Verification

Modeling Usable & Reusable Transactors in SystemVerilog

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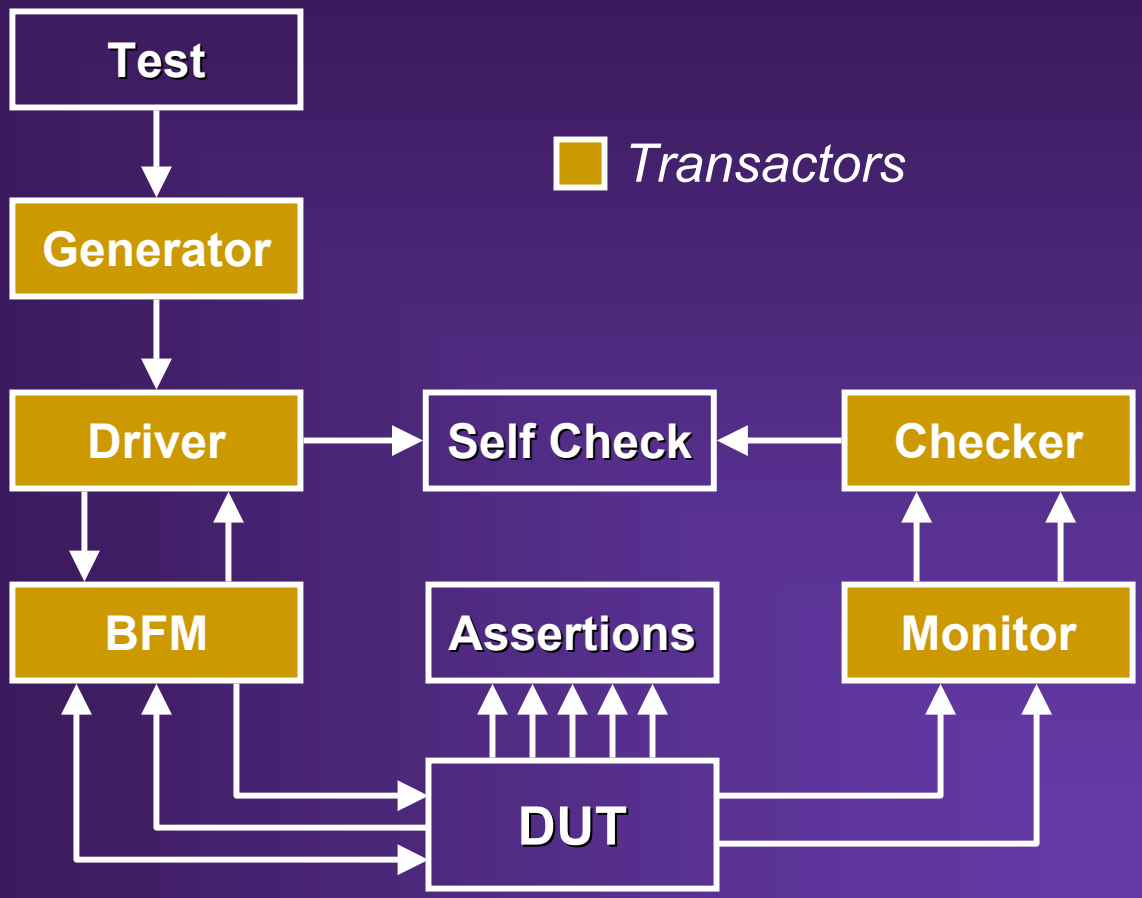
Transactors
Definition

- Building blocks of verification environments
  - Bus-functional models
  - Monitors
  - Checkers
  - Generators
- Few instances
  - Created at the start of simulation
  - Remain in existence for duration
- Data and transactions flow through them
  - Generation
  - Observation
  - Scheduling
  - Transformation
  - Processing

