



# Clarifying design guidelines of level crossing logic with functional resonance analysis method

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East Japan Railway Company

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- Introduction of East Japan Railway Company (JRE)
- Motivation
- Functional resonance analysis method
- Basic warning logic of level crossings
- Analysis of one standardized level crossing logic and extraction of design guidelines
- Evaluation with operating LC logic
- Conclusion

# Introduction of JRE

Operating area: East Japan including Tokyo

Passengers : over 17 million / day

Rail network: 7,401.7 km

Station: 1,655

Interlocking system : 967

Point machine : 9,760

Signal : 12,409

Level crossing (LC) : 6,774

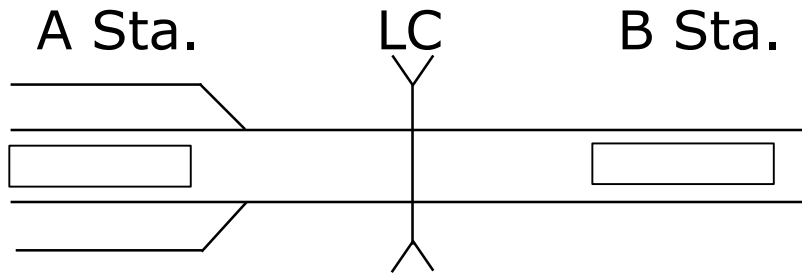
as of Mar. 2019

([https://www.jreast.co.jp/youran/pdf/2019-2020/jre\\_youran\\_all.pdf](https://www.jreast.co.jp/youran/pdf/2019-2020/jre_youran_all.pdf))



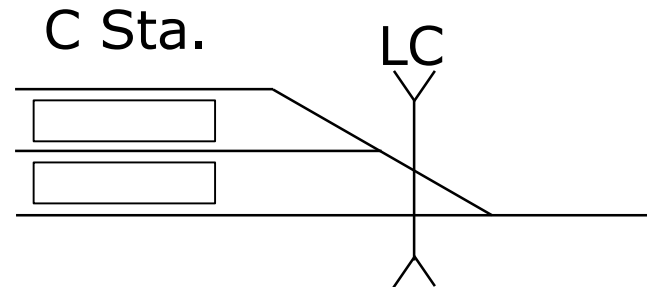
# Two types of level crossings

## Level crossing (LC) between stations



- Simple and common logic
- Software logic

## LC in a station and a yard



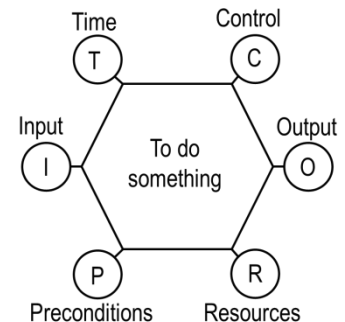
- Complex and LC-specific logic
- Relay logic

Developing software logic for LC in a station can improve maintainability and workability but is not easy

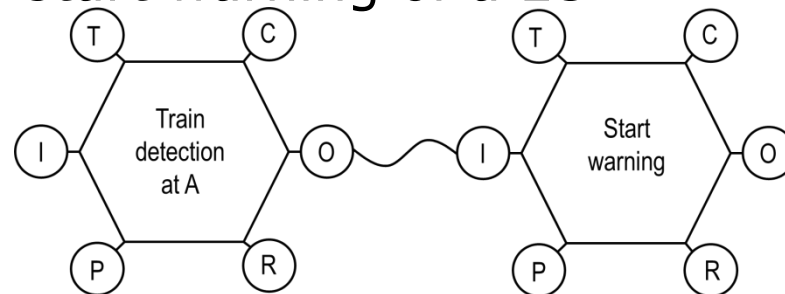


# Functional Resonance Analysis Method (FRAM)

- Safety-analysis method from resilience engineering
- Modelling interactions among functions by using hexagonal elements with six aspects
- FRAM Model helps to extract how a system works or why a system successes and fails

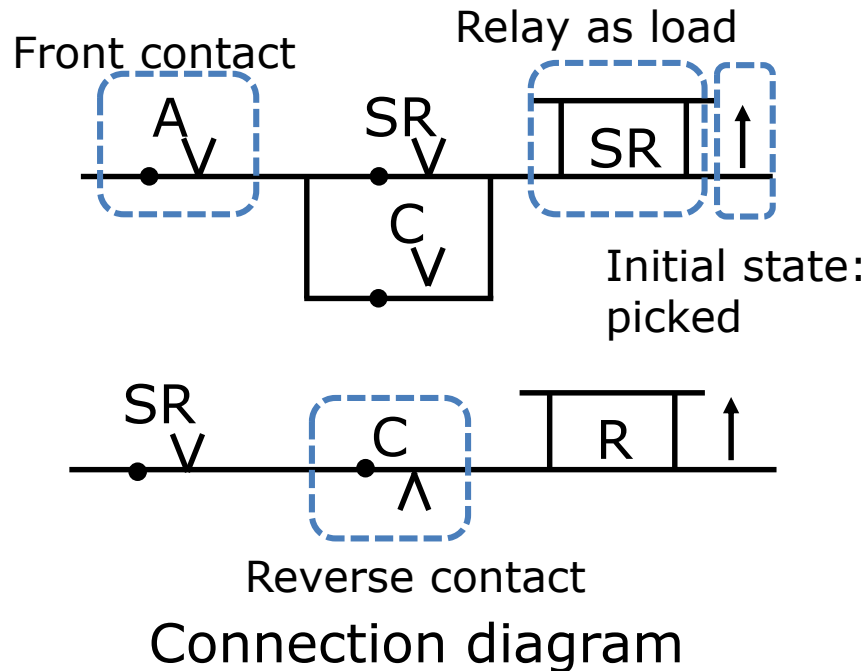
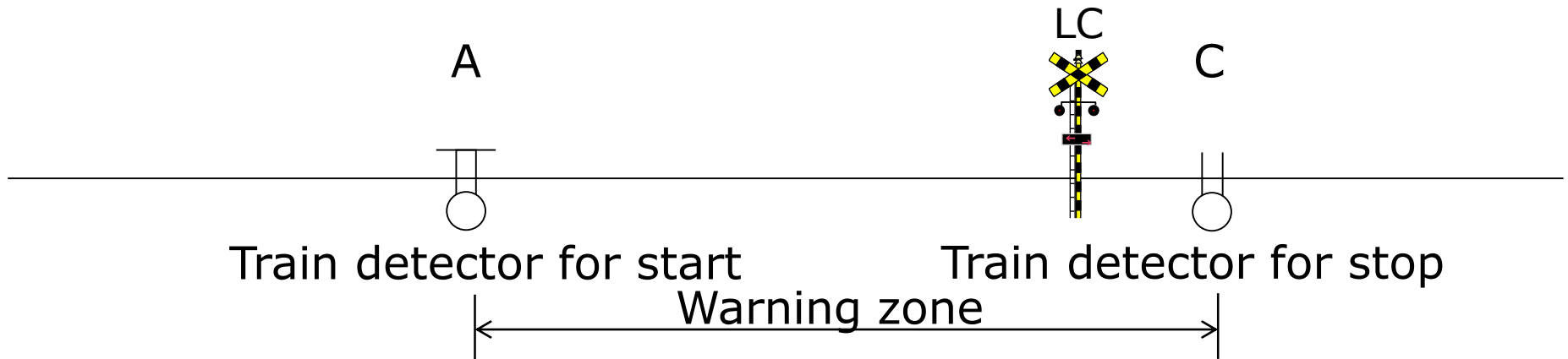


- Simple example of a FRAM model
  - The model that information of train detection at A is used to start warning of a LC



We examined FRAM to extract the design guidelines from standardized relay logic

# Sequence of basic warning logic



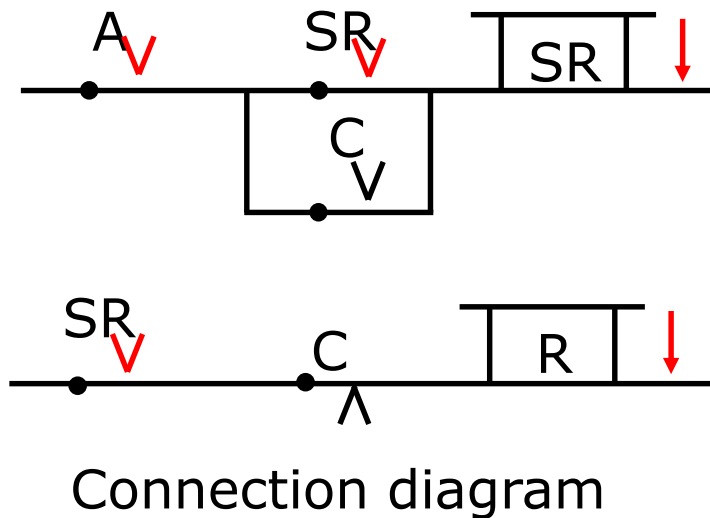
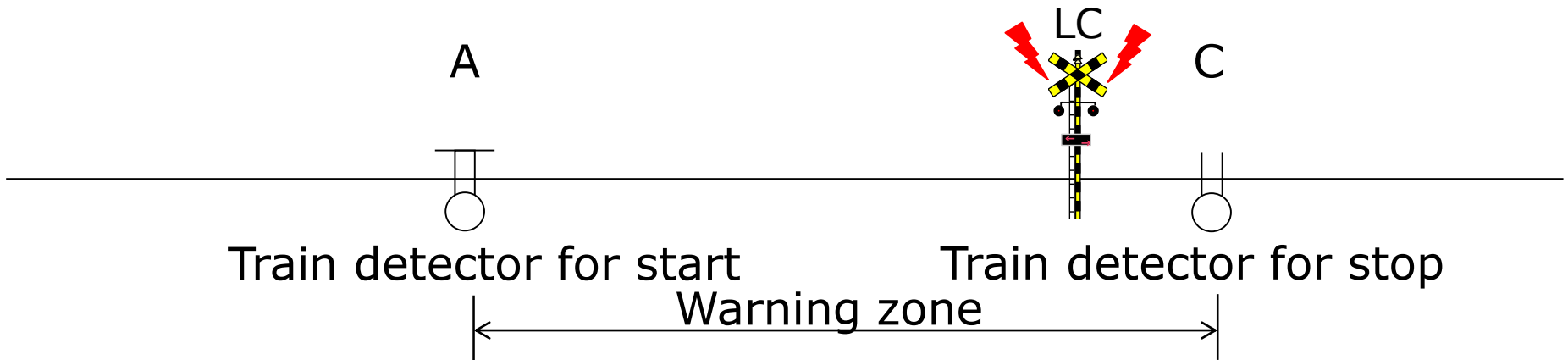
## Start warning

- (1) Detection of a train at A
- (2) Change of SR's state to "dropped"
- (3) Change of R's state to "dropped"

## Stop warning

- (1) Exit from train detection area of A
- (2) Detection of a train at C
- (3) Change of SR's state to "picked"
- (4) Exit from train detection area of C
- (5) Change of R's state to "picked"

