Introduction

Safety Integrity Level (SIL) indicates the degree of risk reduction, provided by an Instrumented Safety Function (SIF), implemented by a Safety Instrumented System (SIS), within a given process. In other words, SIL is a measure of the SIF's performance, in terms of Probability of Failure on Demand (PFD).

IEC 61508 defines four SIL levels, with SIL 4 providing the highest level of safety performance. For example, SIL 1 corresponds to a Risk Reduction Factor (RRF) of at least 10, and SIL 4 to a Risk Reduction Factor (RRF) of at least 10,000.

SIL	PFA Average	RRF Average
1	0.1-0.010	10-100
2	0.01-0.001	100-1000
3	0.001-0.0001	1000-10000
4	0.0001-0.00001	10000-100000

So, the higher the SIL level, the higher the associated safety level, and the lower probability that a system will fail to perform. Normally, a higher SIL level means a more complex system and higher installation and maintenance costs.

Process plants typically only require SIL 1 and SIL 2 SIFs. SIL 3 and SIL 4 SIFs are very rare and normally not economically beneficial to implement since they require a high degree of duplication. In most of these cases, one should reconsider the fundamental design of the process.

Voting logic is applied to minimize the occurrence of complete loss of production caused by single transmitter fault or spurious trip shutdown. The voting configuration can be 2oo3 or 1oo2 based on SIL assessment and verification.

There are 1oo1, 1oo2, 2oo2, 2oo3 etc voting logic in the safety instrumented system architecture. There are two purposes why certain voting logic architecture were chosen, first is to reach certain SIL and secondly to reach certain cost reduction due to spurious platform shutdown.

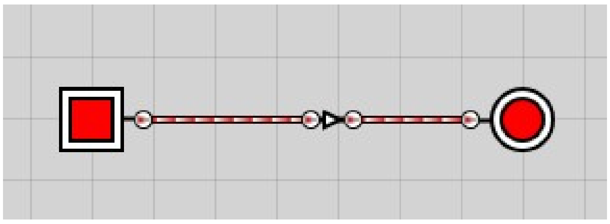
1oo1 Voting Logic

If 1oo1 sensor, 1oo1 logic solver, and 1oo1 shutdown valve can fulfill the SIL 3 requirement, then this architecture is chosen.

Enter 0 or 1

$T_1 = 1$

```
Alarm = if T1 = 1
            "It's an Alarm"
        else
            "Not an Alarm"
```



$\boxed{Alarm = \text{"It's an Alarm"}}$

1oo2 Voting logic

Let’s say after several investigations the voting logic 1oo2 sensor, 1oo2 logic solver, and 1oo2 shutdown valve can fulfill the requirement of SIL 3, then this voting logic is chosen. If the cost reduction study need to minimize spurious trip due to one of the sensor failed, then may be the sensor voting logic architecture must be upgraded to become 2oo3 architecture.

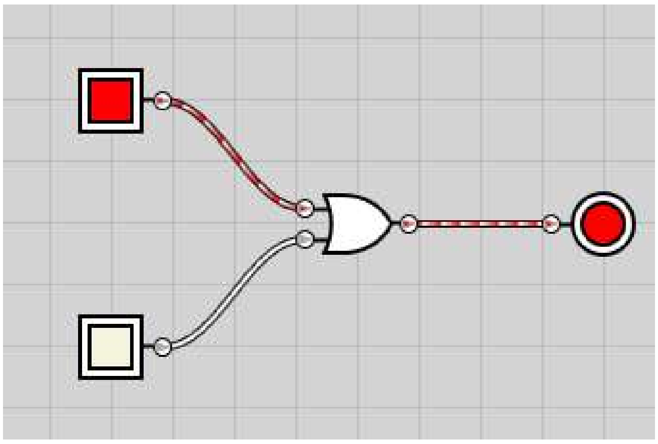
The 1oo2 system offers low probability of failure on demand, but it increases the probability of a "false trip".

