



# Embedded Real-Time Systems

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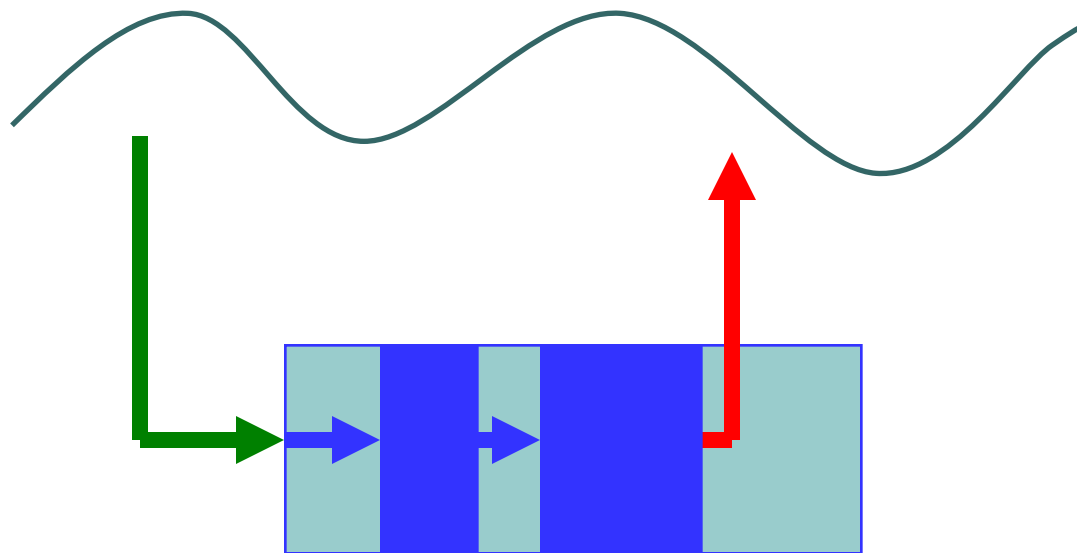
Lecture 6c: Time-Triggered  
Models

# The 5-Minute Review Session

1. What is a *firing function*?
2. What is a *constructive* state machine? How does constructiveness relate to well-formedness?
3. How do actors communicate in a *dataflow* model?
4. What is *synchronous* dataflow? *Homogeneous* dataflow? *Dynamic* dataflow?
5. What is a necessary condition for a *bounded memory infinite execution* of a dataflow model? Is it sufficient?

# Standard Practice

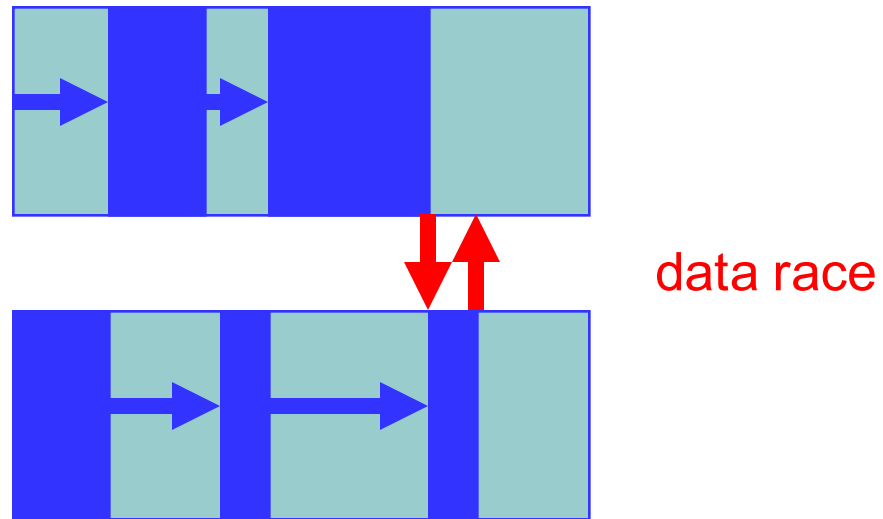
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make output available  
as soon as ready