# Sequence of basic warning logic



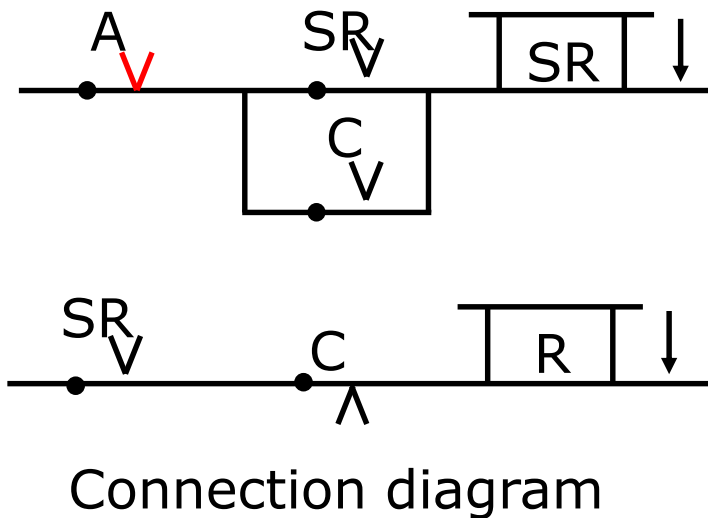
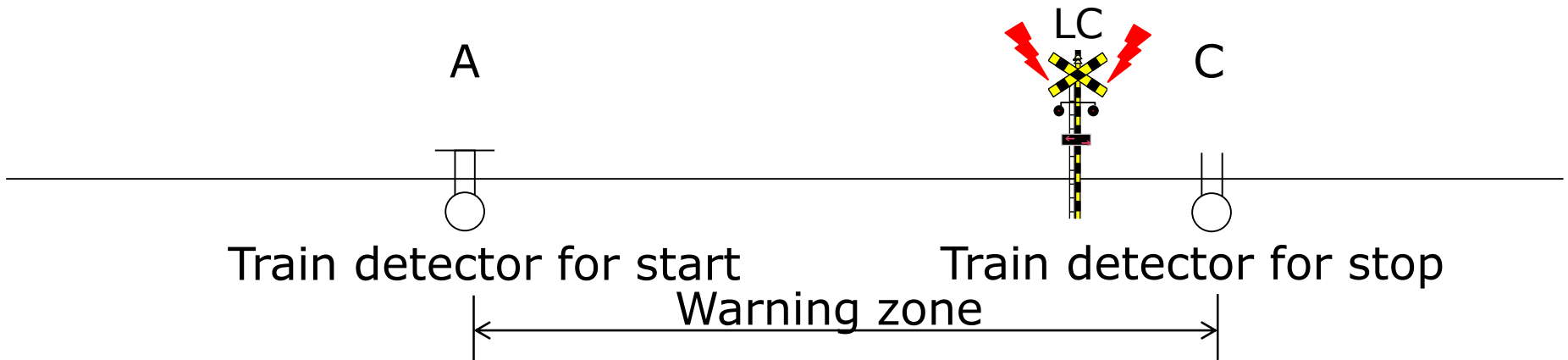
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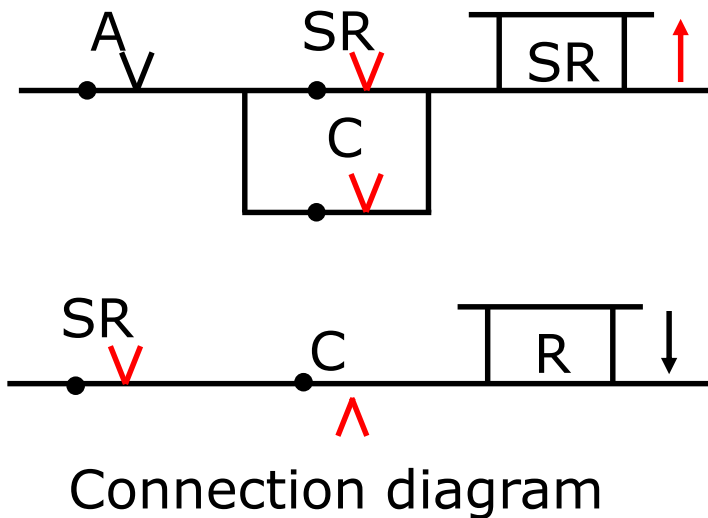
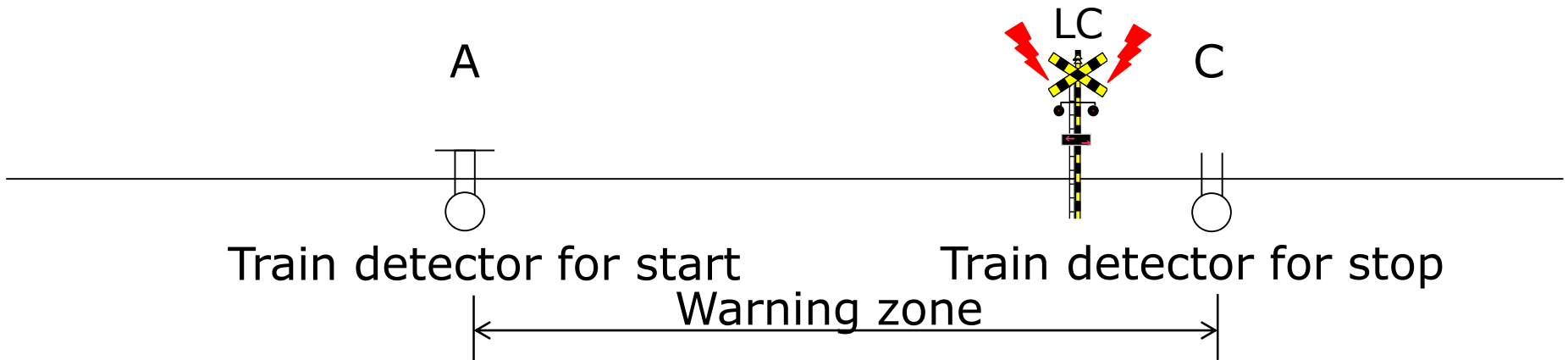
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# Sequence of basic warning logic



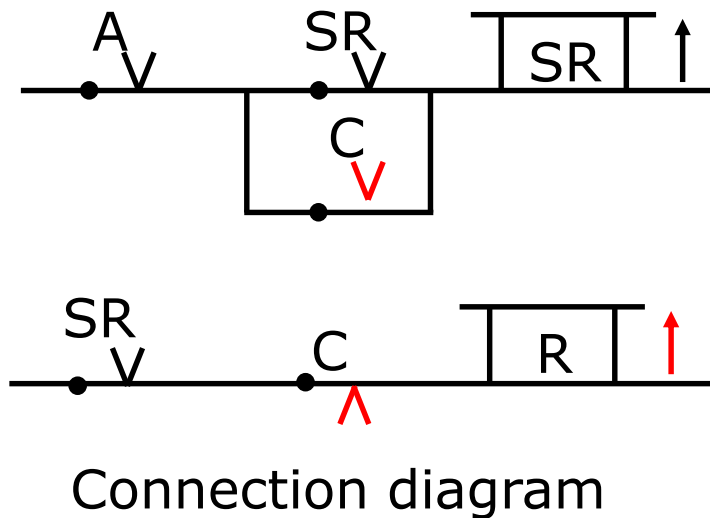
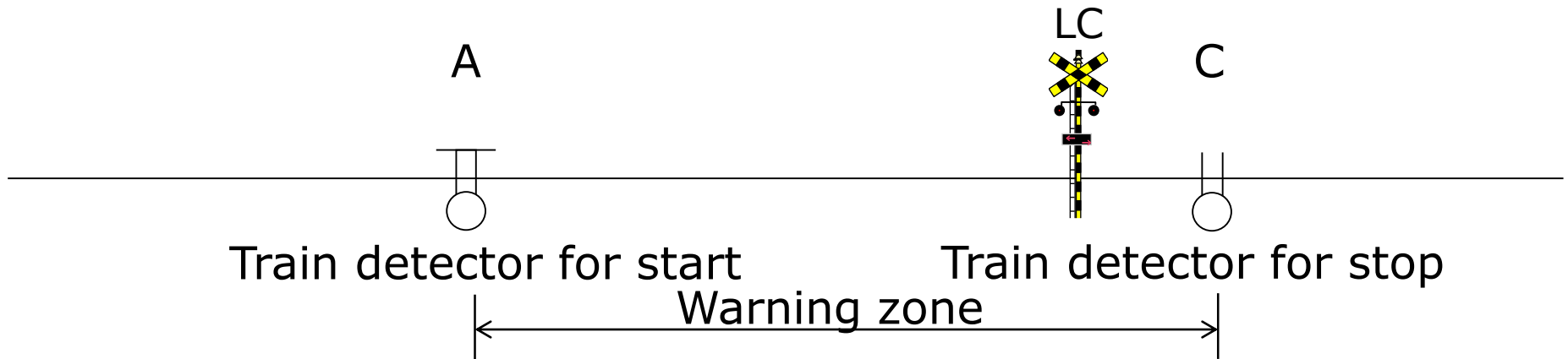
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# Sequence of basic warning logic



## Start warning

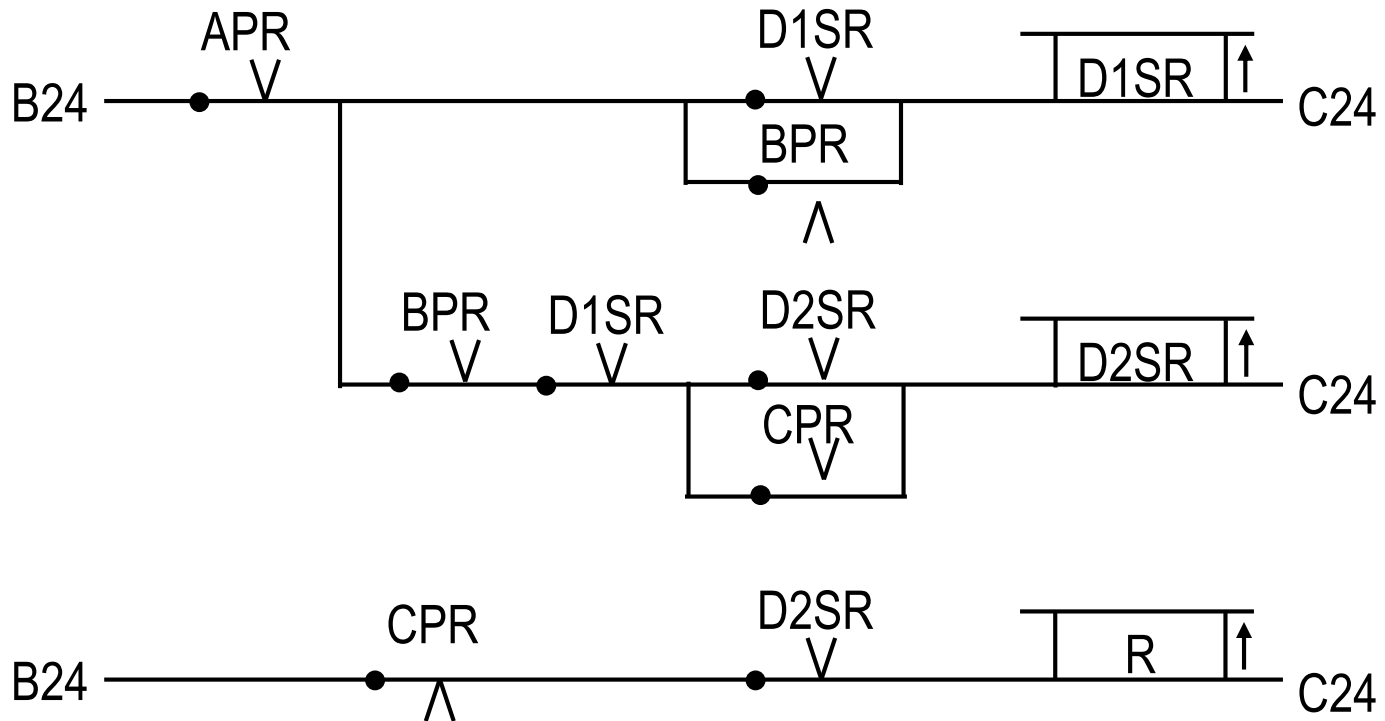
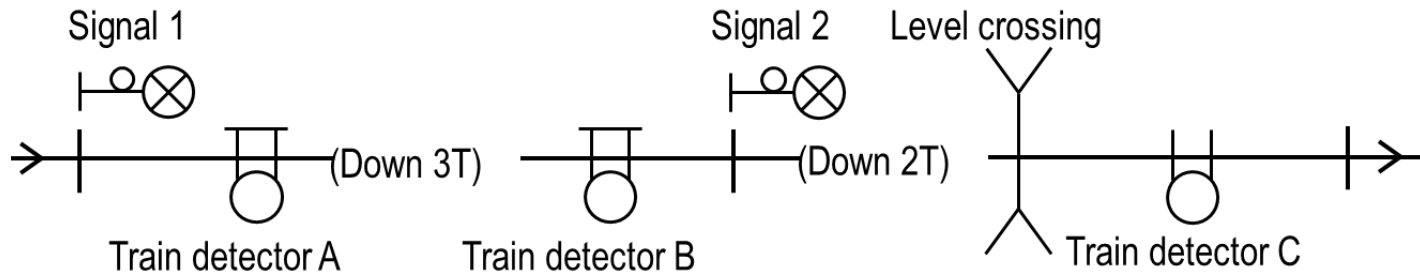
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Connection diagram

