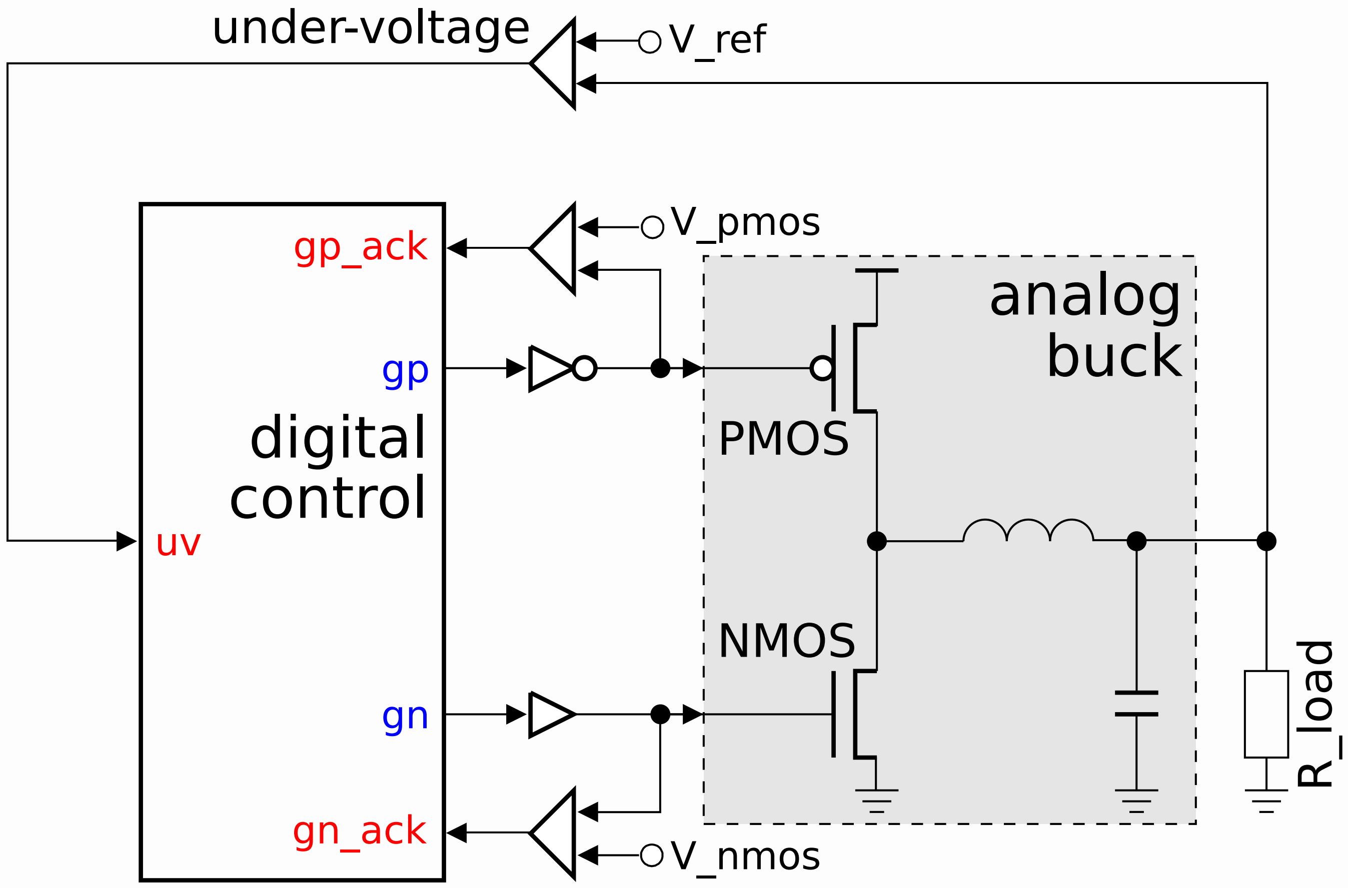
Asynchronous Arbitration Primitives for New Generation of Circuits and Systems

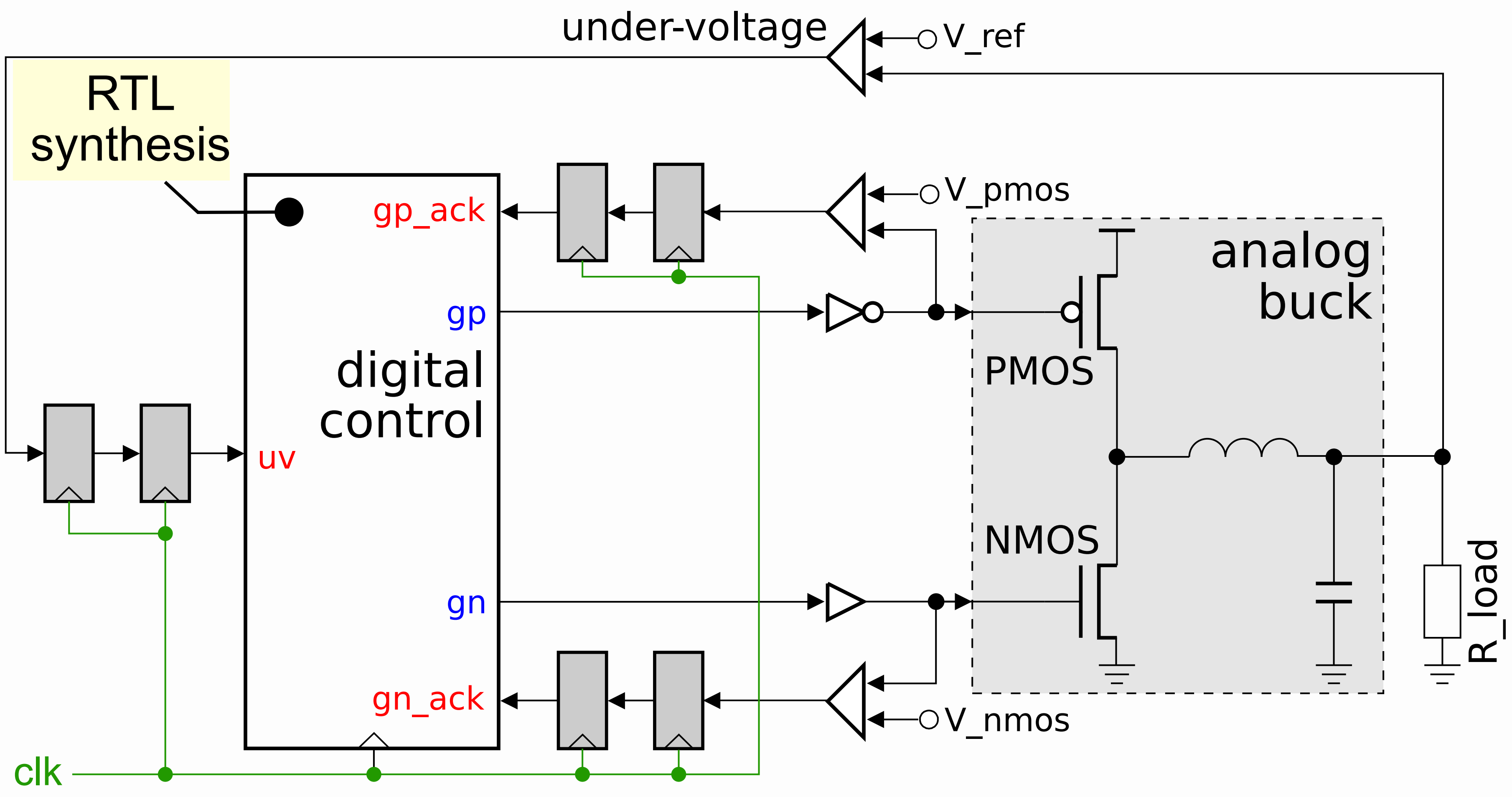
Andrey Mokhov, Danil Sokolov, Victor Khomenko, Alex Yakovlev

