# Formal models in industry standard tools: An Argos block within Simulink

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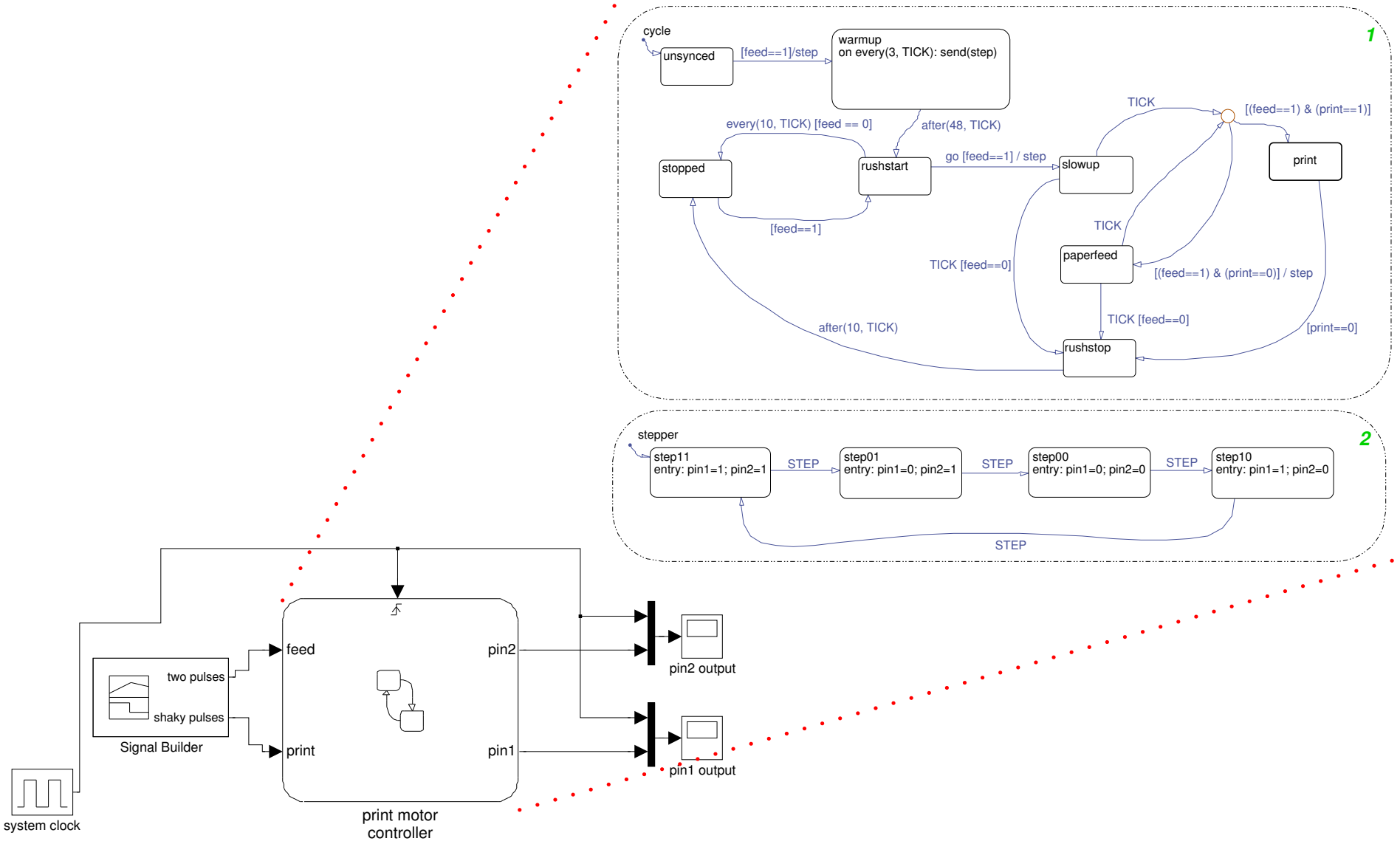
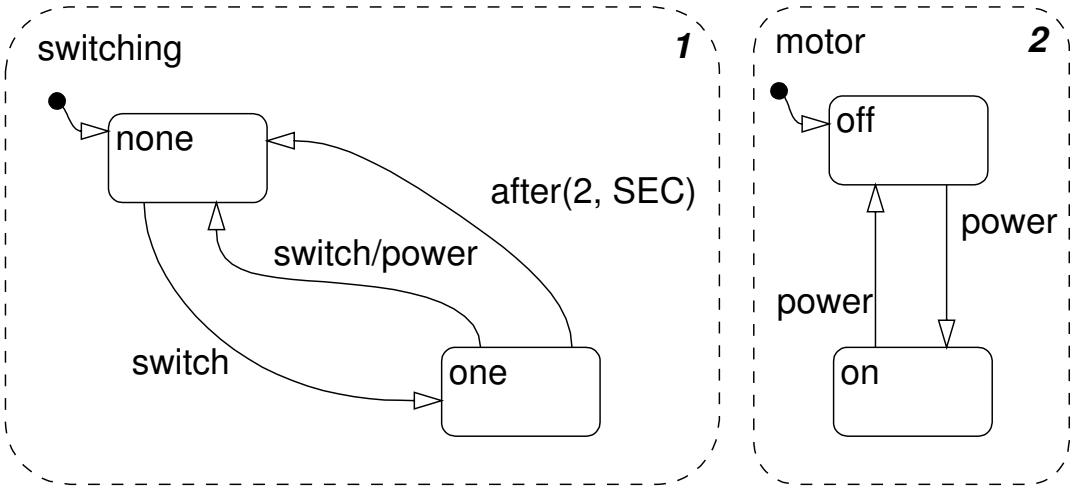
# HYBRID = CONTINUOUS + DISCRETE



# Stateflow




Many Statecharts features:

- hierarchy
- parallelism
- history junctions

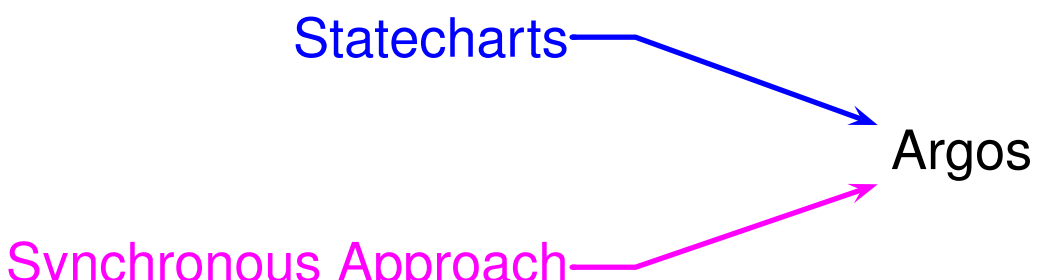
Flowchart-like transitions:

- sequencing
- branching
- loops

**Thinking/communicating about designs is involved:**

1. intricate ordering rules
2. queued event processing
3. stacking of communications
4. implicit assumption of synchrony

