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Accessing On-chip Instruments Through the Life-time of Systems

ERIK LARSSON

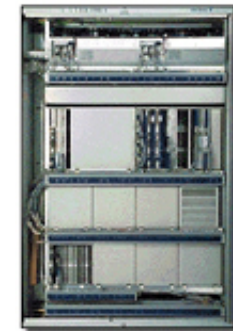


Motivation

- We know:
 - Electronics is used everywhere
 - Transistors increase in number and decrease in size
- It leads to:
 - Many possible defects
 - New defects, such as ageing
- Can be handled with: More embedded (on-chip) instruments
- Lead to: Communication with instruments becomes important
- In this talk: How IEEE 1687 enables such communication
 - through the lifetime; from manufacturing test to reliability handling during operation



Our everyday lives....



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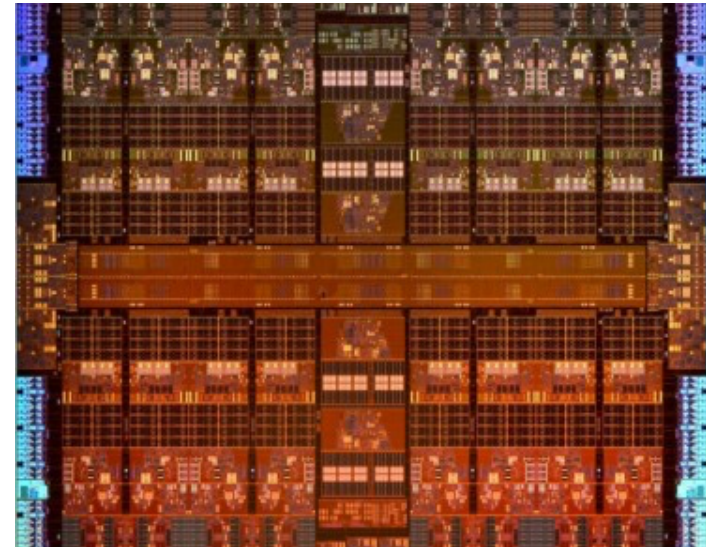
...includes much electronics, ...



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which is characterized by

- Increasing transistor counts
- Decreasing transistor sizes
- An example: SUN M7
 - 10 billion transistors
 - 20 nm technology



and problems...

- Ageing: a working IC slowly degrades and becomes defective after some time in operation
- No Trouble Found (NTF): a system seems defective in operation but when taken for repair no problem can be found.
- Example [ACC08]:
 - Total cost of consumer electronics returns and repairs in USA was estimated at \$13.8 billion in 2007
 - For a typical \$10 billion dollar consumer electronic device manufacturer and large retailer, a 1% reduction in “No Trouble Found” returns can add up to approximately \$37 million in shared savings.

[ACC07] Accenture Research: Big Trouble with No Trouble Found Returns



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need more effort...

- Manufacturing problems which cause more effort:
 - post-silicon validation, debug, wafer sort, package test, burn-in, printed circuit board (PCB) bring-up, and test of PCB assemblies.
- Reliability issues which cause more effort:
 - monitor activity, making configuration, clock control, power management, fault detection, memory built-in self-test (BIST), logic BIST.



which can be handled with...

- Embedded (on-chip) instruments:
 - Memory built-in self-test (BIST), logic BIST, trace buffers, monitor activity, making configuration, clock control, power management, fault detection,...
- The number of embedded instruments increases [FRO09]
- Can be in range of 1000 [POS15]

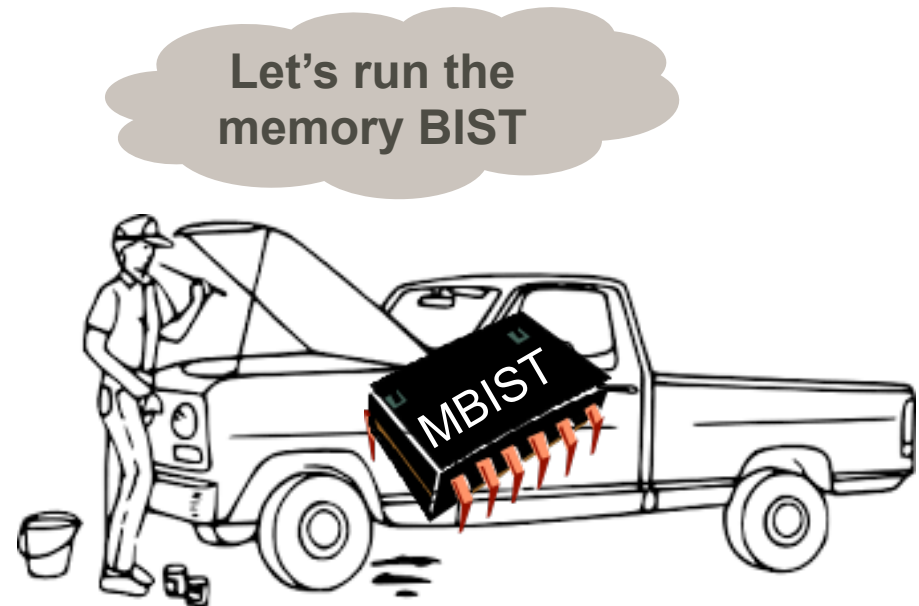
[FRO09] Embedded Instrumentation: Its Importance and Adoption in the Test & Measurement Marketplace. [Online]. Available: <http://www.frost.com/prod/servlet/cio/201638885>

[POS15] K. Posse, "Component Manufacturer Perspective," in Proc. IEEE Int'l Test Conf. (ITC), Oct. 2015.



to be accessed through the lifetime

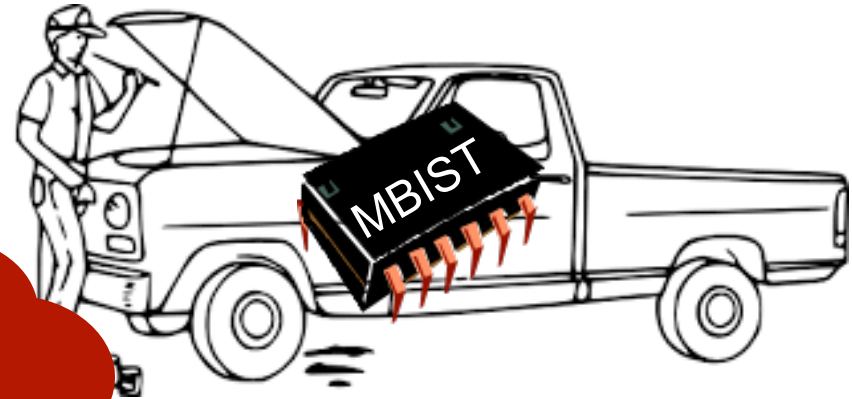
- At manufacturing (offline)
- In-situ test (operation)
- At repair-shop (offline)
- In general, when you buy an IC, you also get ways to access embedded instruments, for example BIST.



to be accessed through the lifetime

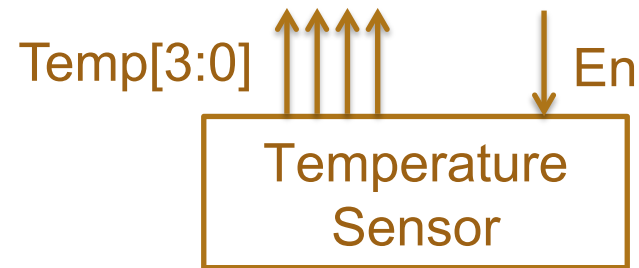
- At memory
- In **IC users:
fantastic**
- At repair-shop (offline)
- In general, when you buy an IC, you also get **IC manufacturer:
not sure I want to
enable access, at
least not to
everything**
instru
BIS

Let's run the
memory BIST

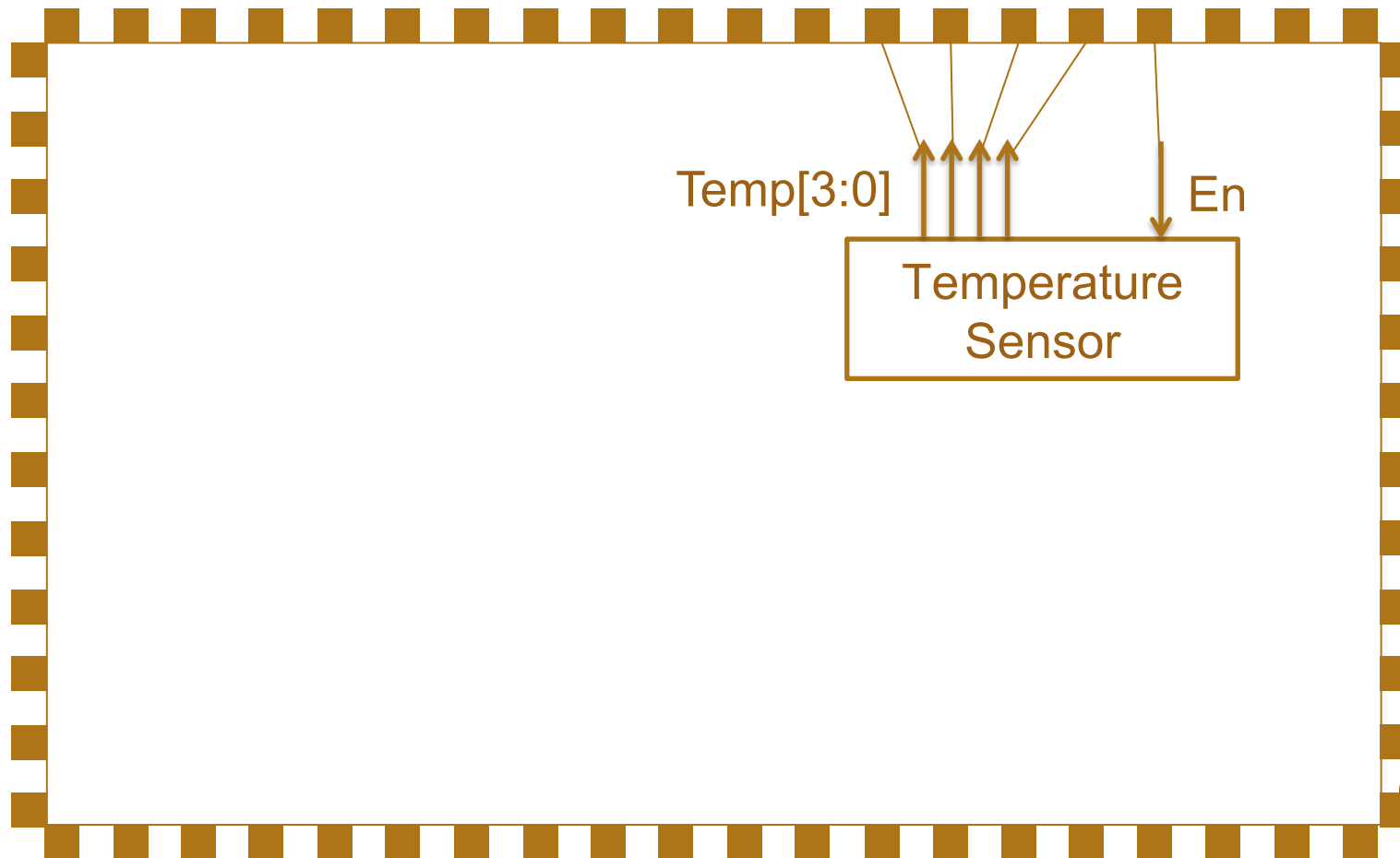


An embedded instrument

- A temperature sensor
 - Enable
 - Wait a while
 - Get temperature

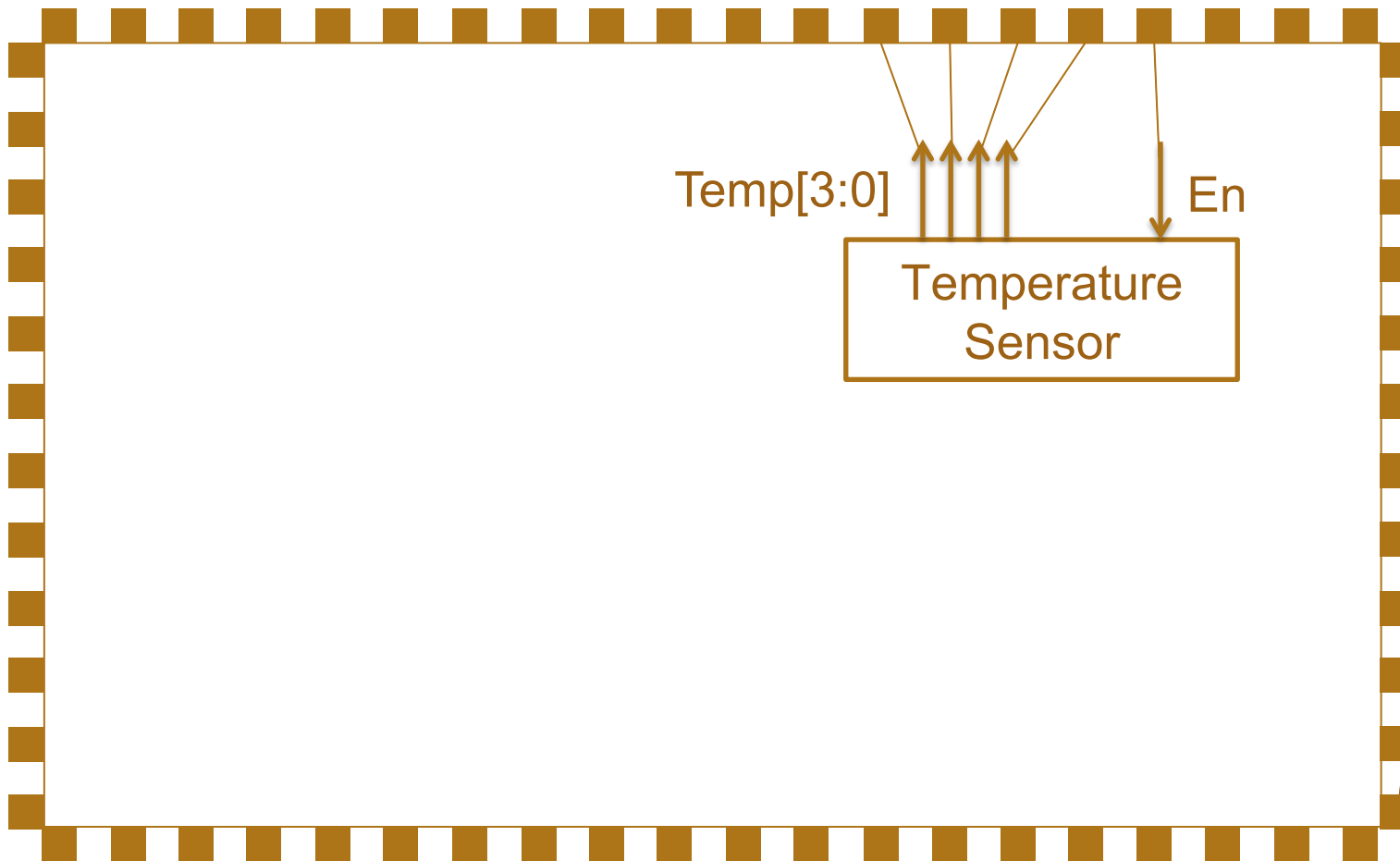


placed in an IC

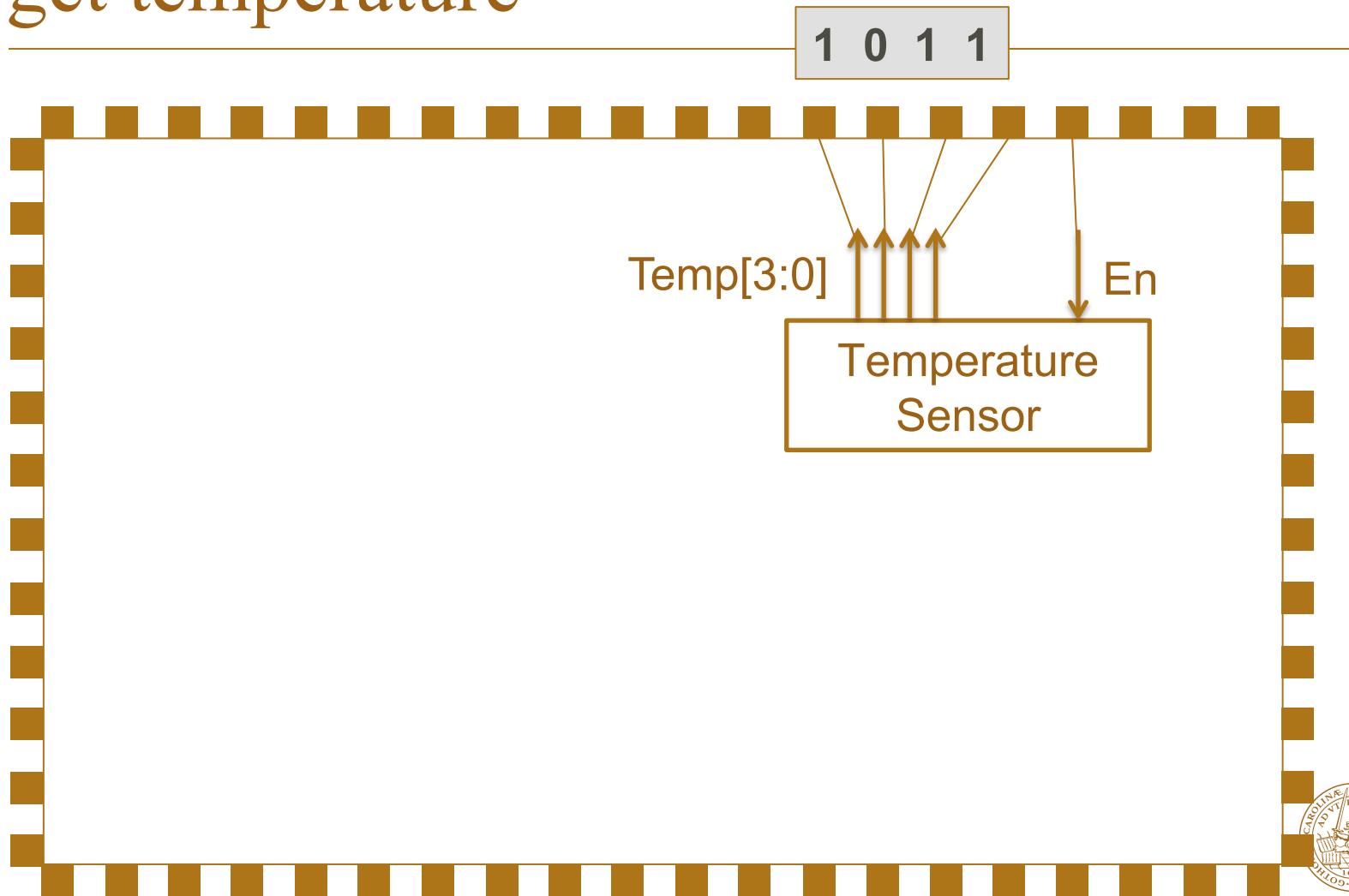


enable, wait,

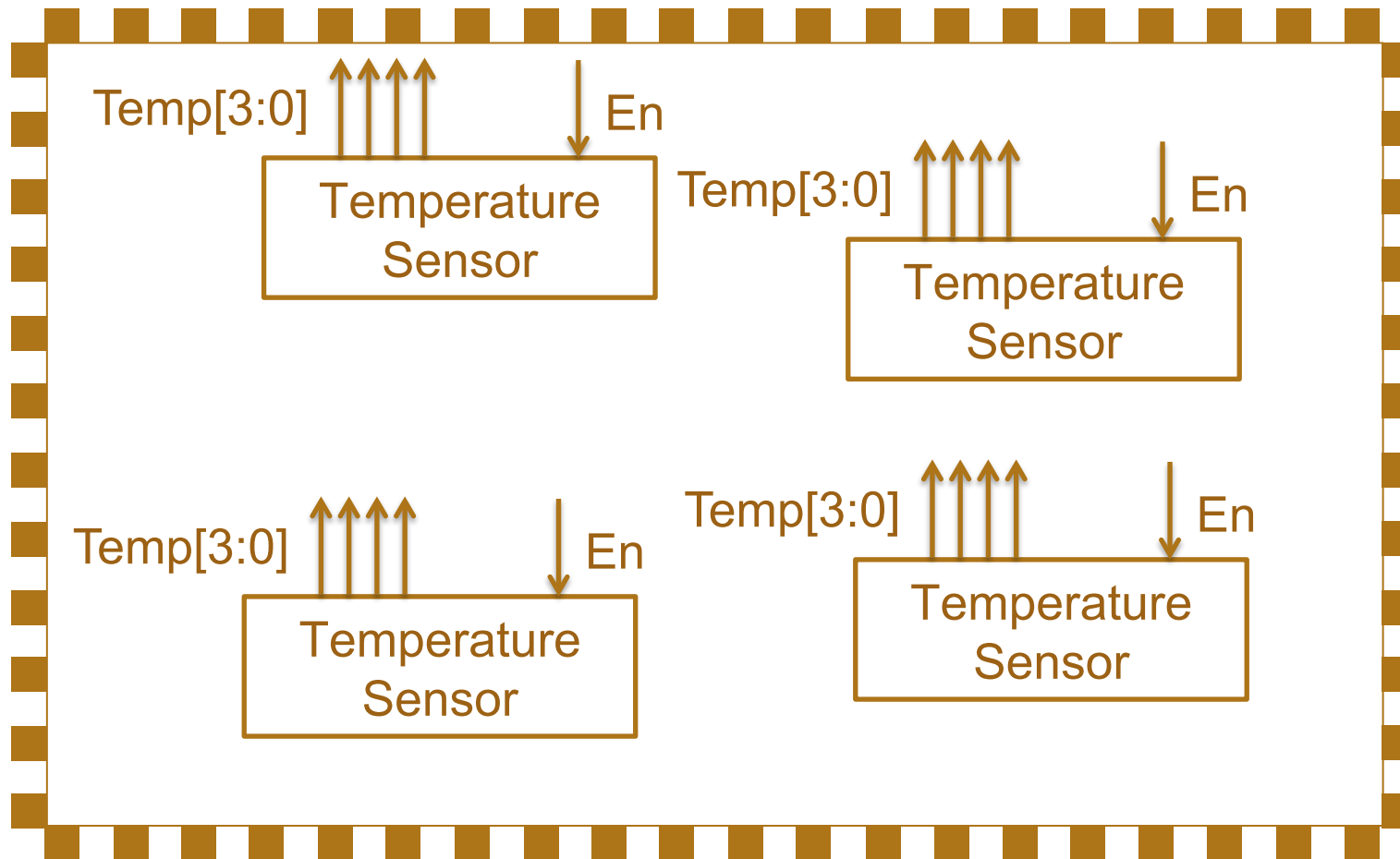
1



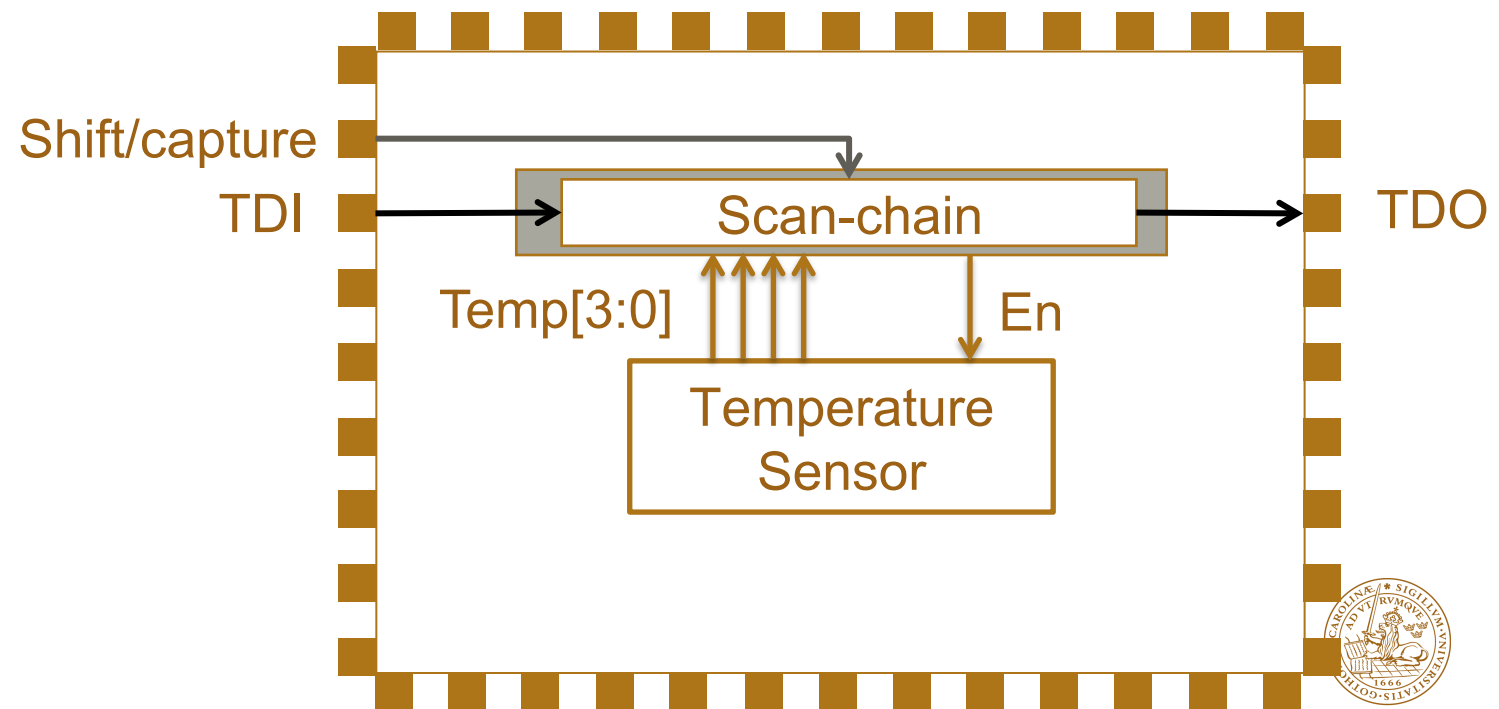
get temperature



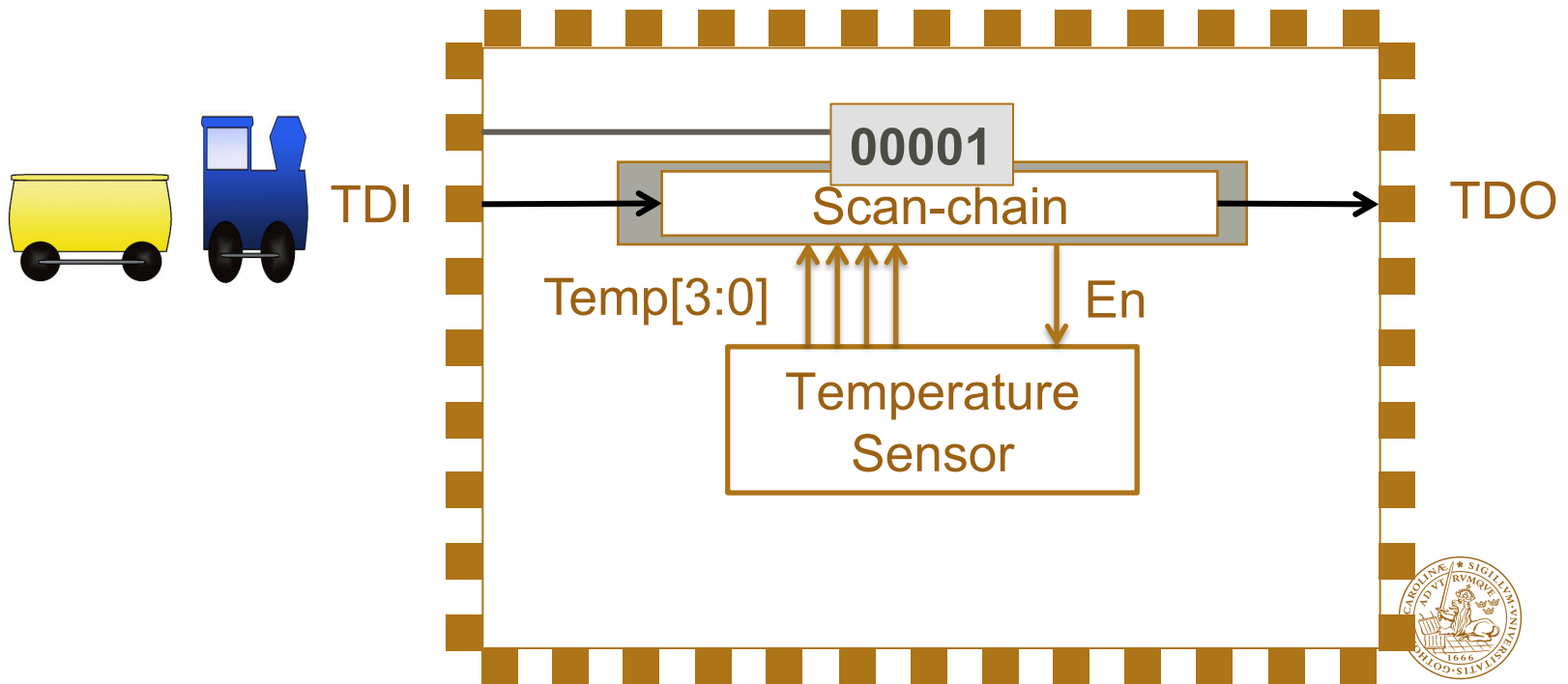
more instruments, but too many pins...