Enter 0 or 1 $P_1 = 0$

Enter 0 or 1 $P_2 = 1$

$Alarm = \text{if } (P_1 \lor P_2) = 1$
"It's an Alarm"
else
"Not an Alarm"

$\boxed{Alarm = \text{"It's an Alarm"}}$



2oo2 Voting logic

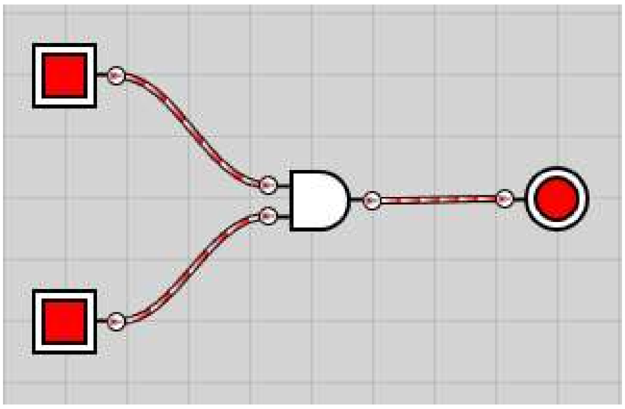
Two-out-of-two voting (2oo2) also employs two devices. In this arrangement, of the two devices, both devices must “agree” to cause a shutdown before the shutdown will occur. I.e., both devices must vote to trip to cause a trip action.

Enter 0 or 1 $P_1 = 1$

Enter 0 or 1 $P_2 = 1$

$Alarm = \text{if } (P_1 \land P_2) = 1$
"It's an Alarm"
else
"Not an Alarm"

$\boxed{Alarm = \text{"It's an Alarm"}}$



2oo3 Voting logic

Two out of three logic is called the triple module redundancy or triple mode redundancy, in which three independent inputs are connected to a system and the output, comes out based on the maximum number of voting.

Enter 0 or 1 $F_1 = 0$

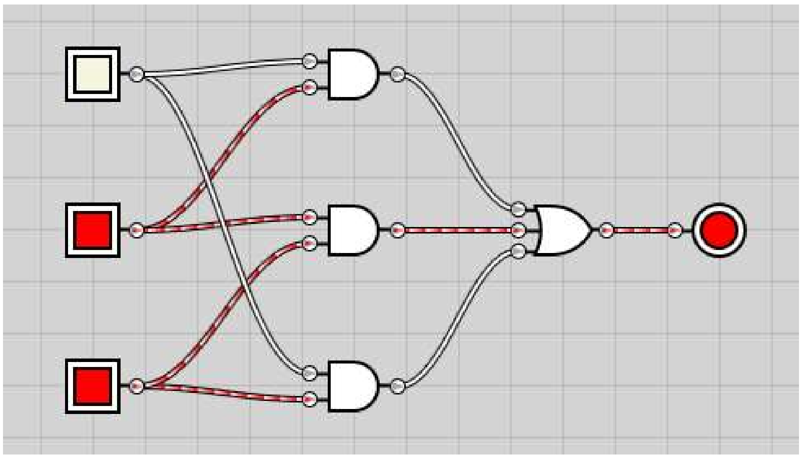
Enter 0 or 1 $F_2 = 1$

Enter 0 or 1 $F_3 = 1$

$And_1 = (F_1 \wedge F_2) = 0$

$And_2 = (F_2 \wedge F_3) = 1$

$And_3 = (F_3 \wedge F_1) = 0$



```
Alarm := if (And_1 ∨ And_2) = 1
            "Its an Alarm"
         else
           if (And_2 ∨ And_3) = 1
             "Its an Alarm"
           else
             if (And_3 ∨ And_1) = 1
               "Its an Alarm"
             else
               "Not an Alarm"
```

$\boxed{Alarm = \text{"Its an Alarm"}}$

2oo4 Voting Logic

The 2oo4 voting logic provides a balanced approach in terms of increased availability of machine due to reduction of spurios trips caused due to faulty instruments in case of 1oo2 and missed shutdown due to 2oo2 voting.