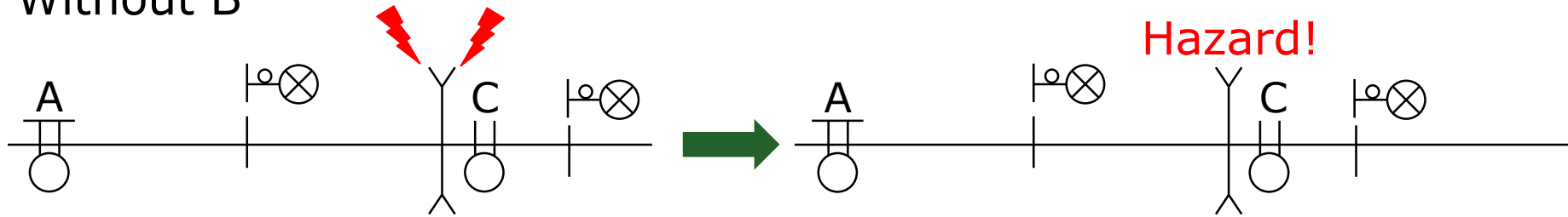
# Analysis of standardized logic



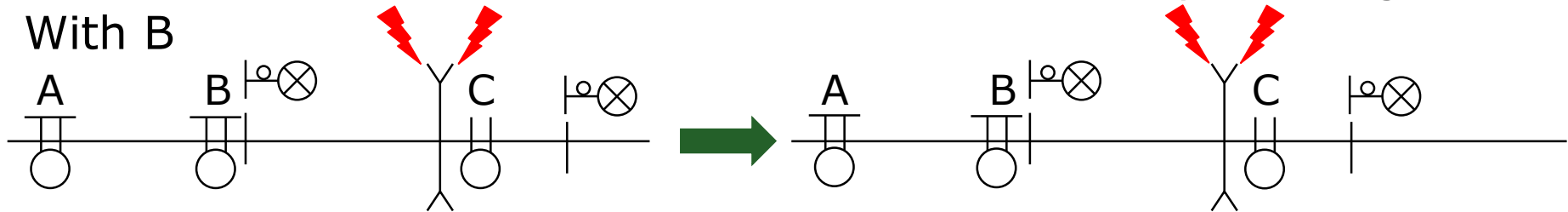
# Functional difference between the basic logic and the analyzed standard logic

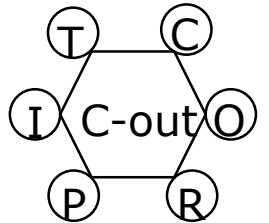
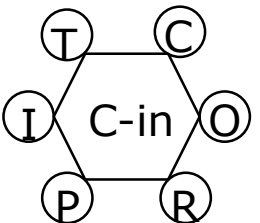
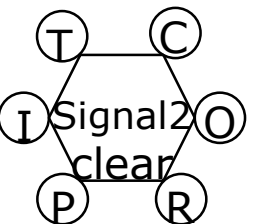
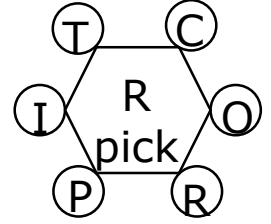
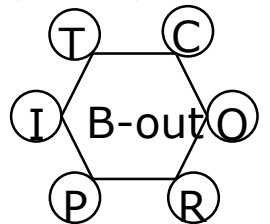
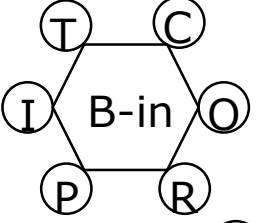
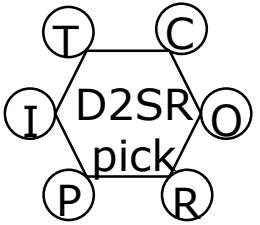
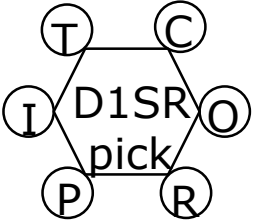
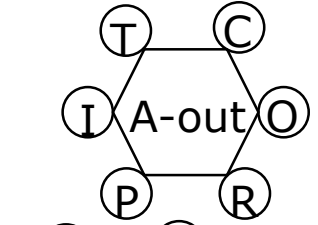
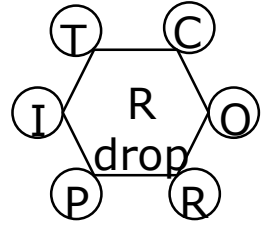
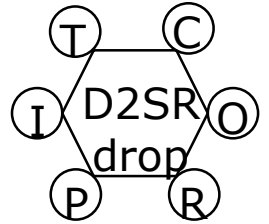
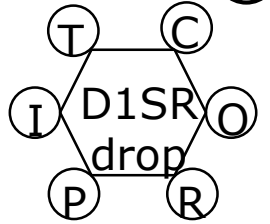
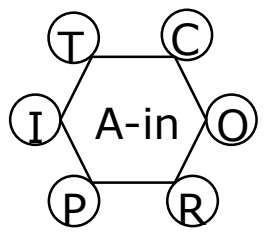
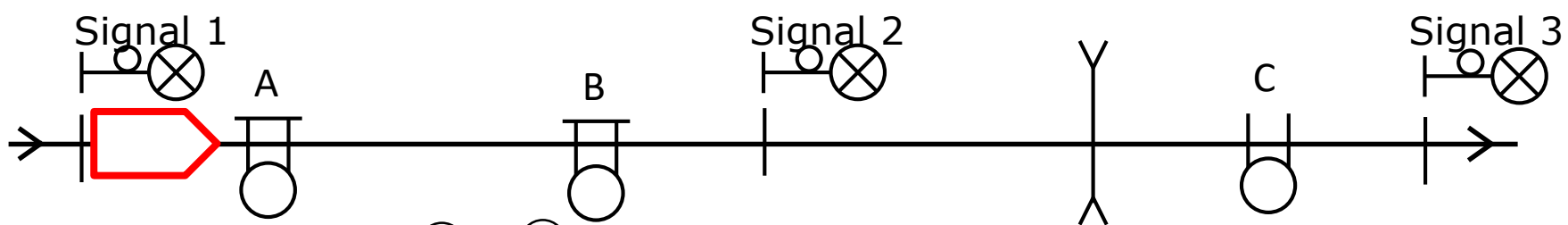
Train detector B is deployed so that two trains can run within the warning zone in the same time.