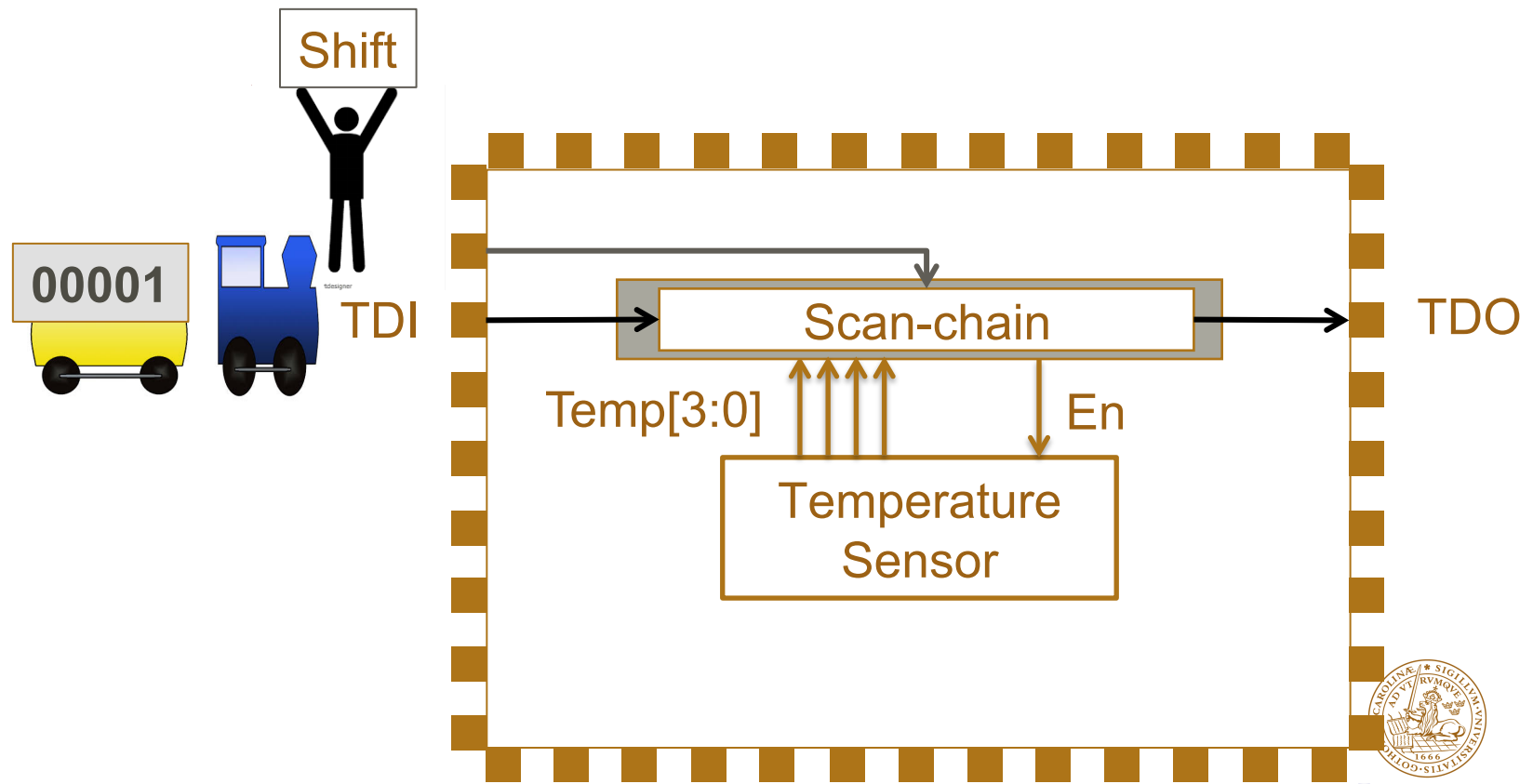
With scan-chains, fewer pins



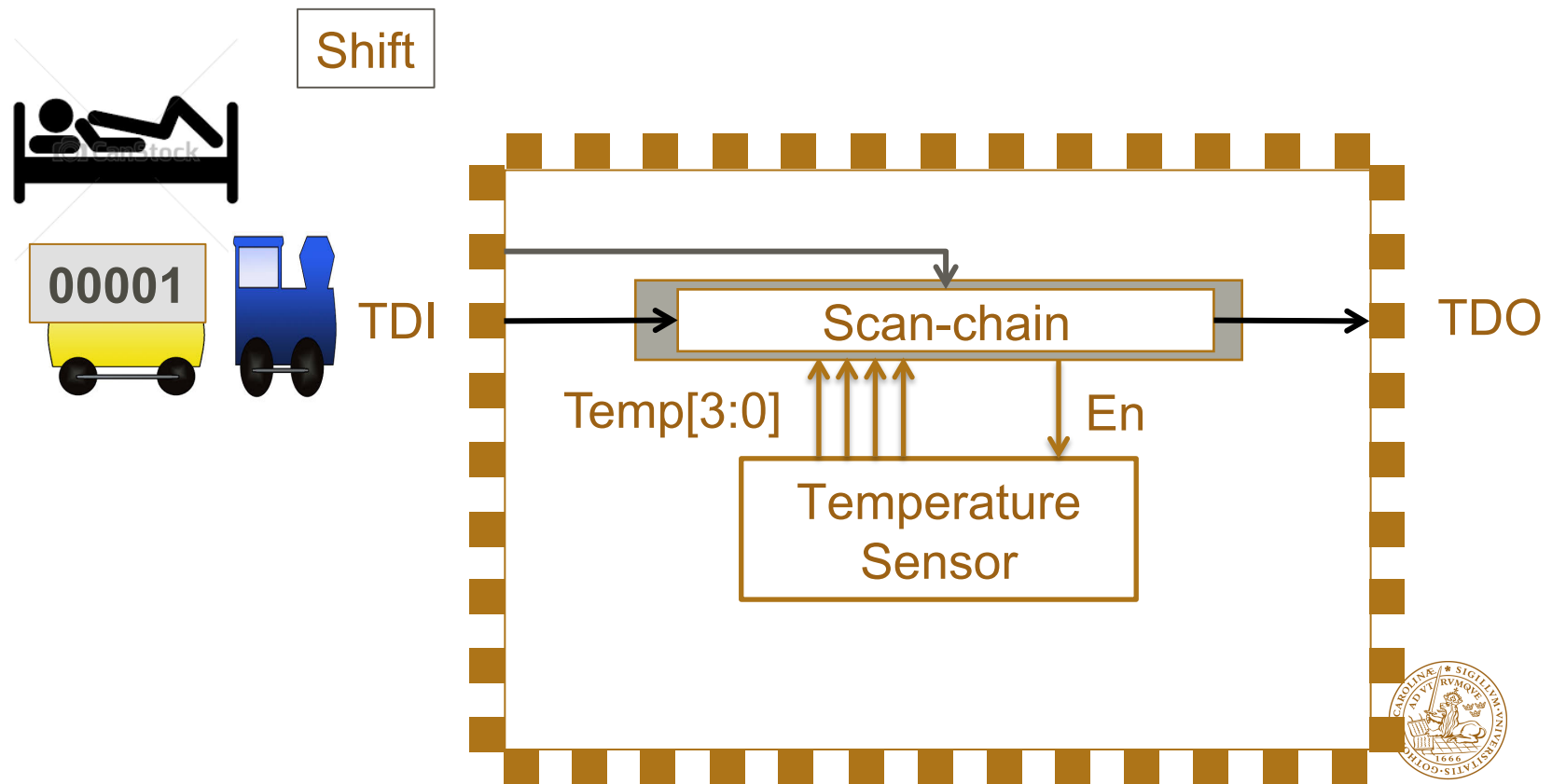
Retarget from parallel to serial



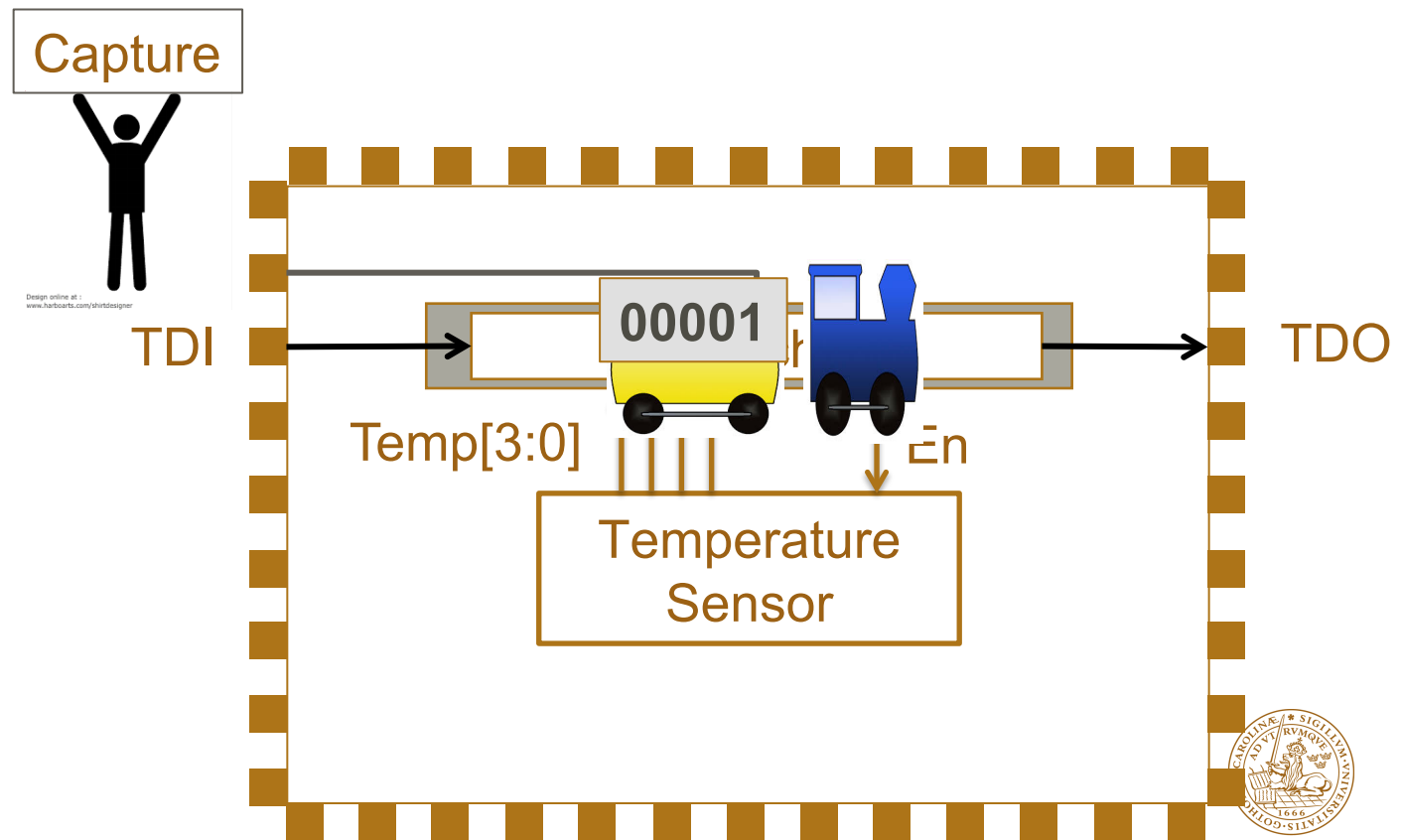
Set to shift



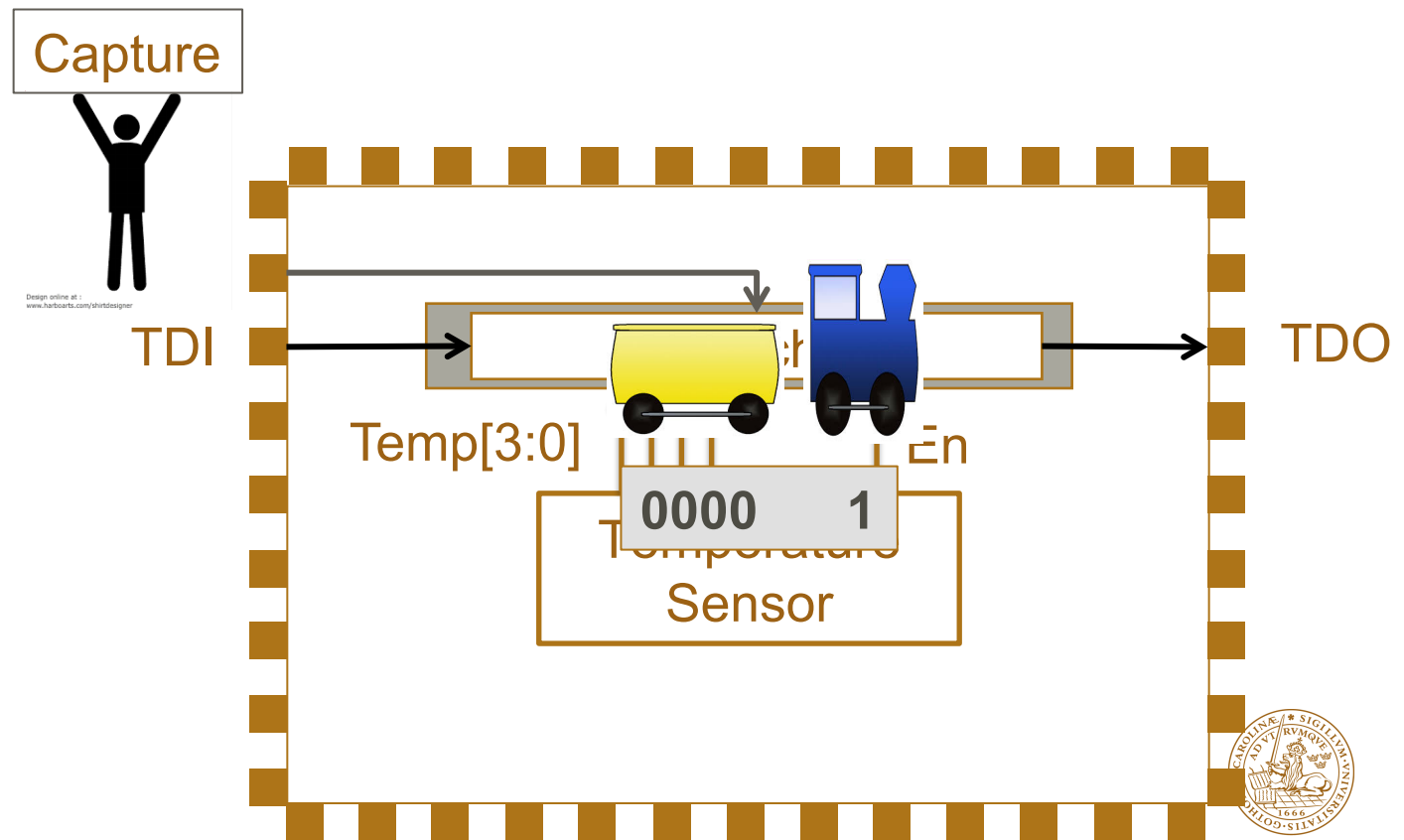
Start shifting



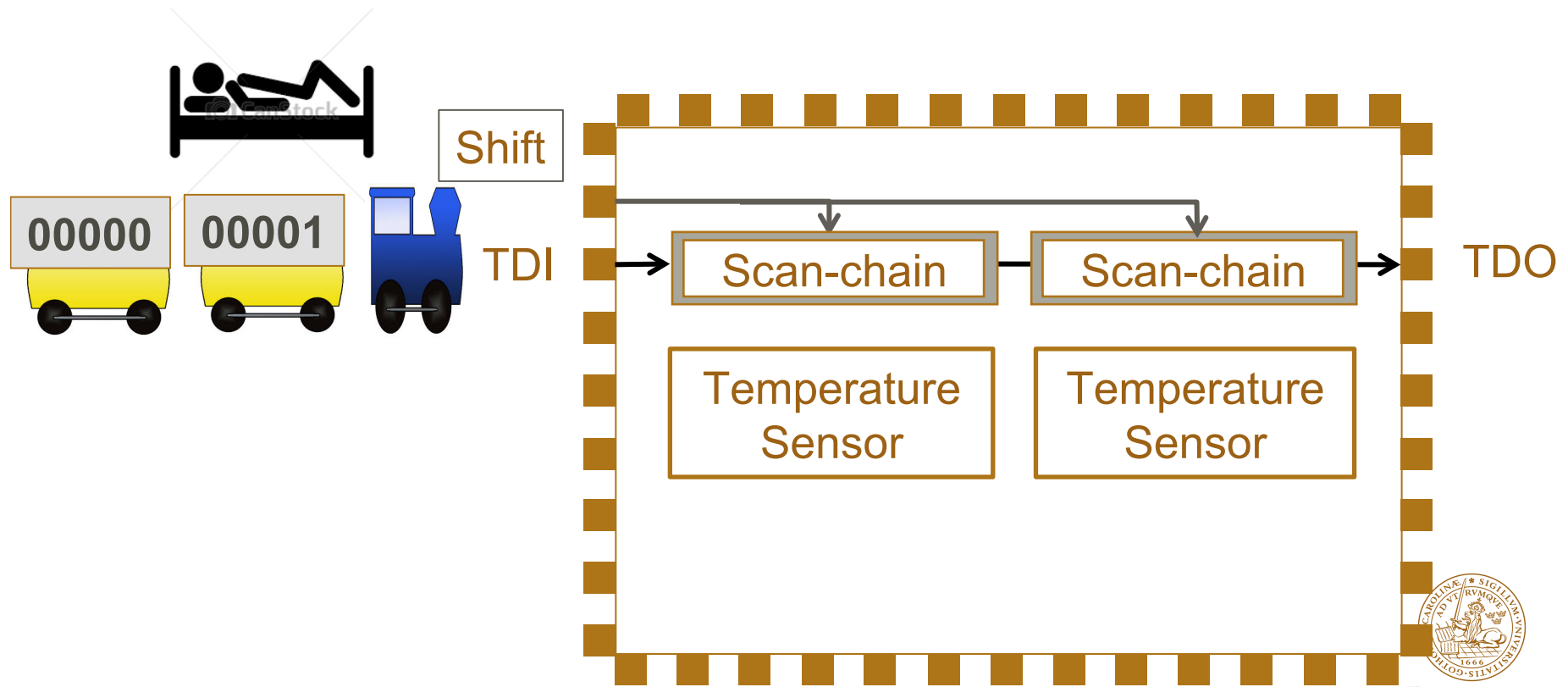
Set to capture



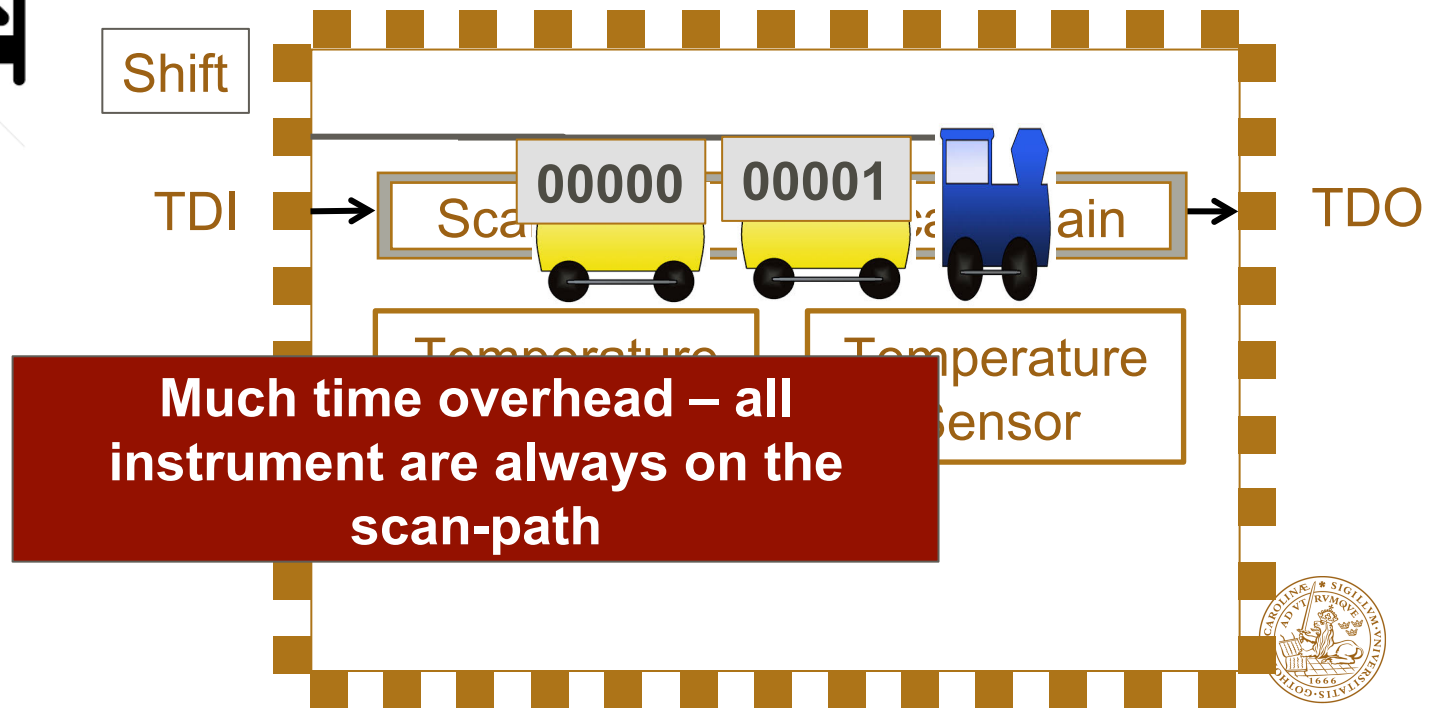
capture



Many instruments



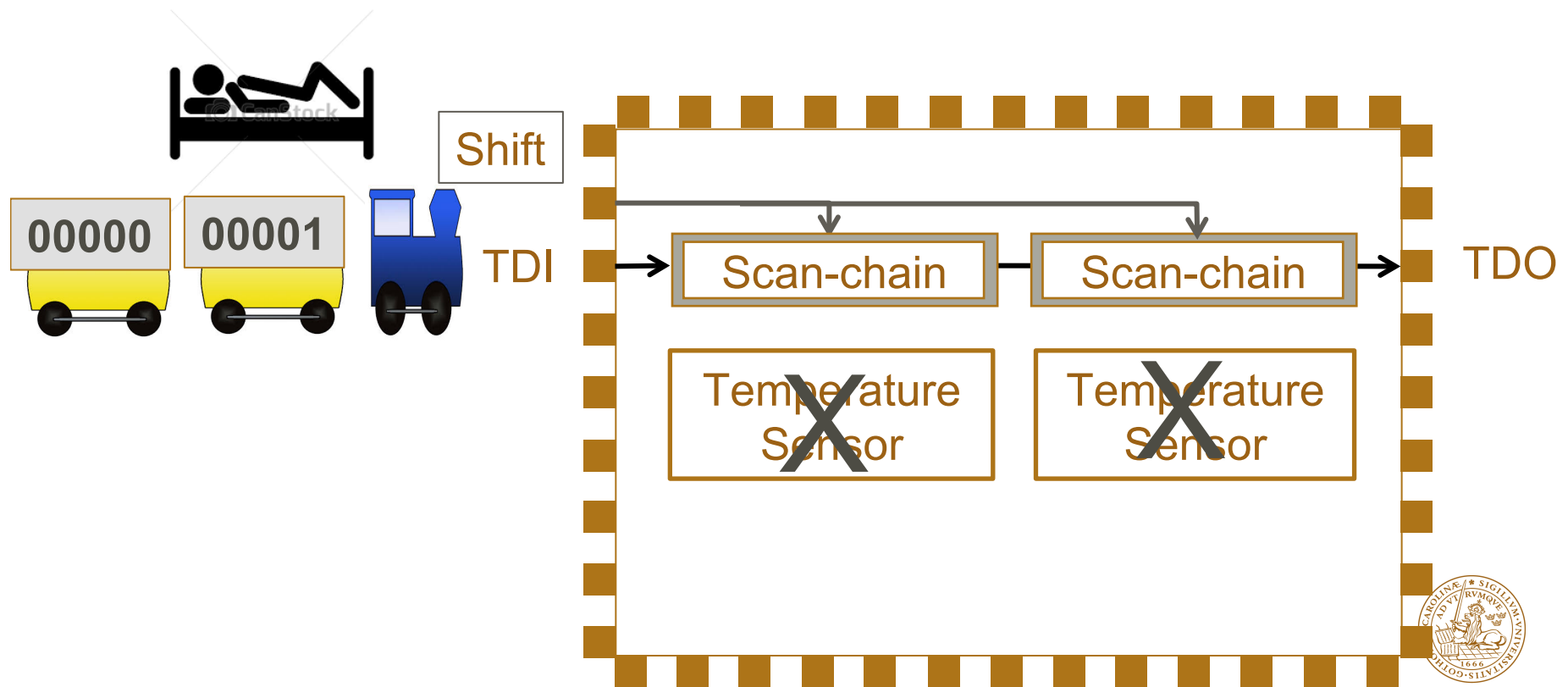
Many instruments



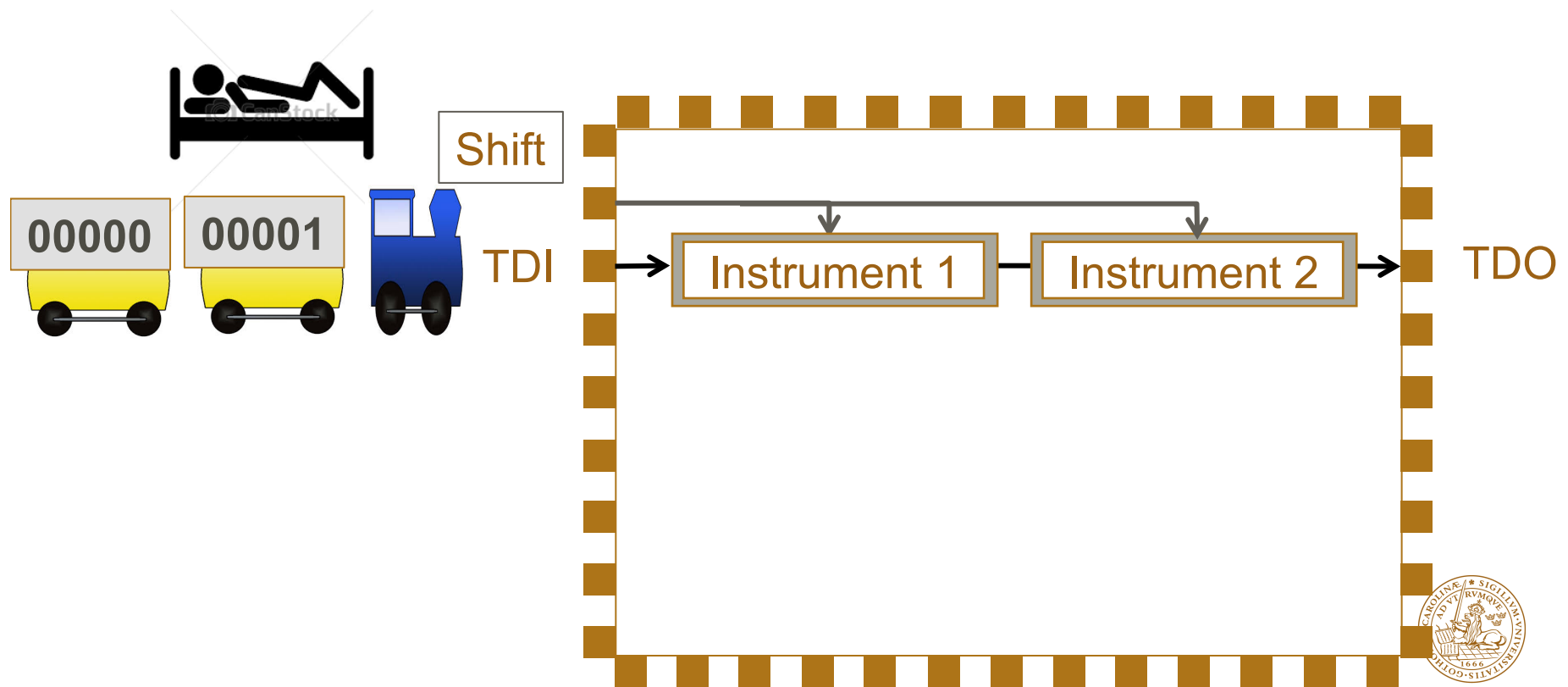
Much time overhead – all instrument are always on the scan-path