Enter 0 or 1	Enter 0 or 1	Enter 0 or 1	Enter 0 or 1
$L_1 = 1$	$L_2 = 1$	$L_3 = 1$	$L_4 = 0$

$And_{12} = (L_1 \wedge L_2) = 1$ $And_{13} = (L_1 \wedge L_3) = 1$ $And_{24} = (L_2 \wedge L_4) = 0$

$And_{34} = (L_3 \wedge L_4) = 0$ $And_{14} = (L_1 \wedge L_4) = 0$ $And_{23} = (L_2 \wedge L_3) = 1$

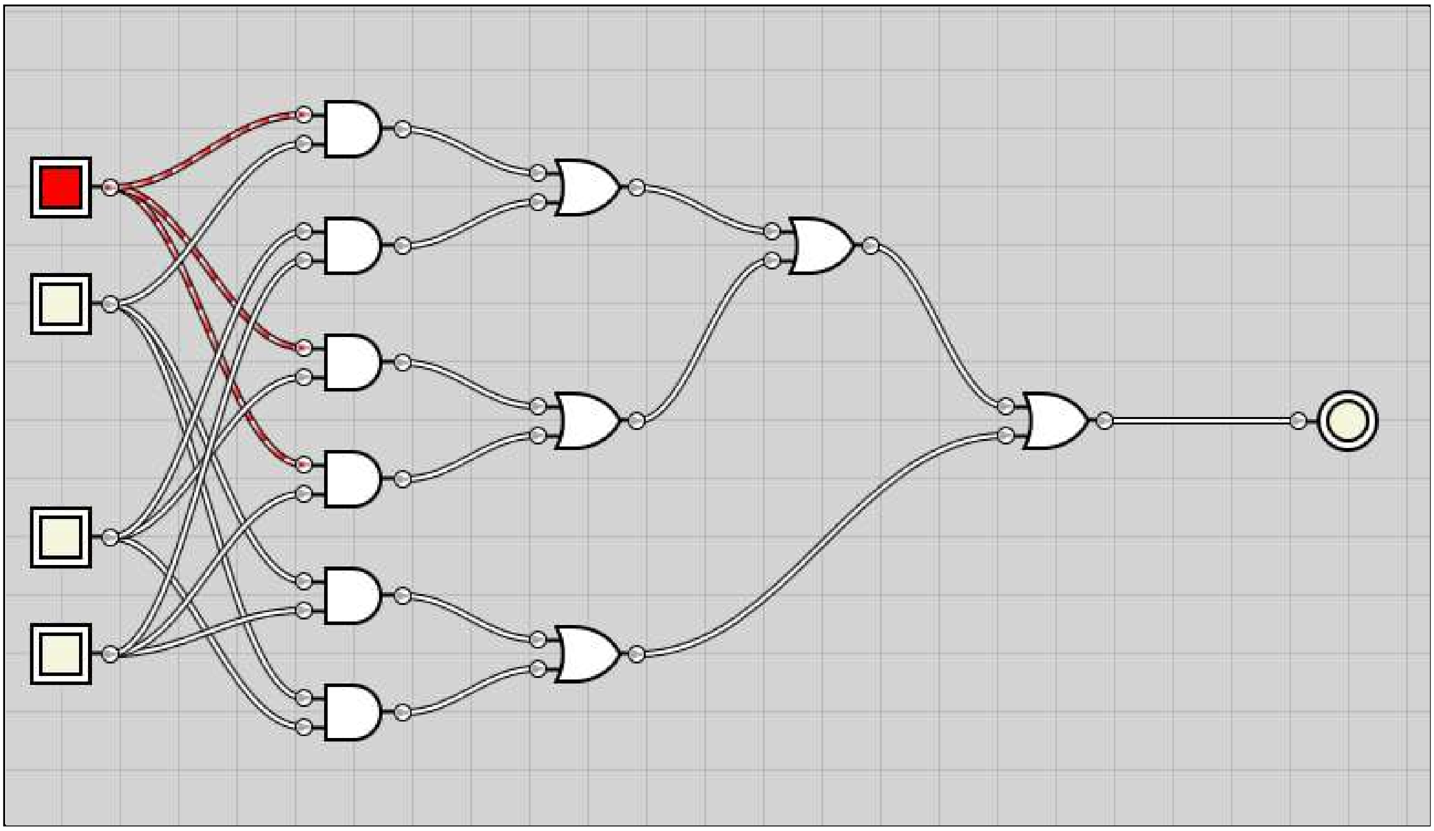
$OR_{12\_34} = (And_{12} \vee And_{34}) = 1$ $OR_{13\_14} = (And_{13} \vee And_{14}) = 1$ $OR_{24\_23} = (And_{24} \vee And_{23}) = 1$

