

Automatic Device Driver Synthesis with Termite

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UNSW, NICTA, Open Kernel Labs (Australia),

John Keys, Intel

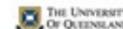


Australian Government
Department of Broadband, Communications
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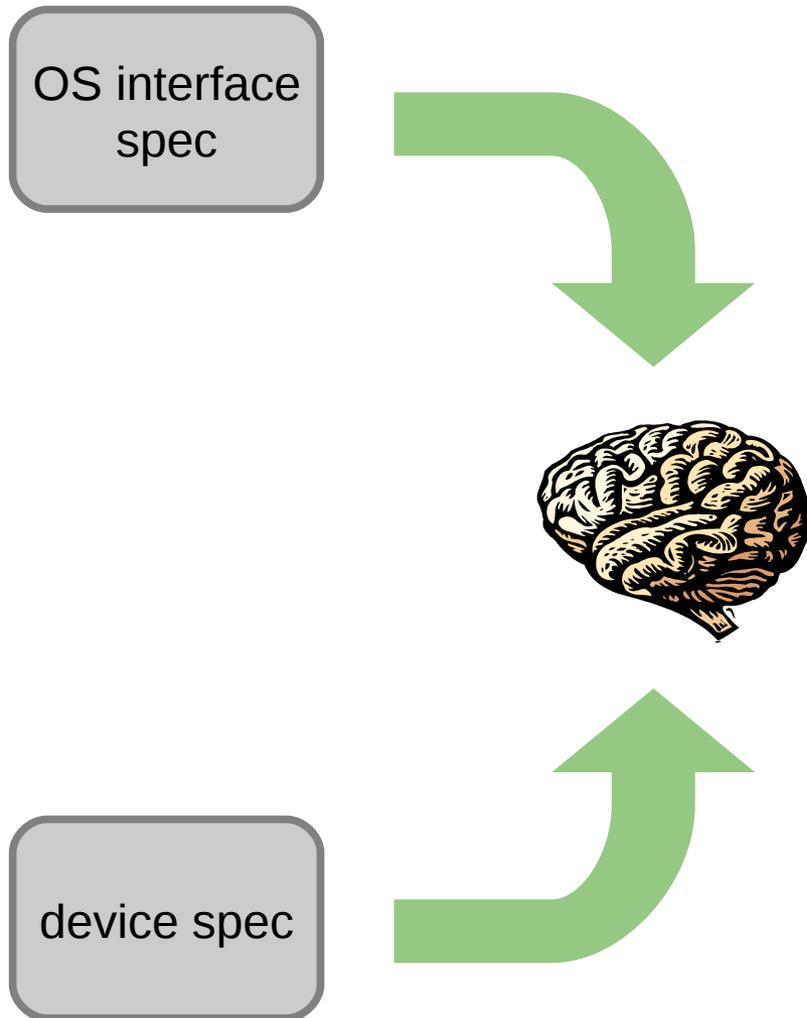
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Conventional driver development

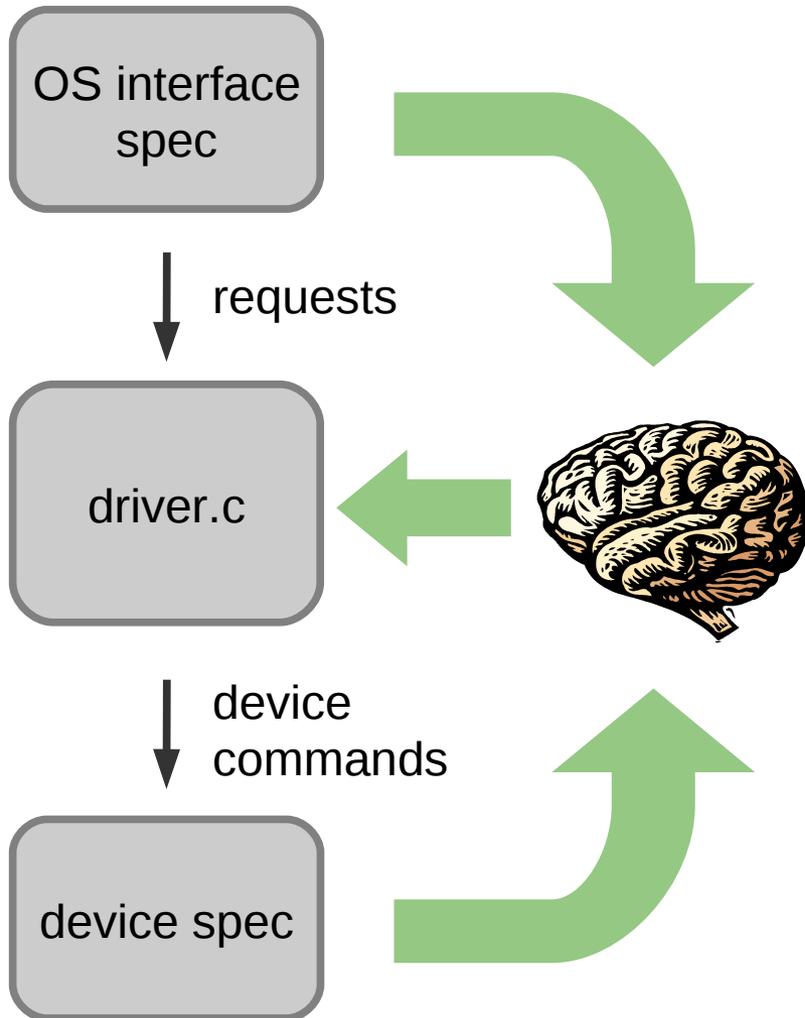
OS interface
spec

device spec

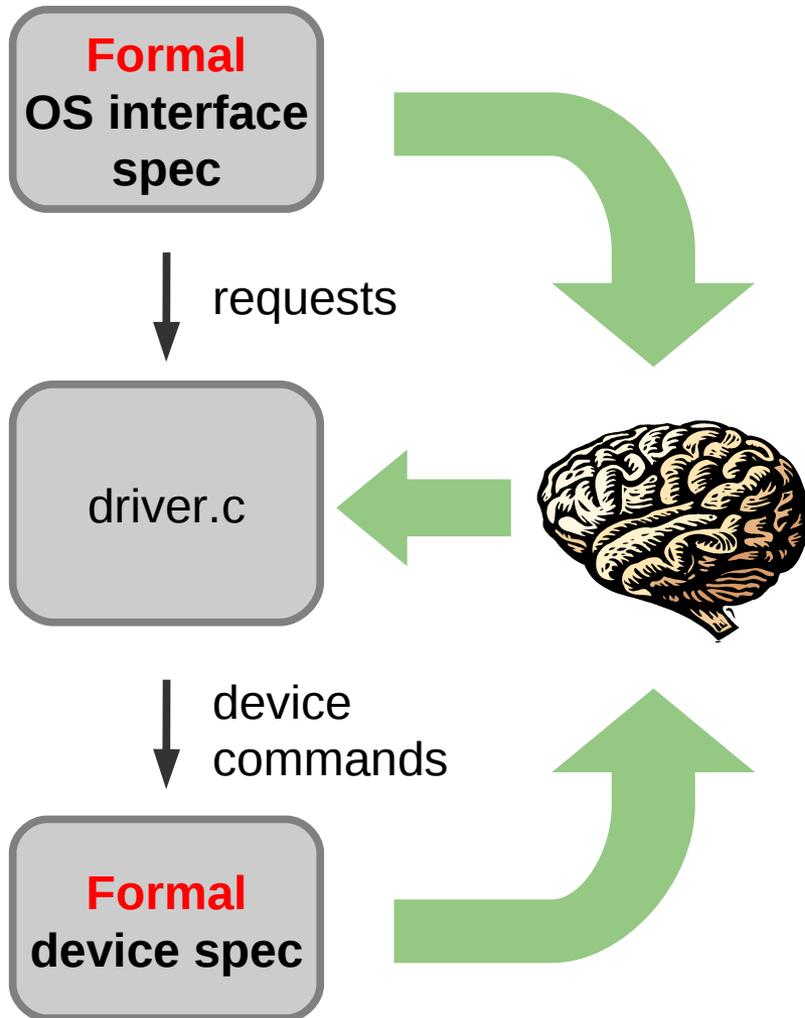
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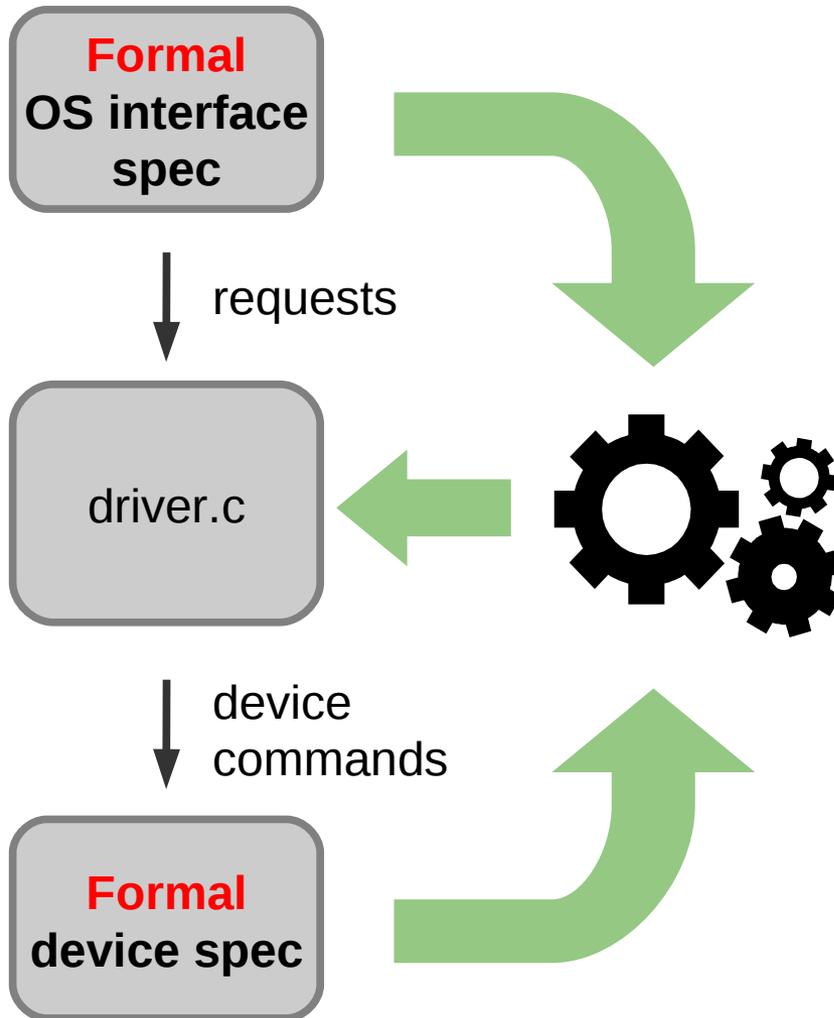
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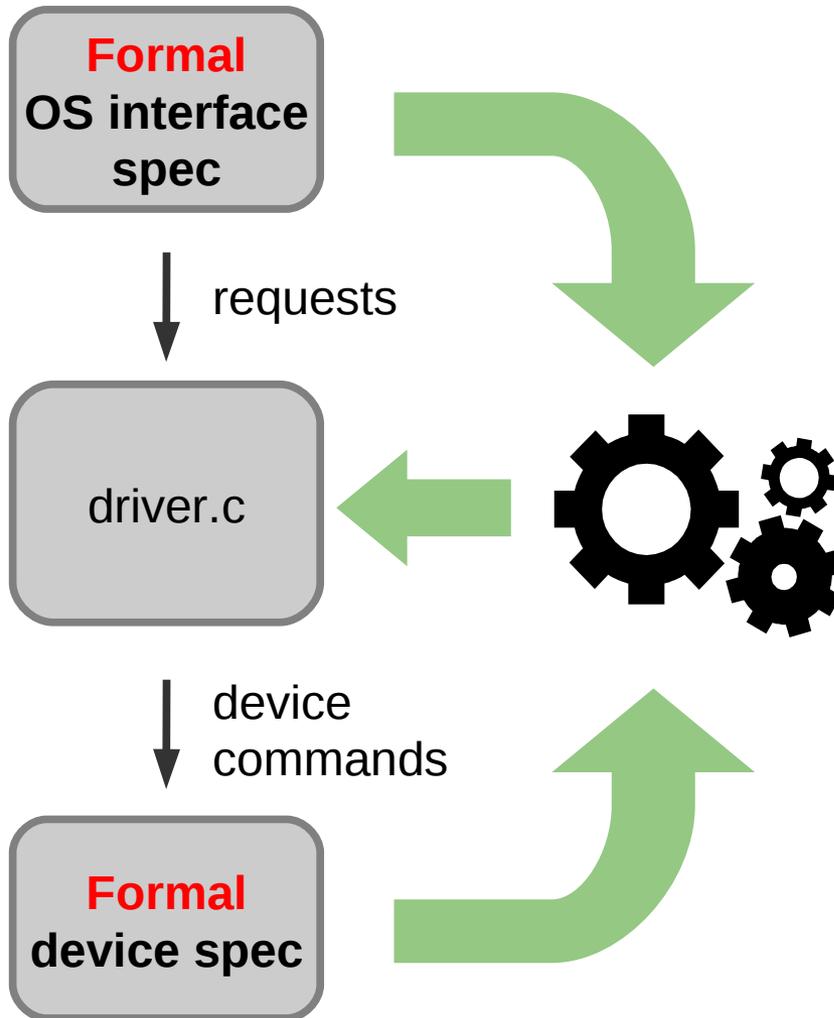
Driver synthesis: high-level view



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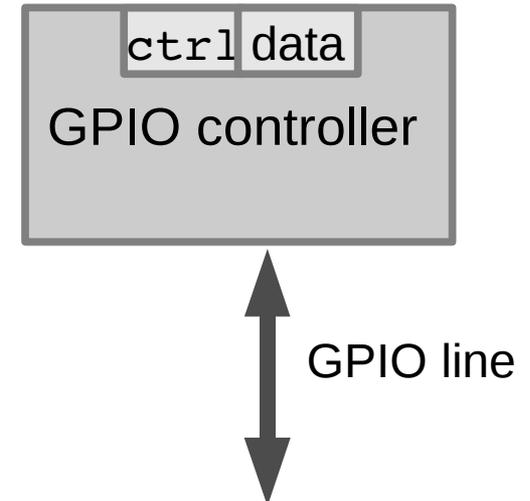
Advantages

- Separation of concerns
 - Know one thing well
- Reuse
 - Specify once, synthesise many

Driver synthesis by example

Formal
OS interface
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Formal
device spec