Verification Environment

Transactors



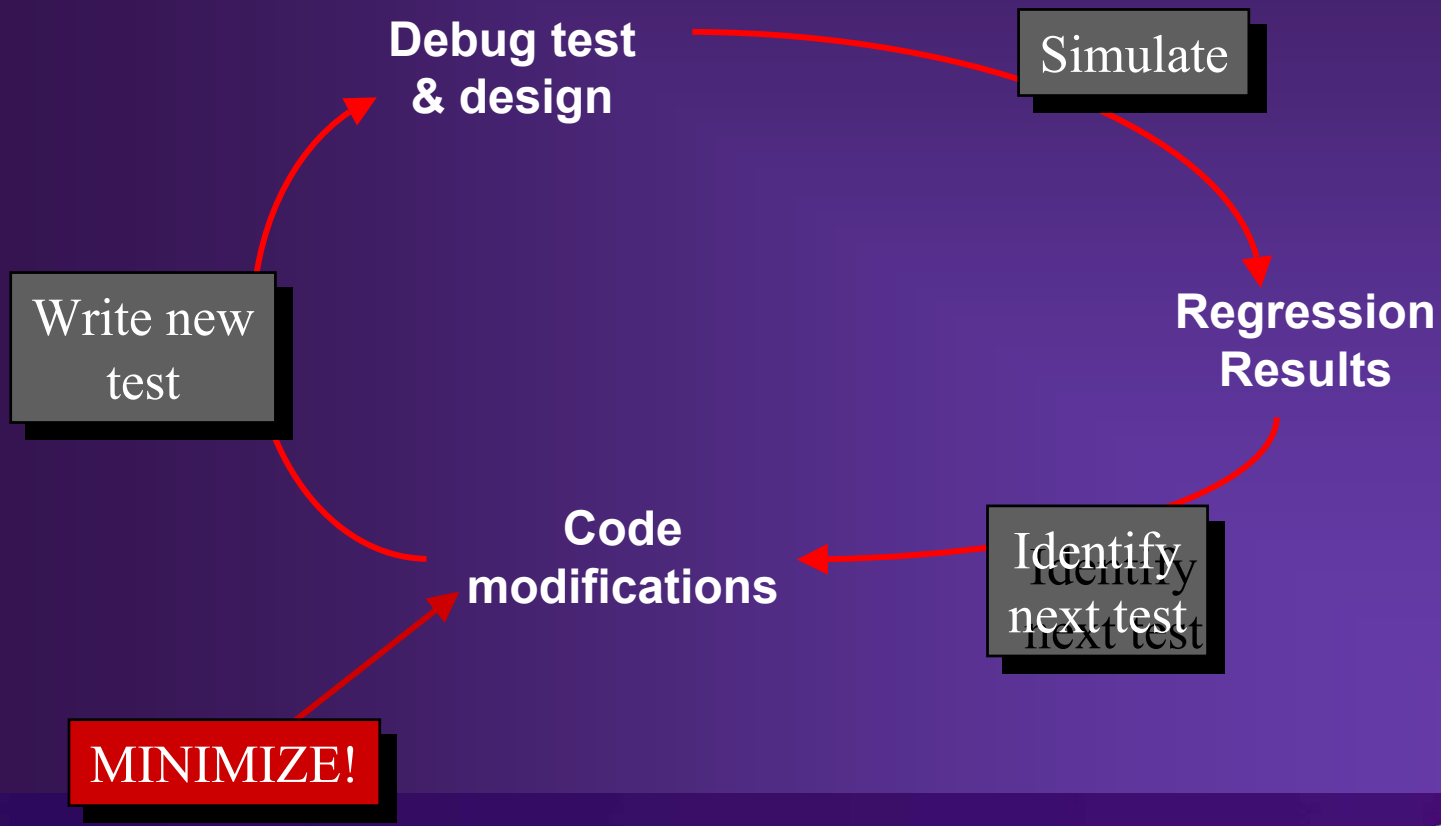
Transactor
Categories

- Active transactors
  - Initiate transactions
  - Supply data to other side
  - Example: AHB master, Ethernet Tx
- Reactive transactors
  - Transaction initiated by other side
  - React by supplying requested data
  - Example: AHB slave
- Passive transactors
  - Transaction initiated by other side
  - Collect transaction data from other side
  - No interaction with monitored interface
  - Example: AHB bus monitor

Verification Process

Why Should You Care About Transactors?

- Verification >60% of design effort
- Transactors enable abstraction & automation



Transactors
Implementation

- Simple to write transactors that
  - Always do the right thing
  - Operate as fast as possible
- How can an environment
  - Integrate a scoreboard?
  - Add functional coverage?
- How can a test
  - Introduce delays?
  - Respond with "*retry*", "*abort*" or not respond?
  - Inject errors?

Without rewriting/modifying original transactor

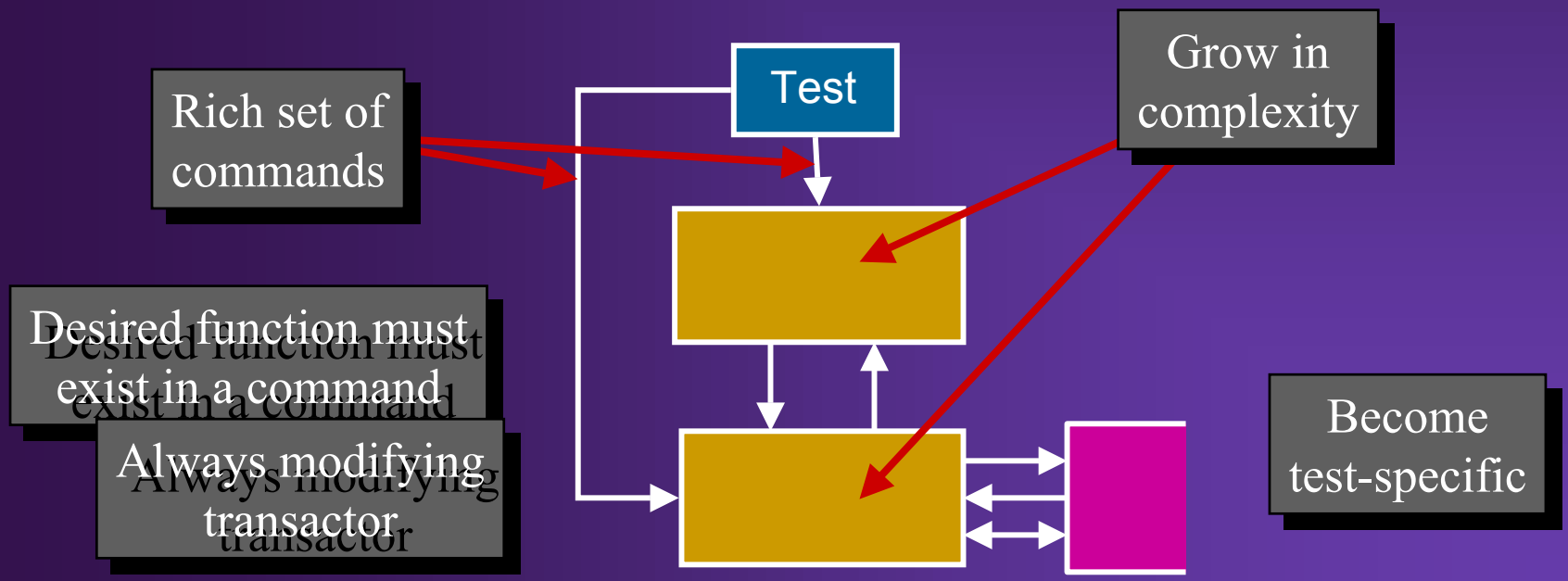
Traditional Transactors

Procedural Interface

- Complex control interface
  - Configuration commands
  - Transaction commands
  - Exception commands

Different concerns
Same mechanism

- Creates new programming language



Usable & Reusable Transactors

- Separate
  - Configuration
  - Transactions
  - Exceptions
- Minimize code required for additional tests
- Support
  - Random configuration
  - Random stimulus
  - Self-checking operations
  - Functional coverage
  - User-defined exceptions
  - Block-level verification
  - System-level verification

Requires HVL features

Object-Oriented Transactors
Configuration Interface

- Implement using *class*
- Configure using *configuration class*
  - Can be randomized
  - Pass via *constructor* and optional *reconfigure()* method

```
class mii_cfg;
   rand bit is_100Mb;
endclass

class mii;
   protected mii_cfg cfg;
   ...
   function new(mii_cfg cfg, ...);
      this.cfg = cfg;
   endfunction;
   function void reconfigure(mii_cfg cfg);
      ...
   endfunction;
endclass
```