$OR_1 = (OR_{12\_34} \vee OR_{13\_14}) = 1$

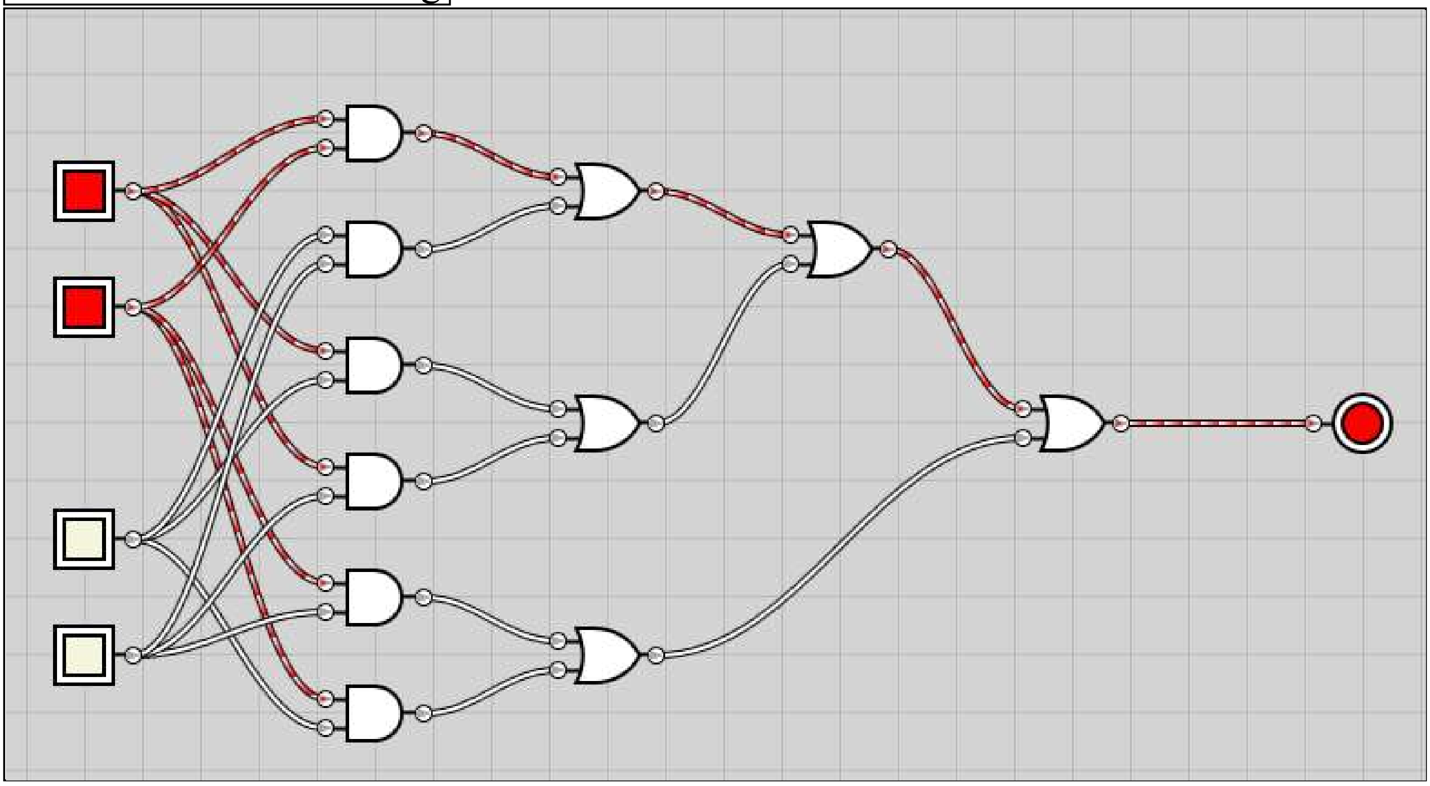
```
Alarm := if (OR_1 ∨ OR_24_23) = 1 = "Its an Alarm"
            "Its an Alarm"
         else
            "Not an Alarm"
```