Newcastle University, UK

Motivating example: toy buck converter

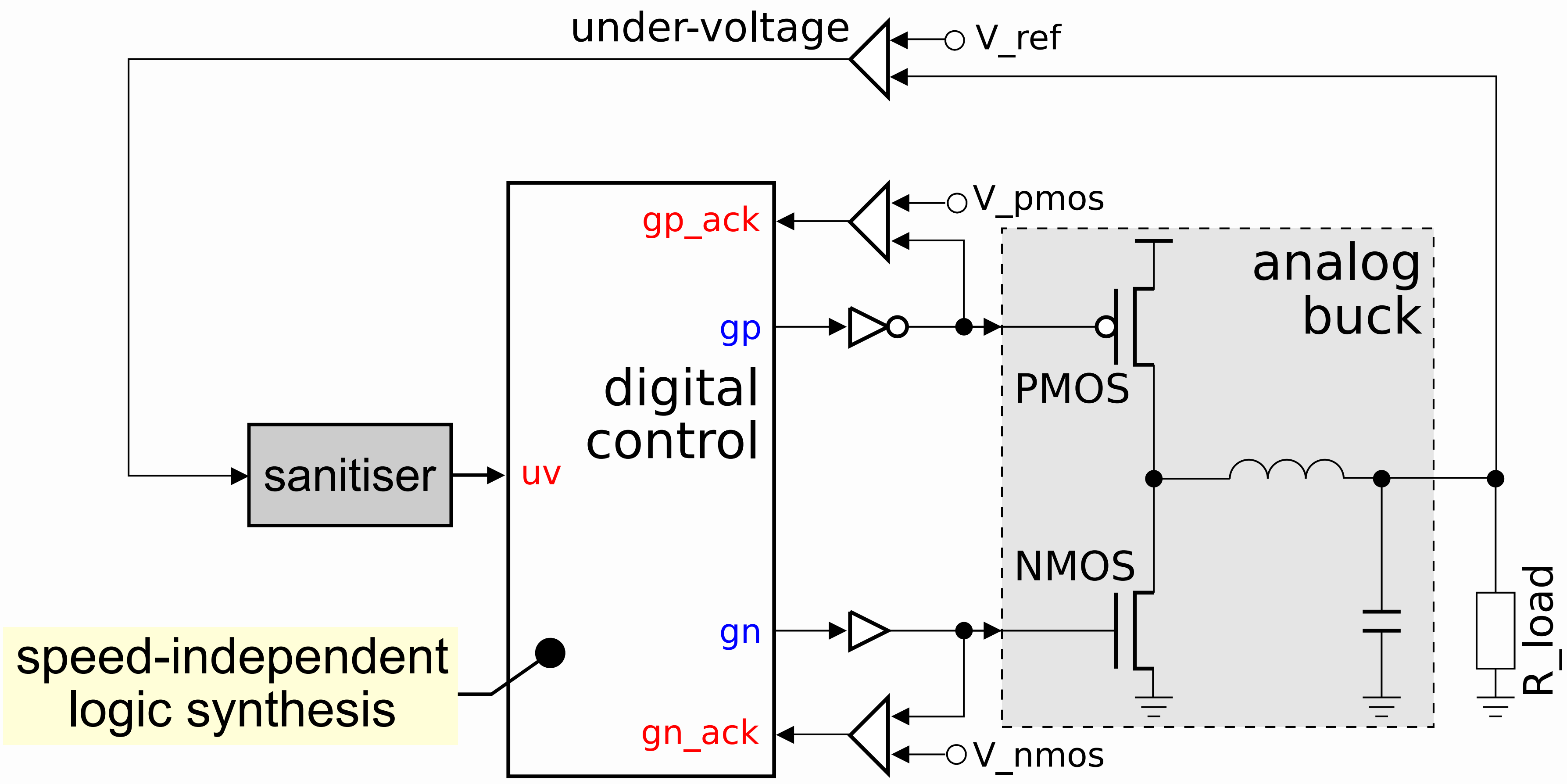


Motivating example: toy buck converter



- Synchronous implementation – requires synchronisers for asynchronous inputs
  - Synchronisers also sanitize hazardous / dirty inputs from analog environment
  - Reaction time – 3 clock cycles

Motivating example: toy buck converter

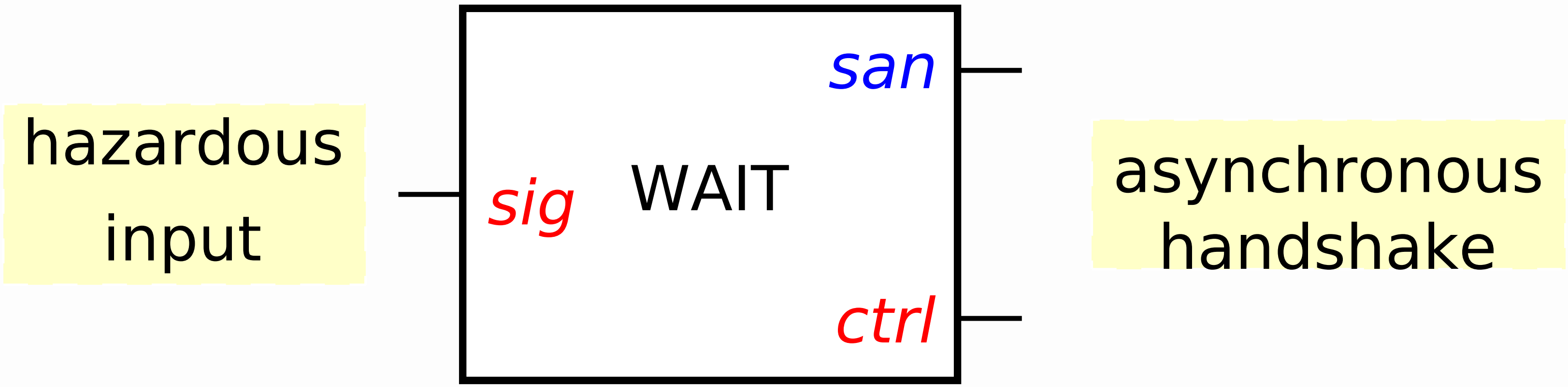


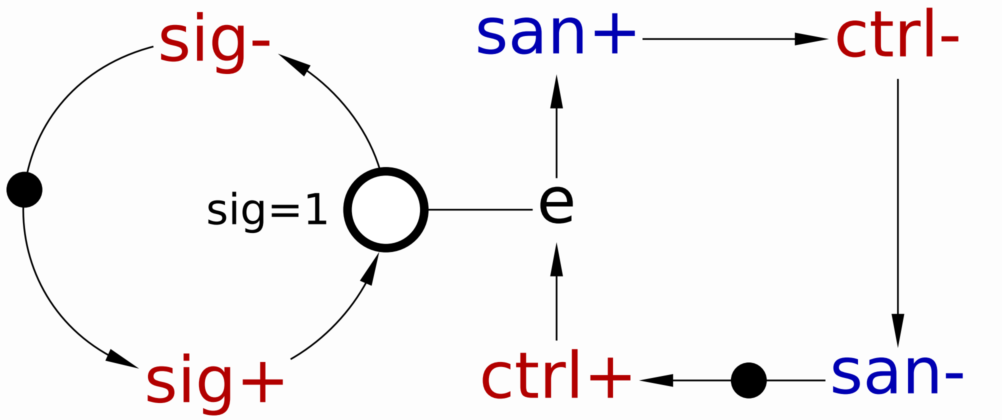
- Asynchronous implementation – natural for asynchronous inputs
  - Reaction time – several gate delays
  - Need to sanitise hazardous under-voltage input

Asynchronous arbitration primitives

- Synchronisation
  - WAIT: synchronise with high level of hazardous input
  - RWAIT: WAIT that can be with released/cancellation
  - WAIT01: synchronise with hazardous rising edge
  - WAIT2: synchronise with both phases of a hazardous input
- Decision-making
  - WAITX: arbitrate between two hazardous inputs
  - OM: merges two request-acknowledgement channels into one

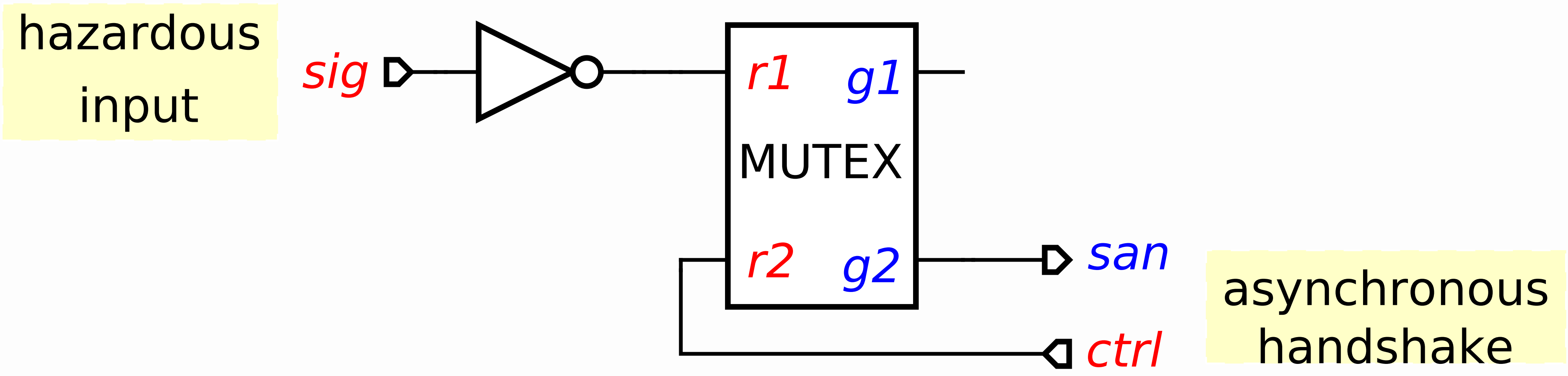
WAIT: synchronise handshake with high level of hazardous input