# Argos: a synchronous language



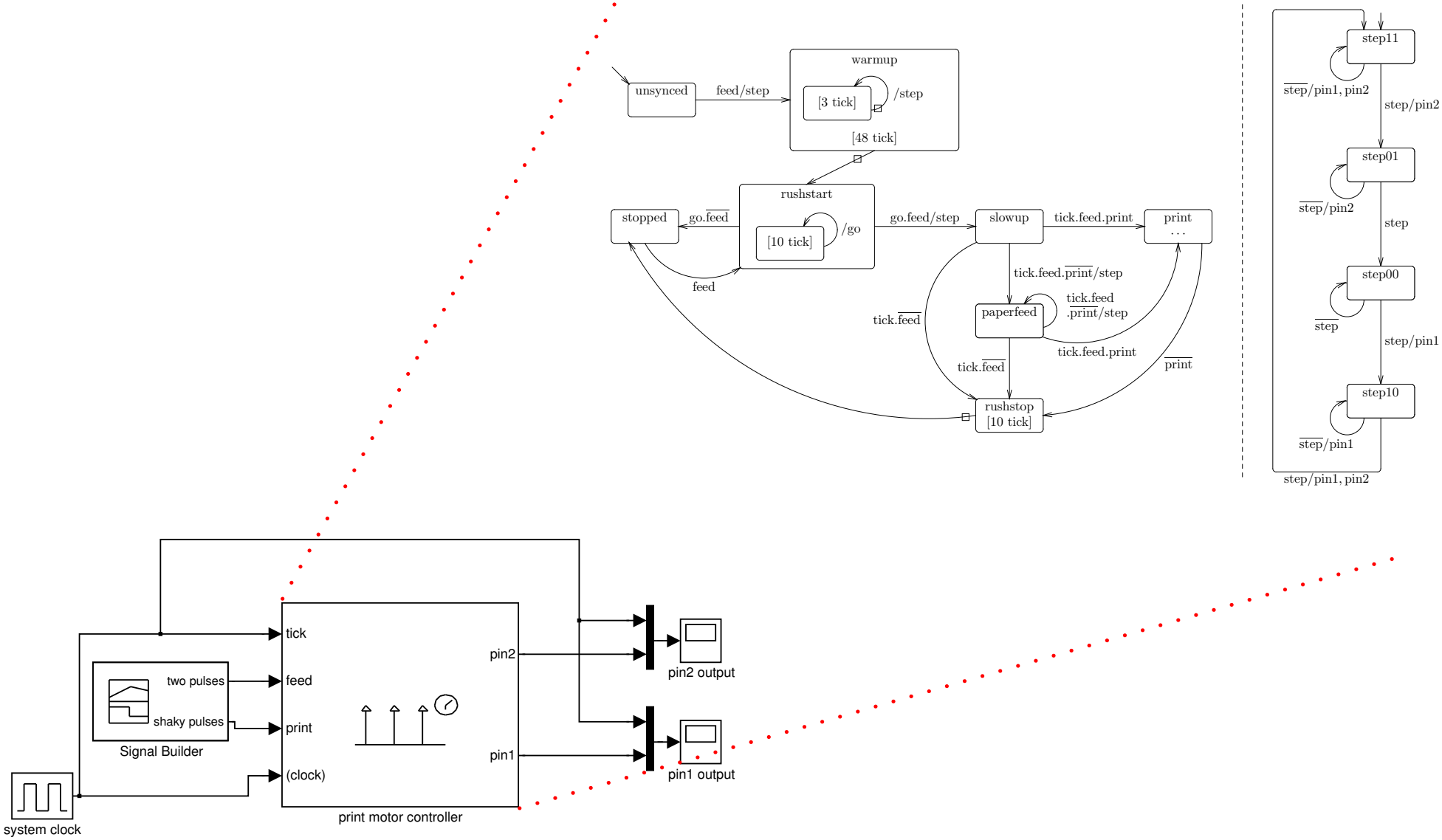

- Mealy machines
- Hierarchy
- Parallelism
- Discrete reactions
- Well-defined internal behaviour

- Esterel, Lustre, Signal
- CMA, INRIA, Verimag, IRISA

**Argos is a synchronous version of Statecharts.**

- Developed by Maraninchi and Rémond [Mar91, MR01].
- Well suited to some reactive programming tasks.

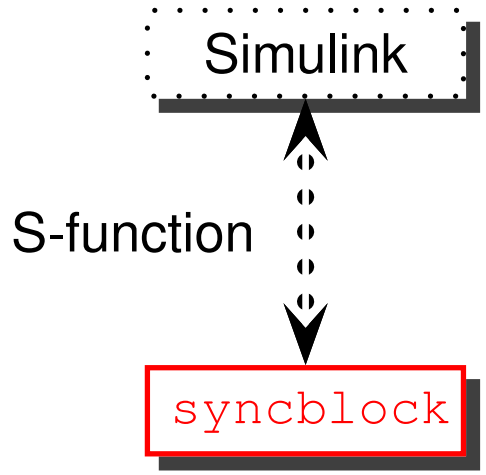
# An Argos block: Syncblock




[CCM+03, SSC+04]

