anti-skidding pin.

v. Fine X drive and fine Y over travel signals should not be present.

vi. FM should not be in clamped condition.

Following is the gated implementation of the same

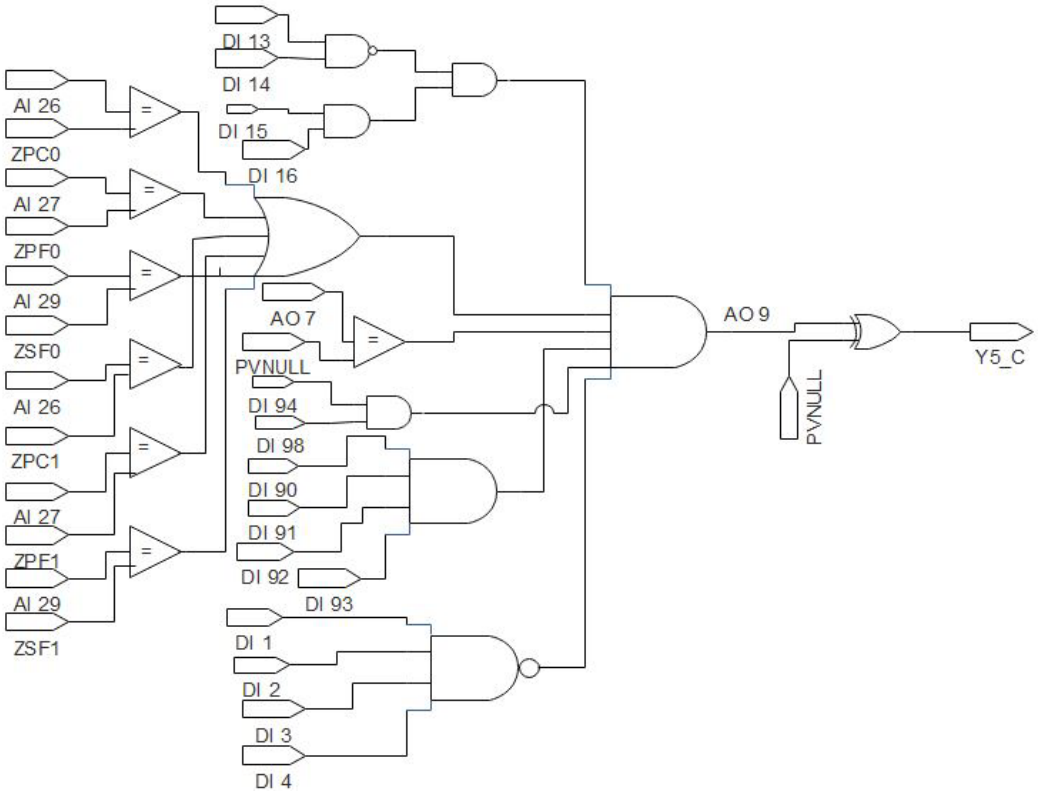


**Figure 3.1.5.c** Gated implementation of sub module 5(c)

d. TO/FRO movement of FM head fine Y

i. FM head should be at Z back or at Z pre stop position.

ii. There should not be any movement for fine X.

iii. Head antenna should not be obstructed.

iv. FM carriage and trolley should be locked by anti-skidding pin.

v. Fine X drive and fine Y over travel signals should not be present.

vi. FM should not be in clamped condition.

Following is the gated implementation of the same

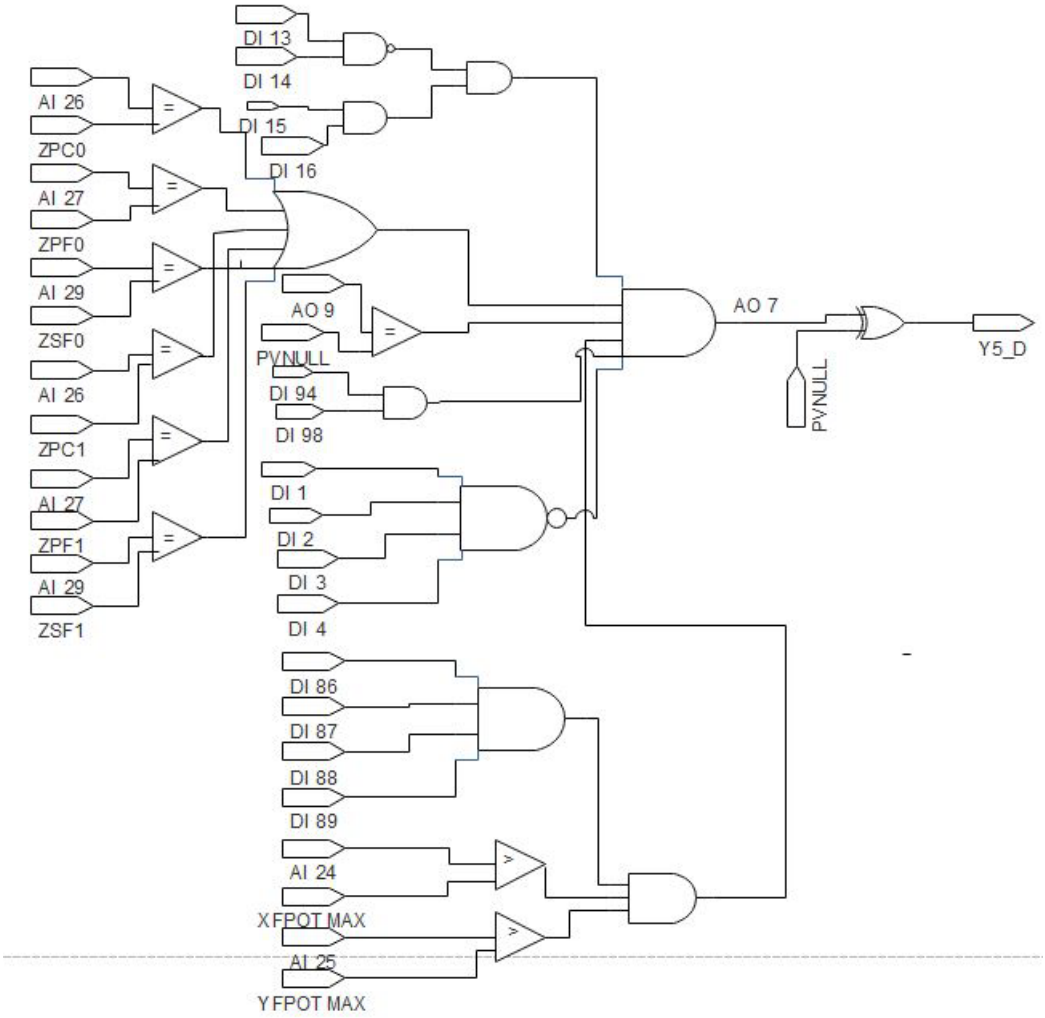


**Figure 3.1.5.d** Gated implementation of sub module 5(d)

6. Carriage & Trolley Assembly

a. TO/FRO movement of FM carriage assembly X drive (long travel)

i. FM head should be at Z back position.

ii. X fine and Y fine travel shall be in middle position.

iii. Snout clamp should be in released condition.

iv. Carriage anti skidding pin should be lifted in up position (unlocked condition).

v. Trolley skidding pin should be locked.

vi. Site clearance should be provided by operator for trolley and carriage movement. (A message should pop up asking operator whether trolley or carriage is cleared to move. If operator confirms clearance, then interlock is satisfied. However, this clearance is valid for only five minutes.)

vii. X drive over travel in the direction of motion should not be present.

viii. Trolley should be in home position (center of the carriage span).

ix. X drive brakes shall be in released condition.