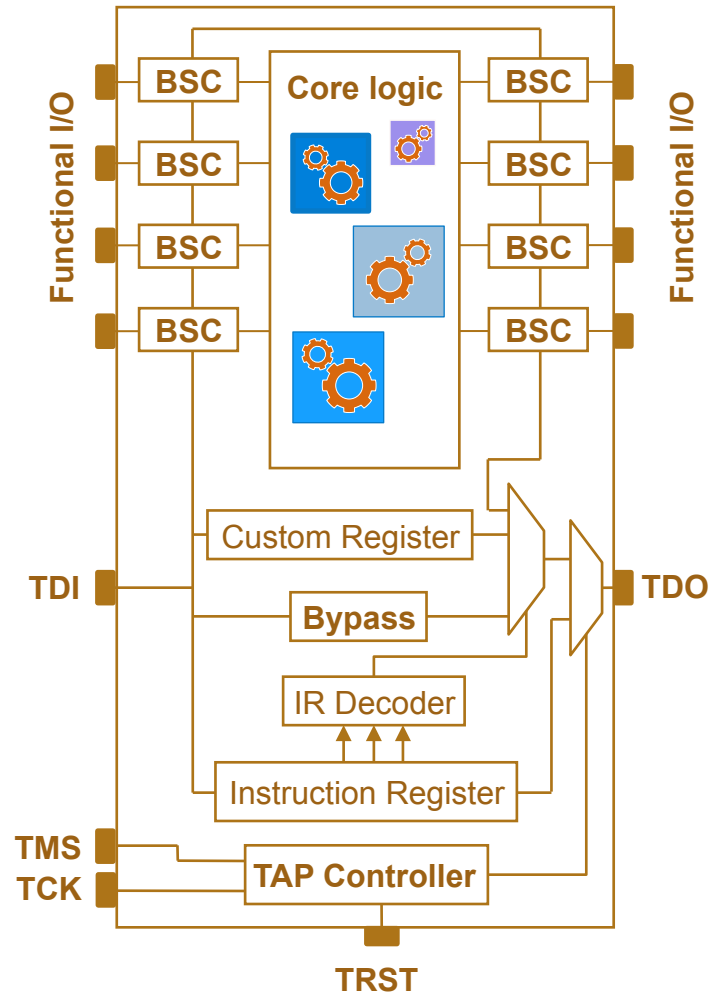
Simpler illustration



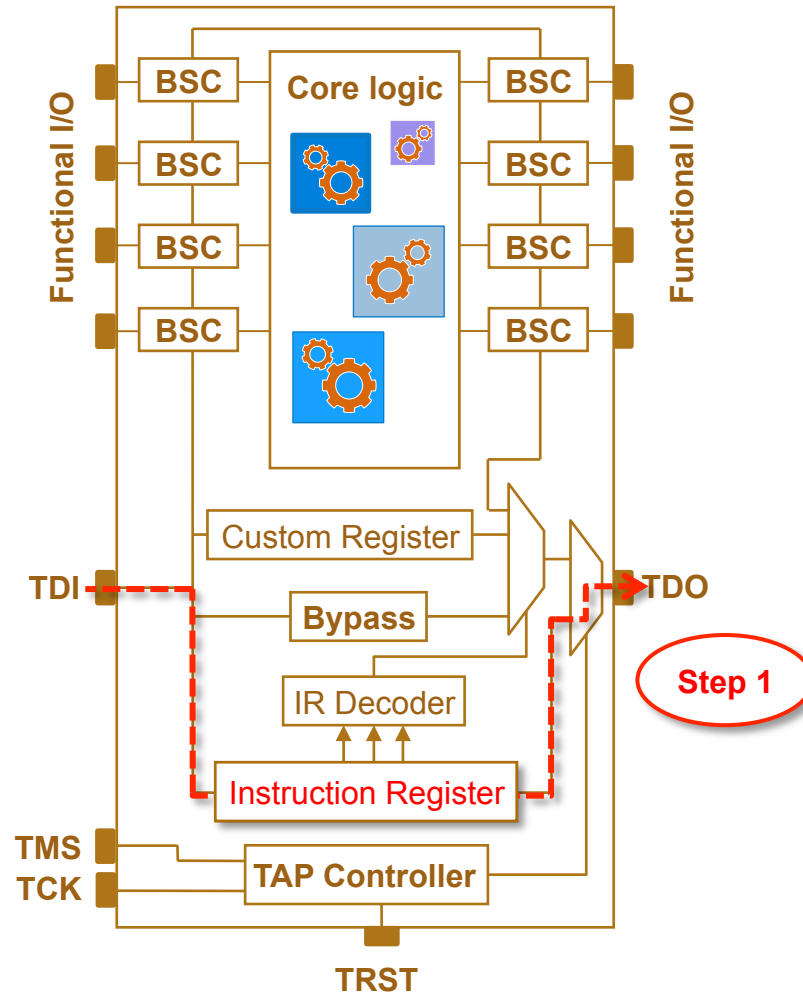
Simpler illustration



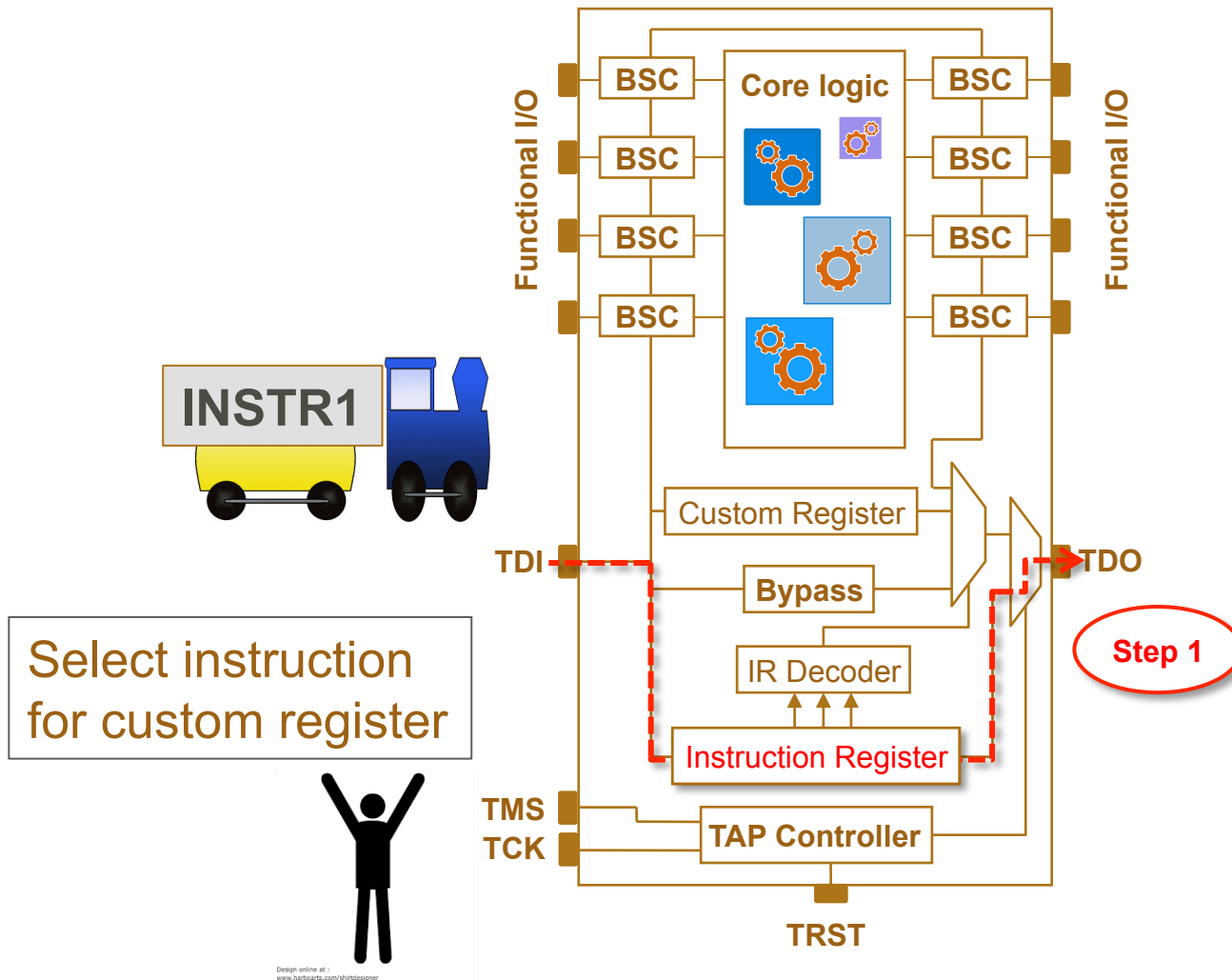
IEEE 1149.1



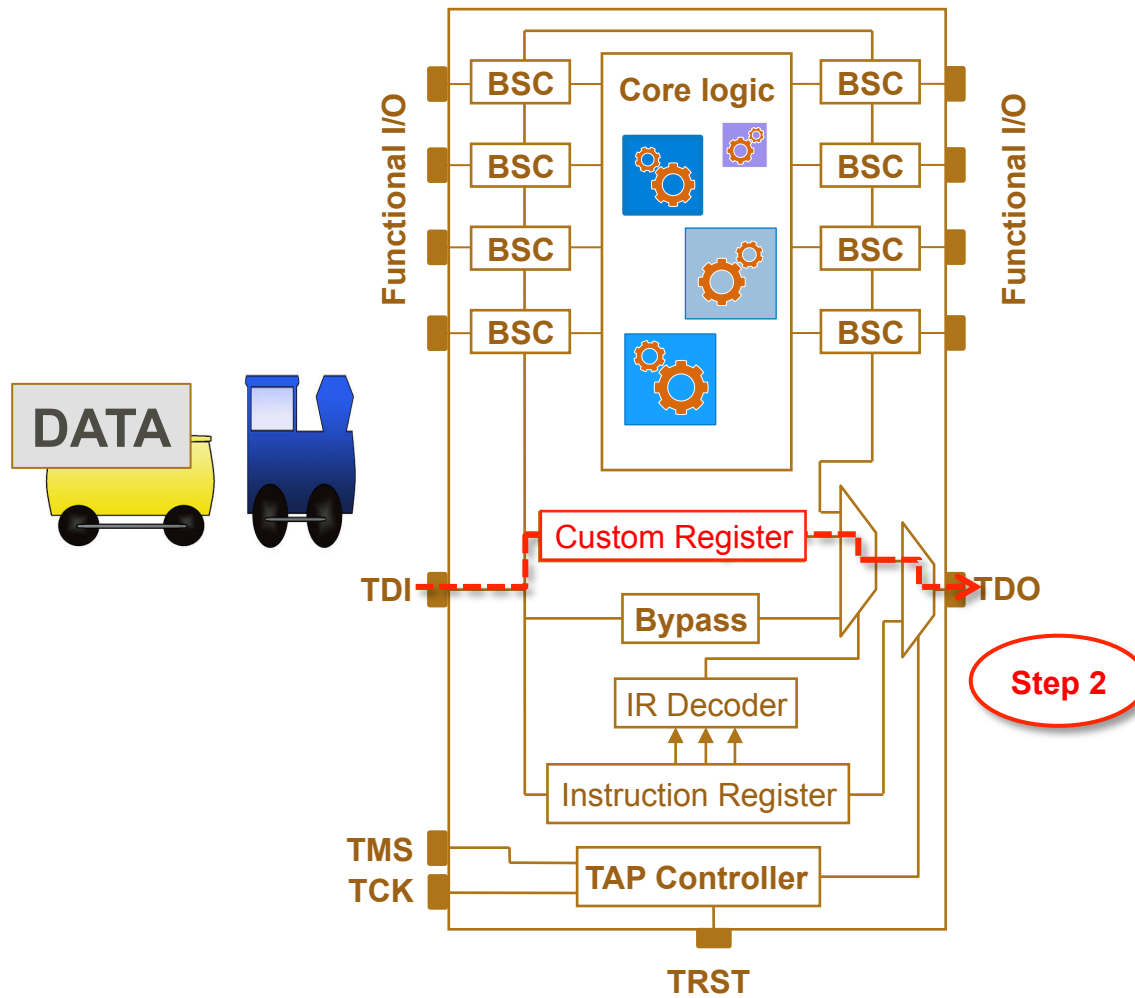
IEEE 1149.1



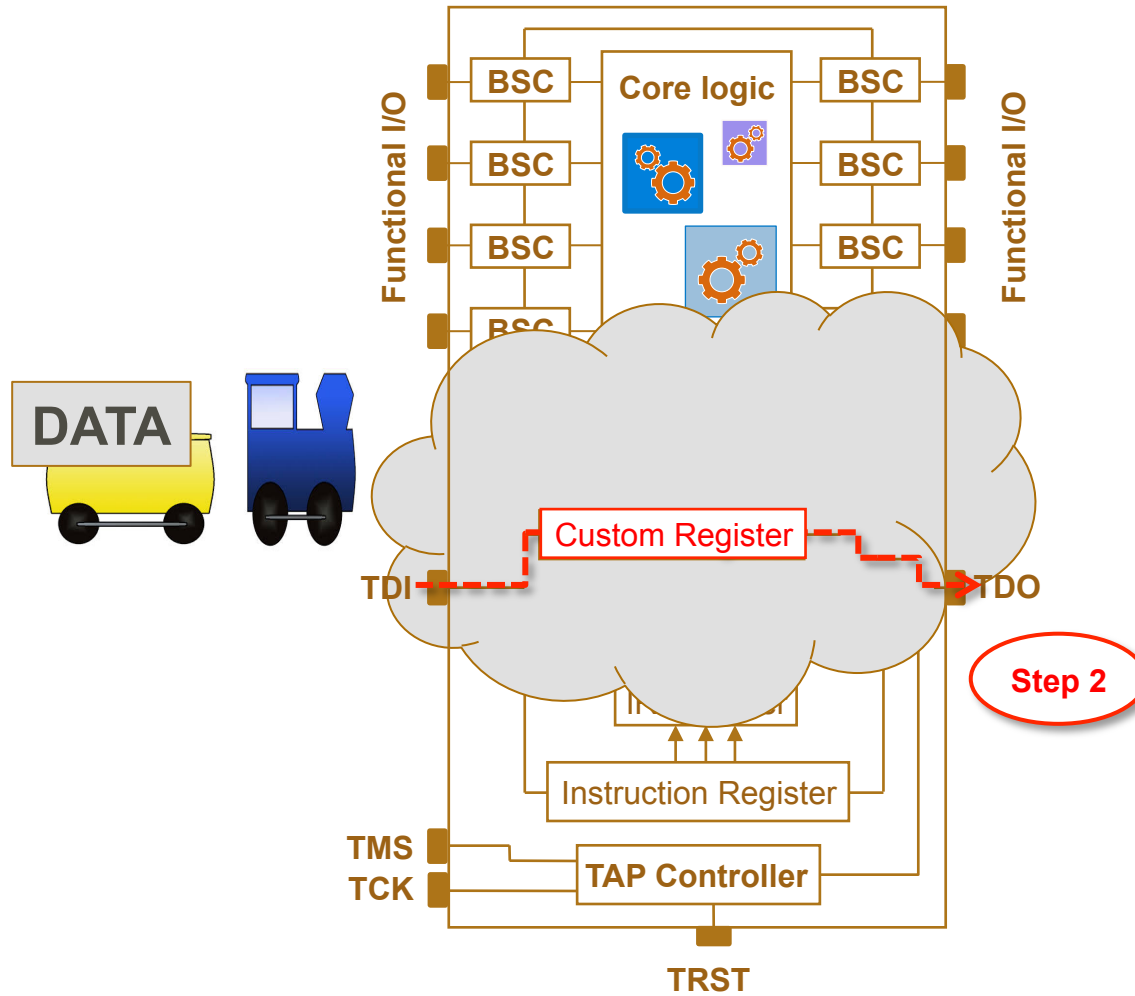
IEEE 1149.1



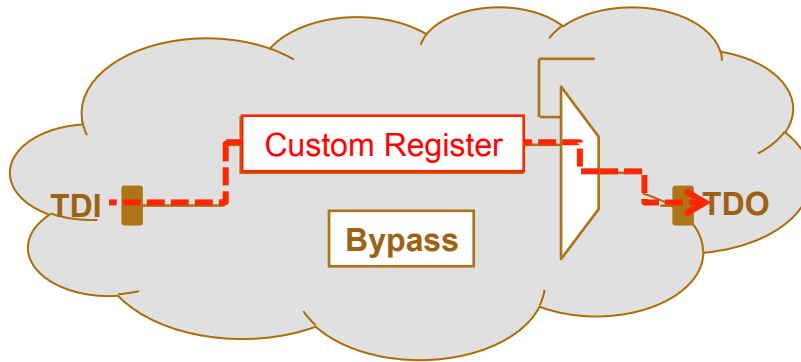
IEEE 1149.1



IEEE 1149.1

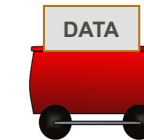
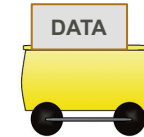


IEEE 1149.1

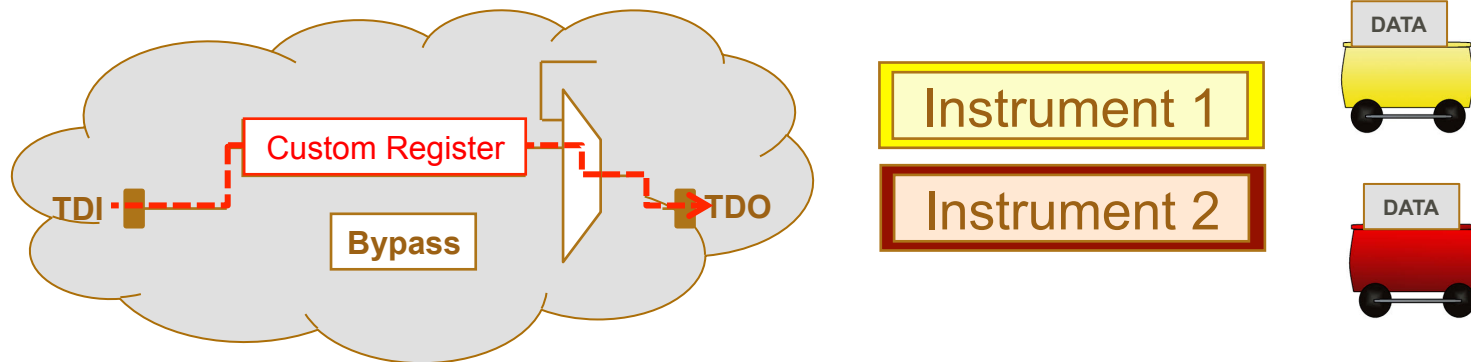


Instrument 1

Instrument 2



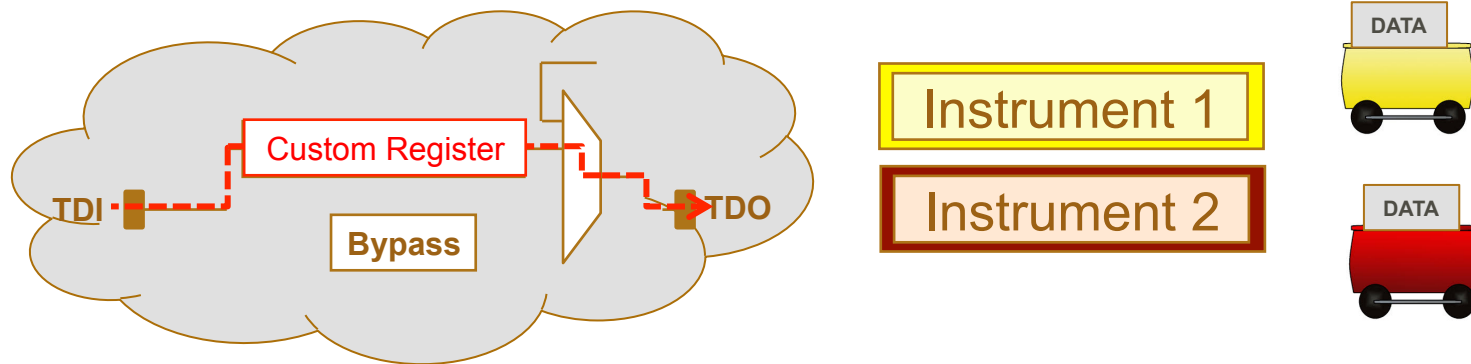
IEEE 1149.1



- Alternative 1: One custom register with both instruments



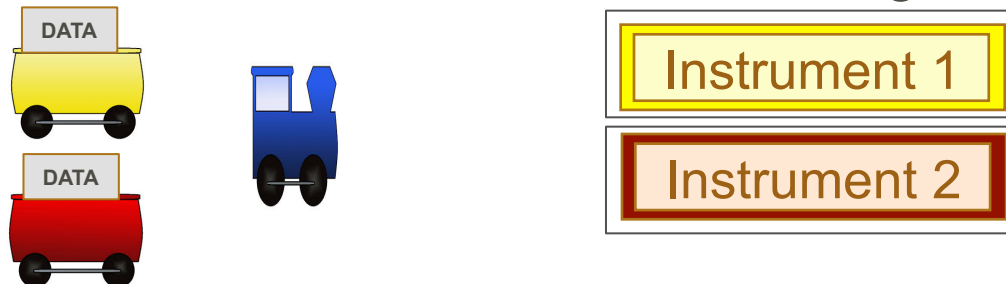
IEEE 1149.1



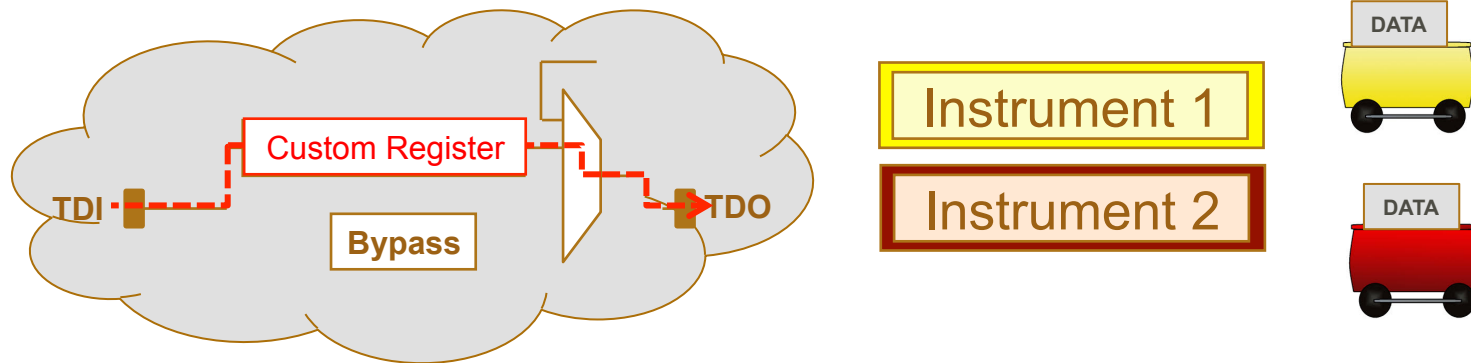
- Alternative 1: One custom register with both instruments



- Alternative 2: One custom register per instrument



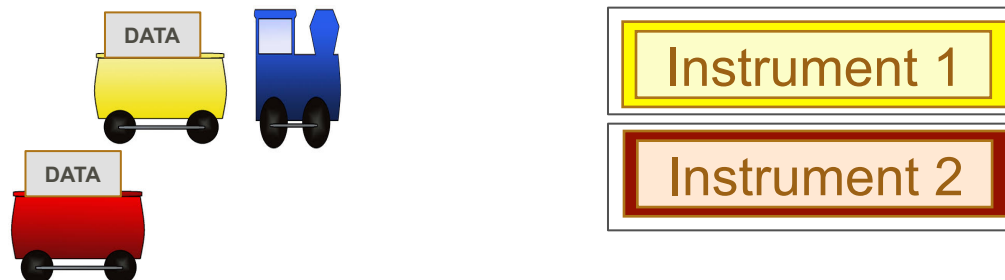
IEEE 1149.1



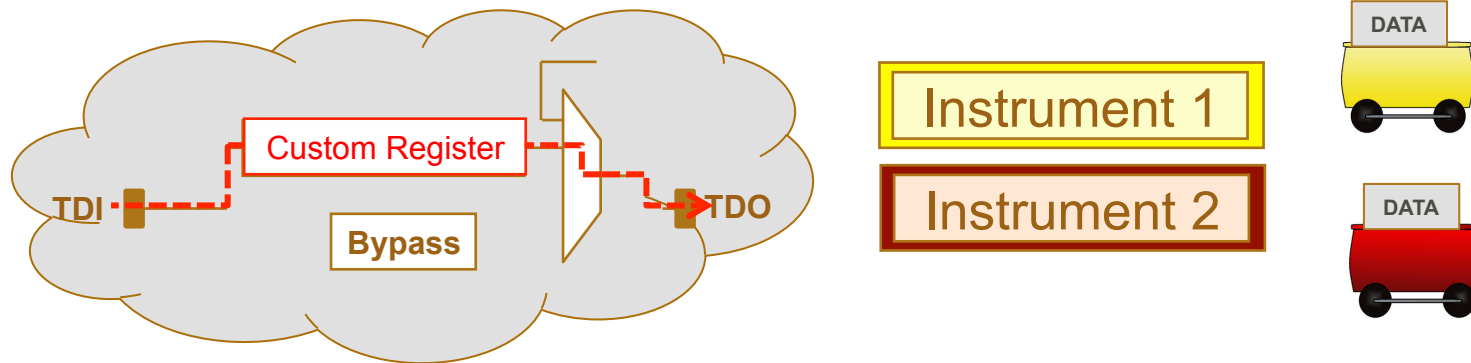
- Alternative 1: One custom register with both instruments



