

## C++ Introduction

1. **Classes**
2. Functions and Operators
3. Template Classes
4. Inheritance
5. Virtual Functions

## C++

## C with additional

- features of object oriented languages
- operator and function overloading
- virtual functions
- call by reference for functions
- template functionality
- exception handling

## Object Orientation

## The sum of

- abstract data types (classes)
- data hiding
- (multiple) inheritance
- polymorphism

## Classes - Introduction

```
typedef int t_fifo;
class fifo {
public:
    fifo(int size);
    ~fifo();

    bool read(t_fifo& val);
    bool write(const t_fifo& val);
    void dump();

protected:
    bool is_empty();
    bool is_full();
    int inc_idx(const int& idx);
protected:
    t_fifo* _buf; int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
}; // Note the semicolon
```

### A **struct** in C

- contains data elements
- used to encapsulate a state

### A **class** in C++

- contains data elements
- contains functions
  - called methods
- used to encapsulate state *and* behavior

**function members  
(methods)**

**data members**

## Classes| Java equivalent

```
typedef int t_fifo;
class fifo {
public:
    fifo(int size);
    ~fifo();

    bool read(t_fifo& val);
    bool write(const t_fifo& val);
    void dump();
protected:
    bool is_empty();
    bool is_full();
    int inc_idx(const int& idx);
protected:
    t_fifo* _buf; int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
}; // Note the semicolon
```

```
// typedef int t_fifo not supported in java
public class fifo {
    public      fifo(Integer size) {...}
    public      void finalize(){...}

    public class IntegerRef
    { public Integer val; };

    public      Boolean read(IntegerRef ref) {...}
    public      Boolean write(Integer val) {...}
    public      void      dump() {...}

    protected Boolean is_empty() {...}
    protected Boolean is_full() {...}
    protected Integer inc_idx(Integer idx) {...}

    protected Vector<Integer> _buf;
    protected Integer      _rd_idx;
    protected Integer      _wr_idx;
    protected Integer      _num_elem;
}
```

## Classes - Declaration Syntax

A Class in C++ is Declared

Either using the keyword **struct**

- still there to maintain compatibility with ANSI C

Or using the keyword **class**

- better fits the object oriented terminology

The Difference Between **class** and **struct**

Default access modifier (explained later)

- **public** for **struct**
- **private** for **class**

```
Syntax:
class class_name
{
// implicit private:
// the class body
};
```

Note the semicolon

```
Syntax:
struct class_name
{
// implicit public:
// the class body
};
```

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## Classes - Access Modifier

Access Modifiers

Accessibility of class members from outside the class

- are available in three different types

**public**

Members can be accessed from outside the class

- default for **struct**

**protected**

Members can only be accessed by methods of derived classes

**private**

members can only be accessed by methods of the class itself

- default for **class**

```
class my_class
{
int _value;
public:
int get_value();
};
```

equivalent

```
struct my_class
{
int get_value();
private:
int _value;
};
```

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## Classes - Constructor Syntax

Every class has a constructor

- special member function
  - has the name of the class
  - has no return type (not even **void**)
- automatically called at object instantiation
  - used to initialize class members to a known state
- if no constructor is defined
  - the compiler automatically generates a default constructor
  - calls the default constructor for all class members

```
class my_class {
public:
my_class();
my_class(int);
};
```



```
int main(){
my_class x; // calls constructor my_class()
my_class y(42); // calls constructor my_class(int)
}
```

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## Classes - Constructor Example

```
typedef int t_fifo;
class fifo {
public:
fifo(int size);
~fifo();

bool read(t_fifo& val);
bool write(const t_fifo& val);
void dump();
protected:
bool is_empty();
bool is_full();
int inc_idx(const int& idx);
protected:
t_fifo* _buf; int _size;
int _rd_idx;
int _wr_idx;
int _num_elem;
};
```

```
fifo::fifo(int size) {
_size = size;
_buf = new t_fifo[_size];
_num_elem = 0;
_wr_idx = 0;
_rd_idx = 0;
for(int idx = 0; idx < _size; ++idx) {
_buf[idx] = 0;
}
}
```

```
int main() {
// create a fifo of size 32
fifo y(32);
return 0;
}
```