# Syncblock Implementation

# Syncblock Implementation



# Syncblock Implementation

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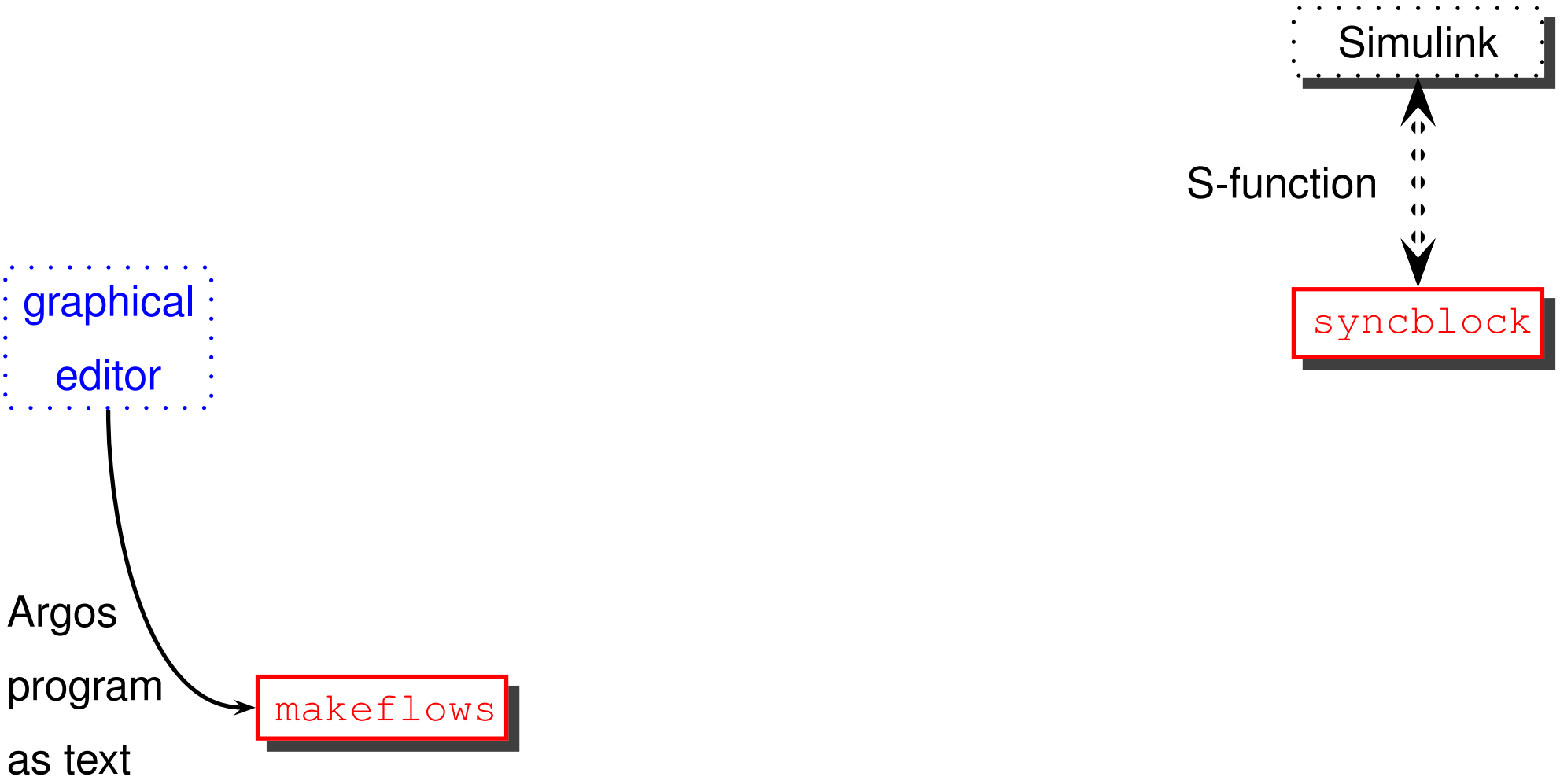
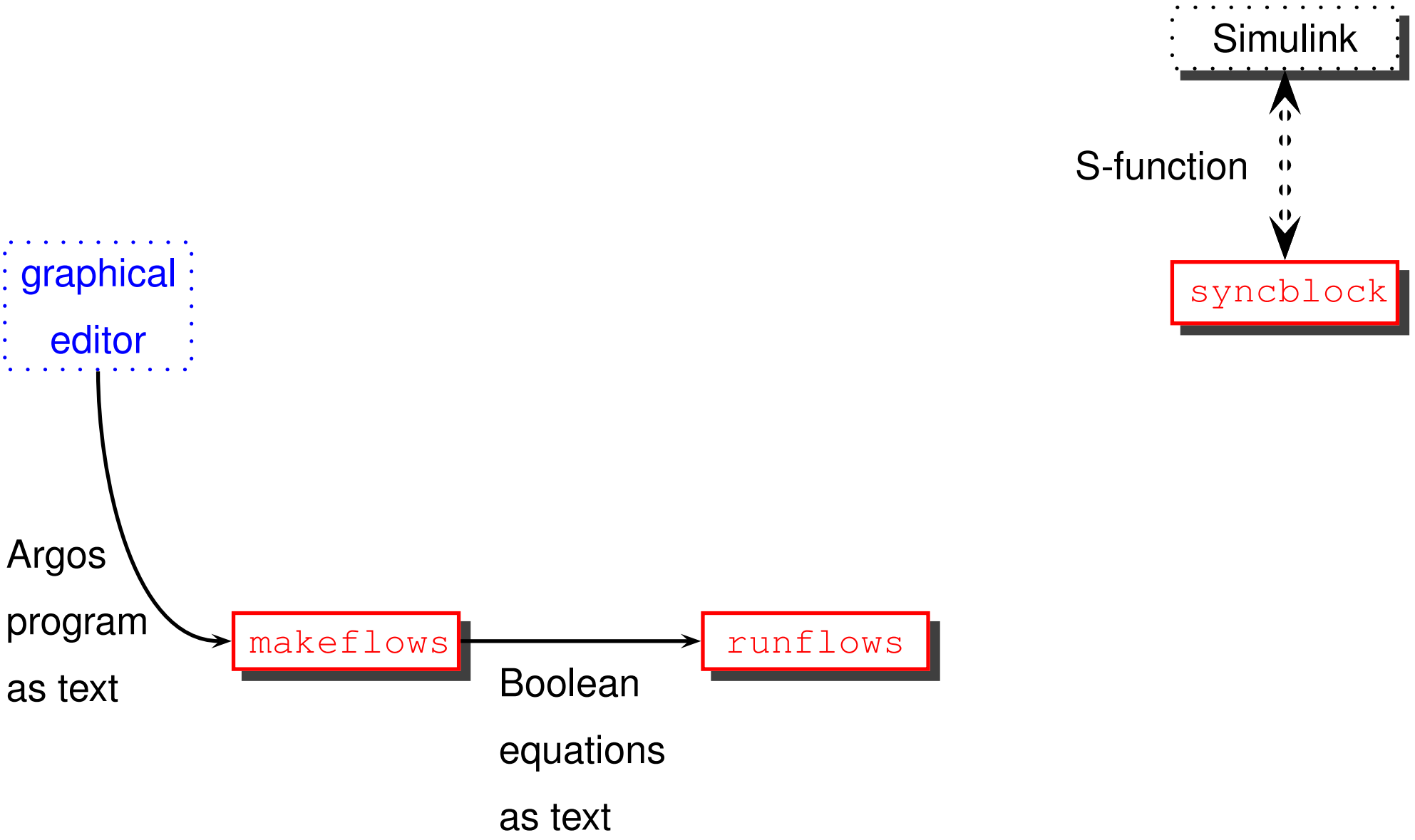
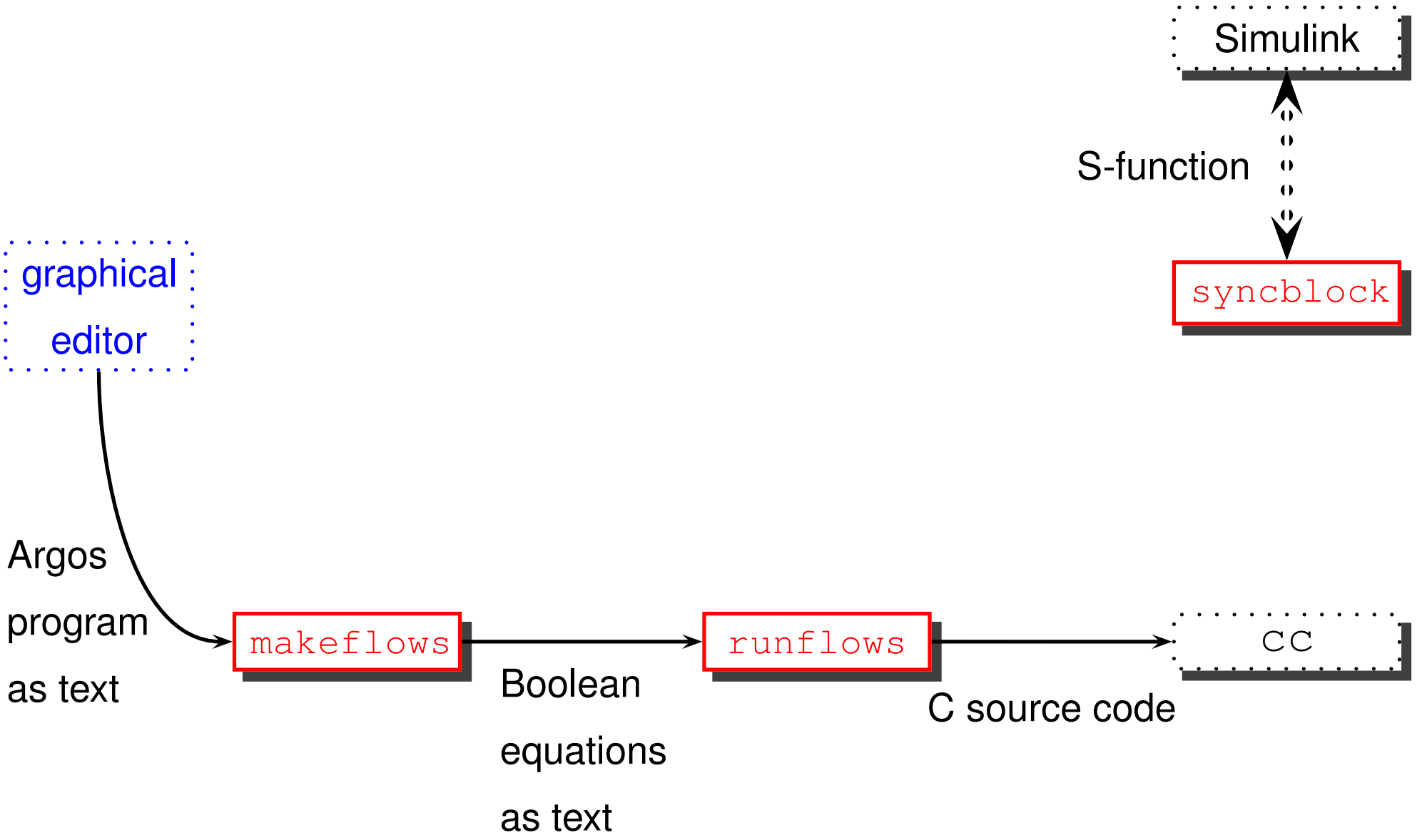


