Objects, Types, and Operations

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Outline

Objects

Object Classes

Class Types

Operations on Types of Classes

Objects

Object: Anything That Has a Name and Is of a Specified Type

- Four Classes of Objects
 - Constants
 - Variables
 - Signals (discussion deferred to later)
 - Files (discussion deferred to later)

Objects

Classes of Objects Can Be of Different Types

Object Declaration

Before an Object Can Be Used, It Must Be Declared

- Declarations
 - Specify a unique identifier
 - Define the type
 - May specify initial (default) value

Constants

- Initialized to a Value That Cannot Change
 - -If not initialized, called a deferred constant
 - -May only appear in package declaration

Insures a Value has a Type

Constant Syntax

```
constant identifier_list : subtype_indication [ :=
   expression ] ;
```

where

```
identifier_list <= identifier { , ... }</pre>
```

Constant Declaration, e.g.,

```
constant PI : real := 3.1415926535897 ;
constant BUS_WIDTH : integer := 32 ;
constant
        INTENSITY_DYNAMIC_RANGE :
        real := 16 # FF . F ;
constant START_TIME_MINUTES :
    integer := 00 ;
```

Variables

■ Variable: an Object Whose Value May be Changed After Creation

- Initialization Value is Optional, if not Initialized the Default for Scalar Types is
 - The first in the list of an enumeration type
 - The lowest in an ascending range
 - The highest in a descending range

Variables Syntax

Only Declare where it can be Accessed by One Process

```
variable identifier_list :
  subtype_indication [ := expression ] ;
```

Variable Declaration, e.g.,

```
variable ControlValue : real := 3 . 68 ;

variable MinTemp, MaxTemp, MeanTemp :
   real := 0 . 0 ;
```

Variable Declaration, e.g.,

```
variable ImageWidth, ImageHeight :
    integer := 256 ;

variable DiskSize, MemUsed, MemLeft :
    integer ;

variable MBus : bit_vector
    ( 31 downto 0 ) ;
```

Variable Assignment Syntax

Immediately Overwrites Variable with New Value Unlike the way a Signal Does

- **:=** Replacement Operator for Variables
- <= Replacement Operator for Signals

```
[ label : ] identifier := expression ;
```

Variable Assignment, e.g.,

```
MinTemp := 0 . 0;
ImageWidth := 128;
MainBus : = 16 # ffff_ffff;
MainBus : = x " FFFF_FFFF ";
```

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■ The Type of a Data Object

- Defines the set of values an object can take on
- Defines operations which can be performed on object

Scalar Type

Consists of a set of single, indivisible values

Types

Composite Type

Many Predefined Types

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Type Syntax

Type Qualification Is Used to Avoid Type Ambiguity in Overloaded Enumeration Literals

```
type_name ' ( expression )
```

Only states type of value

Type Syntax

■ Type Conversion Can Be Used to Perform Mixed Arithmetic

```
New_Type ( Value_of_Old_Type )
```

e.g.,

```
real ( 238 )
positive ( My_Integer_Value )
```

- Rounds to nearest integer
- Changes type of value

Type Declaration Syntax

```
type identifier is type definition ;
type definition <=
                 scalar type definition
                 composite type definition
                 access type definition
                file type definition
```

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Type Declaration, e.g.

■ Identical Type Declarations Are Distinct

```
type MidTermGrades is range 0 to 100 ;
type FinalGrades is range 0 to 100 ;
```

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Scalar Type Declaration

- Scalar Type
 - Number types

Enumerated list

Physical quantities

Scalar Type Declaration Syntax

scalar type definition <=</pre>

enumeration_type_definition

- integer_type_definition
- floating_type_definition
- physical type definition

Predefined Integer Type

- Integer Type
 - A range of integer values within a specified range including the endpoints

- Integer Type Range
 - minimum range $(-2^{31}+1)$ to $(+2^{31}-1)$

Operations on Integer Types

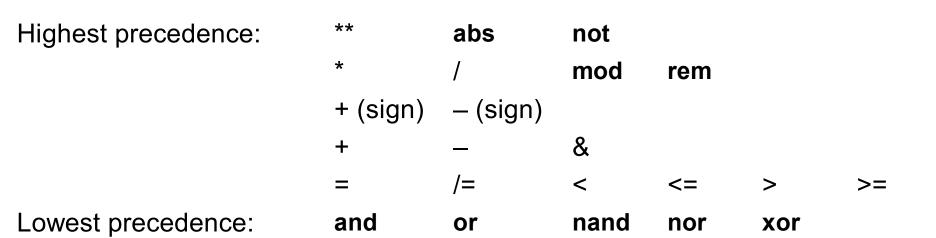


Table 7-1. Operators and precedence.