May have to reset transactor

Object-Oriented Transactors
Transaction Interface

- Data-flow based transaction interface
  - Transaction descriptors
  - See "*Modeling Data and Transactions*", DesignCon '05

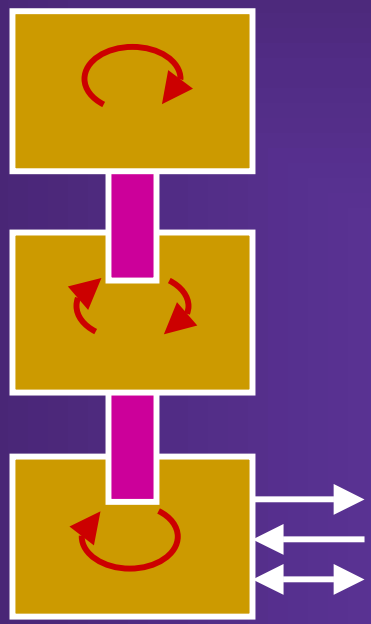
```
class mii;
   eth_frame_channel in_chan;
   eth_frame_channel out_chan;
   ...
   function new(..., eth_frame_chan in_chan  = null,
                     eth_frame_chan out_chan = null, ...);
      if (in_chan == null) in_chan = new;
      this.in_chan = in_chan;

      if (out_chan == null) out_chan = new;
      this.out_chan = out_chan;
      ...
   endfunction;
endclass
```

Object-Oriented Transactors
Transaction Interface

- Flow of data between producer and consumer automatically regulated

As fast as slowest component

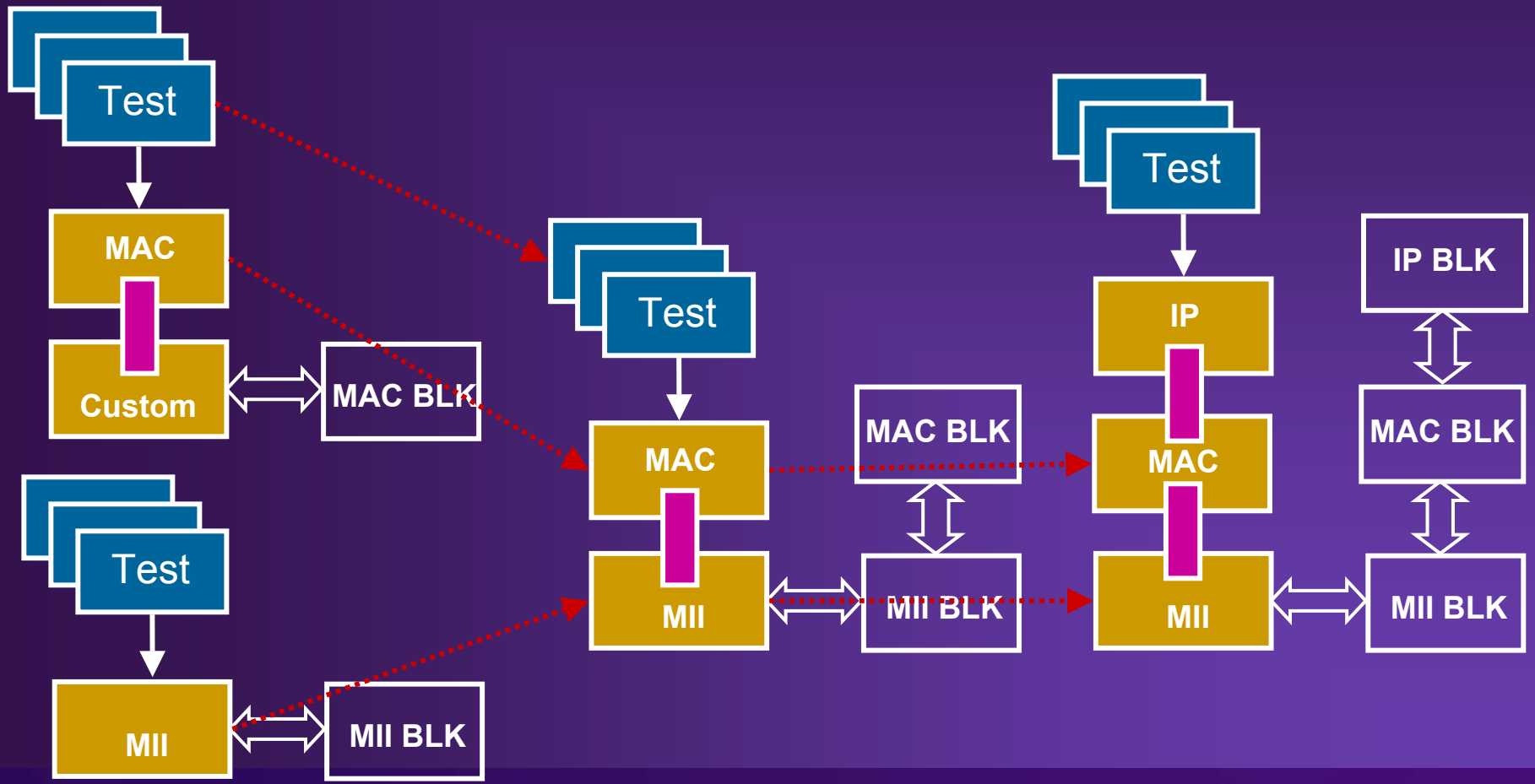


Object-Oriented Transactors
Transaction Interface

- Can implement various transaction completion models
  - Blocking
  - Nonblocking
  - Out-of-order
  - Request / Response