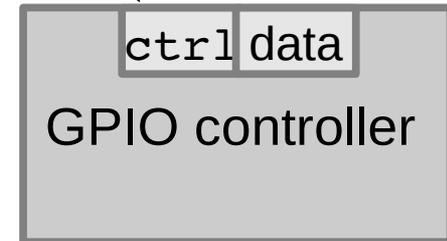
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GPIO controller registers

ctrl	data
0=off	0=low
1=on	1=high



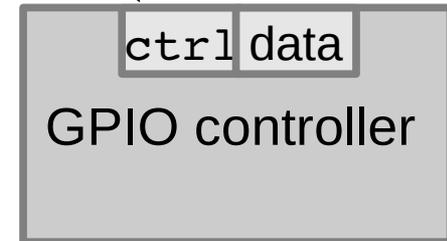
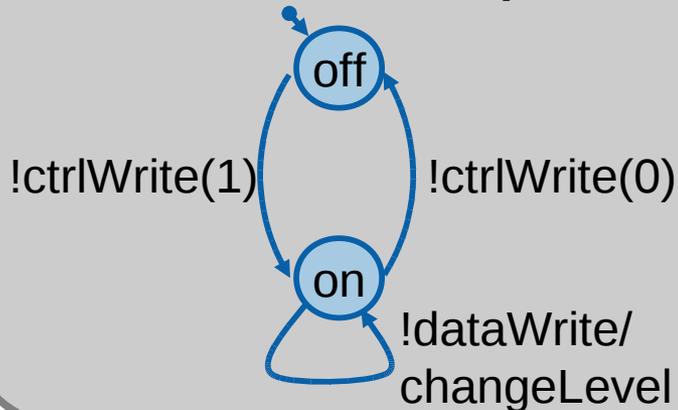
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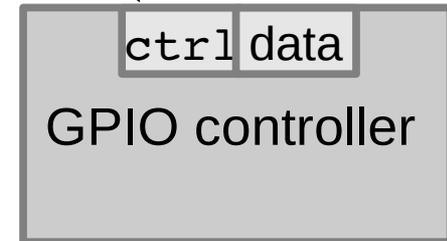
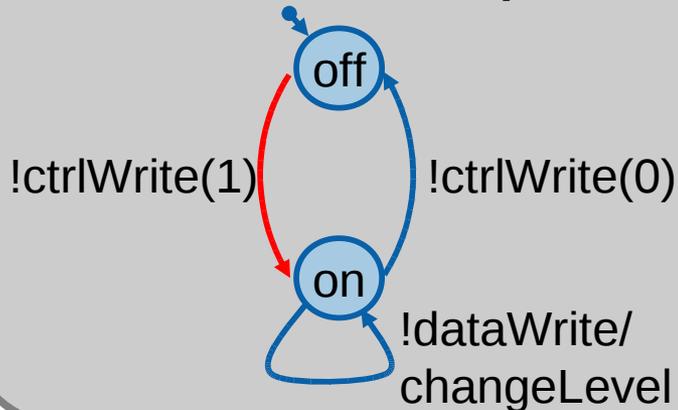
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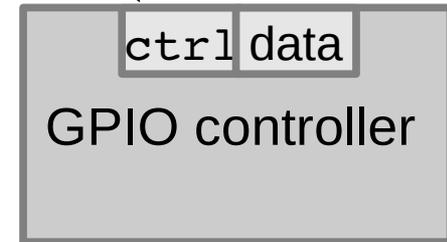
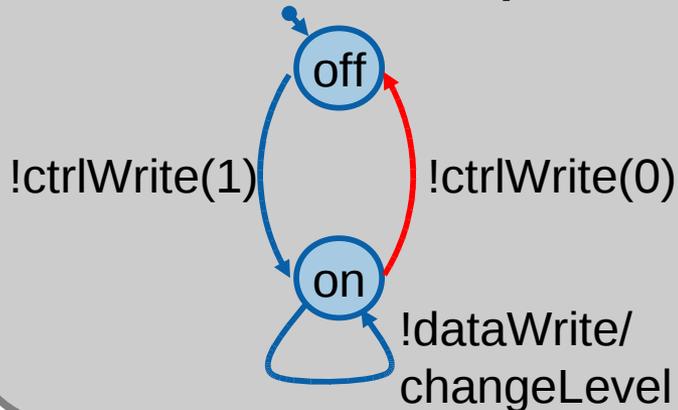
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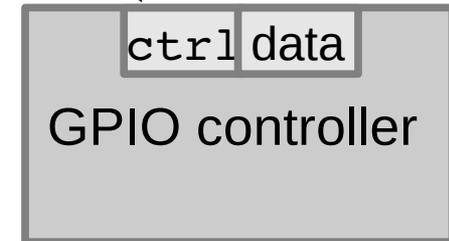
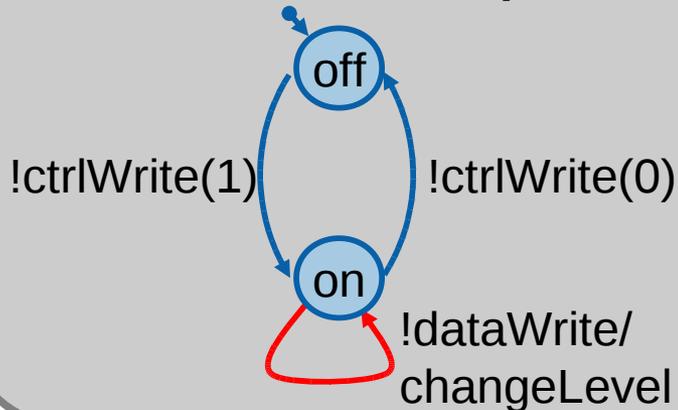
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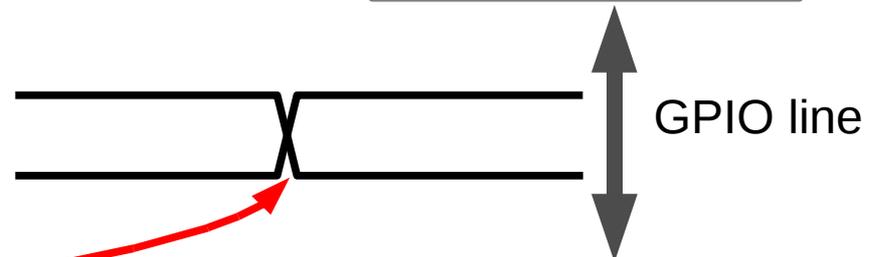
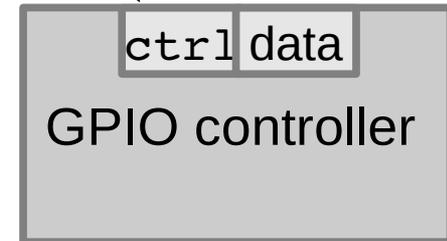
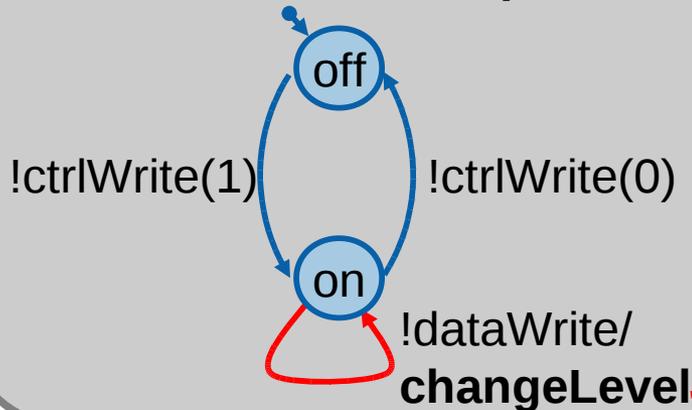
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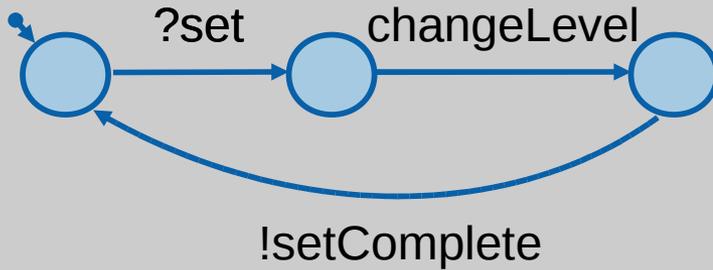
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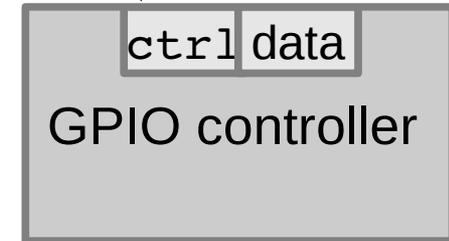
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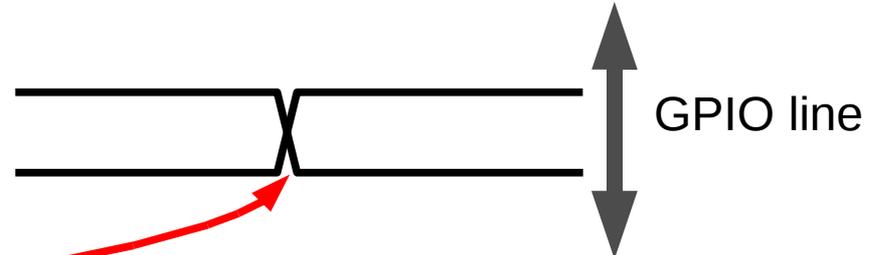
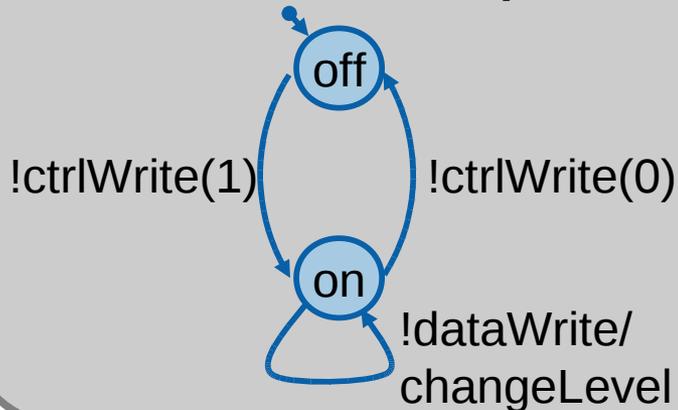


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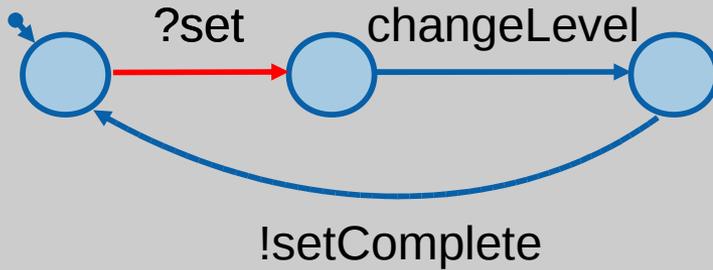


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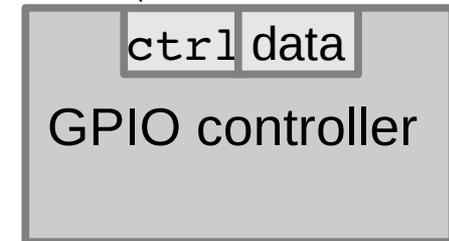
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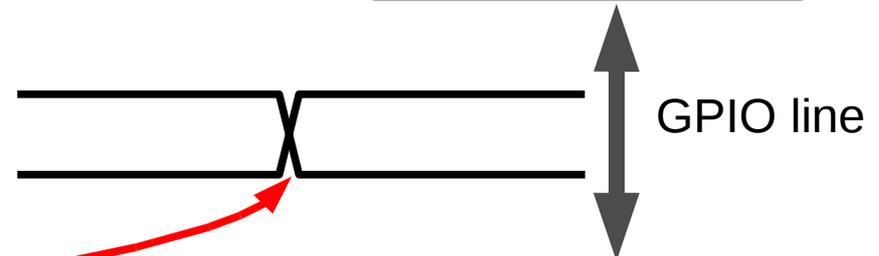
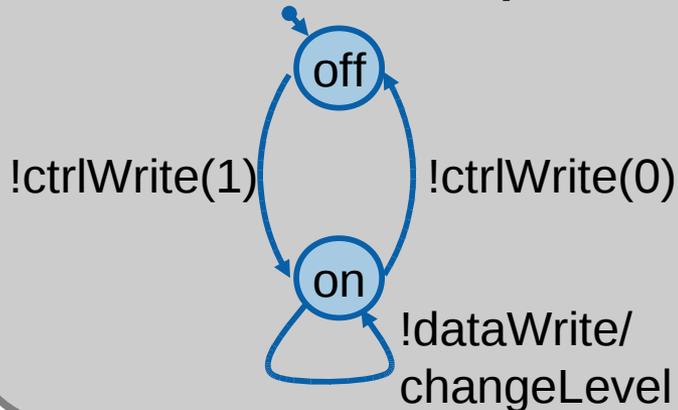


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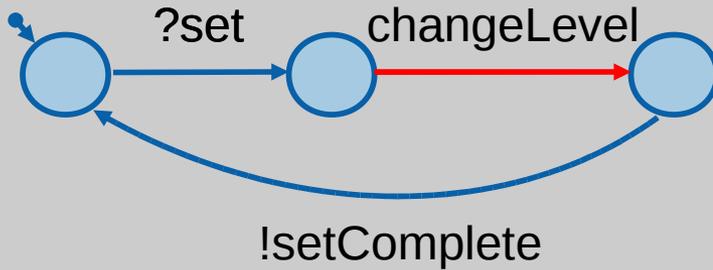


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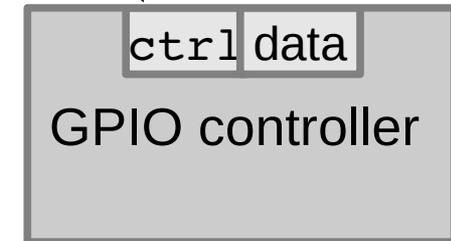
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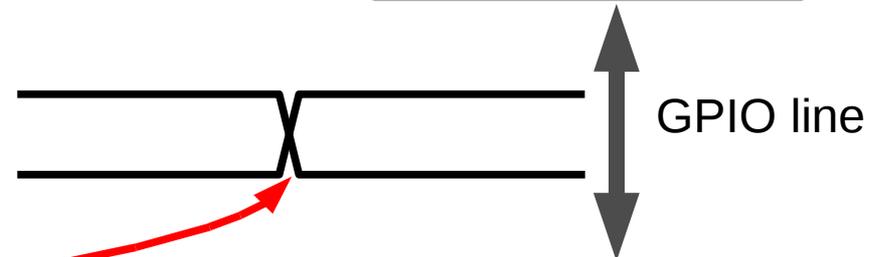
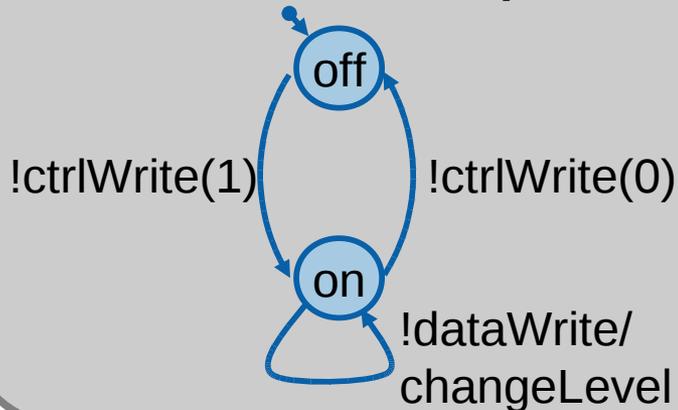


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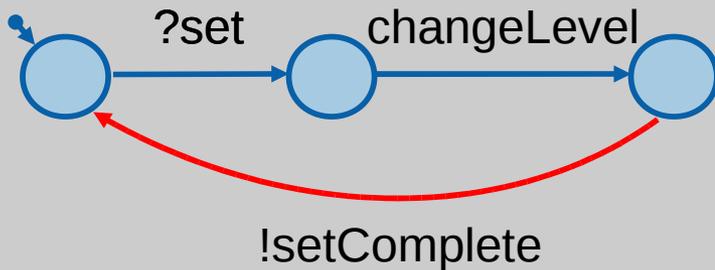