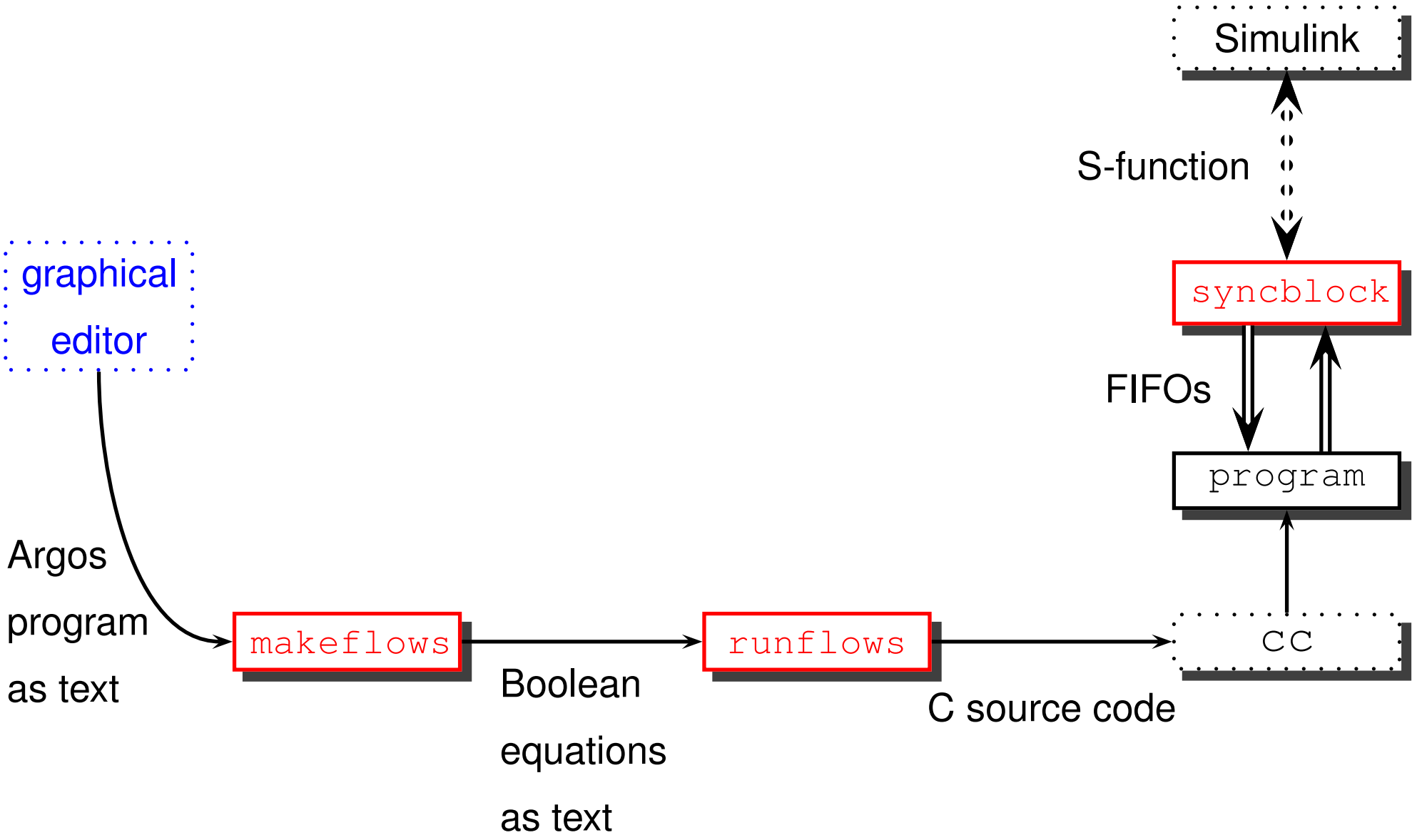
# Syncblock Implementation



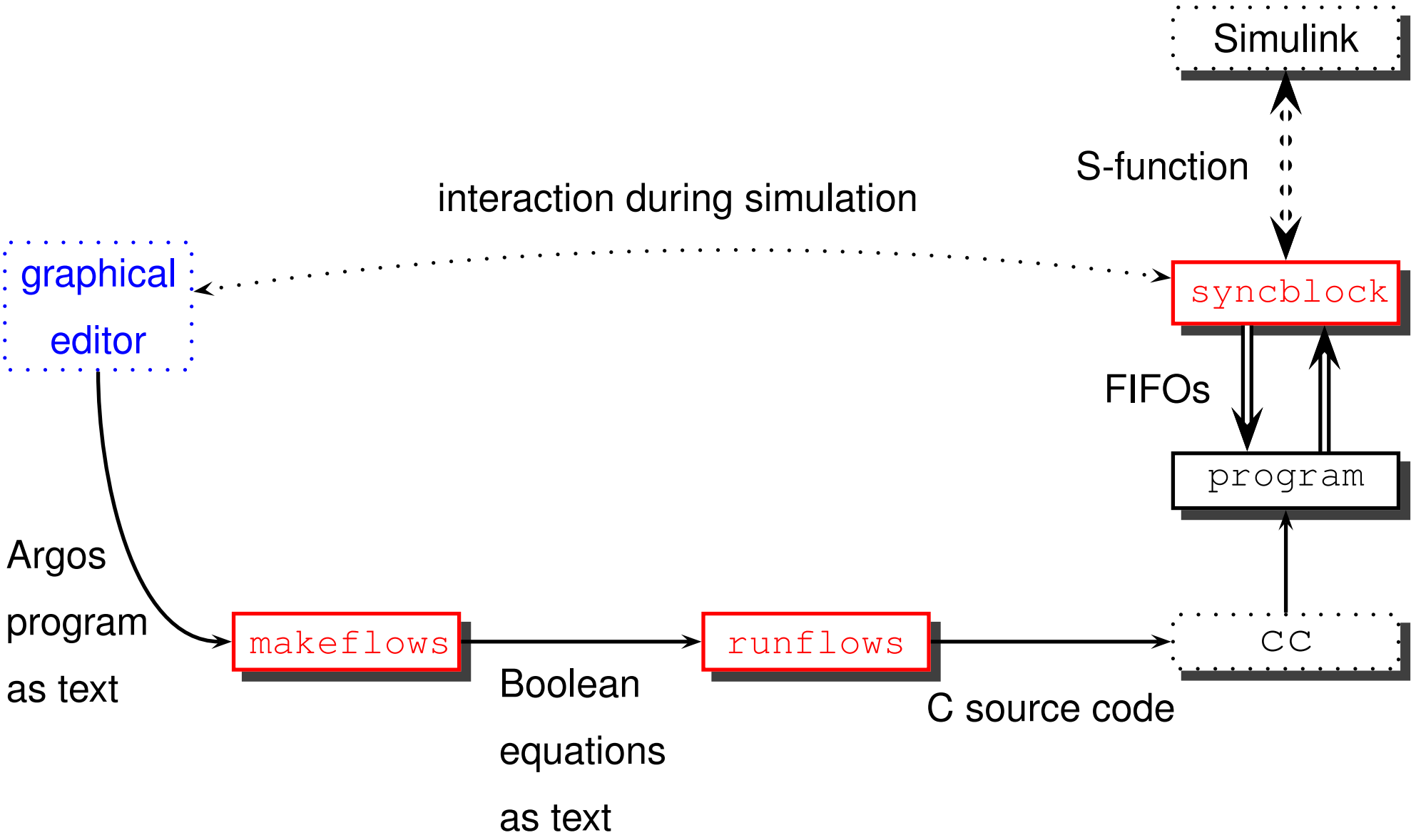
# Syncblock Implementation



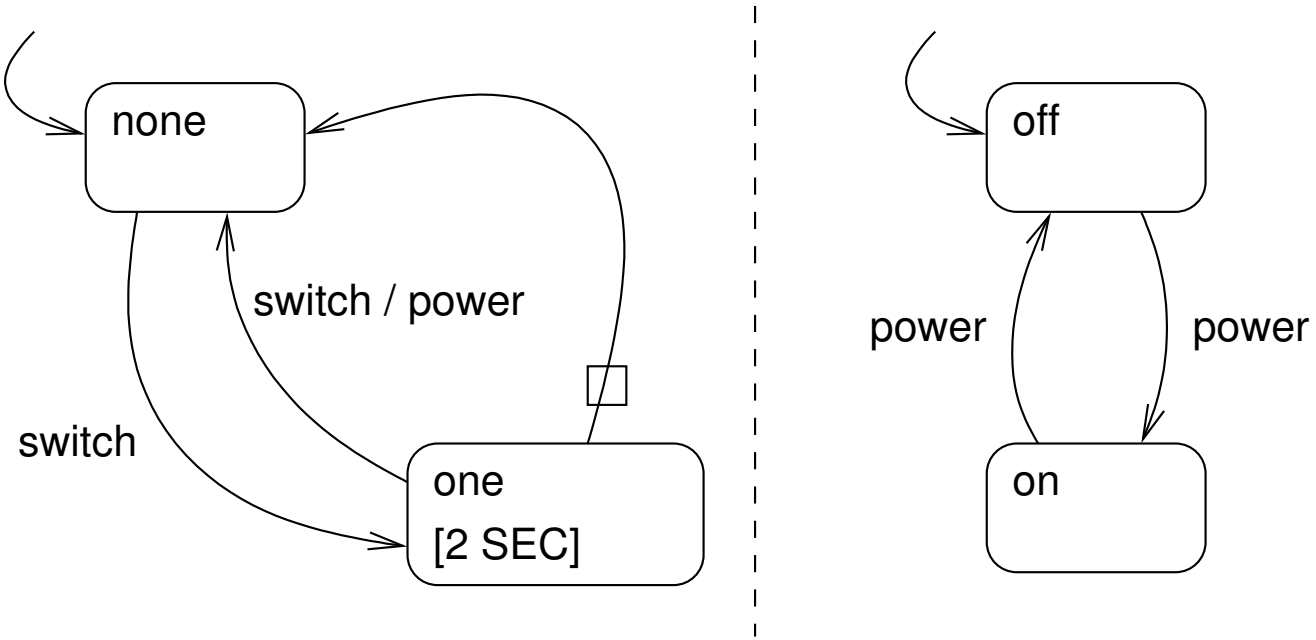
# Syncblock Implementation



# Syncblock Implementation

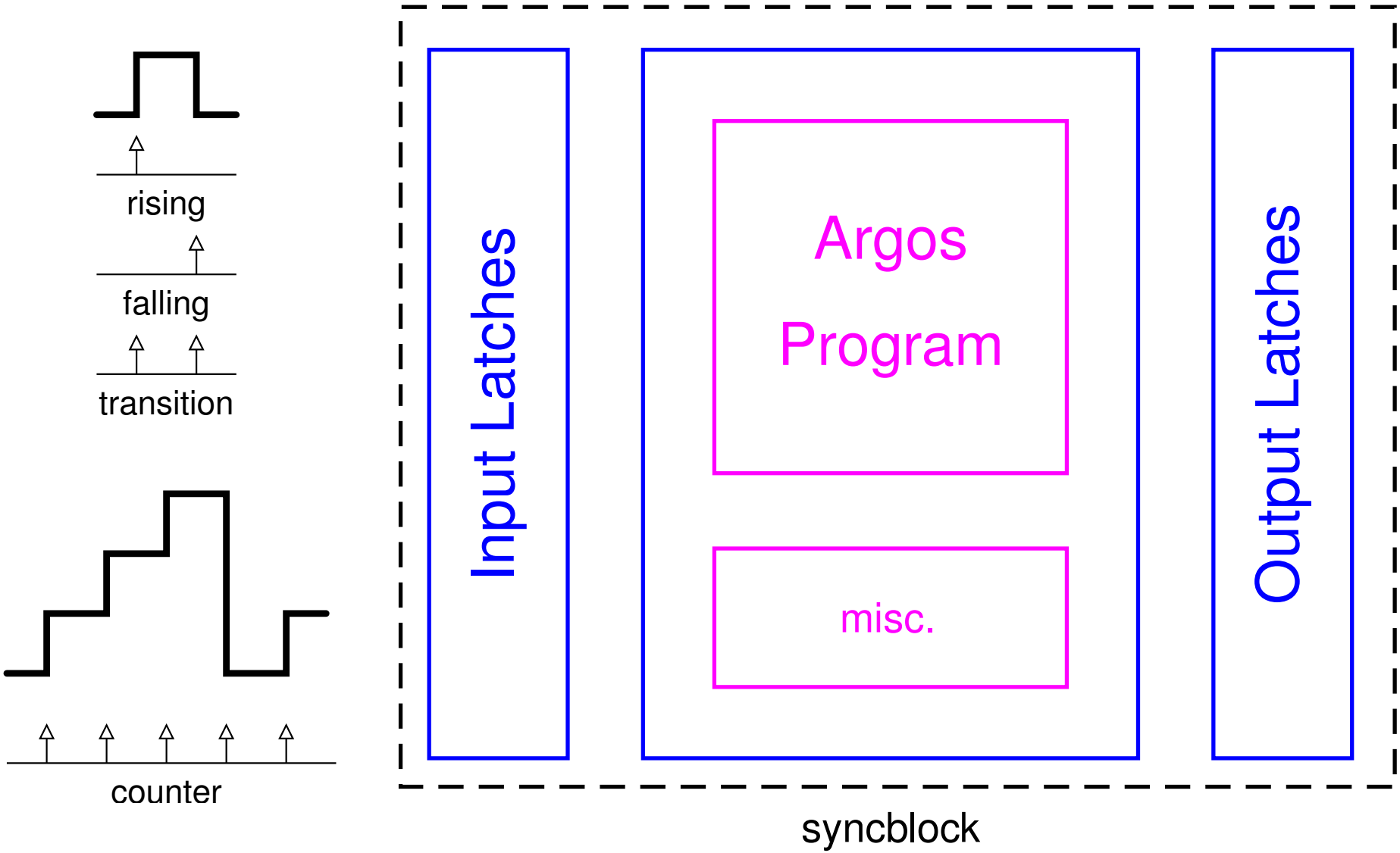


# Compilation [MH96]

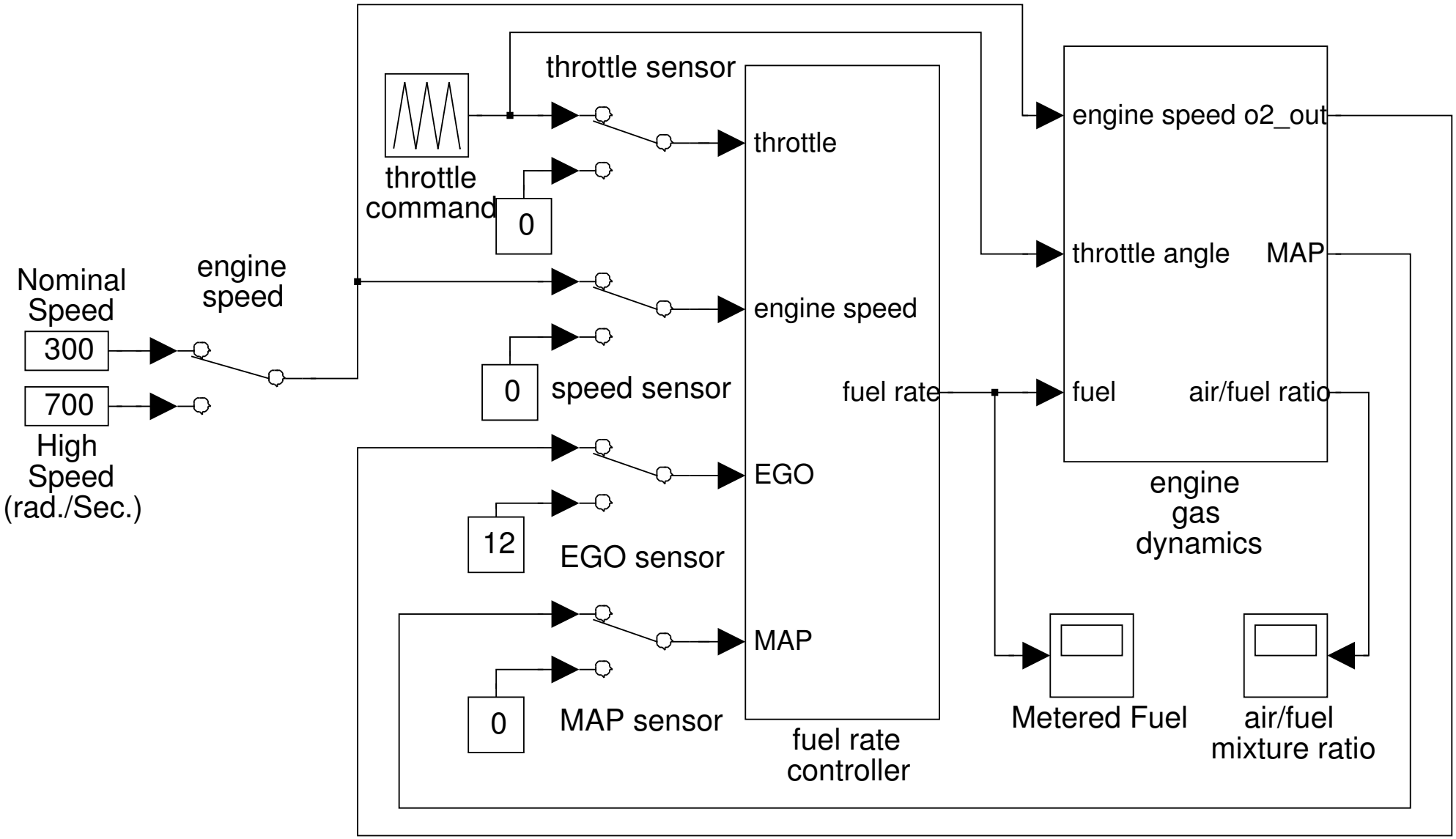