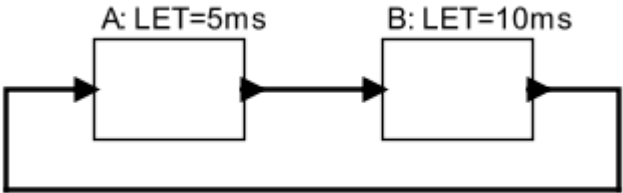
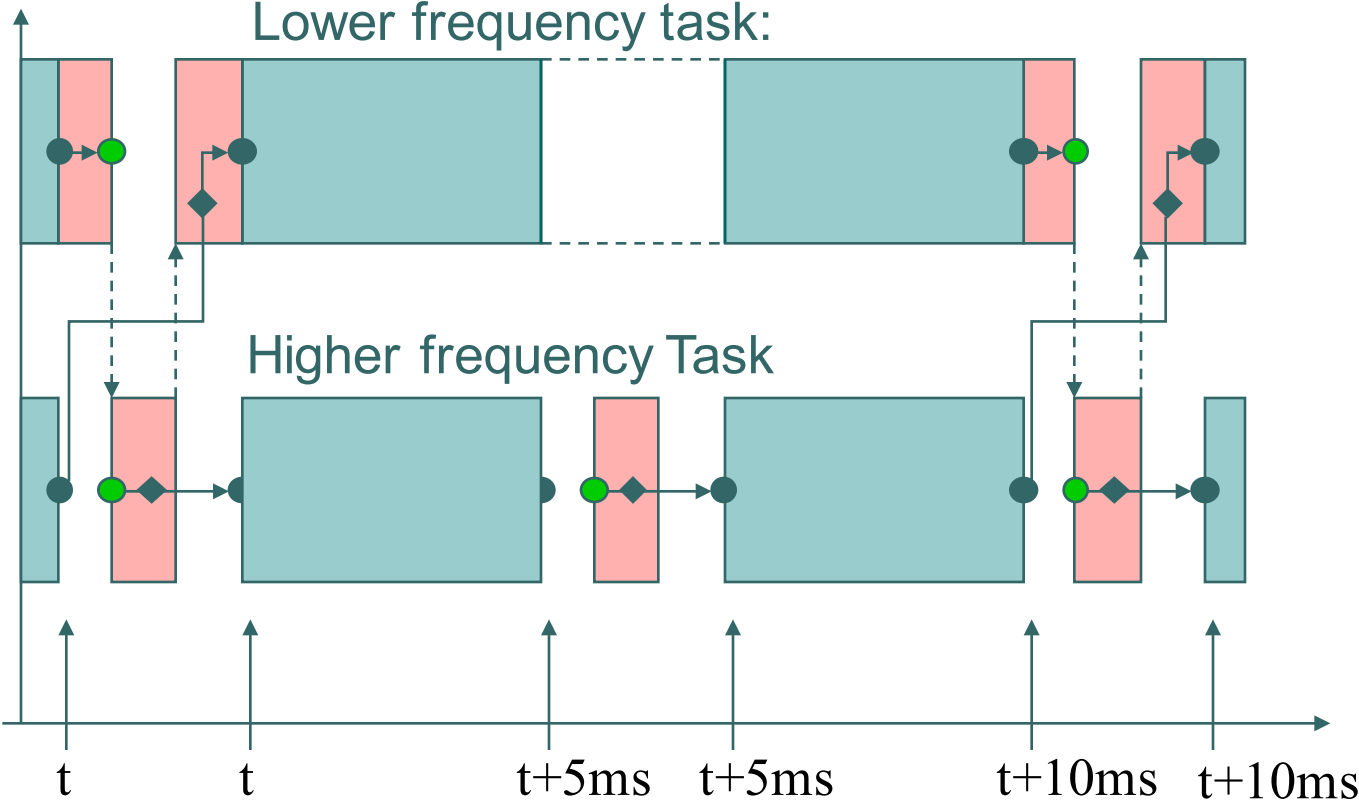
# Standard Practice