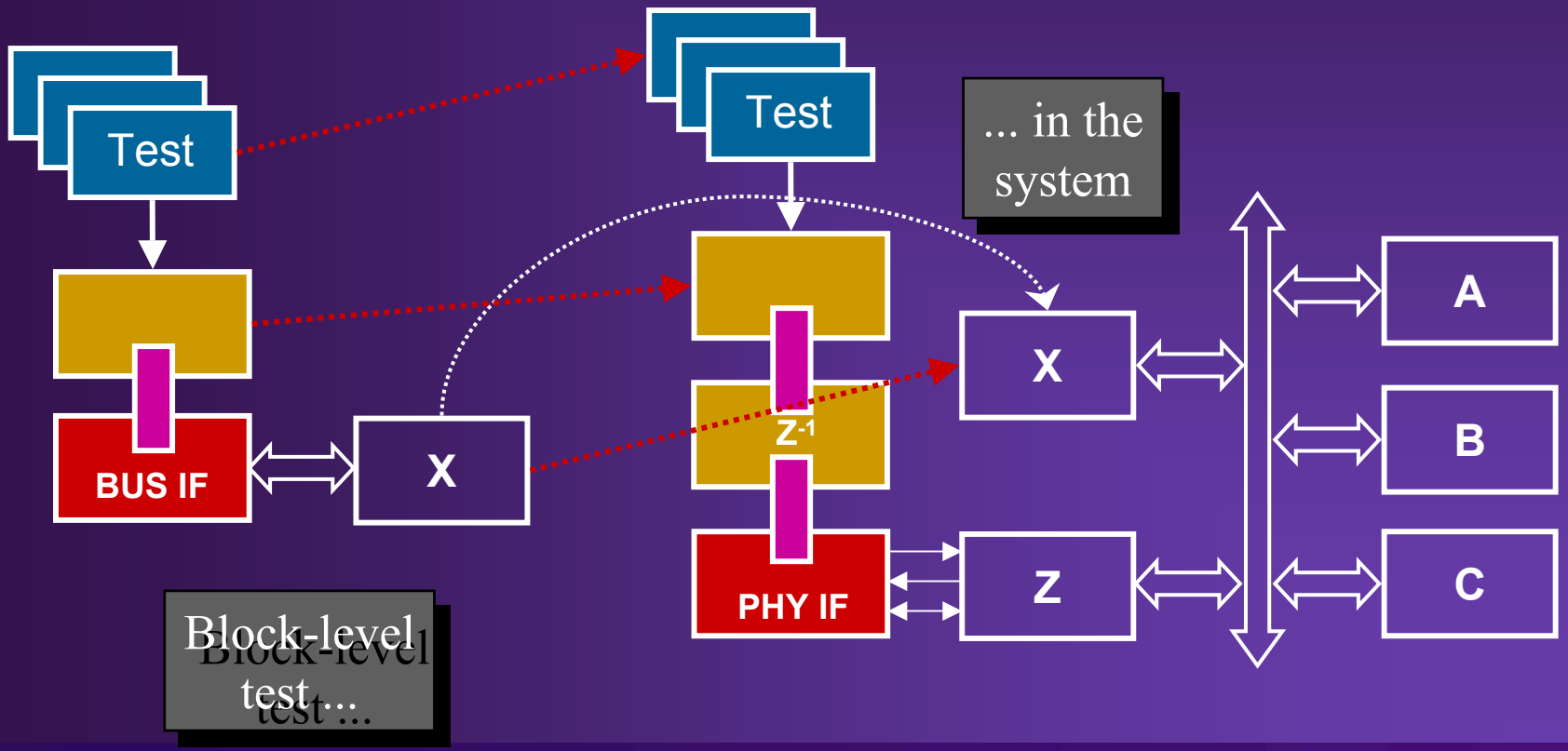
Object-Oriented Transactors
Transaction Interface

- Key to transactor reuse across environments



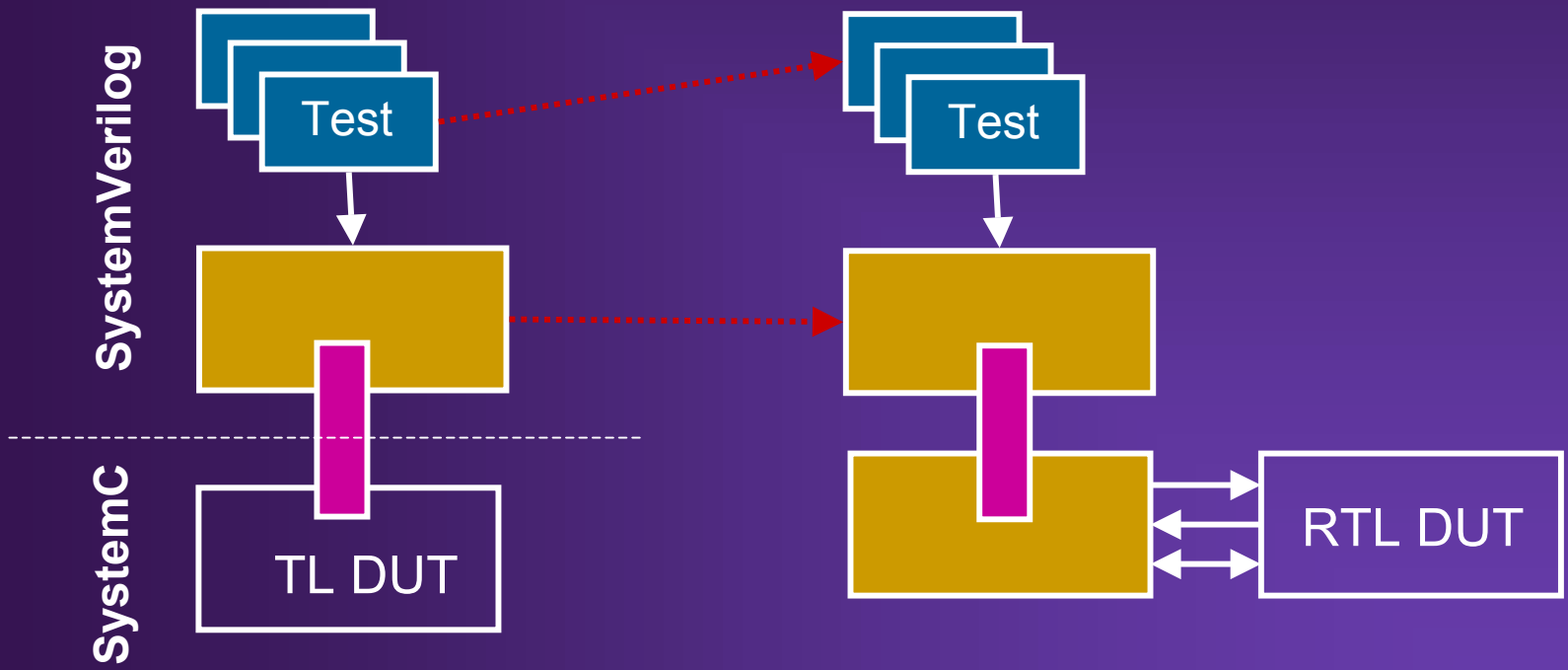
Object-Oriented Transactors
Transaction Interface