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## Classes - Destructor Example

```
typedef int t_fifo;
class fifo {
public:
    fifo(int size);
    ~fifo();

    bool read(t_fifo& val);
    bool write(const t_fifo& val);
    void dump();
protected:
    bool is_empty();
    bool is_full();
    int inc_idx(const int& idx);
protected:
    t_fifo* _buf; int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
};
```

```
fifo::fifo(int size) {
    _size = size;
    _buf = new t_fifo[_size];
    _num_elem = 0;
    _wr_idx = 0;
    _rd_idx = 0;
    for(int idx = 0; idx < _size; ++idx) {
        _buf[idx] = 0;
    }
}
```

```
fifo::~fifo() {
    delete[] _buf;
}
```

```
int main() {
    // create a fifo of size 32
    fifo y(32);
    return 0;
}
```

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## Classes - Scope Resolution Operator

```
typedef int t_fifo;
class fifo {
public:
    fifo(int size);
    ~fifo();

    bool read(t_fifo& val);
    bool write(const t_fifo& val);
    void dump();
protected:
    bool is_empty();
    bool is_full();
    int inc_idx(const int& idx);
protected:
    t_fifo* _buf; int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
};
```

The :: operator is called scope resolution operator. It tells the compiler that `read()` and `write()` belong to the class `fifo`.

```
bool fifo::read(t_fifo& val) {
    // do something
}
bool fifo::write(const t_fifo& val) {
    // do something
}
```

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## C/C++ - Header and Implementation File

```
// Code in header file fifo.hpp
typedef int t_fifo;
class fifo {
public:
    fifo(int size);
    ~fifo();

    bool read(t_fifo& val);
    bool write(const t_fifo& val);
    void dump();
protected:
    bool is_empty() { return _num_elem == 0; }
    bool is_full() { return _num_elem == _size; }
    int inc_idx(const int& idx);
protected:
    t_fifo* _buf; int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
};
```

```
// Code in implementation file fifo.cpp
#include "fifo.hpp"

fifo::fifo(int size) {
    _size = size; _buf = new t_fifo[_size];
    _num_elem = 0; _wr_idx = 0; _rd_idx = 0;
    for(int idx = 0; idx < _size; ++idx) {
        _buf[idx] = 0;
    }
}
fifo::~fifo() {
    delete[] _buf;
}

bool fifo::read(t_fifo& val) {
    /* do something */
}
bool fifo::write(const t_fifo& val) {
    /* do something */
}
void fifo::dump() {
    /* do something */
}
int fifo::inc_idx(const int& idx) {
    /* do something */
}
```

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### A function argument may have a default value

- has to be given in the function prototype (only!)
- if a default value is given for an argument
  - the argument may be omitted
  - the default value will be used for the argument
- if a function has more than one argument
  - specification of default values has to start with last argument
  - omission of parameters has to start with the last parameter

```
class fifo {
public:
    // constructor now with
    // default argument
    fifo(int size = 16);
    ...
};
```

```
int main() {
    // create a fifo of default size 16
    fifo x;
    // create a fifo of size 32
    fifo y(32);
    return 0;
}
```

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### C++ supports references to variables

- a reference to a variable may be generated
  - a reference is an *alias* for the variable
- modifying a reference to a variable implies modifying the original variable
- a reference has to be initialized

#### Reference Syntax:

```
type_name &ref_name = variable_name;
type_name:
    ■ the data type of the reference
```

```
int x = 10;
// int &y; FAILURE
int &y = x;
y++; // now y == 11 AND x == 11 (y is just a reference to x)
```

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## Functions & Ops. - Call by Reference 1

### C++ supports call by reference for functions

- passing a reference as argument to a function
  - does not create a temporary variable for the argument (avoids copying!)
  - if the argument is modified inside the function, the argument variable inside the calling block is also modified
  - often not what you want – use const reference instead

```
bool fifo::read(t_fifo &val)
{
    if( is_empty() ) {
        return false;
    }
    else {
        val = _buf[_rd_idx];
        _rd_idx = inc_idx(_rd_idx);
        _num_elem--;
    }
    return true;
}
```

pass a reference as  
argument to the function

the `read()` method directly  
modifies `y`

```
int main()
{
    fifo x;
    int y = 0;
    x.write(42);
    x.read(y);
    // now y has the value 42
}
```

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## Functions & Ops. - Call by Reference 2