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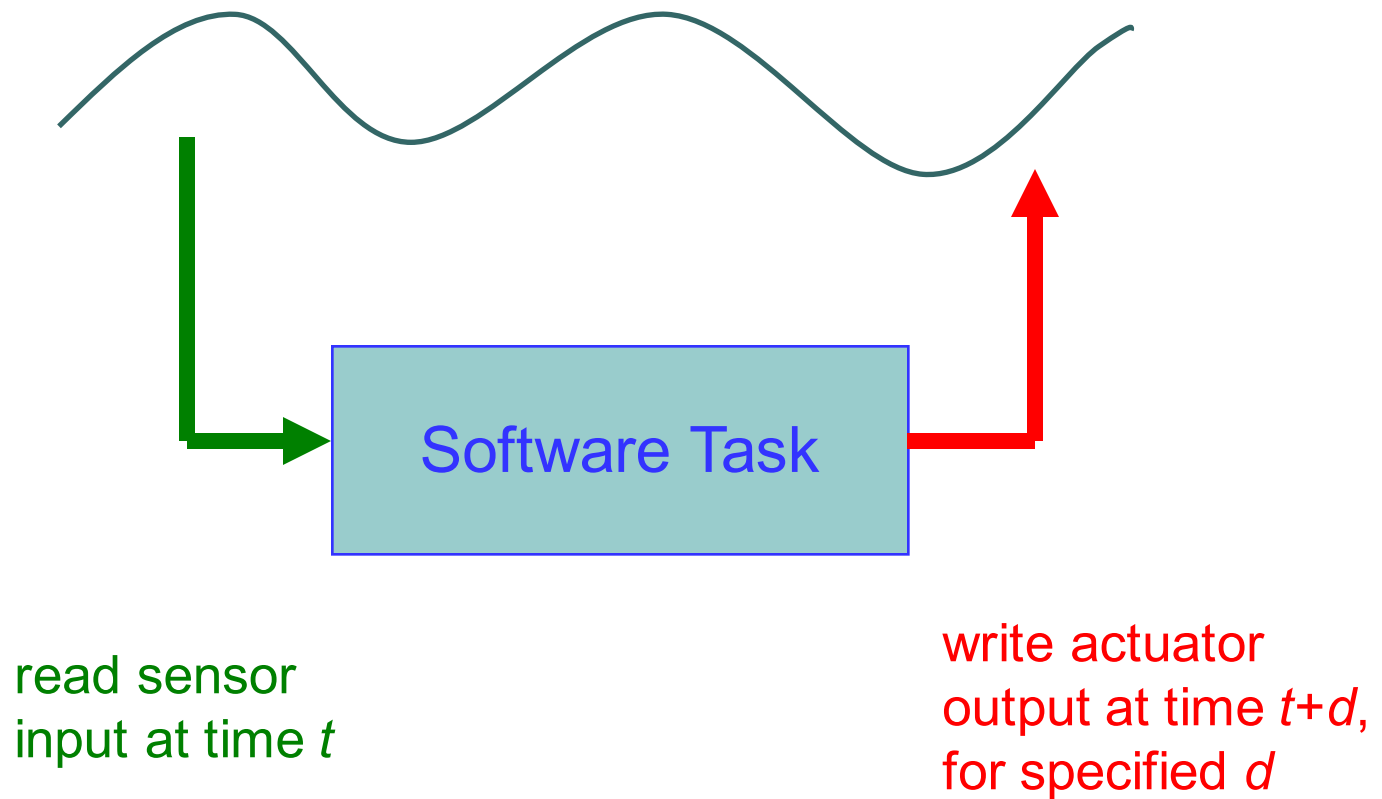
# Example: Time-Triggered Models with LET

In some time-triggered models (e.g. Giotto, TDL), each actor has a **logical execution time (LET)**. Its actual execution time always appears to have taken the time of the LET.