- Allows port of block level tests to chip level



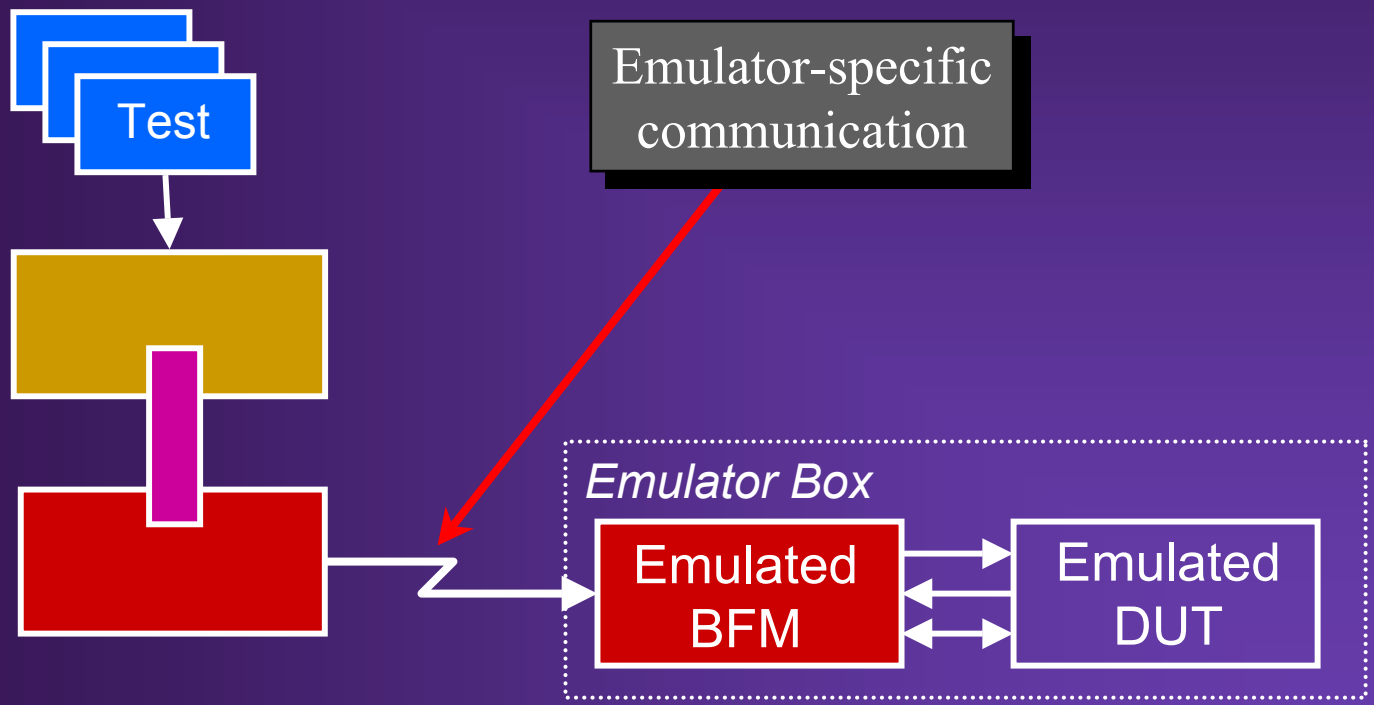
Object-Oriented Transactors
Transaction Interface