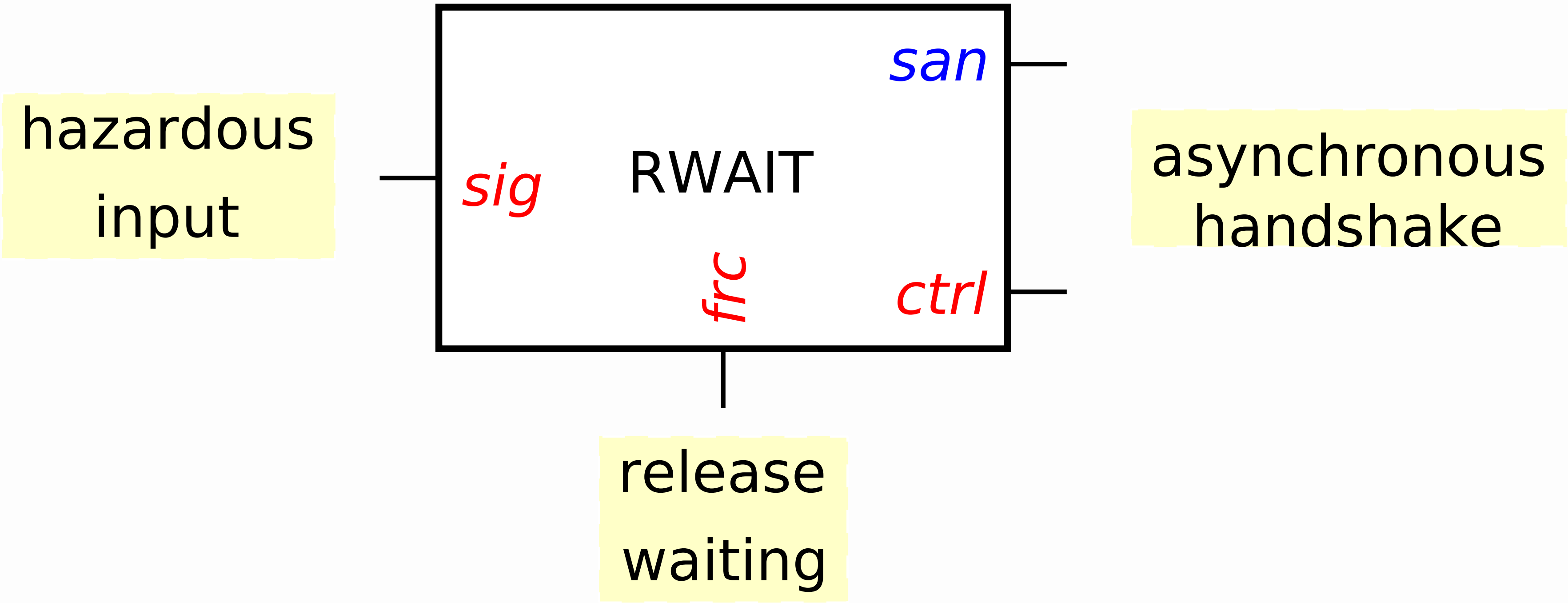
D.Sokolov et.al. *"Design and verification of speed-independent multiphase buck controller"*, ASYNC, 2015.

WAIT: synchronise handshake with high level of hazardous input

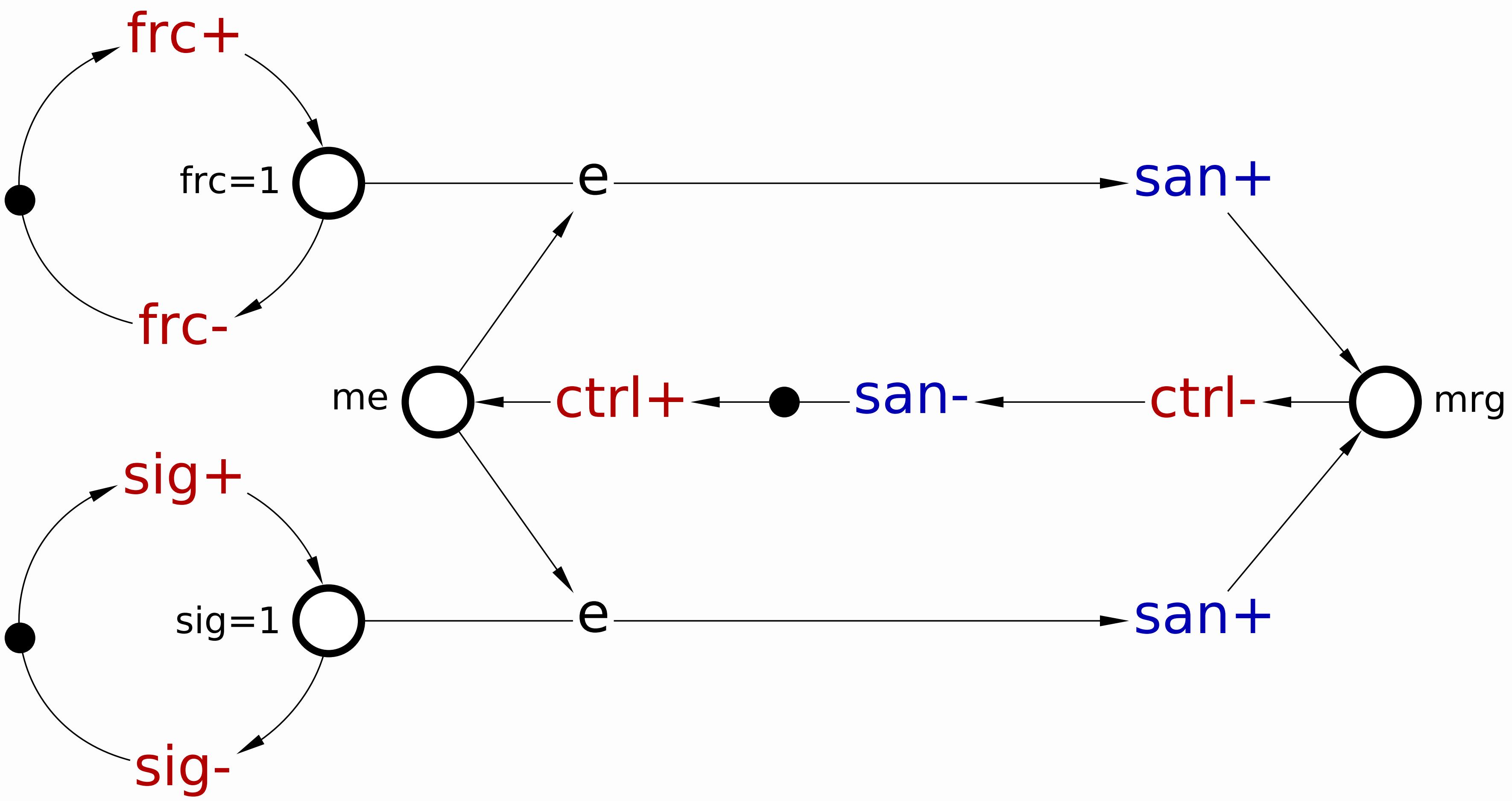


D.Sokolov et.al. *“Design and verification of speed-independent multiphase buck controller”*, ASYNC, 2015.

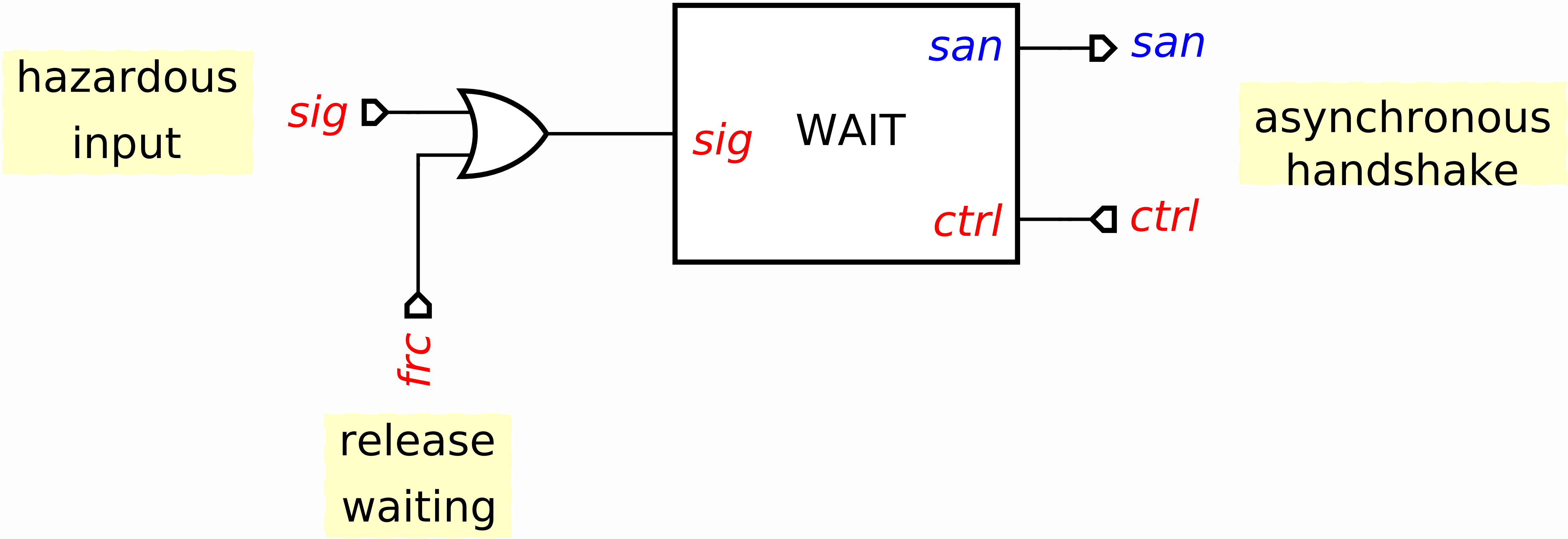
RWAIT: WAIT that can be released/cancelled