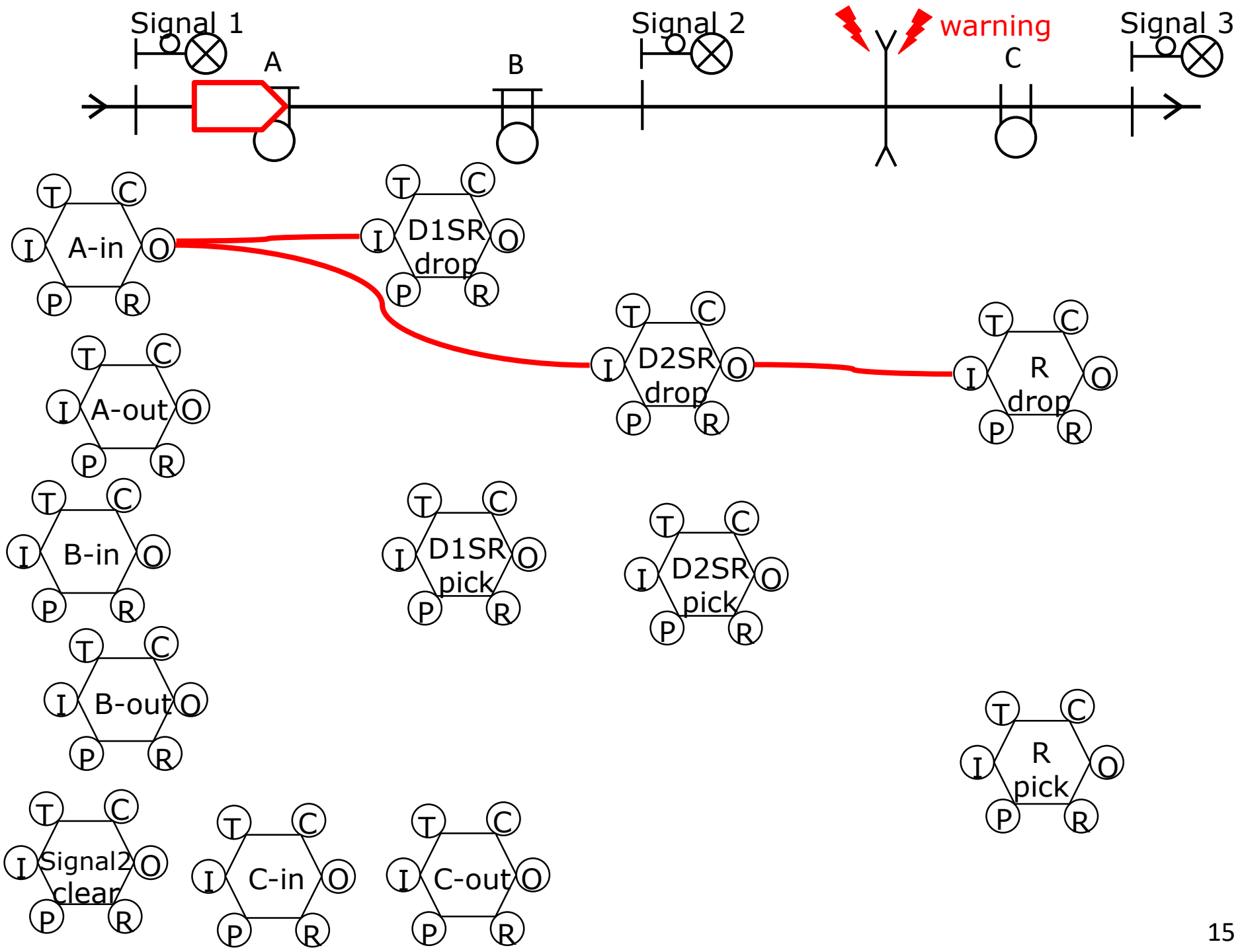
Without B

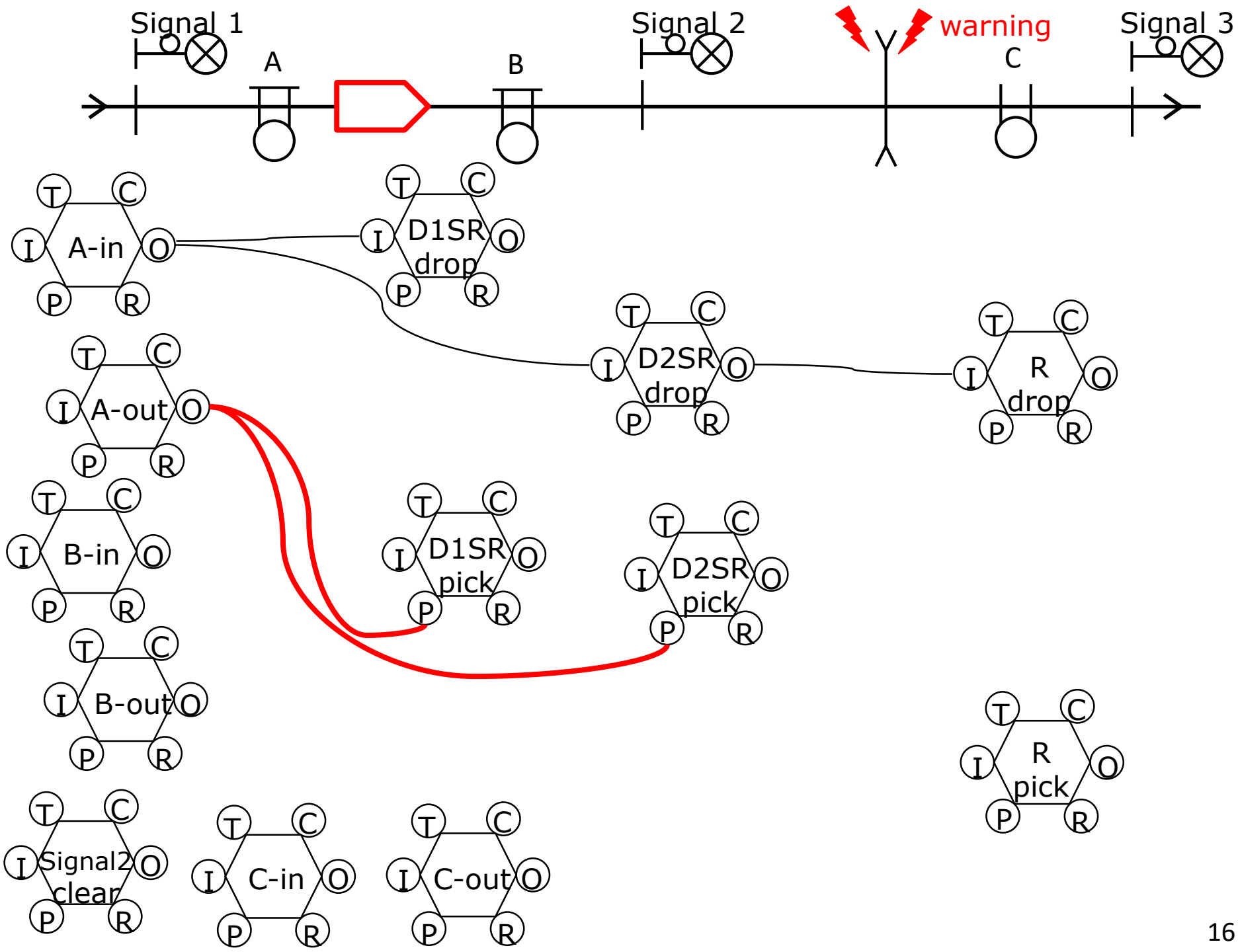


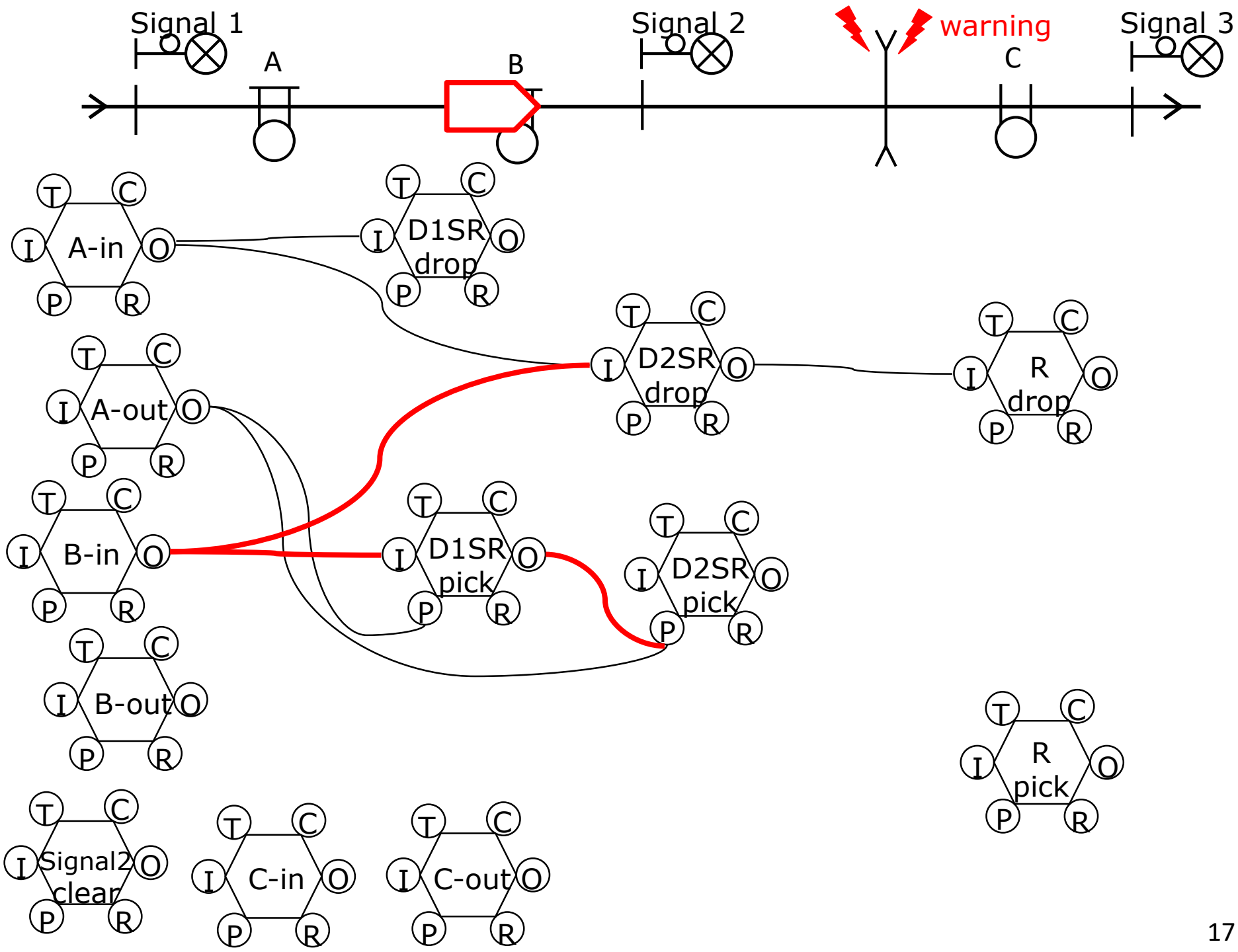
With B

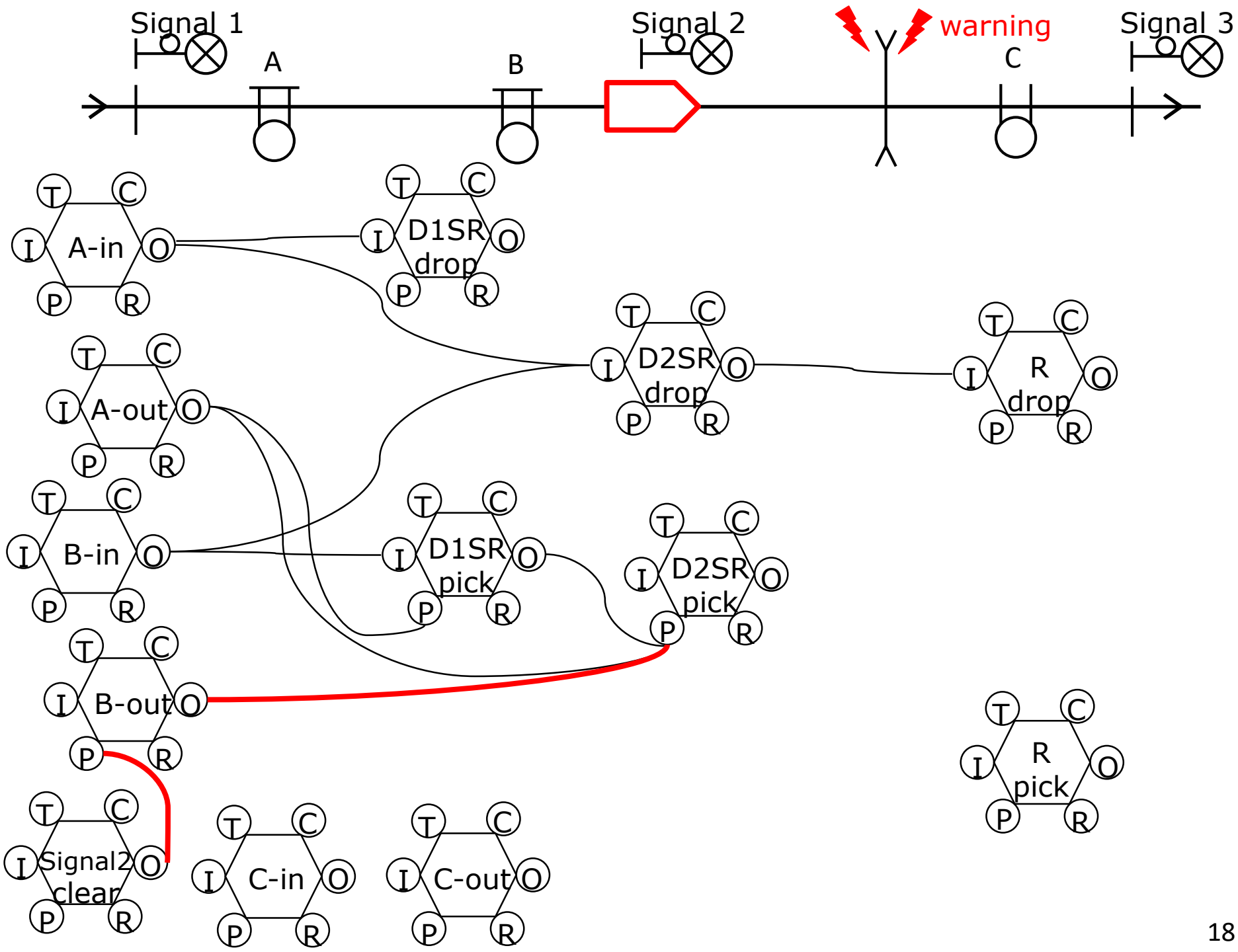


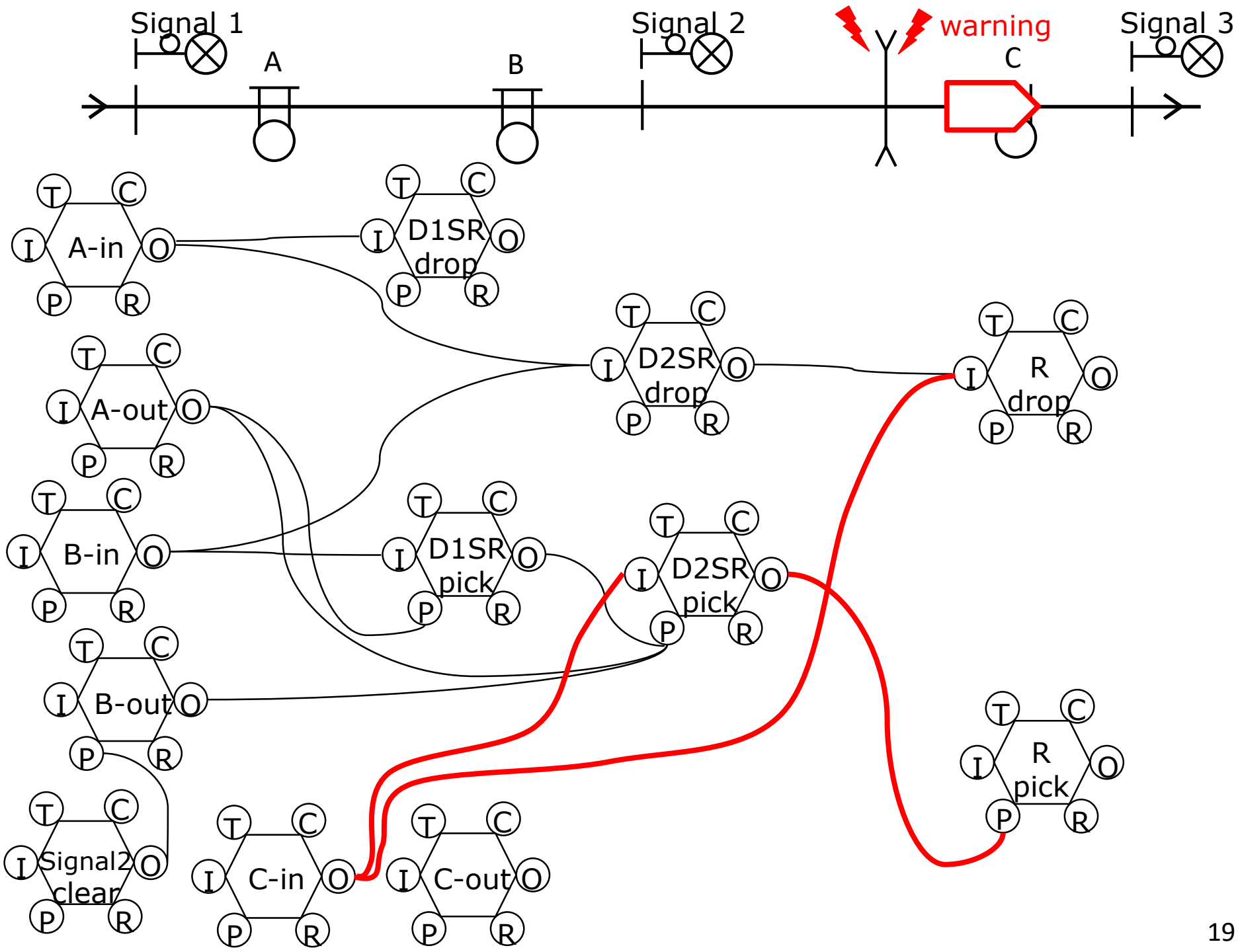


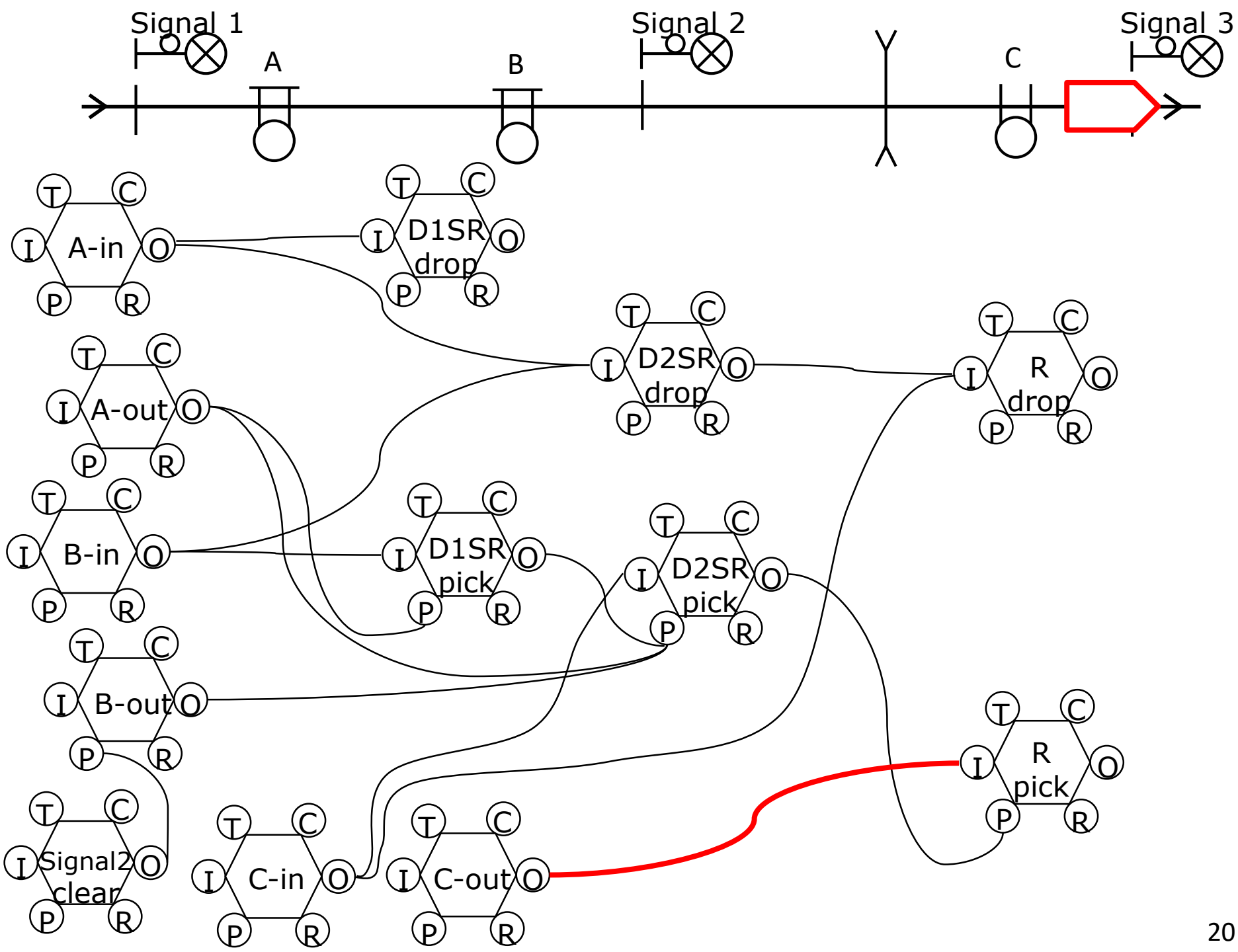