*Ashenden, VHDL cookbook

Integer Type Definition Syntax

```
range simple_expression ( to | downto )
    simple_expression
```

to: left to right from smallest value to largest

downto: left to right from largest value to smallest

Integer Type Definition, e.g.,

```
type StreetNumbers is range 10107 to 12568;

type ImagingSensors is range 0 to 5;

type Celsius is range 100 downto 0;

type PointSpread is range 14 downto 0;
```

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Pre-defined Floating-Point Type Definition

■ Floating-Point Type

A range of real values within a specified range including the endpoints

Real

- Minimum range (-1.0E+38) to (+1.0E+38)
- 6-digits minimum precision
- Corresponds to IEEE 32-bit representation
- Floating-point type

Ops on Floating-Point Types

Binary Operators

+ Add

- Subtraction

* Multiplication

/ Division

** Exponentiation

Ops on Floating-Point Types

Unary Operators

- Negation

+ Identity

abs Absolute value

Floating-Point Type Syntax

to: left to right from smallest value to largest

downto: left to right from largest value to smallest

Floating-Point Type, e.g.,

```
type StreetPosition is range
     101 . 07 to 125 . 68;

type ImagingSensorSensitivity is range
     0 . 0 to 5 . 0;
```

Floating-Point Type, e.g.,

```
type Celsius is range 100.0 downto 0 . 0;
type PointSpread is range 15.0 downto 0 . 0;
```

Physical Type Definition

identifier Is the Primary Unit With the Smallest Unit Represented

■ *identifier-n* Secondary Units Defined in Terms of Primary Unit

Operations on Physical Types

- Binary Operators
 - * Multiplication by an integer or float

- / Division by an integer or float
- » Division by objects of same physical type yields an integer

Operations on Physical Types

- Unary Operators
 - negation

+ identity

Physical Type Definition Syntax

Operations on Physical Types

Multiplication or Division of Different Physical Types Not Allowed

- If Required,
 - Convert to integers
 - Perform operation
 - Convert result to correct type

Predefined Physical Type, e.g.,

```
type time is range implementation defined
units
fs;
ps = 1000 fs; ns = 1000 ps;
us = 1000 ns; ms = 1000 us;
sec = 1000 ms; min = 60 sec;
hr = 60 min;
end units; [ time ]
```

Simulation Time Resolution Limit

- The Resolution Limit Determines the Precision to Which Time Values Are Represented.
- Values of Time Smaller Than the Resolution Limit Round Down to Zero.
- fs Is the Normal Resolution Limit During Model Simulation.

Simulation Time Resolution Limit

- Larger Values of Time Can Be Used As a Secondary Time Resolution Limit
 - Units of all physical literals involving time must not be smaller than the secondary resolution limit

Physical Type Definition, e.g.,

```
type capacitance is range 0 to 1e12
units
   picofarad;
   nanofarad = 1000 picofarad;
   microfarad = 1000 nanofarad;
   farad = 1e6 microfarad;
end units capacitance;
```

Physical Type Resolution

■ 47 picofarad

■ 10.6 nanofarad

- 4.7 picofarad
 - rounds DOWN to 4 picofarads since pf is smallest unit
 - can only have integer value of base unit

Enumeration Type Definition

Enumeration Type

- An ordered set of identifiers or characters
- The identifiers and characters within a single enumeration type must be unique.
- Identifiers and characters may be reused in different enumeration types.

```
( ( identifier | character_literal ) { , ... } )
```

Enumeration Type, e.g.,

```
type Buffer_Direction is ( in , out ,
    tri_state );

type FF_Type is
    ( Toggle , Set Reset , Data , JK );
```

Enumeration Type, e.g.,

Predefined Enumeration Types

Used to model hardware logic levels

type bit is (' 0 ', ' 1 ');

Predefined Enumeration Types

```
type file_open_status is
  ( open_ok , status_error , name_error ,
    mode_error );

type character is ( NUL , SOH , ... );
  - All characters in ISO 8-bit character set
```

■ IEEE std_logic_1164 Accounts for Electrical Properties

Subtypes

Subtype

- Values which may be taken on by an object and
- are a subset of some base type, and,
- may include all values.