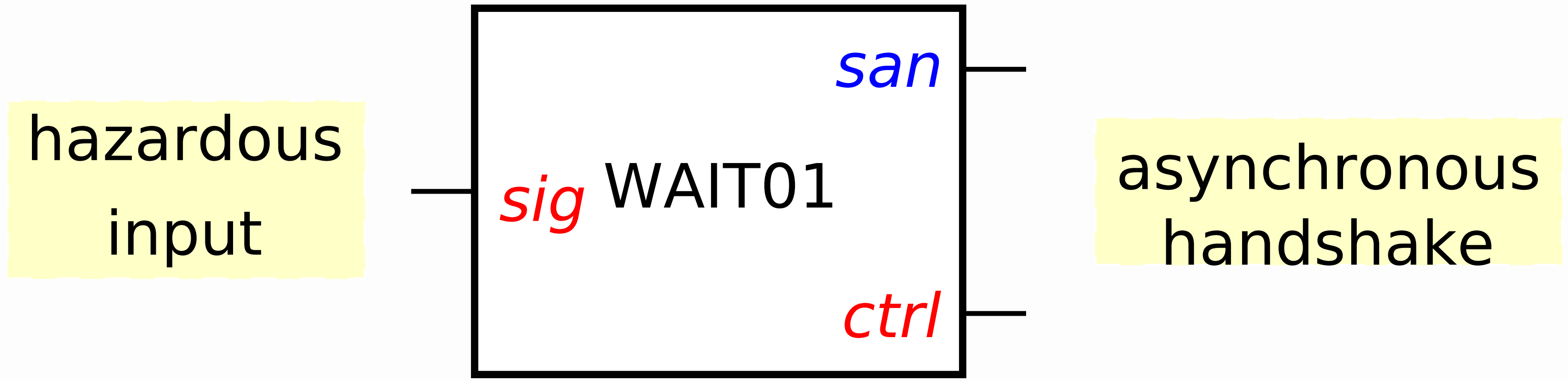
RWAIT: WAIT that can be released/cancelled