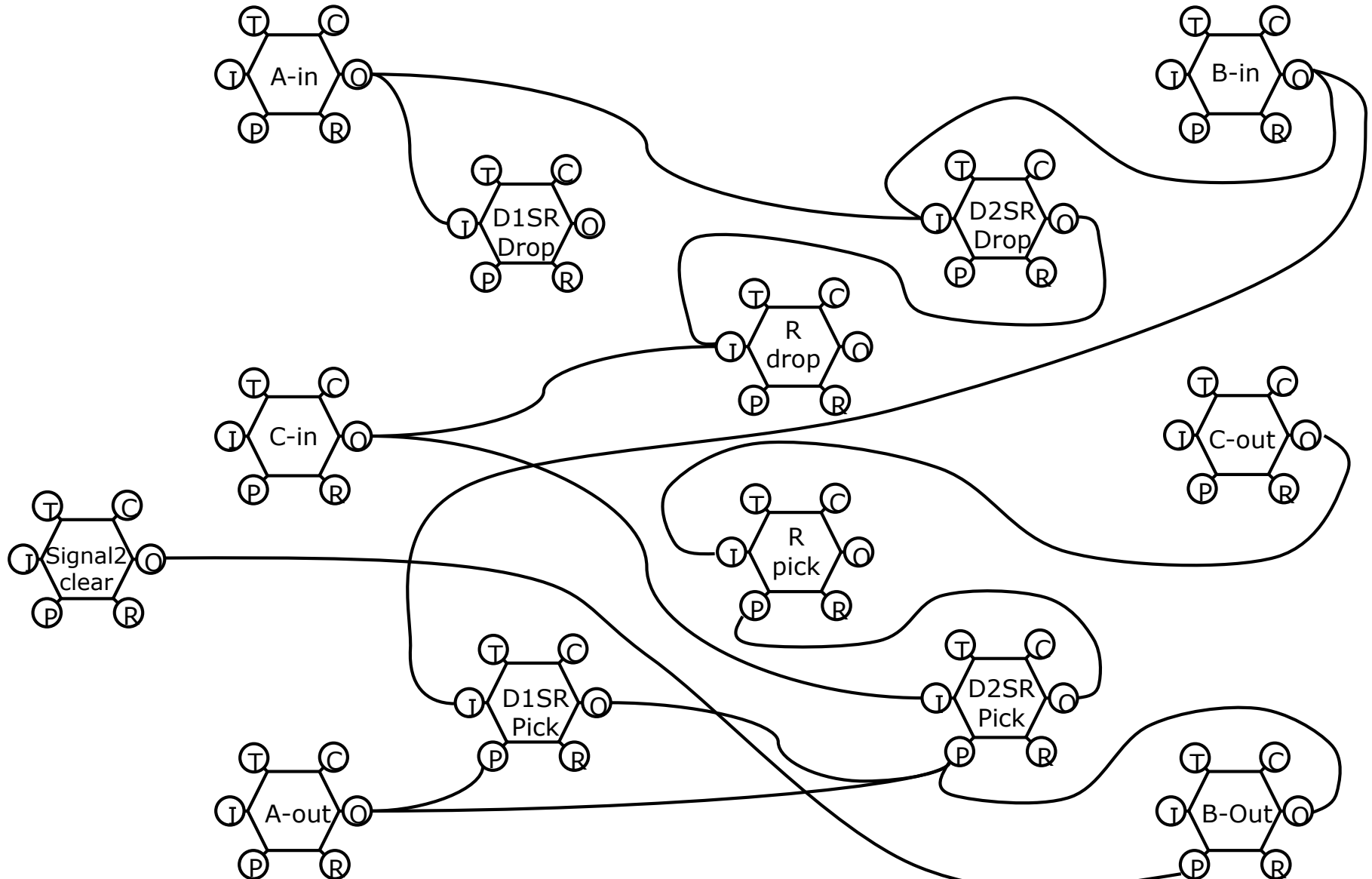






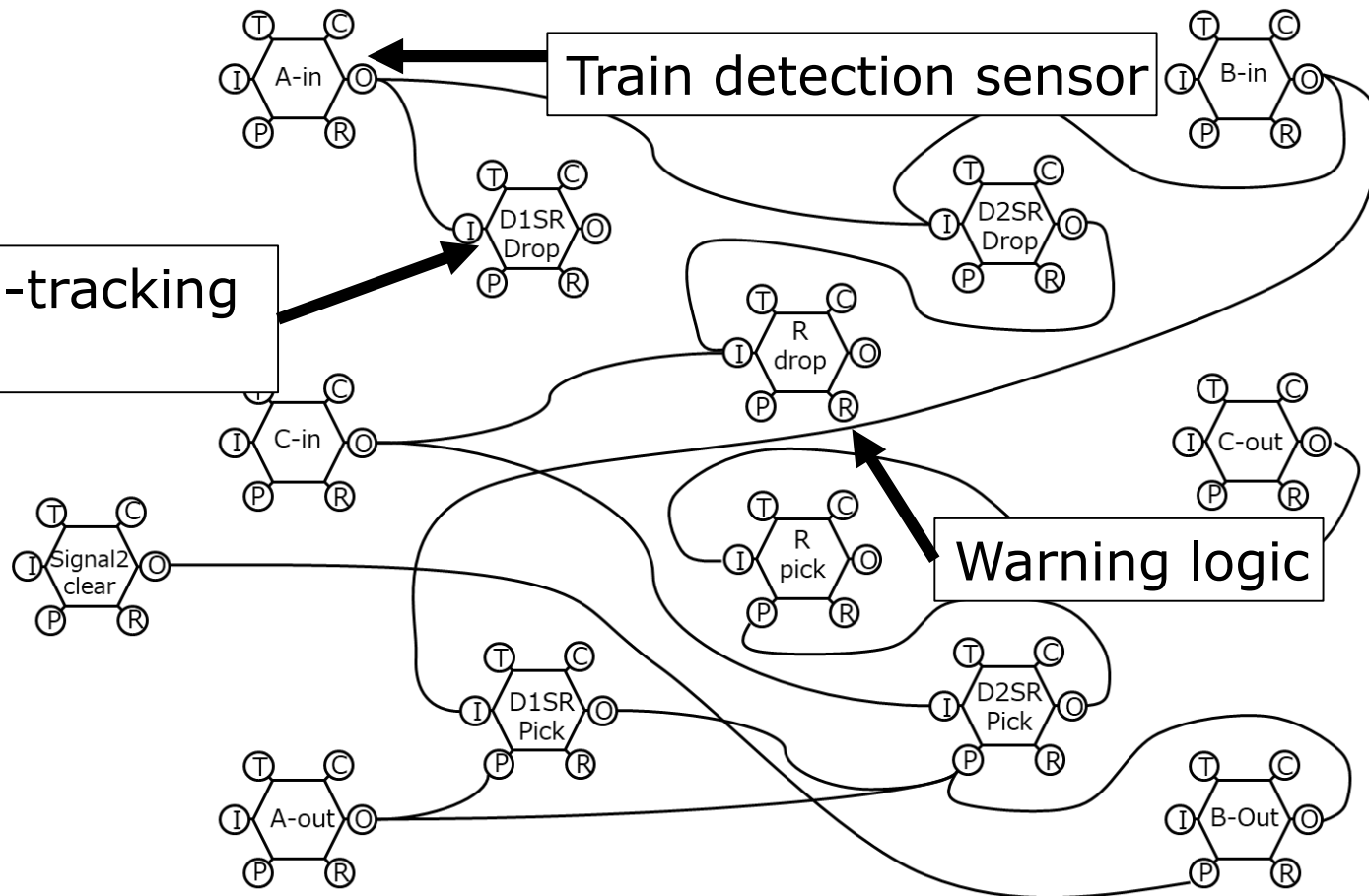


# FRAM model of the analyzed logic



## (1) Layered structure

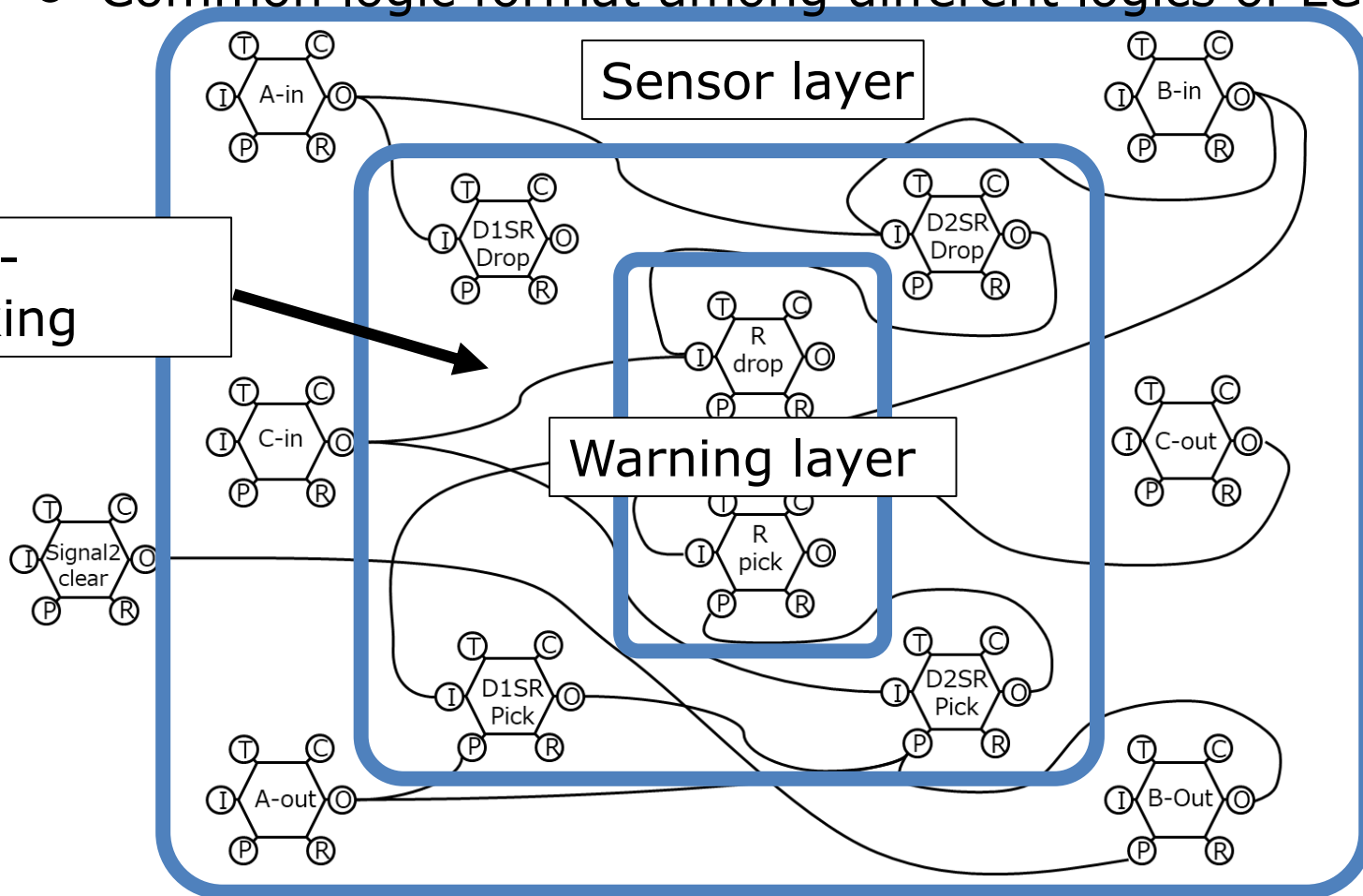
- Transmission of information to the neighboring upper layer