- Components unaware of other endpoint



Object-Oriented Transactors
Transaction Interface

- Interface between testbench and emulator

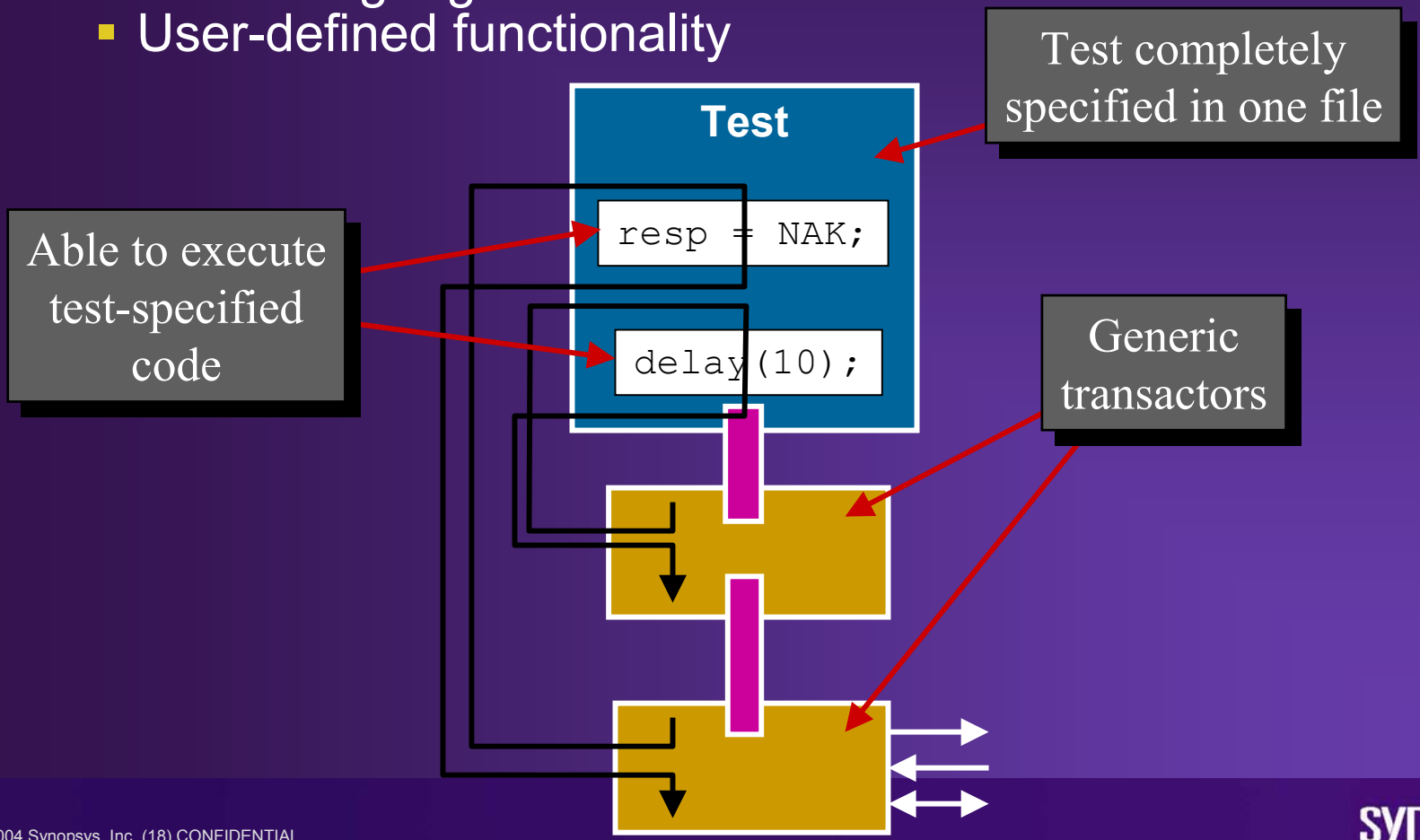


Object-Oriented Transactors
Exception Interface

- Reusable transactors need mechanism to provide services to verification environment
  - Introducing delays
  - Synchronizing different transactors
  - Feedback
  - Recording input into scoreboard
  - Comparing output with expected values
  - Sampling data for functional coverage
  - Modifying transactions to inject errors
  - Deviate from default behavior
- Flexible enough to satisfy unpredictable needs of verification environments and testcases
  - Without modifying transactor

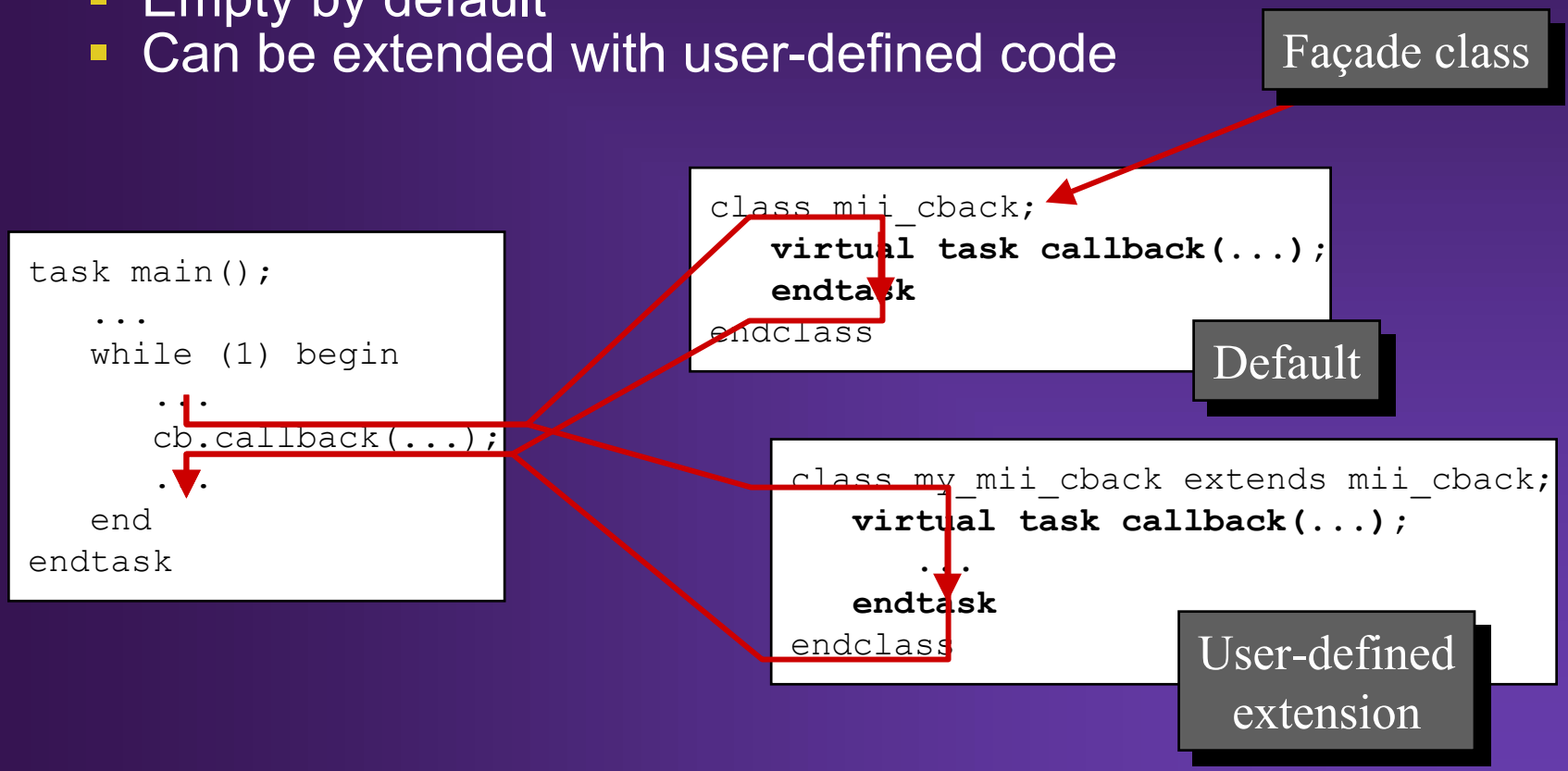
Object-Oriented Transactors
Exception Interface