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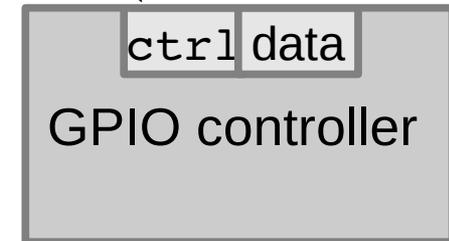
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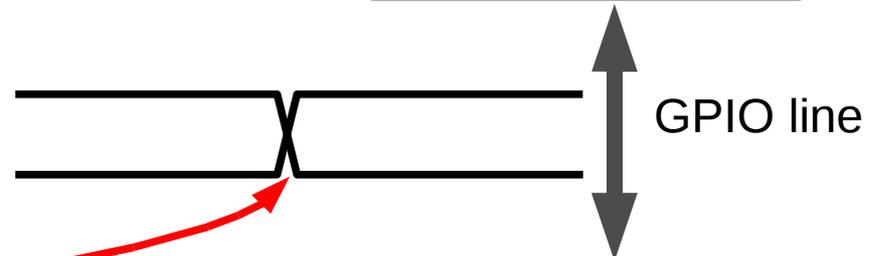
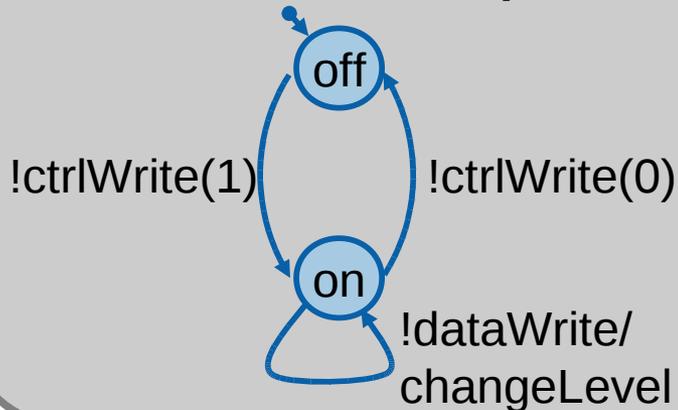


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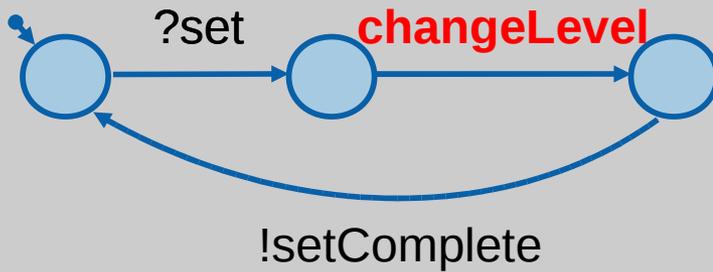


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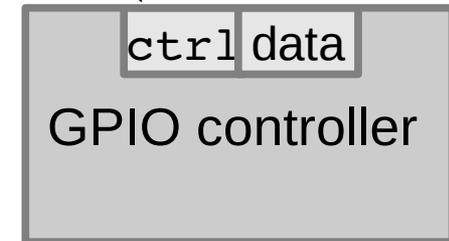
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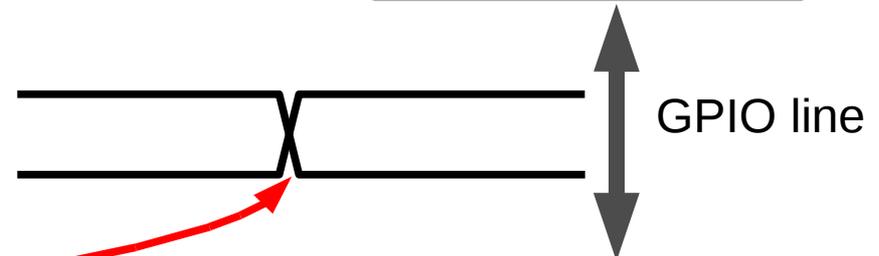
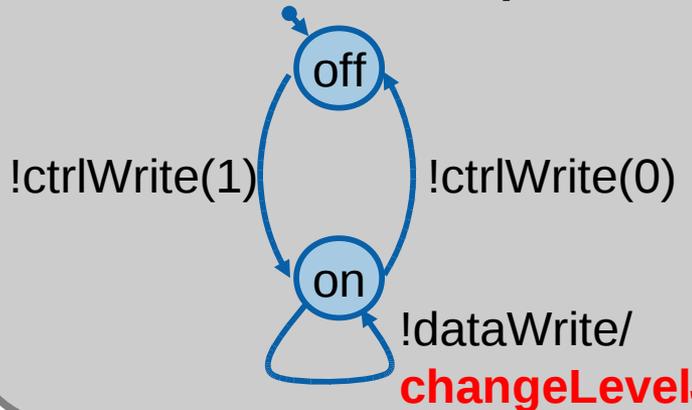


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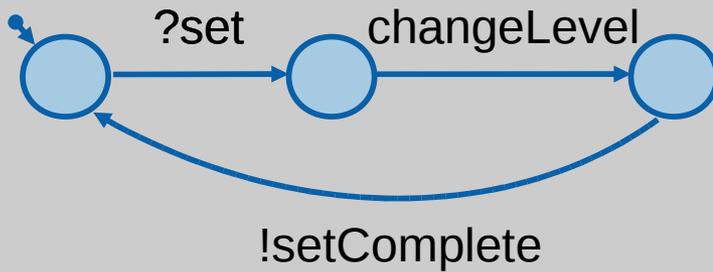


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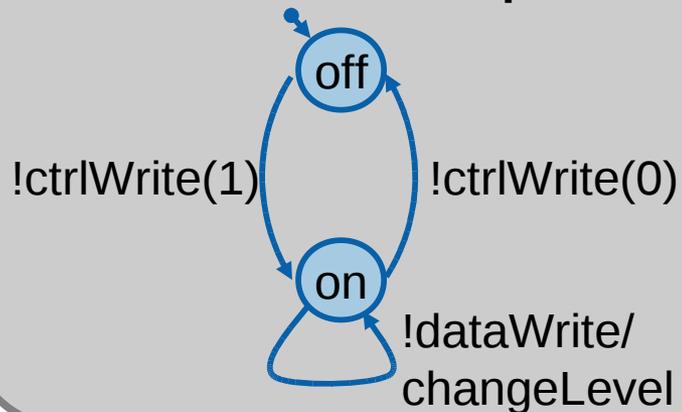


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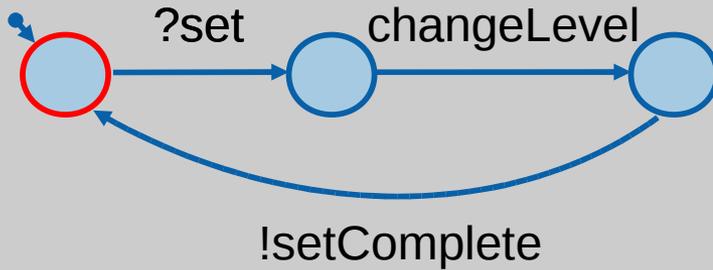


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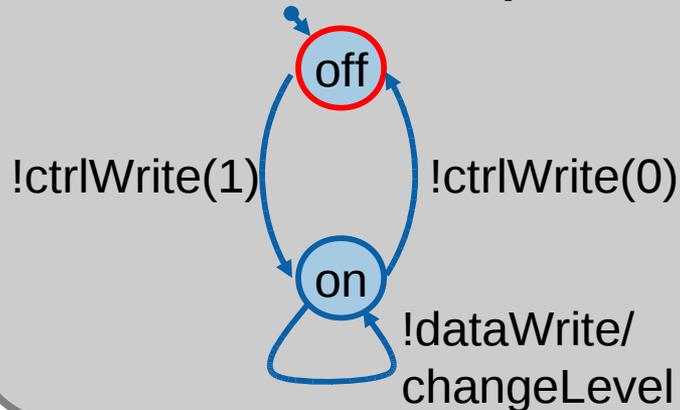
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OS spec || Device spec

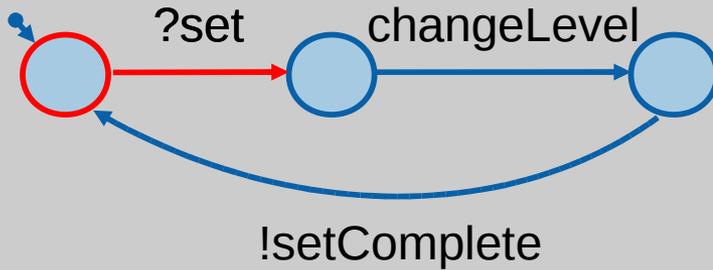


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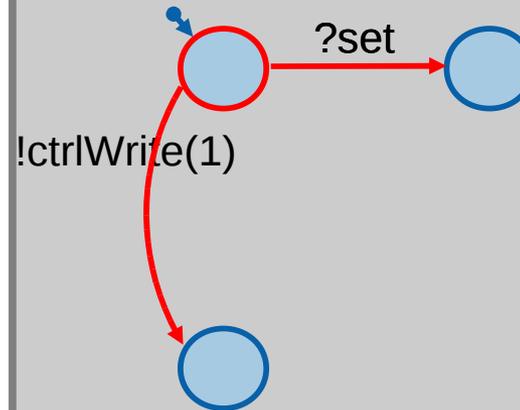


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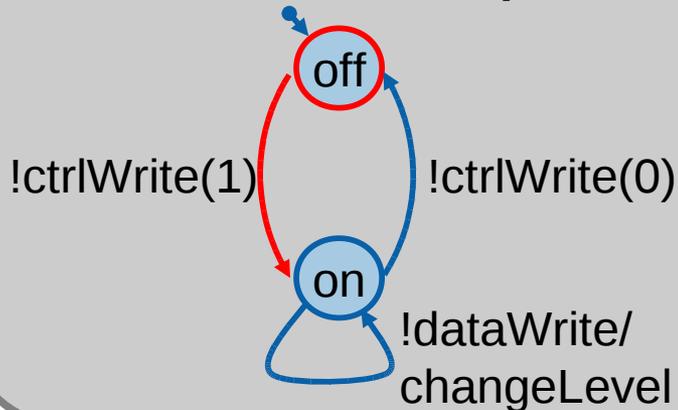
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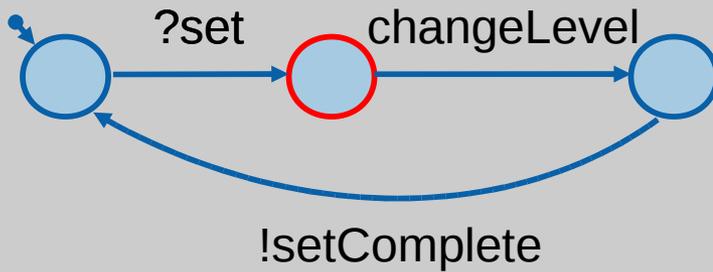


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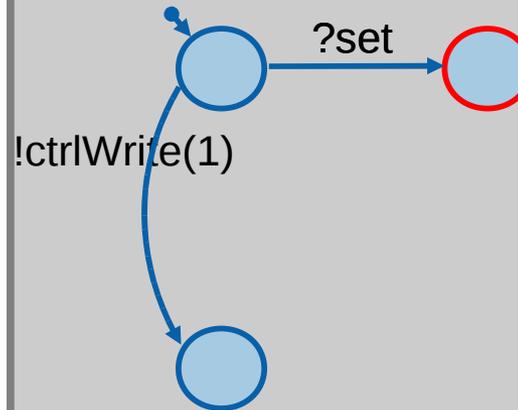


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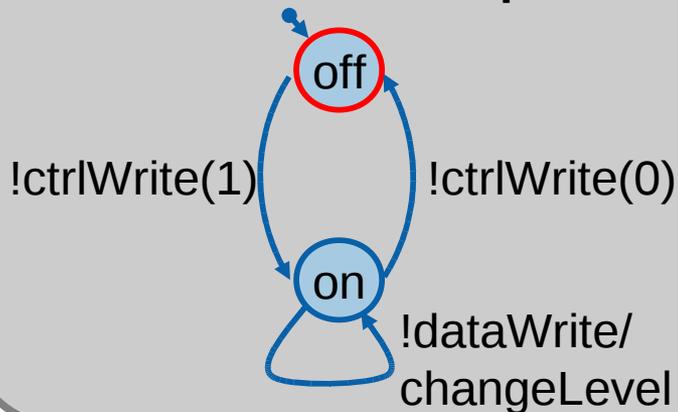
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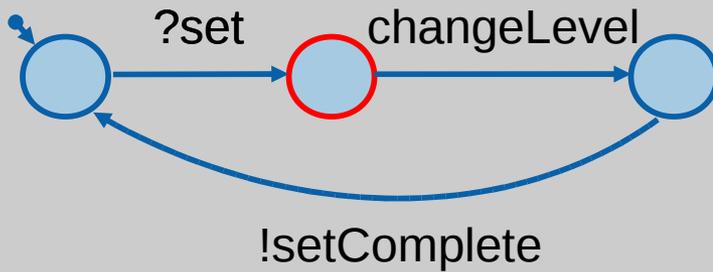


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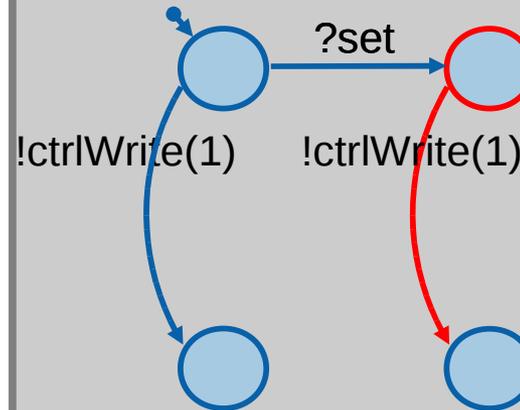


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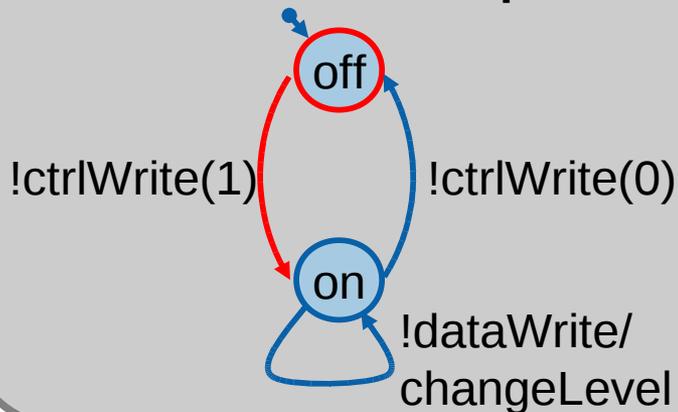
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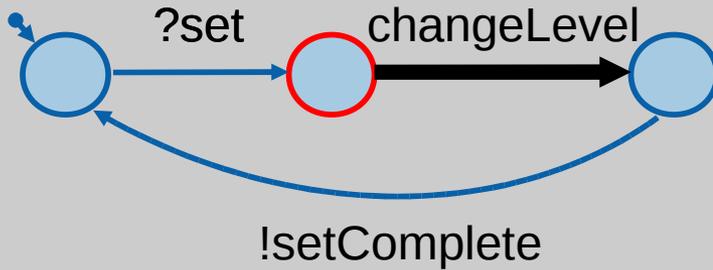


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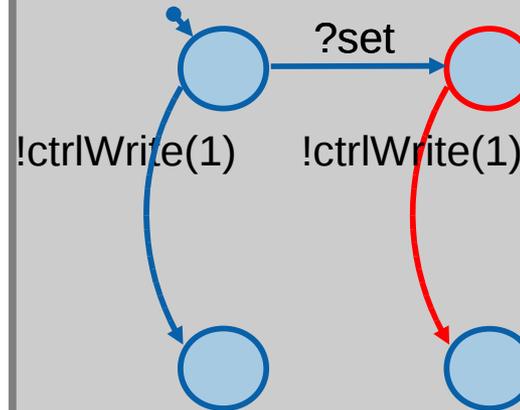