- Common logic format among different logics of LCs



# Extraction of design guidelines

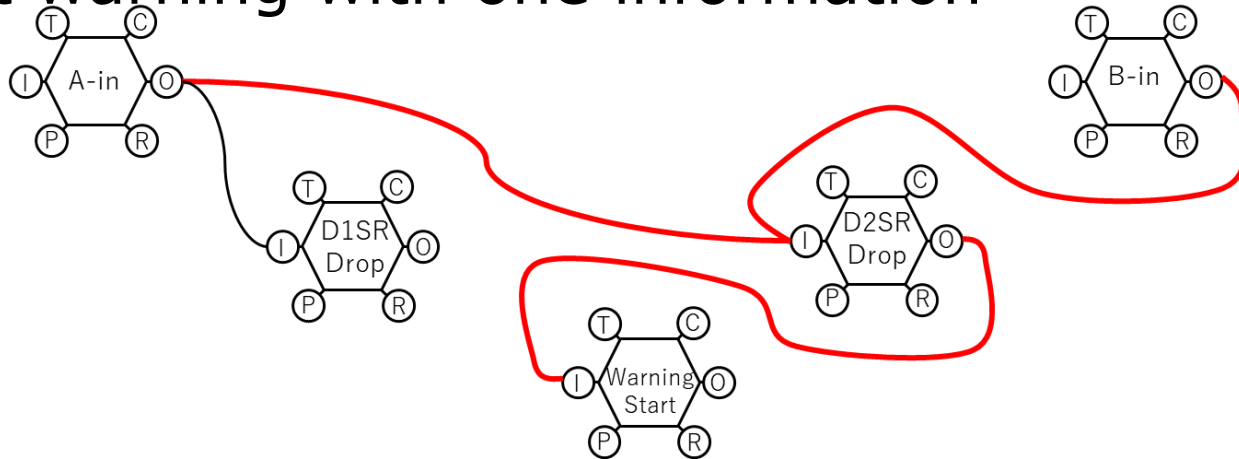
## (1) Layered structure

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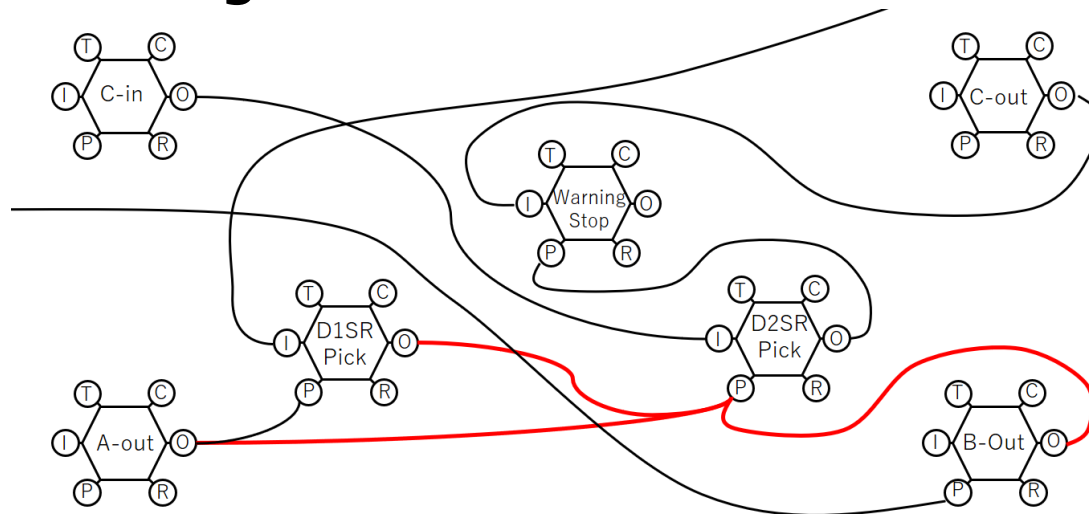