Following is the gated implementation of the same

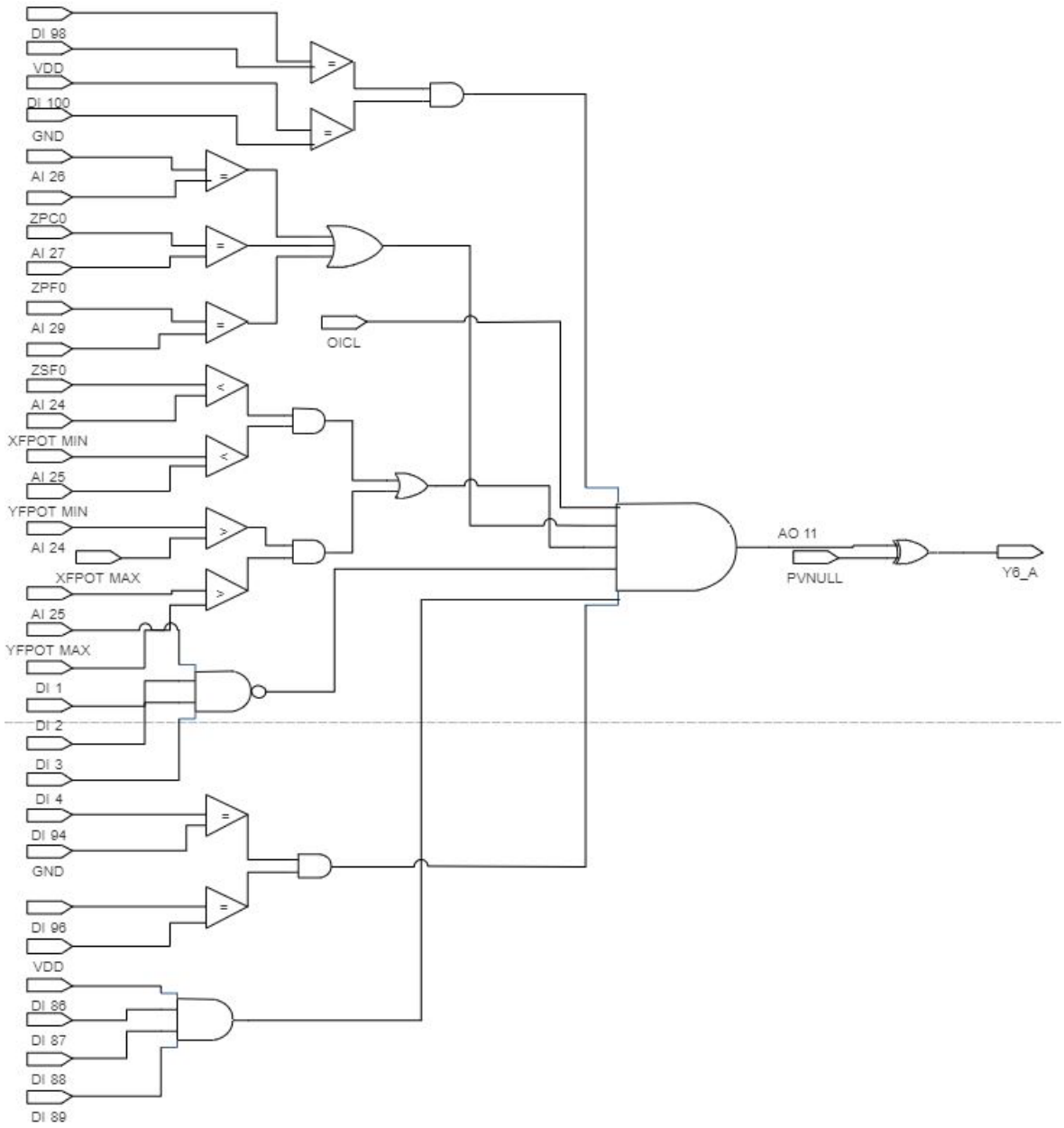


**Figure 3.1.6.a** Gated implementation of sub module 6(a)

b. TO/FRO movement of FM trolley assembly Y drive (cross travel)

i. FM head should be at Z back position.

ii. X fine and Y fine over travel signals should not be present.

iii. Snout clamp should be in released condition.

iv. Trolley anti skidding pin should be lifted in up position.

v. Carriage skidding pin should be locked.

vi. Site clearance should be provided by operator for trolley and carriage movement. (A message should pop up asking operator whether trolley or carriage is cleared to move. If operator confirms clearance, then interlock is satisfied. However, this status should be cleared from memory after five minutes.)

vii. Y drive over travel in the direction of motion should not be present.

viii. Y drive brakes shall be in released condition.