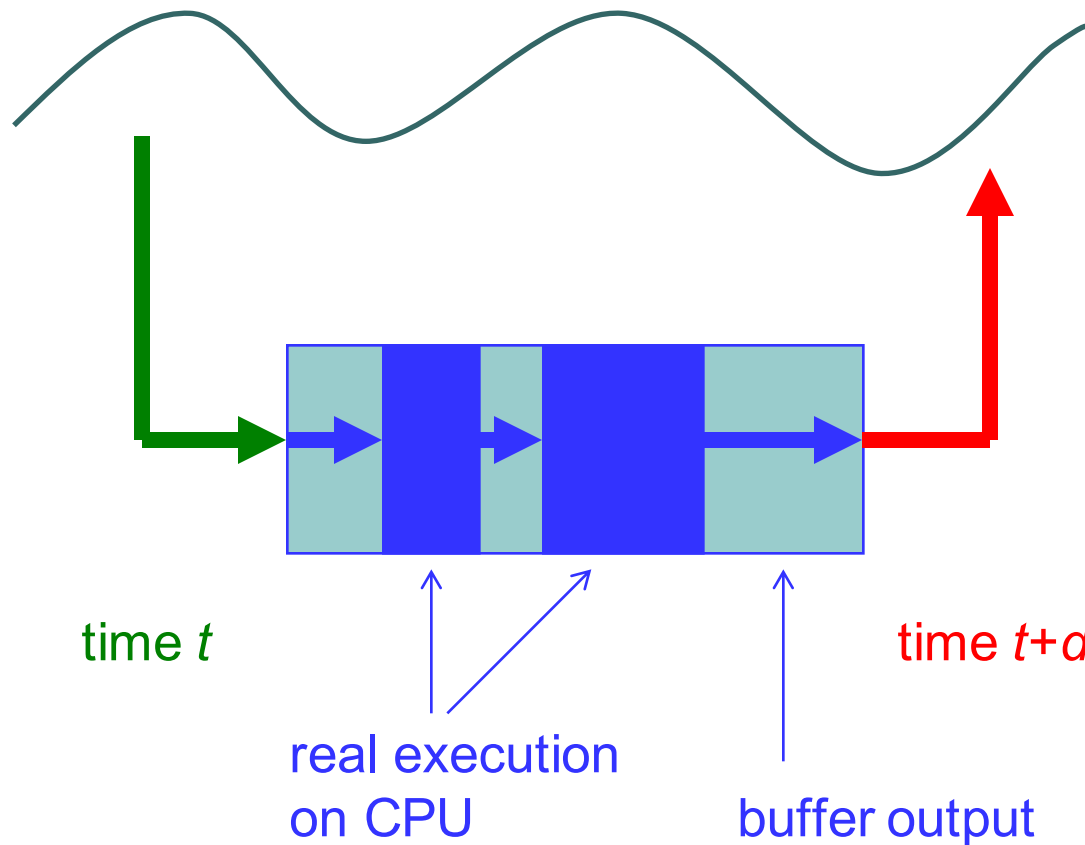
# The LET (Logical Execution Time) Programming Model