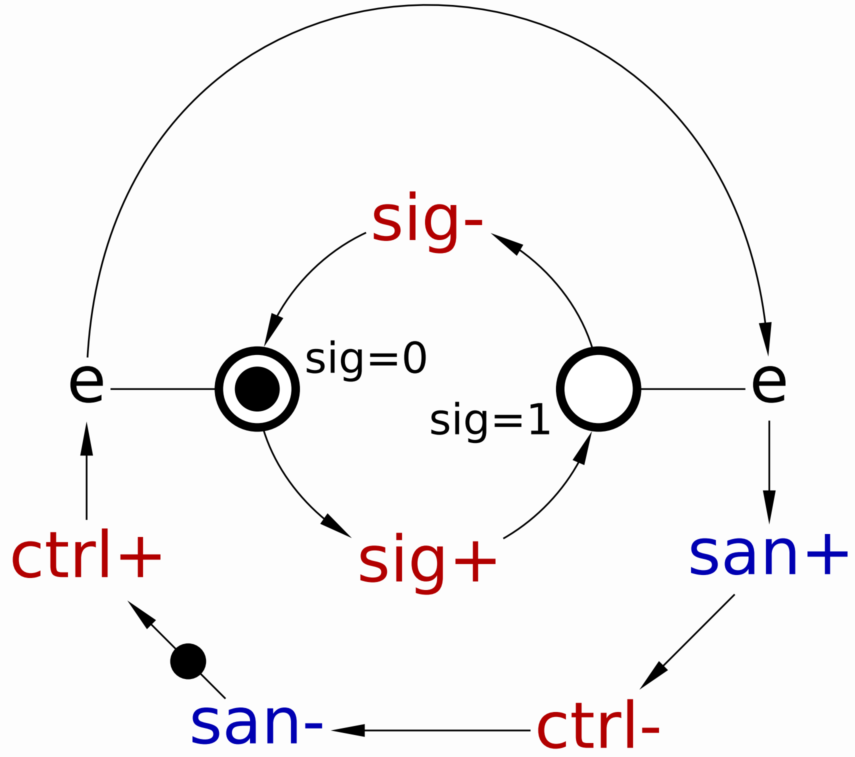


RWAIT: WAIT that can be released/cancelled

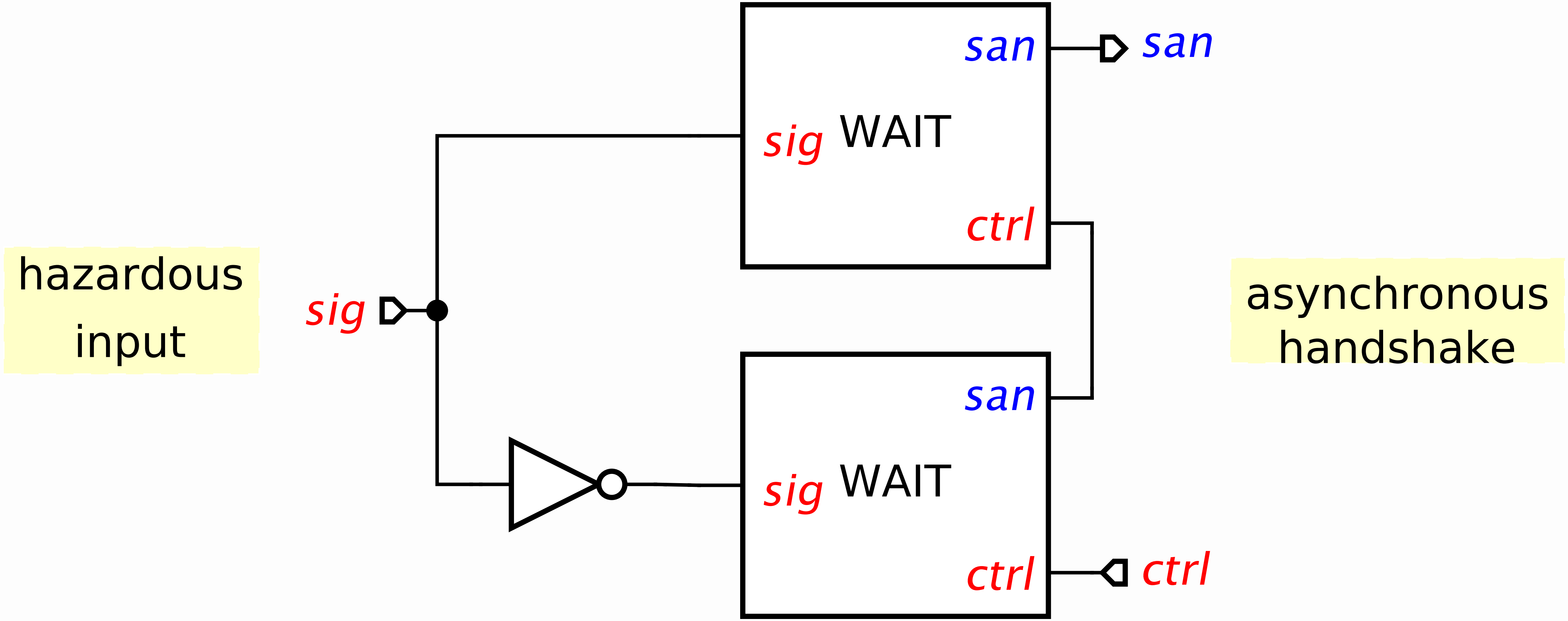


WAIT01: synchronise handshake with rising edge of hazardous input

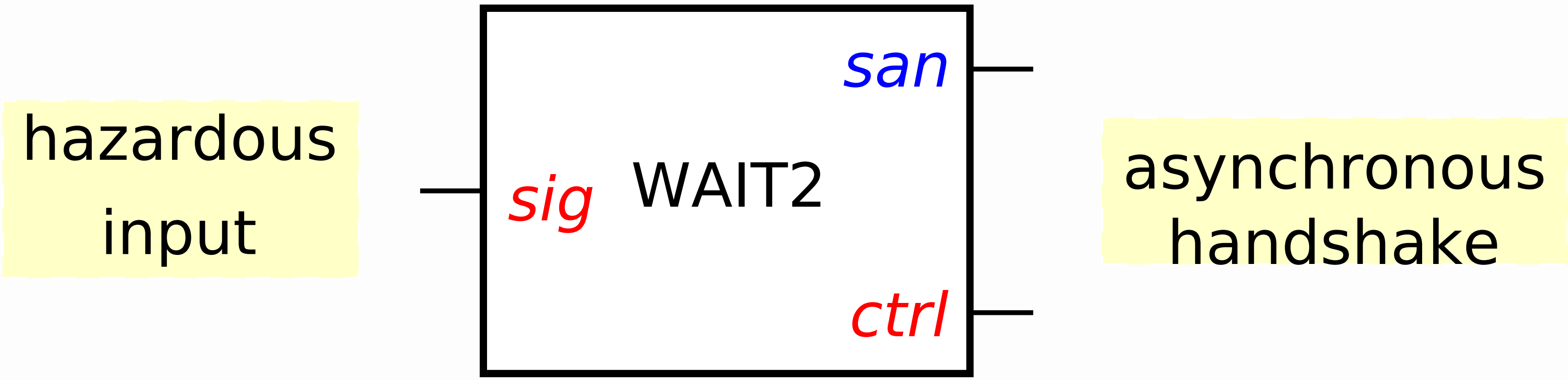


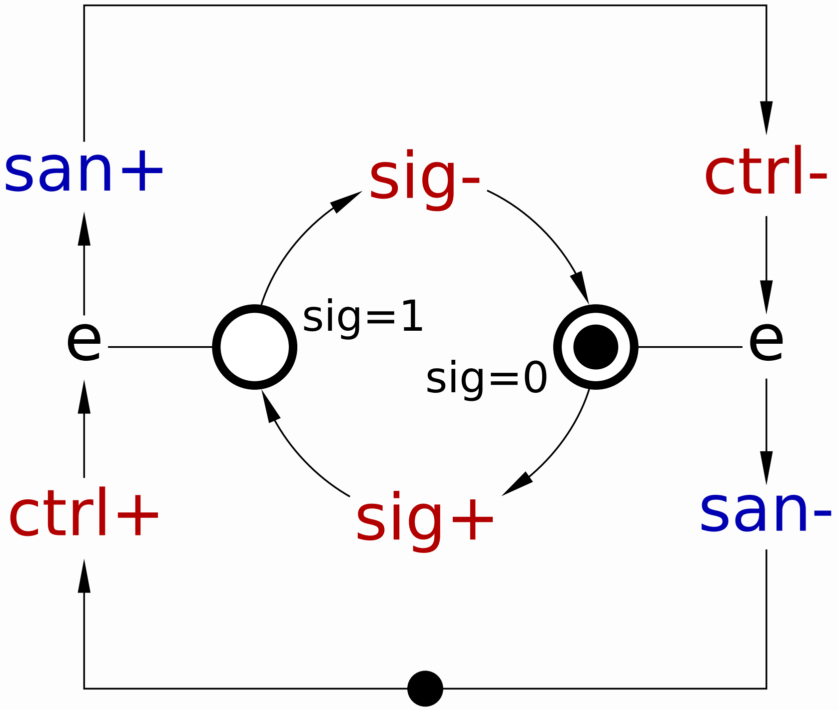


WAIT01: synchronise handshake with rising edge of hazardous input

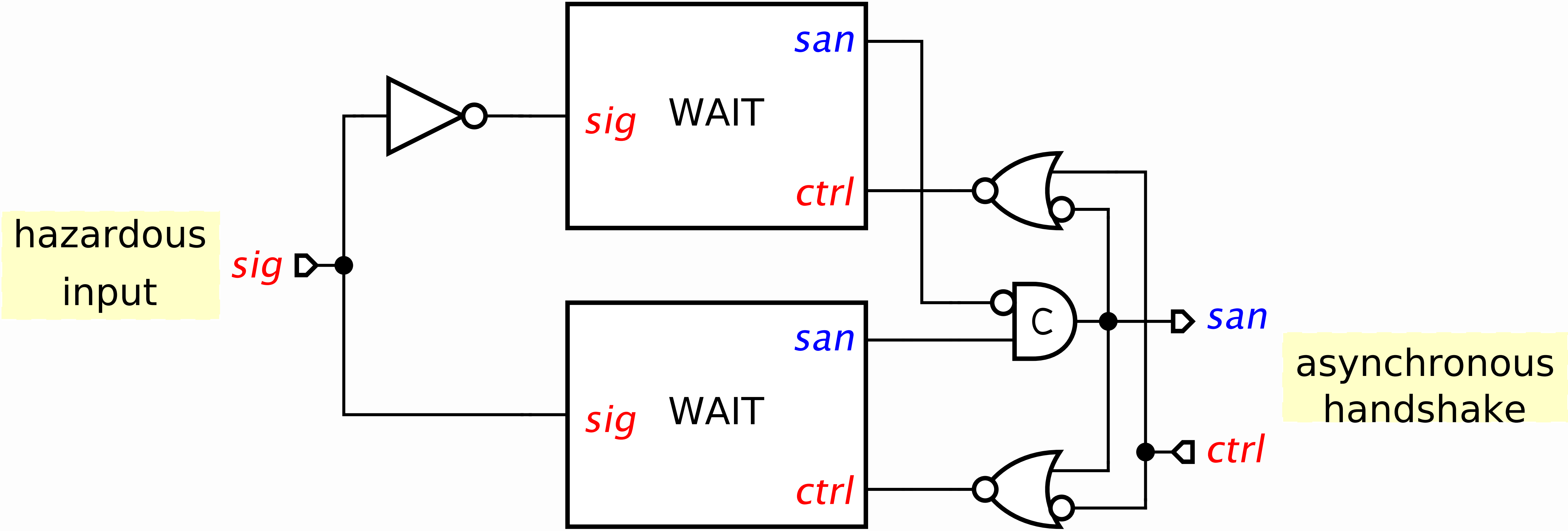


WAIT2: synchronise handshake with both phases of hazardous input