$\boxed{Alarm = \text{"Its an Alarm"}}$

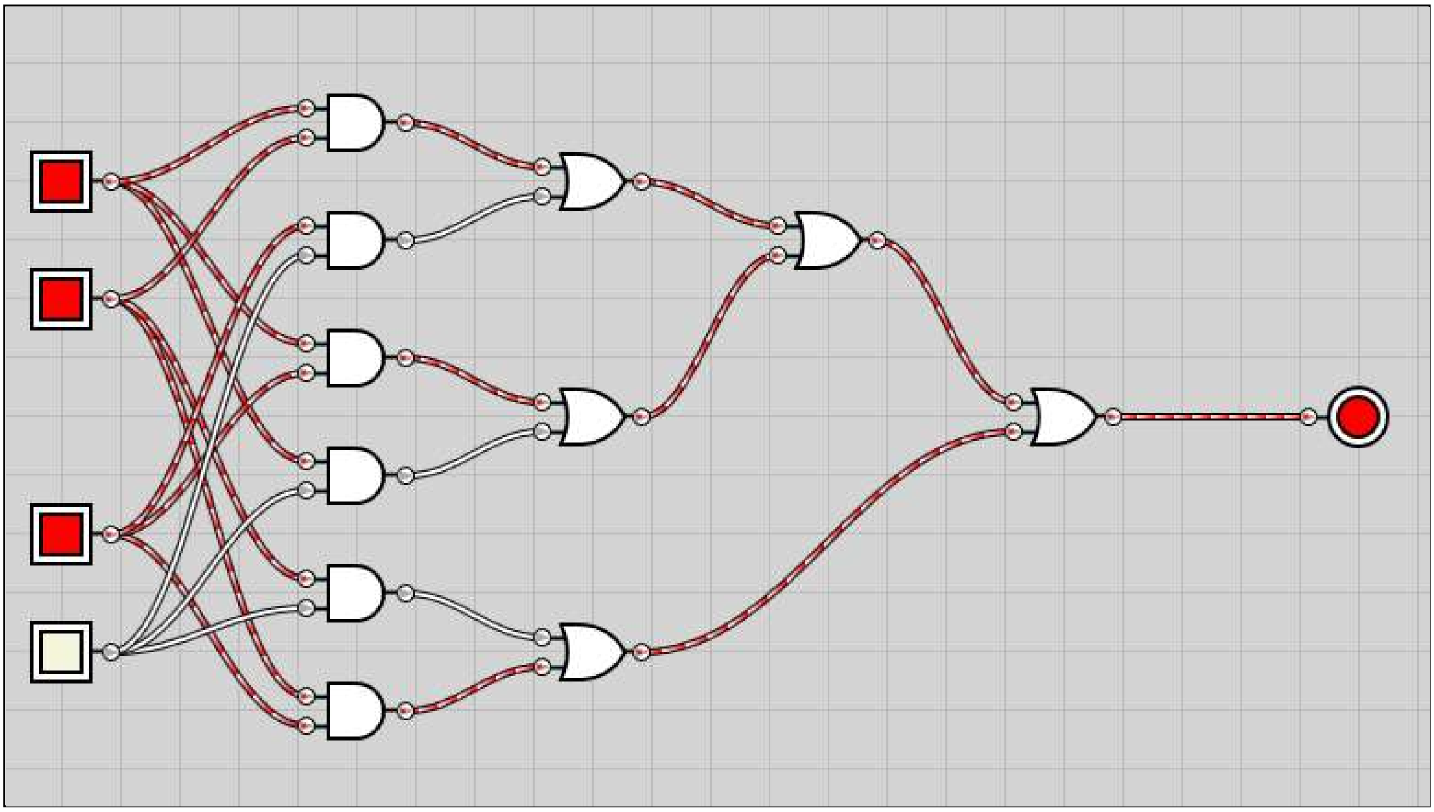
1 Transmitter is sensing



2 Transmitters are sensing



3 Transmitters are sensing



4 Transmitters are sensing