Following is the gated implementation of the same

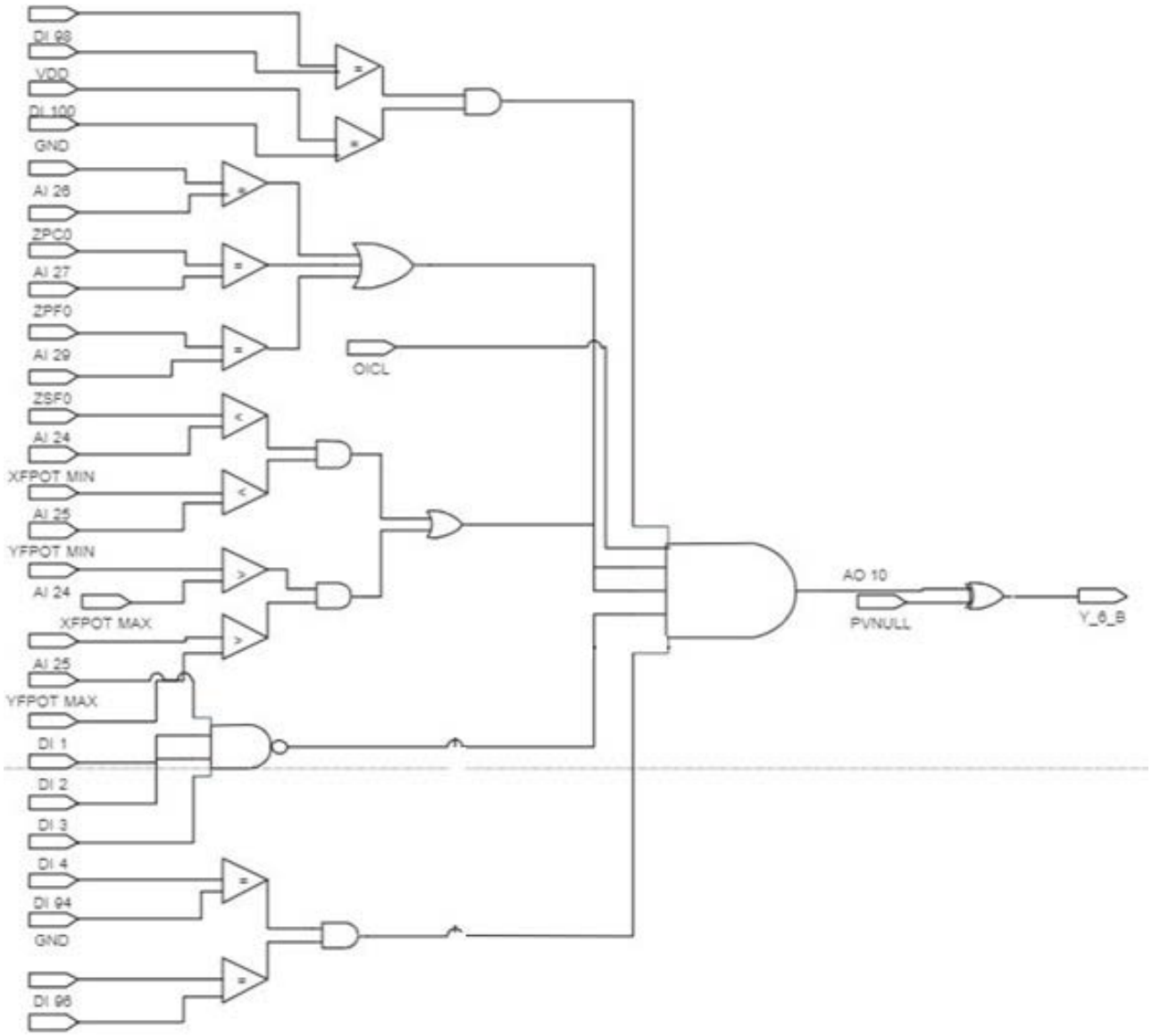


**Figure 3.1.6.b** Gated implementation of sub module 6(b)

## 3.2 SOFTWARE SIMULATION

Each of the modules illustrated and described above were coded in Libero SoC v11.8 and the test benches generated were tested both within the ModelSim© software (integrated with Libero SoC) as well as on the Xilinx® ISE design suite. The latter provides a much more intuitive interface for testing of modules and facilitates easier generation and logging of waveforms in appropriate formats. Hence, for the sake of convenience the output waveforms (given here) have been obtained exclusively from the Xilinx® ISE software.

All the waveforms have been formatted with the inputs (starting from the first sub condition) at the top to the final actuating output at the bottom. All sub modules' simulation has been given in exactly the same order in which they had been illustrated in **section 3.1** excepting their written descriptions. All modules have been tested on a standard test bench of size 1000ns.