- Callbacks used to implement exceptions
  - Same language
  - User-defined functionality



Reusable Transactors
Callback Methods

- Callback methods are *virtual* methods in *façade* class invoked by the transactor itself
  - Empty by default
  - Can be extended with user-defined code



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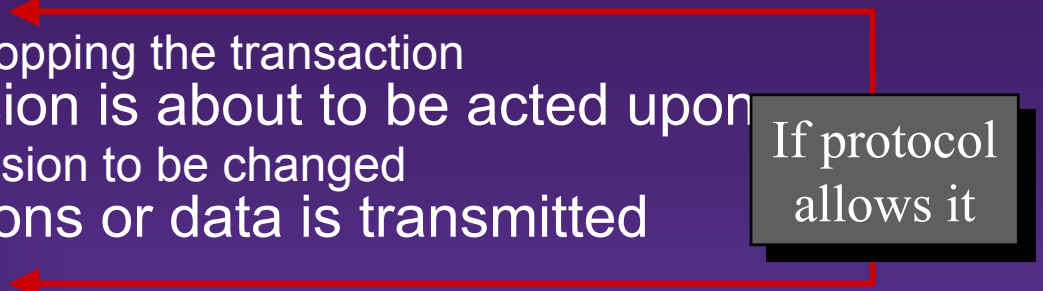
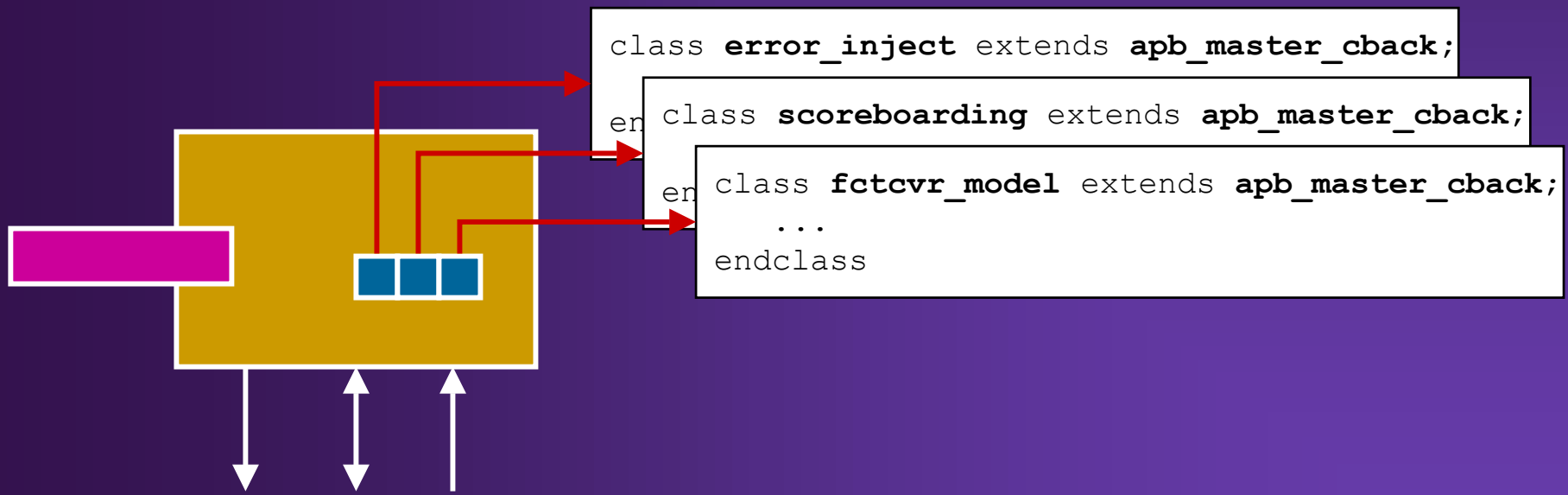
Reusable Transactors
Callback Methods

- Provide rich set of callback methods
  - After a new transaction is about to be started
    - Allow delay insertion
    - Allow modifying or dropping the transaction
  - Before a major decision is about to be acted upon
    - Allow the default decision to be changed
  - Before sub-transactions or data is transmitted
    - Allow delay insertion
    - Allow modifying or dropping
  - After sub-transactions or data has been received
    - Allow modifying or dropping
  - After a transaction has been completed
    - Allow modifying or prevent forwarding to higher layers
  - In the body of every loop
    - Supply loop index via argument
    - Allow modifying the subject of the iteration