- Alternative 2: One custom register per instrument



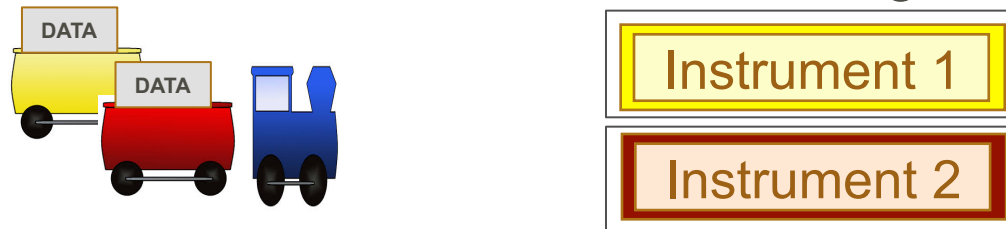
IEEE 1149.1



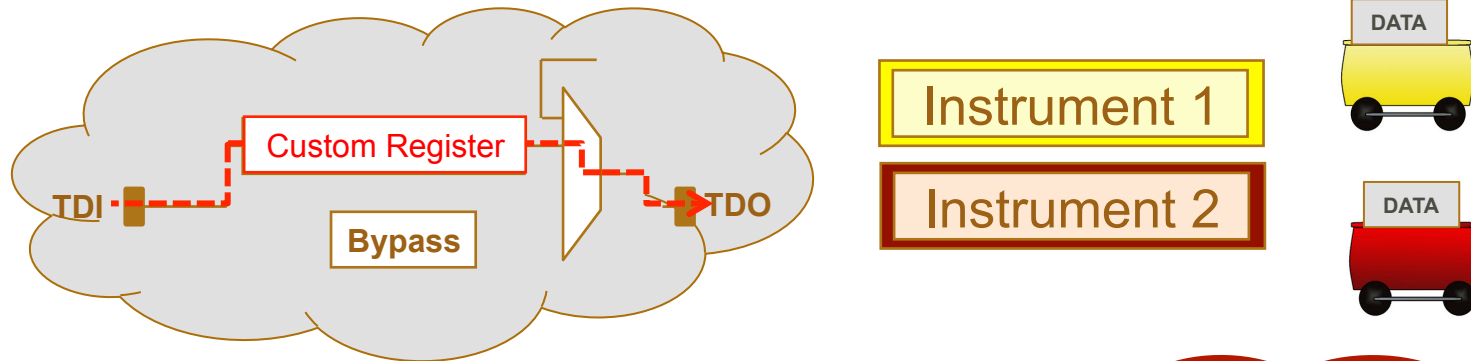
- Alternative 1: One custom register with both instruments



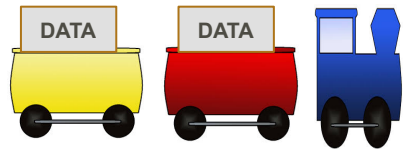
- Alternative 2: One custom register per instrument



IEEE 1149.1

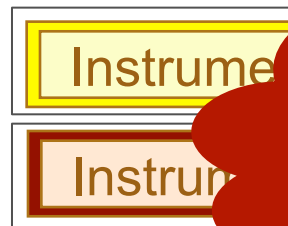
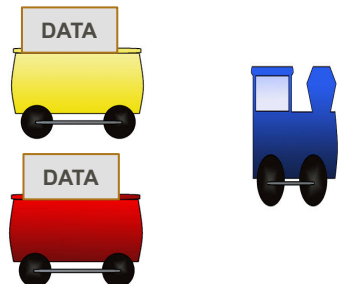


- Alternative 1: One custom register



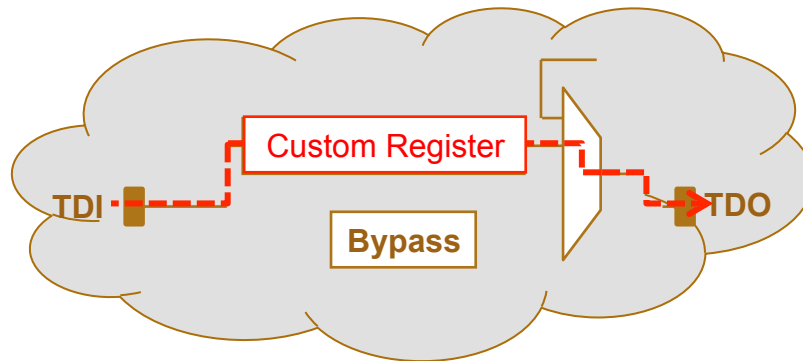
**Alternative 1:
All instruments are
always accessed**

- Alternative 2: One custom register per instrument



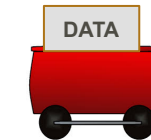
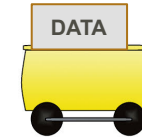
**Alternative 2:
Cannot access both
instruments at the
same time**

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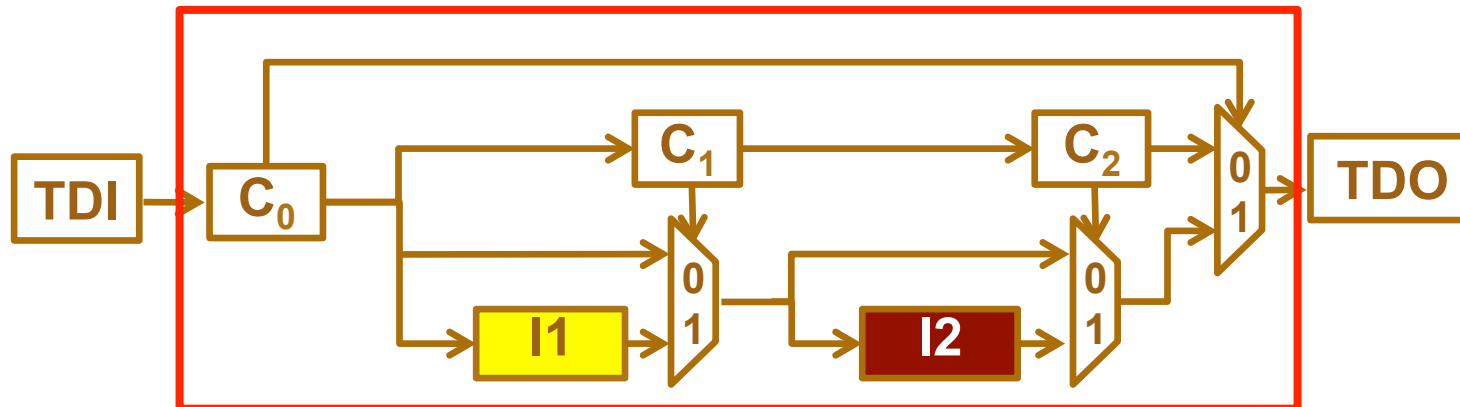


Instrument 1

Instrument 2

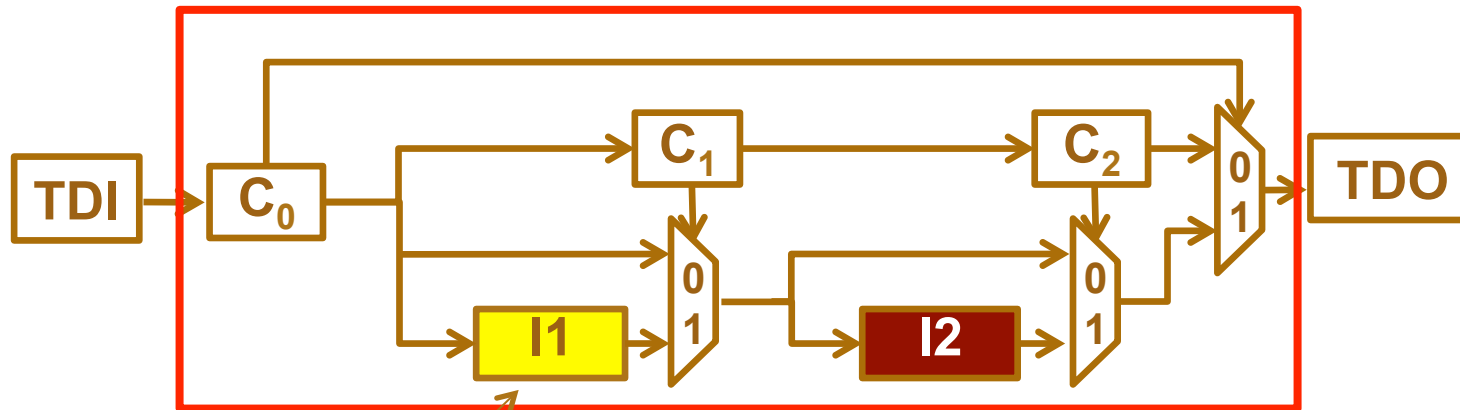


Custom Register



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Custom Register

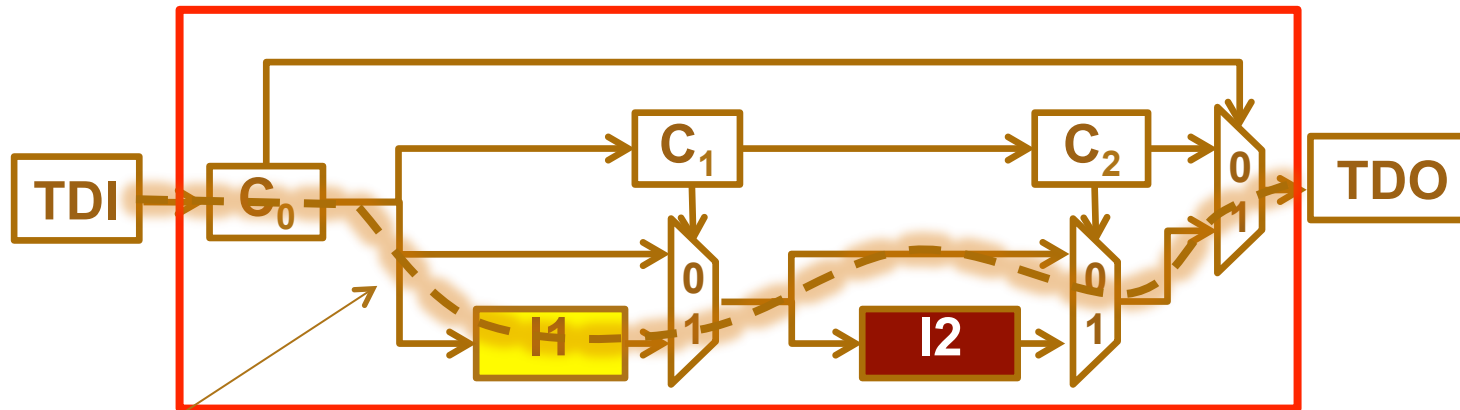


Access this instrument



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Custom Register

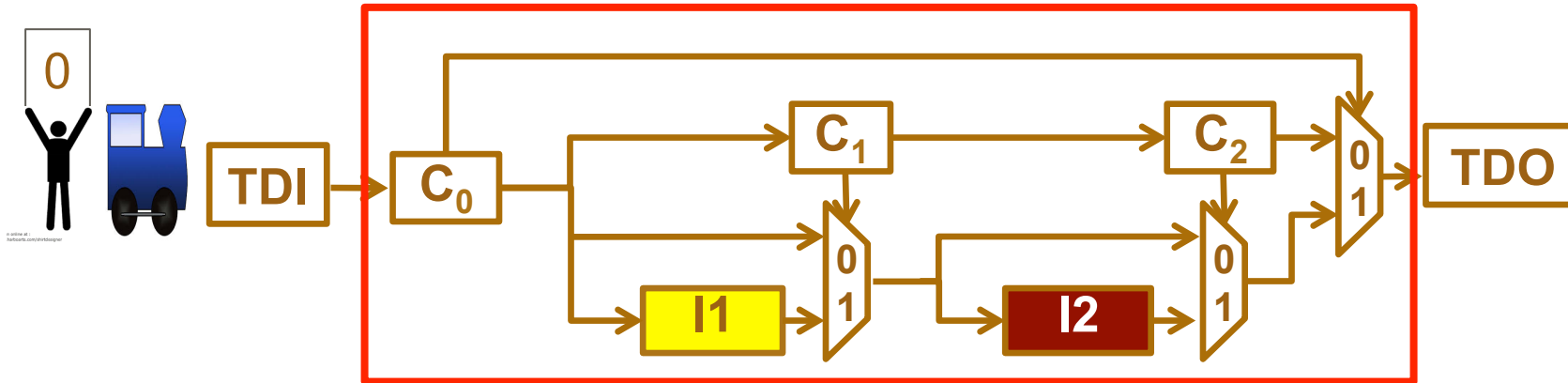


This scan-path
must be active



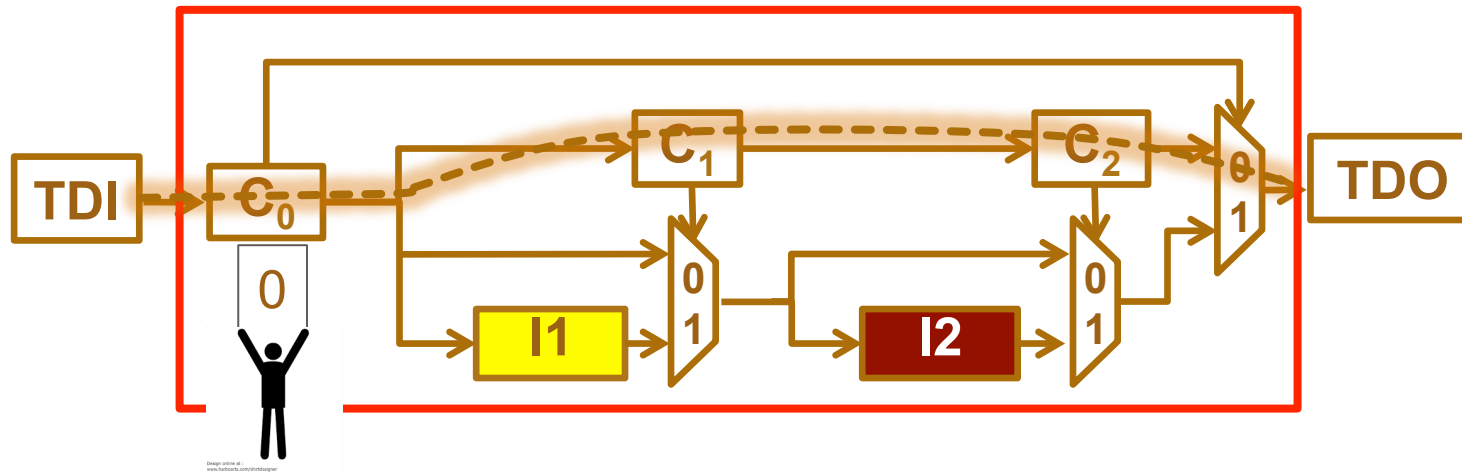
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Custom Register

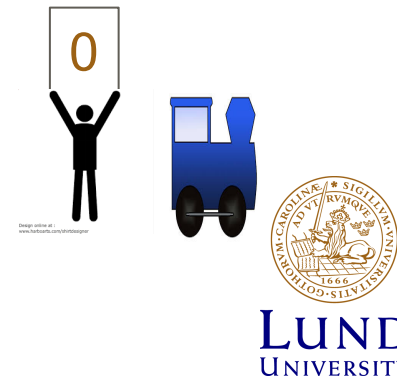


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Custom Register

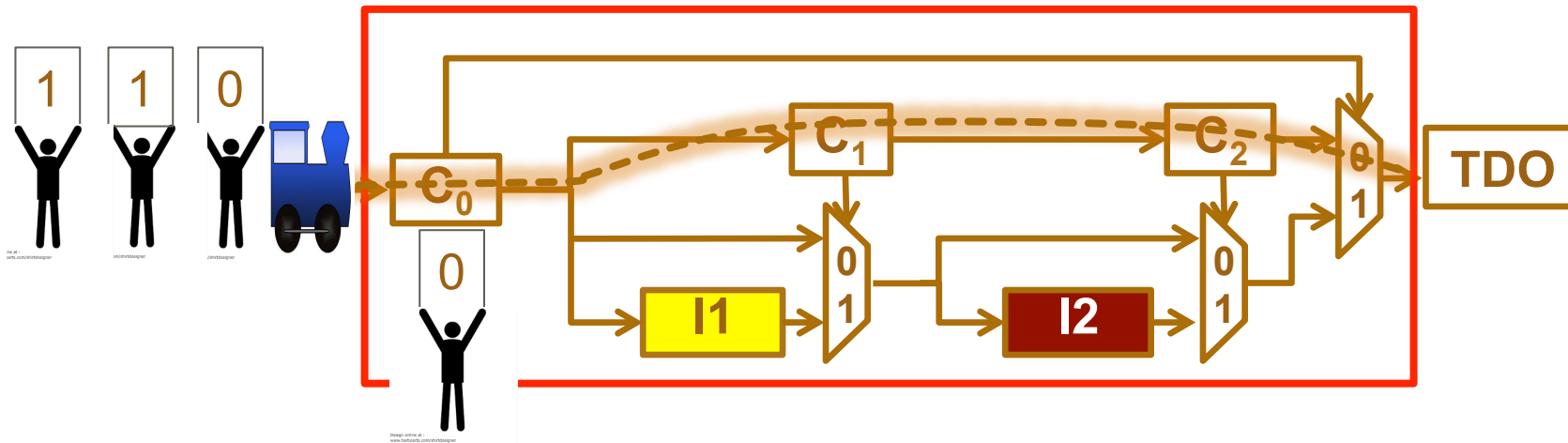


Train ride #1

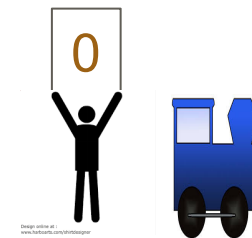


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Custom Register



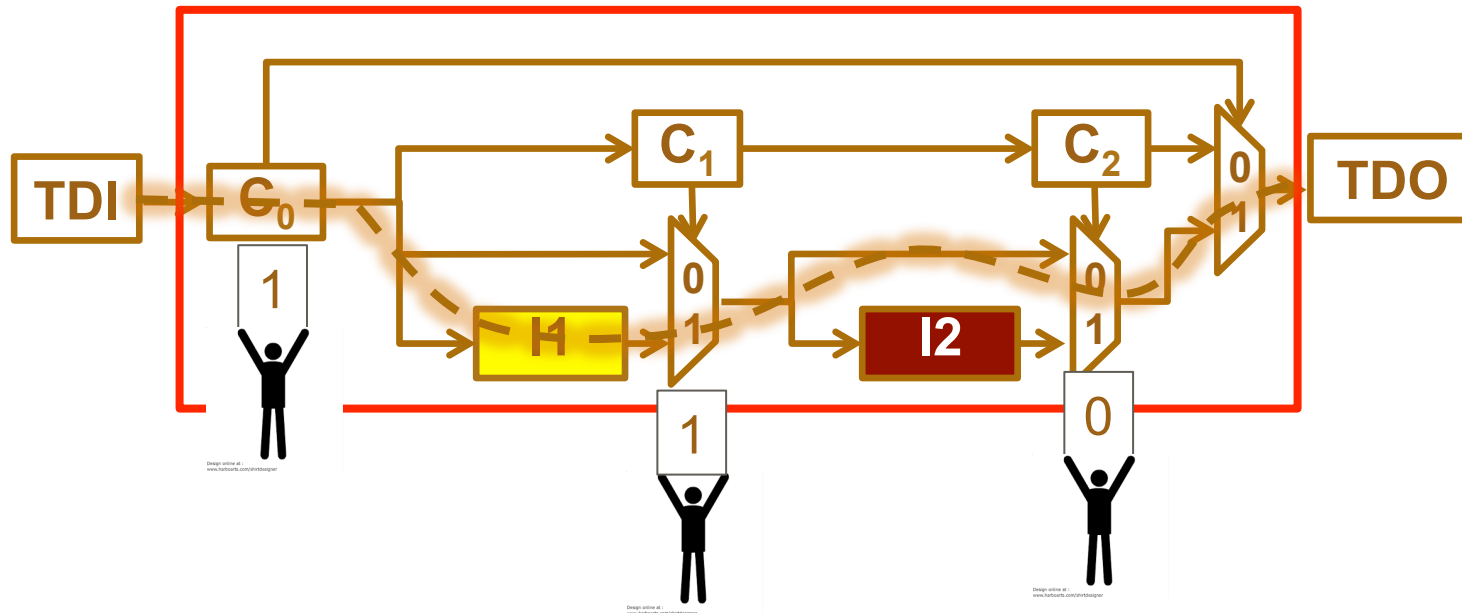
Train ride #1



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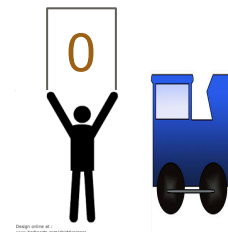
Custom Register



Train ride #2

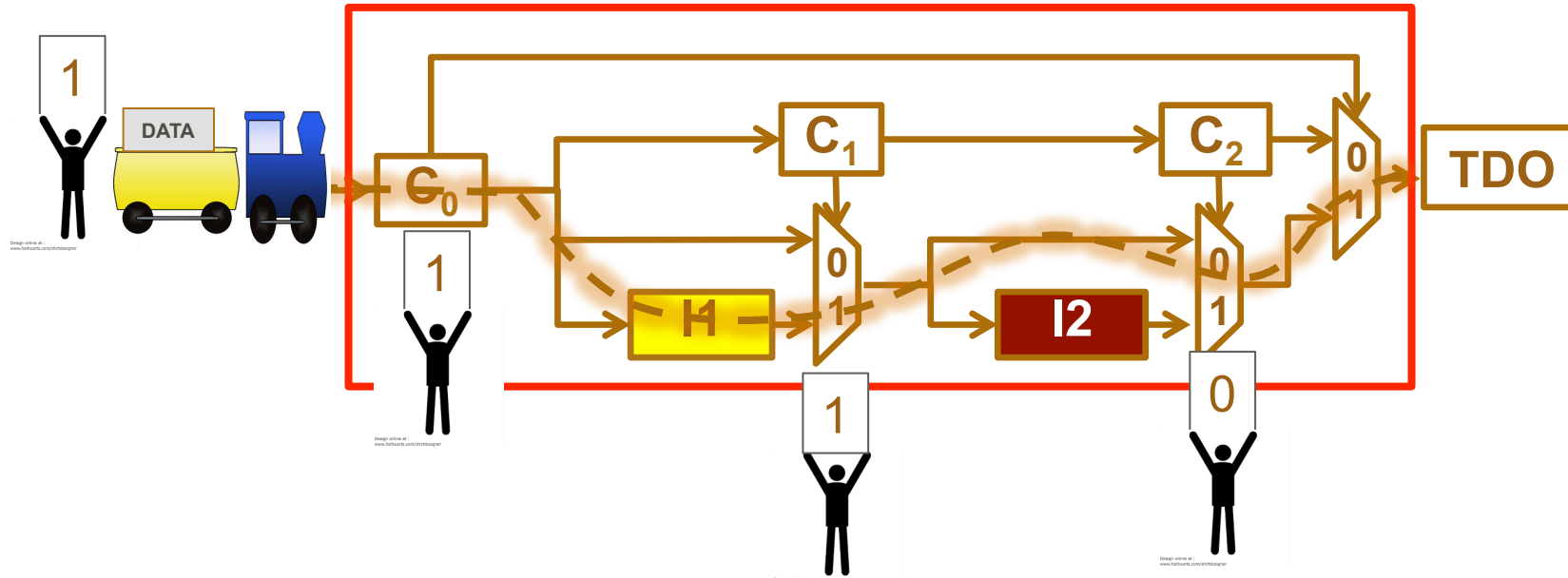


Train ride #1



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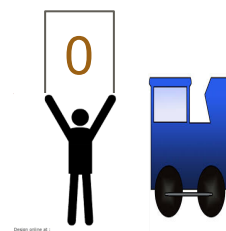
Custom Register



Train ride #2

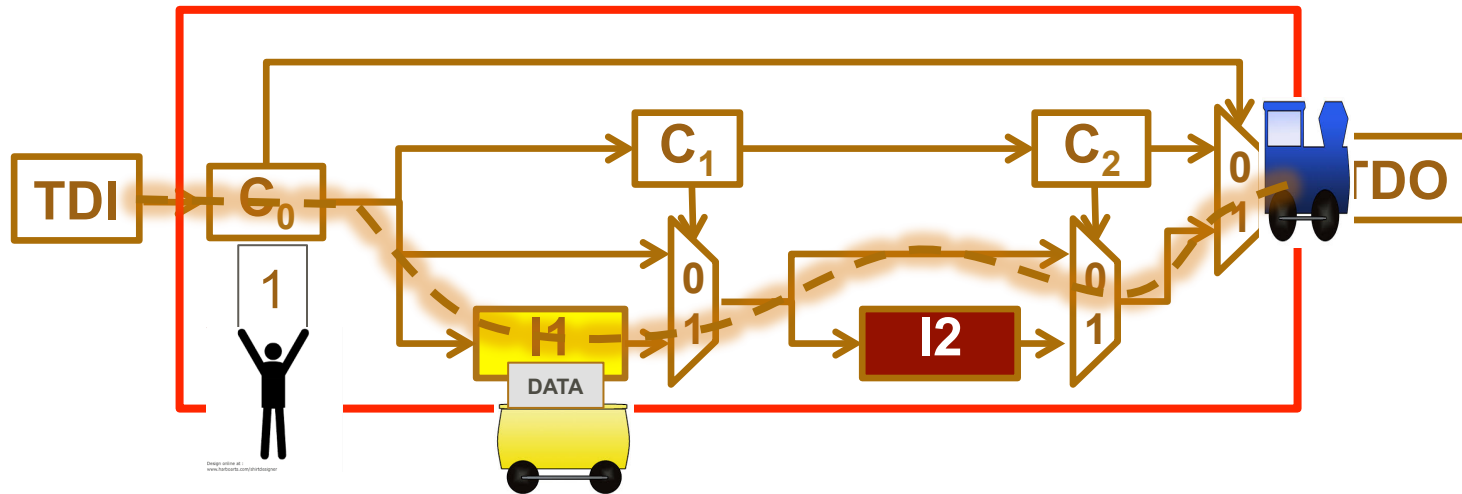


Train ride #1

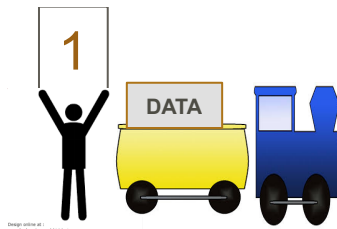


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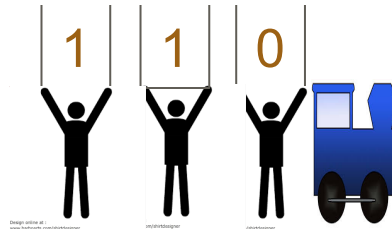
Custom Register