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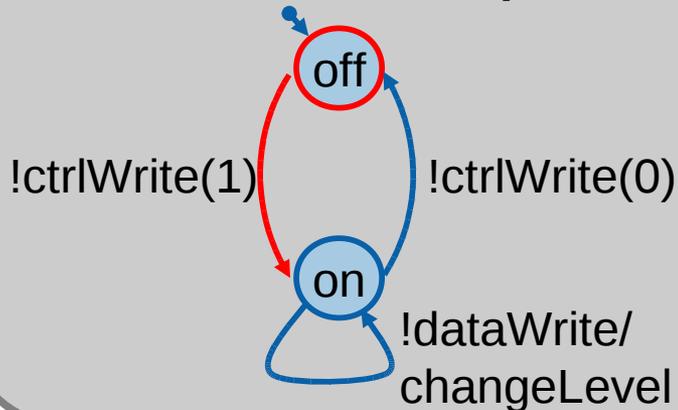
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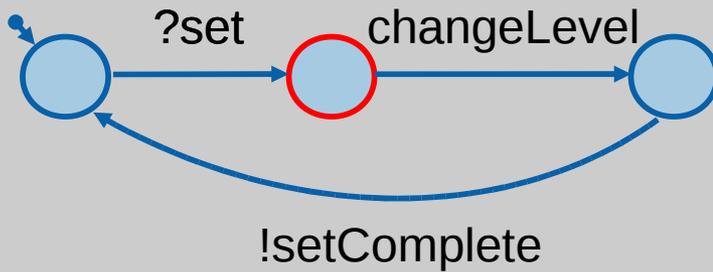


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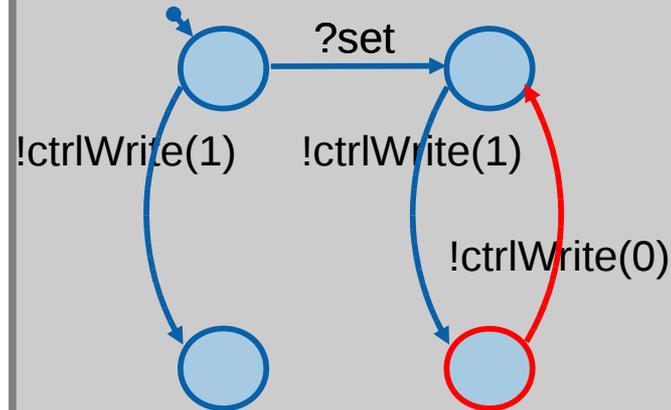


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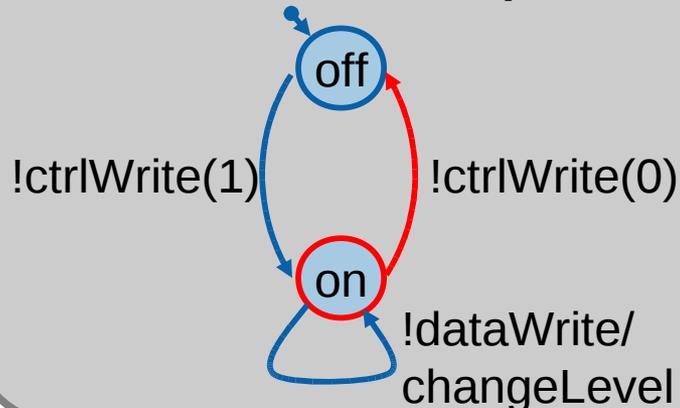
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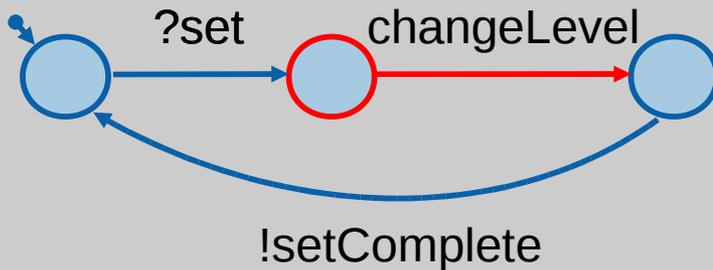


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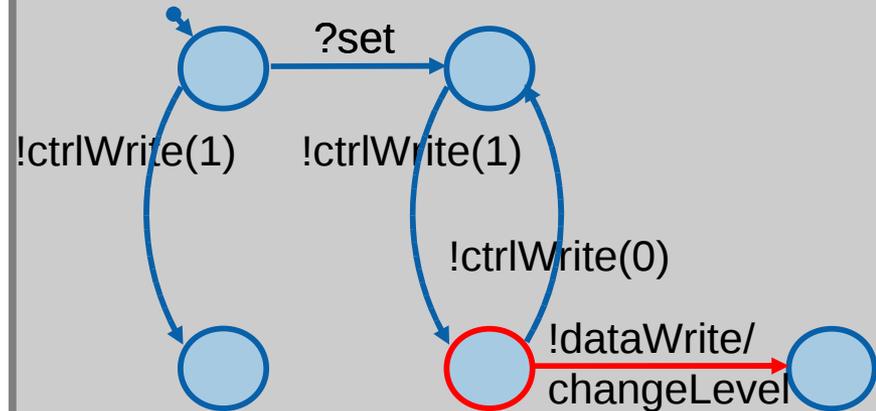


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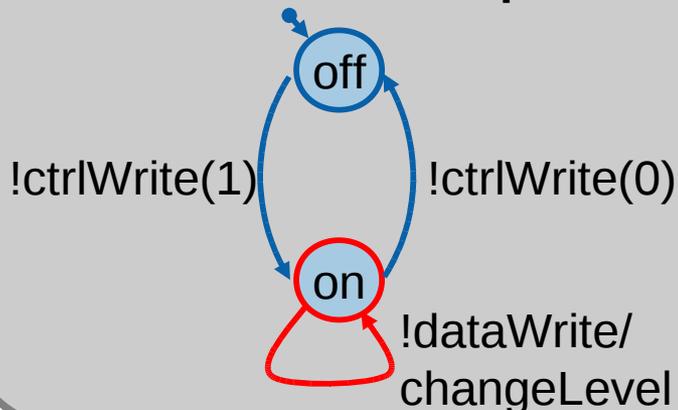
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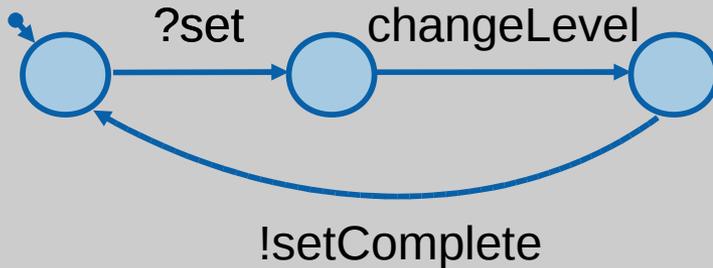


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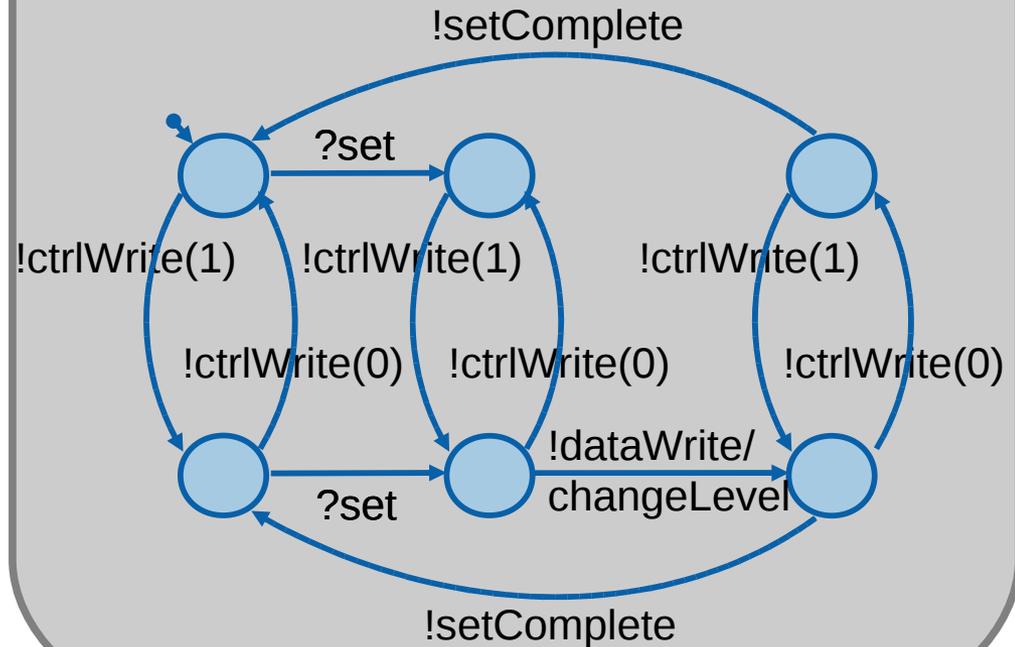


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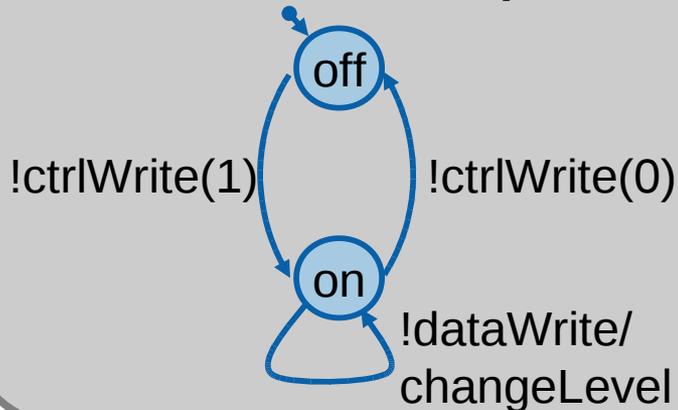
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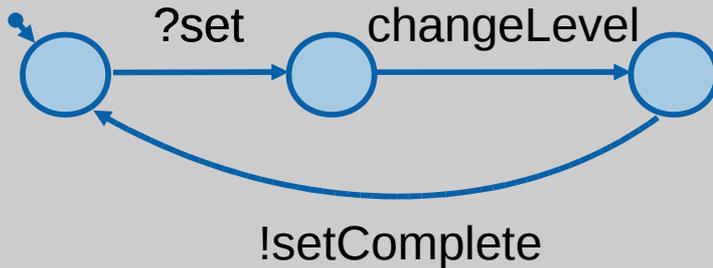


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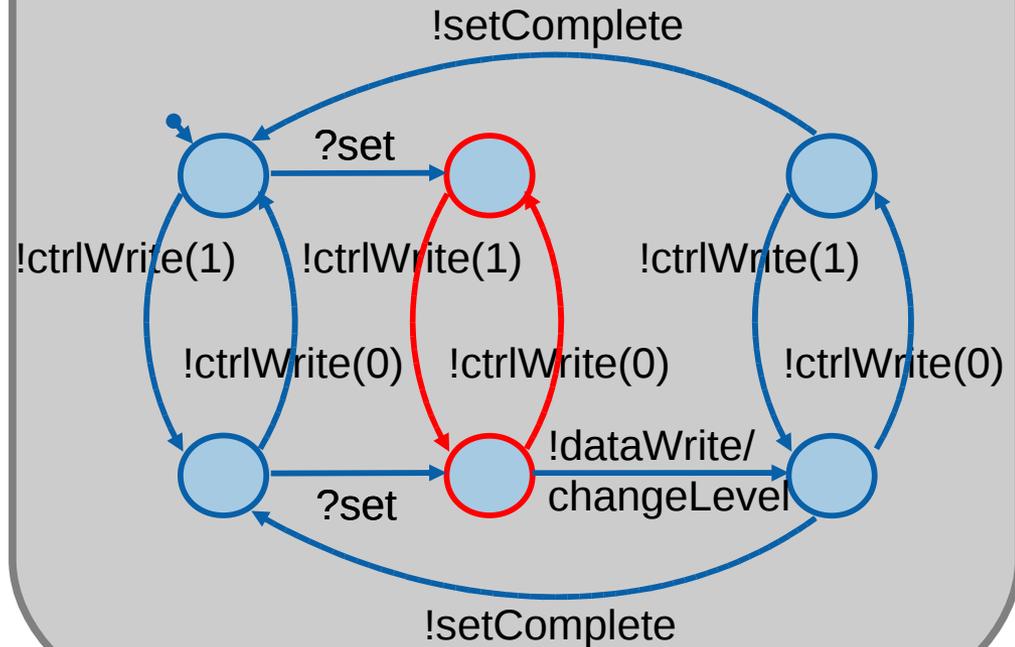


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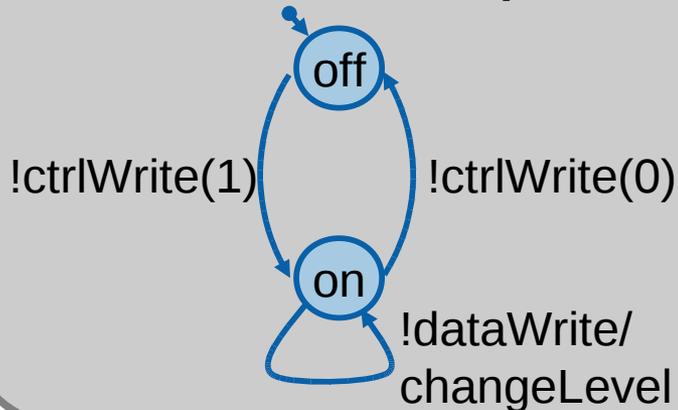
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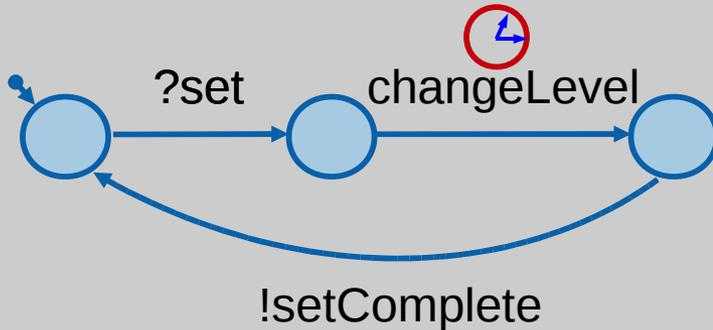