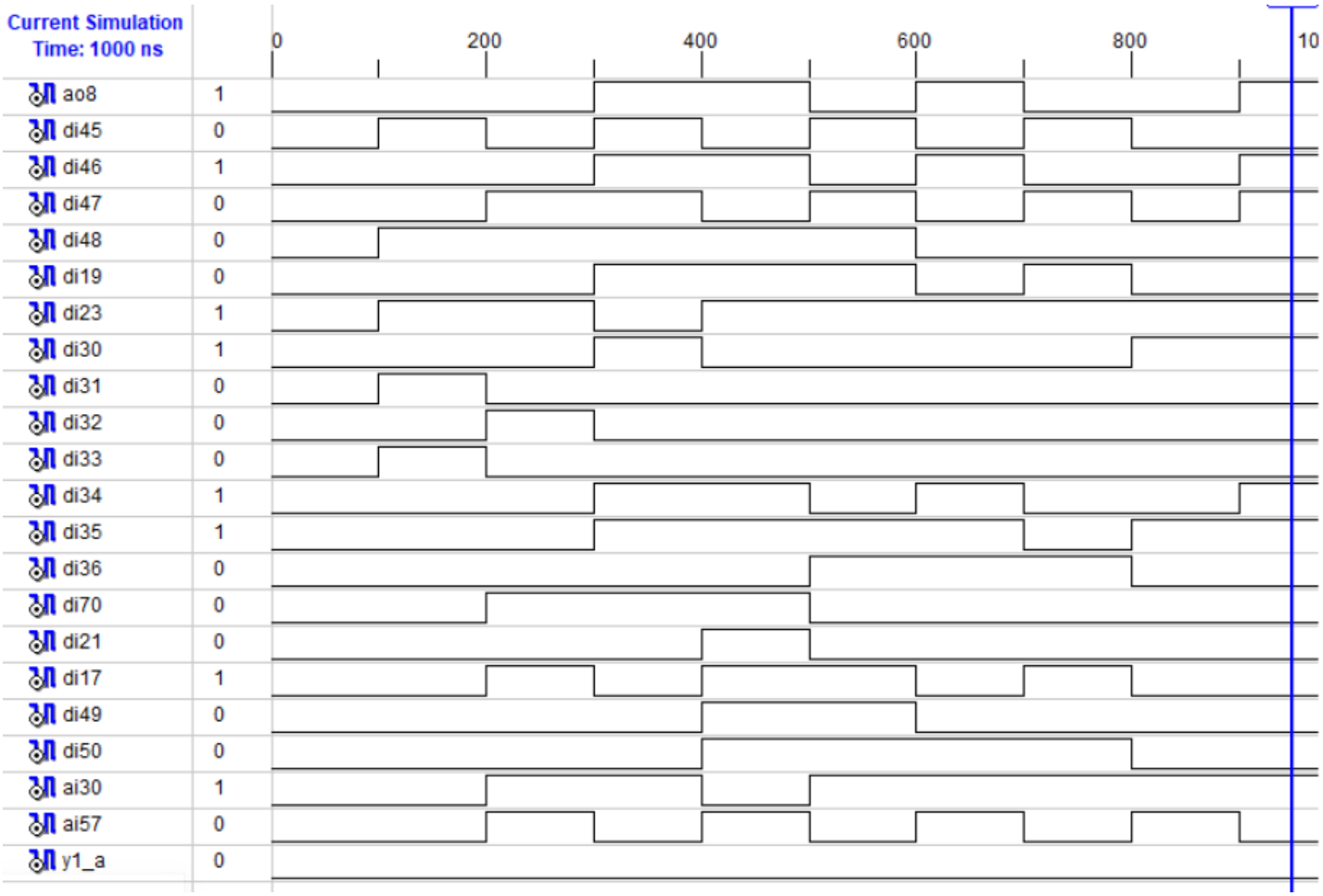


**Figure 3.2.1.a** Output waveforms for sub module 1(a)

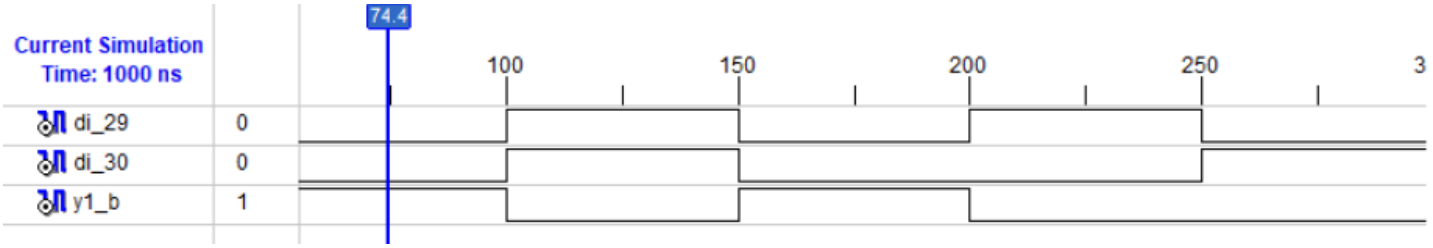


**Figure 3.2.1.b** Output waveforms for sub module 1(b)

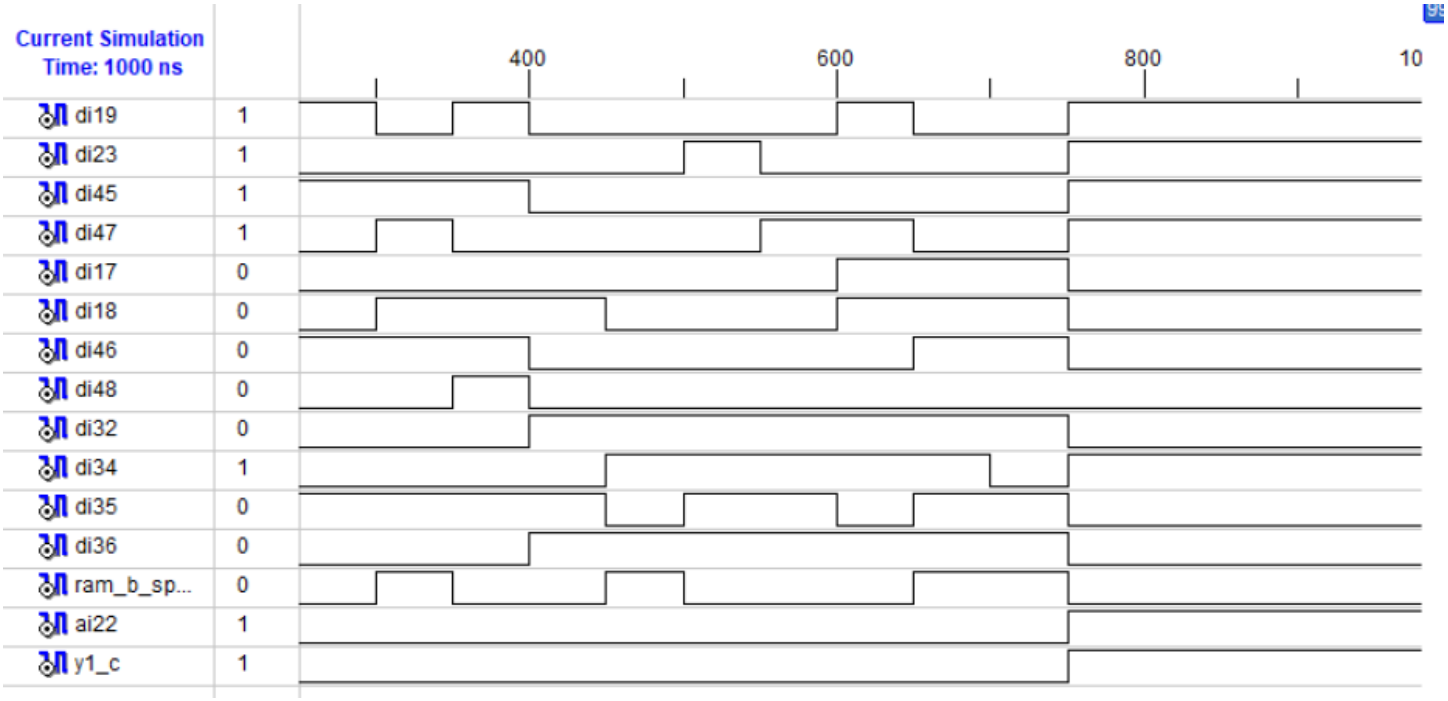


**Figure 3.2.1.c** Output waveforms for sub module 1(c)

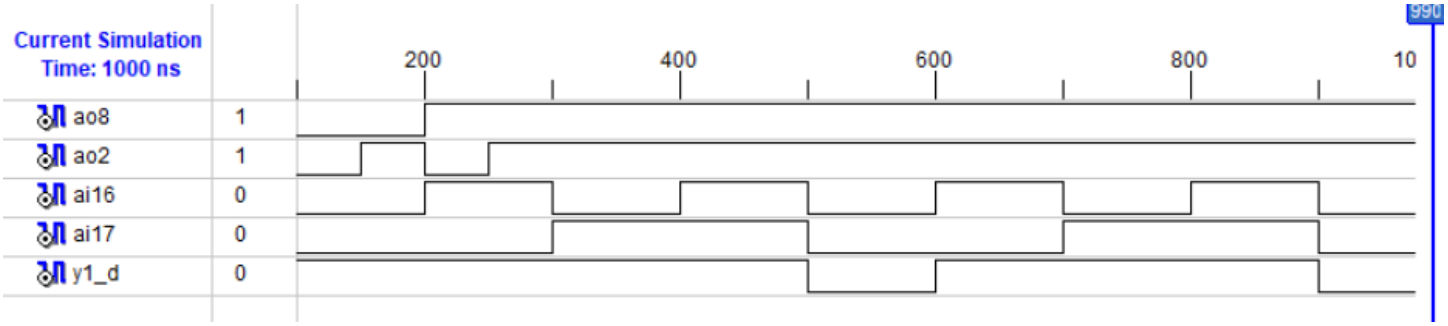