Reusable Transactors
Callbacks Methods

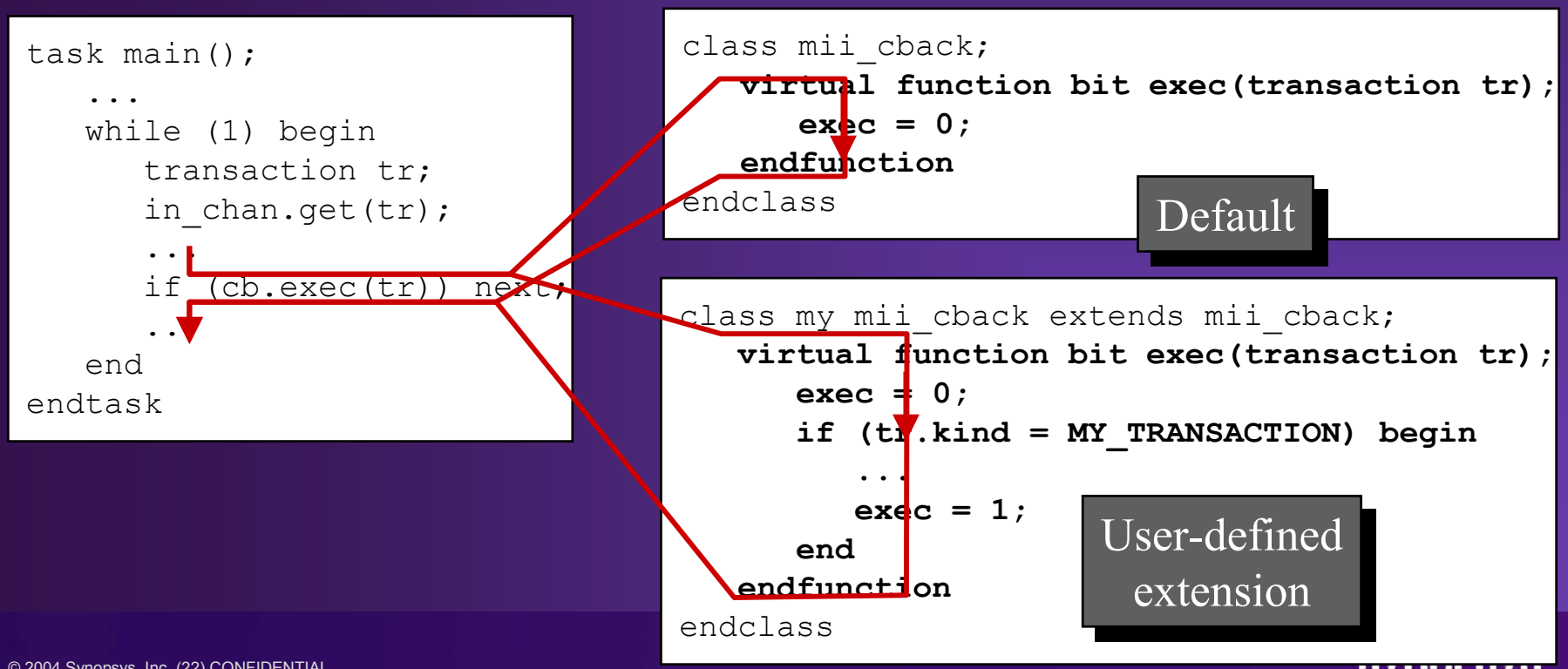
- Transactors have list of registered callback extensions
  - Individual extensions for different purposes
  - No modifications of existing callback functionality



Extensible Transactors

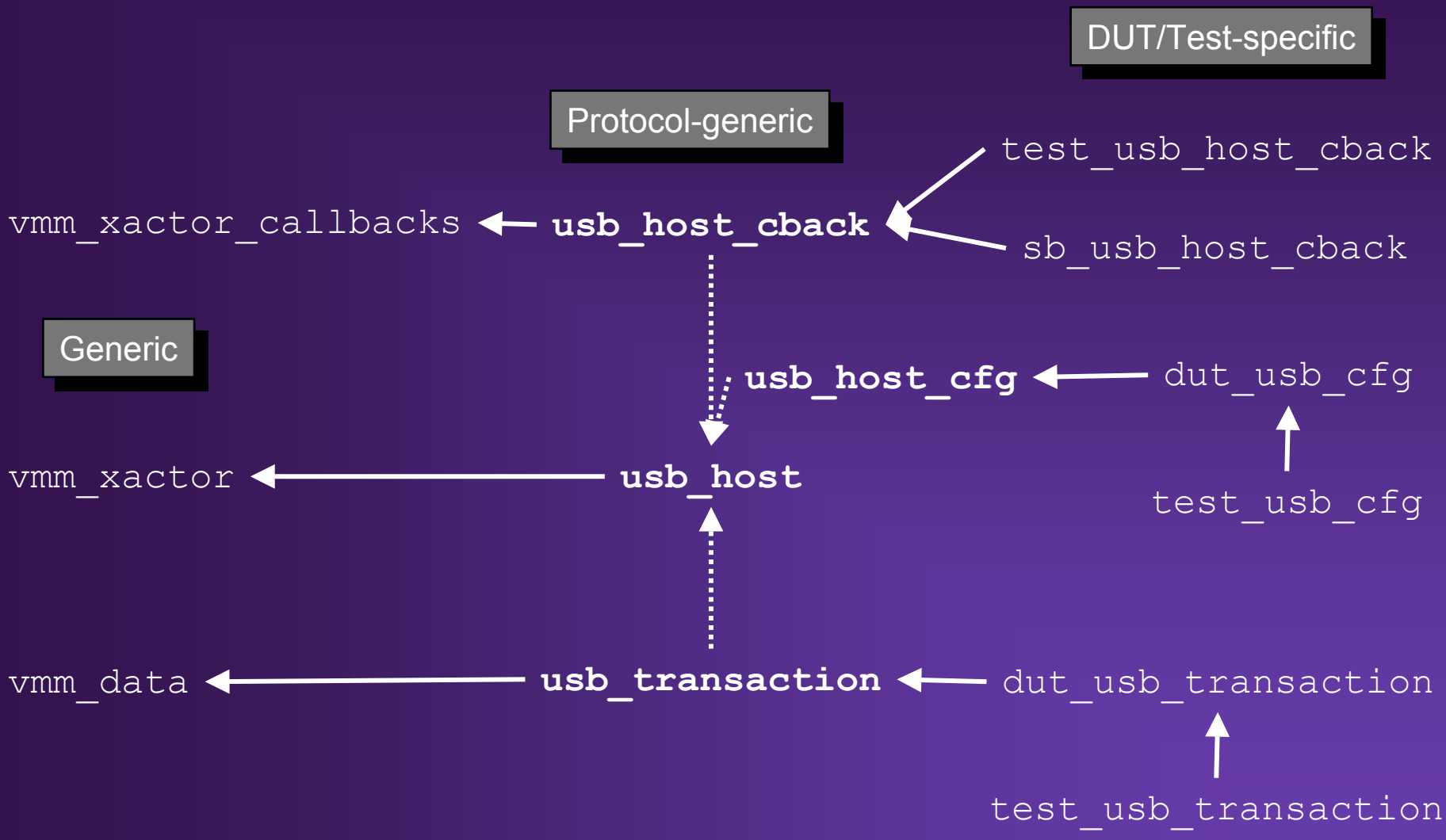
User-Defined Transactions

- Use callback to interpret transaction descriptor
  - Can be overloaded to modify transaction execution
  - Can be overloaded to define new transactions



Transactor Implementation

Class Hierarchy



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Useable & Reusable Transactors

For more information

- SystemVerilog Verification Methodology Manual
  - Kluwer Academic Publishers, 2005
- "*Modeling Data and Transactions*"
  - DesignCon '05, Santa Clara, CA
- Reference Verification Methodology
  - Vera User's Guide, 6.2 and later

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