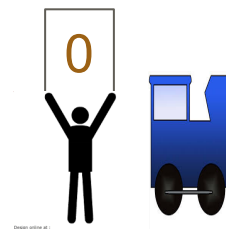
Train ride #3



Train ride #2

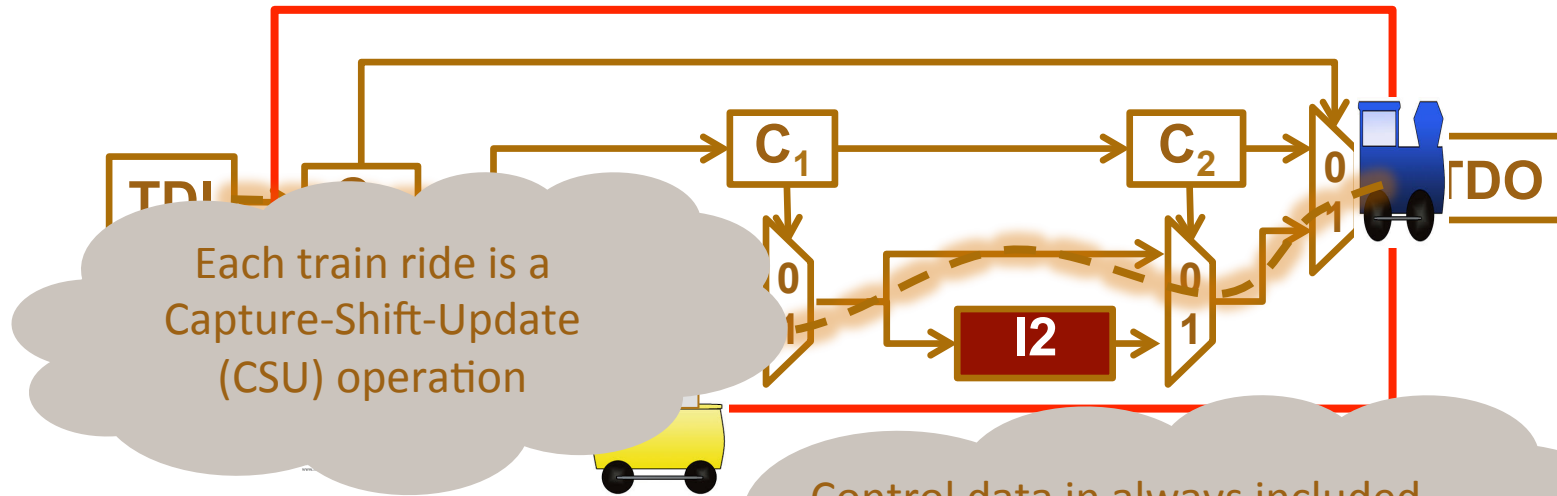


Train ride #1



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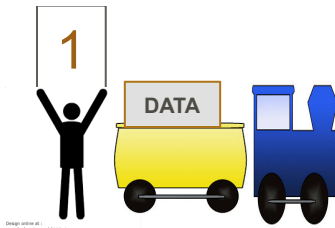
Custom Register



Control data is always included



Train ride #3

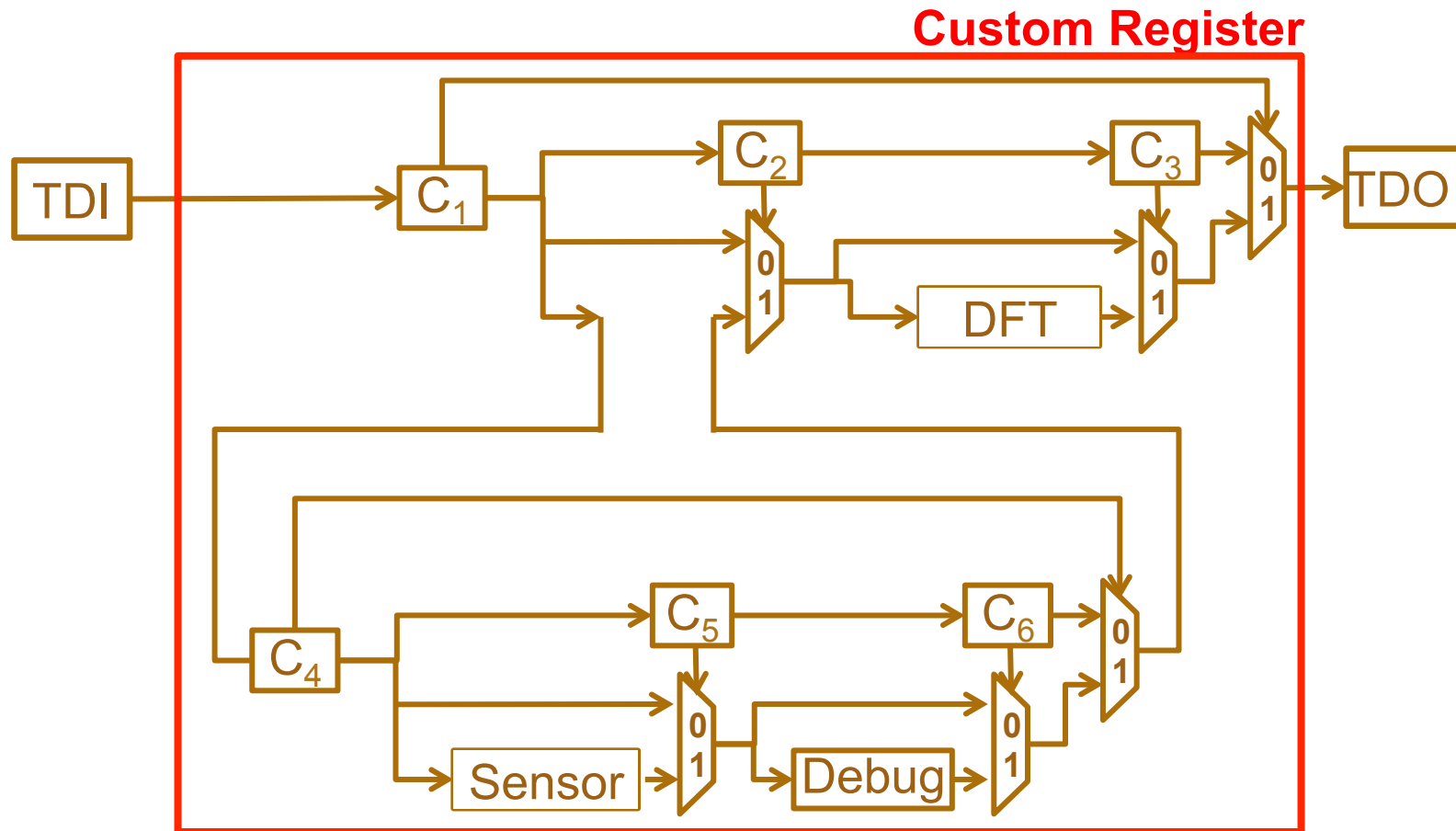


Train



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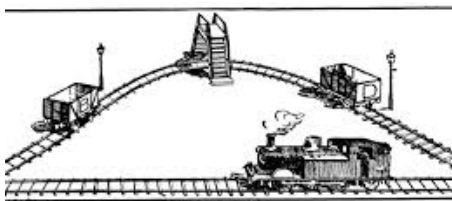
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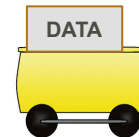
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- Introduced two languages:
 - Instrument Connectivity Language (ICL)
 - Procedural Description language (PDL)

ICL



PDL



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PDL

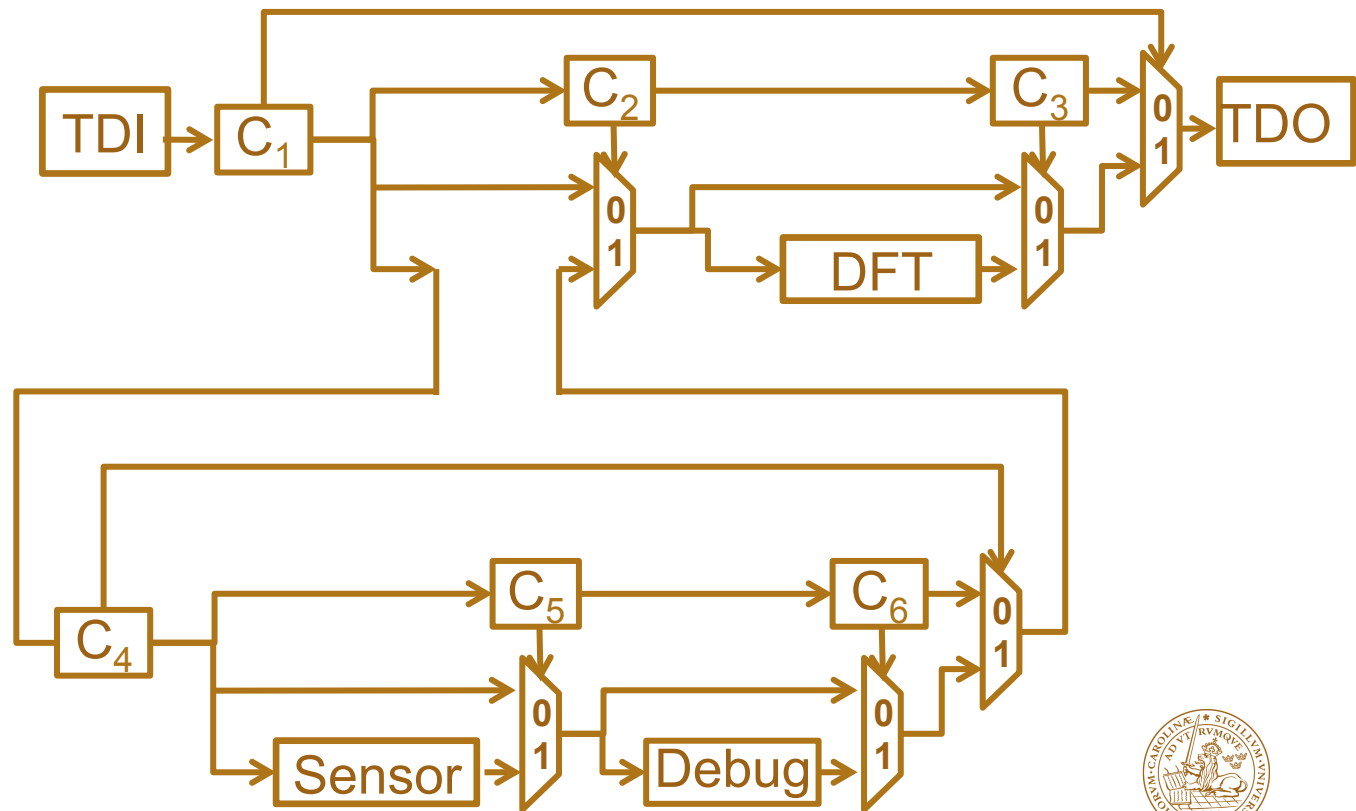
**iWrite DFT 0x01;
iApply;**

**iWrite DFT 0x1F;
iWrite Sensor 8;
iApply;**

**iRead DFT 0x80;
iApply;**

**iRead Sensor 1;
iApply;**

ICL



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PDL

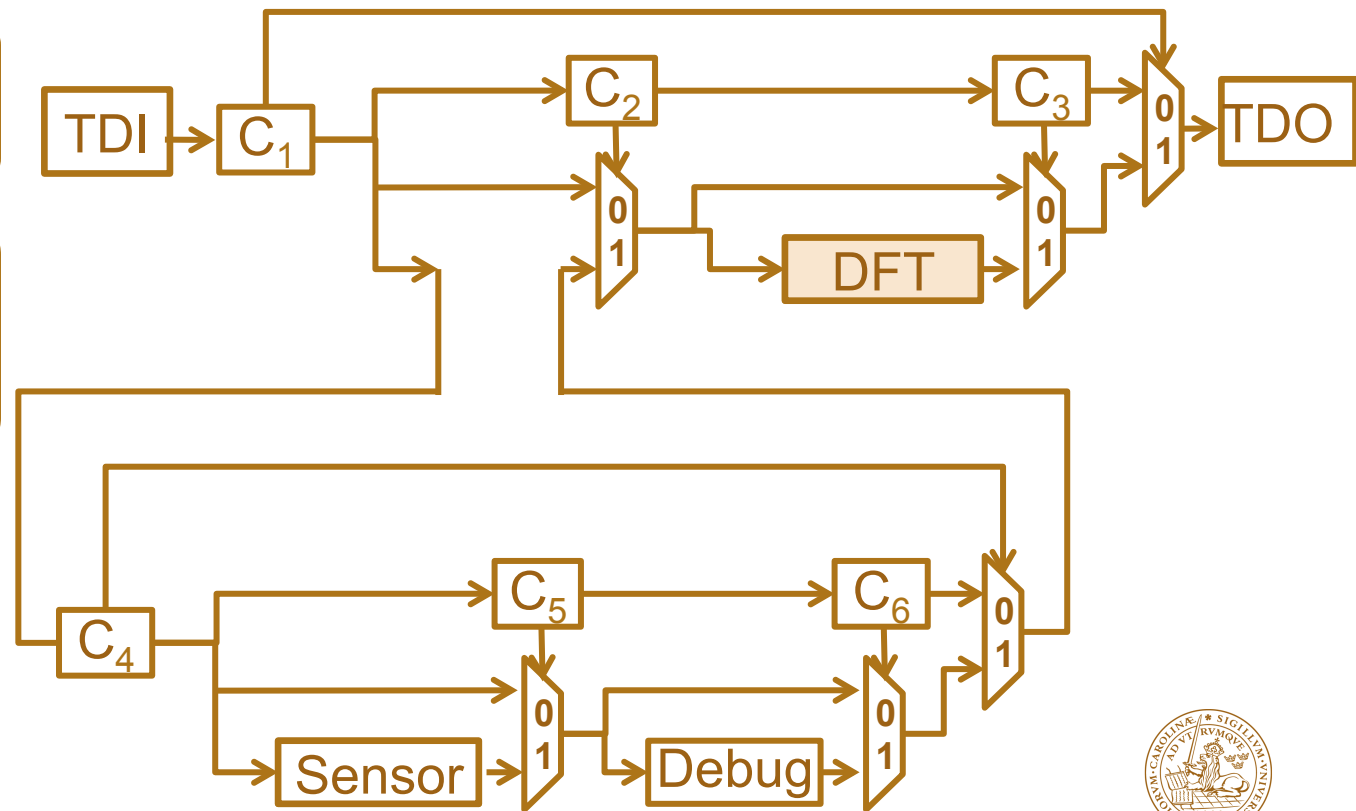
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ICL



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PDL

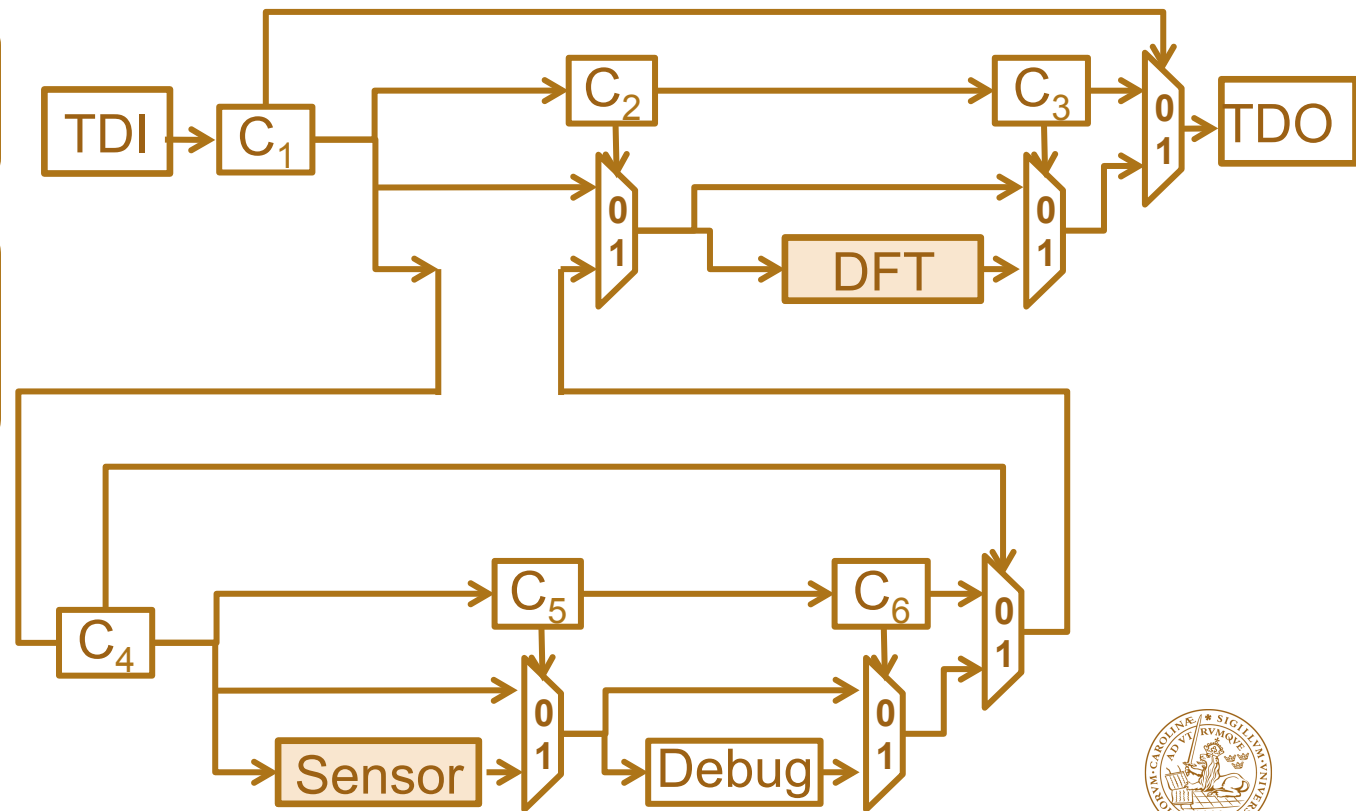
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iApply;**

ICL



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PDL

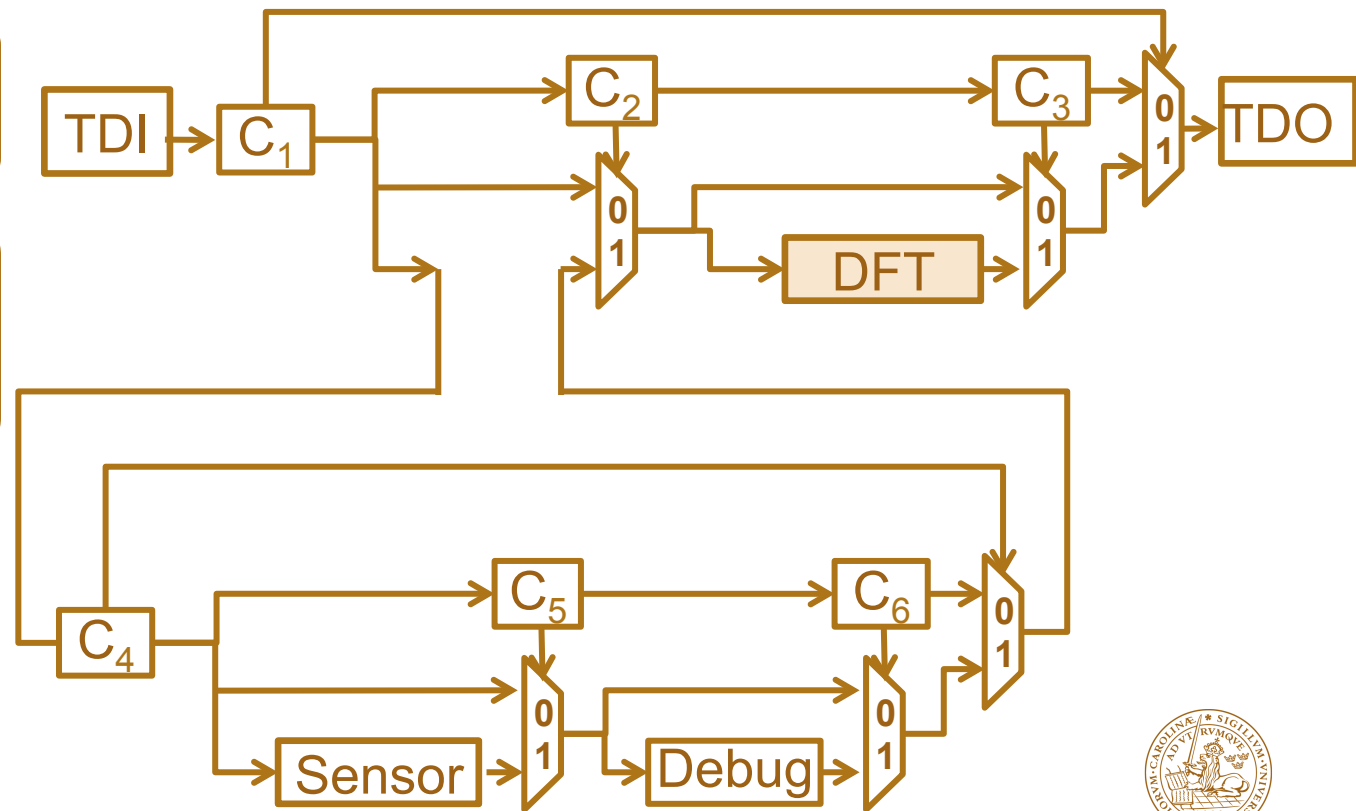
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ICL



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PDL

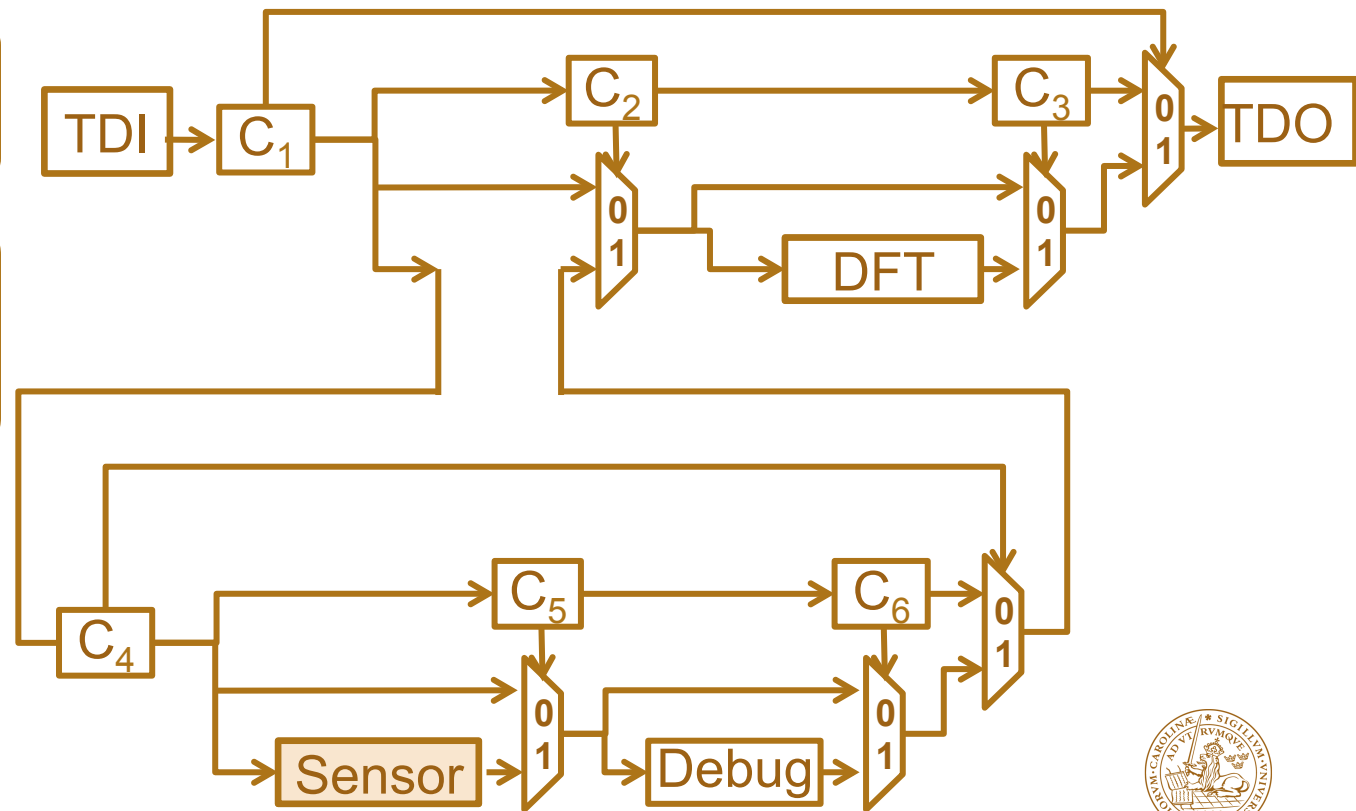
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ICL