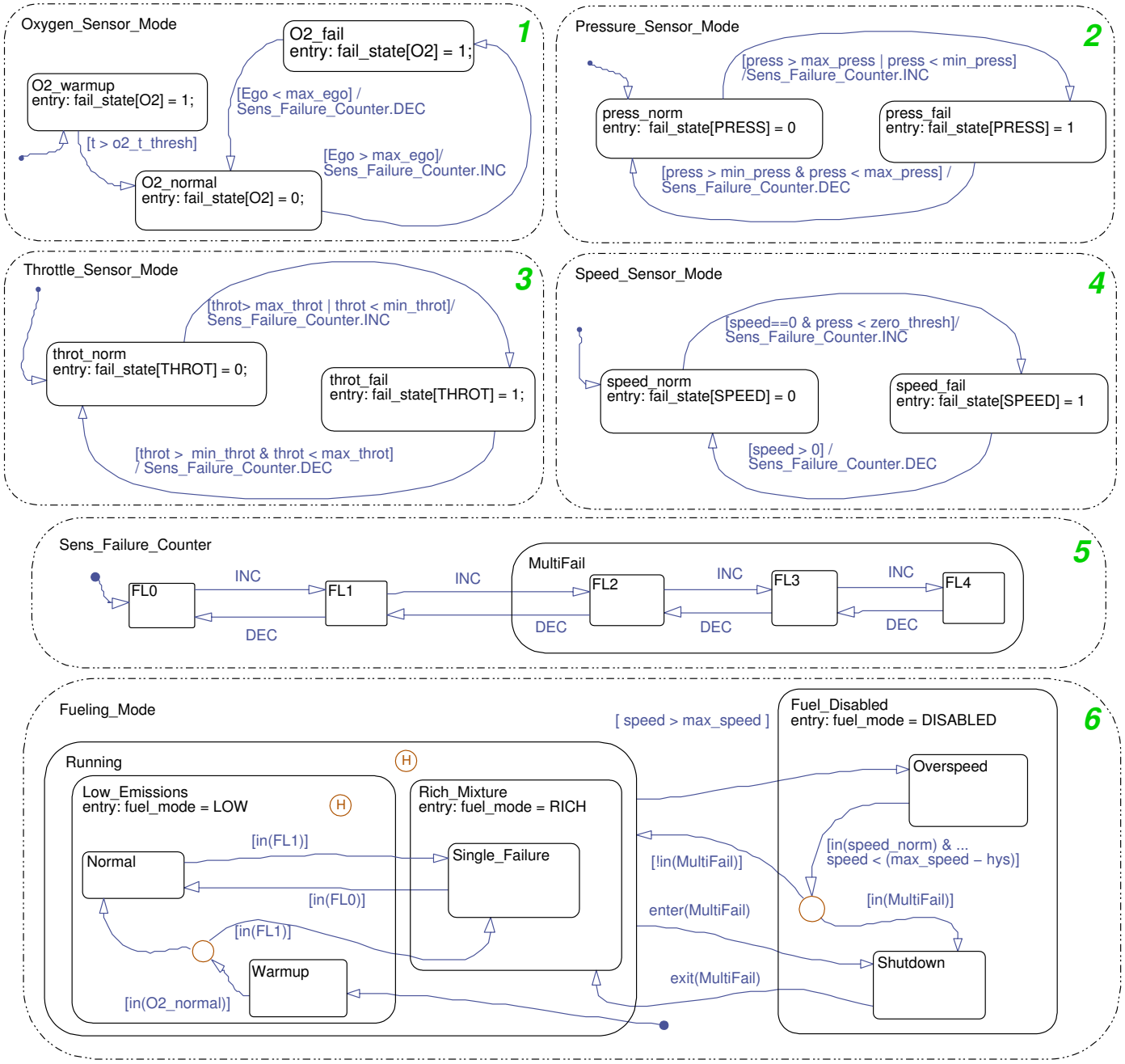

```
power   = (one && switch)
none'   = (one && timeout && !switch) || (one && switch)
          || (none && !switch)
one'    = (none && switch) || (one && !timeout && !switch)
off'    = (off && !power) || (on && power)
on'     = (on && !power) || (off && power)
```