**Figure 3.2.1.d** Output waveforms for sub module 1(d)

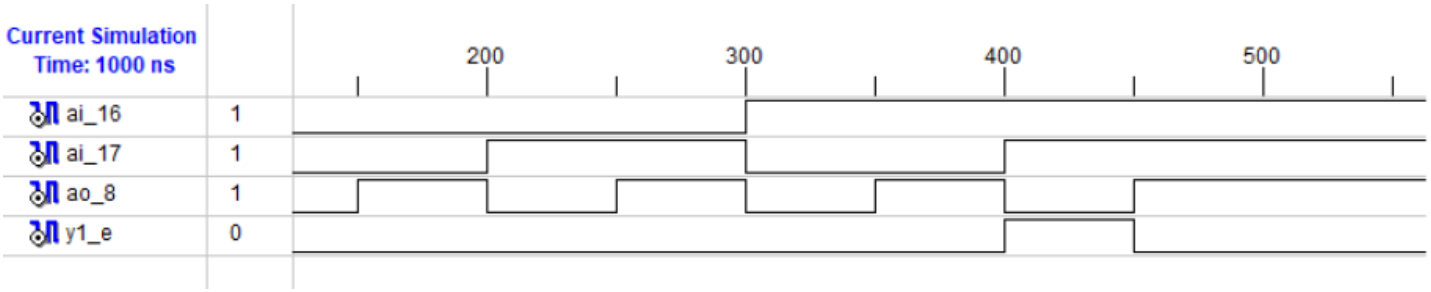


**Figure 3.2.1.e** Output waveforms for sub module 1(e)

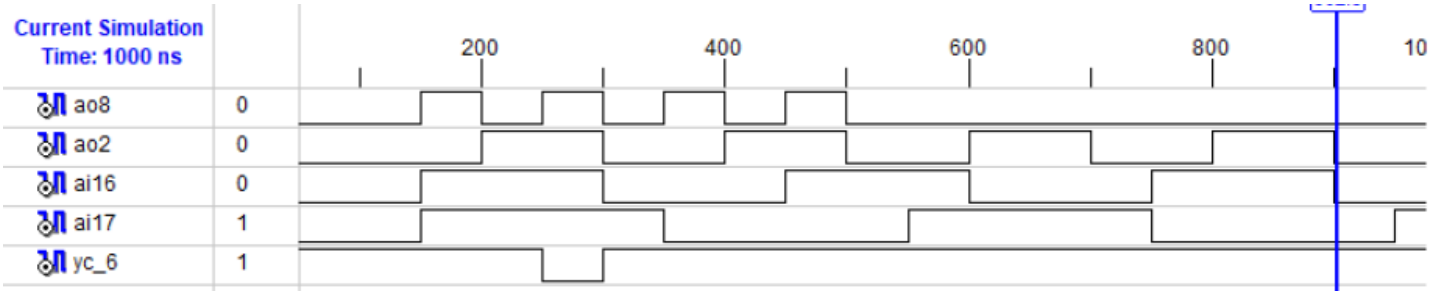


**Figure 3.2.1.f** Output waveforms for sub module 1(f)

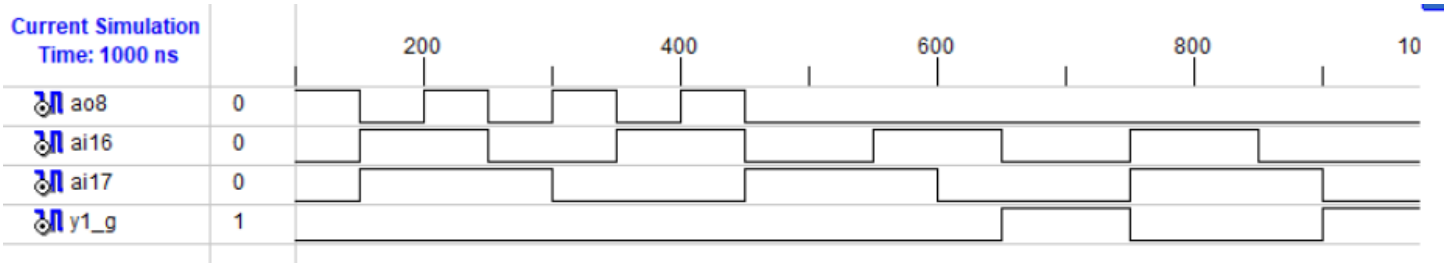


**Figure 3.2.1.g** Output waveforms for sub module 1(g)

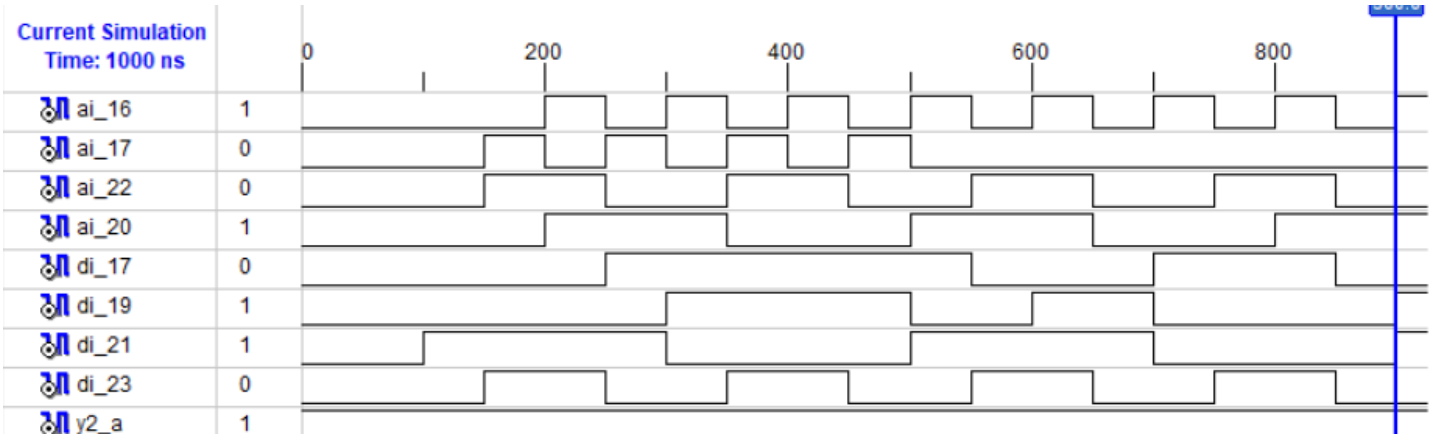