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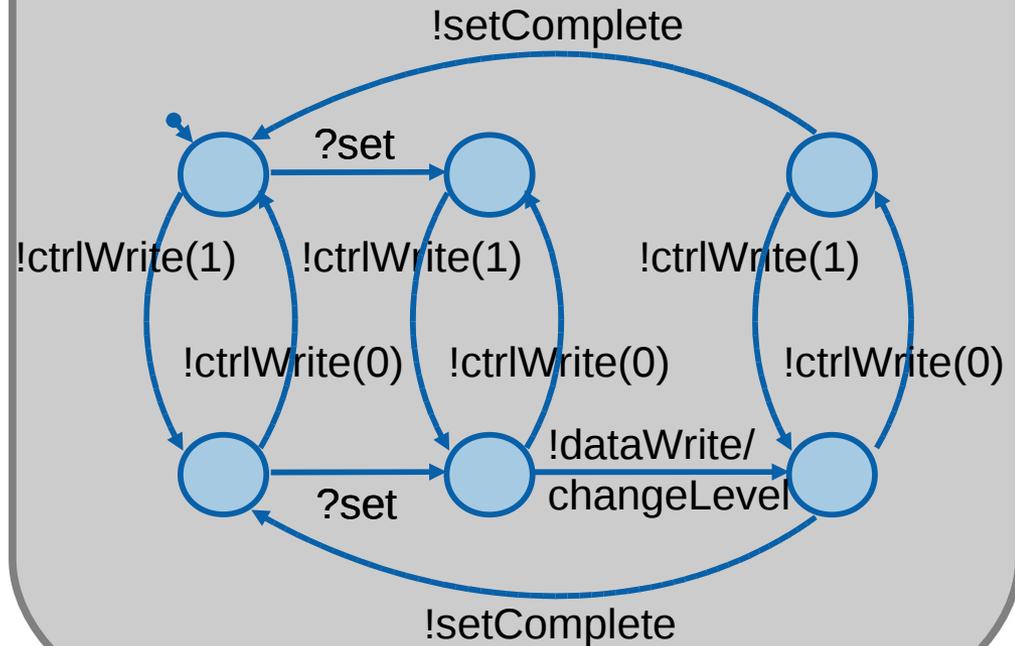


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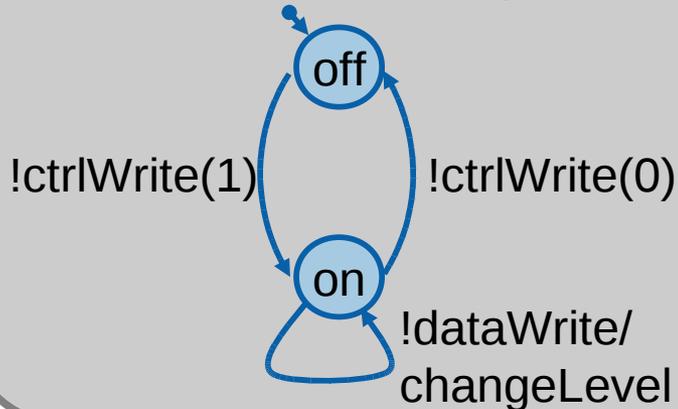
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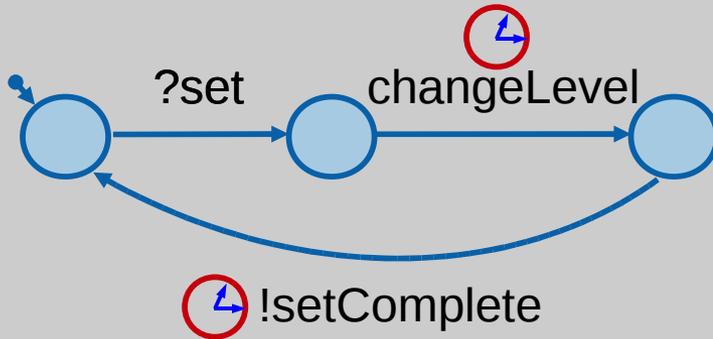


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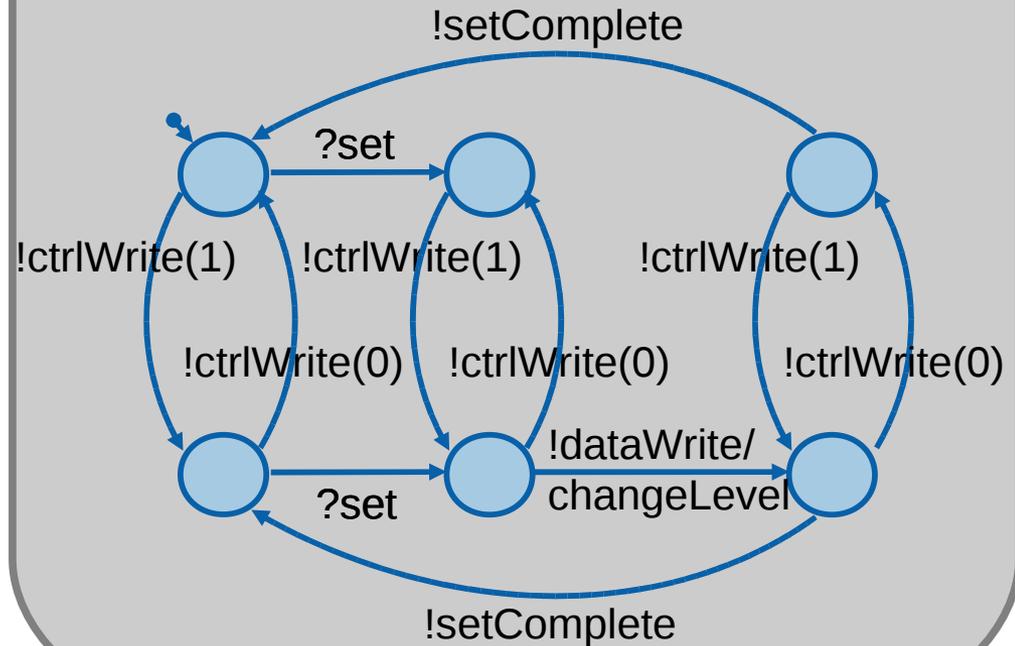


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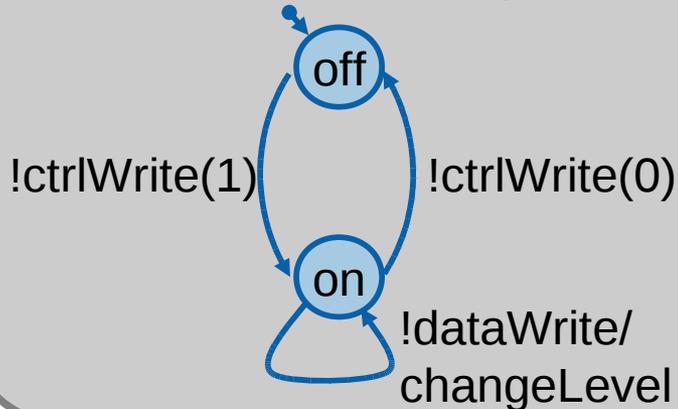
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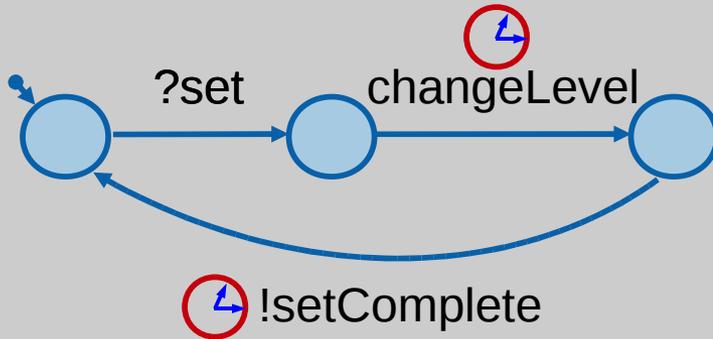


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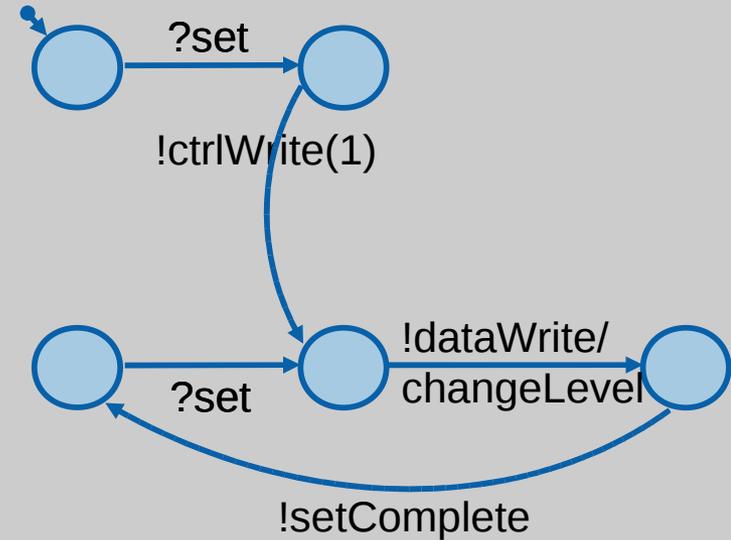


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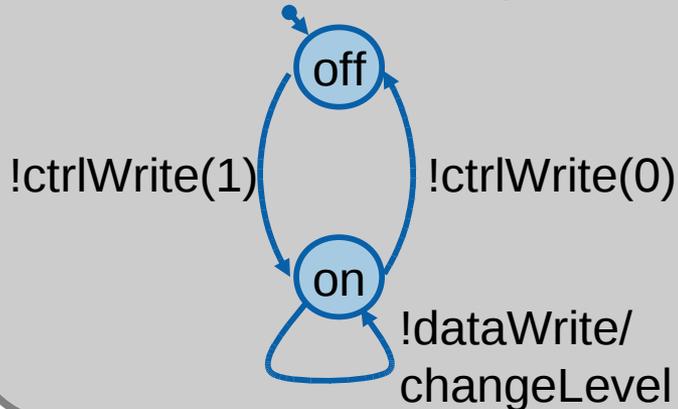
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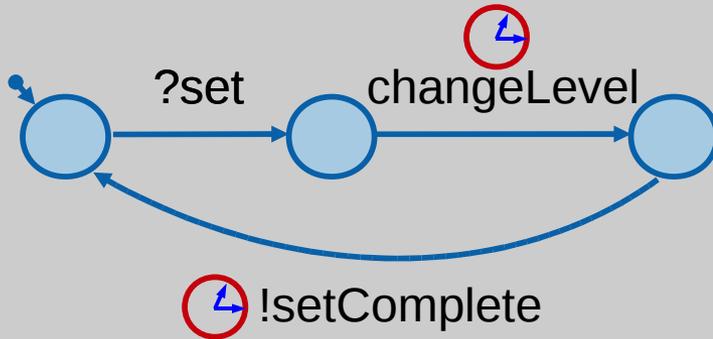


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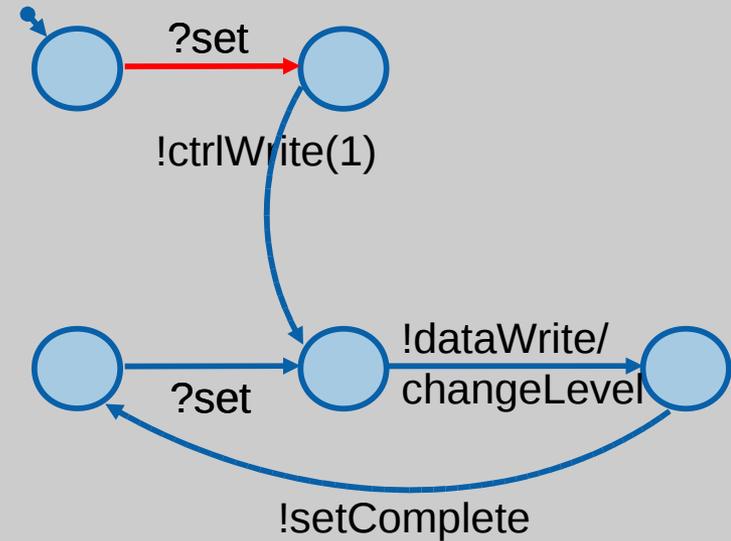


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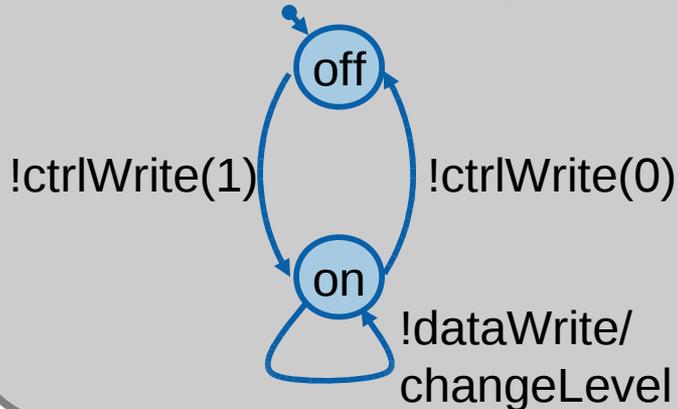
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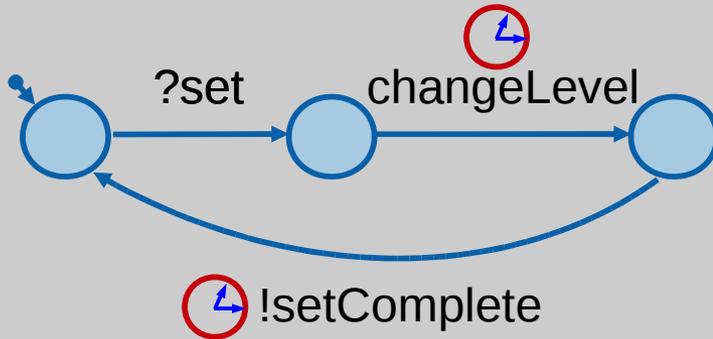


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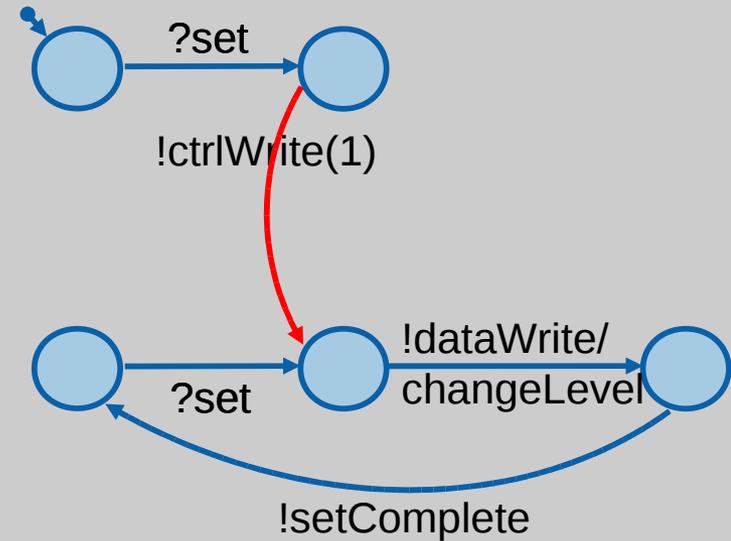


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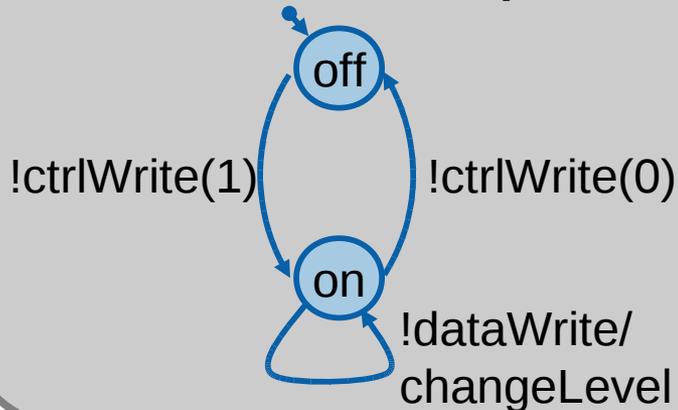
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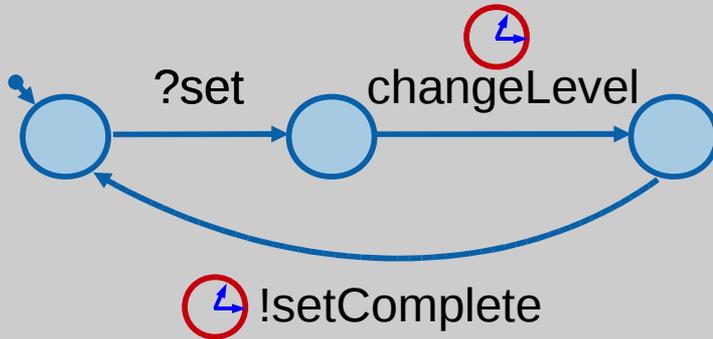