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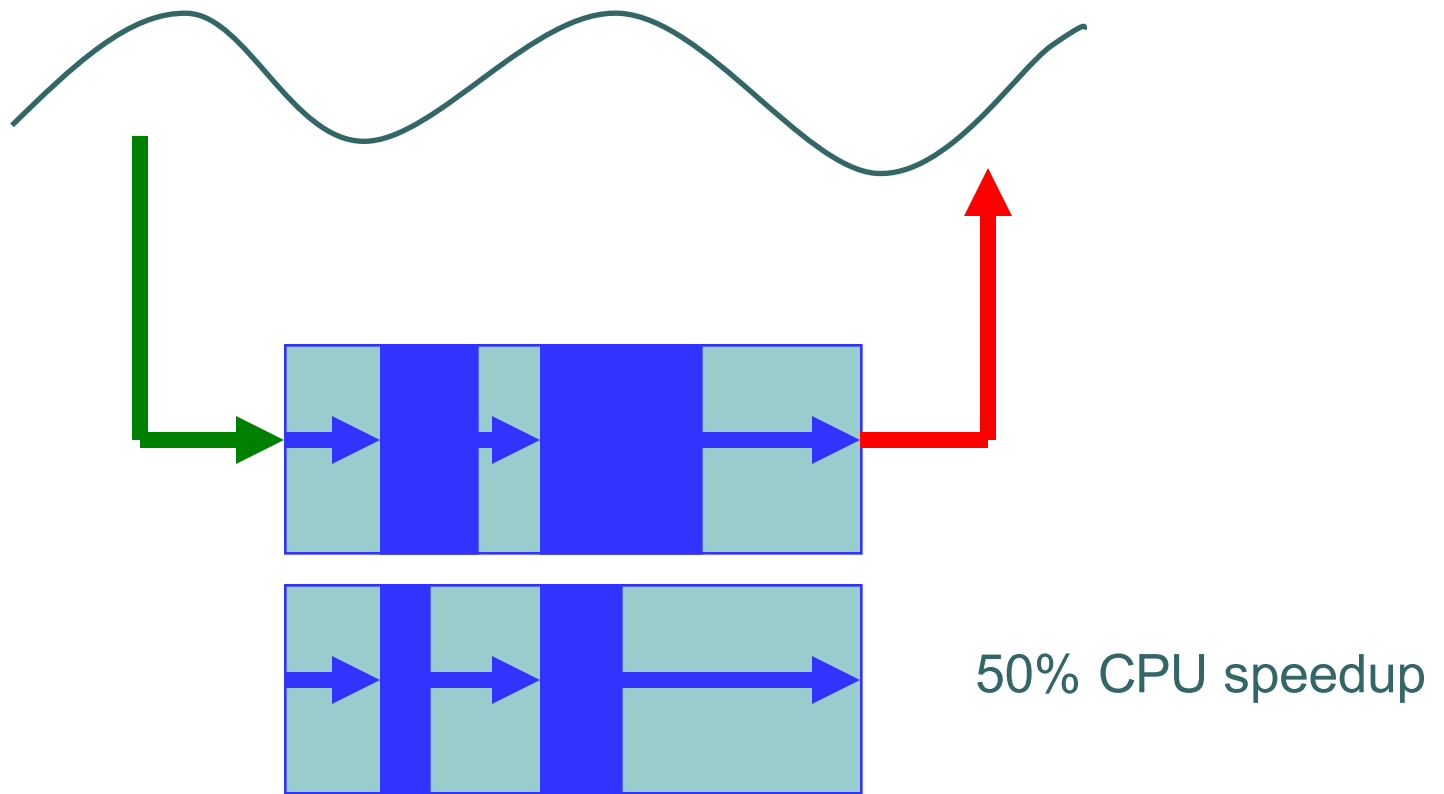
Examples: Giotto, TDL,