### Call by reference may increase program speed

- no temporary objects created at function calls
  - if passed objects are large this will significantly increase program speed
- if argument should not be modified by the function
  - use the `const` keyword
  - if the function tries to modify the argument, a compiler error will be issued

```
bool fifo::write(const t_fifo &val)
{
    if( is_full() ) {
        return false;
    }
    else {
        _buf[_wr_idx] = val;
        _wr_idx = inc_idx(_wr_idx);
        _num_elem++;
    }
    // val = 42; FAILURE
    return true;
}
```

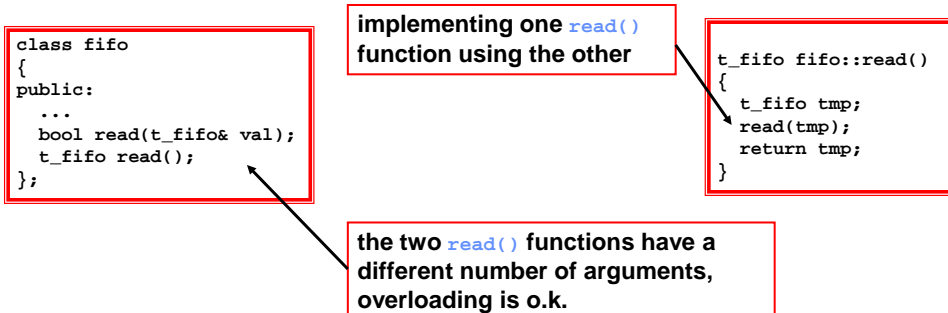
pass a `const` reference to  
the `write()` method

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## A function may have more than one implementation

- called overloading
- the functions must have different type or number of arguments
  - called signature
- it is not sufficient to have different return types

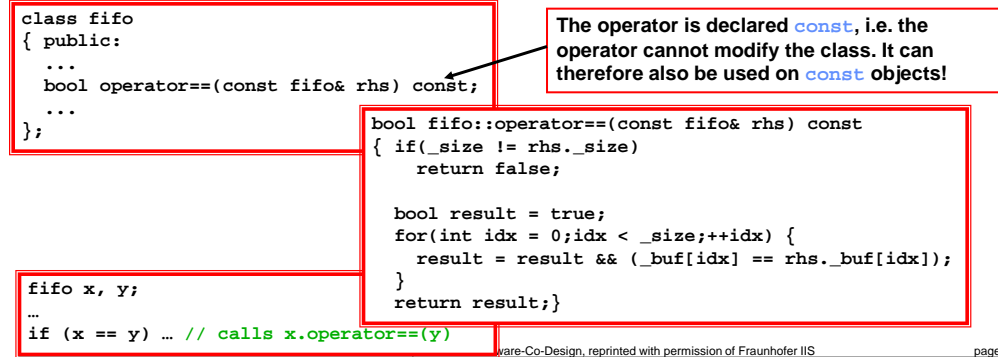


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## Operators are treated as normal functions in C++

- possible to overload operators
- operators are usually class members
  - the right operand is passed as argument
  - the left operand is implicitly the class implementing the operator



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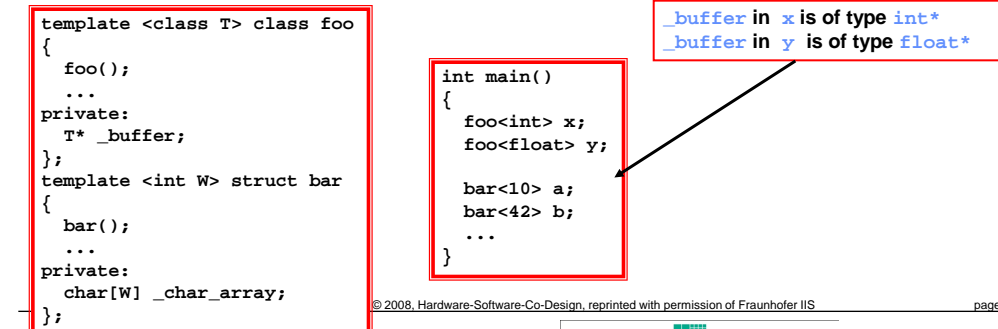
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## Template Classes - Introduction

### C++ supports a template mechanism

- allows to specialize classes with parameters
  - especially useful to create classes that can be used with multiple data types
  - extensively used by SystemC
- the template parameters have to be compile time constants
- the complete implementation of a template class has to appear in the header (.h) file