**Figure 3.2.2.a** Output waveforms for sub module 2(a)

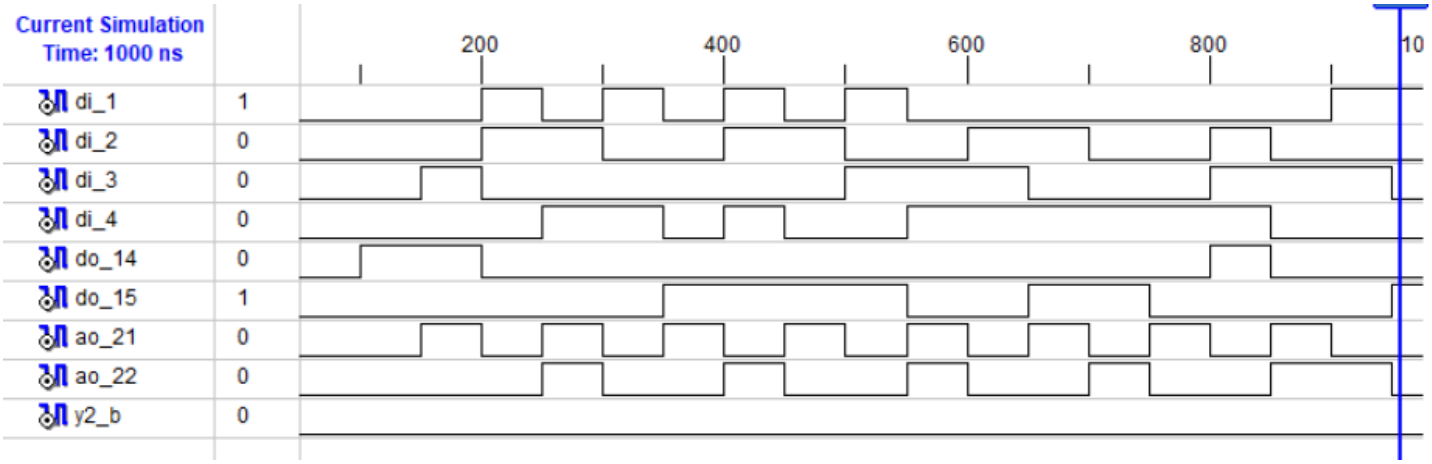


**Figure 3.1.2.b** Output waveforms for sub module 2(b)

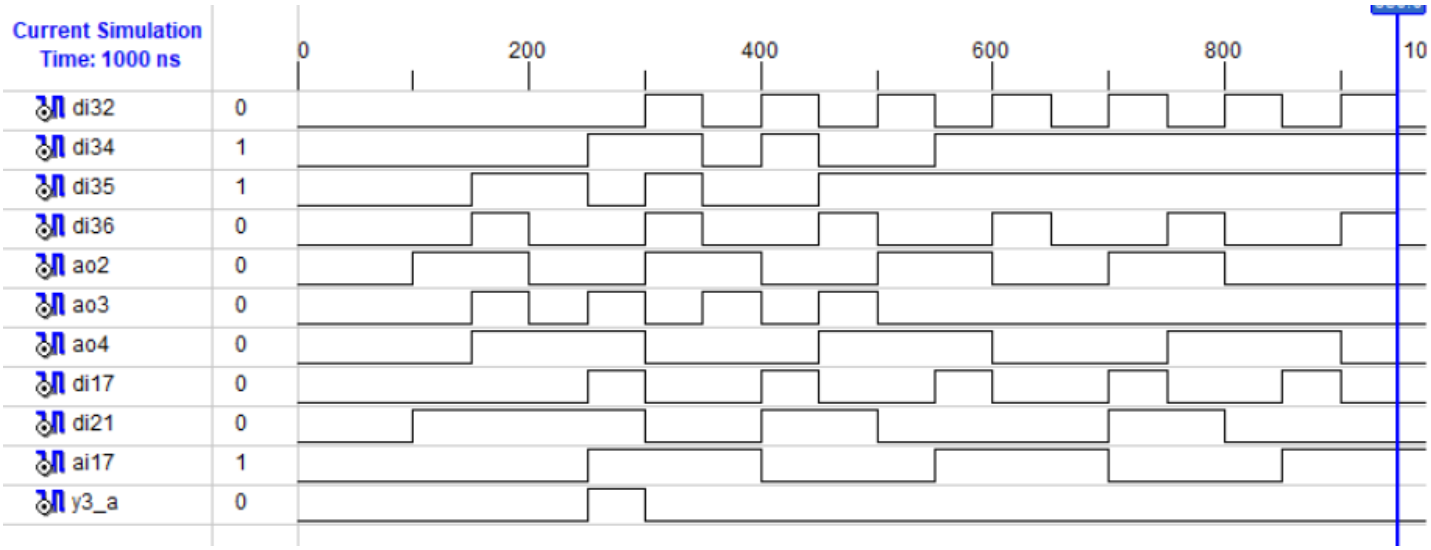


**Figure 3.2.3.a** Output waveforms for sub module 3(a)

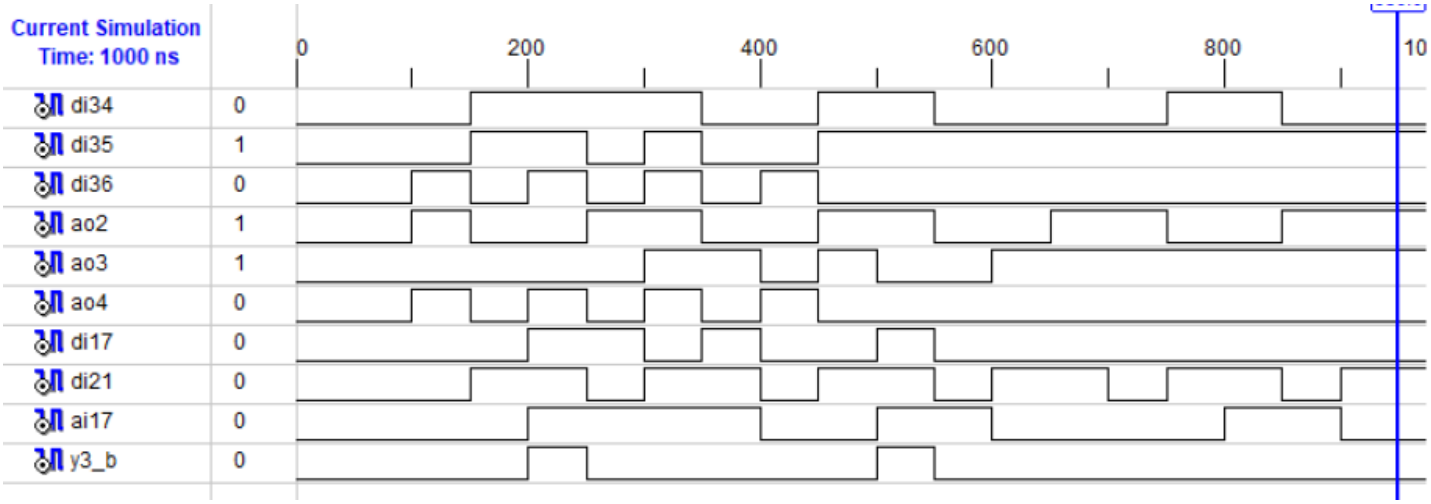