# The LET (Logical Execution Time) Programming Model



# Portability

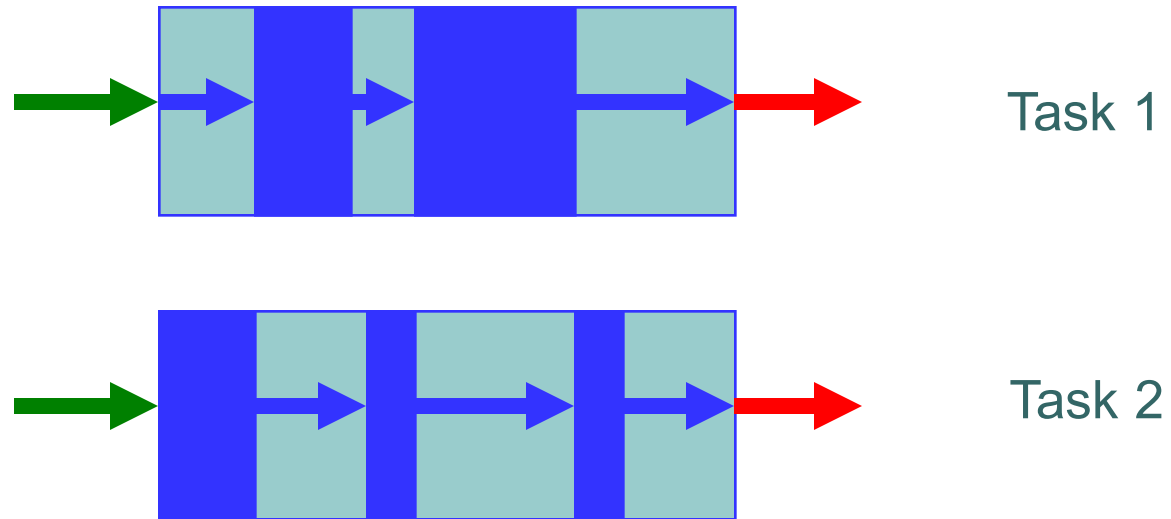
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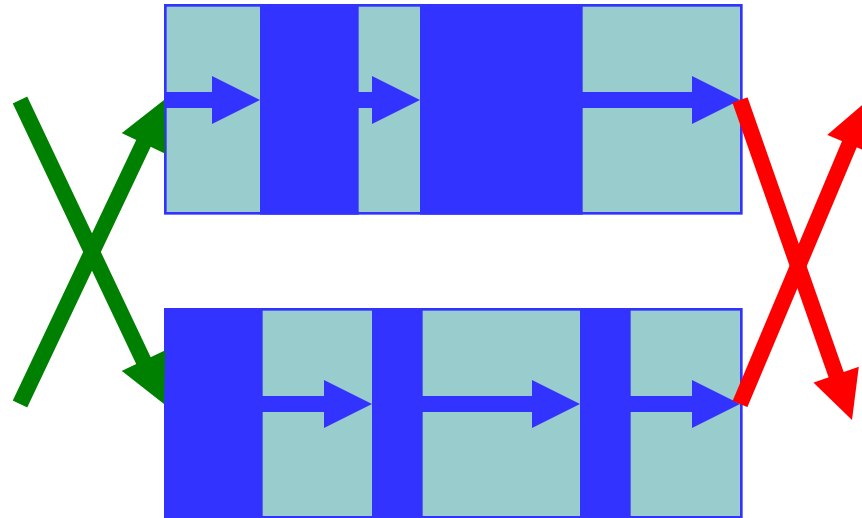
# Composability