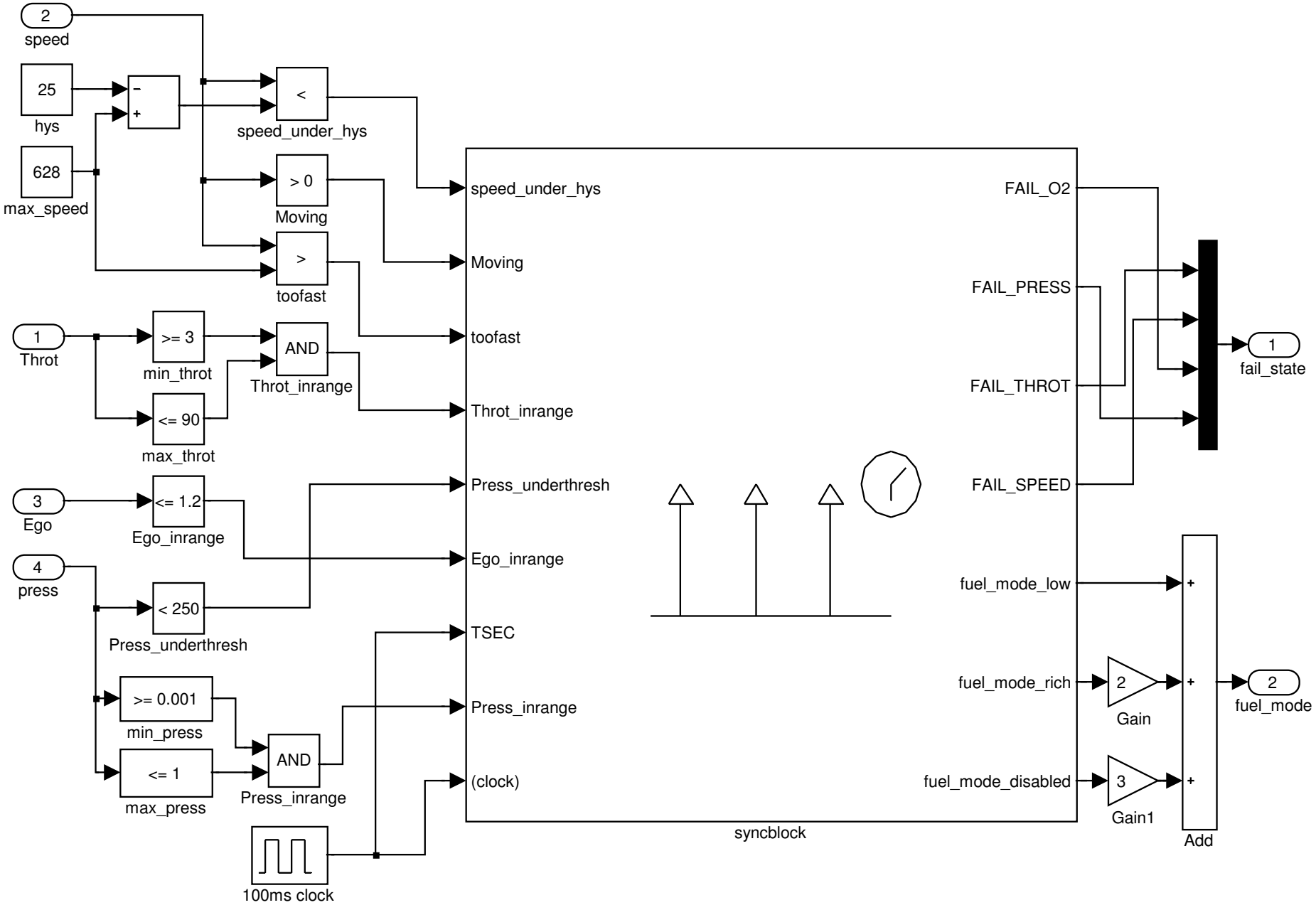
# Block interfacing

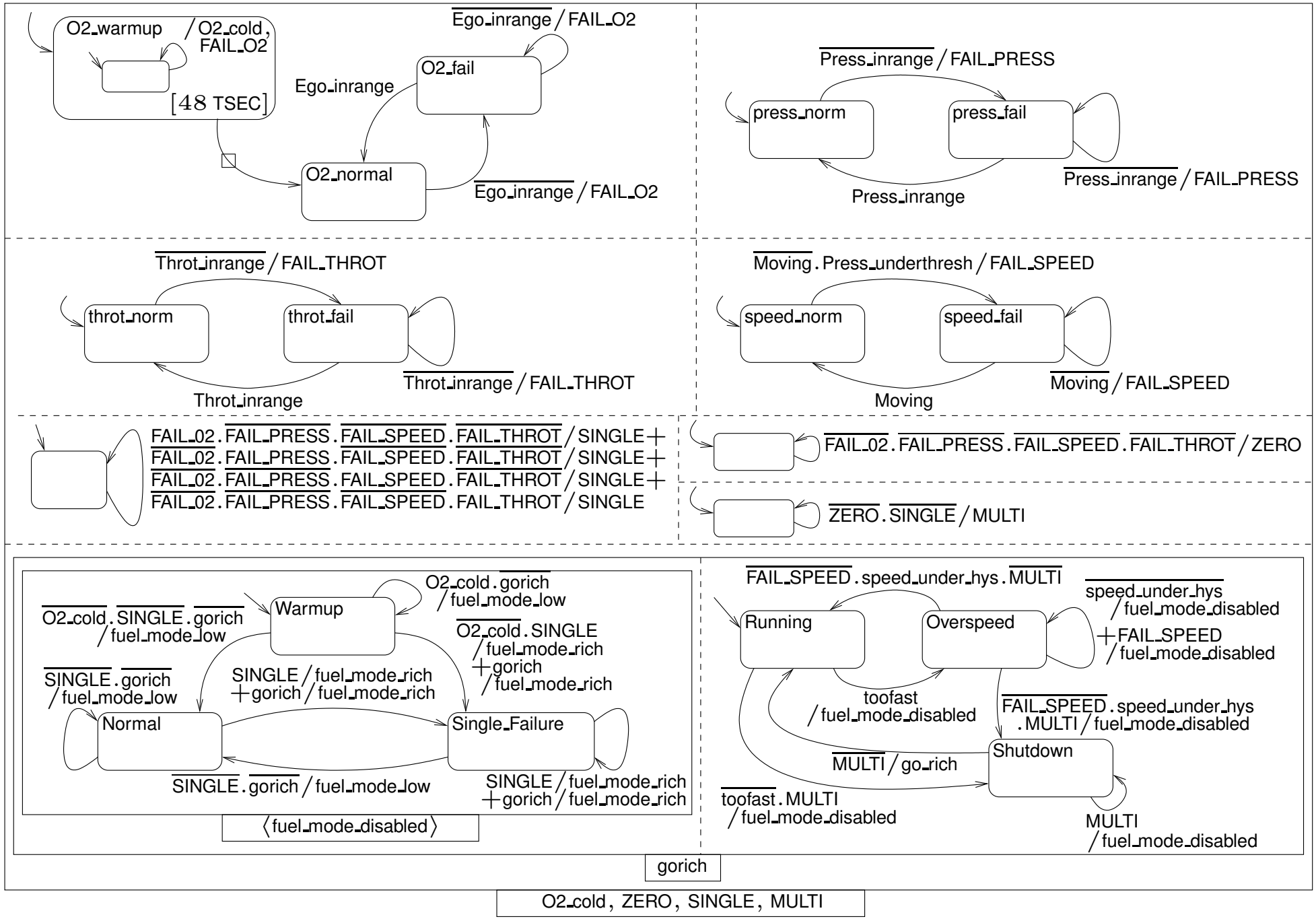


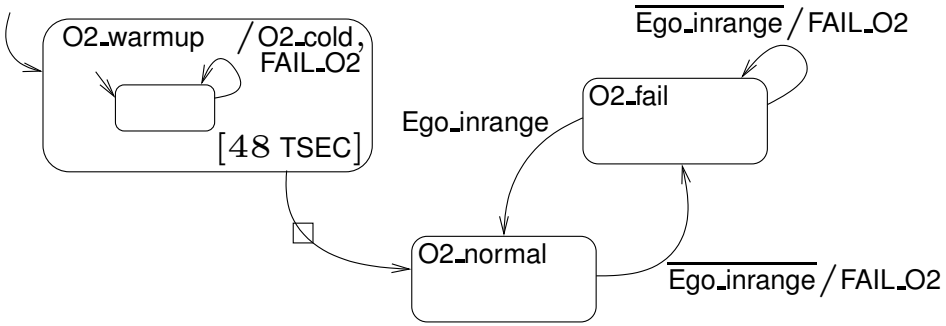
# Example: Fault-Tolerant Fuel Control System [Mat]

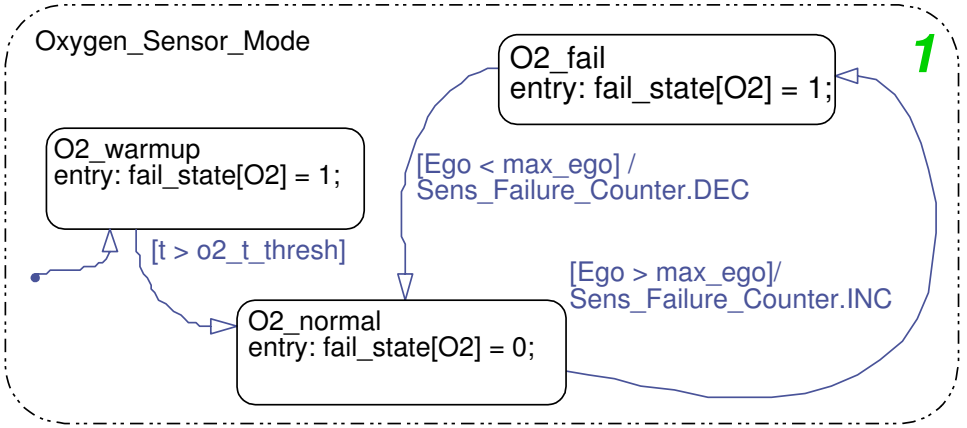



Oxygen_Sensor_Mode
1
O2_fail
entry: fail_state[O2] = 1;
O2_warmup
entry: fail_state[O2] = 1;
[Ego < max_ego] /
Sens_Failure_Counter.DEC
[t > o2_t_thresh]
[Ego > max_ego]/
Sens_Failure_Counter.INC
O2_normal
entry: fail_state[O2] = 0;
Pressure_Sensor_Mode
2
[press > max_press | press < min_press]
/Sens_Failure_Counter.INC
press_norm
entry: fail_state[PRESS] = 0
press_fail
entry: fail_state[PRESS] = 1
[press > min_press & press < max_press] /
Sens_Failure_Counter.DEC
Throttle_Sensor_Mode
3
[throt> max_throt | throt < min_throt]/
Sens_Failure_Counter.INC
throt_norm
entry: fail_state[THROT] = 0;
throt_fail
entry: fail_state[THROT] = 1;
[throt > min_throt & throt < max_throt]
/ Sens_Failure_Counter.DEC
Speed_Sensor_Mode
4
[speed==0 & press < zero_thresh]/
Sens_Failure_Counter.INC
speed_norm
entry: fail_state[SPEED] = 0
speed_fail
entry: fail_state[SPEED] = 1
[speed > 0] /
Sens_Failure_Counter.DEC
Sens_Failure_Counter
5
FL0
INC
FL1
INC
MultiFail
FL2
INC
FL3
INC
FL4
DEC
DEC
DEC
DEC
Fueling_Mode
6
[ speed > max_speed ]
Fuel_Disabled
entry: fuel_mode = DISABLED
Overspeed
[in(speed_norm) & ...
speed < (max_speed – hys)]
[in(MultiFail)]
Shutdown
Running
H
Low_Emissions
entry: fuel_mode = LOW
H
Rich_Mixture
entry: fuel_mode = RICH
[in(FL1)]
Normal
Single_Failure
[in(FL0)]
[in(FL1)]
Warmup
[in(O2_normal)]
[!in(MultiFail)]
enter(MultiFail)
exit(MultiFail)