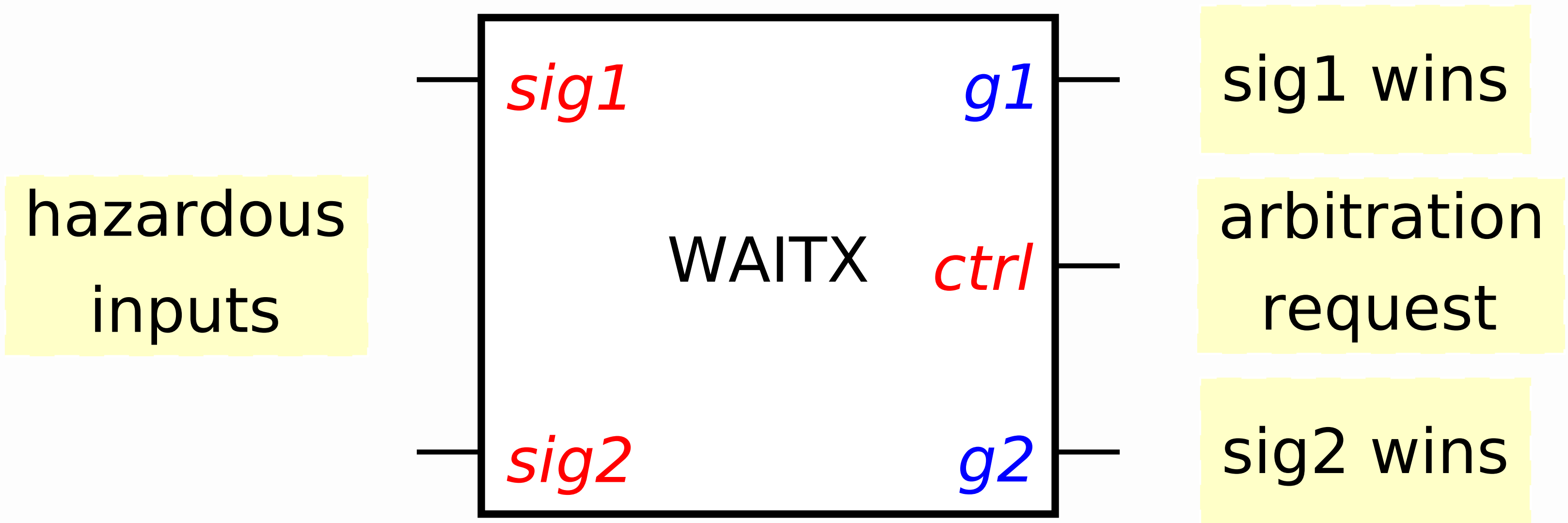




WAIT2: synchronise handshake with both phases of hazardous input

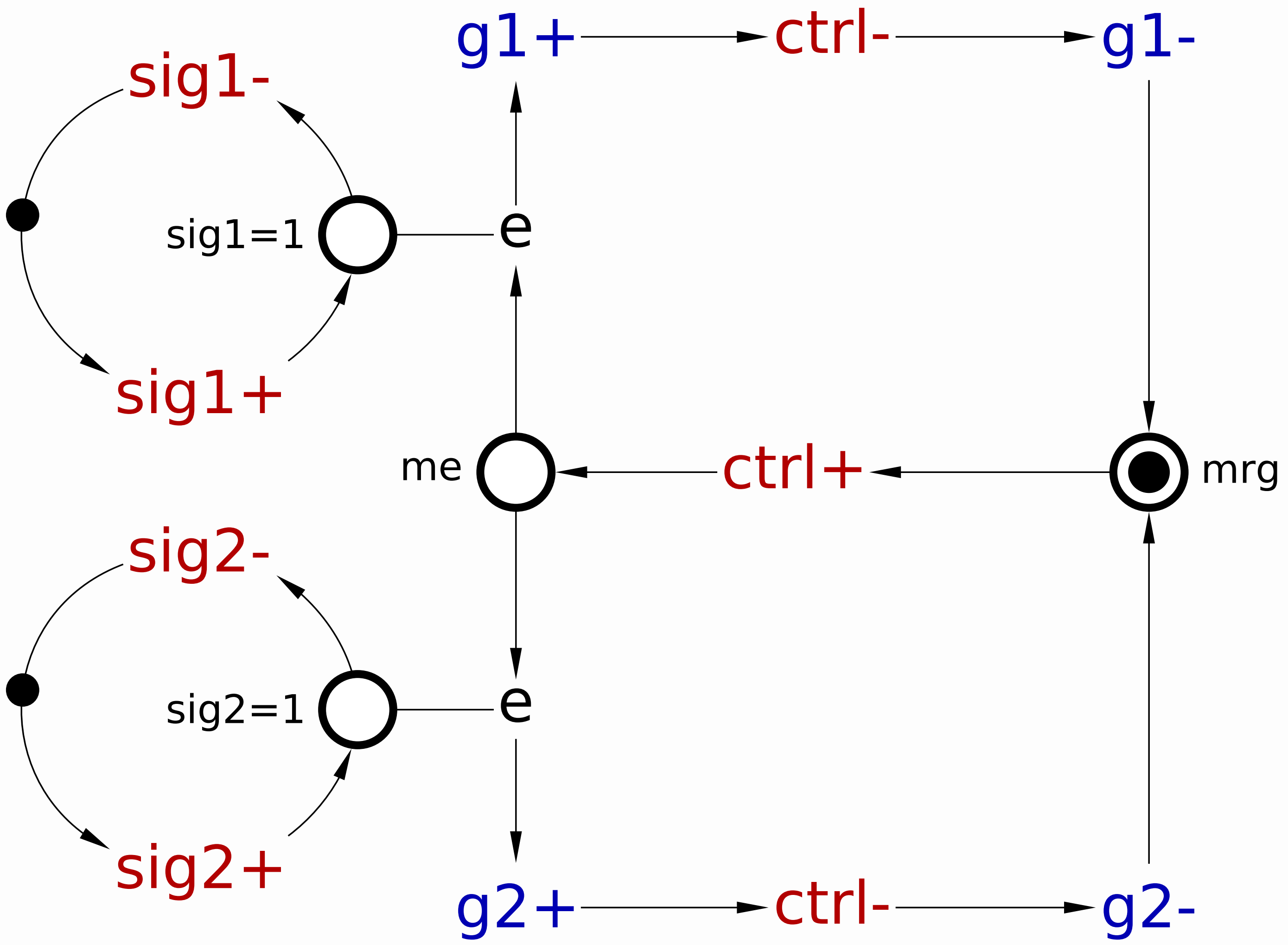


WAITX: arbitrate between two hazardous inputs



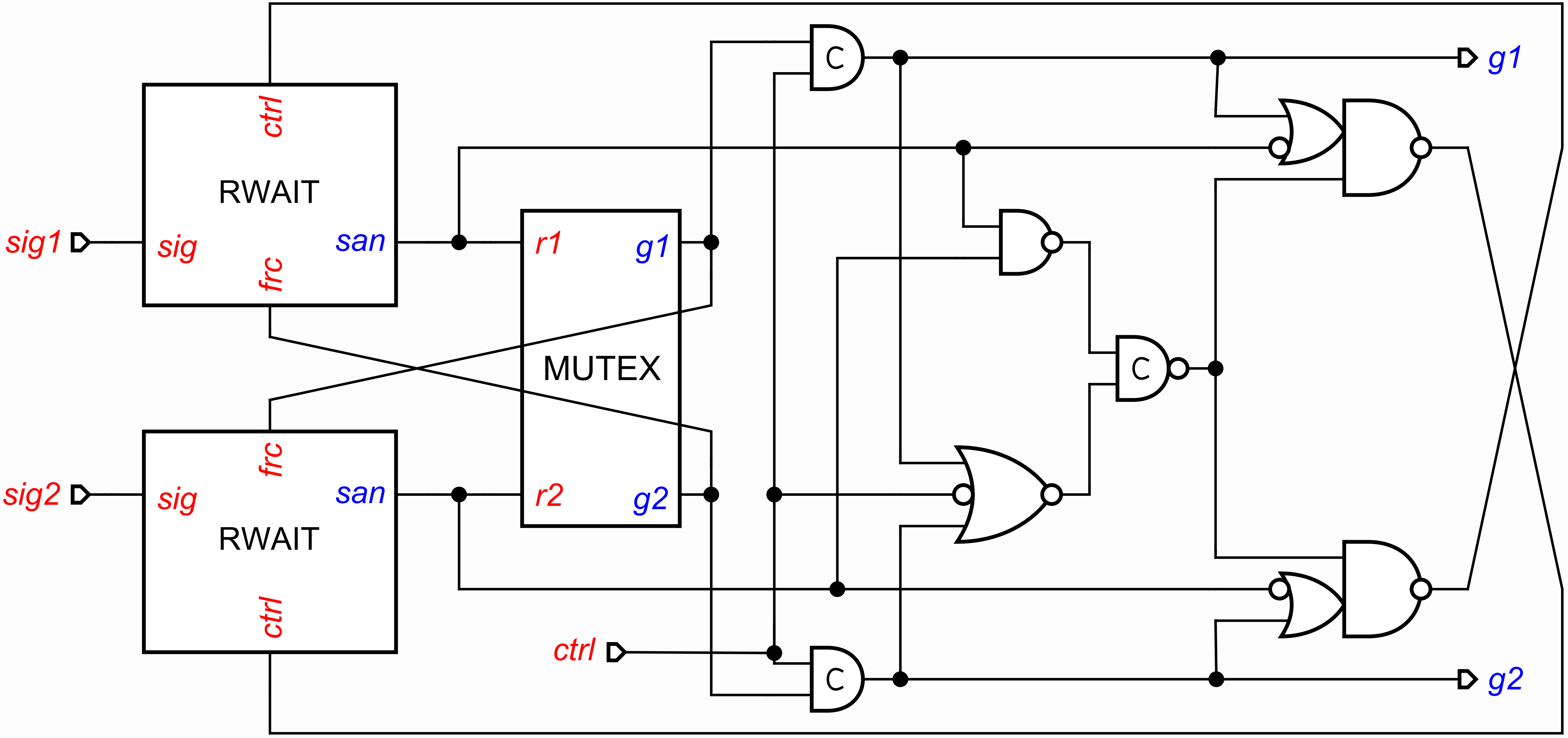
V.Khomenko et.al. *“WAITX: An arbiter for non-persistent signals”*, ASYNC, 2017.

WAITX: arbitrate between two hazardous inputs

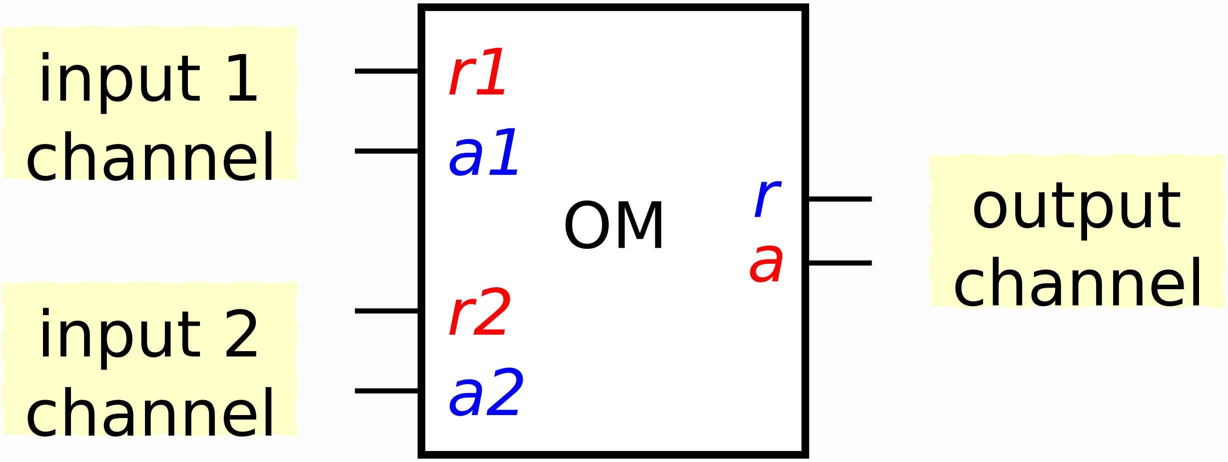


V.Khomenko et.al. *“WAITX: An arbiter for non-persistent signals”*, ASYNC, 2017.