# Extraction of design guidelines

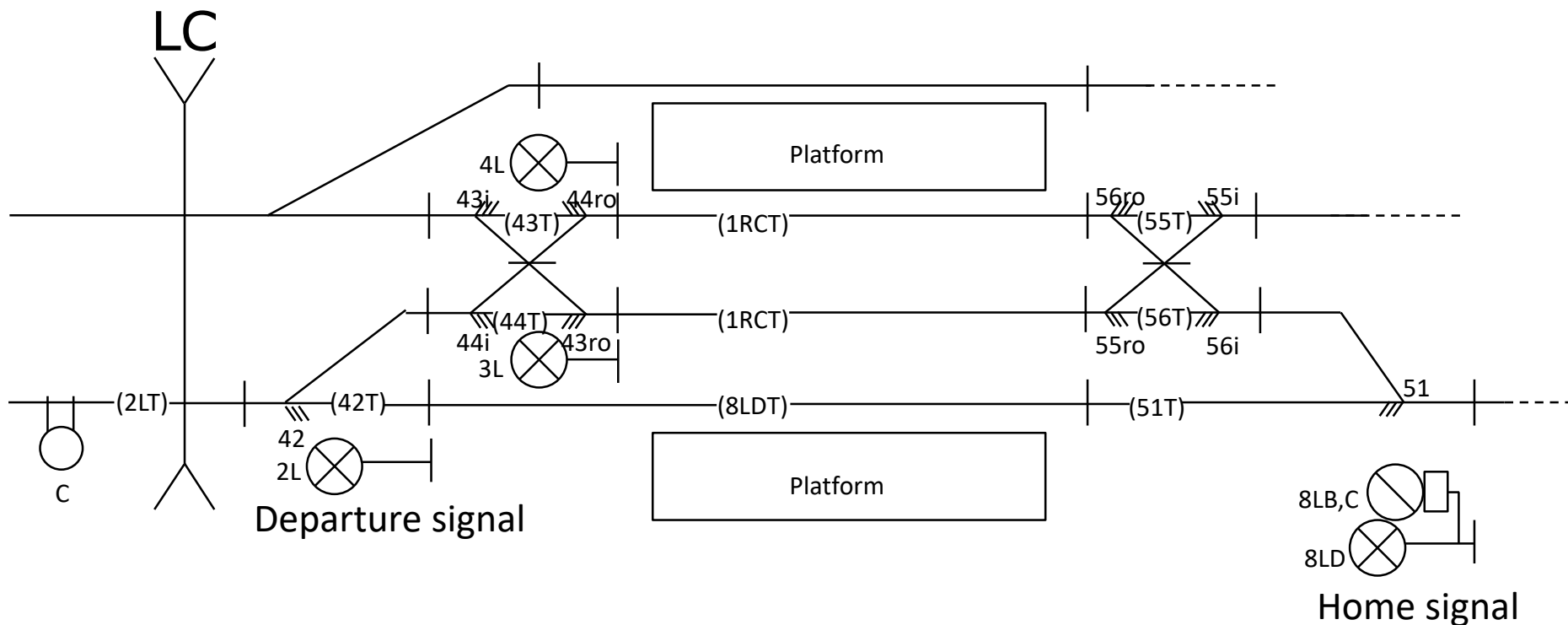
## (2) Start warning with one information



## (3) Stop warning with accumulation of information

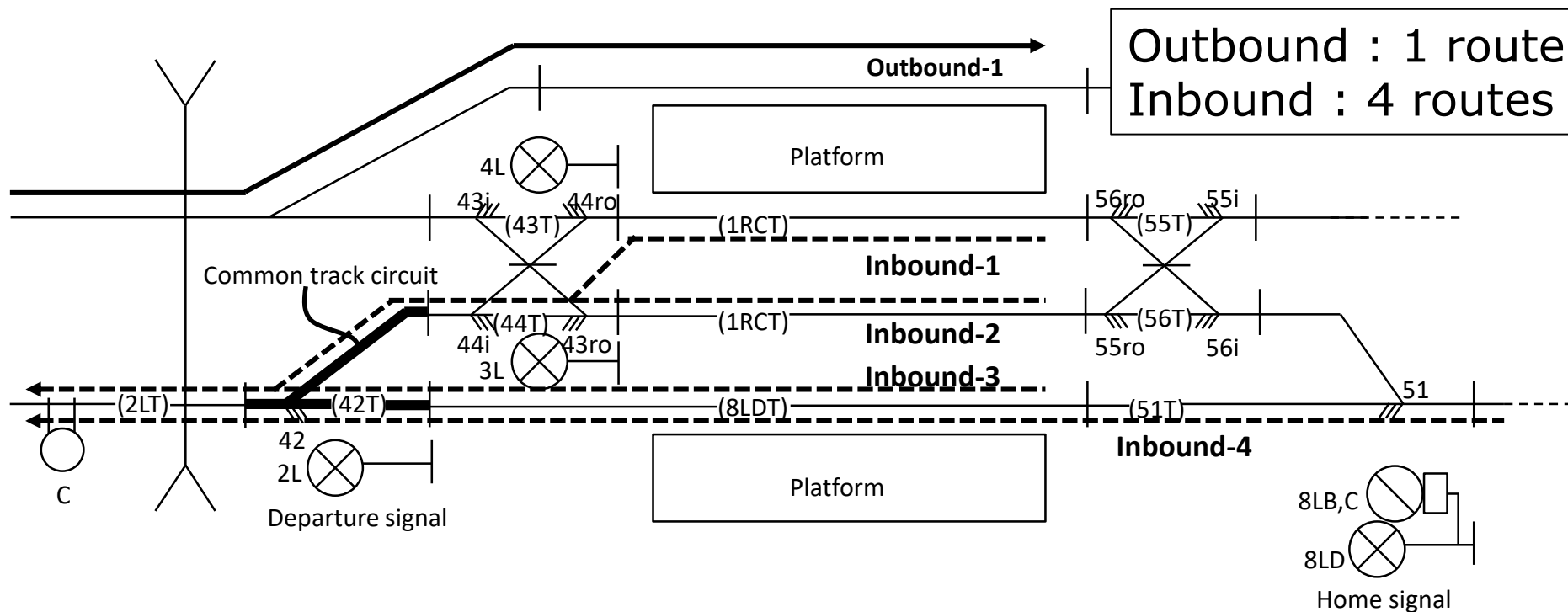


# Evaluation of the extracted guidelines by applying FRAM to an operating LC logic



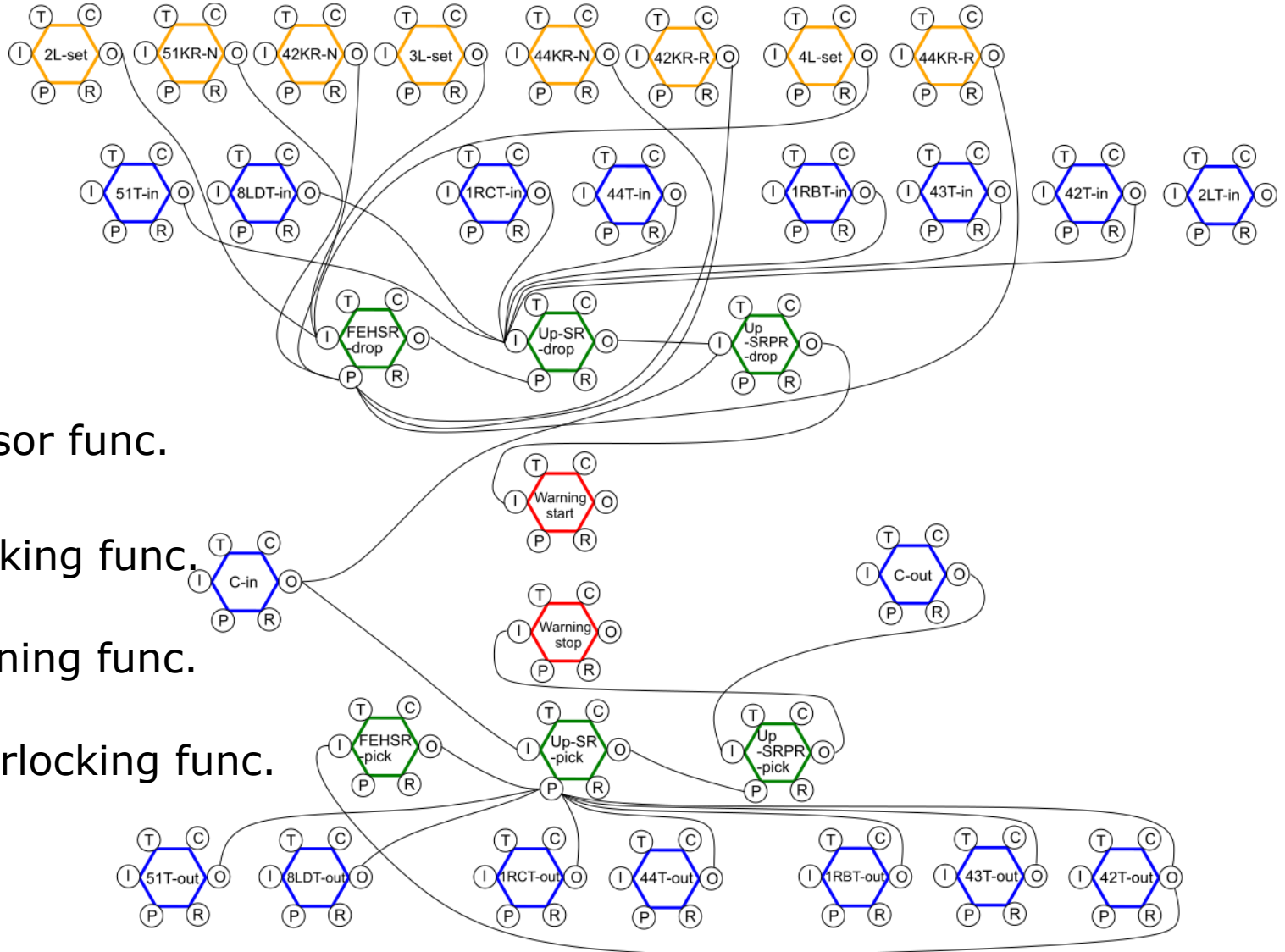
Facility layout of the examined LC and station