2
speed
25
hys
628
max_speed
speed_under_hys
Moving
toofast
1
Throt
min_throt
Throt_inrange
max_throt
3
Ego
Ego_inrange
4
press
Press_underthresh
min_press
max_press
Press_inrange
100ms clock
speed_under_hys
Moving
toofast
Throt_inrange
Press_underthresh
Ego_inrange
TSEC
Press_inrange
(clock)
syncblock
FAIL_O2
FAIL_PRESS
FAIL_THROT
FAIL_SPEED
fuel_mode_low
fuel_mode_rich
fuel_mode_disabled
Gain
Gain1
Add
1
fail_state
2
fuel_mode


O2_warmup
/ O2_cold, FAIL_O2
[48 TSEC]
Ego_inrange / FAIL_O2
O2_fail
Ego_inrange
O2_normal
Ego_inrange / FAIL_O2
Press_inrange / FAIL_PRESS
press_norm
press_fail
Press_inrange
Press_inrange / FAIL_PRESS
Throt_inrange / FAIL_THROT
throt_norm
throt_fail
Throt_inrange
Throt_inrange / FAIL_THROT
Moving . Press_underthresh / FAIL_SPEED
speed_norm
speed_fail
Moving
Moving / FAIL_SPEED
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / ZERO
ZERO . SINGLE / MULTI
O2_cold . gorich / fuel_mode_low
Warmup
O2_cold . SINGLE . gorich / fuel_mode_low
O2_cold . SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
SINGLE . gorich / fuel_mode_low
SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
Normal
Single_Failure
SINGLE . gorich / fuel_mode_low
SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
⟨fuel_mode_disabled⟩
FAIL_SPEED . speed_under_hys . MULTI
speed_under_hys / fuel_mode_disabled
Running
Overspeed
+ FAIL_SPEED / fuel_mode_disabled
toofast / fuel_mode_disabled
FAIL_SPEED . speed_under_hys . MULTI / fuel_mode_disabled
MULTI / go_rich
Shutdown
toofast . MULTI / fuel_mode_disabled
MULTI / fuel_mode_disabled
gorich
O2_cold, ZERO, SINGLE, MULTI