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PDL

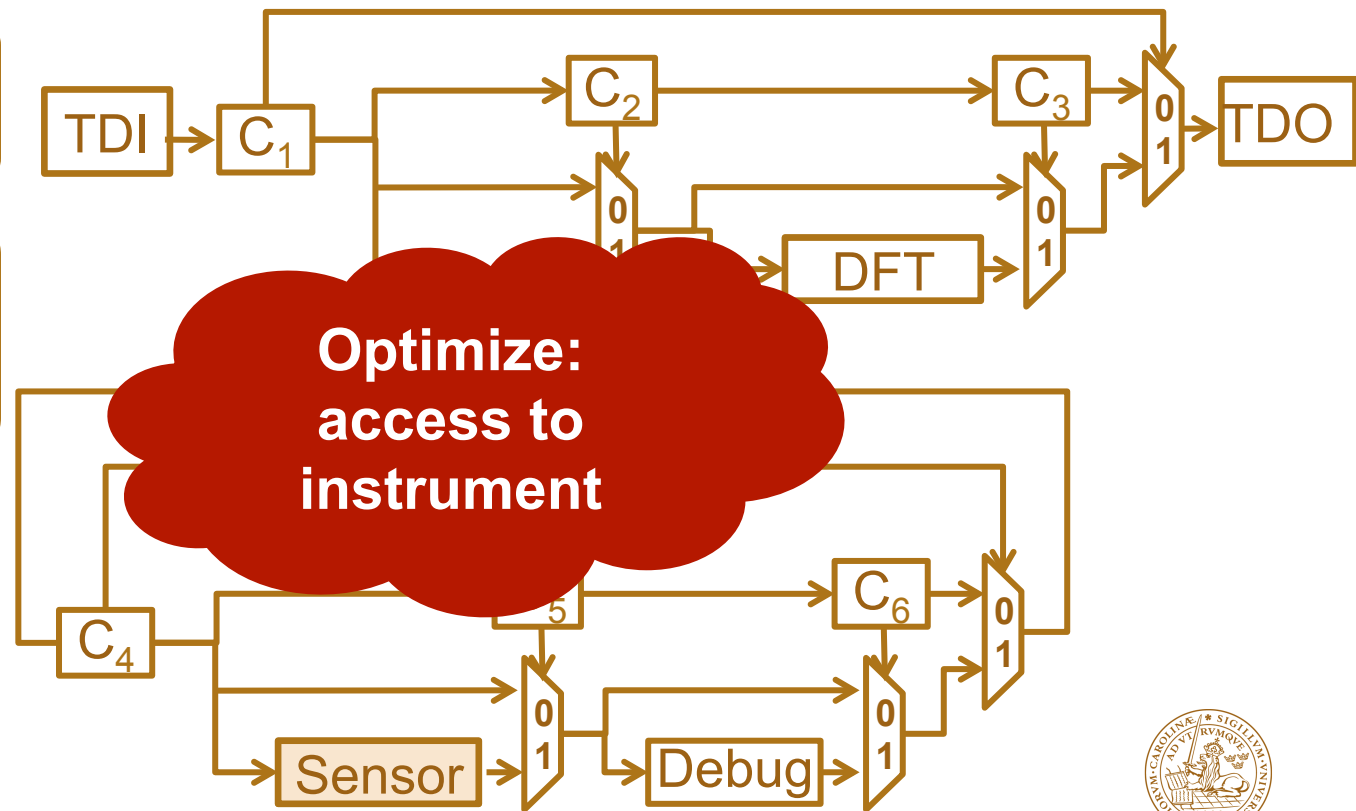
**iWrite DFT 0x01;
iApply;**

**iWrite DFT 0x1F;
iWrite Sensor 8;
iApply;**

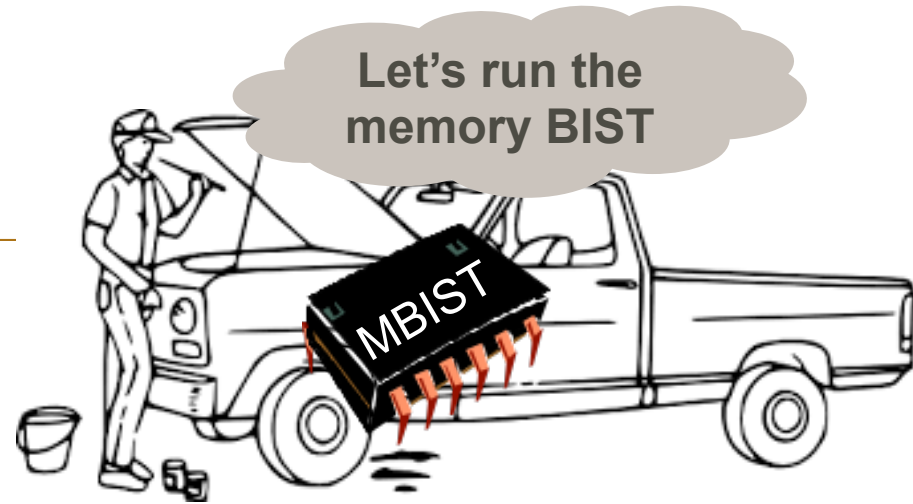
**iRead DFT 0x80;
iApply;**

**iRead Sensor 1;
iApply;**

ICL



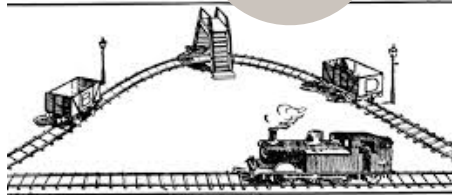
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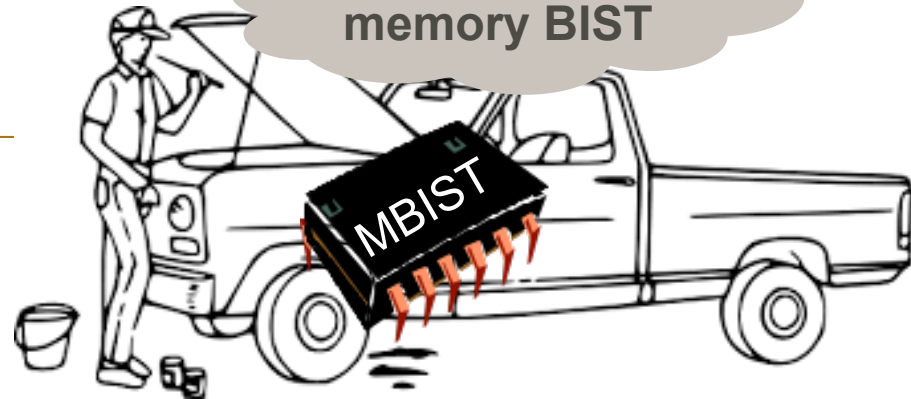
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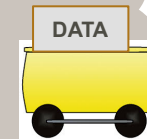
Give the description of how instruments are connected (ICL)



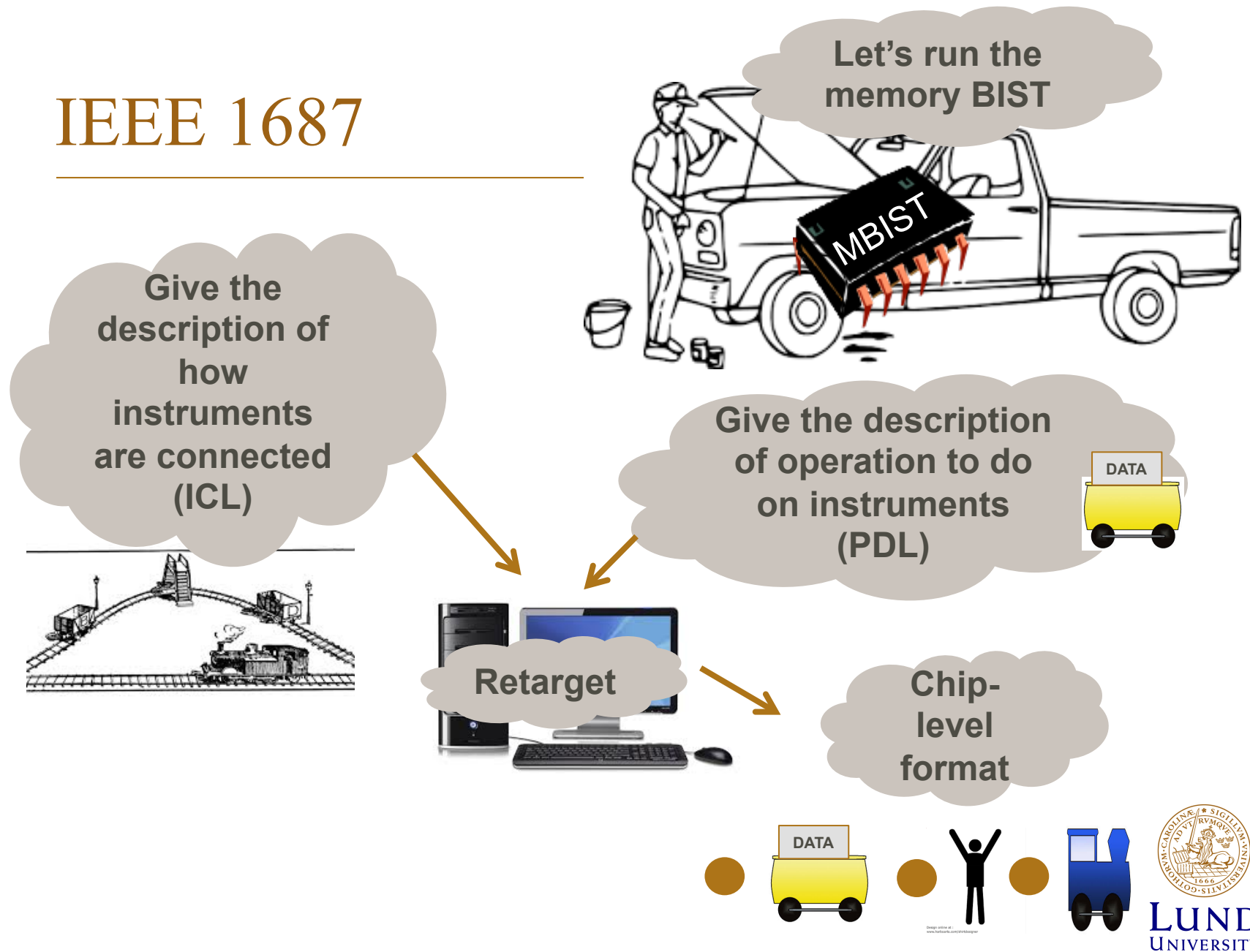
Let's run the memory BIST



Give the description of operation to do on instruments (PDL)

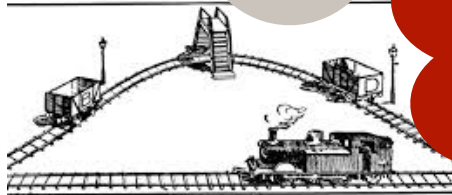


IEEE 1687



IEEE 1687

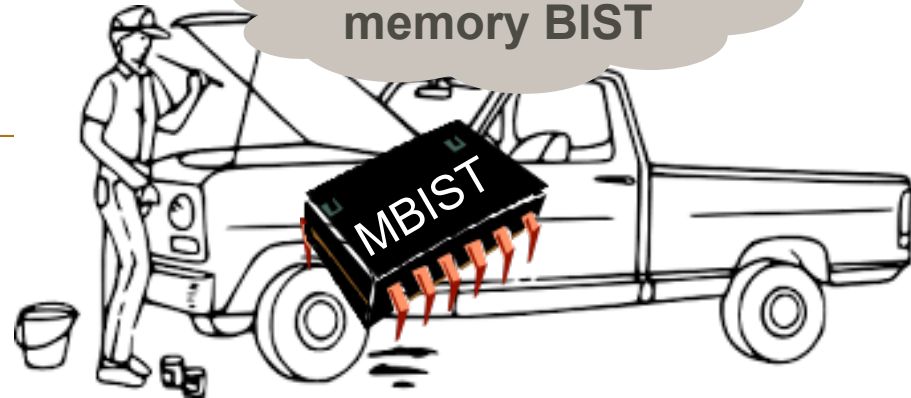
Give him the description of how instruments are connected (ICL)



IC manufacturer:
not sure I want to enable access, at least not to everything

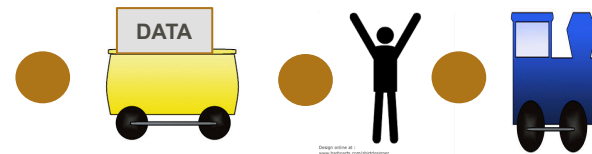


Let's run the memory BIST



Give him the description of how to do on (PDL)

Chip-level format



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PDL

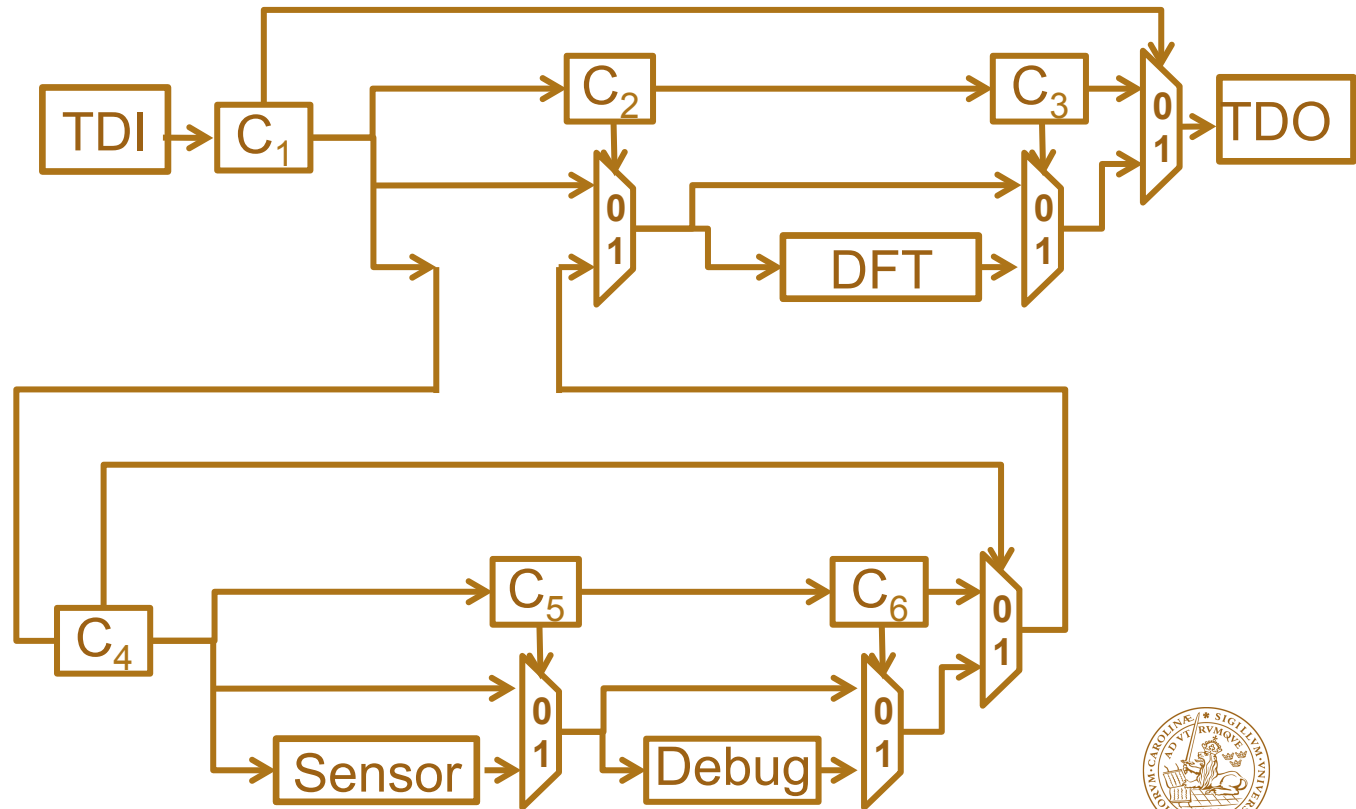
**iWrite DFT 0x01;
iApply;**

**iWrite DFT 0x1F;
iWrite Sensor 8;
iApply;**

**iRead DFT 0x80;
iApply;**

**iRead Sensor 1;
iApply;**

ICL



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PDL

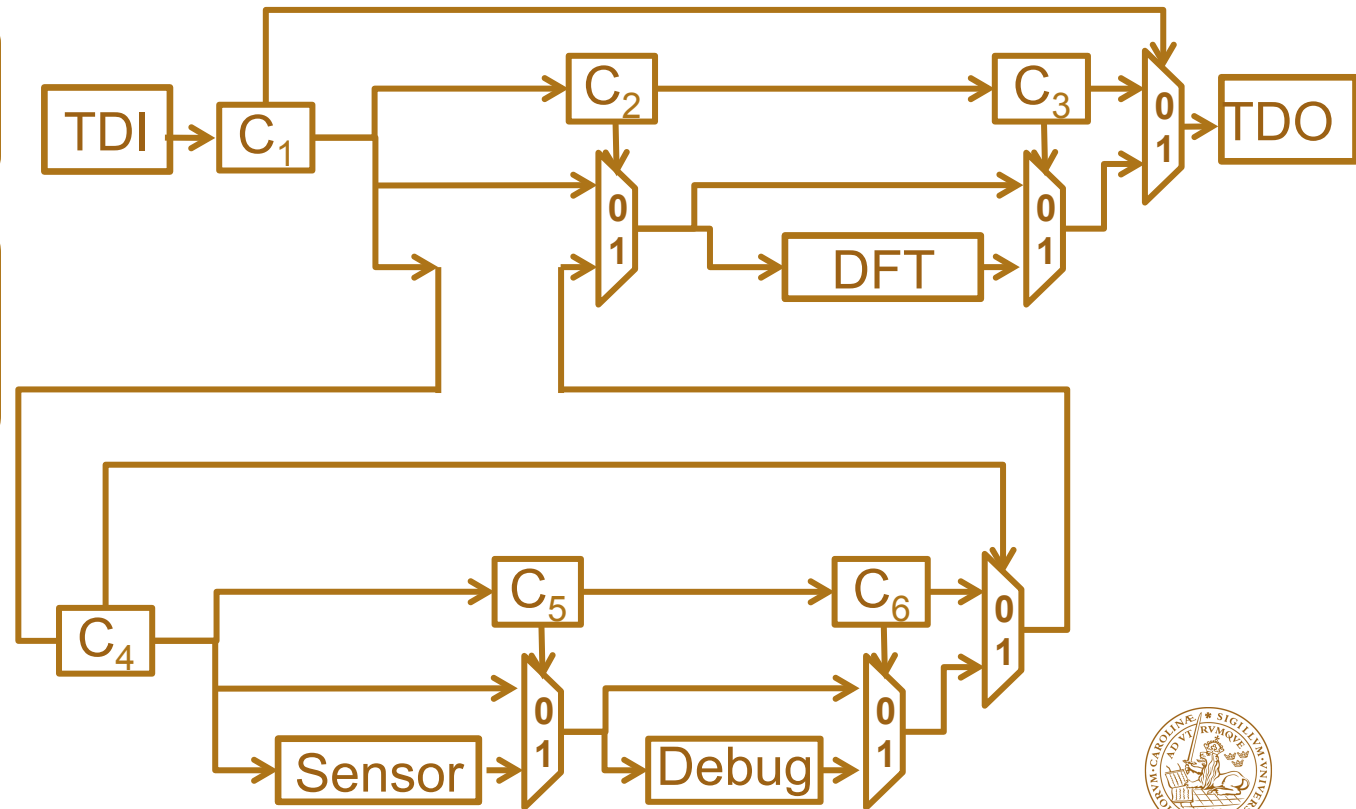
**iWrite DFT 0x01;
iApply;**

**iWrite DFT 0x1F;
iWrite Sensor 8;
iApply;**

**iRead DFT 0x80;
iApply;**

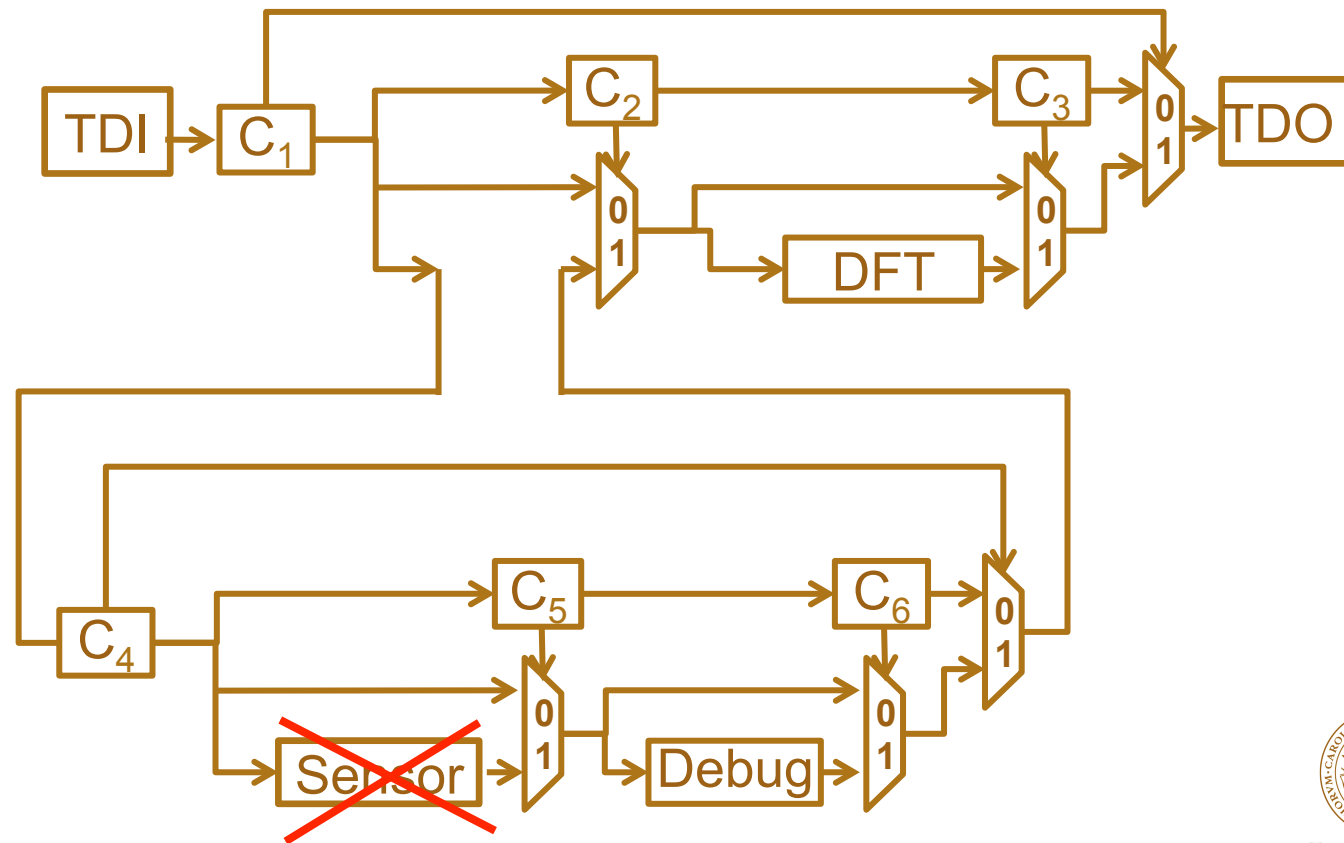
~~**iRead Sensor 1;
iApply;**~~

ICL



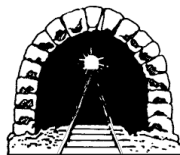
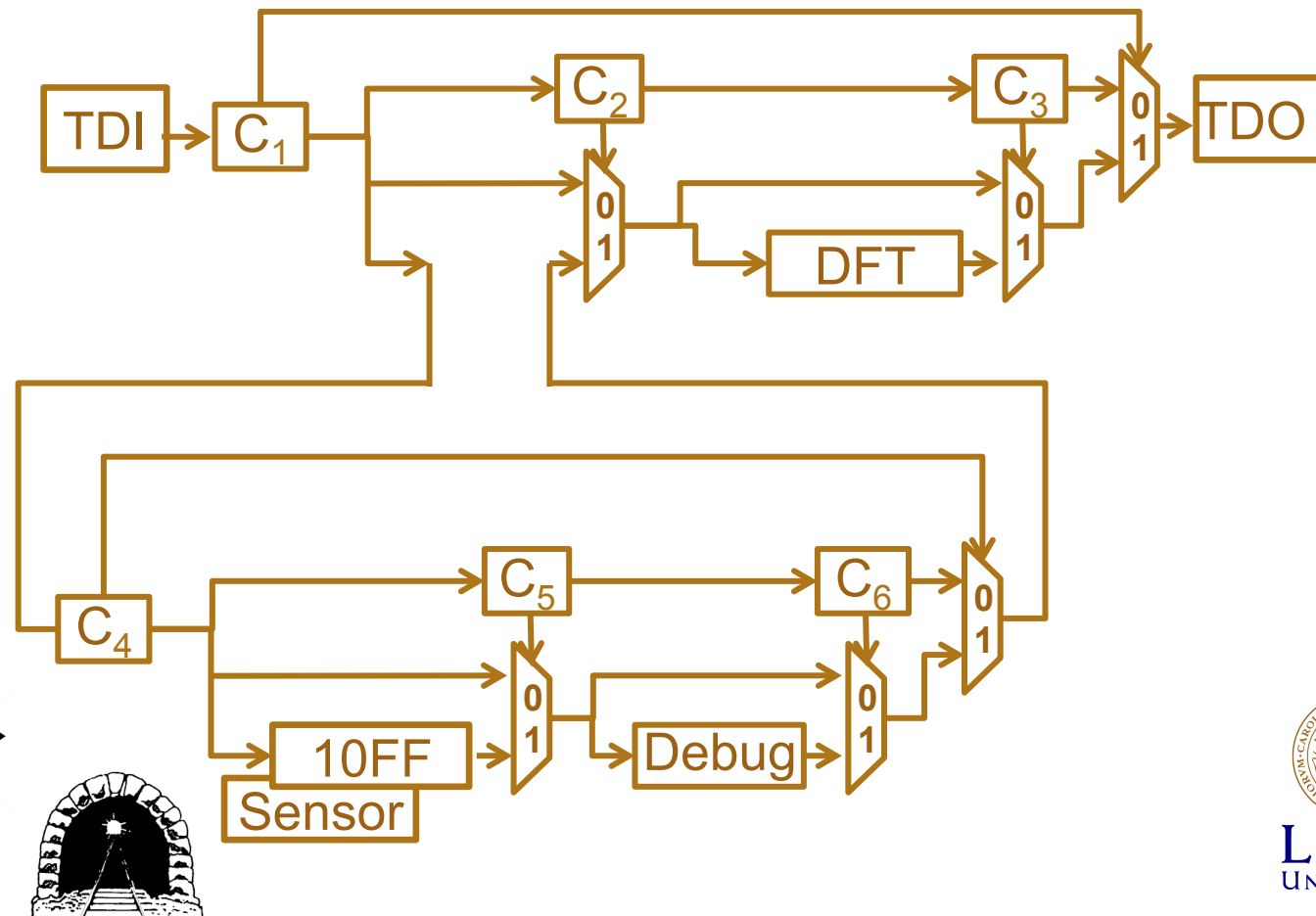
IEEE 1687