Formal device spec

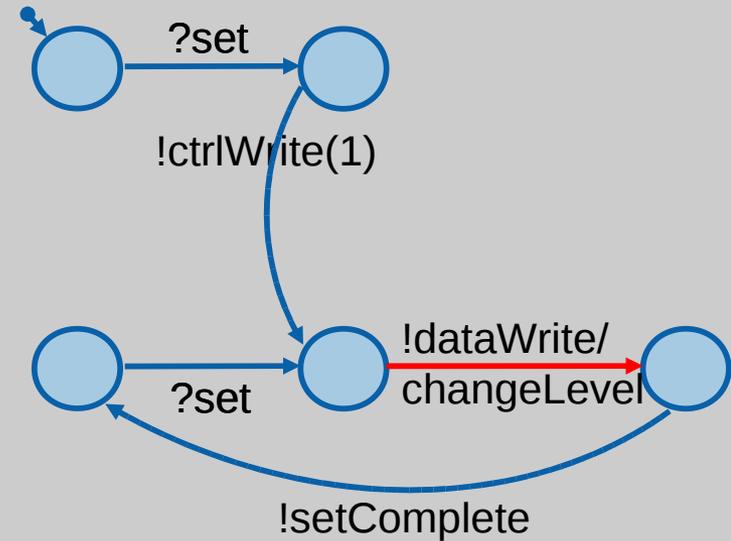


Driver synthesis by example

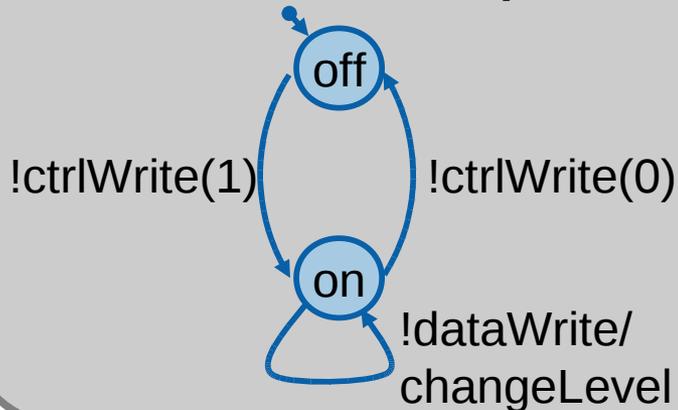
Formal OS interface spec



OS spec || Device spec

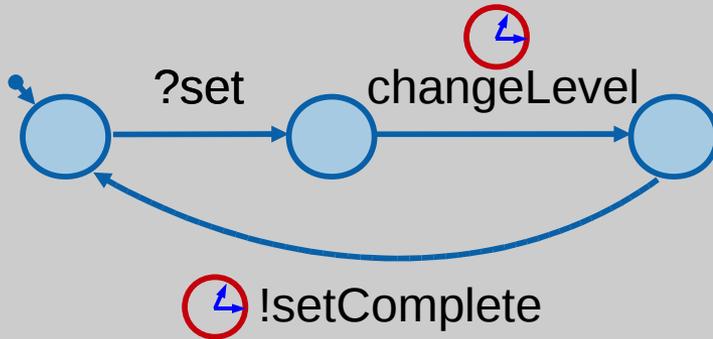


Formal device spec

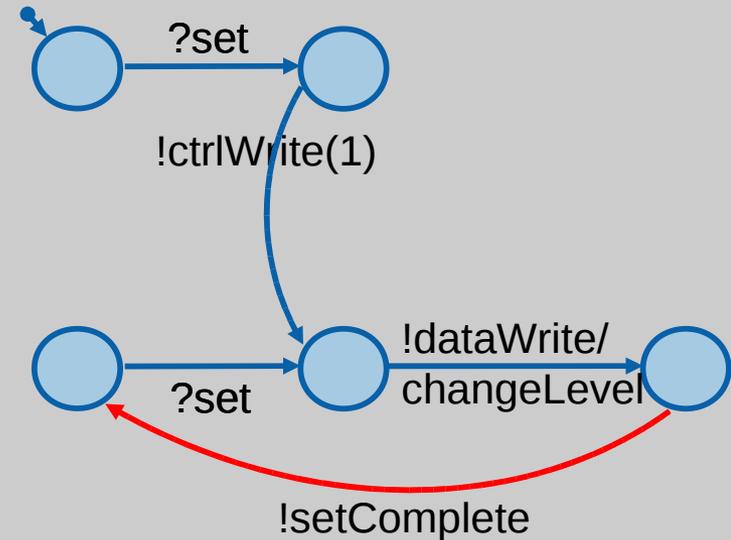


Driver synthesis by example

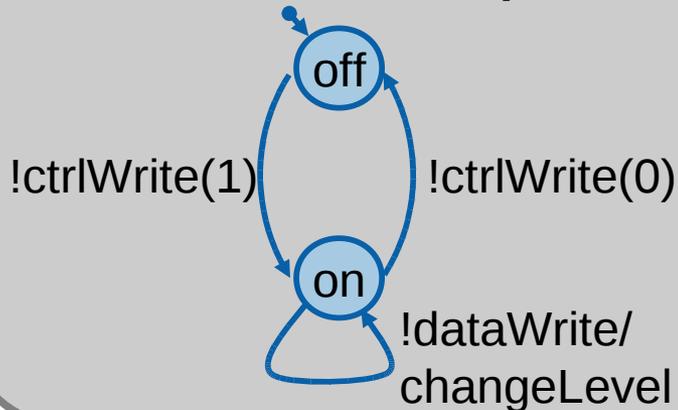
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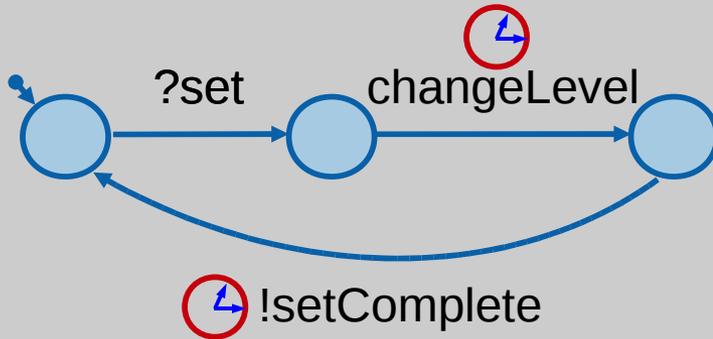


Formal device spec

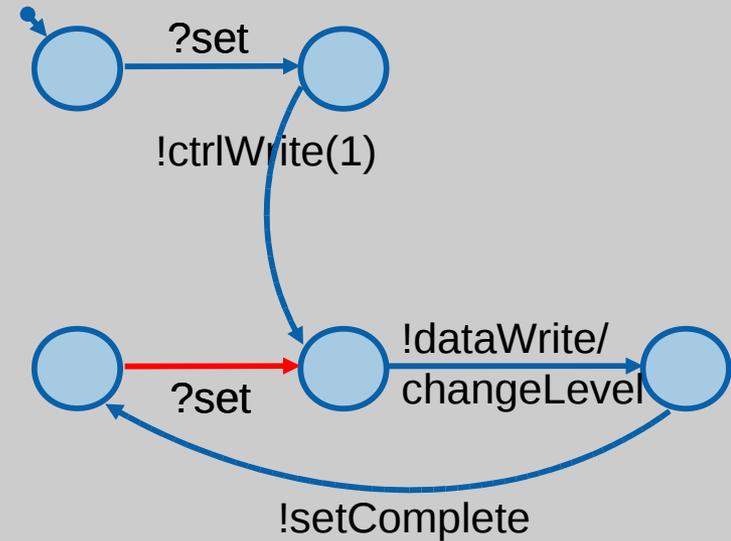


Driver synthesis by example

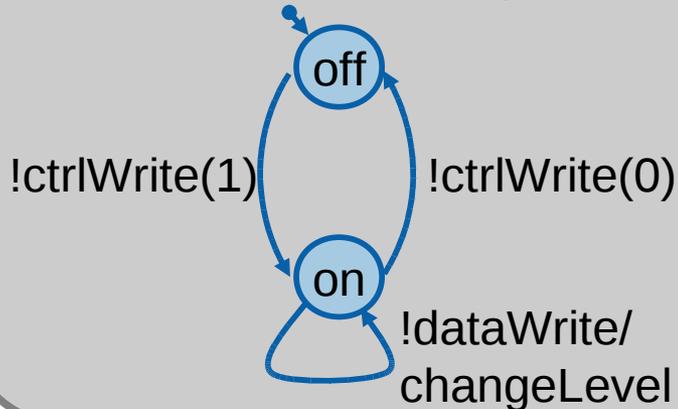
Formal OS interface spec



OS spec || Device spec

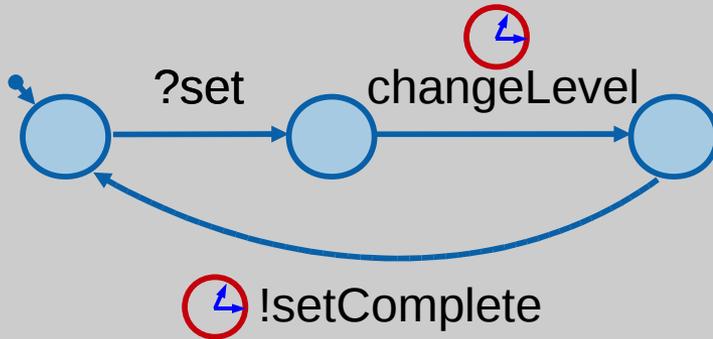


Formal device spec

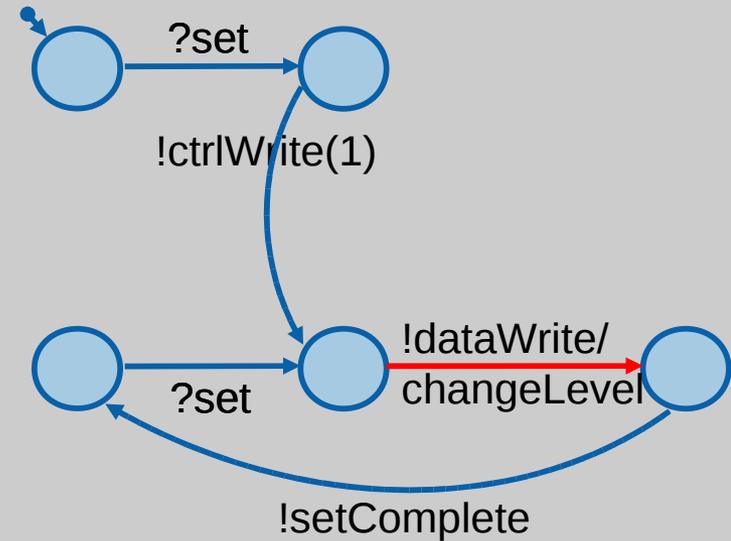


Driver synthesis by example

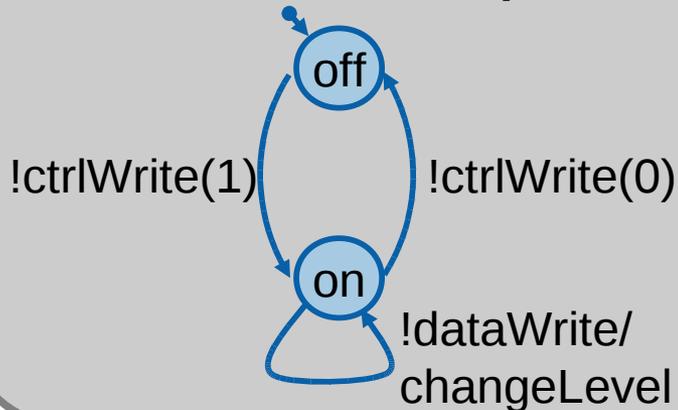
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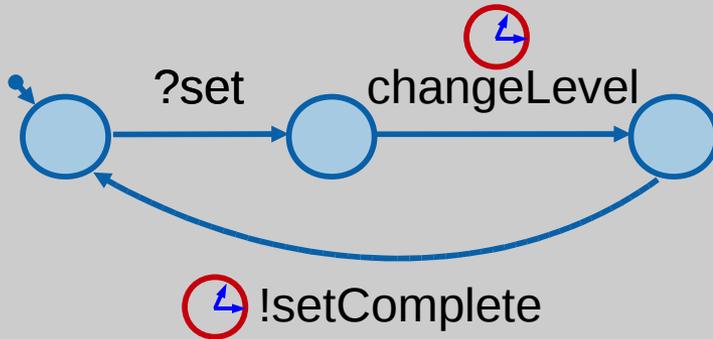