**Figure 3.2.3.b** Output waveforms for sub module 3(b)

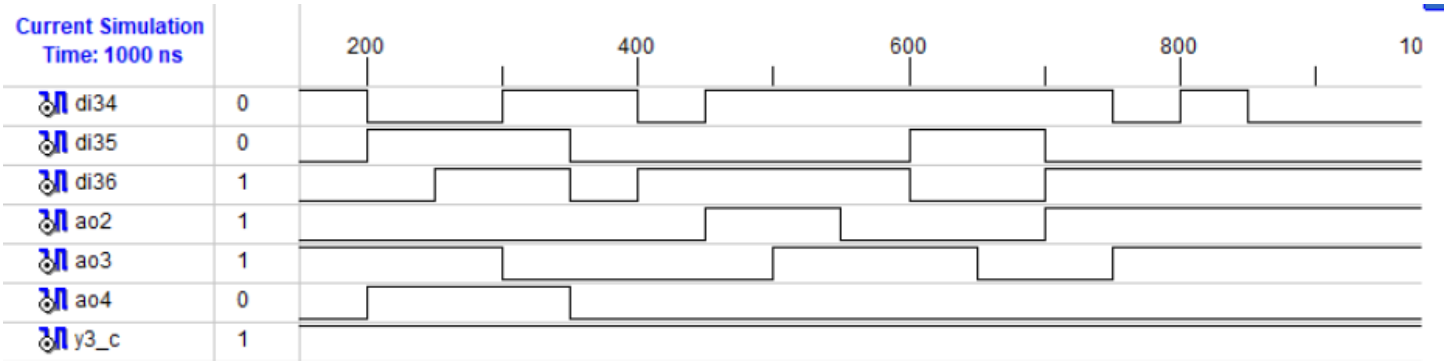


**Figure 3.2.3.c** Output waveforms for sub module 3(c)

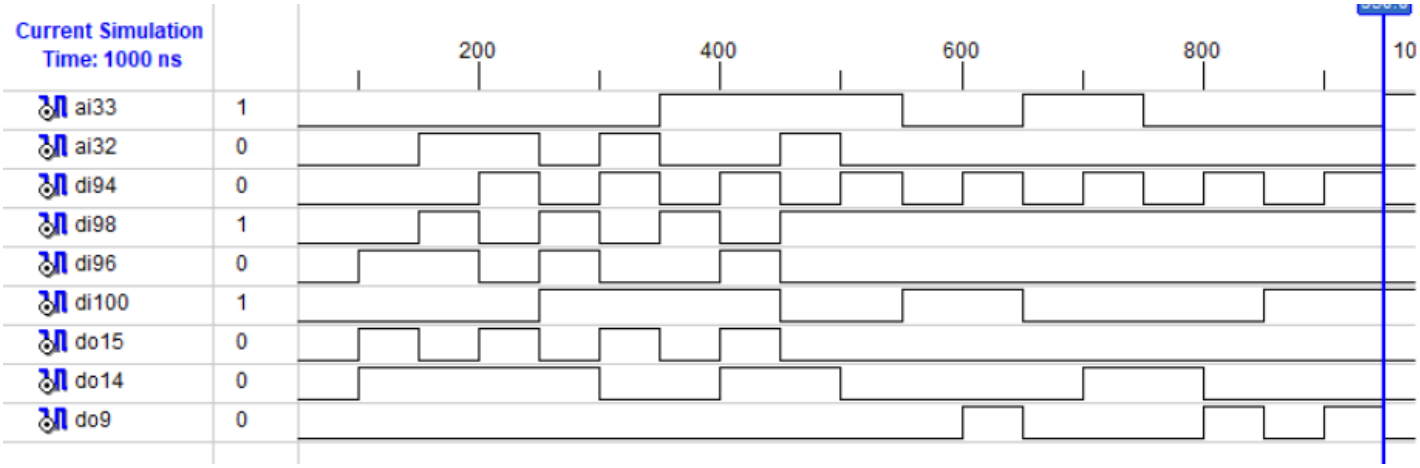


**Figure 3.2.4.a** Output waveforms for sub module 4(a)

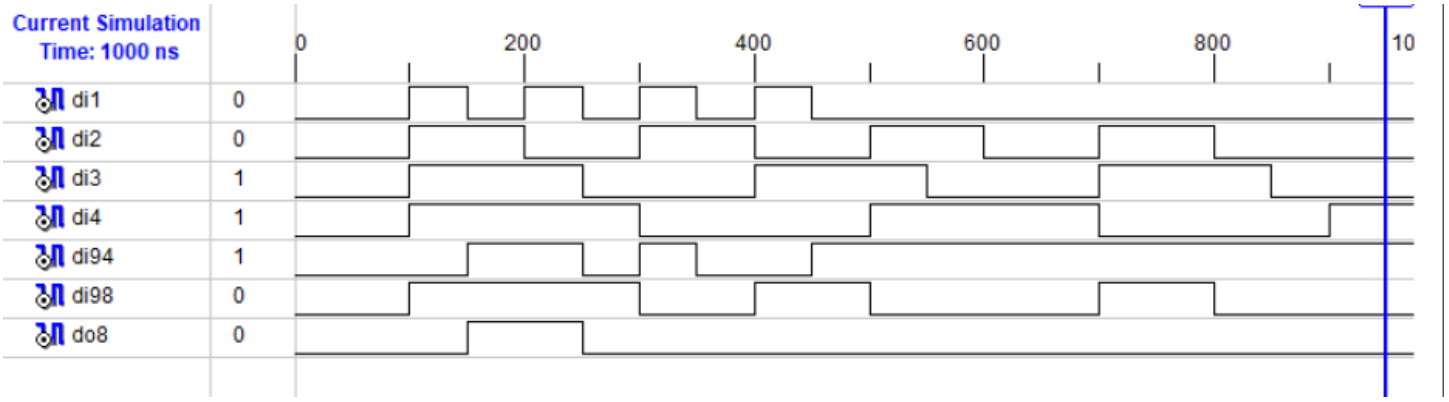


**Figure 3.2.4.b** Output waveforms for sub module 4(b)

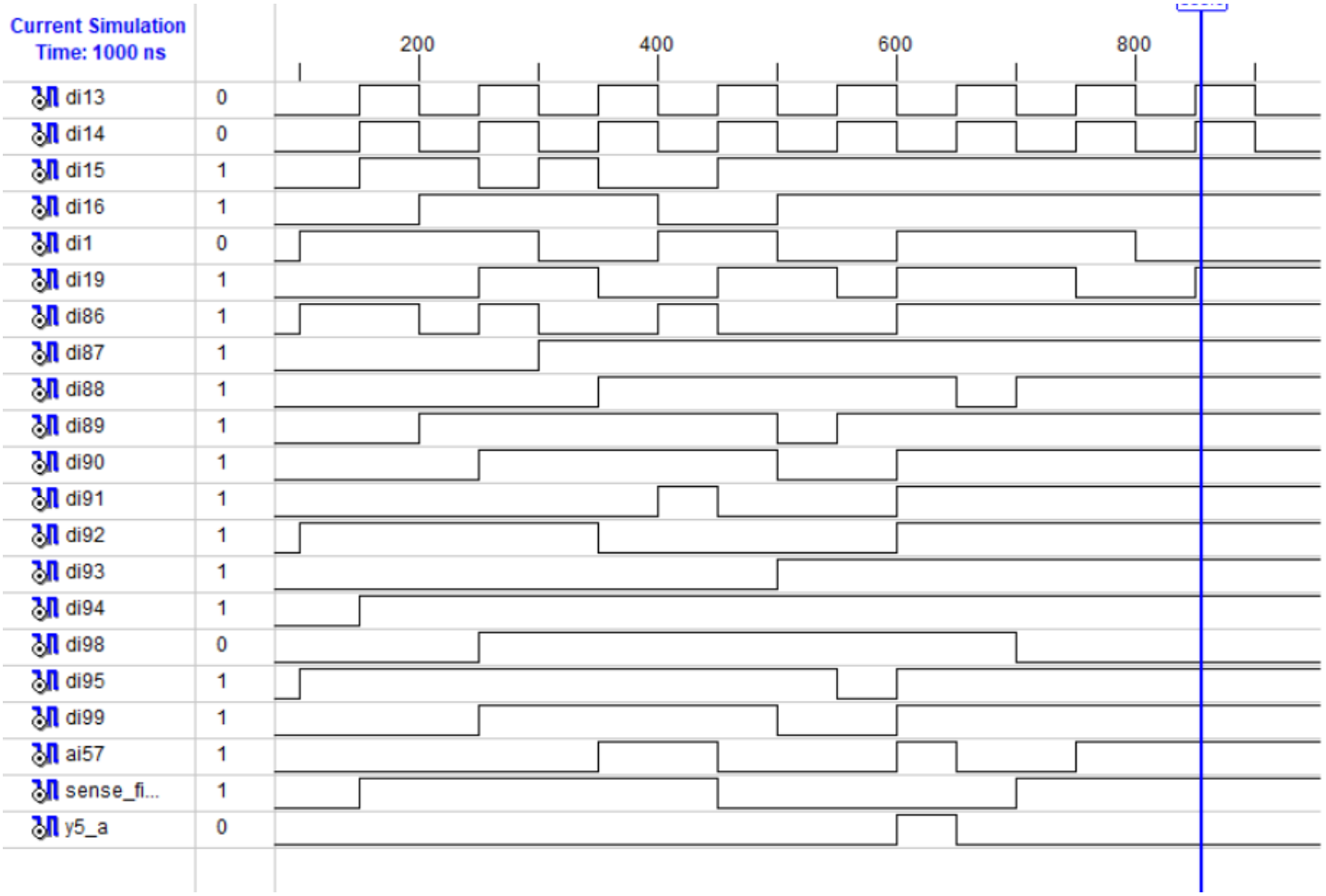