ICL



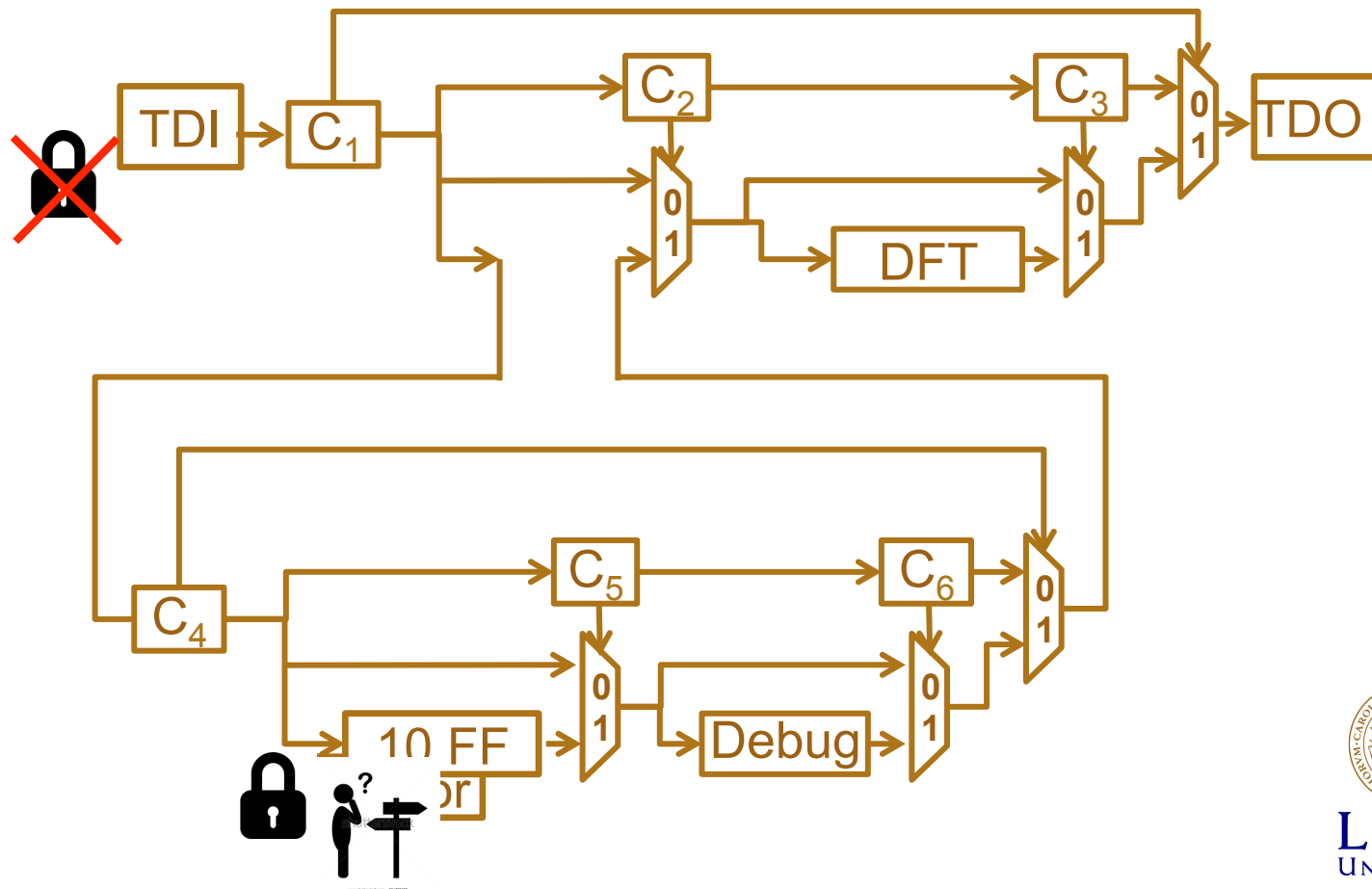
IEEE 1687

ICL



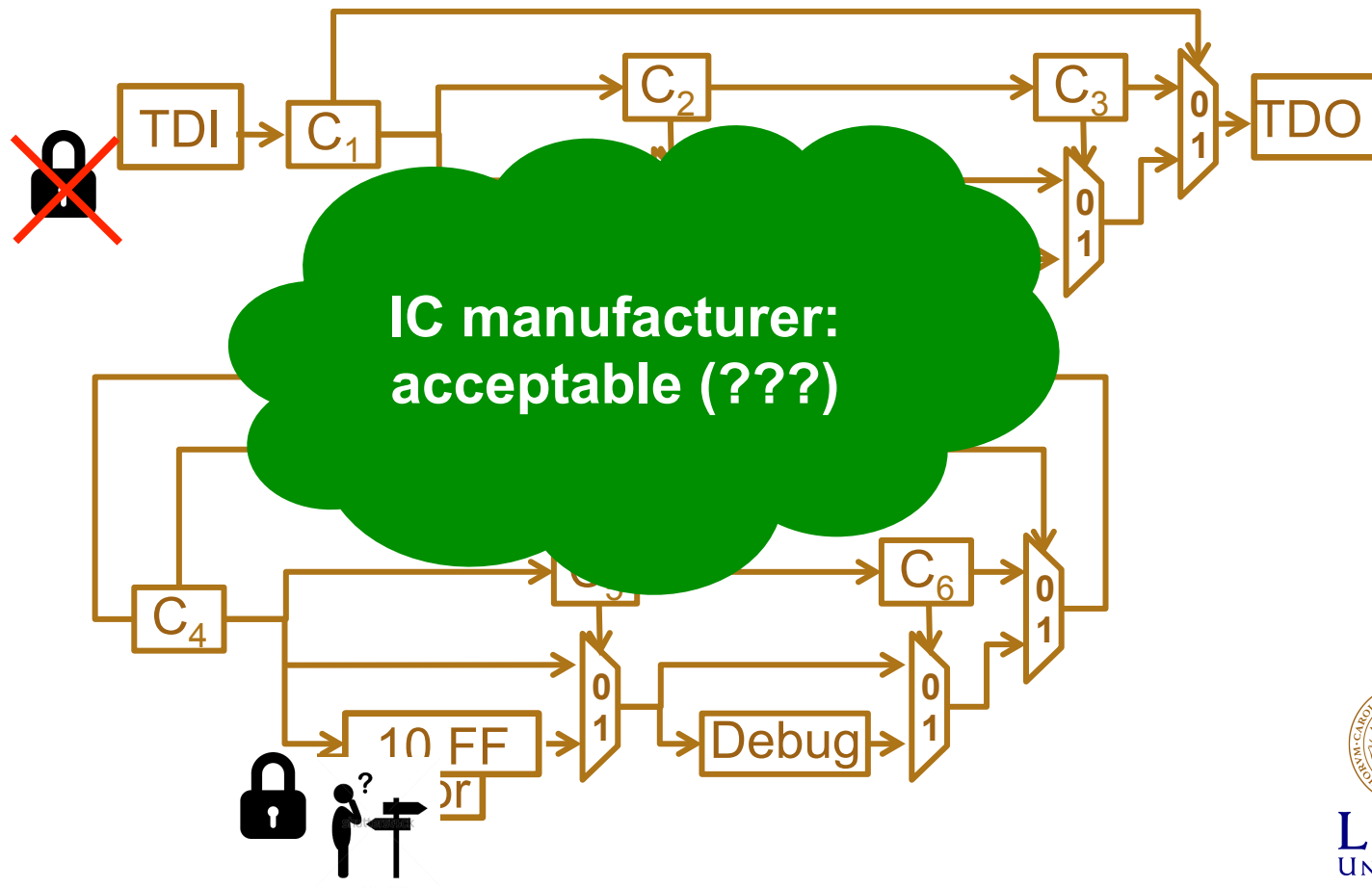
IEEE 1687

ICL

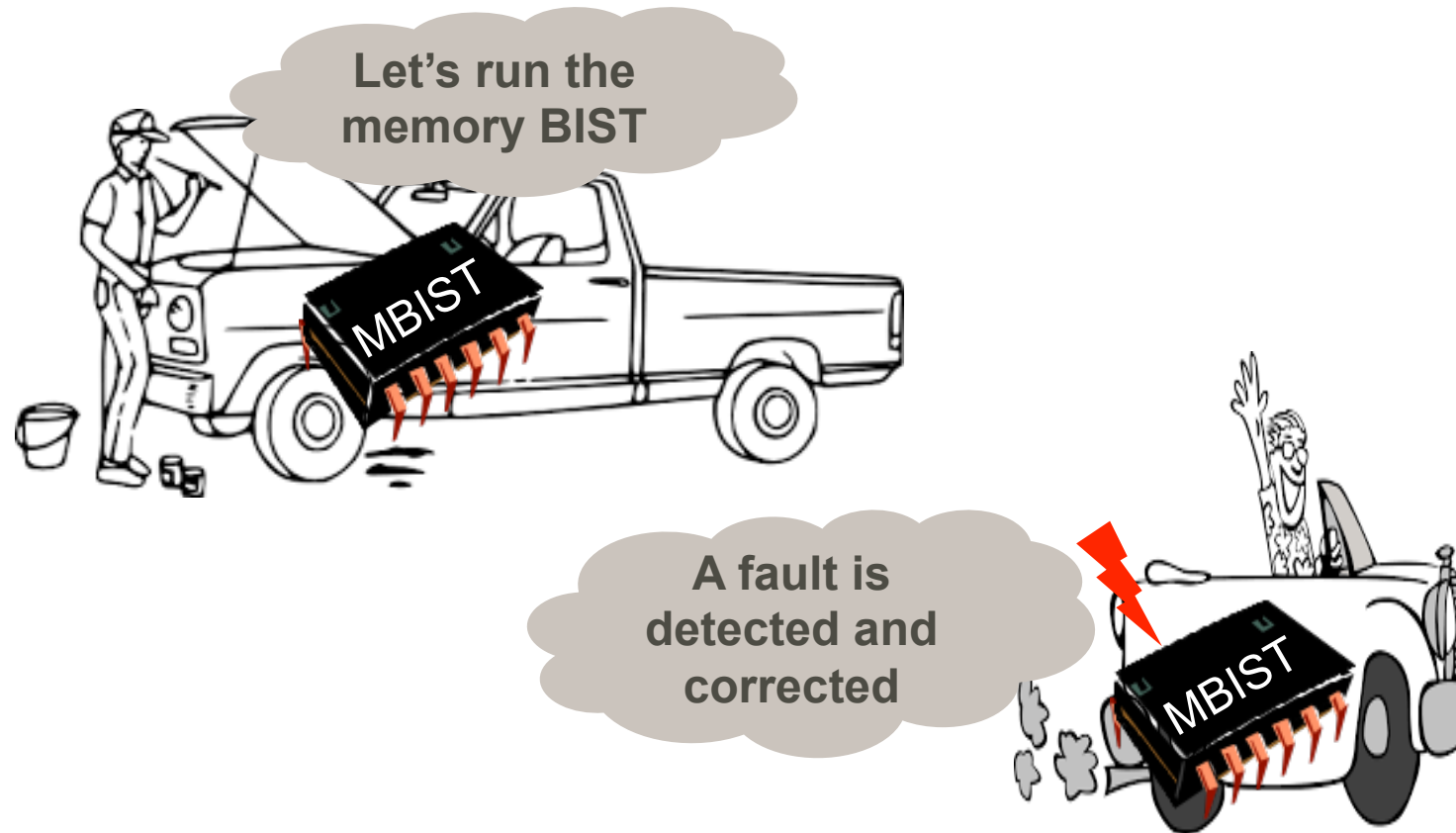


IEEE 1687

ICL



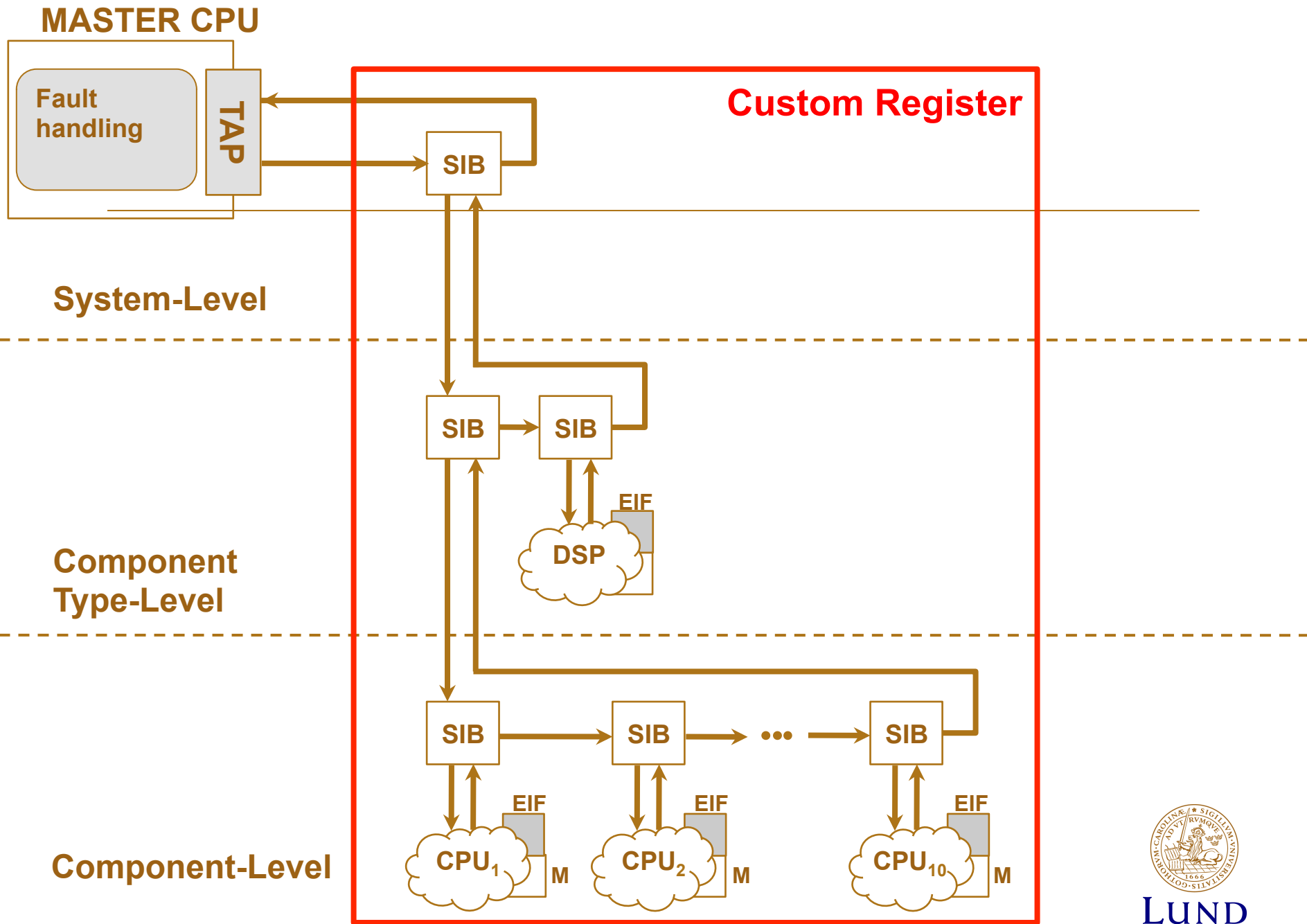
IEEE 1687 for Reliability (In-Situ)

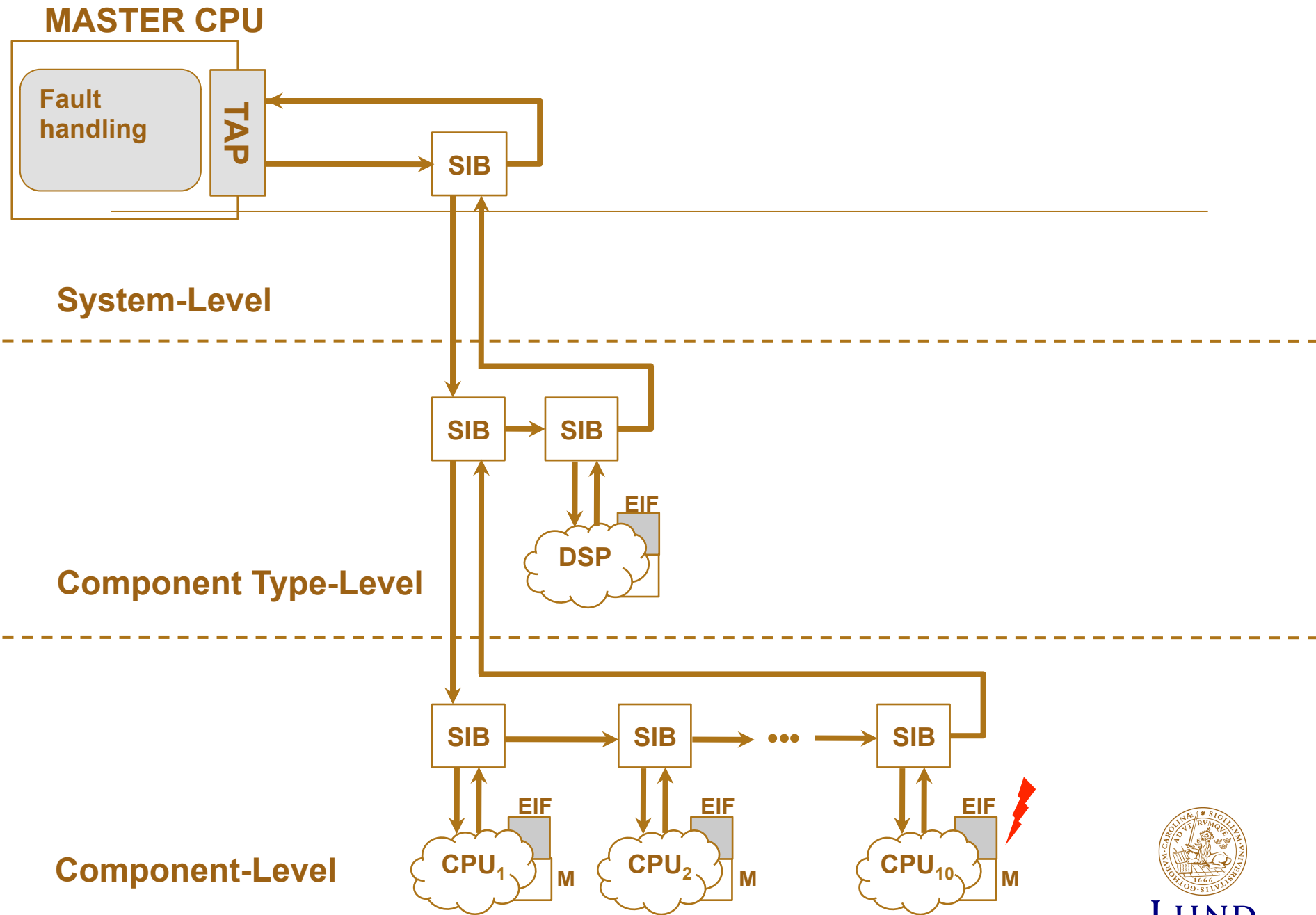


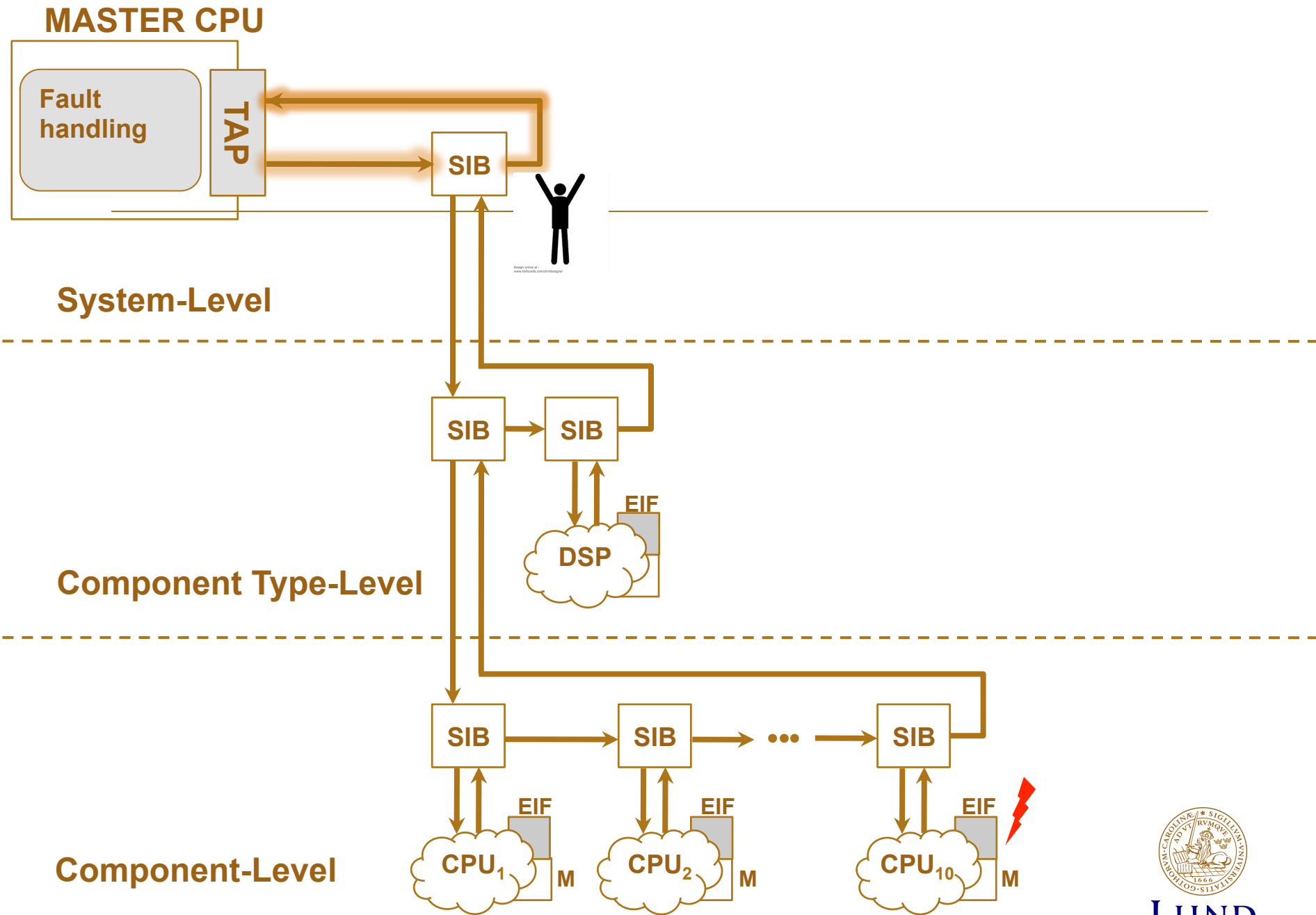
Infrastructure for Fault Handling?

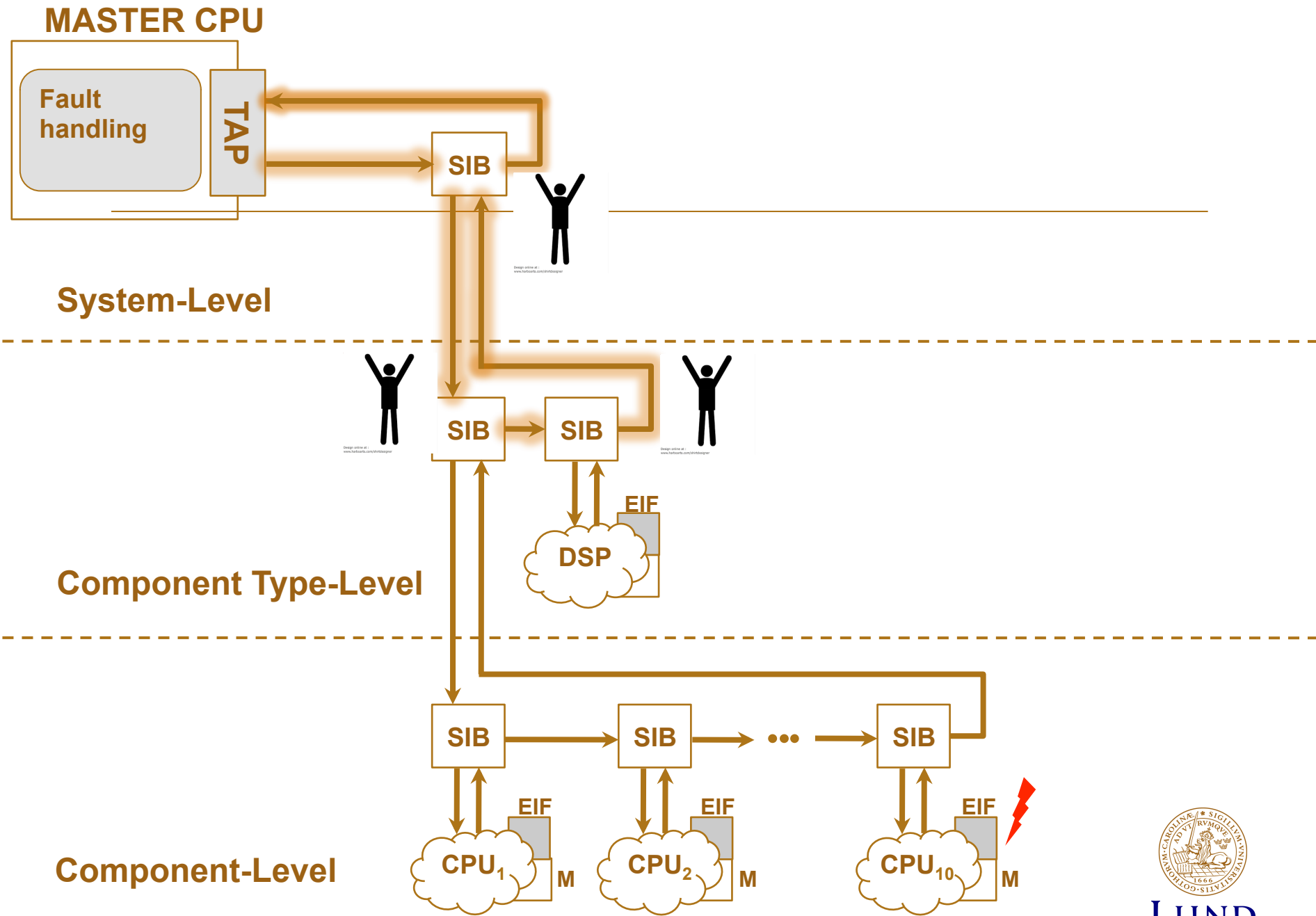
- Functional infrastructure
 - No extra cost, as it already exists, but adding fault handling traffic can degrade performance, both the functional and the fault handling. Predictability might be damaged as it is difficult to know when faults occur.
- Stand-alone infrastructure
 - Adds an extra cost, unless an existing infrastructure such as IEEE 1687 is reused, but is IEEE 1687 good enough in terms of time to:
 - » Detect that faults have occurred
 - » Localize where the faults are