WAITX: arbitrate between two hazardous inputs



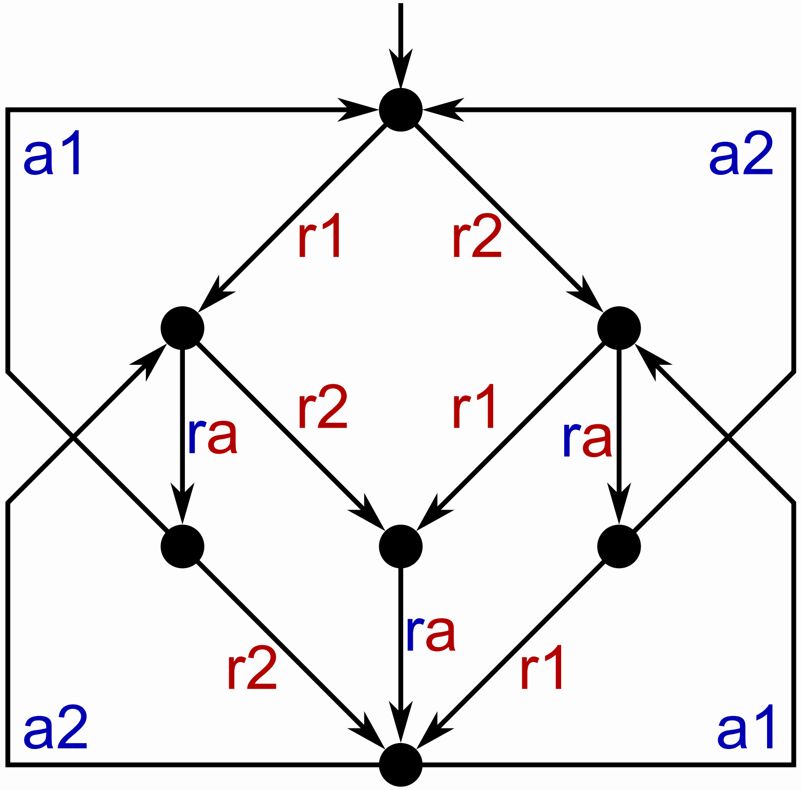
OM: merge two handshake channels into one



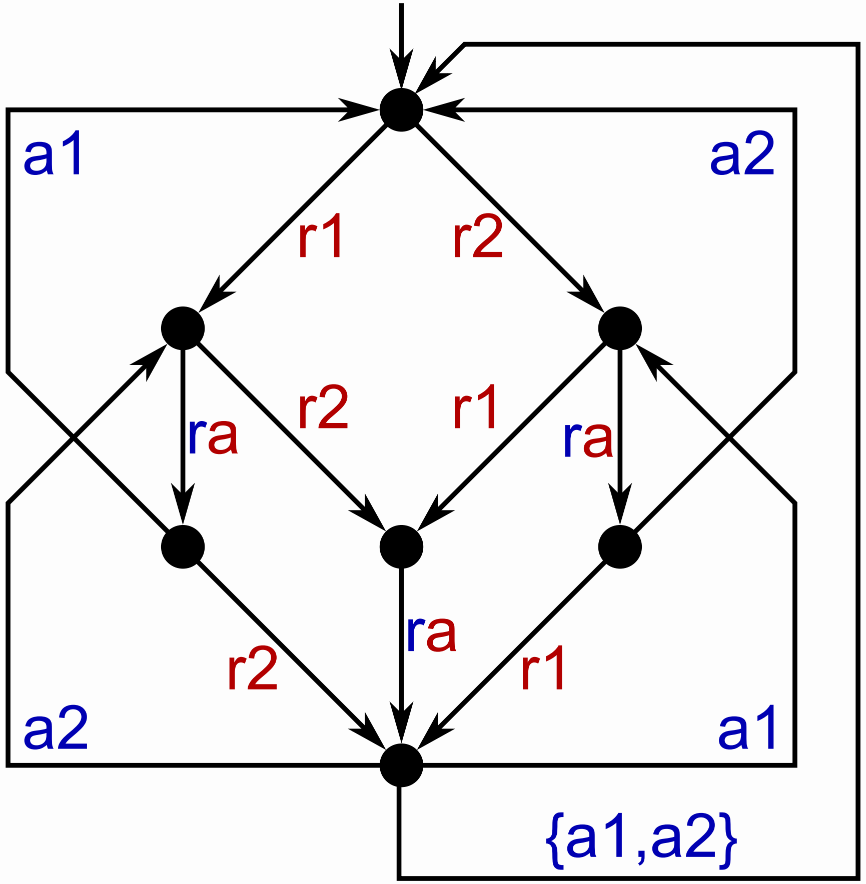
A.Mokhov et.al. *“Opportunistic merge element”*, ASYNC, 2015.