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# Determinism

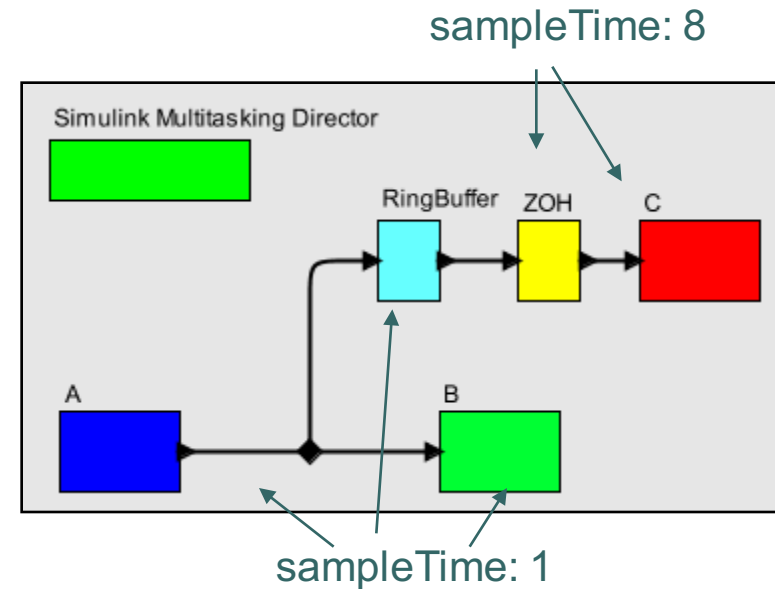
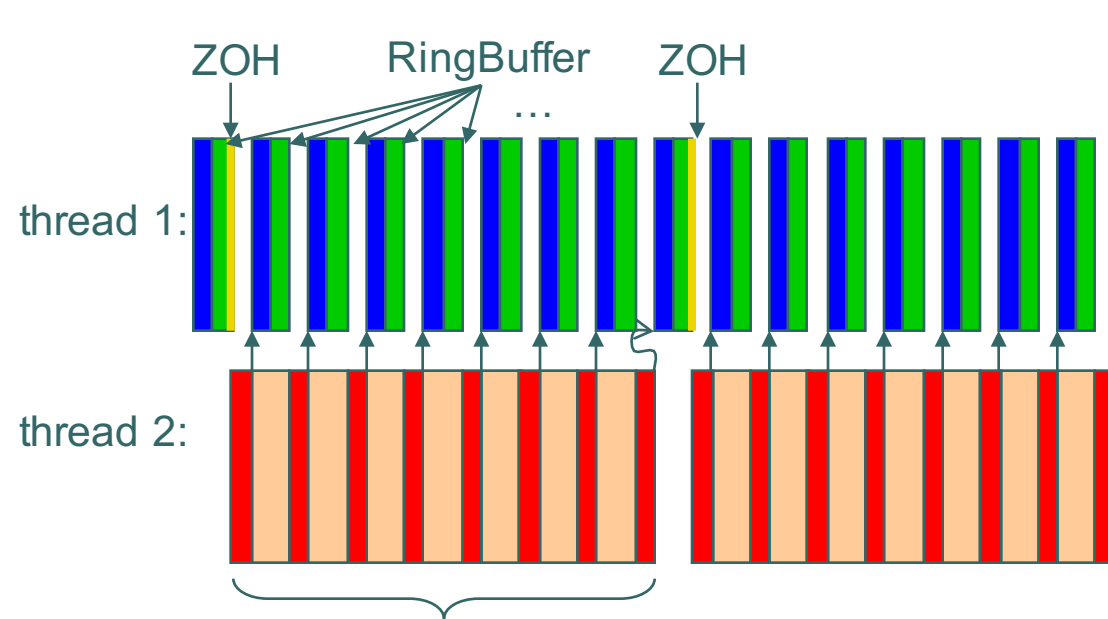
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Timing predictability: minimal jitter

Function predictability: no race conditions

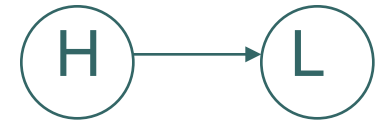
# Recall: Simulink Strategy



Problem: in a naïve implementation, ZOH would copy the entire buffer. Copying large amounts of data can take a long time.

Solution: alternate buffers where A writes to, using clever (and careful) pointer managing.

# The high-to-low-priority protocol [Caspi et al, 2008]



- L keeps a double buffer: **B[0,1]**
- Two (boolean) pointers: **current, next**
- H writes to: **B[next]**
- L reads from: **B[current]**
  
- When L arrives: **current := next**
- When H arrives: **if (current = next) then**  
**next := not next**
  
- Initially: **current=next=0, B[0]= B[1]= default**

No copying of buffers. Works for arbitrary arrival patterns..

# Reading

P. Caspi, N. Scaife, C. Sofronis and S. Tripakis.  
*Semantics-Preserving Multitask Implementation of Synchronous Programs*. In *ACM Trans. Embedded Computing Systems*. ACM, 2008.

# To Go Further

Thomas A. Henzinger, Benjamin Horowitz, and Christoph M. Kirsch

Giotto: A Time-triggered Language for Embedded Programming

*Proceedings of the IEEE* 91:84-99, 2003