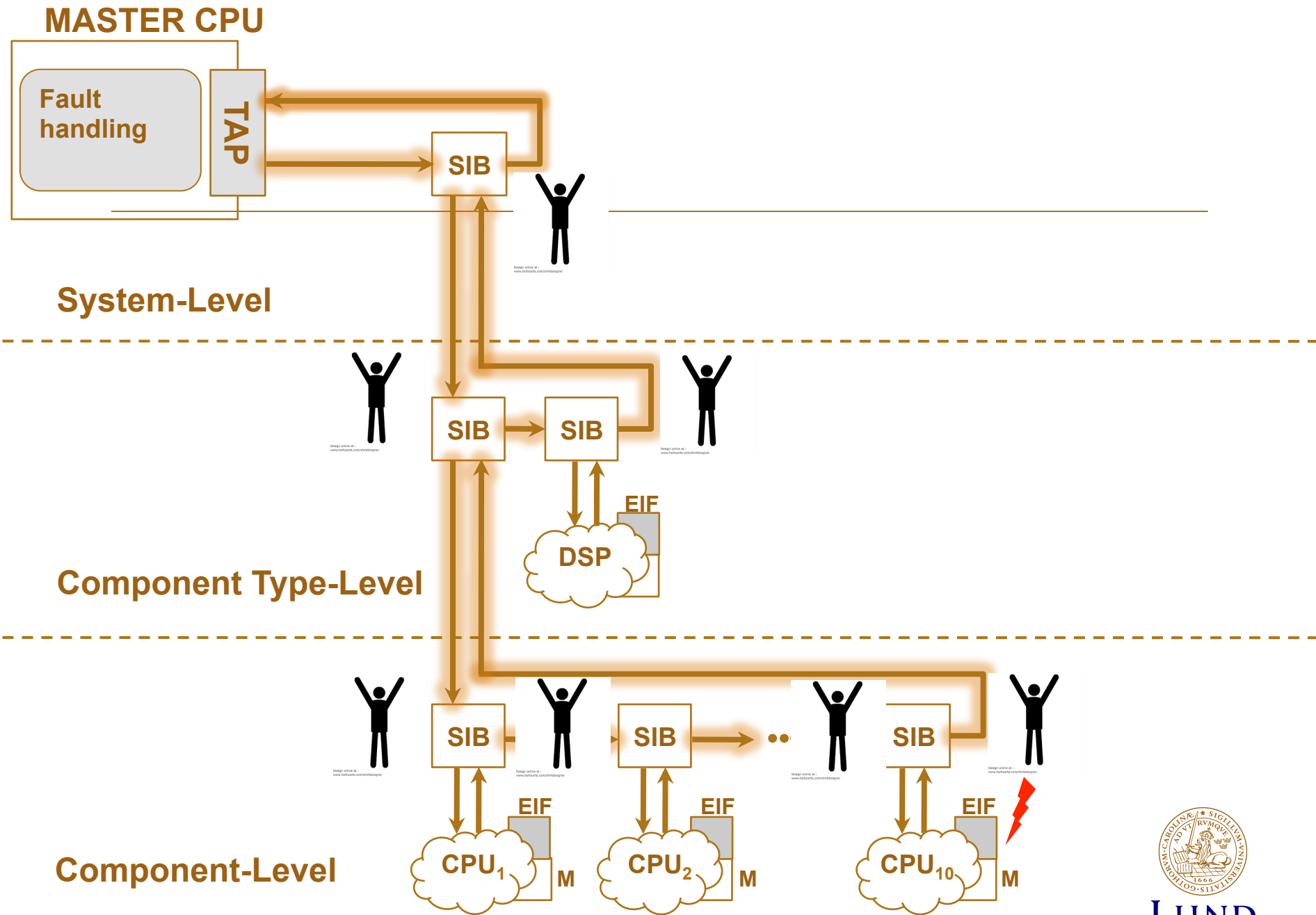


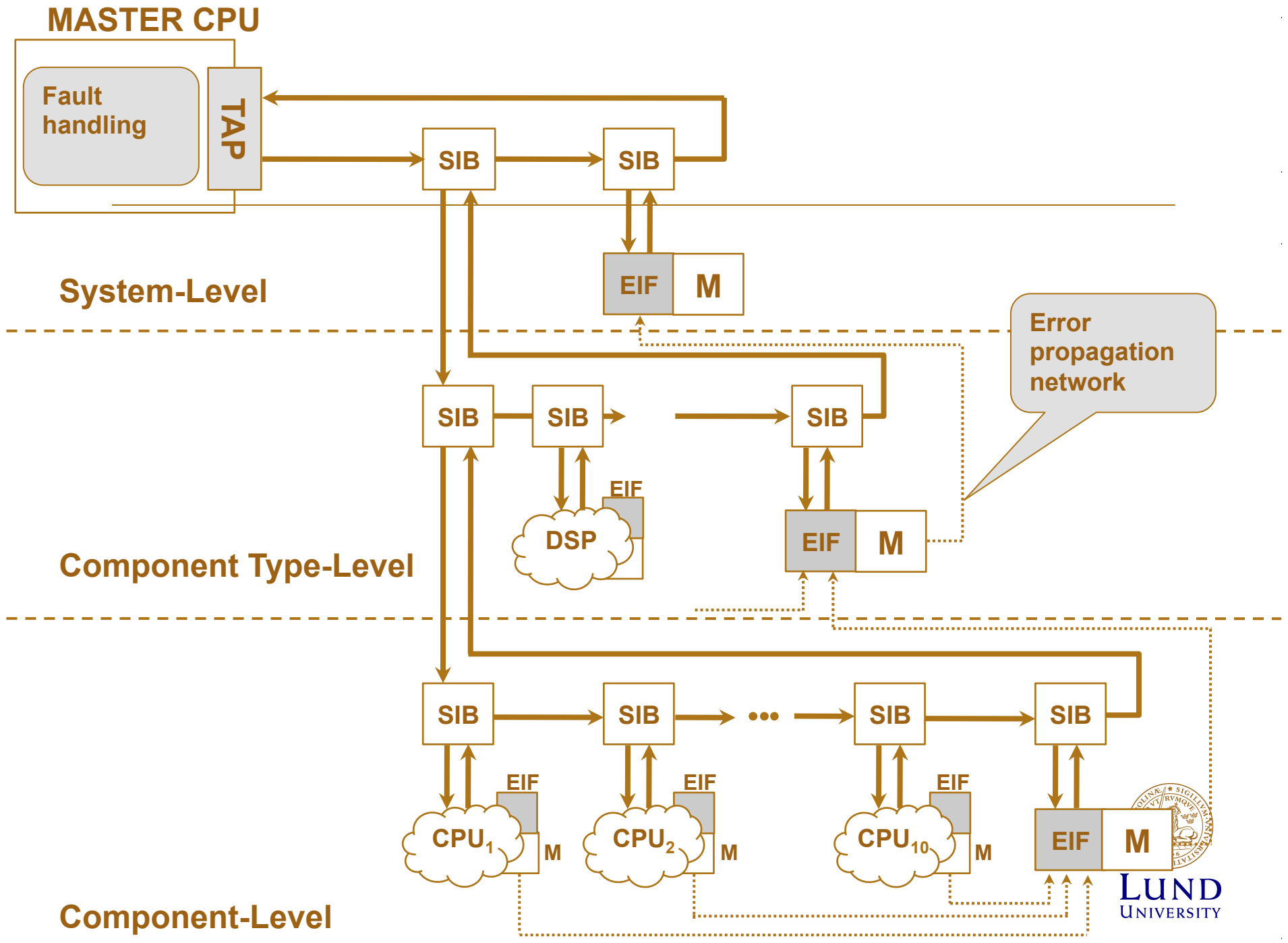


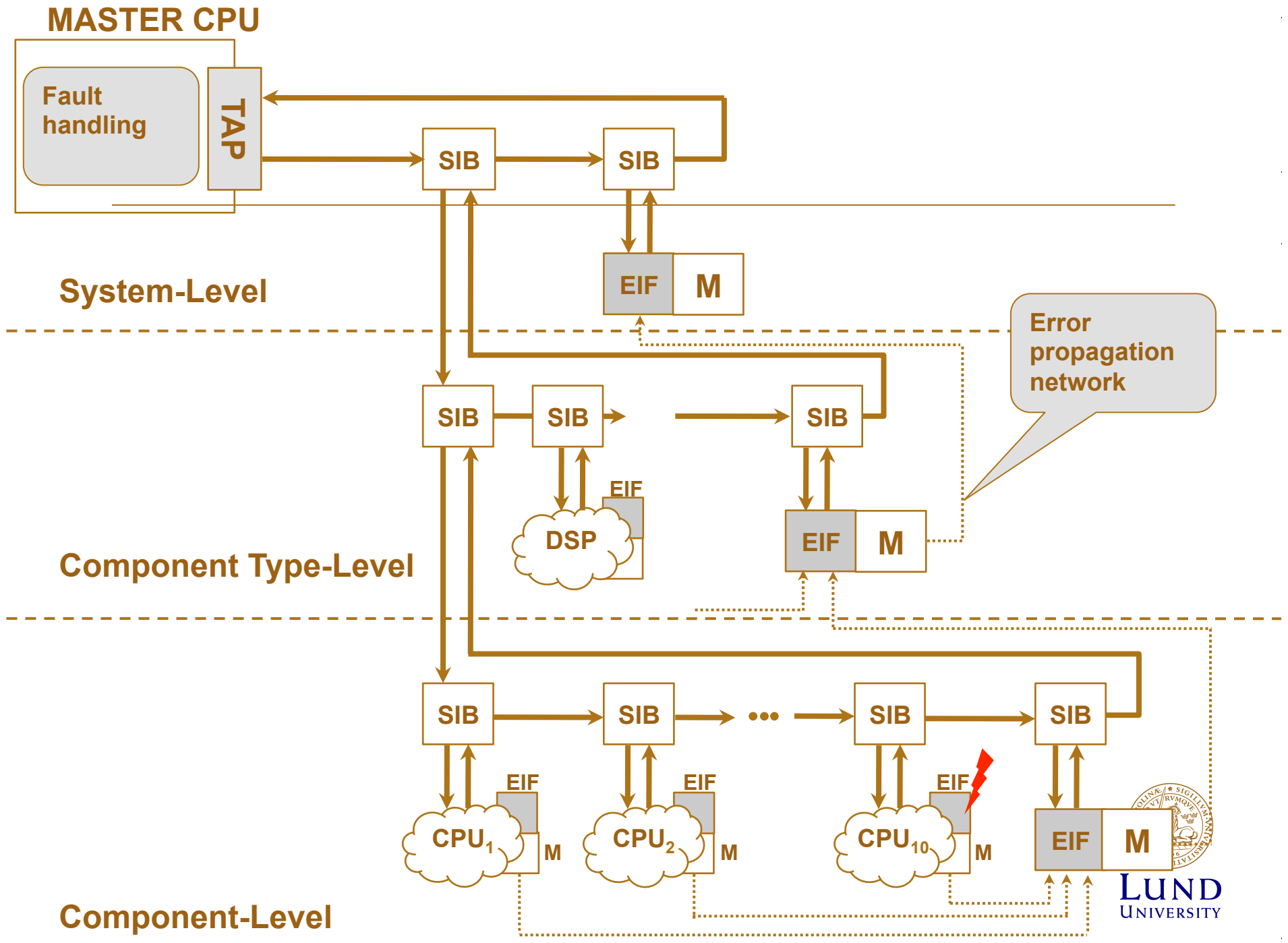


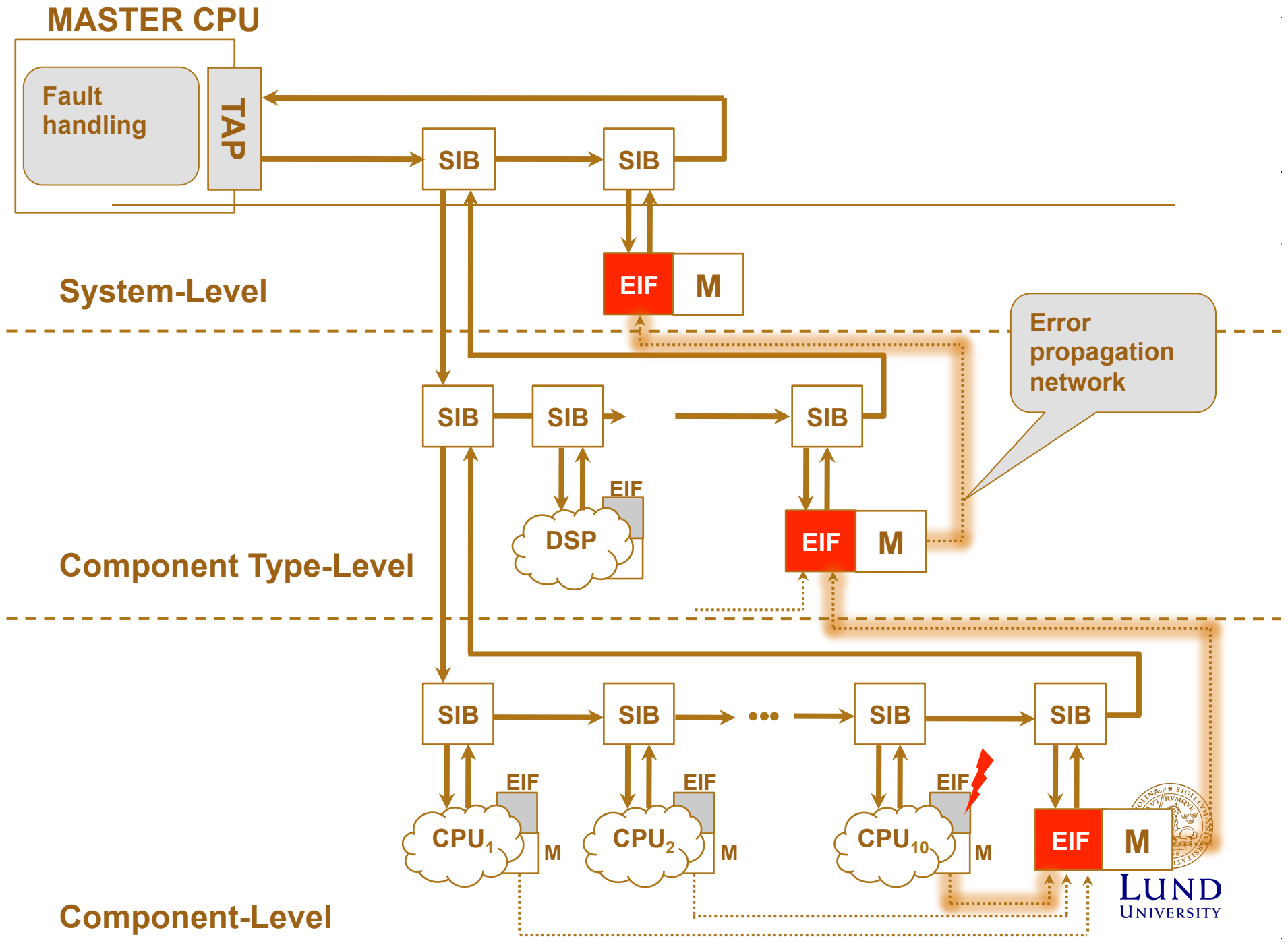


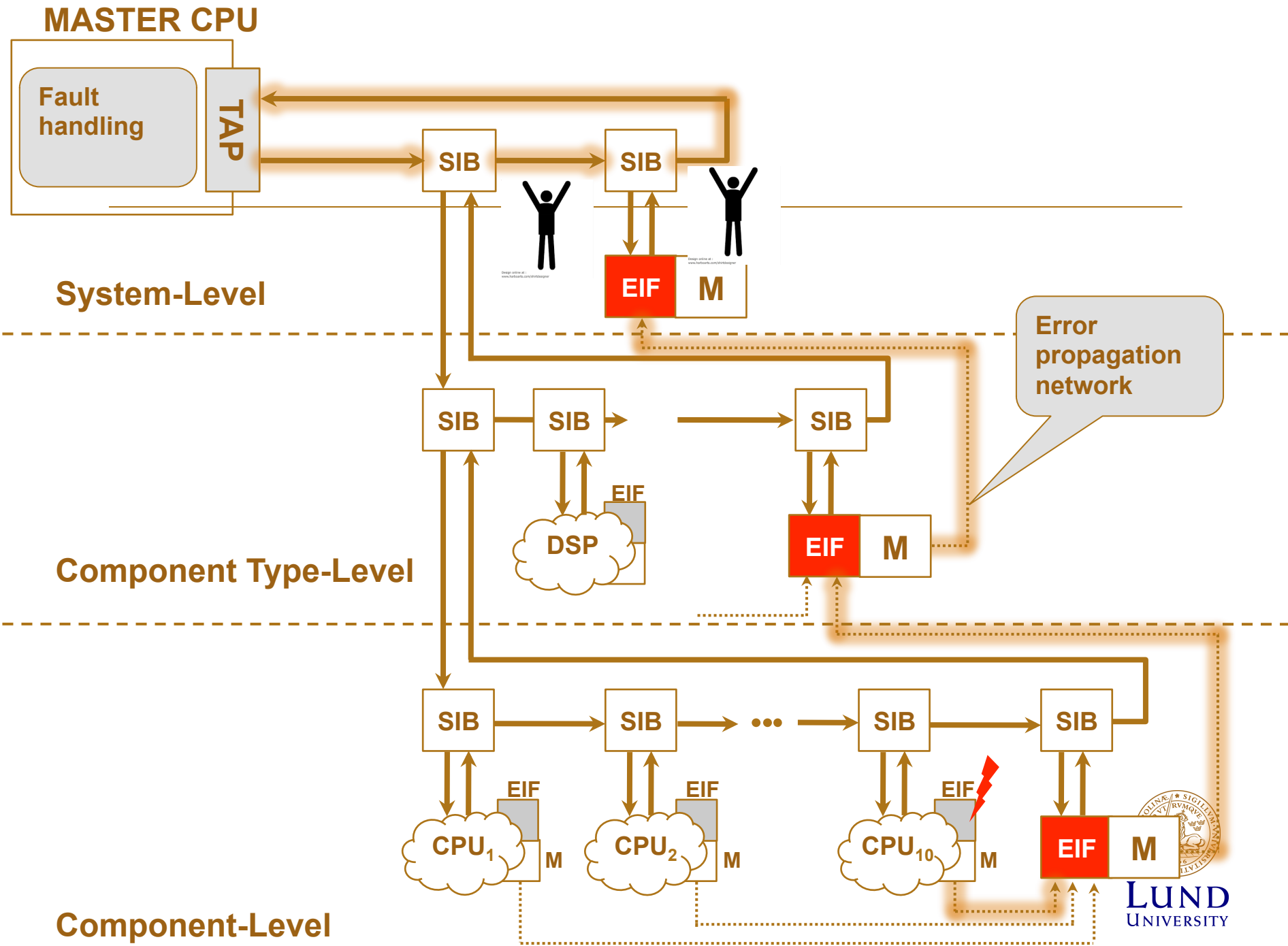


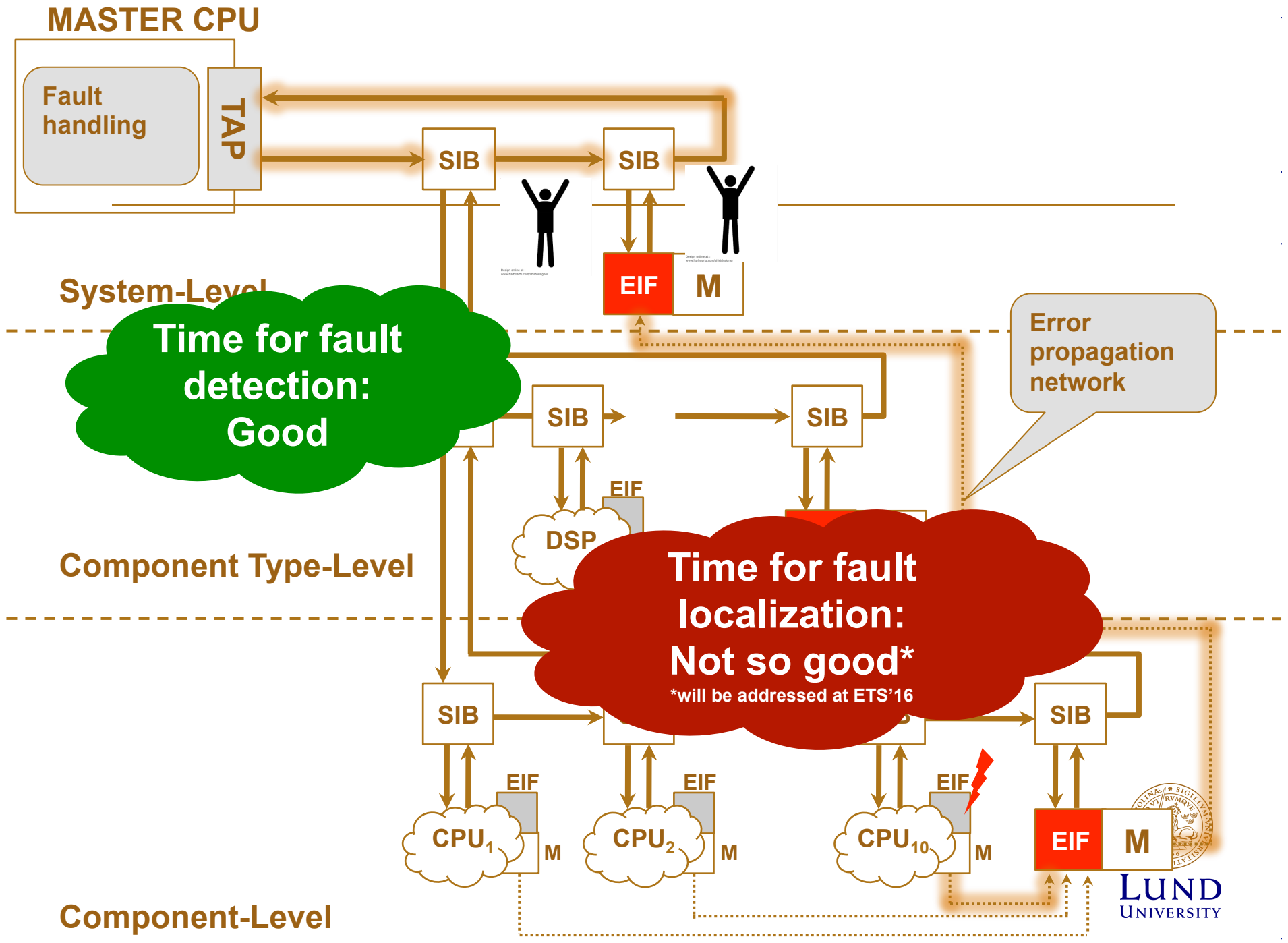












Is there a future for IEEE 1687?

- Tool vendors
- Industrial papers/Case studies

A. L. Crouch, “IJTAG: The Path to Organized Instrument Connectivity,” in Proc. IEEE Int’l Test Conf. (ITC), Oct. 2007, pp. 1–10.

J. Rearick and A. Volz, “A Case Study of Using IEEE P1687 (IJTAG) for High-Speed Serial I/O Characterization and Testing,” in Proc. IEEE Int’l Test Conf. (ITC), Oct. 2006, pp. 1–8.

J. Rearick et al., “IJTAG (Internal JTAG): A Step Toward a DFT Standard,” in Proc. IEEE Int’l Test Conf. (ITC), 2005.

K. Posse et al., “IEEE P1687: Toward Standardized Access of Embedded Instrumentation,” in Proc. IEEE Int’l Test Conf. (ITC), 2006, pp. 1–8.



Is there research on IEEE 1687?

- Optimization of access

F. G. Zadegan et al., “Access Time Analysis for IEEE P1687,” IEEE Transactions on Computers, vol. 61, no. 10, pp. 1459–1472, Oct. 2012.

R. Baranowski, M. A. Kochte, and H.-J. Wunderlich, “Scan Pattern Retargeting and Merging with Reduced Access Time,” in Proceedings of IEEE European Test Symposium (ETS’13). IEEE Computer Society, 2013, pp. 39–45.

R. Cantoro, M. Montazeri, M.S. Reorda, F.G. Zadegan, and E. Larsson, “On the Testability of IEEE 1687 Networks,” 2015. [Online]. Available: <http://lup.lub.lu.se/record/8301410/file/8301425.pdf>

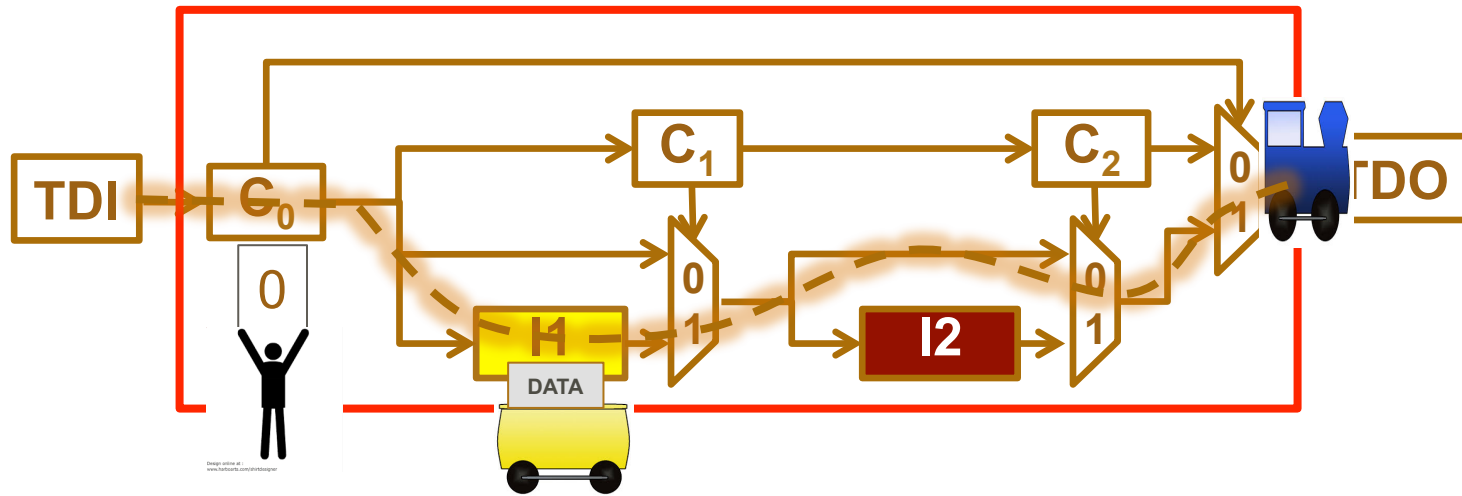
R. Krenz-Baath, F. Zadegan, and E. Larsson, “Access time minimization in IEEE 1687 networks,” in Test Conference (ITC), 2015 IEEE International, Oct 2015, pp. 1–10.

Srinivasa Shashank NUTHAKKI, RAJIT KARMAKAR, Santanu CHATTOPADHYAY, Krishnendu CHAKRABARTY, Optimization of the IEEE 1687 Access Network for Hybrid Access Schedules, VTS’15

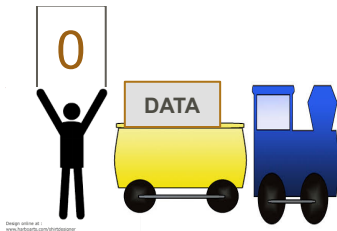


IEEE 1687

Custom Register



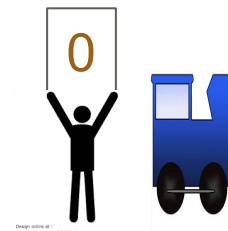
Train ride #3



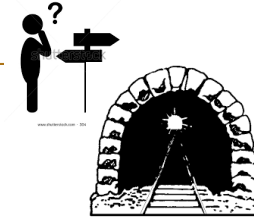
Train ride #2



Train ride #1



Is there research on IEEE 1687?



- Security

T. Payakapan, S. Kan, K. Pham, K. Yang, J.-F. Cote, M. Keim, and J. Dworak, “A case study: Leverage ieee 1687 based method to automate modeling, verification, and test access for embedded instruments in a server processor,” in Test Conference (ITC), 2015 IEEE International, Oct 2015, pp. 1–10

J. Dworak, Z. Conroy, A. Crouch, and J. Potter, “Board security enhancement using new locking sib-based architectures,” in Test Conference (ITC), 2014 IEEE International, Oct 2014, pp. 1–10.

J. Dworak and A. Crouch, “A call to action: Securing ieee 1687 and the need for an ieee test security standard,” in *VLSI Test Symposium (VTS), 2015 IEEE 33rd*, April 2015, pp. 1–4.

R. Baranowski, M. Kochte, and H.-J. Wunderlich, “Securing access to reconfigurable scan networks,” in Test Symposium (ATS), Asian, Nov 2013, pp. 295–300.

R. Baranowski, M. Kochte, and H.-J. Wunderlich, “Fine-grained access management in reconfigurable scan networks,” *Computer-Aided Design of Integrated Circuits and Systems*, IEEE Transactions on, vol. 34, no. 6, pp. 937–946, June 2015.



Is there research on IEEE 1687?


- In-situ access

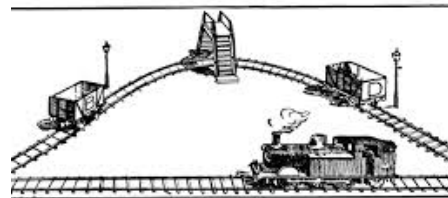
- K. Petersen, D. Nikolov, U. Ingelsson, G. Carlsson, F. Zadegan, and E. Larsson, “Fault injection and fault handling: An mpsoc demonstrator using ieee p1687,” in On-Line Testing Symposium (IOLTS), 2014 IEEE 20th International, July 2014, pp. 170–175.
- A. Jutman, S. Devadze, and K. Shibin, “Effective Scalable IEEE 1687 Instrumentation Network for Fault Management,” IEEE Design & Test, vol. 30, no. 5, pp. 26–35, Oct 2013.
- K. Shibin, S. Devadze, and A. Jutman, “Asynchronous Fault Detection in IEEE P1687 Instrument Network,” in IEEE 23rd North Atlantic Test Workshop (NATW), May 2014, pp. 73–78.
- F. Ghani Zadegan, D. Nikolov, and E. Larsson, “A self-reconfiguring ieee 1687 network for fault monitoring,” in Test Symposium (ETS), 2016 IEEE European, May 2016, pp. 1–6.



Conclusions

- Transistors increase in number and are becoming smaller, which leads to many possible defects and new defect types (ageing) will develop, more embedded instrumentation is needed.

- With PDL  and ICL



IEEE 1687 becomes an attractive way to handle and connect embedded instruments used for manufacturing test purposes and in-situ reliability purposes





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