OM: merge two handshake channels into one

Standard merge

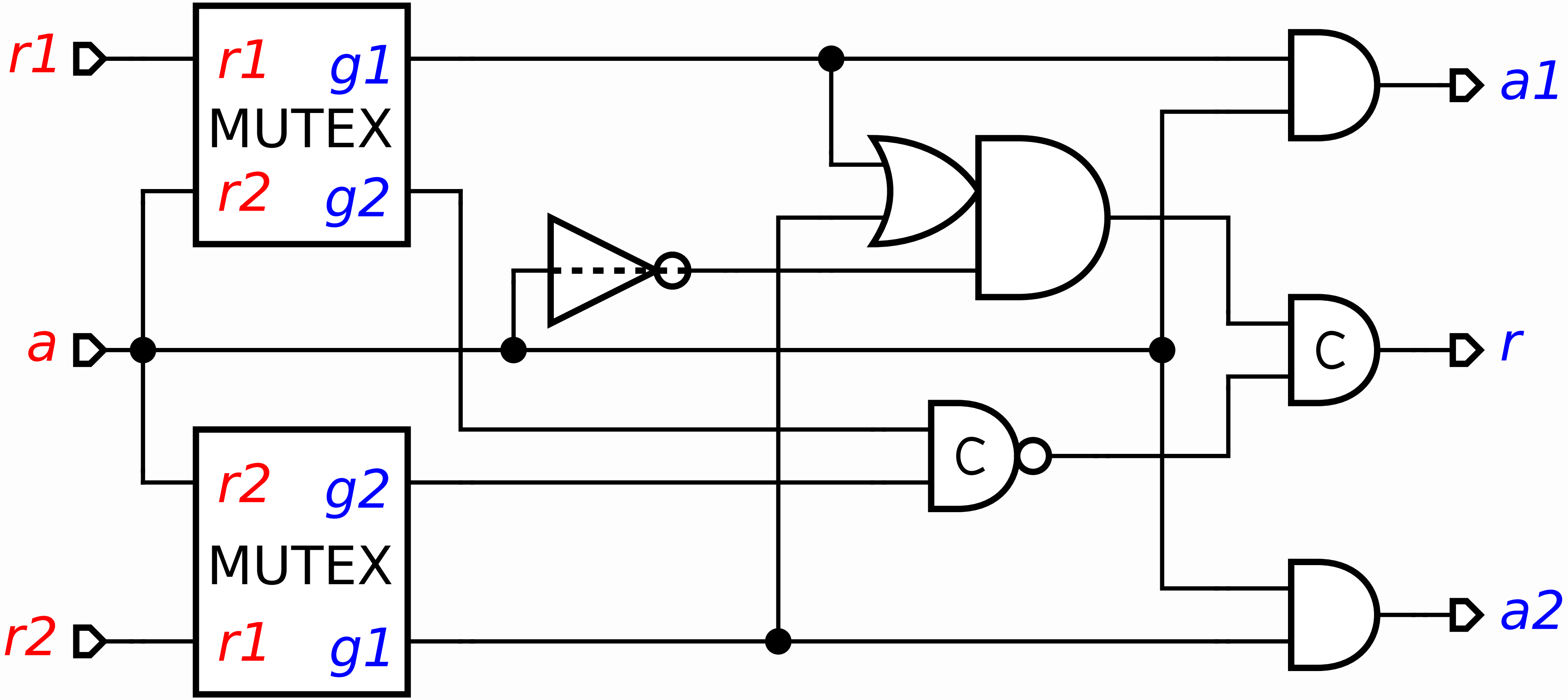


Opportunistic merge



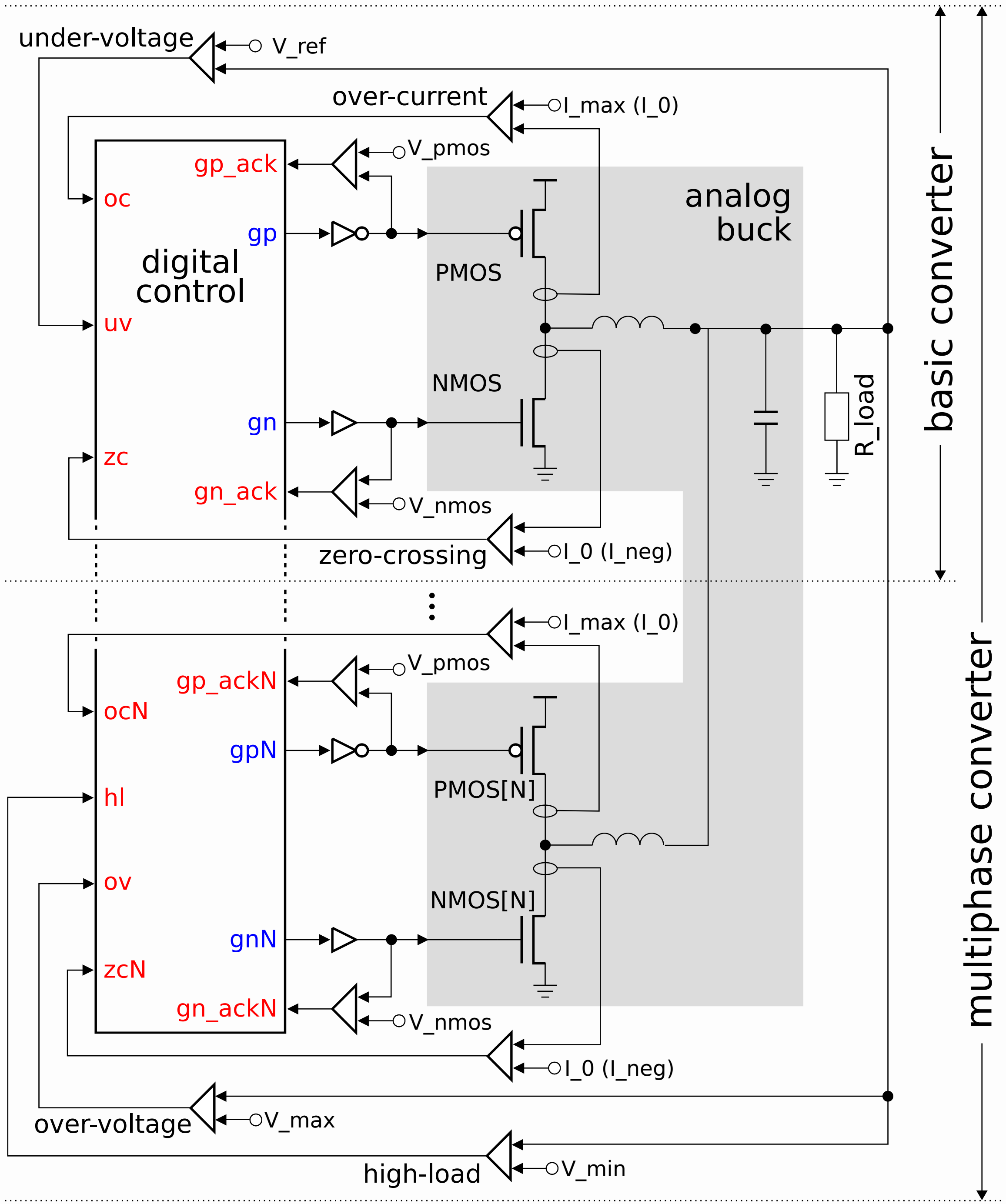
A.Mokhov et.al. *“Opportunistic merge element”*, ASYNC, 2015.

OM: merge two handshake channels into one



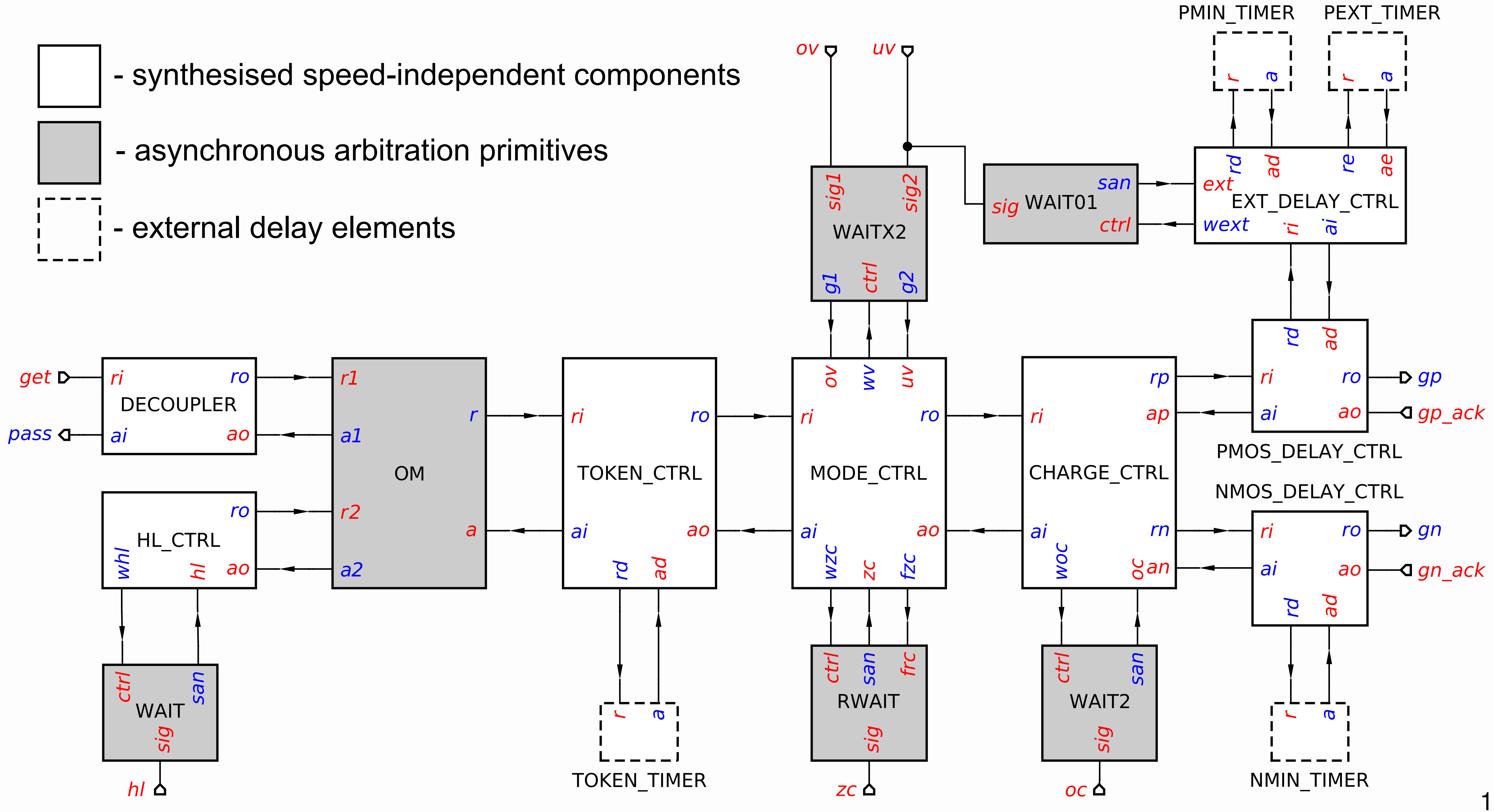
A.Mokhov et.al. *"Opportunistic merge element"*, ASYNC, 2015.

Application example: multiphase buck converter



- Phases – pairs of power regulating transistors
  - Each phase operates as a basic buck
  - Phases are activated sequentially
  - Active phases may overlap
- Many operating modes
  - under-voltage (UV)
  - over-current (OC)
  - zero-crossing (ZC)
  - over-voltage (OV)
  - high-load (HL)

Application example: multiphase buck converter



Application example: multiphase buck converter

- Benefits over conventional synchronous design with synchronisers
  - No synchronisation failures
  - Quick response time (few gate delays)
  - Reaction time can be traded off for smaller coils
  - Lower voltage ripple and peak current

D.Sokolov et.al. *"Benefits of async. control for analog electronics: multiphase buck case study"*, DATE, 2017.

Conclusions

- Library of asynchronous arbitration primitives

  `https://github.com/workcraft/arbitration-primitives`

  - Low-latency synchronisation and decision-making
  - Developed and formally verified in WORKCRAFT (`workcraft.org`)

- Building blocks for applications that require:
  - Efficient synchronisation between clock and voltage domains
  - Sanitising ‘dirty’ signals from analog environment

- Demonstrated benefits in the area of power converters