Formal device spec

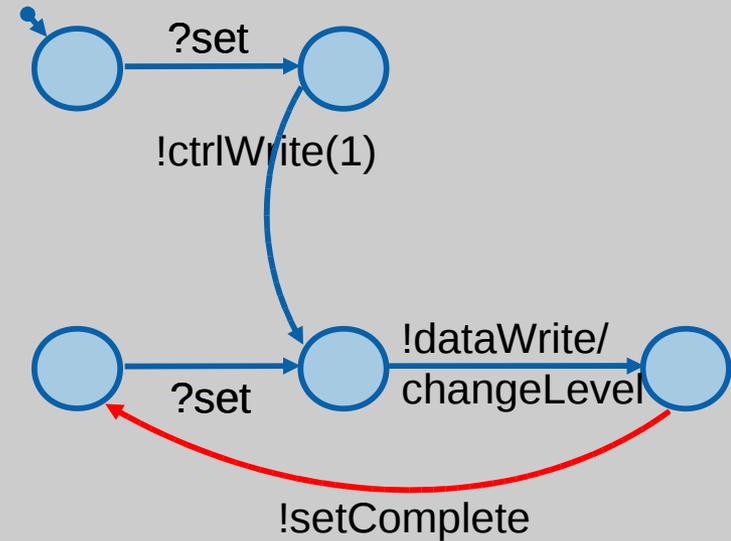


Driver synthesis by example

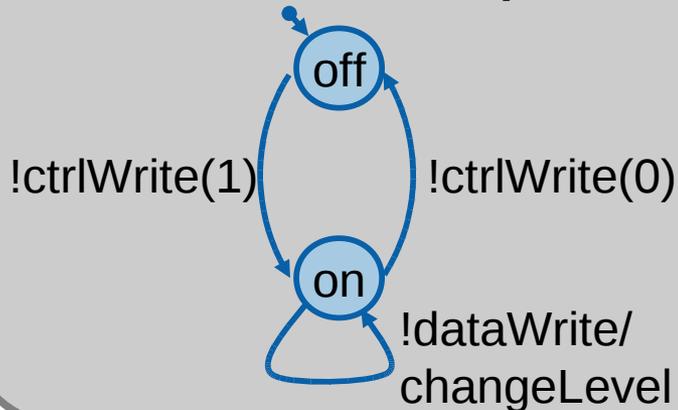
Formal OS interface spec



OS spec || Device spec



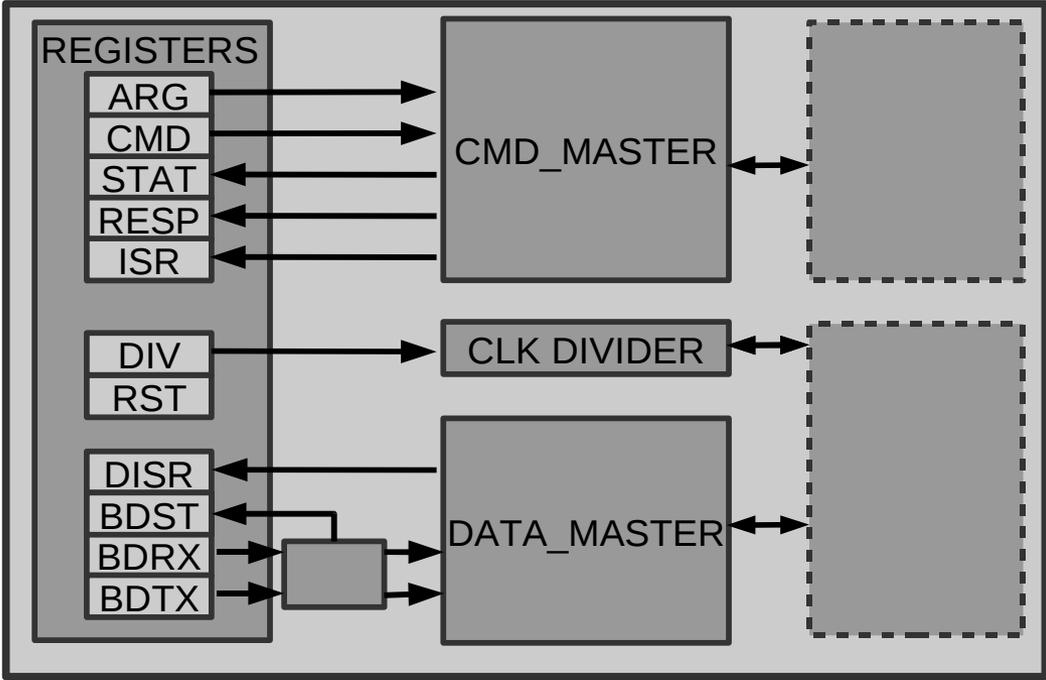
Formal device spec



Modelling real device interfaces

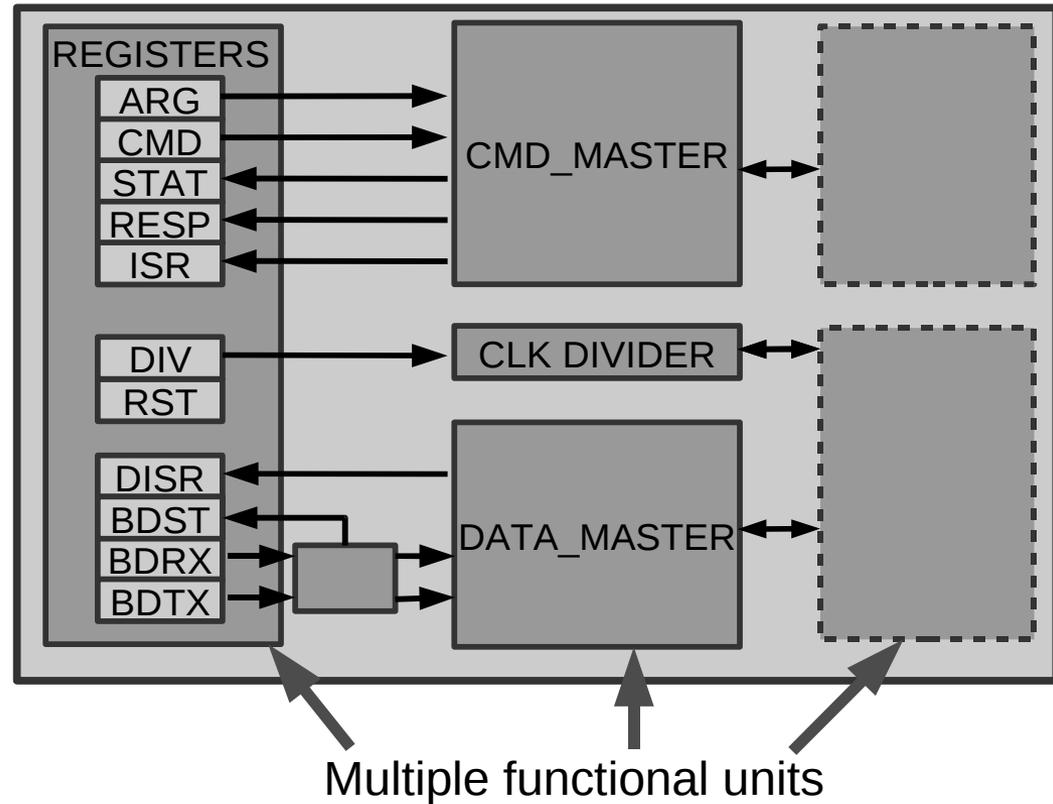


SD host controller device



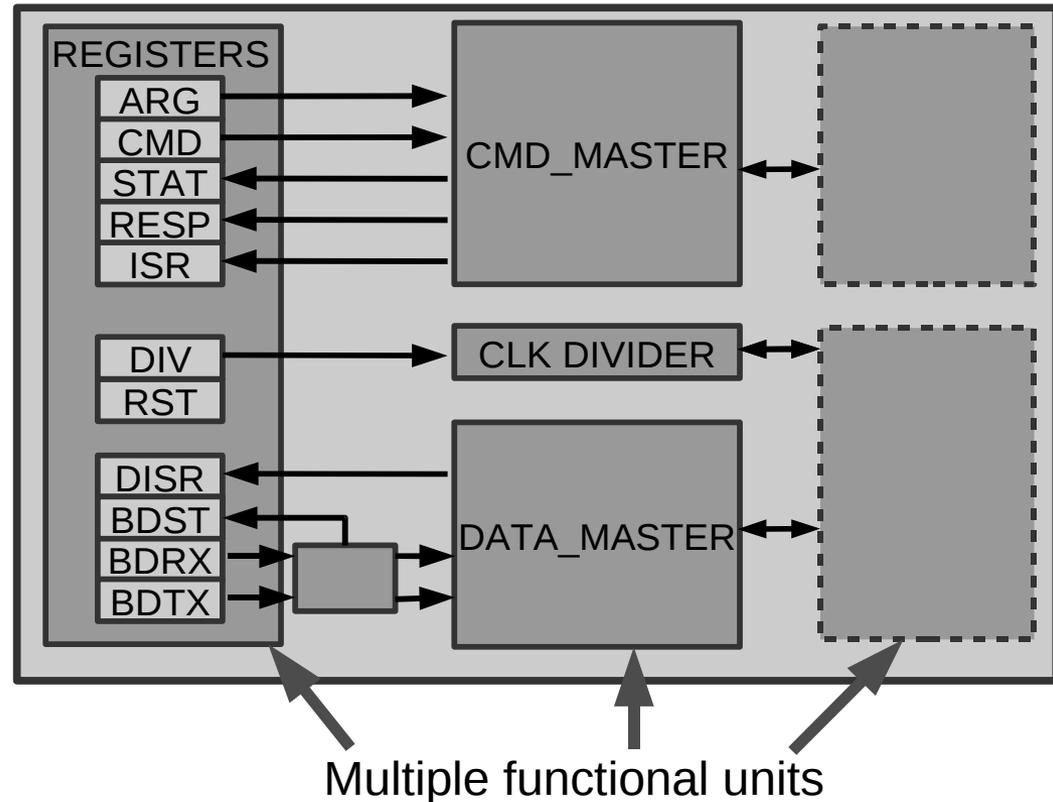
Modelling real device interfaces

SD host controller device



Modelling real device interfaces

SD host controller device



REGISTERS

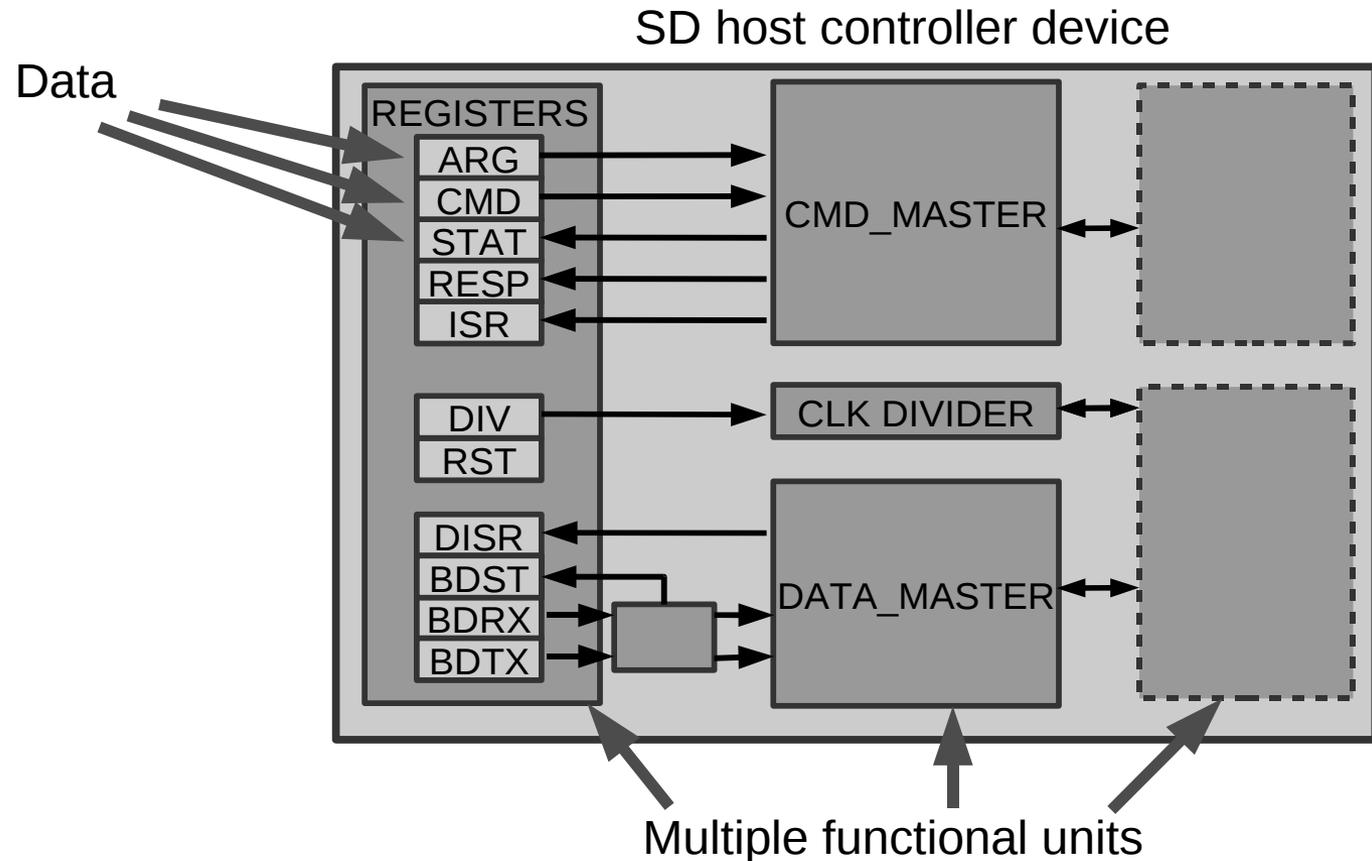
|||

CLOCK_DIVIDER

|||

(COMMAND_MASTER |[class.off]| DATA_MASTER)

Modelling real device interfaces



REGISTERS

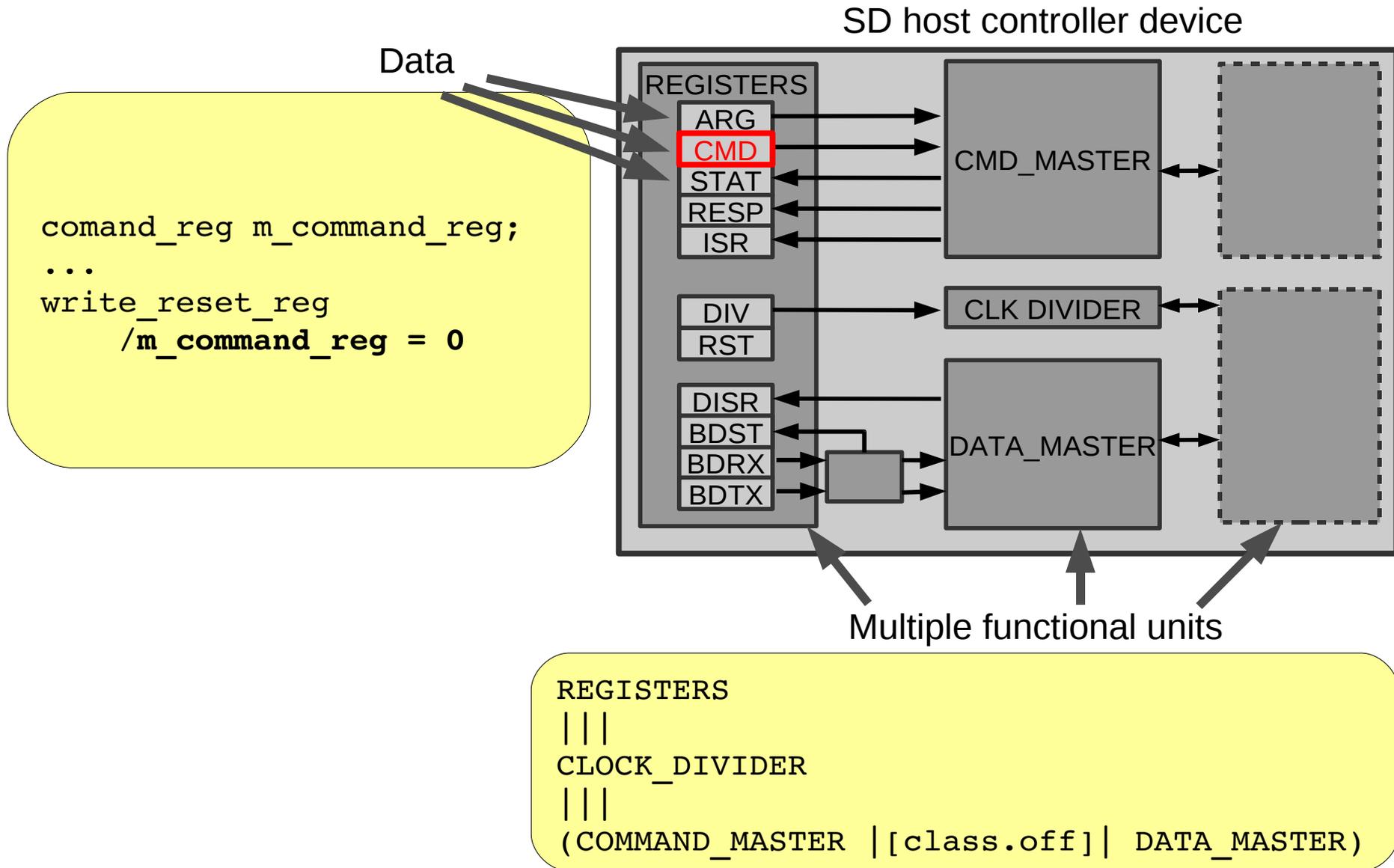
|||

CLOCK_DIVIDER

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Modelling real device interfaces