Subtypes

- Subtypes Mixed in Expressions
 - Computations done in base type
 - Assignment fails if result is not within range of result variable (sub)type

Subtype Syntax

```
subtype identifier is subtype_indication;

subtype_indication <=
   identifier [ range simple_expression ( to |
   downto ) simple_expression ]</pre>
```

Subtype Cases

■ A Subtype May Constrain Values From a Scalar Type to Be Within a Specified Range

```
subtype Pin_Count is integer range 0 to
400;

subtype Octal_Digits is character
  range ' 0 ' to ' 7 ';
```

Subtype Cases

A Subtype May Constrain an Otherwise Unconstrained Array Type by Specifying Bounds for the Indices

```
subtype id is string ( 1 to 20 );
subtype MyBus is bit_vector ( 8 downto 0 );
```

Predefined Numeric Subtypes

```
subtype natural is integer range 0 to
  highest_integer;

subtype positive is integer range 1 to
  highest_integer;

subtype delay_length is time range 0 fs
  to highest_time;
```

Scalar Type Attributes

Predefined Attributes Associated With Each Type

Type_Name \ Attribute_Name

All Scalar Type Attributes

T'left leftmost value in T

T'right rightmost value in T

T'low least value in T

T'high greatest value in T

T'ascending True if ascending range, else false

T'image(x) a string representing x

T'value(s) the value in T that is represented by s

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Discrete and Physical Scalar Type Attributes

T'pos(x) position number of x in T

T'val(n) value in T at position n

T'succ(x) value in T at position one greater

than that of x

T'pred(x) value in T at position one less

than that of x

T'leftof(x) value in T at position one to the left of x

T'rightof(x) value in T at position one to the right of x

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- "Short-Circuit" Operators
 - Behavior with binary operators
 - » Evaluate left operand
 - » If value of operand determines the value of expression, set result
 - » Else evaluate right operand

- Left operand can be used to prevent right operand from causing arithmetic error such as divide by zero
- Reduces computation time by eliminating redundant calculations
- Logic Operators

AND, OR, NAND, NOR

Relational Operators

- Operands must be of the same type
- Yield Boolean results
- Equality, Inequality Operators

Operands of any type

Concatenation Operator



- Operates on one-dimensional arrays to form a new array
- Arithmetic

 Operate on integer, floating point and physical types types.

■ Modulo, Remainder

mod, rem

- Operate only on integer types.
- Absolute Value

abs

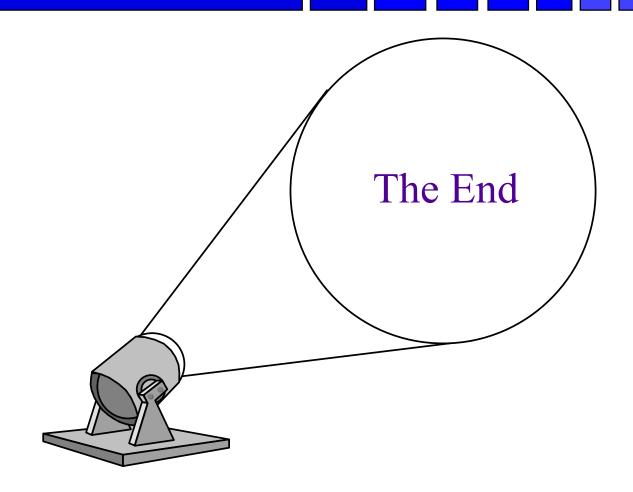
Operates on any numeric type

Exponentiation



- Integer or floating point left operand
- Integer right operand required
- Negative right operand requires floating point left operand

End of Leture



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