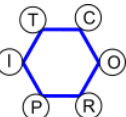
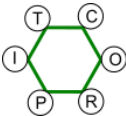
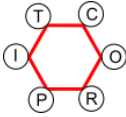
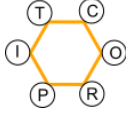
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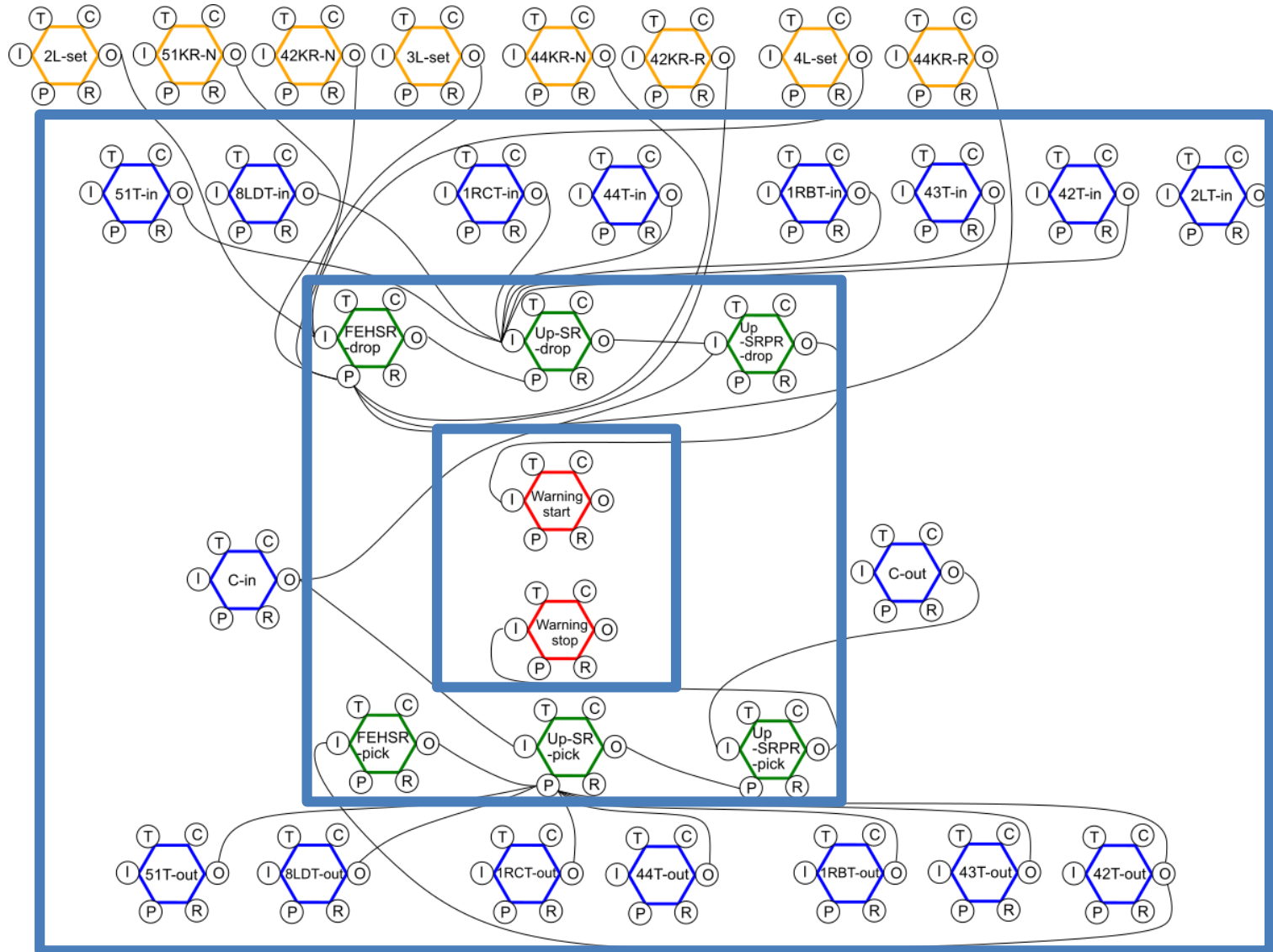
Facility layout of the analyzed LC and station

# FRAM model of the LC logic

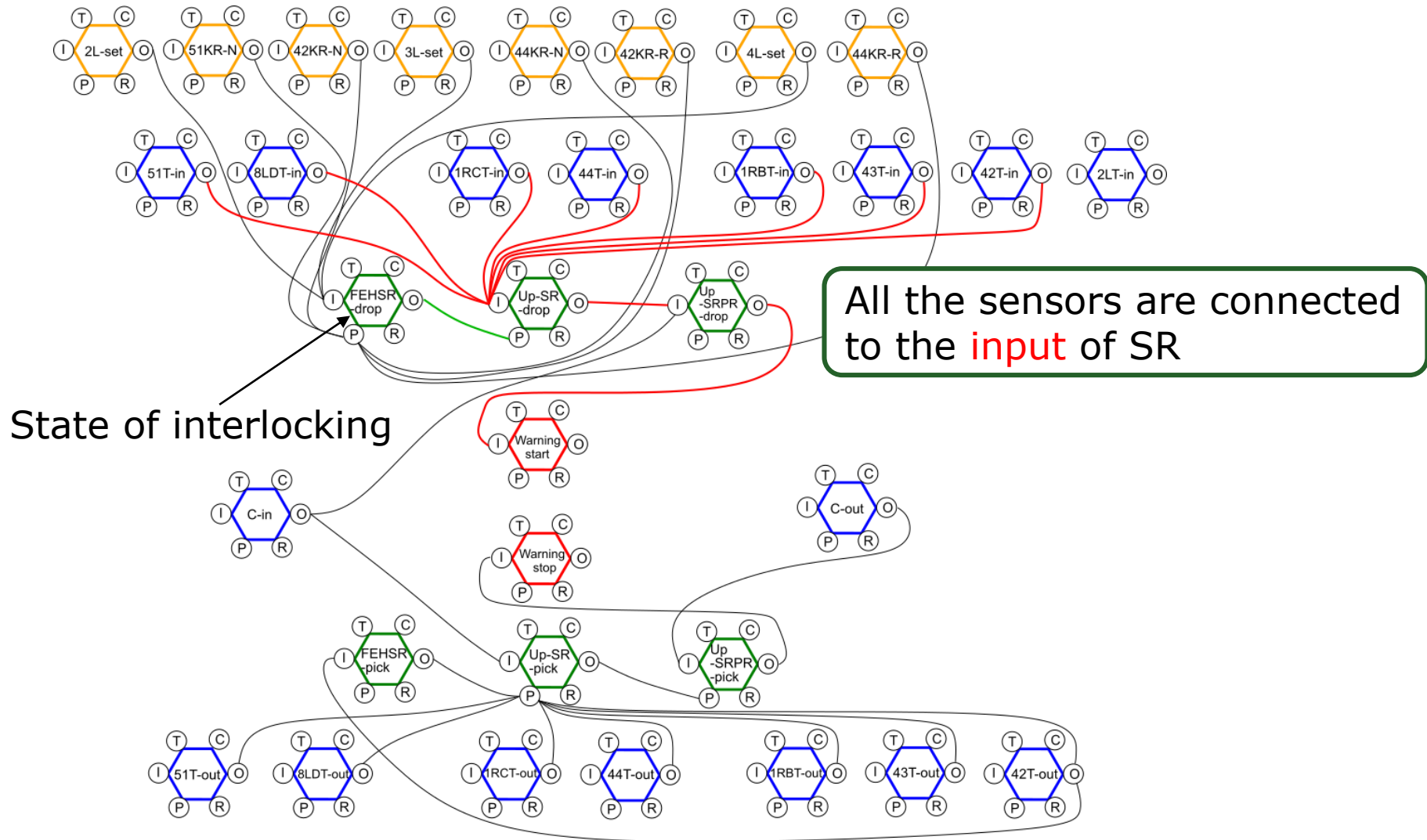


-  : sensor func.
-  : tracking func.
-  : warning func.
-  : interlocking func.

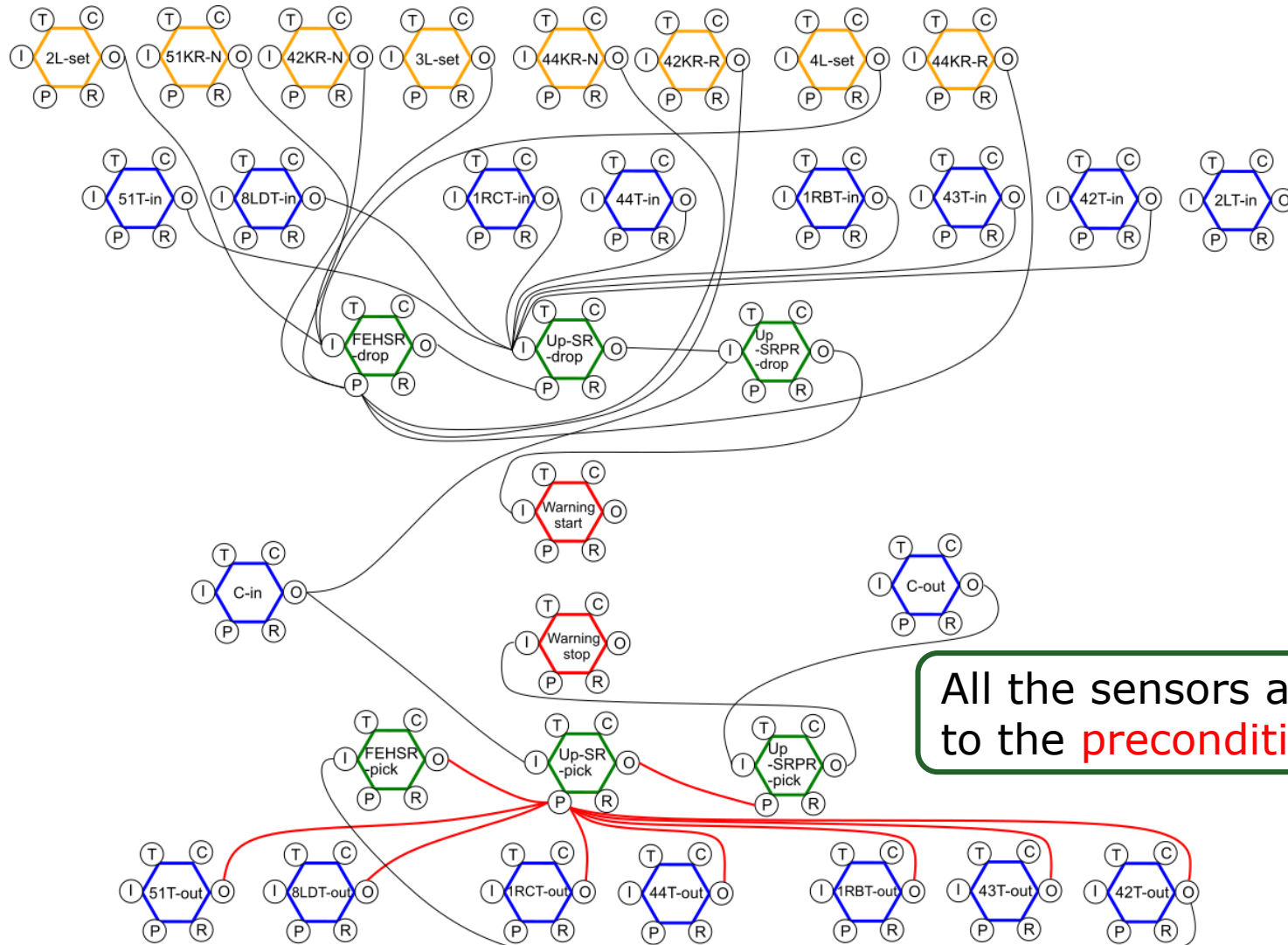
# (1) Layered structure



# (2) Start warning with one information



# (3) Stop warning with accumulation of information



- Safety analysis method, FRAM was applied to standardized relay logic in JRE.
- Guidelines, which are natural for signalling engineers but not documented were extracted and observed in the operating logic
- We confirmed that FRAM offers a different perspective and is useful to analyze operating systems.