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# Template Classes - Example

```
template<class T> class fifo
{
public:
    fifo(int size = 16);
    ~fifo();

    bool read(T& val);
    bool write(const T& val);
    void dump();

protected:
    bool is_empty();
    bool is_full();
    int inc_idx(const int& idx);

protected:
    T* _buf;
    int _size;
    int _rd_idx;
    int _wr_idx;
    int _num_elem;
};
```

code in fifo.h

- re-implementing the `fifo` class to be usable with arbitrary data types

```
template<class T>
inline
bool fifo<T>::write(const T& val)
{
    if( is_full() ) {
        return false;
    }
    else {
        _buf[_wr_idx] = val;
        _wr_idx = inc_idx(_wr_idx);
        _num_elem++;
    }
    return true;
}
```

code in fifo.h

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# Inheritance - Introduction

## Inheritance enables re-use of components

- put common features of multiple classes in base class
- derive classes from the base class
  - all existing features may be re-used
  - new features may be added
- inheritance establishes a "is-a" relationship
  - e.g., a car is a vehicle, so it could be derived from vehicle

### Inheritance Syntax:

```
class derived_class : [access_modifier] base_class
{
};

access_modifier:
    ■ one of the three modifiers public, protected, private
```

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# Inheritance - Access Modifier

## Overview of access modifiers for inheritance

	derived class	public	protected	private
base class				
public	public	public	protected	private
protected	protected	protected	protected	private
private	private	no access	no access	no access

```
class foo
{
public:
    void pub_func();
protected:
    void prot_func();
private:
    void priv_func();
};
```

```
class bar : public foo
{
    // pub_func() is still public
    // prot_func() is still protected
    // priv_func() cannot be accessed from bar
};
```

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## Inheritance - Example

### code in header file

```
typedef int t_fifo;

class resizable_fifo : public fifo
{ public:
    resizable_fifo(int size = 16);
    ~resizable_fifo();
    void resize(int size);
};
```

### code in main program

```
int main()
{ // create a resizable_fifo of size 32
  resizable_fifo x(32);
  // resize fifo to 42 elements
  x.resize(42);
  // write data to the fifo
  x.write(10);
  return 0;
}
```

the constructor of `resizable_fifo` calls the constructor of its base class with the `size` argument

```
resizable_fifo::resizable_fifo(int size) : fifo(size)
{}
void resizable_fifo::resize(int size)
{ // a resize destroys all stored data
  delete [] _buf;
  _size = size;
  _buf = new t_fifo[size];
}
```

### code in implementation file

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## Multiple Inheritance - Introduction

### Multiple Inheritance

- derive a class from multiple base classes
- extensively used by SystemC
  - necessary to allow separation of interface and implementation of a channel
- multiple inheritance is an advanced feature of C++
  - only mentioned in this introduction, not covered in depth

`sc_fifo<T>` is derived from three base classes

```
template <class T> class sc_fifo : public sc_fifo_in_if<T>,
                                   public sc_fifo_out_if<T>,
                                   public sc_prim_channel
```

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## Virtual Functions - Declaration

### Virtual Functions in C++

- provide a mechanism to re-implement methods of a base class
  - a method declared *virtual* may be re-implemented within a derived class
- a so-called pure virtual function
  - *must* be re-implemented in the derived class
  - no implementation provided in the base class
  - enables the implementation of interfaces without any functionality

```
class foo {
public:
    virtual void virt_func() {
        std::cout << "I am a function of foo" << std::endl;
    }
};
class bar { // similar to java interfaces
public:
    virtual void pure_virt_func() = 0;
};
```

a virtual function

a pure virtual function  
without implementation

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# Virtual Functions - Re-Implementation

```
class derived_foo : public foo {
public:
    virtual void virt_func() {
        std::cout << "I am a function of derived_foo" << std::endl;
    }
};

class derived_bar : public bar {
public:
    virtual void pure_virt_func() {
        std::cout << "I am not pure virtual any more" << std::endl;
    }
};
```

```
foo x;
x.virt_func();
// bar cannot be instantiated, because it has a pure virtual function
derived_foo y;
y.virt_func();
derived_bar z;
z.pure_virt_func();
```

## Output:

```
I am a function of foo
I am a function of derived_foo
I am not pure virtual any more
```

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