O2_warmup
/ O2_cold,
FAIL_O2
[48 TSEC]
Ego_inrange / FAIL_O2
O2_fail
Ego_inrange
O2_normal
Ego_inrange / FAIL_O2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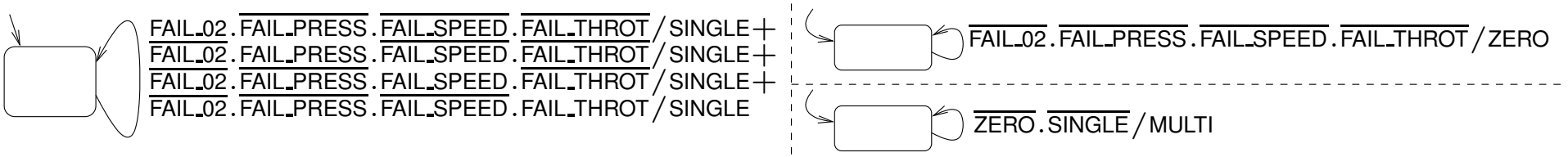
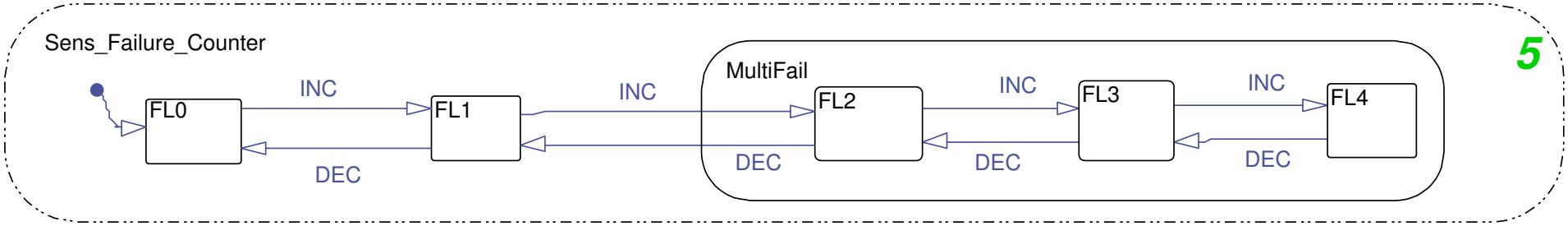
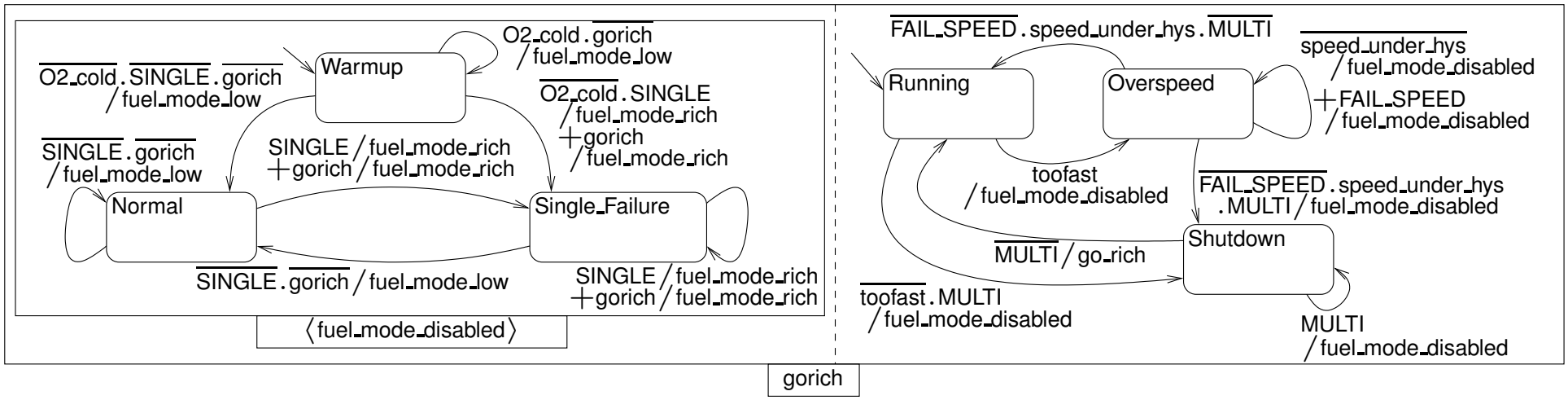
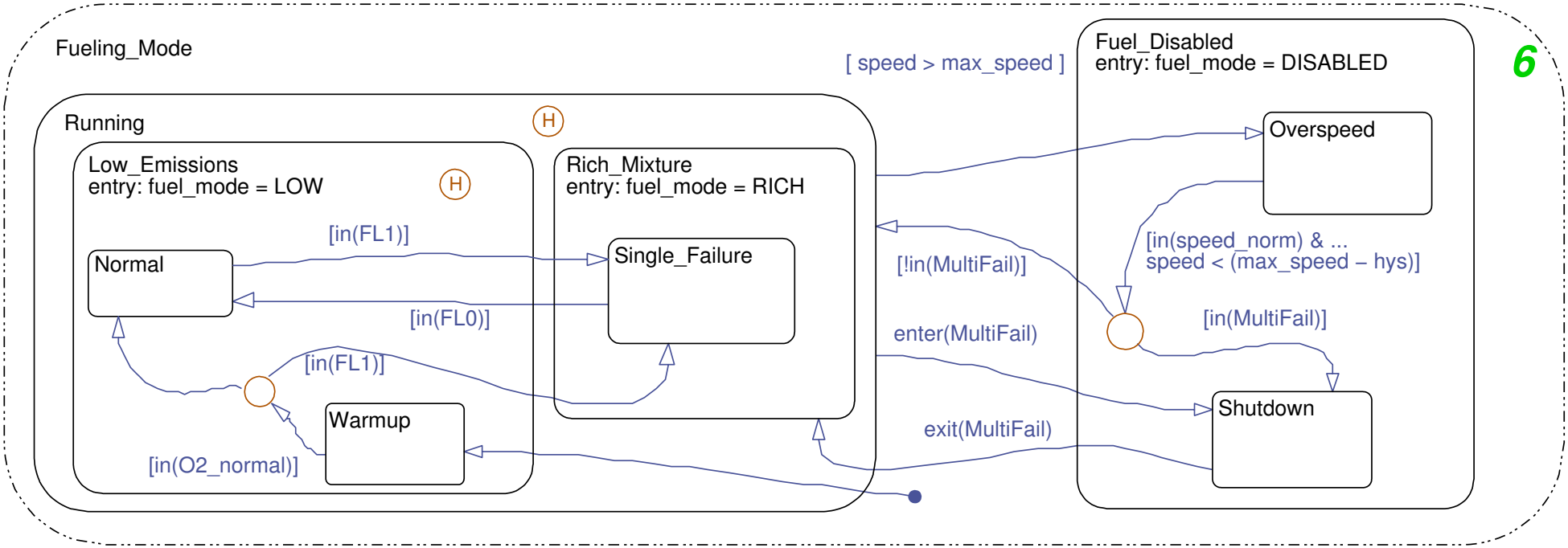
entry: fail_state[O2] = 1;
[Ego < max_ego] /
Sens_Failure_Counter.DEC
[t > o2_t_thresh]
[Ego > max_ego]/
Sens_Failure_Counter.INC
O2_normal
entry: fail_state[O2] = 0;


FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE +
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / SINGLE
FAIL_02 . FAIL_PRESS . FAIL_SPEED . FAIL_THROT / ZERO
ZERO . SINGLE / MULTI


Sens_Failure_Counter
5
FL0
FL1
FL2
FL3
FL4
MultiFail
INC
INC
INC
INC
DEC
DEC
DEC
DEC


Warmup
O2_cold . gorich / fuel_mode_low
O2_cold . SINGLE . gorich / fuel_mode_low
O2_cold . SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
SINGLE . gorich / fuel_mode_low
SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
Normal
Single_Failure
SINGLE . gorich / fuel_mode_low
SINGLE / fuel_mode_rich + gorich / fuel_mode_rich
⟨fuel_mode_disabled⟩
FAIL_SPEED . speed_under_hys . MULTI
Running
Overspeed
speed_under_hys / fuel_mode_disabled
+ FAIL_SPEED / fuel_mode_disabled
toofast / fuel_mode_disabled
FAIL_SPEED . speed_under_hys . MULTI / fuel_mode_disabled
MULTI / go_rich
Shutdown
toofast . MULTI / fuel_mode_disabled
MULTI / fuel_mode_disabled
gorich


Fueling_Mode
[ speed > max_speed ]
Fuel_Disabled
entry: fuel_mode = DISABLED
6
Running
H
Low_Emissions
entry: fuel_mode = LOW
H
Rich_Mixture
entry: fuel_mode = RICH
Overspeed
[in(FL1)]
Normal
Single_Failure
[in(FL0)]
[in(FL1)]
Warmup
[in(O2_normal)]
[!in(MultiFail)]
enter(MultiFail)
exit(MultiFail)
[in(speed_norm) & ...
speed < (max_speed – hys)]
[in(MultiFail)]
Shutdown

## Summary

- Stateflow is powerful but has shortcomings
- Existing research might help
- Argos block developed:
  - contrast with Stateflow
  - simple examples possible
  - paucity of features has pros and cons

**Need the right tool for the task at hand.**

# References


[CCM+03] Paul Caspi, Adrian Curic, Aude Maignan, Christos Sofronis, Stavros Tripakis, and Peter Niebert. From Simulink to SCADE/Lustre to TTA: a layered approach for distributed embedded applications. In *Proc. 2003 ACM SIGPLAN conference on Languages, Compilers, and Tools for Embedded Systems (LCTES '03)*, pages 153–162. ACM Press, 2003.

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[MH96] F. Maraninchi and N. Halbwachs. Compiling Argos into boolean equations. In Bengt Jonsson and Joachim Parrow, editors, *Proc. 4th International Symposium on Formal Techniques for Real-Time and Fault-Tolerance (FTRTFT '96)*, volume 1135 of *Lecture Notes in Computer Science*, pages 72–89, Uppsala, Sweden, September 1996. Springer-Verlag.

[MR01] Florence Maraninchi and Yann Rémond. Argos: an automaton-based synchronous

language. *Computer Languages*, 27(1–3):61–92, 2001.

[SSC+04] N. Scaife, C. Sofronis, P. Caspi, S. Tripakis, and F. Maraninchi. Defining and translating a "safe" subset of Simulink/Stateflow into Lustre. In G. Buttazzo and S. Edwards, editors, *Proc. 4th ACM International Conference on Embedded Software (EMSOFT'04)*, pages 259 – 268, Pisa, Italy, September 2004. ACM, ACM Press.