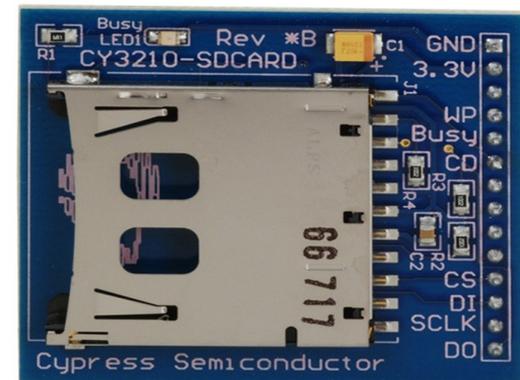


The synthesis algorithm

- The state explosion problem
 - **Problem:** The product state space can be huge
 - **Solution:** Explore the product state space incrementally
- Dealing with data
 - **Problem:** Enumerating all variable assignments is infeasible
 - **Solution:** Manipulate data symbolically

Results

- Successfully synthesised drivers for real devices:
 - Asix AX88772 USB-to-Ethernet adapter
 - Linux
 - Ricoh R5C822 SD host controller
 - Linux
 - FreeBSD



Results

	USB-to-Ethernet	SD
OS interface spec	309 loc	641 loc
Device spec	463 loc	653 loc
Synthesised driver	2620 loc	4667 loc
Linux driver	1200 loc	1174 loc

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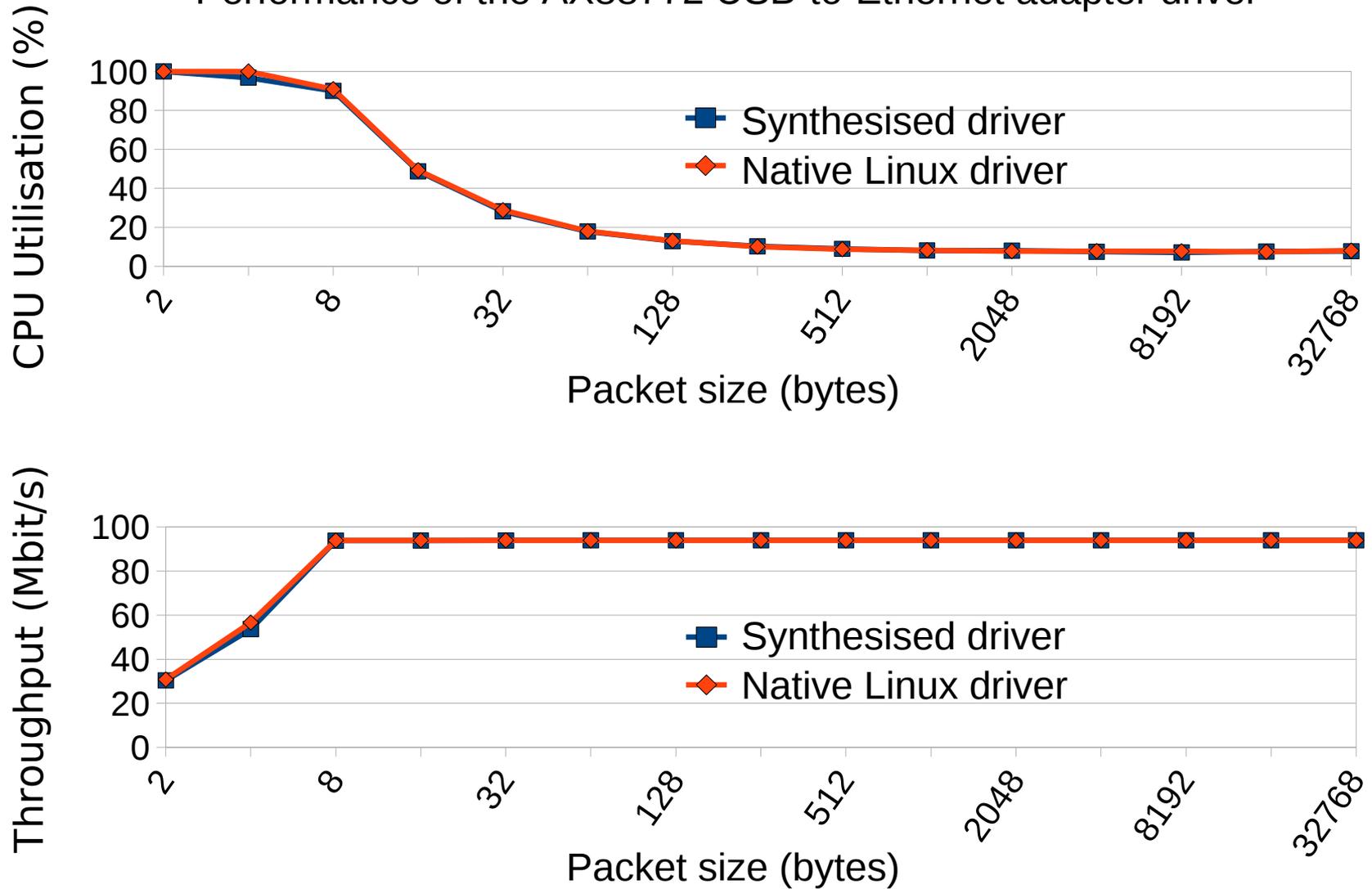
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The Termite Debugger

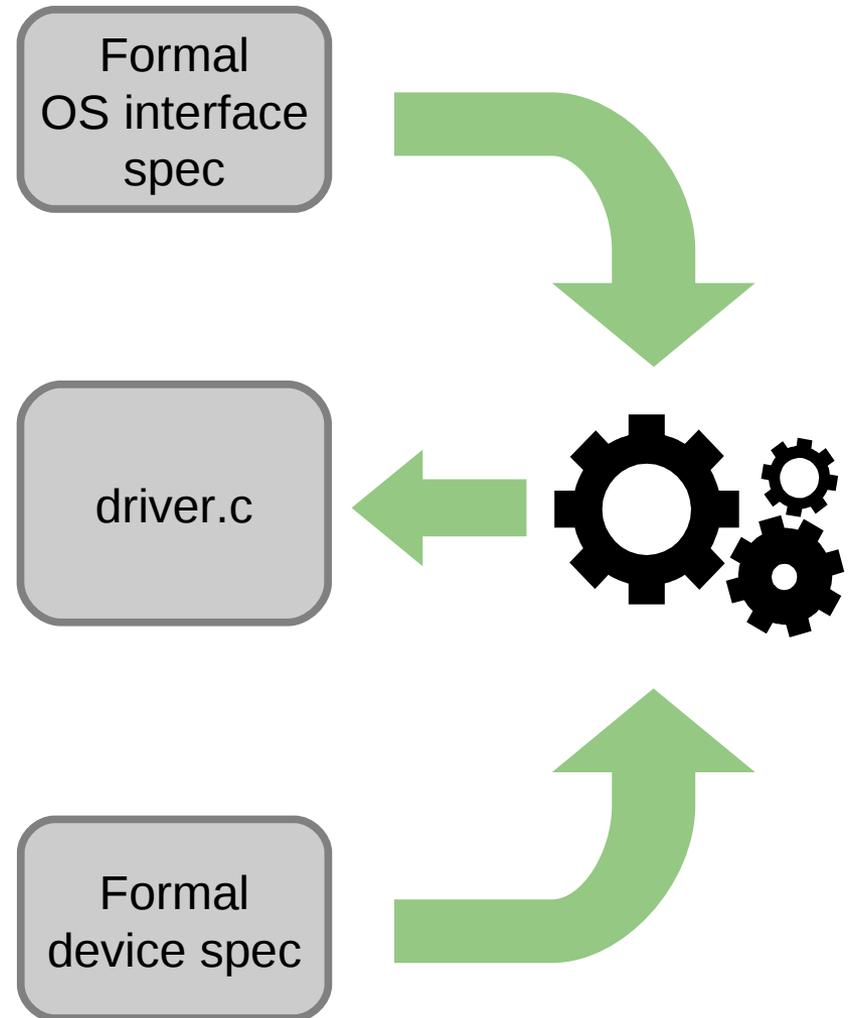
Performance

Performance of the AX88772 USB-to-Ethernet adapter driver

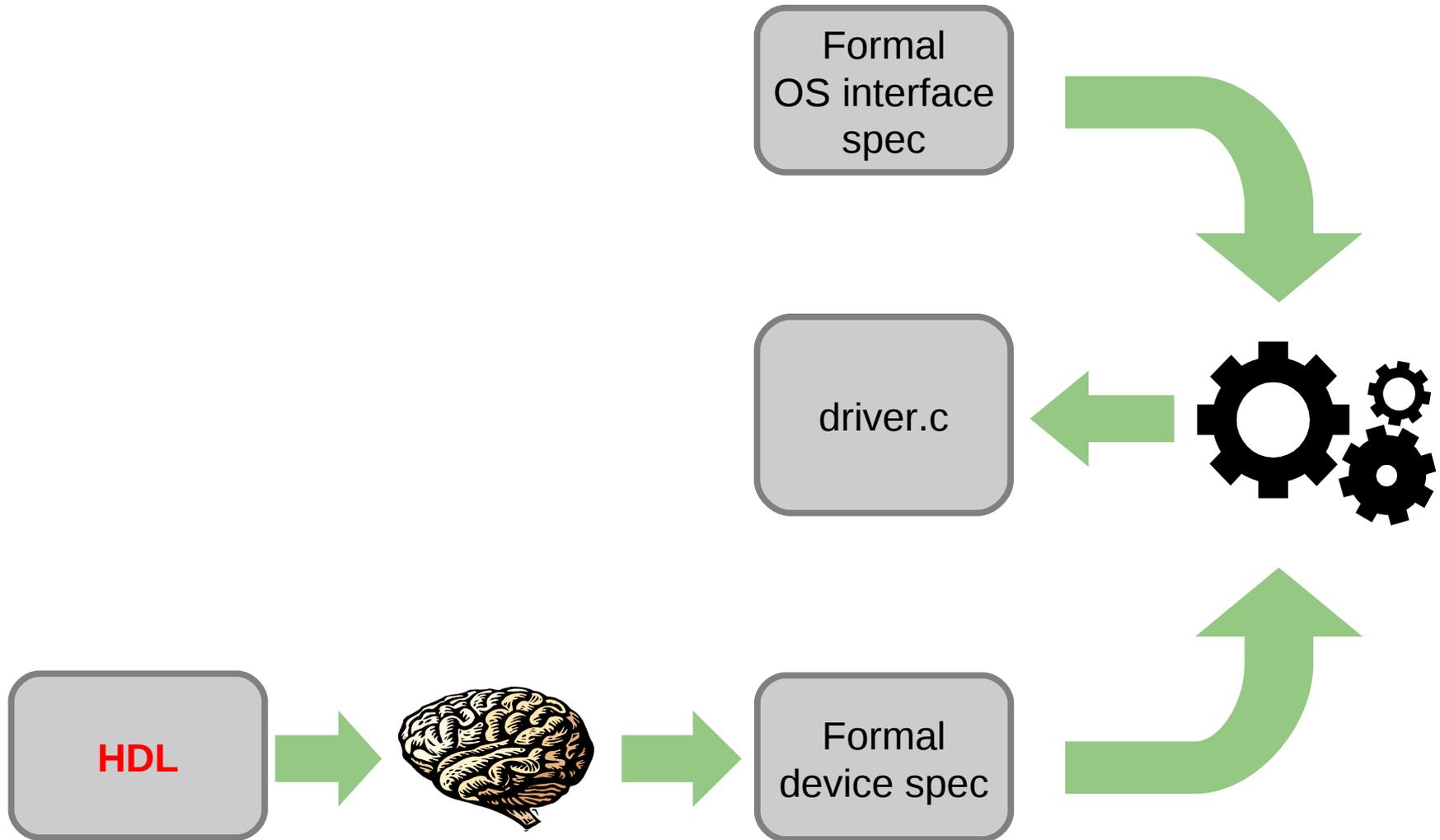


Limitations of Termite

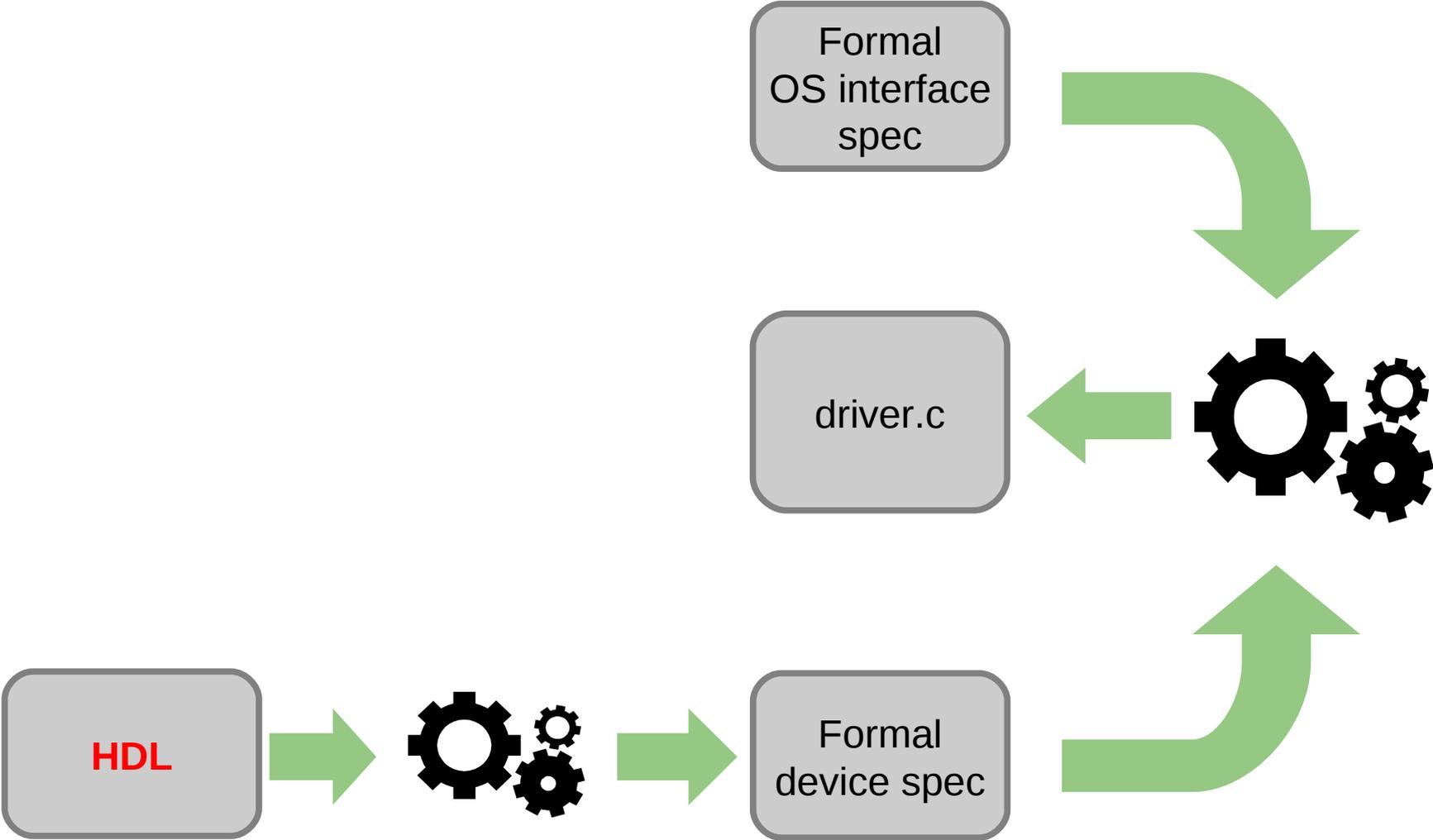
- Cannot specify constraints on data in memory
 - alignment, fragmentation, etc
- Complex relations among variables are not supported
- Restrictions on the structure of specifications
- Termite drivers require runtime support



Future work



Future work



Conclusions

- Driver synthesis is possible
 - Device experts provide device specs
 - OS experts provide OS specs
 - **Termite does the rest**
- Still work-in-progress
 - Addressing current limitations
 - Driver synthesis from HDL

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