**Figure 3.2.5.a** Output waveforms for sub module 5(a)

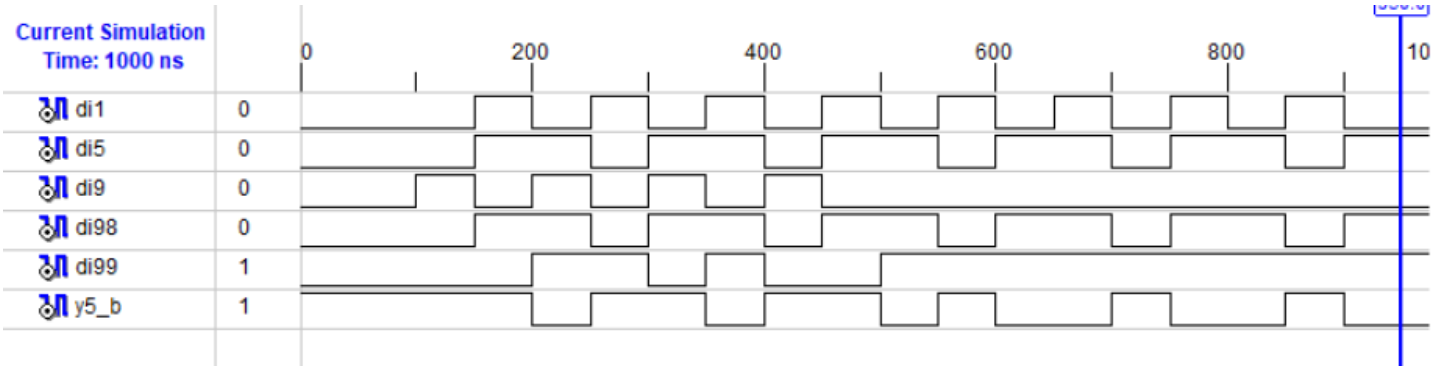


**Figure 3.2.5.b** Output waveforms for sub module 5(b)


**Figure 3.2.6.a** Output waveforms for sub module 6(a)

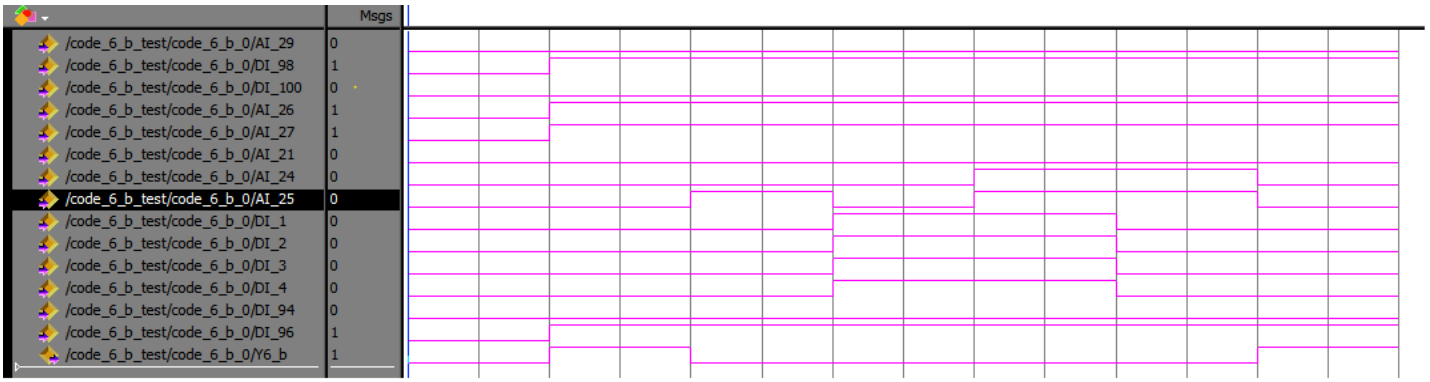


**Figure 3.2.6.b** Output waveforms for sub module 6(b)